NOTICE

All drawings located at the end of the document.

Final
Corrective Measures Study/Feasibility Study

Rocky Flats Environmental Technology Site
881 Hillside Area

(Operable Unit No. 1)

February 1995

EXECUTIVE SUMMARY

This report documents the Corrective Measures Study/Feasibility Study (CMS/FS) performed for the 881 Hillside Area, Operable Unit 1 (OU-1), of the Rocky Flats Environmental Technology Site (RFETS) The study was conducted in accordance with the requirements of the Rocky Flats Interagency Agreement (IAG) of January 1991 This agreement was signed between the U.S Department of Energy (DOE), the U S Environmental Protection Agency (EPA), and the Colorado Department of Public Health and the Environment (CDPHE) The agreement specifies that the CMS/FS shall be conducted following appropriate Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and Resource Conservation and Recovery Act (RCRA) guidance

The primary source of guidance used in the preparation of this report was EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, which outlines and describes the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) Also used was EPA's *RCRA Corrective Action Plan* guidance, published in May 1994 In preparing this report, data on OU-1 were obtained from both the *Phase III RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report*, and the Rocky Flats Environmental Database System (RFEDS) directly Where appropriate, recent soil gas survey data were used to enhance the conceptual model applied in the development of remedial action alternatives

Following standard RCRA/CERCLA guidelines, results of the Phase III RFI/RI report were first examined to determine primary site contaminants and exposure pathways. Once these risk drivers were identified, remedial action objectives (RAOs) and preliminary remediation goals (PRGs) were formulated to address risks to human health and the environment In the case of OU-1, the Environmental Evaluation (EE) portion of the Baseline Risk Assessment (BRA) did not identify any current or future risks to environmental receptors. Therefore, this report focuses on minimizing the risk to human receptors from contaminants identified in the RFI/RI report The RAOs identified for OU-1 are listed below.

1) Prevent the inhalation of, ingestion of, and/or dermal contact with VOCs and inorganic contaminants in OU-1 groundwater that would result in a total excess cancer risk greater than 10^{-4} to 10^{-6} for carcinogens, and/or a hazard index greater than or equal to 1 for non-carcinogens

2) Prevent migration of contaminants from subsurface soils to groundwater that would result in groundwater contamination in excess of potential groundwater applicable or relevant and appropriate (ARARs) for OU-1 contaminants

3) Prevent migration of contaminants in OU-1 groundwater from adversely impacting surface water quality in Woman Creek

These RAOs were selected to address the primary risk exposure pathways identified for OU-1, the pathways associated with groundwater and indirectly, subsurface soils Surface soils were also identified as a medium of concern in the OU-1 RFI/RI, however this medium is being addressed under OU-2 Therefore, PRGs for RAOs dealing with groundwater and subsurface soils were identified by examining both risk- and applicable or relevant and appropriate requirement (ARAR)-based values The exposure route of groundwater ingestion resulted in the highest potential risk to a future on-site resident As a result, the Colorado Basic Standards for Groundwater, found in 5 Colorado Code of Regulations (CCR) 1002-8, 3 11 5 and 3 11 6), were selected as appropriate PRGs for OU-1

After selecting appropriate PRGs for OU-1, remedial action alternatives were assembled that would provide various conceptual approaches for cleanup of the site. The alternatives selected for detailed analysis are the following

- Alternative 0 — No Action
- Alternative 1. — Institutional Controls with the French Drain
- Alternative 2. — Groundwater Pumping and Soil Vapor Extraction
- Alternative 3 — Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement

- Alternative 4 Hot Air Injection with Mechanical Mixing

- Alternative 5 Soil Excavation with Groundwater Pumping

These alternatives were subjected to detailed analysis as required by RCRA and CERCLA guidelines, and the NCP (40 Code of Federal Regulations 300 430) The standards and criteria used to analyze the alternatives are the following (with the exception of state and community acceptance which are analyzed later in the CMS/FS process)

- Overall protection of human health and the environment (including assessment of source control measures)

- Compliance with ARARs

- Long-term effectiveness and permanence

- Reduction of toxicity, mobility, or volume

- Short-term effectiveness

- Implementability

- Cost

- State acceptance

- Community acceptance

The two threshold criteria, overall protection of human health and the environment, and compliance with ARARs, are statutory requirements that must be satisfied by any alternative in order for it to be eligible for selection as the preferred remedial action alternative The five primary balancing criteria of long-term effectiveness and permanence, reduction in toxicity, mobility and volume, short-term effectiveness, implementability, and cost are used to evaluate major performance objectives for each alternative The performance of each alternative in addressing each primary balancing criterion is evaluated and then compared across alternatives to assist in the selection of a preferred alternative

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The two modifying criteria, state acceptance, and community acceptance, evaluate the potential acceptance of the preferred alternative by regulatory agencies and the community These last two criteria are not evaluated until after formal public comment on the CMS/FS and Corrective and Remedial Action Proposed Plan (PP), and are addressed in the final Corrective Action Decision/Record of Decision (CAD/ROD)

The results of the detailed analysis of alternatives are presented in this report To support the analyses conducted herein, groundwater modeling and residual risk assessment calculations are included in Appendices B and C, respectively Cost estimates are likewise included in Appendix A A complete ARARs assessment is included in Appendix D In general these analyses show that most of the alternatives included in this analysis will meet groundwater PRGs at Woman Creek The No Action alternative may not meet these goals at the French Drain, however. In terms of protecting human health and the environment, all of the alternatives presented result in residual risks of less than one in a million at Woman Creek Only the No Action scenario presents a risk near one in ten thousand at the French Drain Costs associated with the alternatives ranged from $1 8 million for the No Action alternative, to over $13 million for Alternative 5 Soil Excavation with Groundwater Pumping Costs for the other alternatives were comparable, and ranged from $6 million to $7 5 million

Based on these results, *Alternative 0 No Action* would be the alternative of choice if performance and compliance are only monitored at Woman Creek. If, however, performance and compliance are monitored at the French Drain, then *Alternative 1 Institutional Controls with the French Drain* would most likely be the preferred alternative. Alternative 1 would also be a viable option if performance is monitored at Woman Creek, as a contingency measure until more recent data are available concerning groundwater migration in OU-1 and how observed data compare to predicted data Further discussion regarding the preferred alternative for OU-1 appears in the OU-1 PP

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LIST OF ACRONYMS

1,1,1-TCA	1,1,1-trichloroethane
ARAR	applicable or relevant and appropriate requirement
BRA	Baseline Risk Assessment
CAD	Corrective Action Decision
CAP	Corrective Action Plan
CCl_4	carbon tetrachloride
CCR	Colorado Code of Regulations
CDOW	Colorado Department of Wildlife
CDPHE	Colorado Department of Public Health and the Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMS	Corrective Measures Study
COC	contaminant of concern
CRS	Colorado Revised Statutes
CWQCC	Colorado Water Quality Control Commission
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
DOE	U S Department of Energy
EE	Environmental Evaluation
EPA	U S Environmental Protection Agency
FS	Feasibility Study
GAC	granular activated carbon
gpd	gallons per day
gpm	gallons per minute
GRAs	general response actions
IAG	Inter-Agency Agreement
IHSSs	Individual Hazardous Substance Sites
IM/IRA	Interim Measure/Interim Remedial Action
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient
LHSU	lower hydrostratigraphic unit
MAC	Maximum Allowable Concentration
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal

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NAPL	non-aqueous phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NESHAP	National Emission Standards for Hazardous Air Pollutants
O&M	operation and maintenance
OSWER	Office of Solid Waste and Emergency Response
OU-1	Operable Unit 1
OU-2	Operable Unit 2
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethene (or tetrachloroethene)
PHE	Public Health Evaluation
PP	Corrective and Remedial Action Proposed Plan
PRG	preliminary remediation goal
RACT	reasonably available control technology
RF	radio frequency
RAOs	remedial action objectives
RCRA	Resource Conservation and Recovery Act
RFEDS	Rocky Flats Environmental Database System
RFETS	Rocky Flats Environmental Technology Site
RFP	Rocky Flats Plant
RFI	RCRA Facility Investigation
RI	Remedial Investigation
ROD	Record of Decision
ROI	radius of influence
scfm	standard cubic feet per minute
SDWA	Safe Drinking Water Act
SID	South Interceptor Ditch
SWMU	Solid Waste Management Unit
SVE	soil vapor extraction
SVOC	semivolatile organic compound
TBC	to-be-considered
TCE	trichloroethene
TMV	toxicity, mobility, or volume
TSD	treatment, storage, and disposal facility
UHSU	upper hydrostratigraphic unit
USC	United States Code
UTL	upper tolerance limit
UV/H_2O_2	ultraviolet/hydrogen peroxide
VOC	volatile organic compound

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1.0 INTRODUCTION

This Corrective Measures Study/Feasibility Study (CMS/FS) report evaluates information necessary to support selection of the preferred remedial alternative(s) for Operable Unit 1 (OU-1) at the Rocky Flats Environmental Technology Site (RFETS) This report is part of a comprehensive program developed pursuant to the Rocky Flats Interagency Agreement (IAG) (January 1991) between the U S Department of Energy (DOE), the U S Environmental Protection Agency (EPA), and the Colorado Department of Public Health and the Environment (CDPHE) In accordance with the IAG, this report addresses CMS provisions of the Resource Conservation and Recovery Act (RCRA) and FS provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

1 1 Purpose and Organization of Report

The CERCLA Remedial Investigation (RI)/FS process provides the overall framework for this report, as specified in the IAG, IX D 1 Relevant RCRA-specific CMS criteria are incorporated within this framework, where appropriate In general, the CERCLA/RCRA process is intended to gather information sufficient to support an informed risk management decision regarding the most appropriate remedy for a given site The process includes

- Characterization of the site's physical conditions
- Characterization of nature and extent of contamination
- Characterization of fate and transport of contamination
- Assessment of risk to human health and the environment
- Treatability testing, if appropriate
- Development, screening, and detailed analysis of remedial alternatives
- Selection and implementation of remedial action(s)

This CMS/FS report documents the development, screening and detailed analysis of remedial alternatives Following CDPHE and EPA acceptance, the results of this report, along with information provided by previous reports, will be summarized in a Corrective and Remedial Action Proposed Plan (PP). The PP is published for public review and comment; public comments will be responded to prior to selecting and implementing a remedy for OU-1

This CMS/FS follows EPA guidance established for general CMS and FS reports, as outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a) and in the RCRA Corrective Action Plan guidance (EPA 1994) The guidances involve three phases shown graphically in Figure 1-1 The three phases are

- Development of remediation goals and identification of process options
- Development and screening of alternatives
- Detailed analysis of alternatives

The development of remediation goals and identification of process options is included in this report as Section 2.0 The Identification and Selection of Technologies and Representative Process Options Representative remedial technologies capable of meeting remediation goals were selected for inclusion in remedial alternatives

The Development of Alternatives phase is presented in Section 3.0 of this report This phase identifies and combines potentially feasible remedial technologies to develop a range of remedial alternatives for OU-1 Specific components of this phase include

- Development of media-specific remedial action objectives (RAOs)
- Development of media-specific general response actions (GRAs)
- Identification of volumes and/or areas of the media which require GRAs
- Identification and screening of technologies and process options for each GRA
- Evaluation of process options within each technology type to select a representative process option for the development of remedial action alternatives

The screening of alternatives is an optional phase that is conducted if the number of alternatives developed is too large to be reasonably carried forward to the detailed analysis This screening is conducted on the basis of effectiveness, implementability, and cost. This screening was not conducted for OU-1.

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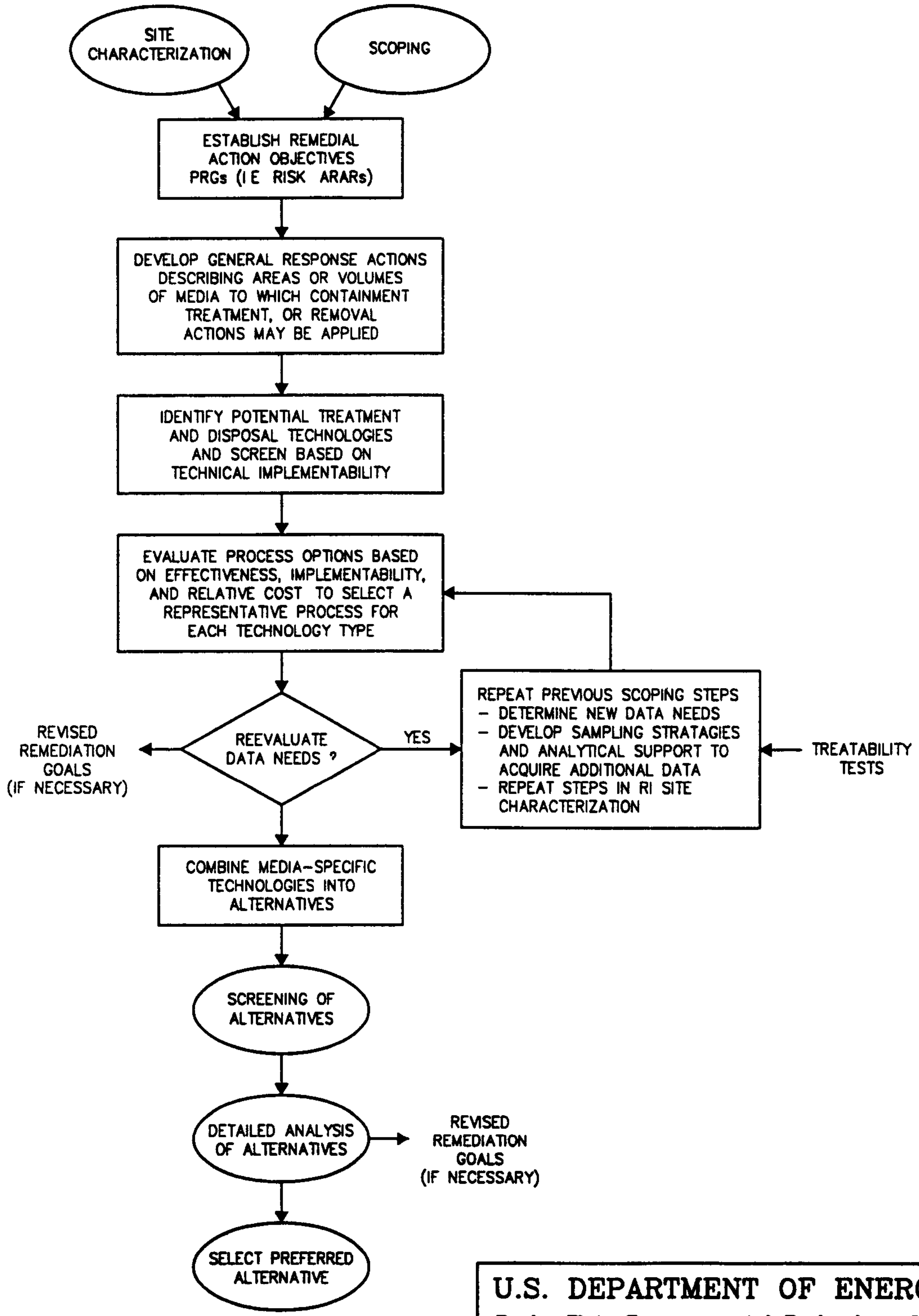

U.S. DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

CMS/FS Logic Flow Diagram

Figure 1-1

OU1-LFD DWG

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Section 4 0 presents the Detailed Analysis of Alternatives for those alternative that were carried forward from the screening phase described above In this phase, the alternatives are further refined and analyzed in detail with respect to CERCLA criteria and RCRA standards that are provided in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and the RCRA Corrective Action Plan guidance (EPA 1994) The CERCLA criteria include

- Overall protection of human health and the environment
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

In the detailed analysis, the first seven of these criteria are evaluated in two ways First, each alternative is evaluated individually on its ability to satisfy each of the seven criteria Second, the alternatives are subjected to a comparative analysis with the other alternatives The State acceptance and community acceptance criteria are addressed in the Corrective Action Decision (CAD)/Record of Decision (ROD) Prior to the issuance of the CAD/ROD, the PP is submitted for public and State comment Table 1-1 provides a comparison of CERCLA evaluation criteria and RCRA standards.

Because these CMS/FS phases - Development of Remediation Goals and Identification of Process Options, Development and Screening of Alternatives, and Detailed Analysis of Alternatives - are based on the results of previously conducted steps of the RCRA Facility Investigation (RFI)/RI, the following subsections briefly summarize the results of the RFI/RI. Section 1.2 discusses the Site Background, Section 1.3 discusses the Physical Characteristics of the site, Section 1 4 discusses the Nature and Extent

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Table 1-1.
Comparison of CERCLA Evaluation Criteria and RCRA Standards

National Contingency Plan, CERCLA Evaluation Criteria 40 CFR 300.430(e)(9)(iii)	RCRA Corrective Action Plan Standards OSWER Directive 9902.3-2A (May 1994)
Overall protection of human health and the environment	Protect human health and the environment
	Control the sources of releases[1]
Compliance with ARARs	Comply with any applicable standards for management of wastes
	Attain media cleanup standards set by the implementing agency
Long-term effectiveness and permanence	Long-term reliability and effectiveness
Reduction of toxicity, mobility, or volume through treatment	Reduction in the toxicity, mobility, or volume of wastes
Short-term effectiveness	Short-term effectiveness
Implementability	Implementability
Cost	Cost

[1] This criterion is addressed under the National Contingency Plan threshold criteria for Overall Protection of Human Health and the Environment This criterion is also directly related to the Long-Term Effectiveness and Permanence criteria

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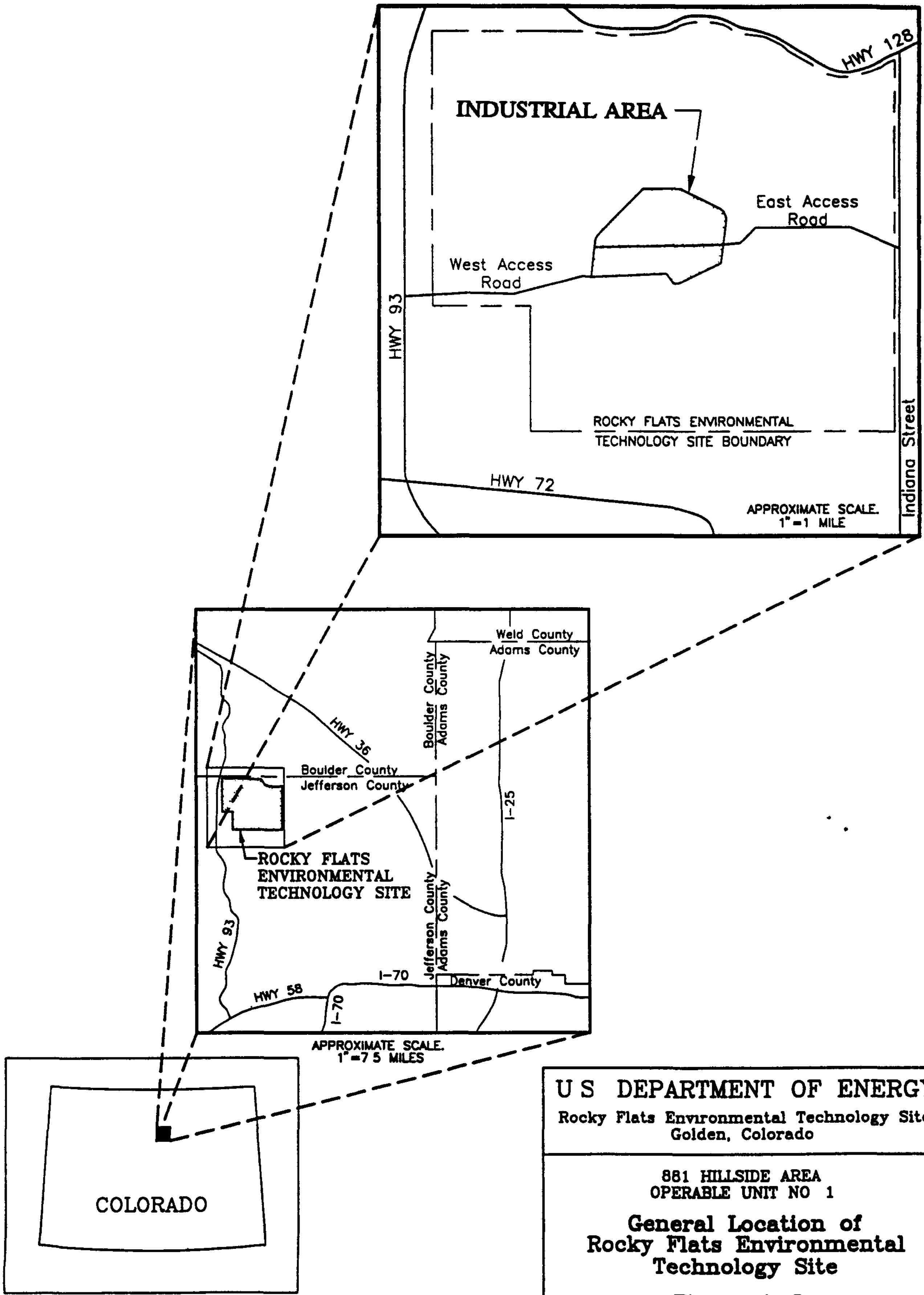
of Contammation; Section 1.5 discusses the Fate and Transport of Contaminants; and Section 1.6 summarizes the Baseline Risk Assessment Section 1.7 discusses interim measures and interim remedial actions

1 2 Site Background

OU-1, also referred to as the "881 Hillside Area", is located at the RFETS, a DOE owned facility located approximately 16 miles northwest of downtown Denver, Colorado (see Figure 1-2) RFETS occupies approximately 6,550 acres of federally-owned land in northern Jefferson County, Colorado The majority of the RFETS buildings are located within a 400-acre area referred to as the RFETS security area The 6,150 acres surrounding the security area are used as a buffer zone

Prior to 1994, the site was referred to as Rocky Flats Plant (RFP) Until 1992, RFP fabricated nuclear weapon components from plutonium, uranium, beryllium, and stainless steel Parts made at the plant were shipped elsewhere for assembly Support activities included chemical recovery and purification of recyclable transuranic radionuclides and research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics These activities generated radioactive, hazardous, and mixed waste On-site storage and disposal of these wastes has contributed to hazardous and radioactive contamination in soils, surface water, and groundwater In July 1994 the plant was renamed to the RFETS to reflect a new mission of environmental restoration and the advancement of new and innovative technologies for waste management, characterization, and remediation

OU-1 is located in the southern portion of the security area, on the hillside south of Building 881 and north of Woman Creek Historically, Building 881 was used for enriched uranium operations and stainless steel manufacturing The laboratories in Building 881 also performed analyses of the materials generated in production. The highest point in the immediate vicinity of OU-1 is Building 881, which is approximately 6,000 feet above mean sea level The lowest point is at Woman Creek, about 5,830 feet above mean sea level. Two surface drainages occur in the vicinity of OU-1· Woman Creek flows along the base of 881 Hillside south of OU-1, and the



U S DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

General Location of Rocky Flats Environmental Technology Site

Figure 1-2

OU1-LOC DWG

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South Interceptor Ditch (SID) crosses OU-1 between the security area and Woman Creek. A French Drain was constructed in 1992 across a significant portion of OU-1 above the SID to collect alluvial groundwater as an Interim Measure/Interim Remedial Action (IM/IRA)

OU-1 includes 11 sub-areas that historical information suggested could exhibit potential contamination of soil, surface water, and/or groundwater These sub-areas are referred to as Individual Hazardous Substance Sites (IHSSs) Figure 1-3 shows the locations of these IHSSs, Table 1-2 presents their descriptions The RFI/RI was specifically designed to investigate the potential contamination at the IHSSs, as well as in the intervening areas of OU-1 The resulting data were used to characterize the physical and chemical conditions at OU-1

1 3 Physical Characteristics

Information on the Physical Characteristics of OU-1 was obtained primarily from the *Phase III RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report* (DOE 1994a) Where appropriate, more recent data from the Rocky Flats Environmental Database System (RFEDS) were used update interpretations and to develop figures and contour maps presented herein Two soil gas surveys conducted after publication of the Phase III RFI/RI report also supplemented current interpretations (DOE 1994b, DOE 1994c)

The physical characteristics of OU-1 which are relevant to the CMS/FS phases can be described considering geomorphologic and hydrogeologic features

1.3 1 Geomorphology

The geomorphology at OU-1 reflects the interaction of several erosional and depositional processes which have produced gently rolling to moderately steep slopes on the Building 881 hillside The terrain has been recontoured in several areas at various times during the construction of Building 881, the placement of fill and waste materials in several areas including the contractor yard and several IHSSs, the grading of roads at the site, the construction of the

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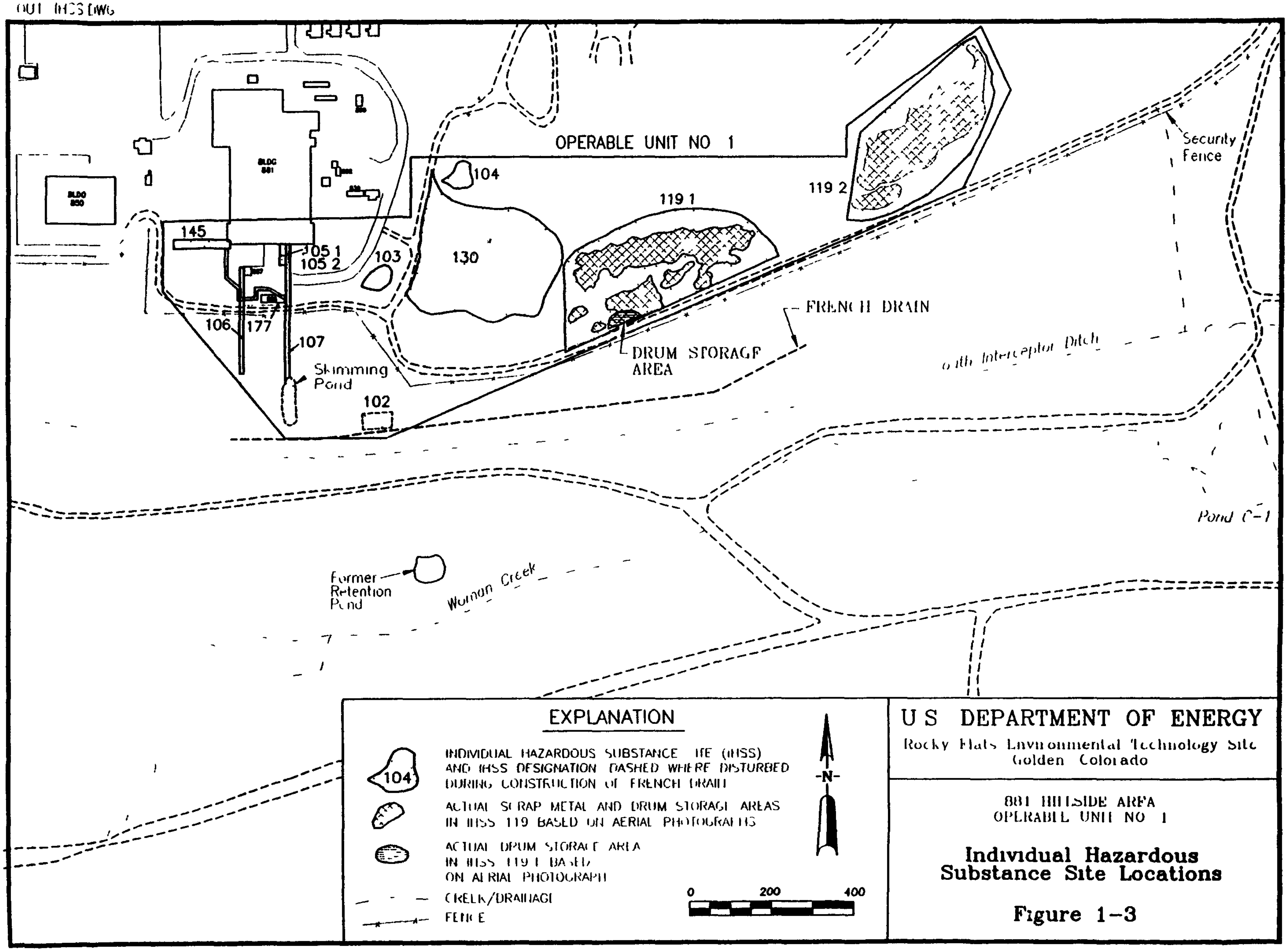

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Individual Hazardous Substance Site Locations

Figure 1–3

Table 1-2.
Individual Hazardous Substance Site Descriptions

IHSS Number	IHSS Name	Description
102	Oil Sludge Pit Site	Approximately 40 x 70 ft^2 area located approximately 180 feet south of Building 881 where 30 to 50 drums of non-radioactive oily sludge were emptied in the late 1950s The sludge was from the cleaning of two No 6 fuel oil tanks, designated as IHSSs 105 1 and 105 2, and was backfilled when disposal operations ceased
103	Chemical Burial Site	Approximately 50 feet in diameter (2,000 ft^2), the pit is circular is shape, and is located approximately 150 feet southeast of Building 881 on 1963 aerial photographs Area was reportedly used to bury unknown chemicals
104	Liquid Dumping Site	Reportedly a former (pre-1969) liquid waste disposal pond in area east of Building 881 - no exact location or dimensions of pit - location is uncertain due to poor quality of 1965 aerial photograph Approximate dimensions are 50 x 50 ft^2
105 1, 105 2	Out-of-Service Fuel Oil Tank Sites	Located immediately south of Building 881, these were storage tanks for No 6 fuel oil Suspected leaks in 1972 Tanks closed in place through filling with asbestos-containing material and cement IHSS 107, the Hillside Oil Leak Site, may have been caused by leakage from these tanks
106	Outfall Site	Overflow line from the sanitary sewer sump in Building 887 The outfall was used for discharge of untreated sanitary wastes in the 1950s and 1960s Due to concern about discharges from the outfall entering Woman Creek, several small retention ponds and an interceptor ditch were built in 1955 and 1979, respectively, to divert the outfall water to Pond C-2
107	Hillside Oil Leak Site	Site of 1972 fuel oil spill from Building 881 foundation drain outfall A concrete skimming pond was built below the foundation drain outfall to contain the oil flowing from the foundation drain, and an interceptor ditch was constructed to prevent oil-contaminated water from reaching Woman Creek
119 1, 119 2	Multiple Solvent Spill Sites	Former drum storage areas east of Building 881 along the southern perimeter road IHSS 119 1 is the larger western drum and scrap metal storage area, and appears to have contained mostly drums in the southern part of the IHSS and mostly scrap metal in the northern part, although material was moved around frequently as documented by aerial photographs IHSS 119 2 is the smaller eastern drum and scrap metal storage area and appears to have contained mostly scrap metal The drums contained unknown quantities and types of solvents and wastes The scrap metal may have been coated with residual oils and/or hydraulic coolants
130	Radioactive Site - 800 Area #1	Area east of Building 881 Used between 1969 and 1972 to dispose of soil and asphalt contaminated with low levels of plutonium and uranium IHSS 130 is referred to as the Contaminated Soil Disposal Area East of Building 881 in the HRR to better match the history of waste disposal, the site is included in the discussion of the 900 area at RFETS in that report IHSS 130 contains approximately 320 tons or 250 cubic yards which came from three sources 1) plutonium-contaminated soil and asphalt, placed in September of 1969, 2) road asphalt and soil rad contaminated by leaking drum in transit and 3) 60 cu yds of plutonium-contaminated soil removed from around the Building 774 process waste tanks in 1972
145	Sanitary Waste Line Leak	Six-inch cast-iron sanitary sewer line that originates at the Building 887 lift station and that leaked on the hillside south of Building 881 The line had conveyed sanitary wastes and low-level radioactive laundry effluent to the sanitary treatment plant from about 1969 to 1973

SID, and most recently, the construction of the French Drain The steepness of the hillside, combined with various construction and excavation activities at OU-1, has resulted in mechanical failure manifested in widespread slumping of material (DOE 1994a) A number of wells on the hillside have been damaged by this slumping These morphologic features influence surface and groundwater flow at the site

Surface water at OU-1 occurs only during precipitation and snow melt events, except in the interceptor ditch and the French Drain Surface runoff generally flows toward Woman Creek, but likely infiltrates, evaporates, transpirates, or encounters the interceptor ditch or French Drain before reaching Woman Creek Surface water in the interceptor ditch is directed toward collection ponds for sampling prior to discharge Surface water in the French Drain is directed to the water treatment system portion of the IM/IRA which removes organics and inorganics.

1 3 2 Hydrogeology

Groundwater hydrogeology has been a central component of the OU-1 RFI/RI The most recent interpretations in the Phase III RFI/RI report represent a comprehensive evaluation of the OU hydrogeology, based on eight years of investigation and monitoring Groundwater at OU-1 is present in various geologic materials including the unconsolidated surficial material and the bedrock. A significant permeability contrast occurs at the base of a weathered zone which typically exists within the upper 5 to 25 ft of the bedrock The weathered zone and overlying unconsolidated materials are generally 100 to 10,000 times more permeable than the underlying unweathered bedrock. This permeability contrast significantly limits the flux of groundwater into and through the unweathered bedrock (relative to the overlying materials), and consequently serves as the basis for defining two hydrostratigraphic units The upper hydrostratigraphic unit (UHSU) consists of saturated portions of the Rocky Flats Alluvium, colluvial material, valley fill alluvium, and weathered bedrock; groundwater in these materials is typically unconfined The lower hydrostratigraphic unit (LHSU) consists of saturated unweathered bedrock Groundwater in the unweathered bedrock can be confined or unconfined.

Over most of the site, groundwater flow in the UHSU occurs in disconnected northwest-southeast trending channels that have been scoured into the bedrock surface Groundwater in both the UHSU and LHSU flows from north to south, toward the Woman Creek paleovalley Bedrock highs and lithologic variability, notably the presence of clay lenses, act to retard the rate of groundwater flow Flow has also been observed in glide planes bounding the slump blocks Parts of OU-1, particularly in the eastern portion, contain groundwater only in the spring months when water table elevations are typically highest Groundwater levels across OU-1 are higher in spring than in the remainder of the year

Recharge to the UHSU is minimal, and occurs primarily through infiltration of precipitation Infiltration rates range from 2 inches per hour for initial infiltration, to 0.5 inches per hour for final (saturated) infiltration Localized sources of recharge include seepage from the Rocky Flats Alluvium to colluvial materials, and former recharge from the Building 881 footing drain, which has since been rerouted to the French Drain collection system Flow from this drain averages 3 5 gallons per minute (gpm) Discharge occurs largely through evapotranspiration and discharge at boundaries such as seeps, Woman Creek, the SID, and the French Drain (DOE 1994a)

From aquifer test data, the average linear flow velocity was estimated at 70 feet per year in the vicinity of IHSS 119.1, 8 feet per year in the vicinity of Building 881, and 180 feet per year within the Valley Fill Alluvium The volume of UHSU groundwater at OU-1 was estimated at 5 8 acre-feet in January 1992, and 5 acre-feet in April 1992 The decrease from January to April is largely due to the rerouting of the foundation drain which was a source of recharge in the western part of OU-1 (DOE 1994a). Water levels screened in the UHSU rise annually in response to spring recharge and decline during the remainder of the year (DOE 1994a)

The overall range of hydraulic conductivity values estimated for UHSU materials was 3×10^{-3} to 2×10^{-6} cm/sec The hydrologic data show a high degree of heterogenerity in the UHSU materials. The overall hydraulic conductivity for the LHSU ranges from 1.2×10^{-3} to $2\ 5 \times 10^{-9}$. Horizontal hydraulic conductivity values in bedrock appear to be 10 to 1,000 times greater than hydraulic conductivity values in the vertical direction

Groundwater level data in the vicinity of the French Drain suggest that the system is effective in capturing UHSU groundwater originating from OU-1. For example, data from most of the UHSU monitoring wells downgradient (south) of the French Drain were dry in April 1993, a month typified by high water table elevations (DOE 1994a)

1 4 Nature and Extent of Contamination

This section summarizes the results of the nature and extent of contamination at OU-1 as presented in the Phase III RFI/RI report Table 1-3 summarizes the contaminants identified in the Phase III RFI/RI report nature and extent assessment for the media of groundwater, surface soils, subsurface soils, surface water, and sediments The investigative programs for these media were designed to characterize the nature and extent of contamination in the vicinity of the eleven IHSSs, as well as the intervening areas of the 881 Hillside Area The resulting data indicate that many of the IHSSs are not sources of contamination. Furthermore, some sources occur outside of IHSS, or even OU-1 boundaries One of these situations involves surface soil contamination by americium and plutonium, which was shown in the Phase III RFI report to originate from within Operable Unit 2 (OU-2) Considering this scenario, all subsequent characterization and remedial activities related to surface soil contamination in OU-1 will be addressed under the OU-2 RFI/RI and CMS/FS programs

1 4.1 Volatile Organic Compounds

Volatile organic compounds (VOCs) are present in subsurface, soils and groundwater at OU-1 Chlorinated solvents occur sporadically in subsurface soils at the IHSSs Sources for VOCs in groundwater appear to correlate with elevated concentrations in subsurface soils. Toluene occurs throughout OU-1 in subsurface soils at relatively low concentrations. The nature and extent of the detections suggest the source of the toluene may be laboratory or field-introduced contamination—however, these hypotheses have not been confirmed.

Table 1-3.
Contaminants Identified in the RFI/RI by Media

Contaminant	Ground Water	Surface Soil[a]	Subsurface Soil[b]	Surface Water[b]	Sediment[b]
Volatile Organic Compounds					
Carbon Tetrachloride	X		X		
Chloroform	X		X		
1,1-Dichloroethane	X			X	
1,2-Dichloroethane	X		X	X	
1,1-Dichloroethene	X		X	X	
1,2-Dichloroethene	X			X	
cis-1,2-Dichloroethene	X				
Tetrachloroethene	X		X	X	
Toluene	X		X	X	X
Total Xylenes	X		X	X	
1,1,1-Trichloroethane	X		X	X	X
1,1,2-Trichloroethane	X				
Trichloroethene	X		X	X	
Metals					
Selenium	X				
Vanadium	X				
Radionuclides					
Americium		X	X	X	X
Uranium		X	X		
Plutonium		X	X	X	X
Polychlorinated Biphenyls (PCBs)					
AROCLOR-1248		X			
AROCLOR-1254		X			X

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Table 1-3.
(Continued)

Contaminant	Ground Water	Surface Soil[a]	Subsurface Soil[b]	Surface Water[b]	Sediment[b]
Polynuclear Aromatic Hydrocarbons (PAHs)					
Acenaphthene		X	X		
Acenaphthylene		X			
Anthracene		X	X		
Benzo(a)anthracene		X	X		
Benzo(a)pyrene		X	X		
Benzo(b)fluoranthene		X	X		X
Benzo(ghi)perylene		X	X		
Benzo(k)fluoranthene		X	X		X
Chrysene		X	X		X
Dibenzo(a,h)anthracene		X			
Fluoranthene		X	X		X
Fluorene		X	X		
Indeno(1,2,3-cd)pyrene		X	X		
2-Methylnaphthalene			X		
Naphthalene		X	X		
Phenanthrene		X	X		X
Pyrene		X	X		X

[a] Contaminants in surface soils are being addressed under OU-2

[b] Contaminants in shaded media did not result in a cancer risk greater than 10^{-6}, nor a hazard index greater than one

X- Contaminant is a COC which has been detected in the medium

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Groundwater chemistry data indicate VOCs occur in three general areas (DOE 1994a)

- South of Building 881
- IHSS 119 1 area
- Southeast of IHSS 119 2

Within these three areas (see Figure 1-4), concentration gradients and variations in analytes suggest that multiple release points are likely Random isolated detections of relatively lower concentrations (0 11 to 6 ug/l total VOCs) occur in the intervening areas Each of these areas is discussed in the following subsections

Area South of Building 881

Groundwater in the area south of Building 881 exhibits relatively low concentrations of chlorinated solvents (ranging up to 130 $\mu g/\ell$) The spatial distribution of these detections is quite random, suggesting potential multiple point sources Historical information corroborate this interpretation—the use or disposal of chlorinated compounds in discreet areas (including proximal IHSSs 145, 107, and 106) is not documented The maximum VOC detection, 130 $\mu g/\ell$ of 1,1,1-trichloroethane (1,1,1-TCA), occurred at well 0187. Although this well is immediately down-gradient of IHSS 145, a subsequent soil gas survey presented in the previous Phase I RFI/RI Report revealed no 1,1,1-TCA in the soil gas sample collected closest to well 0187

Soil gas survey results reveal a high concentration of tetrachloroethene (PCE) in soil gas approximately 30 feet southwest of well 5287 (DOE 1994b). This detection is the second highest out of several hundred soil gas samples collected at OU-1, and suggests a potential source for PCE in subsurface soils The detected concentration suggests the possible existence of residual or pooled dense non-aqueous phase liquid (DNAPL). However, PCE was not detected in groundwater samples collected from wells located immediately down-gradient of the soil gas detection (wells 5487/5387) suggesting that either the solvent release did not reach the water table (as a free phase wetting front) or that groundwater is not present at the location of

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the release These scenarios illustrate the sporadic nature and relatively low concentrations of VOCs in this area and suggest that multiple point sources exist south of Building 881

IHSS 119 1 Area

Documented waste storage practices at this IHSS included the release of chlorinated solvents Investigative activities confirm that these releases pose a continuing source for VOCs in groundwater VOC concentrations are highest in the southwest portion of this IHSS, an area exhibiting drummed waste in historical aerial photographs The Phase I soil gas survey identified several locations in this area which may represent discreet release points

A comparison of the chemical suite detected in groundwater at several locations within the drum storage area revealed at least two distinct chemical mixtures One is dominated by trichloroethene (TCE) and 1,1,1-TCA (well 0974) while the other is dominated by carbon tetrachloride (CCl_4) (well 1074)

Phase III RFI/RI results suggest VOCs occur in the form of DNAPLs in a zone directly beneath IHSS 119.1 An aqueous plume of TCE, TCA, and several other VOCs emanates from this DNAPL zone along the preferential groundwater flow pathway This pathway is currently being intercepted by the French Drain.

The historical maximum concentration of VOCs in groundwater at OU-1 occurred at well 4787, although detections at this well have been characteristically sporadic and have involved relatively low concentrations This probably reflects the effectiveness of the French Drain which was installed upgradient of well 4787. As discussed previously, most monitoring wells downgradient of the French Drain are dry.

Area Southeast of IHSS 119.2

Concentrations of chlorinated solvents detected in two closely-spaced monitoring wells downgradient of IHSS 119.2 (wells 6286 and 6386) are attributed to potential VOC release areas at both IHSS 119 2 and upgradient of the operable unit The occurrences of these VOCs in groundwater within the IHSS include one-time detections of 9.3 $\mu g/\ell$ in UHSU well 34791, and 0 1 $\mu g/\ell$ LHSU well 4587 Chloroform detections occurred three times in well 4587, with a maximum detection of 18 $\mu g/\ell$

Wells 6286 and 6386 exhibited VOC concentrations and are located in a drainage hydraulically downgradient from IHSS 119 2 Therefore a VOC release point is suspected in IHSS 119 2 and is shown on Figure 1-4 based on the location of suspected waste disposal features depicted on aerial photographs The size of this suspected VOC release point is uncertain It is speculated that contamination from the 903 Pad is also contributing to the VOCs detected in monitoring wells on the Hillside The 903 Pad is upgradient of the impacted wells and is known to be a source for CCl_4 and other dissolved chlorinated solvents in groundwater.

The occurrence of chlorinated solvents in subsurface soils in this area is limited to a detection of 140 μg/kg in borehole BH5887 The occurrence of VOCs in soil gas is limited to low levels of PCE and 1,1,1-TCA at one location within the IHSS However, the magnitude of the soil gas detections is several orders of magnitude less than those noted near Building 881 and IHSS 119 1 and are more representative of the local background around IHSS 119.2 Nevertheless, as was the case at IHSS 119 1, the presence of a VOC release point within IHSS 119.2 boundaries is suspected based on the downgradient groundwater chemistry

In summary, VOC contamination occurs in subsurface soils, soil gas, and groundwater at OU-1 The nature and extent of VOCs in these media indicate that three general source areas exist· (1) the area south of Building 881, (2) IHSS 119.1, and (3) IHSS 119 2. Other IHSSs in OU-1, and the intervening areas, occasionally exhibit random, low level concentrations which may reflect sources upgradient of OU-1

1.4.2 Metals

Metal contaminants detected at OU-1 include vanadium and selenium These metals were significantly elevated in groundwater, but not in subsurface soils. Historical information does not indicate that these metals associated with wastes stored or disposed of at OU-1, but elevated concentrations in areas where VOC wastes were stored It is unlikely that these metals were leached from the soil by organic wastes disposed of at OU-1 since hydraulic oil and chlorinated solvents have poor chelation properties, and are not strongly acidic or basic Four areas have been identified at OU-1 with elevated selenium and/or vanadium as discussed below

IHSS 119 1 Area

Multiple detections of selenium and vanadium were noted in monitoring wells located in the southwestern portion of IHSS 119.1 (Figure 1-5) Typically, the elevated metals were seen in association with VOCs In particular, the highest metal concentration (2200 $\mu g/\ell$ of Se) was detected in a well with one of the highest VOC concentrations anywhere at OU-1 (Well 1074) The maximum downgradient extent of selenium in groundwater at IHSS 119.1 appears to be in the vicinity of well 0487. The occurrence of vanadium is similar to selenium except that vanadium only occurs above background in UHSU wells.

Area South of Building 881

One detection of vanadium was noted at well 5387 at approximately six times the background level of 30 mg/ℓ This well exhibits concentrations of various chlorinated compounds in the 1 to 25 $\mu g/\ell$ range Several potential VOC source areas have been identified in the area south of Building 881, however well 5387 is not particularly close to the suspected source areas. Nevertheless, it is conceivable that the vanadium present in groundwater at 5387 represents a plume originating from one of the VOC source areas previously discussed. The extent of vanadium concentrations above background near Building 881 appears to be limited to the immediate vicinity of well 5387.

Area East of IHSS 102

One detection of vanadium and three detections of selenium were noted above the background level in well 6986 No detections of VOCs have been noted at this well It is unclear whether these detections represent contamination or naturally occurring levels as the maximum vanadium and selenium concentrations represent 126 percent and 194 percent of background, respectively Based on these relatively low levels, a contaminant source is not suspected in this area

Southeast Corner of IHSS 130

Vanadium is the only contaminant detected at this location over background levels A maximum of 403 $\mu g/\ell$ was detected at well 37191 which represents approximately five times the background level Only exceedingly low levels of VOC contamination ($<0.5\ \mu g/\ell$) were found in association with the vanadium The extent of vanadium and selenium contamination in the southeast corner of IHSS 130 appears to be limited to the immediate vicinity around well 37191

In summary, metals detected at OU-1 were selenium and vanadium These metals are found above background levels primarily in groundwater Detections occurred in four areas IHSS 199 1, IHSS 119 2, south of building 881, and east of IHSS 102

1 4 3 Semivolatile Organic Compounds

The only semivolatile organic compounds (SVOCs) identified at OU-1 are PAHs and PCBs PAHs occur over most of OU-1, but are limited to surface soils; concentrations tend to decrease with depth In the Phase III RFI/RI, PAHs are generally not considered to be of OU-1 origin. However, asphalt and residues from a fire reportedly disposed in IHSS 130 (DOE 1994a) may be a source for PAHs. PAHs have also been detected in sediments. Several areas of OU-1 have been identified where PAHs appear more concentrated relative to the surrounding area. These areas, however, do not coincide with IHSS locations Given this distribution, the sources for the PAHs at OU-1 are presumed to be general urban fallout including asphalt dust and larger

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particles, vehicle exhaust, furnace exhaust, and fires on plant site. Similar distributions of PAHs occur at other OUs at RFETS, corroborating this presumption.

PCBs occur primarily in IHSSs 106, 119.1 and 119 2 surface and subsurface soils; generally lower concentrations were randomly detected in surrounding areas The contaminant release mechanism for PCBs is unknown One PCB detection has also been noted in sediments, however, the observation was at the western OU-1 boundary, upgradient of the OU-1 source areas For this reason, PCB occurrence is not considered to be of OU-1 origin

1 4 4 Radionuclides

Americium, plutonium, and uranium have been identified as OU-1 contaminants and are elevated in surface and subsurface soils In addition, plutonium and americium are elevated in surface water and sediment The widespread plutonium and americium contamination in surface soil appears to be a result of deposition of wind-disseminated plutonium/americium-contaminated dust originating from the 903 Pad Area Consistent with this hypothesis, there is a general decrease in activities from east to west (ranging from a maximum of 22 7 pCi/g to 0.0076 pCi/g of plutonium and 4 15 pCi/g to 0 0129 pCi/g of americium). As mentioned earlier, since the source of uranium contamination is surface soils is located in OU-2, this contamination will be addressed by the OU-2 RFI/RI and CMS/FS programs

In contrast to the wide-spread plutonium/americium contamination, localized "hotspots" of plutonium/americium or uranium are present at OU-1. These "hotspots" are postulated to reflect releases of radionuclide-contaminated liquids stored in drums at OU-1, and have been addressed through an early removal action discussed in section 1.7. Areas within IHSS 130 contain low activities of americium and plutonium above the upper tolerance limit (UTL) in the shallow subsurface soils indicating a near surface, widespread source. Localized areas within the IHSS do contain low activities of plutonium and americium above the UTL at depth

Unlike plutonium and americium, uranium contamination is not wide-spread. Instead, uranium occurs at discrete locations in surface and subsurface soils at OU-1. In some areas, uranium-

233,-234/uranium-238 ratios of approximately 1 to 2 suggest detections represent naturally occurring uranium In other areas, uranium-233,-234/uranium-238 ratios are higher, suggesting contamination by enriched uranium As is the case for other radionuclides, surface soil contamination by uranium will be addressed by the OU-2 RFI/RI and CMS/FS programs

Aside from areas within IHSS 130, the distribution of radionuclides at OU-1 appear random, rather than correlating with the IHSSs

1 4 5 Summary of Nature and Extent of Contamination

In summary, contaminant groups represented in OU-1 media include VOCs, SVOCs, PCBs, metals and radionuclides One or more contaminants from these groups has impacted surface soils, subsurface soils, surface water, sediments, or groundwater The distribution of these contaminants in these media is largely random, only IHSSs 119 1, and 119.2, and the area south of Building 881, exhibit clear evidence for consideration as sources IHSSs 102, 130, and 106 also exhibit contamination, but the nature and distribution of detections in these areas is indicative of potential background contamination or off-site sources

1 5 Fate and Transport of Contaminants

This section discusses potential mechanisms by which contaminants identified in the Phase III RFI/RI can migrate. Although several mechanisms are identified in the following sections, the groundwater medium is the most significant pathway. Figure 1-6 depicts potential groundwater migration pathways Note that this figure does not represent the volume and velocity of groundwater flow in these pathways Many areas of OU-1 are currently dry and remain dry throughout the year. The migration pathways presented in the figure present potential pathways assuming adequate groundwater is present.

1.5.1 Volatile Organic Compounds

The release mechanisms for VOCs at OU-1 are varied and include product leakage from stored drums, possible leakage of dilute aqueous solutions of VOCs from pipelines, and seepage of aqueous VOC solutions or product from impoundments and disposal pits In the area south of Building 881, a release mechanism may include leaking sanitary sewer lines (IHSS 145) In the western portion of OU-1 (IHSS 119.1), the release mechanism is most likely leakage from drums stored on the land surface

Once the contaminant has entered the subsurface the pathways for VOC migration include gravity driven wetting fronts of aqueous solutions and/or small volumes of product through the vadose zone to the water table In the case of product, otherwise known as non-aqueous phase liquid (NAPL), the density and relative immiscibility of chlorinated solvent can result in vertical migration of non-aqueous phase contamination through the saturated zone This vertical non-aqueous phase migration can be arrested if the geologic material retains the NAPL as residual or if impermeable material is encountered In either case, dissolution to groundwater from residual or pooled NAPL can form an aqueous phase plume Precipitation and infiltration would also contribute to VOC migration as chlorinated solvents are dissolved and transported downward by infiltrating snowmelt and rainwater

Dissolved phase contaminants migrate in the direction of groundwater flow The rate of migration is dependent on the groundwater velocity and the affinity (or attraction) to the geologic materials In the case of OU-1, the migration rates of organic contaminants identified in the Phase III RFI/RI report are retarded, relative to the groundwater velocity, due primarily to relatively elevated attraction to the clayey materials. Retardation is particularly significant for OU-1 contaminants with high octanol-water partition coefficient (K_{ow}) values like CCl_4 (DOE 1994a).

At OU-1, UHSU groundwater flow patterns are controlled to a large degree by the topography of the bedrock surface. Active channels in the bedrock are covered by unconsolidated material of varying thickness that is variably saturated Typically, groundwater will flow towards the axis of the bedrock channel and continue downgradient along the axis of the channel toward the south The existing French Drain acts as a hydraulic barrier which intercepts contaminated groundwater in the western and central portions of OU-1 prior to reaching Woman Creek In the eastern portion of OU-1, where the French Drain does not extend, the potential for contaminant migration to Woman Creek exists, but has not been confirmed

VOC-contaminated groundwater may also discharge to surface water through seeps which have historically been observed at OU-1 (DOE 1994a) While VOCs in surface water have been previously detected in the SID, the more recently constructed French Drain has intercepted this pathway

Other migration pathways for VOCs include volatilization of product into soil gas and subsequent migration of soil gas laterally and vertically away from the source area VOCs can also partition out of contaminated groundwater into soil gas move from soil gas into groundwater, or desorb from geologic material into soil gas. Considering the volatile nature of VOCs, they should not migrate in significant quantities through surface water or via wind transport of VOC contaminated surface soil

1 5 2 Metals

The mechanism for the release of metal contaminants into the environment is less clear than for VOCs Selenium and vanadium are undocumented RFETS contaminants that are presumed to be associated with the VOC wastes stored and disposed of at OU-1 It is unlikely that selenium and vanadium were leached from the soil by organic wastes disposed of at OU-1 since hydraulic oil and chlorinated solvents have poor chelation properties, and are not strongly acidic or basic Nevertheless, the potential for leaching of these metals exists. Alternatively, these constituents may be naturally occurring; however, there is insufficient data to support either conclusion In either case, the primary migration pathway is as a dissolved phase contaminant plume in groundwater This migration is the same pathway discussed in Section 1 5.1 for VOCs

1.5 3 Semivolatile Organic Compounds

It is presumed that PAHs were deposited at OU-1 from fallout of combustion products or wind blown asphalt dust Asphalt dust and larger particles may also have been transported and deposited by vehicles traversing OU-1 or by disposal of asphalt waste at OU-1

Once in place, the dispersion mechanisms for PAHs include vertical migration by infiltrating surface water carrying dissolved PAHs or small particles with sorbed PAHs The low solubility and high organic carbon partition coefficient (k_{oc}) values of PAHs limit mobilization of significant quantities in the dissolved form, and a direction of particulate matter through the porous media at OU-1 is unlikely to transport significant non-aqueous PAH mass Therefore, PAH transport via groundwater at OU-1 is not significant Other transport mechanisms include surface water and wind transport of particulate, but soil and sediment data indicate these migration pathways are also insignificant for PAH transport

Transport mechanisms for PCBs are similar to those for PAHs PCBs are expected to be very immobile given the high k_{oc} values and the high carbon and clay content in surface soils at OU-1 Adsorption of PCBs at OU-1 is expected to be substantial on soils and clay particles (DOE 1994a)

1.5 4 Radionuclides

Transport mechanisms relevant to radionuclides are similar to PAHs In particular, plutonium has a strong affinity for the solid phase and will not be readily mobilized by precipitation and infiltration Plutonium is strongly adsorbed to clay particles and is expected to undergo strong cation-exchange reactions due to its strong positive charge (DOE 1994a) The primary transport mechanism for plutonium is wind dispersion

1 5 5 Summary of Fate and Transport of Contaminants

The primary mode of contaminant transport at OU-1 is through groundwater The distribution of contaminants in groundwater illustrates the flow directions and pathways which trend south towards Woman Creek These pathways are intercepted by the French Drain system prior to reaching Woman Creek, except possibly in the far eastern portion of OU-1 Chemical data indicate that the pathways transport contaminants from three primary source areas IHSS 119 1, 119 2, and south of building 881 Groundwater contamination outside of these pathways is random and generally involves relatively low concentrations

1 6 Baseline Risk Assessment

The OU-1 Baseline Risk Assessment (BRA) consists of both a public health evaluation and an environmental evaluation The primary purpose of each evaluation is to examine the current and future risks associated with contaminants identified during the analysis of the nature and extent of contamination The following subsections summarize each evaluation and provide an overall summary of the risks associated with OU-1

1 6 1 Public Health Evaluation

During the course of the Public Health Evaluation (PHE), site, population, and land use data were analyzed in order to devise several representative exposure scenarios (potentially exposed receptors) for assessing the risk to current and future human health from identified contaminants at the 881 Hillside Area For each of these scenarios, pathways were analyzed which represented exposure routes from the source to potential receptors

Pathway elements were examined relative to the results of the Phase III field investigation which indicated that contamination exists in the following media. groundwater, surface soils, subsurface soils, sediments, and surface waters The contaminants identified in these areas included VOCs, PAHs, PCBs, inorganic contaminants, and radionuclides. The contaminant release mechanisms evaluated for OU-1 included leaching, volatilization, and resuspension of particulates by wind Potential transport media identified were surface water, groundwater, air, soil, and biota The exposure route (the route of entry into the human body) for these media included ingestion, inhalation, and dermal contact In accordance with the *Risk Assessment Guidance for Superfund, Volume I - Human Health Evaluation Manual (Part A)* (EPA 1989a), if any of the above-mentioned pathway elements is missing, the projected receptor will not receive a chemical or radionuclide dosage and no excess risk will exist from that contaminant

The OU-1 physical environment, including the French Drain and treatment system, was considered with information about the potentially exposed population, land use scenarios, and exposure pathways to form the conceptual site model This was evaluated to identify complete pathways for credible and plausible exposure scenarios The following list describes specific exposure scenarios, and associated pathways, that were selected for quantitative assessment

- Current Off-Site Resident
  - Inhalation of airborne particulates
  - Soil ingestion (following deposition of particulates on residential soil)
  - Dermal contact with soil (following airborne deposition of particulates)
  - Ingestion of homegrown vegetables/fruit (following surface disposition and uptake of particulates)
- Current On-Site Worker
  - Inhalation of airborne particulates
  - Soil ingestion
  - Dermal contact with soil
  - Sediment ingestion
  - Dermal contact with sediment
  - Surface water ingestion
  - Dermal contact with surface water
- Future On-Site Worker
  - Inhalation of VOCs in indoor air (office worker only) and outdoor air (construction worker only)
  - Inhalation of airborne particulates
  - Soil ingestion
  - Dermal contact with soil
  - Sediment ingestion (office worker only)

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— Dermal contact with sediment (office worker only)
— Surface water ingestion (office worker only)
— Dermal contact with surface water (office worker only)

- Future On-Site Ecological Researcher

  — Inhalation of airborne particulates
  — Soil ingestion
  — Dermal contact with soil
  — Sediment ingestion
  — Dermal contact with sediment
  — Surface water ingestion
  — Dermal contact with surface water

- Future On-Site Resident

  — Inhalation of indoor VOCs from basement vapor
  — Inhalation of particulates
  — Soil ingestion
  — Dermal contact with soil
  — Sediment ingestion
  — Dermal contact with sediment
  — Surface water ingestion
  — Dermal contact with surface water
  — Ingestion of homegrown vegetables/fruit (following surface deposition of particulates and uptake).

The results of the BRA indicate that only the media of groundwater and surface soils present a risk greater than the acceptable risk range of 10^{-4} to 10^{-6}. The risk to a human receptor from exposure to groundwater contaminants of concern (COCs) is driven primarily by the exposure routes of ingestion, and inhalation of volatiles. For a future on-site resident, this risk is on the order of 10^{-3} to 10^{-2}, but applies only to exposures occurring directly at IHSS 119.1

The risk to a human receptor from exposure to surface soil COCs is driven primarily by the exposure routes of ingestion of vegetables, and inhalation of particulates. For a standard future on-site resident, this risk is on the order of 10^{-3}. It should be noted, however, that this risk is based on OU-1 sitewide average radionuclide concentrations These average radionuclide concentrations include a few areas of high contaminant concentrations (i.e., "hotspots") that are limited in extent and only exist within the boundaries of IHSSs 119.1 and 119.2 These hotspots

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were remediated under an early removal action for OU-1 to measured (local) background concentrations The risk to a future on-site resident, excluding the hotspots, is much lower than calculations indicate when including the hotspots Risk results are summarized in Tables 1-4 and 1-5

1 6 2 Environmental Evaluation

As part of the overall BRA, an environmental evaluation (EE) conducted to ascertain whether contamination resulting from RFETS activities in OU-1 may have impacted or could adversely impact ecological receptors in the vicinity Ecological receptors are operationally defined as plants and animals other than humans and domesticated species

COCs were selected for the EE based on a comparison of maximum concentrations of OU-1 contaminants to benchmark values. COCs identified in the EE include VOCs, PAHs, PCB, radionuclides, and selenium The EE evaluated the impact that these COCs had on the following endpoints

- Vegetative Community
- Small Mammal Community
- Mule Deer Population
- Toxic Exposure to Top Predators

The results of the EE indicate that the concentrations of VOCs in groundwater, and PAHs and PCBs in soils are potentially toxic to ecological receptors, however, the restricted distribution of these contaminants limits the duration and frequency of contact with receptors and therefore limits exposures

1 6 3 Risk Summary

As indicated by the PHE portion of the BRA, risks to human receptors at OU-1 are primarily associated with exposure to groundwater COCs Although this medium is not available for

Table 1-4.
Summary of OU-1 Point Estimates of Carcinogenic Risk

Scenario	Total Excess Cancer Risk	Dominant COC[a]	Dominant Pathway
Current			
On-Site Worker (Security Specialist)	1×10^{-4}	Plutonium-239, -240	Inhalation of dust
Off-Site Resident (Adult)	2×10^{-6}	Plutonium-239, -240	Inhalation of dust
Standard Future			
Future On-Site Worker (Office)	2×10^{-3}	Plutonium-239, -240	Inhalation of dust
Future On-Site Worker (Construction)	4×10^{-7}	1,1-Dichloroethene	Inhalation of volatiles
On-Site Ecological Researcher	2×10^{-3}	Plutonium-239, -240	Inhalation of dust
On-Site Resident (Adult)	3×10^{-3}	Plutonium-239, -240	Inhalation of dust
Other Future			
On-Site Resident (Adult) (Sitewide With Groundwater)	6×10^{-3}	1,1-Dichloroethene	Ingestion of groundwater
On-Site Resident (Adult) (Assuming Adequate Groundwater At Source)	7×10^{-2}	1,1-Dichloroethene	Ingestion of groundwater
On-Site Resident (Adult) (Groundwater At Source With Public Water)	4×10^{-2}	Plutonium-239, -240	Inhalation of dust
On-Site Resident (Adult) (Without Source/Without Groundwater)	5×10^{-5}	Dibenzo(a,h)anthracene	Ingestion of vegetables

[a] Plutonium concentrations are biased high by the presence of several hotspots which have been removed under an early removal action

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Table 1-5.
Summary of OU-1 Point Estimates of Noncarcinogenic Risk

Scenario	Total Hazard Index		Dominant COC	Dominant Pathway
	Child	Adult		
Current				
On-Site Worker (Security Specialist)	N/A	8×10^{-5}	Pyrene	Dermal contact with soil
Off-Site Resident	1×10^{-7}	6×10^{-8}	Fluorene	Ingestion of vegetables
Standard Future				
Future On-Site Worker (Office)	N/A	3×10^{-3}	1,1,1-Trichloroethane	Inhalation of volatiles through foundation
Future On-Site Worker (Construction)	N/A	1×10^{-4}	1,1,1-Trichloroethane	Inhalation of volatiles during excavation
On-Site Ecological Researcher	N/A	2×10^{-3}	Pyrene	Dermal contact with soil
On-Site Resident	2×10^{-2}	5×10^{-3}	1,1,1-Trichloroethane	Inhalation of volatiles through foundation
Other Future				
On-Site Resident (Sitewide With Groundwater)	$2 \times 10^{+1}$	9×10^{0}	Carbon Tetrachloride	Ingestion of groundwater
On-Site Resident (Assuming Adequate Groundwater At Source)	$3 \times 10^{+2}$	$1 \times 10^{+2}$	Carbon Tetrachloride	Ingestion of groundwater
On-Site Resident (Groundwater At Source With Public Water)	$3 \times 10^{+1}$	$1 \times 10^{+1}$	Carbon Tetrachloride	Ingestion of groundwater
On-Site Resident (Without Source/Without Groundwater)	7×10^{-3}	3×10^{-3}	Fluorene	Ingestion of vegetables

current residential use, this scenario presents the highest, and only, unacceptable risk per the NCP guideline of 10^{-4} to 10^{-6} Environmental risks currently have not been identified by the Phase III RFI/RI and therefore do not warrant further examination

OU-1 risks are a result of widespread contamination found in low concentrations and in various media throughout the site The Phase III RFI/RI results indicate that for the most part individual IHSSs cannot be associated directly with any one contaminant group or area Table 1-6 lists the primary contaminants present at each IHSS IHSS 119 1, 119 2, and the area south of Building 881, represent the primary sources for contaminant migration

1 7 Interim Measures/Interim Remedial Actions

The IM/IRA that was completed for OU-1 consists of a French Drain designed to collect contaminated alluvial groundwater from the operable unit and to prevent further downgradient migration of contaminants The IM/IRA included a geotechnical investigation that was performed in order to evaluate the site characteristics along the proposed French Drain alignment (EG&G 1990) Construction of the French Drain began in November 1991 and was completed in April 1992 The water treatment plant located in Building 891 is part of the IM/IRA and will be converted to sitewide uses Hereinafter this plant is referred to as the Building 891 water treatment plant

The French Drain was constructed by excavating a trench approximately 1,435 feet in length (DOE 1994a). The trench was keyed into bedrock material that exhibited a hydraulic conductivity on the order of 1 x 10^{-6} cm/sec A permeable membrane was placed on the upgradient side of the drain and an impermeable polyvinyl chloride membrane was placed on the downgradient side of the drain. A perforated pipe was placed along the drain to collect groundwater, and the drain was backfilled with gravel and then soil. Currently, groundwater collected from the drain is fed into an ultraviolet and hydrogen peroxide (UV/H_2O_2) treatment unit for treatment of organic compounds. Inorganic contaminants are removed via a series of ion exchange columns.

Table 1-6.
Summary of Primary IHSS Contaminants

IHSS Number	Primary Contaminants[a]	Disposition
102	Groundwater contaminated with PCE and TCE	Considered in Building 881 Area
103	Possible groundwater and subsurface soils contaminated with low levels of PCE and TCE	Considered in Building 881 Area
104	Potential toluene in subsurface and groundwater, wide array of PAHs	Not identified as a source - no action required
105 1 & 105 2	Low levels of VOCs in groundwater, PCE detected below detection limit, potential solvent contamination in soils at north end	Considered in Building 881 Area, although not identified as a source
106	Groundwater contaminated with chlorinated solvents, potential solvent contamination in soils at north end	Considered in Building 881 Area, although not identified as a source
107	Groundwater contaminated with chlorinated solvents	Considered in Building 881 Area, although not identified as a source
119 1 & 119 2	Groundwater contaminated with chlorinated solvents and selenium, possible DNAPL sources in subsurface, radionuclide hotspots	Considered under IHSS 119 1 and Area East of 119 2
130	Radionuclide-contaminated soil and asphalt, PAHs in subsurface soils	No risk pathway for rads and PAHs in subsurface soils - no action required, Not identified as a source of VOCs
145	Groundwater contaminated with chlorinated solvents, potential low level rad contamination	Considered in Building 881 Area, although not identified as a source

[a] Radionuclide and PAH contamination in near surface soils is being addressed under OU-2.

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2.0 IDENTIFICATION AND SELECTION OF TECHNOLOGIES AND REPRESENTATIVE PROCESS OPTIONS

This section summarizes the results of the identification, and selection of technologies and representative process options used in the development of remedial action alternatives for OU-1 Technologies and representative process options were identified, screened, evaluated, and then selected for further evaluation in the CMS/FS This sequential task is outlined and discussed in both CERCLA RI/FS and RCRA CAP guidance Briefly summarized, EPA guidance identifies the following elements for selecting representative process options

- Identify list of contaminants of concern
- Develop media-specific RAOs
- Identify Preliminary Remediation Goals (PRGs)
- Develop media-specific GRAs
- Identify volumes and/or areas of the media for GRAs
- Identify and screen technologies and process options applicable to each GRA
- Evaluate process options within each technology type to select a representative option for developing remedial action alternatives

2 1 Contaminants of Concern

The list of contaminants identified in the Phase III RFI/RI nature and extent assessment is summarized in Section 1.0 of this report Potential contaminants identified early in the RFI/RI process were subjected to a multi-level screening process that resulted in public health and ecological COCs for inclusion in the PHE and EE. The screening process shortened the list of potential contaminants that are also risk contributors. Contaminants that survived the risk-based screening process are designated as COCs in the BRA

The COCs screened in the PHE and EE were·

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- carbon tetrachloride
- 1,1-dichloroethene
- tetrachloroethene
- 1,1,1-trichloroethane
- trichloroethene
- toluene
- selenium
- PAHs
- PCBs
- americium
- plutonium
- uranium

The screening of COCs for significant risk to ecological receptors found that none of these contaminants contribute a significant risk to ecological receptors In addition, adverse impacts to the environmental receptors have not been identified in the EE Therefore COCs for ecological receptors are not further evaluated in this report

The screening of the contaminants for human health risk found some contaminants do contribute a significant risk The risks associated with some of the contaminants in groundwater exceed 10^{-4} for future residential receptors within the OU-1 boundaries The following groundwater COCs are identified at IHSS 119 1

- carbon tetrachloride
- 1,1-dichloroethene
- tetrachloroethene
- 1,1,1-trichloroethane
- selenium.

These COCs only represent a portion of the contaminants identified at OU-1 The complete list, presented in Section 1 0, will be examined relative to remedial action alternatives

2 2 Remedial Action Objectives

RAOs were formulated using appropriate regulatory guidelines (i.e., EPA RI/FS and CAP guidances and the NCP) and by examining the relevant COCs and their associated exposure

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pathways. In general, RAOs are contaminant- and medium-specific goals for protecting human health and the environment In developing appropriate RAOs, guidance states that "...objectives should be as specific as possible but not so specific that the range of alternatives that can be developed is unduly limited " In order to quantify RAOs, PRGs were developed that provide an identification of what an acceptable contaminant level or range of levels would be for each exposure route of concern Note that a risk range is presented for those RAOs that specify a protectiveness level The range is necessary since PRGs are typically estimated based on a risk level of 1 x 10^{-6} for each contaminant Depending on the number of contaminants present, the summed residual risk may therefore be slightly higher than 1 x 10^{-6}, hence the defined acceptable range.

Review of the groundwater COCs and the associated exposure pathways resulted in the following RAOs

1) Prevent the inhalation of, ingestion of, and/or dermal contact with VOCs and inorganic contaminants in OU-1 groundwater that would result in a total excess cancer risk greater than 10^{-4} to 10^{-6} for carcinogens, and/or a hazard index greater than or equal to 1 for non-carcinogens

2) Prevent migration of contaminants from subsurface soils to groundwater that would result in groundwater contamination in excess of potential groundwater ARARs for OU-1 contaminants

3) Prevent migration of contaminants in OU-1 groundwater from adversely impacting surface water quality in Woman Creek

These RAOs have been used to determine the area or areas within OU-1 requiring remedial action evaluation The RAOs have been further quantified through the development of PRGs

2.3 Preliminary Remediation Goals

This section presents the sources of information used for identifying appropriate PRGs for OU-1 PRGs are generally identified through use of "readily available information, such as chemical-specific ARARs or other reliable information" (EPA 1990a). Where ARARs or "to-be-considered" (TBC) criteria are not available, PRGs are developed on the basis of a 10^{-6} point-of-departure risk for each chemical within a given medium. This also applies when ARARs are not considered sufficiently protective because of the presence of multiple contaminants or multiple pathways of exposure

Note that PRGs developed at this stage are considered initial goals which may be modified through the course of the CMS/FS Final remediation goals are not selected until the remedy selection phase of the CMS/FS, according to the NCP requirements The ARARs presented in Section 2 3, as well as the risk-based PRGs, can be considered initial cleanup goals, however, exact criteria for final remediation will be selected as the CERCLA process proceeds Either set of criteria could be used, a combination could be used, or revised PRGs could be used, if necessary The decision as to whether or not revised PRGs are required is based on the criteria described in the preamble to the NCP (55 Federal Register [FR] 8717, March 8, 1990) which states that,

> Preliminary remediation goals may be revised based on the consideration of appropriate factors including, but not limited to exposure factors, uncertainty factors, and technical factors

Referring to the detailed analysis of alternatives, the preamble also states that,

> The final selection of the appropriate risk level is made when the remedy is selected based on the balancing criteria

Generally, chemical-specific ARARs take precedence over risk-based PRGs, however, as noted above, final cleanup goals will depend on a variety of factors and will be agreed upon by the participating agencies (i e , DOE, EPA and CDPHE)

2.3 1 Definition of Applicable or Relevant and Appropriate Requirements

CERCLA Section 121(d)(2), provides a statutory basis for determining ARARs in a remedial action context Concerning hazardous substances, pollutants, or contaminants that will remain on site,

> If any standard, requirement, criteria or limitation under any federal environmental law or any [more stringent] promulgated standard, requirement, criteria or limitation under a state environmental or facility siting law is legally applicable to the hazardous substance concerned or is relevant and appropriate under the circumstances of the release or threatened release of such hazardous substance, pollutant or contaminant, the remedial action shall require, at the completion of the remedial action, a level or standard of control for such hazardous substance, pollutant or contaminant which at least attains such legally applicable or relevant and appropriate standard, requirement, criteria or limitation [42 United States Code (USC) -----§ 9621(d)(2)]

where "applicable requirements" are those

> cleanup standards, standards of control, or other substantive environmental protection requirements, criteria or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable

According to the NCP and the *CERCLA Compliance with Other Laws Manual* (EPA 1988b)

> Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, or state environmental or facility siting laws that, while not applicable to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site so that their use is well suited to the particular site Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

Potential chemical-specific ARARs have been identified in accordance with CERCLA guidance and the requirements of the NCP [see Title 40 Code of Federal Regulations (CFR) Part 300, Subsection 430(e)(2)(i)] Chemical-specific requirements under a variety of Federal and state laws were reviewed to identify potential groundwater chemical-specific ARARs

The NCP also requires an evaluation of current or potential uses of the groundwater, as part of the determination of ARARs (40 CFR 300 430(e)(2)(i)(A)(3) The groundwater classification at RFETS is discussed in the context of current and potential future uses of groundwater beneath OU-1

2 3 2 Current Groundwater Classification

The Colorado Water Quality Control Commission (CWQCC) designated the Quaternary and Rocky Flats Aquifers beneath the RFETS as domestic use quality, agricultural use quality and surface water protection according to 3 12 7 of 5 Colorado Code of Regulations (CCR) 1002-8 The intent of these classifications "is to protect specified groundwater from uncontrolled degradation and thereby protect existing and future uses of groundwater "(5 CCR 1002-8, Subsection 3 11 9)

2 3 3 Selection of Groundwater PRGs

Various laws and regulations have been reviewed for general applicability in the search for potential groundwater cleanup standards at the OU-1 site The laws and regulations reviewed are

- Safe Drinking Water Act and the implementing Federal and State programs (40 CFR 140, 141 and Colorado Revised Statutes (CRS) 25-1-107-109, 25-1-114, and 24-4-104 through 105, including the State drinking water regulations
- Resource Conservation and Recovery Act and the State's implementing regulations (6 CCR 1007-3), and
- State Water Quality Control Act and the groundwater quality implementing regulations

(5 CCR 1002-8, 3 11 0 and 3 12 0)

Table 2-1 identifies the numerical standards associated with each of the regulations related to quality of groundwater Further review of each set of related groundwater regulations and the guidance established specific to the NCP regulations (40 CFR 300 430 (d)(2)(i)), refined this list of potential numerical standards The most stringent numeric standards that have been promulgated and which meet the definition of general applicability in 40 CFR 300.400(g)(4) are the State Groundwater Standards in 5 CCR 1002-8, 3 11 5 The maximum contaminant levels (MCLs) established in the State and Federal drinking water program are less stringent than the State Basic Standards for Groundwater The Resource Conservation and Recovery Act groundwater protection standards do not include MCLs for most of the contaminants of concern at OU-1 Therefore, the State Basic Standards for Groundwater were selected as the potential chemical-specific ARARs The numeric site-specific standards in 5 CCR 1002-8, 3 12 0 are to be considered in the evaluation of remediation alternatives for OU-1

The statewide standards for groundwater are identified as the initial PRGs for OU-1 and are presented in Table 2-2

2 4 General Response Actions

GRAs are general response strategies that are designed to satisfy remedial action objectives Examples of GRAs include treatment, containment, excavation, and extraction GRAs are medium-specific and therefore, a list of GRAs are developed for each medium of concern GRAs were identified for the groundwater medium at OU-1 because contaminants of concern and PRGs are focused on this medium Since subsurface soils are a potential continual source of groundwater contamination, subsurface soil GRAs were also developed which seek to protect groundwater from possible residual contamination

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Table 2-1
Comparison of Potential Chemical-Specific ARARs
($\mu g/\ell$)

Chemical	Federal MCL[1]	Federal MCLG[2]	State RCRA Groundwater Protection Standards[3]	State MCL[4]	State Basic Standards for Groundwater[5]	State Site-Specific Standards for Groundwater[6]			CDPHE PQL[7]
						Table 1 Human Health	Table 3 Agriculture	Table 5 Chronic	
Volatile Organic Compounds									
Carbon Tetrachloride	5	0	—	5	0 3	—	—	—	1
Chloroform	<100	—	—	<100	6	—	—	0 19	1
1,1-Dichloroethane	—	—	—	—	—	—	—	—	—
1,2-Dichloroethane	5	0	—	5	0 4	—	—	—	1
1,1-Dichloroethene	7	7	—	7	7	—	—	—	1
1,2-Dichloroethene	—	—	—	—	—	—	—	—	1
cis-1,2-Dichloroethene	70	70	—	70	70[a]	—	—	—	1
Tetrachloroethene	5	0	—	5	5	—	—	0 8	1
Toluene	1,000	1,000	—	1,000	1,000	—	—	—	1
Total Xylenes	10,000	10,000	—	10,000	10,000[a]	—	—	—	1
1,1,1-Trichloroethane	200	200	—	200	200	—	—	—	1
1,1,2-Trichloroethane	5	3	—	5	3	—	—	0 6	1
Trichloroethene	5	0	—	5	5	—	—	—	1
Semi-Volatile Organic Compounds									
Naphthalene	—	—	—	—	—	—	—	—	—

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Table 2-1
(Continued)

Chemical	Federal MCL[1]	Federal MCLG[2]	State RCRA Groundwater Protection Standards[3]	State MCL[4]	State Basic Standards for Groundwater[5]	State Site-Specific Standards for Groundwater[6]			CDPHE PQL[7]
						Table 1 Human Health	Table 3 Agriculture	Table 5 Chronic	
Metals									
Selenium	50	50	10	50	—	10	—	20	—
Vanadium	—	—	—	—	—	—	—	100	—

[1] National Primary Drinking Water Regulations, 40 CFR 141
[2] Maximum Contaminant Level Goals, 40 CFR 141 50
[3] 6 CCR 1007-3, 264 94
[4] CRS 25-1-107, 25-1-108, 25-1-109, and 25-1-114
[5] CDPHE/WQCC, Basic Standards for Groundwater, 3 11 0
[6] CDPHE/WQCC, Classification and Water Quality Standards for Ground Water, 3 12 0
[7] PQLs from CDPHE/WQCC, Basic Standards for Groundwater, 3 11 0
[a] Listed as drinking water MCL in State groundwater standards Table A

Table 2-2.
Comparison of Existing Concentrations and Groundwater PRGs
(State Basic Standards for Groundwater)
($\mu g/\ell$)

Chemical	Existing Concentration (grand mean)[1]	IHSS 119.1 Concentration (grand mean)[1]	Preliminary Remediation Goal[2]
Volatile Organic Compounds			
Carbon Tetrachloride	81 20	360 6	1[a]
Chloroform (total trihalomethanes)	4 68	16	6
1,1-Dichloroethane	2 10	4 94	1,010[b]
1,2-Dichloroethane	6 10	3 7	1[a]
1,1-Dichloroethene	283 23	1,270	7
1,2-Dichloroethene	N/A	N/A	328[b]
cis-1,2-Dichloroethene	0 52	2 62	70
Tetrachloroethene	103 48	459 5	5
Toluene	4 68	16 48	1,000
Total Xylenes	3 23	6 09	10,000
1,1,1-Trichloroethane	363 29	1,630 1	200
1,1,2-Trichloroethane	2 69	7 67	3
Trichloroethene	371 65	1,667	5
Semi-Volatile Organic Compounds			
Naphthalene	N/A	N/A	N/A
Metals			
Selenium	283 4	503 2	10[c]
Vanadium	8 68	43 3	256[b]

[1] Final Phase III RFI/RI BRA, June 1994
[2] CDPHE/WQCC, Basic Standards for Groundwater, 3 11 0
[a] PQLs from CDPHE/WQCC, Basic Standards for Groundwater, 3 11 0
[b] Programmatic Risk-Based Preliminary Remediation Goals - SGS-545-94, October, 1994 (construction worker scenario)
[c] RCRA Groundwater Protection Standard, 6 CCR 1007-3, 264 94

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2 4 1 Subsurface Soil General Response Actions

The GRAs identified for the OU-1 subsurface soil medium are no action, institutional controls, containment, removal, disposal, in-situ treatment, and ex-situ treatment These GRAs target the subsurface soil RAO identified earlier in Section 2.2 The RAO is focused on prevention of groundwater degradation from residual subsurface soil sources. A brief description of each GRA is provided below

- *No Action* - Required by CERCLA as a benchmark for comparison against other remedial action alternatives This implies that no direct action will be taken to alter the existing situation, other than short- and long-term monitoring of site conditions

- *Institutional Controls* - Refers to legal controls or management policies which minimize exposure to potential contaminants, such as restricting land use

- *Containment* - For subsurface soils, containment would consist of actions which minimize the spread of contamination and/or minimize the infiltration of groundwater which could be contaminated by subsurface soil contaminants

- *Removal* - For OU-1, removal implies excavation of contaminated soils for treatment or disposal May be combined with extraction of contaminated groundwater in areas of subsurface soil excavation May also include dust control measures during excavation to minimize contaminant migration

- *Disposal* - Disposal involves permanent deposition of excavated soils either in an on-site or permitted off-site disposal facility It includes disposal without treatment, if possible, or disposal subsequent to treatment measures

- *In-Situ Treatment* - In general, in-situ treatment technologies seek to treat contaminants in place without extraction or removal of large volumes of soil. Treatment would seek to remove, destroy, and/or immobilize contaminants through biological, chemical, or physical means This category includes bioremediation, chemical oxidation/reduction, soil washing, thermal recovery enhancement, and vapor extraction techniques

- *Ex-Situ Treatment* - This GRA is similar to in-situ treatment except that contaminated soils would be removed before treatment above ground Treated soils would be disposed of on-site or in a licensed disposal facility.

2 4 2 Groundwater General Response Actions

The GRAs identified for the OU-1 groundwater medium are no action, institutional controls, containment, removal, in-situ treatment, and ex-situ treatment These GRAs target the RAOs for groundwater The RAOs are focused on prevention of migration of contaminants in groundwater and on prevention of ingestion or inhalation of organic compounds in groundwater A brief description of each GRA is provided below

- *No Action* - Required by CERCLA as a benchmark for comparison against other remedial action alternatives This implies that no direct action will be taken to alter the existing situation, other than short- and long-term monitoring of site conditions

- *Institutional Controls* - Refers to legal controls or management policies which minimize the public's exposure to potential contaminants Examples include controlling well placement and restricting land use

- *Containment* - For groundwater, containment would consist of actions which minimize the flux of vapor-phase VOCs to the surface and/or minimize the migration of groundwater contaminants

- *Removal* - For OU-1, removal implies extraction of contaminated groundwater for treatment in the existing Building 891 water treatment system or other facilities Extraction of contaminated groundwater in areas of DNAPL may be possible through soil extraction

- *In-Situ Treatment* - In general, in-situ treatment technologies seek to treat contaminants in place without extraction or removal of large volumes of groundwater or soil Treatment would seek to remove, destroy, and/or immobilize contaminants through biological, chemical, or physical means.

- *Ex-Situ Treatment* - This GRA is similar to in-situ treatment except that contaminants would be extracted/removed before treatment above ground. Treated groundwater would be discharged through existing channels (i.e , the existing Building 891 water treatment system)

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2 4 3 Volume and Area Estimates

A volume calculation was conducted for subsurface soils at IHSS 119 1 to estimate a volume for the potential residual DNAPL sources assumed to be present in IHSS 119 1 The amount of soil requiring remediation was estimated by visually inspecting the potential source areas described in the Phase III RFI/RI report, and by assuming that subsurface soil remediation activities would attempt to remediate saturated zone soils to a depth of five feet into bedrock Figure 2-1 depicts the potential soil excavation area identified for IHSS 119 1 The exact amount of contaminated subsurface soils cannot be calculated due to the limited data available for this medium Limitations on data is typical of sites contaminated with residual DNAPLs The excavation area, however, is estimated to contain approximately 17,500 cubic yards of soil

Based on the results of the OU-1 Phase III RFI/RI report and the BRA in particular, contaminated groundwater in OU-1 was found to contribute a significantly higher risk to those receptors exposed to IHSS 119 1 groundwater than to receptors exposed to groundwater from other locations in OU-1 IHSS 119 1 was designated a "source" location in the PHE for this reason. Other areas of the operable unit contain groundwater contaminant concentrations above detection limits, however, the concentrations are greatest at this IHSS (see Figure 2-2)

The quantity of groundwater requiring remedial action in the IHSS 119 1 source area cannot be calculated precisely because of seasonal variations in the water table. Instead, a lower bound was estimated using computer codes that compared the bedrock topography beneath the IHSS to the water level data from wells located in this area The wells used to identify and delineate this area were 0487, 0974, 1074, 4387, 32591, and 37991. This lower bound groundwater volume assumes groundwater beneath the IHSS is confined to the identified bedrock paleochannel. This assumption is valid only during low water table conditions. An upper bound cannot be calculated directly, since during spring runoff the water table elevation rises above the bedrock paleochannel and no lateral extent of groundwater contamination specific to IHSS 119.1 can be measured distinctly from other groundwater at OU-1

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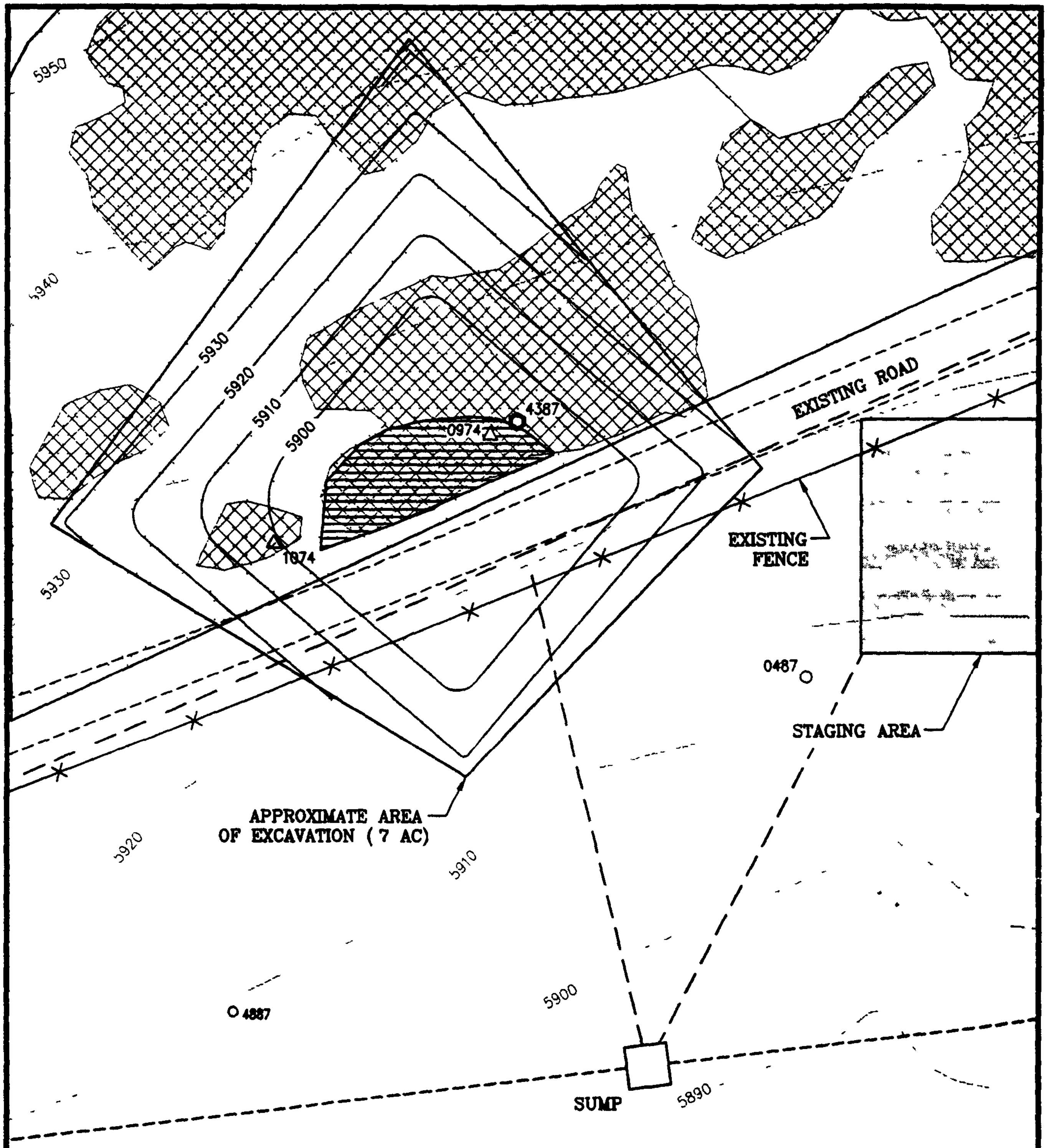

EXPLANATION

104 — INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN

ACTUAL SCRAP METAL AND DRUM STORAGE AREAS IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS

ACTUAL DRUM STORAGE AREA IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS

○ B301889 ALLUVIAL WELL
△ 0271 PRE-1986 WELL
⬡ BH1587 BOREHOLE

N

0 25 50

U S DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site
Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

Potential Soil Excavation Area For IHSS 119.1

Figure 2-1

OU1-EXC2 DWG

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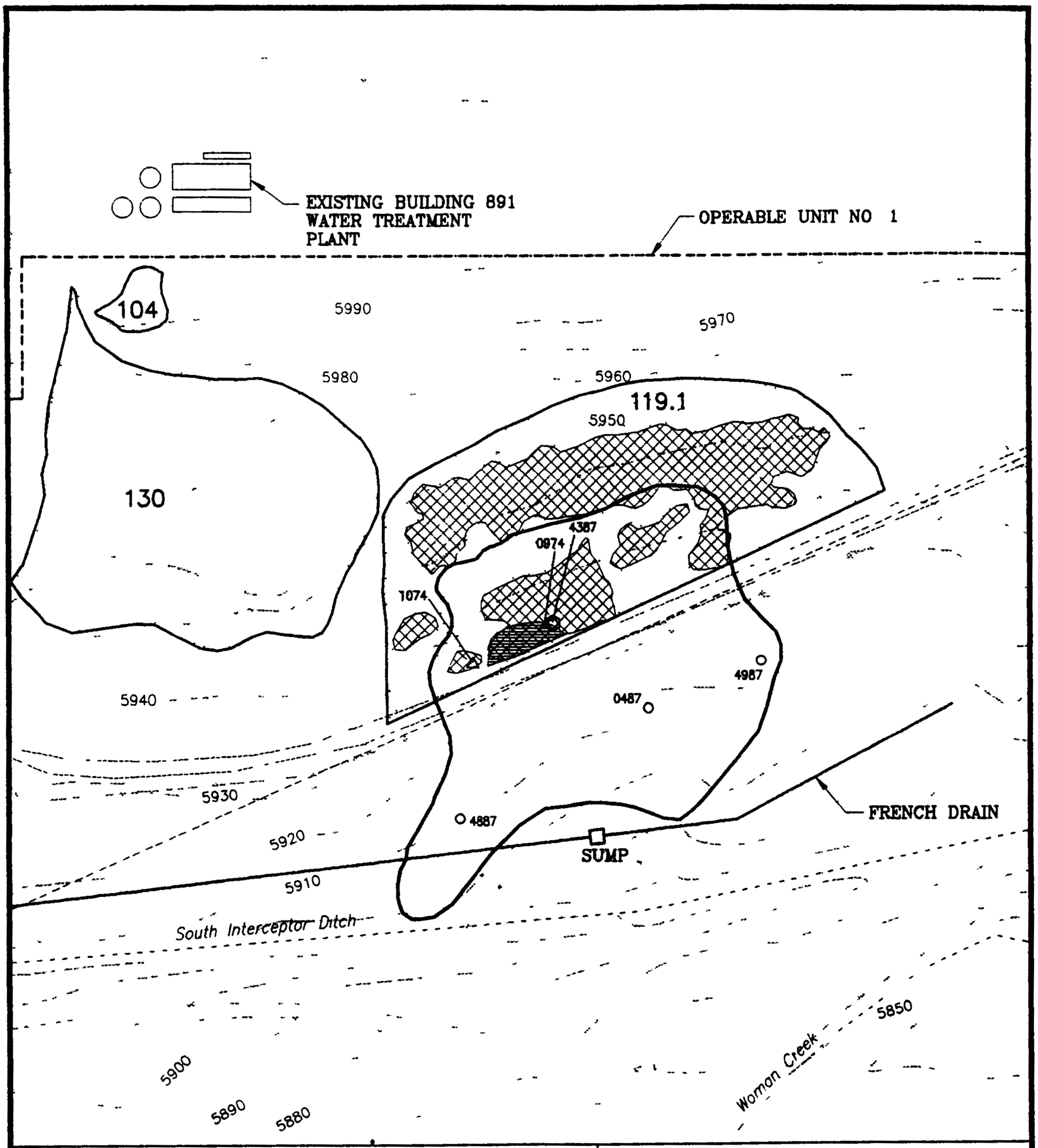

EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN (104)
- ACTUAL SCRAP METAL AND DRUM STORAGE AREAS IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS
- ACTUAL DRUM STORAGE AREA IN IHSS 119 1 BASED ON AERIAL PHOTOGRAPHS
- INFERRED EXTENT OF CONTAMINATION BASED ON 1/92 DETECTION
- B301889 ALLUVIAL WELL
- 0271 PRE-1986 WELL
- BH1587 BOREHOLE

N

0 100 200

U S DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site
Golden Colorado

IHSS 119 1
OPERABLE UNIT NO 1
CMS/FS REPORT

Potential Extent of Contamination at IHSS 119.1

Figure 2-2

TAKEN FROM JUNE 1994 OU1 FINAL PHASE III RFI/RI REPORT

TST-4124 DWG

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The Phase III RFI/RI report contains several saturated thickness maps for OU-1 during a typical dry period These maps were used to estimate the volume of contaminated groundwater in the source location when groundwater levels were at their lowest Using an average porosity of 0 10 (DOE 1994a), the volume of groundwater estimated to be present in the southwest corner of IHSS 119 1 during the dry season is 80,000 gallons This volume represents a single pore volume, although more than one pore volume would likely have to be removed to achieve RAOs During wetter periods, groundwater in this area may rise above the paleochannel and thus result in much larger volumes requiring treatment

In addition, the Phase III RFI/RI report estimated that the volume of available groundwater in OU-1 is between 5 0 and 5 8 acre-feet (1 6 and 1 9 million gallons) The volume of groundwater estimated to be beneath IHSS 119 1 and the volume of groundwater beneath OU-1 are used to estimate remediation requirements, however, because groundwater elevations in OU-1 are highly dependent on seasonal variations in precipitation, these values are engineering estimates only

2 5 Identification and Screening of Technologies and Process Options

This section summarizes the technologies and process options that were identified for remediation of OU-1 The section also describes the options that were maintained for further evaluation based on an initial screening of technologies The initial screening considered technical implementability, applicability, and feasibility for site-specific contaminants and conditions This initial screening eliminated remedial technologies and process options that did not warrant further consideration at OU-1 A summary of the initial screening of technologies for both groundwater and subsurface soils are presented in the following sections

2.5.1 Identification and Screening of Technologies and Process Options for Subsurface Soils

The remedial technologies and process options initially identified for subsurface soils at OU-1 by GRA are listed in the following bulleted list:

Institutional Controls

- Access restrictions
  - Legal restrictions on land use

Containment

- Horizontal subsurface flow control
  - Subsurface drains
  - Grout curtains
  - Slurry walls
  - Sheet pilings
  - Cryogenic barrier

- Vertical subsurface flow control
  - Grout injection
  - Block displacement

Removal

- Excavation
  - Loader/excavator/dozer

- Dust control
  - Dust suppressants
  - Temporary structures

Disposal

- On-Site disposal
  - Engineered on-site disposal facility
  - Permitted off-site disposal facility

In-situ Treatment

- Biological
  - Bioremediation

- Chemical
  - Chemical oxidation/reduction

- Physical
  - Soil flushing
  - Vitrification
  - Radio frequency/ohmic heating

- Vapor extraction
- Hot air/steam stripping with mechanical mixing

Ex-Situ Treatment

- Biological
  - Bioremediation
  - Land application
- Chemical
  - Ultraviolet photolysis with chemical oxidation
  - Solvent extraction
- Physical
  - Soil washing
  - Stabilization/Solidification
- Thermal
  - Incineration
  - Thermal desorption
  - Vitrification

The preceding technologies and process options were systematically screened to reduce the number to a more representative group of remedial technologies and options. The screening was performed by examining the technical implementability of each technology and/or process option for subsurface soils at OU-1 Figure 2-3 depicts the subsurface soil remedial technology and process options screening activities

Subsurface soil remedial technologies and process options that were maintained for further evaluation are as follows

Institutional Controls

- Access restrictions
  - Legal restrictions on land use

Containment

- Horizontal subsurface flow control

- Subsurface drains
- Grout curtains
- Slurry walls
- Sheet pilings
- Cryogenic barrier

- Vertical subsurface flow control
  - Grout injection
  - Block displacement

Removal

- Excavation
  - Loader/excavator/dozer

- Dust control
  - Dust suppressants

Disposal

- On-Site disposal
  - Engineered on-site disposal facility
  - Permitted off-site disposal facility

In-situ Treatment

- Biological
  - Bioremediation

- Physical
  - Soil flushing
  - Radio frequency/ohmic heating
  - Vapor extraction
  - Hot air/steam stripping with mechanical mixing

Ex-Situ Treatment

- Biological
  - Bioremediation

- Chemical
  - Ultraviolet photolysis with chemical oxidation
  - Solvent extraction

- Physical
  - Soil washing

- Thermal

  - Incineration
  - Thermal desorption

2 5 2 Identification and Screening of Technologies and Process Options for Groundwater

The following remedial technologies and process options were identified for groundwater at OU-1

No Action

- Monitoring
  - Groundwater monitoring

Institutional Controls

- Access restrictions
  - Legal restrictions on well placement
  - Legal restrictions on land use

Containment

- Horizontal subsurface flow control
  - Subsurface drains
  - Grout curtains
  - Slurry walls
  - Sheet pilings
  - Cryogenic barrier

- Vertical subsurface flow control
  - Grout injection
  - Block displacement

Removal

- Passive removal
  - Subsurface drains

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- Active removal
  - Horizontal and/or vertical extraction wells or sumps

In-situ Treatment

- Biological
  - Bioremediation

- Chemical
  - Polymerization
  - Chemical oxidation

- Physical
  - Air sparging
  - Vapor extraction
  - Permeable treatment beds
  - In-situ adsorption with wells (proprietary process)

Ex-situ Treatment

- Biological
  - Bioremediation

- Chemical
  - Solvent extraction
  - Ultraviolet photolysis with chemical oxidation

- Physical
  - Gamma irradiation
  - Activated carbon or carbonaceous adsorbents
  - Air stripping
  - Membrane processes
  - Evaporation
  - Freeze crystallization

- Thermal
  - Incineration
  - Plasma arc discharge
  - Catalytic oxidation

These technologies and process options were systematically screened to reduce the number of options to a smaller and more representative number appropriate for the development of remedial alternatives The screening was performed by examining the technical implementability of each

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technology and/or process option for OU-1 groundwater. The screening process is depicted in Figure 2-4 Technologies and/or process options that were maintained for further evaluation are as follows

No Action

- Monitoring
  - Groundwater monitoring

Institutional Controls

- Access restrictions
  - Legal restrictions on well placement
  - Legal restrictions on land use

Containment

- Horizontal subsurface flow control
  - Subsurface drains

Removal

- Passive removal
  - Subsurface drains

- Active removal
  - Horizontal and/or vertical extraction wells or sumps

In-Situ Treatment

- Biological
  - Bioremediation

- Physical
  - Vapor extraction

Ex-Situ Treatment

- Biological
  - Bioremediation

- Chemical
  - Ultraviolet photolysis with chemical oxidation

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- Physical
  - Activated carbon or carbonaceous adsorbents
  - Air stripping

- Thermal
  - Plasma arc discharge
  - Catalytic oxidation

2 6 Evaluation and Selection of Representative Process Options

Remedial technologies and process options determined to be implementable at OU-1 were subjected to a more detailed evaluation to determine which process options should be used to develop alternatives This more detailed evaluation was performed by comparing the ability of each process option to satisfy three criteria; effectiveness, implementability, and cost.

Site specific conditions were considered in the evaluation of remedial technologies and process options The following site characteristics were prominent factors in the evaluation

- In general, levels of contamination in groundwater are relatively low
- Contaminant distribution is largely sporadic or ubiquitous
- Aqueous concentrations at IHSS 119.1 indicate the potential for DNAPLs
- Underlying low-permeability unweathered bedrock surface serves to channel groundwater flow
- Overall low permeability and high degree of heterogeneity of saturated unconsolidated surficial materials contributes to preferential flow potential.

The evaluation of process options for subsurface soils is presented in Figure 2-5, while the evaluation of process options for groundwater is presented in Figure 2-6.

Rather than evaluating each potential process option, representative process options were designated to represent a class of remedial technologies that could be applied at OU-1. This improves the efficiency of the evaluation and allows for flexibility in the final selection of process options within the chosen class of remedial technologies. Preference was given to technologies and process options which address both groundwater and subsurface soil contamination at OU-1.

Considering these factors, the following representative process options were selected for alternative development:

- Groundwater monitoring
- Legal restrictions on well placement
- Legal restrictions on land use
- Subsurface drains
- Horizontal and/or vertical extraction wells or sumps
- Loader/excavator/dozer
- Hot air/steam stripping with mechanical mixing
- Vapor extraction
- radio frequency (RF)/ohmic heating

The evaluation of process options to treat extracted groundwater favored the selection of the existing Building 891 water treatment system. Since the system has been proven to effectively treat the contaminants present in OU-1 groundwater (except CCl_4 - planned modifications to the system will effectively address this deficiency), and since the capital costs have already been incurred for designing and constructing this system, this process option is the most favorable for aboveground treatment of groundwater. Thus, other process options for ex-situ treatment of groundwater, including plasma arc discharge, catalytic oxidation, and air stripping, were not considered in the development of remedial action alternatives. Plasma arc discharge and catalytic oxidation have prohibitive operating costs for low contaminant concentrations such as those at OU-1. Air stripping does not destroy or immobilize contaminants, and would require treatment of large quantities of off gases.

The limited ability to uniformly and appreciably remove contaminated groundwater from the low permeability heterogeneous unconsolidated materials, combined with the complex nature of the bedrock system beneath OU-1 favored treatment that would remove residual sources (e.g., DNAPL zones) to the greatest extent possible. Removal of these sources should be conducted

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in a manner that minimizes the potential for mobilizing contaminants to move further into the bedrock system, as well as introducing new potential contaminants to the subsurface Consequently, process options such as surfactant flushing are not appropriate This is the case because the subsurface geology may seriously limit uniform distribution of surfactants in the subsurface, meaning treatment effectiveness throughout the entire contaminated zone may not be significantly increased Further, the decreased surface tension induced by surfactants can enhance the mobility of contaminants through otherwise relatively impermeable materials OU-1 bedrock has been characterized as fractured meaning a decreased surface tension between DNAPLs and groundwater could cause significantly greater contaminant migration into bedrock Finally, surfactants will adversely affect operation of the Building 891 water treatment facility, meaning an additional surfactant recycle unit operation would be necessary prior to water treatment The increased capital costs of a recycle system along with the high operating costs for separation processes, such as surfactant recycle, negate the marginal effectiveness increase in treatment associated with surfactant flooding

Other process options that require injection of additional fluids into the subsurface (e g , bioremediation and soil flushing), are also not favorable at OU-1 The complex nature of OU-1 subsurface geology and the limited availability of groundwater make systems which rely on homogenous distribution of flushing agents or nutrients difficult to implement Preferential groundwater flow pathways and tightly consolidated soil matrices make injection difficult to control Moreover, since DNAPL zones are likely to exist in isolated areas, injection technologies are unlikely to be effective in remediating these areas

In addition to the problems related to preferential flow through the heterogeneous low permeability materials, bioremediation was not included in the development of remedial action alternatives for the following additional reasons.

- The effectiveness of bioremediation at OU-1 is limited by the nature of the contaminants identified Although laboratory studies have shown up to 90 percent reduction of TCA and TCE concentrations under ideal conditions, researchers are skeptical as to the full-scale applicability of bioremediation under field conditions, stating that "implementation of biodegradation of chlorinated hydrocarbons in field

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situations may be limited by the toxicity of high concentrations of these compounds to microorganisms and by the slow rate of degradation possible" (Baker et al 1994)

- PCE, a major OU-1 contaminant, is a highly refractory compound (resistant to decay) for which there is no established field method for degradation at rates which make treatment practical

- Bioremediation is not effective in treating inorganics such as selenium An aboveground treatment system could be used to remove selenium from extracted groundwater, however, this would most likely limit the effectiveness of reinjection systems that recycle nutrients or non-indigenous bacteria

- Site conditions at OU-1, particularly fluid circulation, limit the technical implementability of bioremediation at OU-1 The Phase III RFI/RI demonstrates the lack of a consistent, defined water source beneath IHSS 119.1 Well and borehole data in the area have indicated varying water table levels and depths of saturated zones Implementation of bioremediation at OU-1 would require injection of large volumes of water to provide nutrients and/or non-indigenous bacteria to treatment zones This might mobilize and spread contamination and accelerate slumping at OU-1 Experience with installation of the french drain system has indicated that slumping is a serious concern for unsaturated conditions, and would be more serious for the highly saturated conditions that would be required to implement bioremediation

For the medium of subsurface soils, thermal desorption was chosen as the representative process option for ex-situ treatment of contaminated subsurface soils Thermal desorption offers the most cost effective method of contaminant removal for the sporadic contaminant distribution found at OU-1 Chemical and physical treatments, such as ultraviolet photolysis, chemical oxidation, solvent extraction, and soil washing require the addition of liquids to effect a mass transfer from solid to liquid media The resulting liquid could not be treated in the Building 891 water treatment facility without pre-treatment due to the presence of strong oxidizers, solvents, and/or dissolution agents Thus a separate liquid treatment process to treat the secondary liquid waste would be required The capital costs associated with such a treatment process, as well as the expense of solvents, washing agents, and oxidation reagents, exceed the energy costs associated with thermal processes Thermal desorption was selected over incineration due to the low levels of contamination at OU-1 and the relatively low heating value of chlorinated organics The higher temperatures required for incineration would require excessive secondary fuel sources. Since thermal desorption operates at significantly lower temperatures, energy costs

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would be substantially lowered relative to incineration

Due to the limitations of soil flushing and bioremediation discussed previously, standard and thermally-enhanced vapor extraction process options were selected as in-situ subsurface soil treatments for alternative development and will be used in conjunction with limited groundwater pumping to remove contaminated groundwater and potential residual DNAPLs from OU-1 subsurface soils

Other options retained for alternative development include excavation, which was retained to provide conceptual variety to the alternatives presented for remediation at OU-1 Excavation could be used to remove subsurface soils or to locate pools of contaminated groundwater, ensuring that any residual DNAPL zones are removed In addition, process options were retained that would result in the assembly of limited or minimal action alternatives, including groundwater monitoring, use of the existing French Drain system, and institutional controls These options are also discussed in Section 3 0

2 7 Existing IM/IRA Treatment System

The existing Building 891 water treatment system (UV/H_2O_2 and ion exchange) will be essential for proposed remedial action alternatives for OU-1 and other operable units that require aboveground groundwater treatment. The system constitutes a comprehensive process treatment train for treating water contaminated with organic and inorganic (including radionuclide) contaminants (see Figure 2-7) The system consists of a collection and pumping system to supply the treatment facility, an influent storage and transfer system, separate treatment systems for organic and inorganics contaminants, and an effluent storage and discharge system The system is designed for a 30 gpm flow rate capacity and has equalization tanks to normalize treatment rates

The french drain collection and pumping system includes the recovery well pump located in IHSS 119.1, and two french drain sump pumps These pumps are normally controlled by level

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switches in the well or sump that determine whether the pumps operate. The collection system connects to the influent transfer system, which includes two influent equalization tanks and two influent transfer pumps The influent transfer pumps supply water from the influent equalization tanks to a UV/H_2O_2 treatment unit at a constant rate The UV/H_2O_2 unit is designed to destroy organic contaminants in the influent stream

Treatment efficiency depends on flow rate (residence time), H_2O_2 concentration, and UV wavelength intensity The system has a design throughput of 30 gpm or 14,400 gallons per day (gpd) with an 8-hour operating shift It uses 50 mg/ℓ of H_2O_2, with sixteen 15-kW UV lamps providing an equivalent power of 240 kW for breaking down organics.

When the water leaves the UV/H_2O_2 system, it enters the ion exchange system, which consists of the ion exchange surge tank, four columns containing beds of ion exchange resins, and a degassing tower The ion exchange system processes the water in the following sequence

1 The water enters the ion exchange surge tank and is pumped at a constant rate into the first ion exchange column This column contains 28 cubic feet of Ionac A-440, a strong base anion resin for removing uranium.

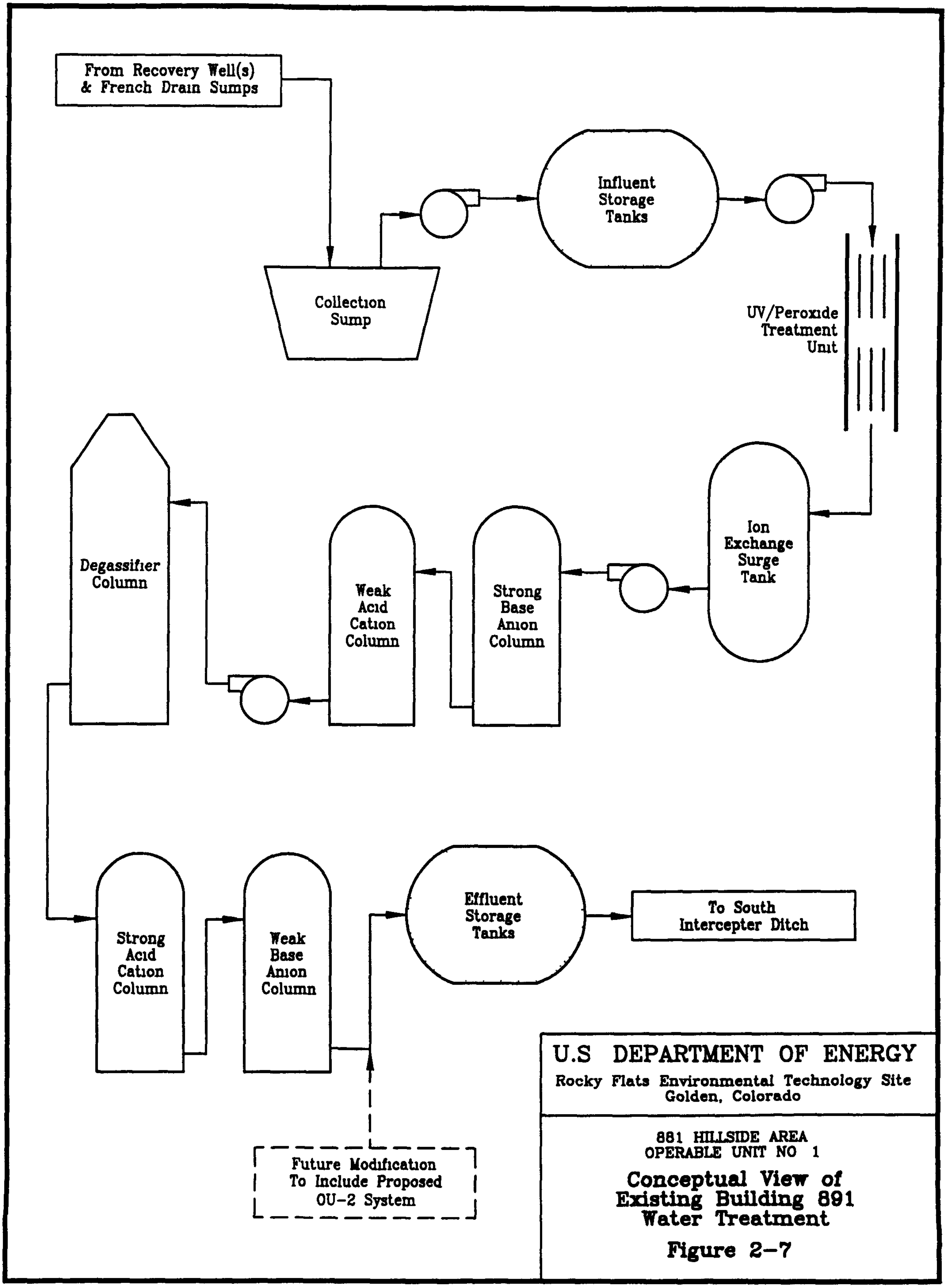
2 The water then flows directly to the second column, which contains 32 cubic feet of Ionac CC, a weak acid cation resin, for removing heavy metals

3. The water then enters the degassing tower to allow carbon dioxide and other gases produced during the UV/H_2O_2 process to escape Excessive gas content in the ion exchange columns could cause short circuiting of the resins thereby reducing the efficiency of the system

4 The water is then pumped to the third ion exchange column, which contains 56 cubic feet of Ionac C-240H, a strong acid resin for removing hardness and metals.

5. The water then enters the fourth and final column, which contains 56 cubic feet of Ionac AFP-329, a weak base anion resin, for removing anions

6 The water, which is now treated, is stored in one of three effluent storage tanks and discharged by gravity feed



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Conceptual View of Existing Building 891 Water Treatment

Figure 2-7

OU1-PTS DWG

3.0 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

This section presents the alternatives that were assembled for remediating the groundwater medium at OU-1 These alternatives were assembled using the technologies identified in Section 2 0, which summarizes the evaluation and selection of technologies and process options

Utilizing the existing Building 891 water treatment system is an integral component of all the alternatives presented in this section with the exception of the No Action alternative The Building 891 treatment system is currently used for treating water from OU-1 and may also be used for treating contaminated water from other areas of the RFETS Planned modifications to the system will allow it to treat higher concentrations of contaminants prior to initiation of any remedial activities at OU-1 The details of the planned modifications are discussed in Section 2 0

3 1 Introduction

Remedial action alternatives were developed by combining process options selected as "representative" based on results of the evaluation of process options and technologies Process options were combined to develop alternatives ranging from treatment alternatives that eliminate or minimize the need for long-term management to limited or no action alternatives This range of alternatives includes containment options that involve little or no treatment but achieve RAOs by preventing exposures or by reducing the mobility of contaminants. The No Action alternative was developed to provide a baseline alternative against which other alternatives could be compared In all cases, the alternatives were developed with the goal of achieving the RAOs of preventing inhalation, ingestion, and dermal contact with VOCs, preventing migration of contaminants from subsurface soils to groundwater, and protecting Woman Creek surface water from contamination as presented in Section 2 0 by combining appropriate GRAs to form site-specific remediation strategies.

The alternatives that were developed for remediation of OU-1 are the following:

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- Alternative 0 No Action
- Alternative 1 Institutional Controls with the French Drain
- Alternative 2 Groundwater Pumping and Soil Vapor Extraction
- Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement
- Alternative 4 Hot Air Injection with Mechanical Mixing
- Alternative 5 Soil Excavation with Groundwater Pumping

Figure 3-1 depicts a summary of the development of remedial action alternatives The figure presents the GRAs and process options that were combined to form the various alternatives After developing alternatives for remediation of OU-1, the alternatives were evaluated in detail, and the results of this analysis are presented in the Detailed Analysis of Alternatives in Section 4 0

3 2 Remedial Action Alternatives

Groundwater remedial action alternatives were developed that could potentially achieve the RAOs described in Section 2 0 The primary risk pathways that determined which GRAs would be used to develop alternatives were based on the OU-1 BRA, which indicated that ingestion of groundwater and inhalation of vapors rising up through unsaturated soils were of most concern The following alternatives were designed to achieve RAOs by removing and destroying the contaminants in groundwater, removing subsurface sources of residual contamination, restricting access to wells positioned within the boundaries of OU-1, and/or limiting access to the entire site. These alternatives assume that surface soil hotspots would be removed prior to commencing remedial activities, and would be put into temporary storage for treatment with similar wastes from OU-2 or shipped off site for immediate treatment and/or disposal

3 2 1 Alternative 0. No Action

The No Action alternative was developed to meet the requirements of the NCP which specifies that a No Action alternative should be developed regardless of site-specific conditions (EPA 1990a) The No Action alternative provides a baseline against which other alternatives can be compared during the detailed analysis of alternatives The No Action alternative uses the results of the BRA to define exposure levels to receptors at the site under existing conditions and does not include any remedial activities

The existing French Drain collection system would be discontinued under this alternative Collection of groundwater from the existing collection well and French Drain would be discontinued Groundwater would be allowed to flow down the hillside and around the French Drain toward Woman Creek

The only activity associated with the No Action alternative is groundwater monitoring to detect changes in contaminant concentrations or migration patterns Monitoring would begin immediately and would continue until it is determined that monitoring is no longer required Existing wells no longer deemed necessary would be abandoned as appropriate

There is no remedial time frame for this alternative, since the alternative relies solely on natural degradation and attenuation processes to meet RAOs For the purposes of detailed analysis, a 30-year monitoring time frame is assumed in accordance with EPA guidance

3 2 2 Alternative 1 Institutional Controls with the French Drain

Alternative 1 seeks to achieve RAOs by restricting access to wells impacted by OU-1 contaminants through institutional controls while continuing to treat groundwater collected by the existing French Drain at the Building 891 water treatment system. Institutional controls would also be employed to prevent unauthorized construction and groundwater usage in all areas of OU-1. Degradation of groundwater would be minimized by continued containment and

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treatment of groundwater. Subsurface residual sources would eventually be depleted by dissolution to groundwater The capture of groundwater with the French Drain and use of institutional controls to reduce exposure are both established remedial options This alternative targets groundwater in the areas of IHSS 119.1, south of Building 881, and a portion of IHSS 119 2 for remediation Institutional controls would be employed throughout OU-1

The existing French Drain and Building 891 treatment system would continue to operate until it is deemed no longer necessary The modifications discussed in Section 2 0 are assumed to have been completed for the purposes of detailed analysis Groundwater monitoring would begin immediately and continue for as long as required to verify that contaminant concentrations in groundwater have been permanently reduced below appropriate limits Wells no longer deemed necessary for monitoring would be abandoned as appropriate

The Building 891 treatment system has a design flow rate of 30 gpm, but the system currently operates intermittently as volumes of collected groundwater dictate Current average flow from OU-1 sources is estimated at 10% of the design capacity, or 3 gpm (DOE 1994d) The rate of treatment is dependent on the amount of groundwater available at the French Drain

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion-exchange resin regeneration from the Building 891 water treatment system, and wastes associated with monitoring well installation such as drill cuttings and decontamination water The decontamination water could be sent to Building 891. The regenerant solution from the spent ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation in accordance with current operational practices. The spent GAC will be sent off site for regeneration. Alternative 1, however, does not present any administrative or legal difficulties since it represents a continuance of current operations at OU-1

There is no remediation time frame defined for Alternative 1 since the French Drain system is currently operational and would continue to operate until acceptable contaminant concentrations are achieved. Based on current operations of the existing French Drain system, it is reasonable to assume that due to the slow groundwater collection rate, operation of the French Drain system would be required for an extensive period of time Experience with similar remedial actions at DNAPL contaminated sites suggests extremely long time frames for complete residual depletion For the purposes of detailed analysis cost estimates, a 30-year time frame for remedial activities is assumed based on EPA guidance

3 2 3 Alternative 2 Groundwater Pumping and Soil Vapor Extraction

This alternative seeks to achieve RAOs by dewatering the IHSS 119 1 source area using conventional pumping techniques, and the implementation of a localized SVE system Risk from contaminated groundwater will be eliminated by extraction and treatment, while further degradation of groundwater will be minimized by removal of residual DNAPL sources through SVE The combined technologies proposed under this alternative are considered "emerging technologies" which may be more effective combined than when applied individually In general, this alternative targets only the identified source area within IHSS 119 1, although additional vapor extraction wells could be installed in other areas to treat suspected DNAPL sources based on the results of a detailed soil gas survey to be conducted prior to remediation

SVE would assist the vaporization and subsequent recovery of contaminants present in the saturated soils, unsaturated soils, and groundwater at OU-1 The technology targets contaminants that have partitioned to the aqueous phase in the subsurface, adsorbed onto subsurface soils, exist as pools of DNAPL, or occupy soil pore spaces as vapor. Groundwater residing in shallow pools throughout IHSS 119 1 would be extracted via the existing French Drain, and one to three additional recovery wells. Collected groundwater would be treated by the existing Building 891 water treatment system or another appropriate facility with the modifications discussed in Section 2. These same areas, once desaturated, would be subjected to SVE to enhance the removal of any residual contaminants

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In general, soil vapor extraction is an in situ physical treatment technology that has been used primarily to remediate soil and groundwater contaminated with VOCs. A typical SVE system consists of either a single, or if necessary, a network of vapor extraction wells screened at depths consistent with the contaminated soils. If multiple vapor extraction wells are used, they are usually joined together by a common header pipe. Makeup or clean air, replacing the contaminated soil gas removed through SVE, enters the soil either passively via the ground surface and/or inlet wells, or actively via air injection wells. Channeling, or short-circuiting, of the makeup air may be minimized, and the air redirected through the desired treatment zones, by the placement of a geotextile liner on the ground surface surrounding the SVE wells.

The basic principle behind SVE involves inducing vapor flow through the unsaturated zone towards an extraction well by applying a vacuum to that well. Contaminants volatilized from the soil matrix, and those that are already in the vapor phase, are swept by the carrier gas flow (air) to the extraction well(s). The carrier gas also tends to increase the volatilization of any aqueous phase or free phase DNAPL contaminants in the vicinity. There are three main factors that control the performance of an SVE operation: (a) the vapor flow rate through the unsaturated zone, (b) the flow path of carrier vapors relative to the location of the contaminants, and (c) the chemical composition of the contaminants (Johnson et al. 1989).

To successfully design and operate an SVE system, site geology and contaminant properties must be considered. Site geology can have a significant influence on a vapor extraction well's radius of influence. Geological factors include depth to groundwater, subsurface soil/rock type, and subsurface permeability, which must be great enough to allow carrier vapors to strip VOCs from the subsurface matrix and carry them to an extraction well. Soil vapor extraction performance is also dependent on the characteristics of the contaminants targeted for extraction. A compound is a likely candidate for SVE if it has a vapor pressure of 1.0 mm or more of mercury at 20°C and a dimensionless Henry's Law constant greater than 0.01 (Danko 1989). Table 3-1 presents these values for the primary VOCs under consideration at OU-1 as well as other general physical and chemical data. These five VOCs were chosen for evaluation of SVE due to their high concentrations relative to other VOCs detected and their wide range of Henry's Law constants.

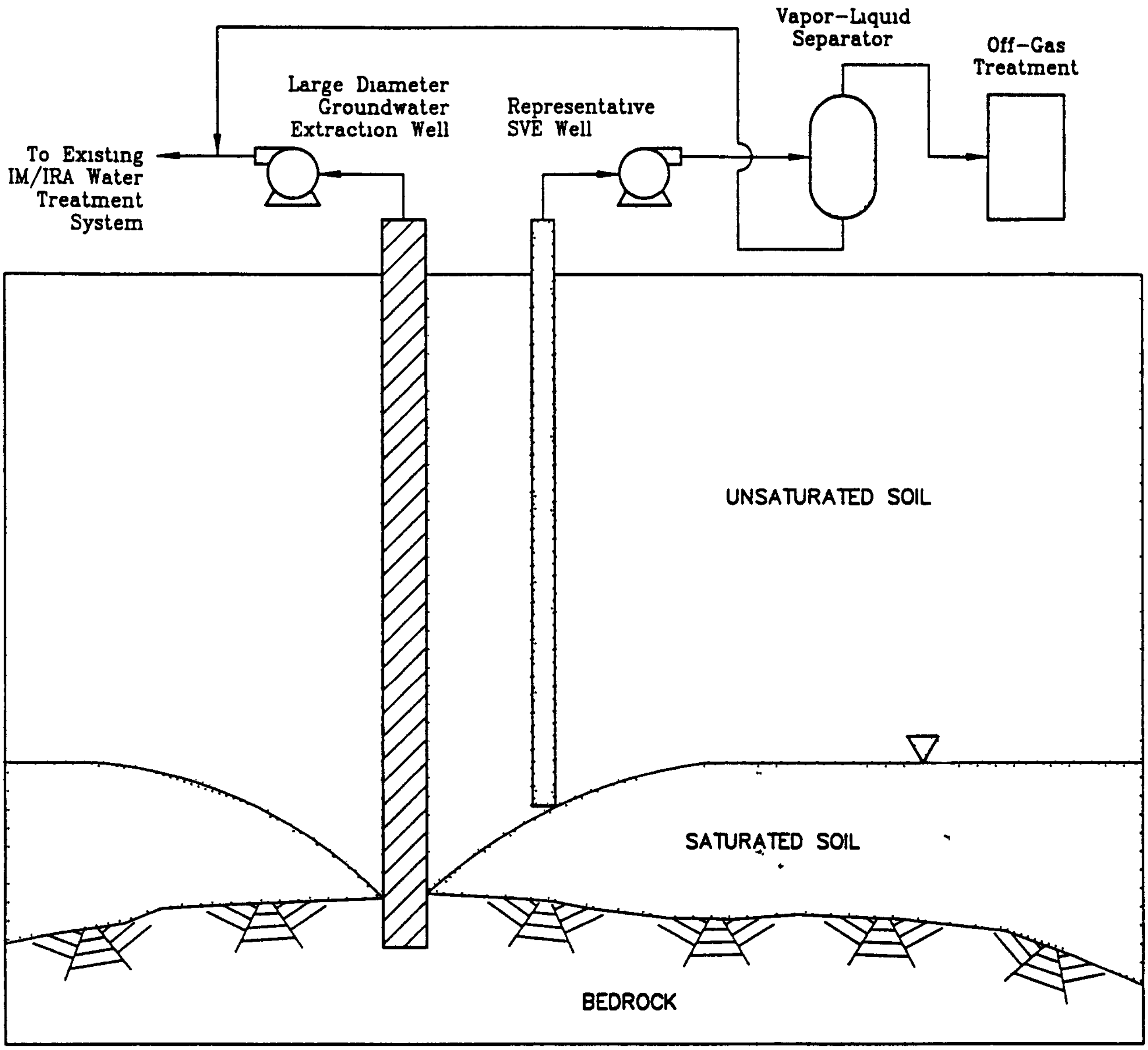
Table 3-1.
Physical and Chemical Properties of the Primary VOCs in Groundwater

Chemical	Formula[a]	Molecular Weight[a]	Specific Gravity[b]	Boiling Point (°C)[b]	Aqueous Solubility (mg/ℓ)[a]	Vapor Pressure (mm Hg)[a]	Henry's Law Constant (Dimensionless)[a,c]
Carbon Tetrachloride	CCl_4	153 82	1 59	76 5	757	90	1 002
1,1-Dichloroethene	$C_2H_2Cl_2$	96 94	1 22	37 0	2,250	182	1 414
Tetrachloroethene	C_2Cl_4	165 83	1 62	121	150	17 8	1 076
1,1,1-Trichloroethane	$C_2H_3Cl_3$	133 39	1 34	75 1	1,500	100	0 599
Trichloroethene	C_2HCl_3	131 38	1 45	87	1,100	57 9	0 378

[a] from ***Basics of Pump-and-Treat Ground-Water Remediation Technology***, EPA/600/8-90/003, Office of Research and Development, March 1990

[b] from ***Selecting Process Equipment, vol 1***, Woods, McMaster University, Canada, 1990

[c] at 20 °C



Not To Scale

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Conceptual View of SVE System

Figure 3-2

OU1-CS1 DWG

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The use of these five compounds for analysis of the SVE alternatives should yield a good approximation of the actual performance of SVE for the site The data shown in Table 3-1 indicate that all of the VOCs under consideration are amenable to recovery by SVE A conceptual view of the proposed configuration of an SVE system is presented in Figure 3-2

For this alternative it is assumed that approximately 36 vapor extraction wells would be installed in IHSS 119 1 and in other areas if deemed appropriate A detailed soil gas survey would be conducted prior to installing these wells in order to determine exact well locations and any additional areas warranting remediation Wells would be installed to a depth of approximately 20 feet and would be 4 to 6 inches in diameter These wells would be operated cyclically to enhance recovery and would be used in combination with a granular activated carbon (GAC) unit to treat extracted vapors Cyclical operation would allow contaminant concentrations in soil gas to return to near equilibrium levels during non-operation, thus increasing the mass of contamination removed per volume of air extracted Higher concentrations in the extracted air stream would decrease operating costs, while the cycled operation of various wells would allow the use of less expensive equipment due to decreased capacity needs

The existing French Drain and Building 891 treatment system would continue operation during remedial activities to collect any contaminated groundwater existing downgradient of the treatment area and not removed through dewatering activities After source removal and groundwater plume remediation, the French Drain could be decommissioned Without regular pumping of the sump pumps located in the French Drain, water would begin to flow around the French Drain and continue toward Woman Creek Groundwater monitoring would be employed for the entire duration of this alternative to ensure water flowing around the drain meets PRGs

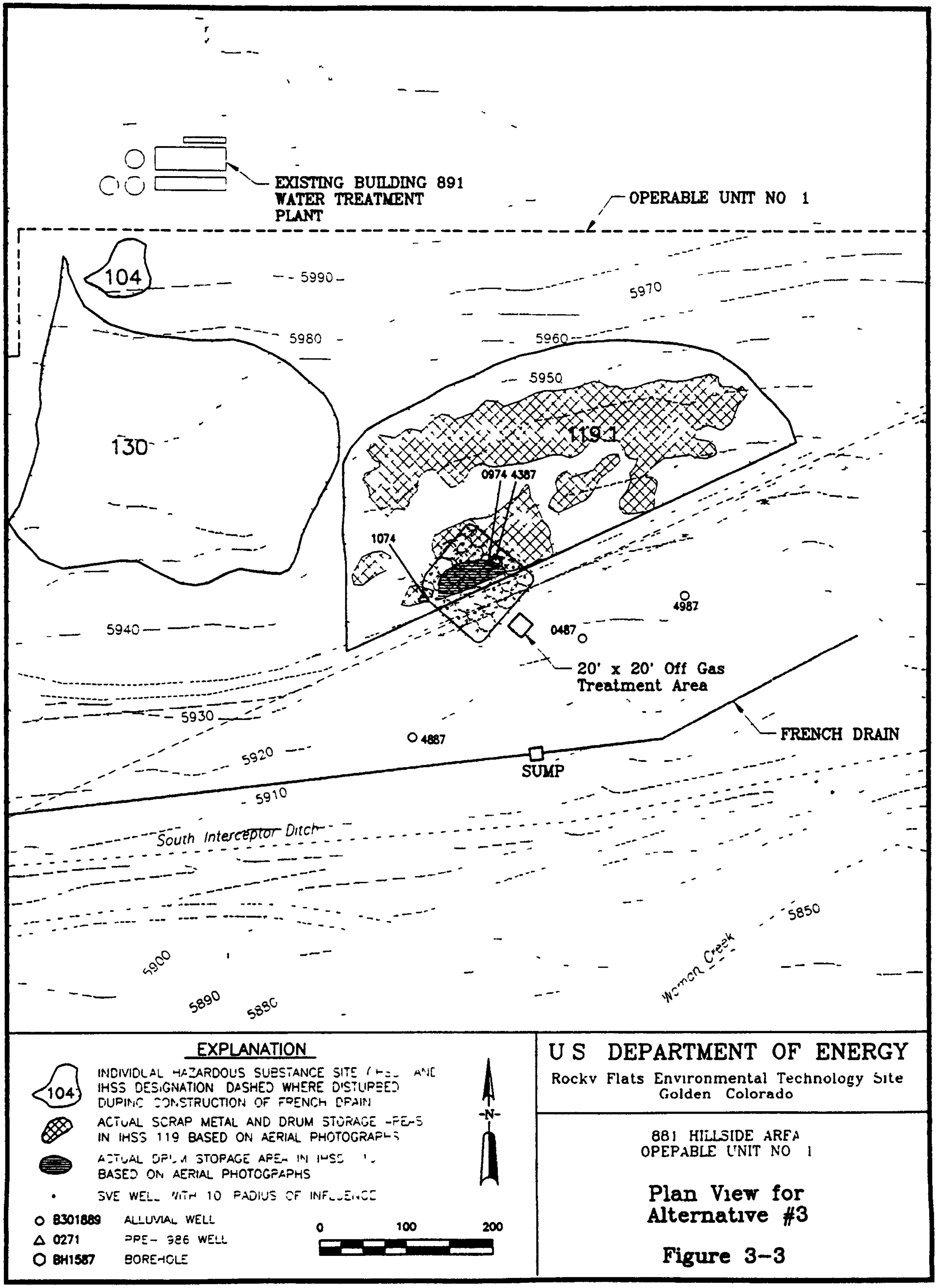
Wastes generated as a result of this alternative will be managed in compliance with applicable regulations. The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion-exchange resin regeneration from the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water The decontamination water could be sent to Building 891.

The regenerant solution from the spent ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation in accordance with current operational practices. The spent GAC will be sent off site for regeneration

The total remediation time frame associated with this alternative is approximately seventeen years Estimated time frames associated with various component remedial activities are three months for the detailed soil gas survey, three months for mobilization/demobilization, and four years for treatment Once the SVE system was decommissioned, the French Drain would continue operating for 10 years to remediate the groundwater plume currently flowing down the hillside Monitoring would continue for an additional three years after decommissioning the French Drain to ensure that contaminant levels remain below PRGs The GAC air treatment unit for SVE unit would most likely require a National Emission Standards for Hazardous Air Pollutants (NESHAPs) permit to operate, however this would not present any unusual administrative constraints

3 2 4 Alternative 3 Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement

This alternative seeks to achieve RAOs through combining SVE as described in Alternative 2 with thermal recovery enhancement techniques Groundwater extraction is employed to treat contaminated groundwater, while SVE with thermal enhancement is used to remove residual contamination sources The alternative considers two innovative treatment technologies that can effect an increase in subsurface soil temperatures — radio frequency heating and electrical resistance (ohmic) heating Both technologies are discussed below, although for the purposes of detailed analysis, radio frequency heating is analyzed further, whereas ohmic heating is merely assumed to be potentially applicable at OU-1 and is not included in the detailed analysis of alternatives A plan view of the alternative, including the treatment area with approximate well locations, is included as Figure 3-3



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Plan View for Alternative #3

Figure 3-3

OU1 SVE1.DWG

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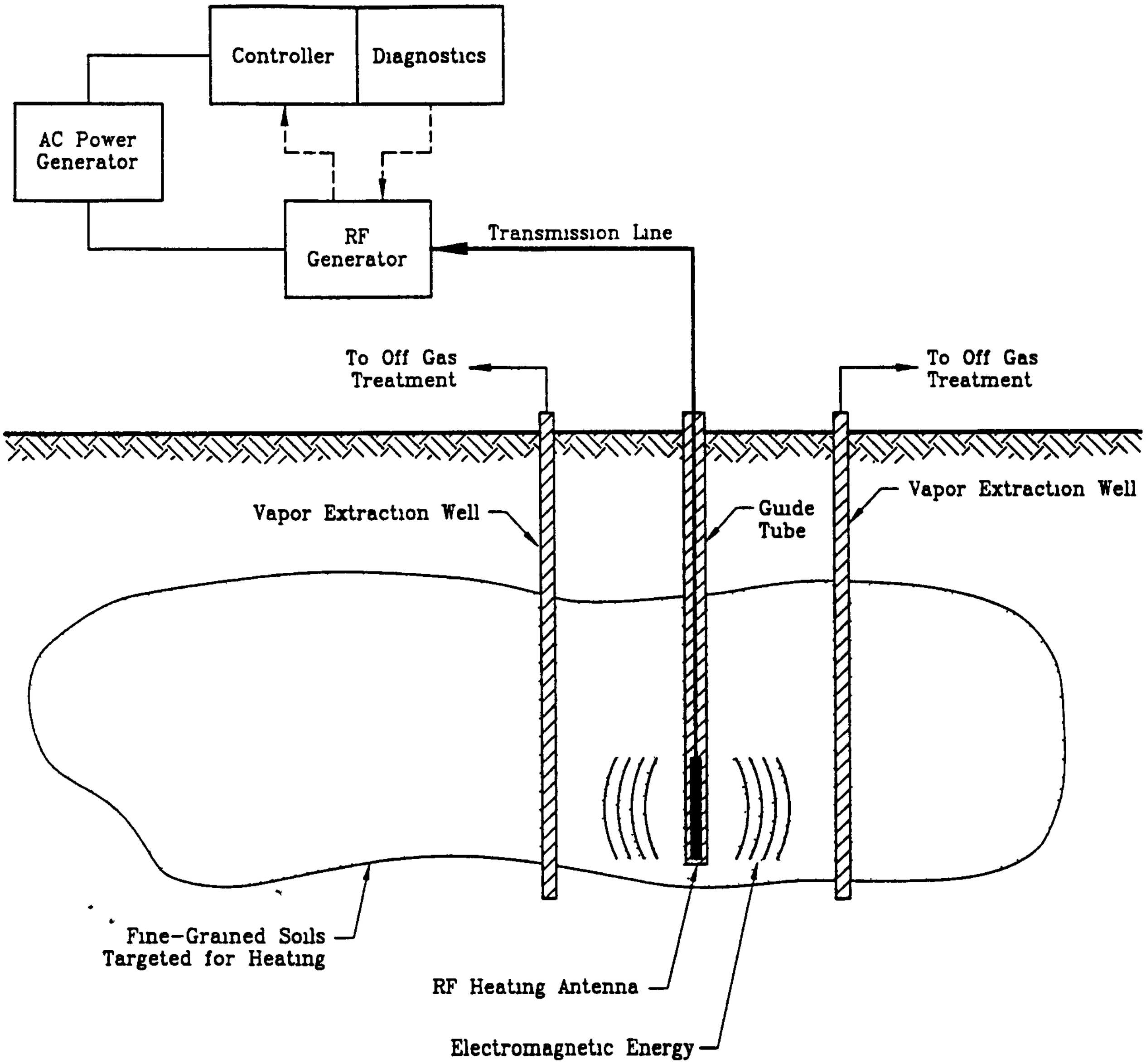
Radio Frequency Heating

RF heating was selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU-1 that are contaminated with those contaminants that are VOCs RF heating is an innovative in-situ technology for volatilizing organic constituents in soil and water as well as vaporizing pore space moisture The technology is desirable since additional chemicals are not introduced into the subsurface and no special arrangement (e g , grids) are necessary as in conventional ohmic heating

The in-situ RF heating process requires minimal intrusion, using 3- to 6-inch diameter boreholes containing strategically placed antennae in the desired treatment area Through a combined mechanism of ohmic and dielectric heating, the temperature in the media is raised and the volatile and semivolatile organic constituents are volatilized (Kasevich 1992) Volatilized organics are then collected with the vapor extraction system and subjected to further treatment RF heating is expected to supplement vapor extraction in a manner that allows for quicker recovery of VOCs from certain areas of the subsurface Specifically, heating VOC source areas can expedite VOC recovery in the vapor form (i e , hotspots are likely to contain aqueous, DNAPL, and adsorbed phase VOCs which would be driven to vapor under elevated temperature conditions) Figure 3-4 illustrates a simple application of RF heating combined with vapor extraction for this alternative

The dielectric loss of a material (i e , the amount of energy a material dissipates as heat when placed in a varying electric field) contributes to the heating of the contaminated media An indicator of a material's ability to successfully absorb electromagnetic energy is its dielectric constant Most soils have suitable dielectric constants that allow for effective treatment Water and/or soil moisture is vaporized by RF energy; however, steam is transparent to RF energy and does not continue to absorb radiation energy. While the steam may become superheated, this occurs only by energy conduction from the solid media and not from direct electromagnetic energy absorption. The steam in turn serves to heat surrounding materials, enhancing additional vaporization Thus, water and/or soil moisture does not present a hindrance to the treatment



Note Figure represents information provided in part by KAI Technologies, Inc

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Conceptual View of Radio Frequency Heating System

Figure 3-4

OU1-CS2 DWG

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process Fractures and voids within the contaminated matrix also do not present treatment problems since thermal conduction is not the primary heat transfer mechanism Densely packed soils are well suited to this treatment as are other consolidated geologic materials A variety of heating profiles can be generated by manipulating the subsurface placement of RF antennae, their operating frequencies, and the phase output of the different antennae Virtually uniform heating within a specified volume can be achieved with minimal heating of surrounding material using a properly designed configuration Thus, localized treatment can be attained with proper design

RF heating has been shown to be capable of increasing soil temperature to approximately 500°F This temperature would be great enough to volatilize both sorbed and potentially dissolved phase contaminants (e g , aqueous phase) in the subsurface materials as well as drive off any moisture in nearby pore spaces The temperature of the subsurface medium would be raised gradually, therefore, vapor extraction wells would be able to extract vapor as it is generated The heating and resulting steam/vapor generation rate could be controlled so that the capacity of the vapor recovery system would not be exceeded Such control would prevent the spread of contamination by steam plume expansion Also, RF heating would only be implemented in the vicinity of a vapor extraction well Placement of an RF heating antennae in this manner would provide assurance that RF heating would not lead to a spread of contamination A vapor recovery system supplemented with RF heating would likely require additional air drying capacity since it is expected that the RF heating system would lead to the extraction of a greater amount of soil moisture than conventional vapor extraction

The primary piece of equipment of this alternative is the applicator antenna, which is placed in a borehole This antenna is generally a flexible component of varying length that radiates electromagnetic energy in the form of radio frequency waves The energy originates from a generator at the surface and is transmitted to the antenna via a metal coaxial cable. Standard drilling equipment can be used to complete a borehole The borehole is generally cased with fiberglass or a similar material that is transparent to electromagnetic radiation The antenna can be placed in vertical or horizontal boreholes Also, several antennae may be used concurrently in various areas with elevated contaminant concentrations.

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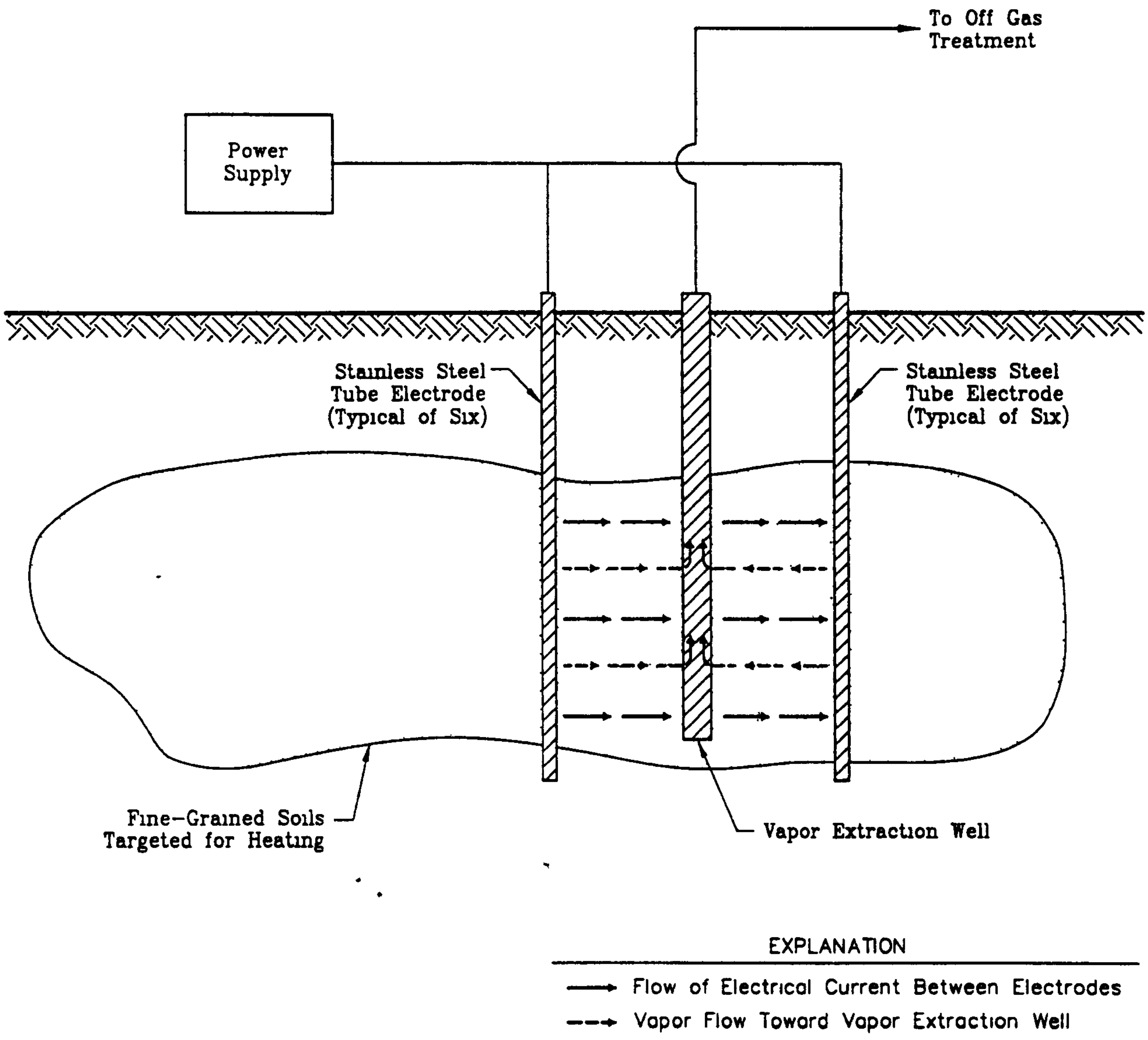
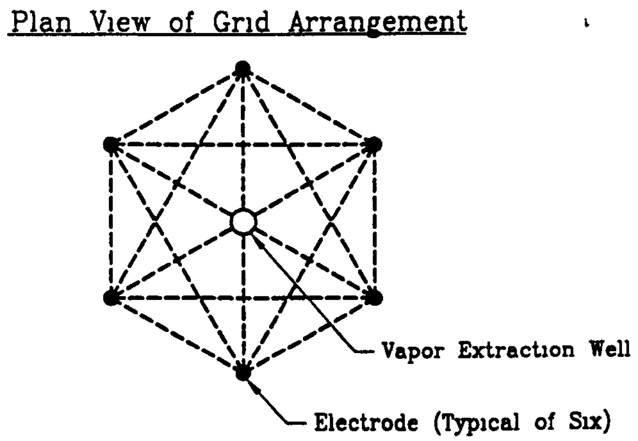
Locations of RF antennae and vapor extraction wells for cleanup of the volatile subsurface contaminants at OU-1 are contingent on detailed design through which the optimum system design would be defined; however, it is assumed under this alternative that RF heating antennae would be installed in vapor extraction wells near the vapor extraction wells being operated The number of vapor extraction wells required would range from 20 to 40 depending on saturation levels The spacing between boreholes can range depending on the RF heating frequency, depth interval of heated volume, and properties of the materials heated An array of multiple boreholes can provide uniform heating of a given subsurface volume Control devices monitor performance of the RF generator and adjust the outputs to optimize system performance Soil gas monitoring wells must be in place in the vicinity of the RF heating antennae These wells are necessary to monitor for potential increased migration of contaminant outside of the radius of influence of the vapor extraction well(s)

Ohmic Heating

Ohmic heating was also selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU-1 that are contaminated with volatile contaminants This technology is considered an "emerging" technology which is currently being examined under the OU-2 treatability study program Like RF heating, ohmic resistance heating is an innovative in-situ technology for enhancing the performance of soil vapor extraction by volatilizing organic constituents in soils and groundwater, and by vaporizing pore space moisture Unlike RF heating, however, ohmic resistance heating results from the transmission of an electrical current through the media targeted for cleanup As such, a prerequisite for ohmic heating is that the media must be able to conduct an electrical current Ohmic heating requires the placement of a grid of electrodes and sometimes the addition of water in the area targeted for remediation. The process requires only minimal intrusion and has most often been implemented using six electrodes installed in a hexagonal pattern to the depth of the contaminants, with a vapor extraction well placed in the center of the pattern as shown in Figure 3-5 (Aines et al)





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Conceptual View of Electrical Resistance Heating System

Figure 3-5

OU1-CS3 DWG

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Six- or three-phase power can be used to supply current to the installed electrodes There is some benefit with six-phase power in that a more uniform heating pattern can be realized in the area being treated (Buettner et al) However, the increased uniformity comes at the expense of needing additional equipment to split normal three-phase power into six-phase Electrodes are usually constructed of stainless steel tubing, which can also serve as passive air inlets

The principle of ohmic heating is simple Basically, electrical currents are made to flow between electrodes placed in a contaminated region causing resistance heating (much the same way that passing an electrical current through an oven heating element generates resistance heating) Current flow through subsurface materials tends to be greatest in fine-grained soils such as silts and clays These types of soils are generally less permeable than sands and gravel, thus, heating the clays and silts can drive off contaminants contained therein that are not easily accessible with conventional soil vapor extraction Once the volatile contaminants are driven out of the less permeable clays and silts into the more permeable sands and gravel, they are more susceptible to recovery by vapor extraction As with RF heating, soil moisture can be heated with ohmic heating to generate steam Steam can provide additional stripping of adsorbed contaminants Also, the removal of soil moisture can increase the air flow permeability of the soil being treated, thus enhancing the capability of vapor extraction to remove contaminants (but lessening the ability to continue heating the subsurface with electrical current)

The primary pieces of equipment needed to support ohmic heating include stainless steel piping (for electrodes), a 60 Hz power supply, an optional six-phase transformer, thermocouples for monitoring subsurface temperature, and a vapor recovery/treatment system Electrode grids may be placed at various locations targeted for treatment Extracted vapors from multiple locations may be directed to a central treatment location or to individual treatment units

The location of the electrode grid(s) and vapor extraction well(s) for cleanup of the volatile subsurface contaminants at OU-1 are contingent on treatability test results in which the optimum system design would be defined, however, for this alternative it was assumed that one grid would be installed at IHSS 119.1. This grid would have six electrodes inserted to approximately

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20 feet below the surface in a hexagonal arrangement making up a circle with a diameter of approximately 20 feet Additional grids would be required to remediate the entire site As previously discussed the conceptual approach presented for RF heating is carried forward for detailed analysis The information presented here on ohmic heating may be beneficial if it is selected as the preferred technology prior to implementation of any remedial actions at OU-1

A soil gas survey, consisting of approximately 100 probes, will be conducted to determine exact locations of wells and to identify any additional areas warranting remediation There is a possibility that DNAPL pools will be encountered during the remediation and may present a fire hazard or health and safety concern Procedures will be in place during the remediation to minimize any hazards or concerns

Based on historical photographs of the drum storage area at IHSS 119 1 and an assumed lateral DNAPL dispersion through the subsurface soil, the dimensions of the primary contaminant source were estimated at 100 feet by 100 feet by 20 feet Because SVE extraction rates are optimal in dry soil, the treatment zone will be dewatered by groundwater extraction wells Initial dewatering is required with intermittent operations to keep the treatment zone dewatered throughout the entire remedial action

Extracted groundwater will be pumped to the French Drain where it will be transferred to the Building 891 water treatment system described in Section 2 The French Drain will continue to capture groundwater for 10 years following source removal activities in order to capture the contaminated groundwater plume Three additional years of monitoring will be used to verify that the groundwater concentrations remain below PRGs

The SVE system will operate as described in Alternative 2, with the exception that radio frequency antennae will be placed in wells as necessary to maintain elevated subsurface temperatures Approximately 36 vapor extraction wells fitted for radio-frequency antennae will be drilled with a 30% radius of influence (ROI) overlap in the treatment area. Based on the OU-2 SVE treatability study, it is estimated that 4-inch diameter wells will produce a well head pressure of 120 inches of water and a ROI of 10 feet under normal operating conditions With an estimated soil permeability of 0 05 darcy, it is anticipated that vapor extraction rates will approach 10 standard cubic feet per minute (scfm) The treatability study at OU-2 indicated that extraction rates are optimal during dry conditions so the treatment area will be dewatered during the remediation Extraction rates, documented during the SVE treatability study, at OU-2 decreased from 40 scfm to 5 scfm during wet conditions

Intermittent operation will be utilized to increase the removal efficiency of the SVE system Preferential vapor channeling, or short-circuiting, will be minimized by a geotextile liner Increased vaporization caused by the elevated temperatures will reduce remediation time as well as increasing removal efficiencies of the contaminants

Extracted vapors will be transferred to an off-gas treatment system such as GAC unit A GAC system would require two skid-mounted GAC vessels placed in series and each containing 1,500 pounds of activated carbon each The GAC will need to be replaced approximately every three months, i e , 1,500 pounds every 6 weeks, depending on the COC concentrations, loading efficiencies, competitive adsorption rates, and type of carbon The spent GAC will be regenerated at an off site facility

Vapor sampling from portals near the wells and GAC units will be used to determine the effectiveness of the enhanced SVE system, replacement rates for the GAC vessels, temperature, and humidity. In addition, pressure will be monitored at the wells and probes to determine extraction rates, radii of influence, and if short-circuiting is occurring.

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion-exchange resin regeneration from the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water The decontamination water can be sent to Building 891 The regenerant solution from the spent ion-exchange resins will be pH neutralized and sent to

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Building 374 for evaporation in accordance with current operational practices The spent GAC will be sent off site for regeneration

This alternative would require a remediation time frame of approximately 15 5 years This includes three months for a detailed soil gas survey, three months for mobilization and demobilization, two years for treatment, ten additional years of French Drain operation, and three years of groundwater monitoring to ensure that groundwater concentrations remain below PRGs This would be required to verify that all residual sources of DNAPLs in the subsurface have been remediated NESHAPs permits would be required for any other gas treatment systems

3.2 5 Alternative 4. Hot Air Injection with Mechanical Mixing

This alternative seeks to achieve RAOs through an innovative in-situ technology that combines hot air stripping with vigorous mixing of subsurface media Contaminated groundwater is remediated through extraction and treatment in the Building 891 facility, while the subsurface residuals are addressed by source removal with hot air injection and mechanical mixing This alternative targets the identified source area in IHSS 119 1, but additional areas could be included based on the results of a detailed soil gas survey preceding treatment The IHSS 119 1 source area is estimated at 100 feet by 100 feet, with a depth to bedrock of approximately 20 feet

This innovative technology operates under the same basic principles of SVE and thermal enhancement discussed in the previous alternatives, but combines these with vigorous mechanical mixing to increase treatment effectiveness by ensuring carrier gas contact with all contamination The mixing of the soils by an auger allows homogenous treatment, avoiding the possibilities of preferential subsurface flow channels that could result in non-uniform treatment. This system represents an innovative combination of technologies to increase treatment effectiveness and decrease treatment time.

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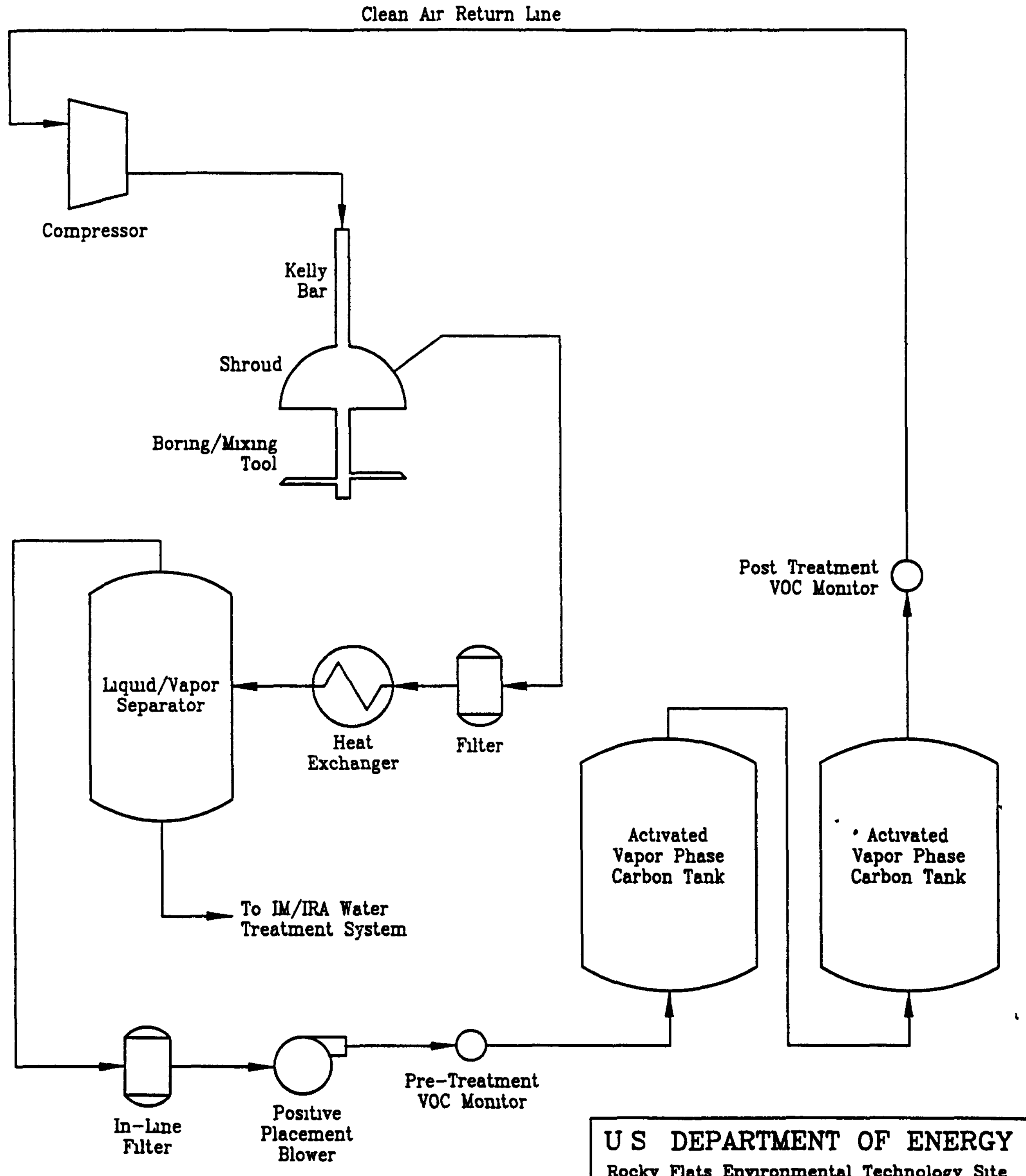
The primary treatment system in this alternative consists of a caterpillar mounted drill rig with specialized drilling equipment The drill equipment is capable of delivering treatment reagents, such as hot air or steam, via piping in a hollow drill bit shaft The drill bit has a cutting/mixing blade, which can vary in diameter from 4 to 12 feet Groundwater extraction wells would be placed in previously treated soil columns Dewatering of a small area prior to treating the initial soil column would be accomplished via an extraction well drilled with conventional drilling equipment Extracted groundwater would be treated through the existing Building 891 treatment system The drill rig can produce up to 350,000 ft lbs of torque, sufficient to provide excellent mixing of subsurface soils as the drill bit descends through the soil column The drill bit also has multiple injection ports for hot air delivery. The multiple ports provide uniform delivery of hot air throughout the treatment zone The caterpillar mounted drill rig is moved from one treatment zone to another sequentially until the entire site is remediated. The treatment columns, or drill shafts, are overlapped by 30% to ensure adequate treatment throughout the entire site 4 to 6 columns can be treated per day, depending on site conditions. A conceptual view of the hot air injection and mechanical mixing technology is included as Figure 3-6

For volatile compounds such as those at OU-1, a negative pressure shroud is placed over the entire treatment zone to capture off-gases for delivery to an onboard off-gas treatment system Mats are placed under and around the rig to ensure that contaminants do not reach the atmosphere by surfacing outside the shroud The shroud vacuum is connected to an off-gas treatment system A vapor-liquid separator removes entrained liquids for delivery to the Building 891 water treatment system. Vapors continue through the off-gas treatment system For the contaminants and concentrations at OU-1, vapor phase carbon adsorption is the preferred treatment option. Once treated, the air is recycled to a compressor and heater and reinjected to the subsurface

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion-exchange resin regeneration from the Building 891 water treatment system, and wastes associated with monitoring well installation



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Conceptual View of Hot Air Injection System

Figure 3-6

OU1-WTS DWG

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such as drill cuttings and decontamination water The decontamination water can be sent to Building 891 The regenerant solution from the spent ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation in accordance with current operational practices The spent GAC will be sent off site for regeneration

Approximately 141 soil columns will be necessary to remediate the identified source area in IHSS 119 1, which could be accomplished in three months The total remedial time frame for this alternative is 13 75 years, with three months for the detailed soil gas survey, three months for mobilization and demobilization, three months for treatment, ten additional years of French Drain operation to remediate the contaminated groundwater plume, and three additional years of monitoring to ensure groundwater concentrations remain below PRGs A plan view for this alternative is included as Figure 3-7

3 2 6 Alternative 5. Soil Excavation with Groundwater Pumping

This alternative is intended to achieve RAOs through excavation of contaminated groundwater and soil beneath a discreet portion of the IHSS This alternative differs from the in situ treatment alternatives in that a portion of unsaturated and potentially saturated soils at the IHSS would be excavated down to the water table to allow for the removal of localized groundwater contamination The excavated soils would be treated by thermal desorption to minimize any further degradation of groundwater beneath the IHSS from residual DNAPLs present in the soils. This is a worst-case scenario which would enable contaminated water to be located and subsequently removed Such efforts may be required based on the current understanding of the hydrogeologic conditions at OU-1, which suggest complex geology in the area Excavation and groundwater pumping are established remedial technologies which can be combined with no significant difficulties

This alternative would require excavation of approximately 17,500 cubic yards of unsaturated and potentially saturated soils in the southwest corner of IHSS 119 1 based on the results of the Phase III RFI/RI (see Figure 2-1). Excavation of the required volume would result in an

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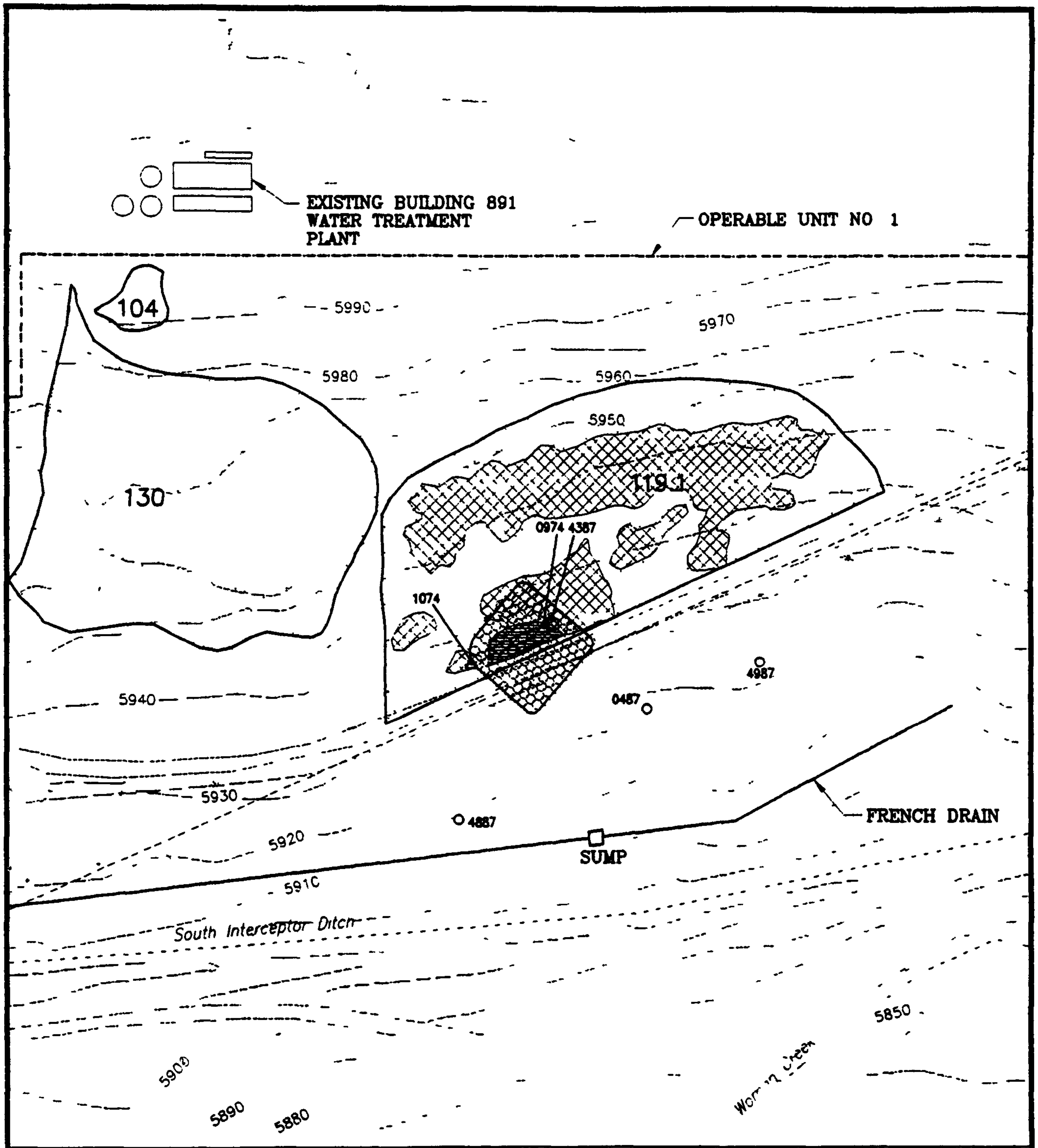

EXPLANATION

104	INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
	ACTUAL SCRAP METAL AND DRUM STORAGE AREAS IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS
	ACTUAL DRUM STORAGE AREA IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS
	10 DIAMETER BOREHOLE
O B301889	ALLUVIAL WELL
△ 0271	PRE-1986 WELL
O BH1587	BOREHOLE

N

0 100 200

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Plan View for Alternative #4

Figure 3-7

OU1-BRS2 DWG

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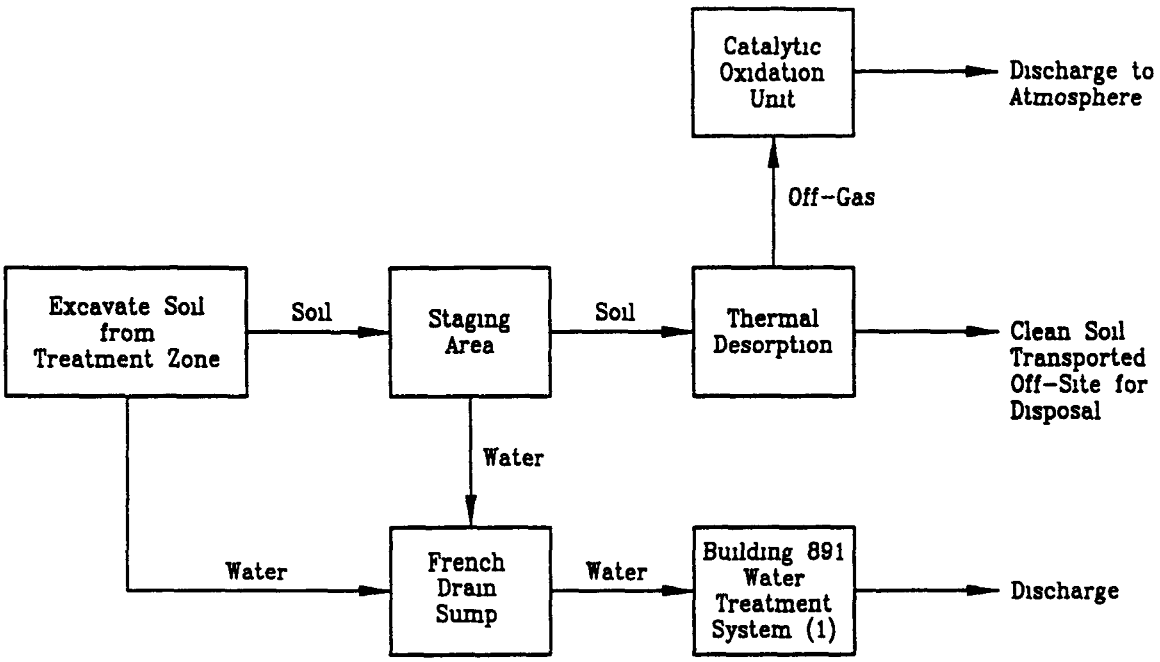
excavated area of 0 7 acres, based on excavating a 100 ft. by 100 ft area down to bedrock (20 ft) with sloping around the area of 2 to 1

Excavation would be terminated slightly below the underlying bedrock to ensure that all contaminated groundwater pools are reached The groundwater would be collected using sump pumps installed within the excavation Standard submersible pumps would be used to direct collected groundwater to the existing French Drain sump pumps The groundwater would then be transferred to the Building 891 water treatment system at OU-1 for final treatment and discharge A conceptual view of the excavation and treatment process is shown in Figure 3-8 A piping system from the excavation to the OU-1 treatment facility would be required and would most likely be constructed of PVC and buried to a sufficient depth to prevent freezing

Surface soils located within the excavation area will be scraped and stockpiled on site to be treated with surface soil from OU-2 at a later time The subsurface soil will be excavated and transported to a staging area for treatment It is anticipated that the staging area can be constructed within 300 feet of the excavation Management of the surface and subsurface soil will comply with 40 CFR 264 and may include creating a roof or other cover over the staging area to minimize precipitation onto the soil and prevent fugitive dust losses, landscaping the area to create adequate drainage, placing a pad or liner under the storage areas to prevent infiltration, and limiting access to the storage sites The actual excavation would be accomplished using conventional construction equipment although breathing apparatus may be included as part of the machinery or may be handled separately on an individual basis

The excavated soil in the staging area will be dewatered and treated by a skid-mounted thermal desorption unit to below detection limits for PCE, TCE, 1,1-DCE, CCl_4, and 1,1,1-TCA The treated soil should meet the RCRA Land Disposal Restrictions, including restrictions for radionuclides and metal compounds, prior to disposal in a permitted treatment, storage, and disposal (TSD) facility. It is assumed that an appropriate facility is located within 100 miles of the site. The treated soils could be disposed of on site, however due to the administrative difficulties of delisting hazardous wastes, it has been assumed the treated soils will be shipped



(1) See Figure 2-2

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Conceptual View of Excavation and Treatment Process

Figure 3-8

OU1-ETP DWG

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off site for disposal.

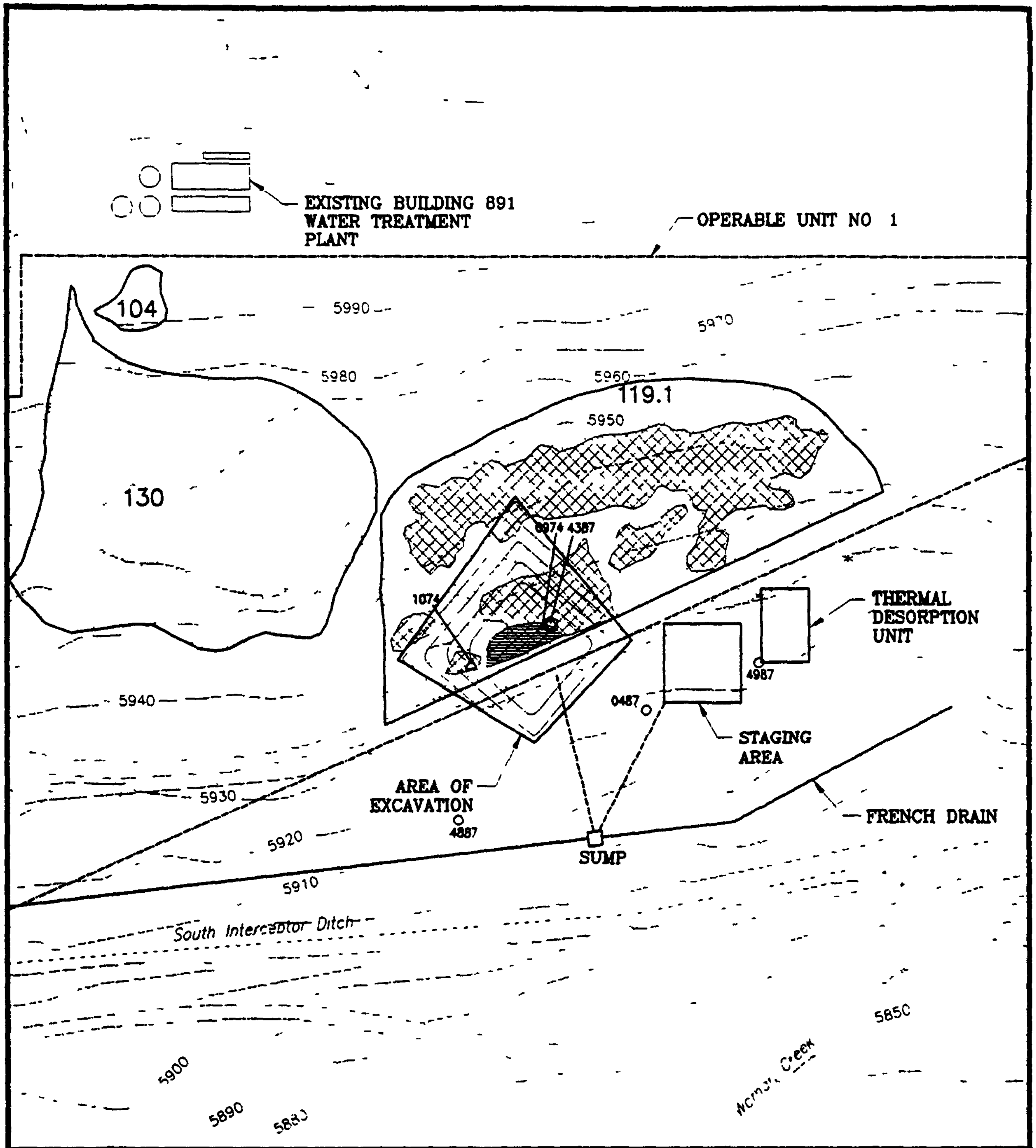
Groundwater extracted from the excavation will be pumped to the French Drain where it will be transferred to the Building 891 water treatment system The French Drain will continue operating for 10 years after remediation to collect contaminated groundwater Groundwater monitoring will continue for an additional 3 years following French Drain discontinuation of French Drain operation to verify that the concentrations remain below the PRGs at the French Drain

Radiological monitoring would be conducted for the duration of the excavation due to the potential presence of plutonium in the soils Although Alternative 5 involves removal of the source of contamination to groundwater at IHSS 119.1, groundwater monitoring of groundwater would still be required once the remedial action is complete to verify that all sources of residual DNAPL contamination have been remediated Short-term monitoring of vapor concentrations in air would also be required during the excavation and prior to its closure.

A buried gas transmission line is located in the vicinity of IHSS 119 1 and the French Drain Site utility maps will be consulted during the excavation and prior to laying the PVC pipe to ensure that the transmission line is not damaged Standard health and safety practices will also be used to ensure that the transmission line remains intact

All wastes generated as a result of this alternative will be managed in compliance with applicable regulations They include spent GAC from the off gas treatment system and Building 891 water treatment system, regenerant solution from ion-exchange resins in Building 891, treated soil, and wastes associated with installation of monitoring wells such as drill cuttings and decontamination water The regenerant solution from the ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation. Treated soil will be managed before final disposal in essentially the same manner as untreated soil and the spent GAC will be sent off site for regeneration

The total remedial time frame for this alternative is 14 years. This includes three months for a detailed soil gas survey, three months for mobilization and demobilization, nine months for excavation, ten additional years of French Drain operation for plume remediation, and three subsequent years of continued monitoring to ensure groundwater concentrations remain below PRGs A plan view of Alternative 7 is illustrated in Figure 3-9



EXPLANATION

104 — INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN

ACTUAL SCRAP METAL AND DRUM STORAGE AREAS IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS

ACTUAL DRUM STORAGE AREA IN IHSS 119.1 BASED ON AERIAL PHOTOGRAPHS

○ B301889 ALLUVIAL WELL

△ 0271 PRE-1986 WELL

○ BH1587 BOREHOLE

N

0 100 200

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Plan View for Alternative #5

Figure 3-9

OU1-EXC1 DWG

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4.0 DETAILED ANALYSIS OF ALTERNATIVES

4 1 Description of Evaluation Criteria

This section analyzes the proposed remedial action alternatives using the criteria specified at 40 CFR 300 430 of the NCP and the *RCRA Corrective Action Plan* (CAP) (EPA 1994) Details of the alternatives presented in Section 3 0 are used as the basis for these analyses which address both the CERCLA criteria and RCRA standards There are nine criteria designated in the NCP regulations and nine standards under the RCRA CAP guidance The NCP and CERCLA guidance divides the criteria into threshold, balancing, and modifying criteria Threshold criteria are statutory requirements that must be satisfied for an alternative to be eligible for selection The two threshold criteria for this detailed analysis are overall protection of human health and the environment and compliance with ARARs

The five primary balancing criteria of (1) long-term effectiveness and permanence, (2) reduction in toxicity, mobility, and volume, (3) short-term effectiveness, (4)implementability, and (5) cost are used to evaluate each alternative's major performance objectives The relative performance of each alternative is evaluated and then compared to others to identify if any one alternative meets all the criteria

The two modifying criteria, state acceptance and community acceptance, evaluate the feasibility of implementing an alternative in terms of its acceptance by regulatory agencies and the public These criteria are not evaluated until after the formal public comment period on the CMS/FS report and proposed plan The criteria are addressed in the CAD/ROD

4.1.1 Overall Protection of Human Health and the Environment

Under CERCLA criterion and RCRA standards, each alternative is evaluated for the overall protectiveness of the proposed action. Proposed alternatives describe how human health and environmental risks are eliminated, reduced, or controlled through treatment, engineering

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controls, or institutional controls The overall protection of human health and environment criteria is a threshold criteria which an alternative must meet to be the selected action In particular, each alternative is required to be evaluated in meeting RAOs established for the site The assessment also involves analyzing whether PRGs are satisfied through implementability, long-term effectiveness and permanence, and short-term effectiveness The evaluation of overall protectiveness examines whether an alternative results in any unacceptable risks or cross-media impacts to a site The other threshold criteria is compliance with ARARs Each alternative is required to be evaluated on the basis of how it complies with ARARs

4 1 2 Compliance with Applicable or Relevant and Appropriate Requirements

The selection of ARARs for an alternative is governed by the regulations of the NCP and EPA's Office of Solid Waste and Emergency Response (OSWER) Directives Such directives include the *Compliance with Other Laws Manual* (EPA 1988b) and the RCRA CAP guidance A discussion of the selection of chemical-specific ARARs for OU-1 has been presented in Section 2 Briefly summarized, ARARs are

- Applicable, a requirement that applies, under circumstances other than CERCLA, to the contaminant, action, situation, or location, or
- Relevant and appropriate, a requirement not normally applicable to the site but because the requirement addresses an activity, location, or situation similar to the site and the requirement is well-suited to the remedial action proposed at the site, it is judged relevant and appropriate. It is possible for a requirement to be relevant but not appropriate for a site

As remedial action alternatives are developed and screened through the CMS/FS process, environmental standards are further analyzed and screened for the site. Action-specific and location-specific ARARs previously identified in the OU-1 CMS/FS process have been further screened to check the jurisdictional and circumstantial ARAR prerequisites. Each identified standard has been noted as applicable, or relevant and appropriate, or not applicable or relevant and appropriate for each alternative at OU-1. Any proposed standard or guidance which could be relevant to the circumstances at OU-1, was considered in the screening process. Proposed

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standards and current guidance are described as TBCs in the detailed analyses. The criteria used to evaluate applicable requirements are

- Is the substance or contaminant addressed under the regulation
- Is the time period in the regulation applicable
- Does the regulation require, limit, or prohibit the activities
- Who is subject to the regulation
- Who is exempt from the regulation

The criteria used to evaluate relevant and appropriate requirements are

- The substance or contaminant addressed under the regulation is similar to the situation at OU-1

- The media affected by the requirement is similar to the circumstances at OU-1

- Activities affected by the regulation are similar to activities proposed at OU-1

- The area addressed by the regulation is similar to the area affected by the proposed alterative at OU-1

- Structures, facilities, or technologies addressed by the regulation are similar to those proposed at OU-1

- Exemptions or variances of a requirement are appropriate to the circumstances at OU-1.

Each specific alternative is assessed to determine if the proposed action can comply with each identified ARAR or TBC Section 121(d) of CERCLA requires remedial actions to comply with or exceed the ARARs designated at a site. It is a threshold criteria designated in the NCP regulations for proposing an alternative at a site. Compliance with applicable standards for waste management is also one of the criteria under the RCRA CAP guidance.

Compliance with an ARAR can be waived under specific circumstances as designated in CERCLA, as amended [Section 121(d)(4)] and in the NCP regulations. Any proposed waivers from the ARARs are presented in the Proposed Plan and Record of Decision along with the

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reasons for such an action   Reasons for a waiver include

- A State standard has not been consistently applied in similar circumstances
- The proposed action is an interim action
- Compliance with the ARAR will result in greater risk to human health and the environment than other alternative options
- Compliance is not technically feasible
- The selected action will attain a standard equivalent to an applicable standard using another approach

The RCRA CAP guidance does not include a specific method for obtaining waivers from ARAR compliance during a CMS   The Guideline does allow for some latitude in the establishment of media cleanup standards, however

Media cleanup standards may be proposed by the permittee/respondent in the CMS Report based on promulgated federal and state standards, risk derived standards, site specific information, and/or applicable guidance documents   Alternatively, standards may be set by the implementing agency prior to the CMS stage   If media cleanup standards are set by the implementing agency, the permittee/respondent may propose to modify them during the CMS   Final media cleanup standards will be determined by the implementing agency when the remedy is selected

In addition to attaining the established media cleanup standards, potential remedies considered during the CMS process are required to comply with all applicable state or federal regulations

State of Colorado Regulations allow for petitioning for the modification or waiving of RCRA regulations   General requirements for the petitioning process are found in 6 CCR 1007-3, Subpart C - Rulemaking Petitions. This section provides that any person may petition to modify or revoke any provision in Parts 260 through 265 of the Colorado Hazardous Waste Regulations. For example, wastes at a facility may be excluded from the list of hazardous wastes if the petitioner can demonstrate to the satisfaction of the CDPHE that the waste produced at the

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facility does not meet any of the criteria under which the waste was listed as a hazardous waste The results of the ARAR analysis conducted at OU-1 for each alternative is presented in a tabular form in Appendix D Key ARARs selected from Appendix D for discussion in the detailed analysis of alternatives are those which are judged to be most critical to an alternative's implementation Key ARARS include

- Colorado Basic Standards for Groundwater - 5 CCR 1002-8, 3 11 5 and 3 11 6
- Colorado RCRA Regulations - 6 CCR 1007-3 Parts 264 and 268 and proposed changes to Part 261
- Colorado Air Pollution Control Regulations - 5 CCR 1001-5, Regulation 7
- Colorado Nongame, Endangered or Threatened Species Conservation Act - CRS 33-2-101

<u>Key Applicable or Relevant and Appropriate Requirements</u>

Since the State of Colorado is authorized by EPA to implement the RCRA program, the RCRA ARARs under the State program are designated as key ARARs Releases and spills at OU-1 occurred prior to the effective date of the RCRA regulations so many of the RCRA regulations are designated relevant and appropriate rather than applicable to OU-1 The exception to this is the Colorado regulations regarding solid waste management units (SWMU) in 6 CCR 1007-3, 264 90(a)(1) which are applicable to the circumstances at OU-1 They state that the owner or operator of constituents in SWMUs must comply with 264 101 Releases of hazardous constituents from SWMUs according to 264 101, Subpart F, require corrective action for protection of human health and the environment

Subpart F of the Colorado RCRA regulations also concern groundwater protection Many of the subsections of this subpart are directed to regulated units but OU-1 is not a regulated unit. However, OU-1 lists SWMUs in a RCRA Part B permit application inventory. Therefore, sections of Subpart F that are relevant and appropriate to OU-1 include:

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- 6 CCR 1007-3, 264 92 Groundwater protection standards
- 6 CCR 1007-3, 264 93 Hazardous constituents
- 6 CCR 1007-3, 264 94 Concentration limits
- 6 CCR 1007-3, 264 95 Point of compliance
- 6 CCR 1007-3, 264 96 Compliance period
- 6 CCR 1007-3, 264 97 General groundwater monitoring requirements
- 6 CCR 1007-3, 264 98 Detection monitoring program

These subsections are focused on the specifics of conducting a groundwater monitoring program and detecting exceedances of the groundwater protection standards

The other requirements of the Colorado RCRA program that are applicable to OU-1 are contained in 6 CCR 1007-3, 264 101 This section requires that corrective actions be located between the SWMU and the downgradient facility boundary or beyond the facility boundary where necessary to protect human health and the environment, unless specifically prohibited due to a lack of property ownership Onsite measures are determined on a case-by-case basis

Implementation of groundwater protection measures are also part of the Colorado Water Quality Control Commission's Basic Standards for Groundwater (5 CCR 1002-8, 3 11 0) Since the Colorado State Basic Standards for Groundwater are potential chemical-specific ARARs, the implementation approach within the standards would be relevant and appropriate but not applicable CDPHE has implementation responsibility as detailed in 5 CCR 1002-8, 3 11.6(B) The regulations of 5 CCR 1002-8, 3 11 6(C) and (D) provide some discretion in the selection of the point of compliance. Briefly summarized, the point of compliance could be established at any one of the following locations

- The site boundary

- The hydrologically downgradient limit of the area in which contamination exists at the time identified

- At some distance hydrologically downgradient from the activity causing the contamination and closest to the activity as determined by site-specific factors, such as the established wellhead protection areas, the potential of the site as an aquifer recharge area, and the recommendations of the owner or operator.

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Another part of the Colorado RCRA regulations that are relevant and appropriate to OU-1 is the closure and post-closure requirements for regulated units The closure requirements of 6 CCR 1007-3, 264 112 require preparation of a closure plan that is consistent with the requirements of the groundwater protection standards of Subpart F Elements of the State post-closure care requirements in 6 CCR 1007-3, 264 117 that are relevant and appropriate to OU-1 are the post-closure care period and the requirements for maintenance and monitoring of waste containment systems in accordance with Subpart F The post-closure period is 30 years after completion of remediation unless changed by CDPHE Reasons for a reduced period include a demonstration that the groundwater protection standard has not been exceeded for a period of three consecutive years In addition, it must be verified that the reduced time is protective of human health and the environment

Air emission standards under the Colorado RCRA regulations (6 CCR 1007-3, 264 1033, 264 1052, 264 1054, and 264 1057) and Regulation 7 of Colorado's Air Pollution Control Regulations are potentially applicable to the remediation alternatives that involve VOC emissions Regulation 7 requires the use of reasonably available control technology (RACT) to control VOC emissions of over two tons/year or two lbs/hour

Colorado's RCRA regulations require that VOC emissions from air stripping RCRA treatment units to be monitored and operated in accordance with the RCRA closed vent and control device system standards The standards require condensers or adsorbers to achieve 95 percent weight efficiency and to institute exhaust vent stream monitoring [6 CCR 1007-3, 264.1033(f), (g), or (h)] Valves and equipment leaks are required to be monitored and maintained in a condition to achieve the no detectable emissions level

The Colorado Nongame, Endangered, or Threatened Species Conservation Act (CRS 33-2-101 et seq) requires that indigenous species found to be endangered or threatened in Colorado be protected in order to maintain and enhance their numbers It is a relevant and appropriate requirement for the OU-1 earth-disturbing remediation alternatives The Colorado Division of

Wildlife (CDOW) has the responsibility of determining management needs that will allow for the continued sustainability of populations of nongame species.

The Colorado Nongame, Endangered, or Threatened Species Conservation Act is particularly significant to RFETS because it has the largest known population of Preble's meadow jumping mouse (Zapus hudsonius ssp preblei) in Colorado The Preble's meadow jumping mouse is a species of special concern in Colorado A special concern species is not legally protected but CDOW favors maintaining the species and enhancing its habitat where possible Federal authorities currently consider the Preble's meadow jumping mouse a Category 2 species which is a candidate for listing as a Federal threatened or endangered species Studies to gather information concerning the species and its need for Federal and State protection are ongoing. Should the mouse be listed on the Federal Endangered Species Act List, the requirements of Section 7 of the Act would be a key ARAR Section 7 requires consultation with the U S Fish and Wildlife Service and in particular, preparation of a biological assessment concerning the species and its habitat

Habitat requirements for the Preble's meadow jumping mouse include intact riparian corridors such as those found along Woman Creek There has been positive identification of Preble's meadow jumping mouse in riparian areas adjacent to the OU-1 boundary As a Federal facility, it is the obligation of the operator of RFETS to minimize the impact of remediation to riparian areas RFETS staff will coordinate activities with CDOW to ensure that the population of Preble's meadow jumping mouse at RFETS is protected to the extent possible during implementation of the selected alternative at OU-1.

4.1.3 Long-Term Effectiveness and Permanence

One of the balancing criteria listed in the NCP is long-term effectiveness and permanence; in the CAP guidance it is listed as long-term reliability and effectiveness. Each alternative is also required to be evaluated against this criteria. The NCP emphasizes the preference for treatment to achieve long-term protection and permanence for a site. RCRA CAP guidance also emphasizes long-term reliability and effectiveness as a factor in selecting a proposed alternative Criteria for evaluating long-term effectiveness and permanence include the following

- Persistence, toxicity, and mobility of hazardous substances and their constituents and their tendency to bioaccumulate
- Long-term uncertainties associated with containment
- Long-term potential for adverse health effects
- Long-term cost of monitoring and maintenance
- Ease of undertaking future remedial action

Considerations are focused on the residual risk remaining after implementation of the alternative In particular, the evaluation of the alternative is to consider whether RAOs will be met RAOs often are focused on long term effectiveness and permanence The evaluation of a proposed alternative must include an analysis of the potential threat to human health and the environment from untreated waste or treatment residuals remaining at the site after remediation This analytical process includes the following elements

- Volume and concentration of contaminants in untreated media
- Volume and concentration of contaminants in treated residuals
- Requirements for 5-year site reviews and long-term monitoring
- Difficulties associated with long-term operations and maintenance
- Adequacy and reliability of controls
- Potential need to replace technical components
- Potential exposure pathways and risks posed should the remedial action need replacement

4.1 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Another one of the balancing criteria in the NCP and RCRA CAP guidance is reduction of toxicity, mobility, or volume of wastes through treatment The CERCLA criterion evaluates the ability of an alternative to reduce the risks at a site through the destruction of toxic contaminants, reduction of the mass of toxic contaminants, reduction in contaminant mobility, and reduction of the volume of contaminated media The NCP states a preference for remedial alternatives that include treatment which achieves this criterion as a principal element of the remedy RCRA CAP guidance also specifies reduction in the toxicity, mobility, or volume of waste as a standard for the selection of a preferred alternative Specific considerations for reduction of toxicity, mobility, or volume (TMV) include the following

- Adequacy of the treatment process to address PRGs
- Specific requirements and limitations of the treatment process
- Volume of the contaminated media treated
- Extent of TMV reduction
- Irreversibility of treatment
- Quantities and toxic characteristics of treatment residuals or byproducts

4 1 5 Short-Term Effectiveness

Short-term effectiveness is another of the NCP balancing criteria and a standard of the RCRA CAP guidance In evaluating alternatives, the CERCLA criterion and RCRA standards relevant to short-term effectiveness consider the period of time required for construction and implementation of each alternative The criterion evaluates community and worker protection during the remediation activity as well as potential adverse environmental impacts that may result from the alternative. The consideration of environmental impacts during remediation includes elements as an evaluation of the impact of the alternatives on the quality of habitat at the site

4 1.6 Implementability

Implementability is a criteria under both the NCP regulations and RCRA CAP guidance. This

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criterion addresses the technical and administrative feasibility of implementing an alternative including the availability of materials and services. Implementability is particularly important for evaluating the reliability of technologies that are innovative or proprietary Specific considerations relevant to implementability include the following

- Ability to construct and operate the alternative within a 10- to 30-year time frame
- Availability of equipment and specialists
- Availability and reliability of the components of the alternative
- Ability to monitor the effectiveness of the alternative
- Demonstrated performance level of the treatment components and equipment
- Difficulty in implementing future remedial actions once the alternative is in place

The RCRA implementability standard also requires addressing these same considerations for each alternative The implementability evaluation is required to identify the administrative and coordinated local, State, and federal requirements The CAP guidance requires identification of necessary permits

4 1 7 Cost

Cost is a criterion under the NCP regulations and RCRA CAP guidance It is one of the balancing criteria under the NCP Cost is to be evaluated via the capital costs, long-term operation and maintenance (O&M) costs, and post-closure costs Present worth costs are used to compare expenses of each alternative that occur over different time periods. By discounting all costs to a common base year, the cost of each alternative can be reduced to a single figure for comparative analysis This report assumes a discount interest rate of 5 percent (as specified in the CMS/FS guidance) to calculate the present worth of each alternative In addition, a maximum implementation period of 30 years has been used for alternative analysis.

Cost can be a significantly different from one alternative to another and may be the major difference in providing equivalent long-term effectiveness and permanence An alternative with an excessive cost when compared to overall effectiveness may not be feasible as a preferred alternative. Also, an alternative with a low initial capital cost may have a larger total cost when

O&M is considered Higher costs may be offset by improved performance or greater long-term risk reduction in the comparative analysis of alternatives. However, the alternative that satisfies the CERCLA requirements in the most cost-effective manner is selected as the preferred alternative

4 1 8 State Acceptance

State (and community) acceptance of the proposed preferred alternative are modifying criteria according to the NCP regulations and the RCRA CAP guidance on public involvement Changes to the proposed corrective measures may be made after consideration of public comments and a determination by CDPHE that changes are necessary to the preferred alternative State acceptance refers to CDPHE's or other state agencies' comments on the appropriateness of the proposed preferred alternative CDPHE's concerns about the preferred alternative and other alternatives are to be assessed as early in the regulatory process as practicable, usually in the remedial action plan/proposed plan The State's comments on ARARs or proposed use of wavers are to be addressed by the lead agency

4 1 9 Community Acceptance

The community acceptance criteria/public involvement policy of the NCP regulations and RCRA CAP guidance is the last criteria to be evaluated prior to final selection of a remedy. The DOE, EPA, and the State will evaluate the issues and concerns raised by the public in their comments on the proposed remedial action plan/proposed plan Interested people or groups in the community may support, have reservations about, or oppose some components of the preferred alternative; their concerns may influence the final selection of an alternative in the CAD/ROD

4 2 Background Analyses

Background analyses have been conducted to obtain data to assist in the detailed analysis of alternatives including establishing groundwater monitoring requirements, groundwater modeling,

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and residual risk assessment. Each of these analyses are described in the following subsections

4 2 1 Groundwater Monitoring

Groundwater monitoring is included as part of each alternative presented in this report For the purposes of the detailed analysis of alternatives, it is assumed that a performance monitoring system would be used to comply with the RCRA regulations New wells would be installed including one deep cluster and one shallow well cluster downgradient of IHSS 119 1 and possibly two additional wells upgradient of Woman Creek It is suggested that installation of the well clusters be preceded by geological and geophysical support such as photographic lineament analysis or three-dimensional seismic surveys This would enable paleochannels and faulted zones to be clearly identified prior to the well installations

Samples would also be collected semiannually from the French Drain Samples would be analyzed for organic and inorganic contaminants including individual species of inorganic contaminants to identify individual metal species with a potential to bioaccumulate This additional analysis should not be a routine component of the sampling program

4.2 2 Groundwater Modeling

Groundwater modeling has been performed to support the detailed analysis of the alternatives Groundwater modeling was completed to predict downgradient contaminant concentrations resulting from suspected DNAPL sources at IHSS 119.1. Three conceptual models were identified and used to predict future contaminant concentrations at the downgradient side of the French Drain and in the alluvium of Woman Creek (Alternative 0) The No Action model was used to examine contaminant migration patterns with no source removal and decommissioning the French Drain The Institutional Controls model (Alternative 1) was used to examine contaminant migration patterns with the French Drain and extraction well in operation The remediation model (Alternatives 3, 4, and 5) was used to examine the effect of remediating the suspected sources within IHSS 119.1 to the PRGs, and to predict downgradient concentrations

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once this goal was achieved. Based on the modeling results, the historic use of the site, and the sporadic nature of the observed contamination, it is assumed that the contamination occurred because of small episodic spills and that large pools of DNAPL do not exist

The model is considered to be conservative (i e , overpredicts contaminant concentrations) because

- It is two-dimensional and does not simulate dispersion transverse to the plane of the model Therefore, the concentrations are consistently overestimated by the model

- The model assumes a constant groundwater flow when the site frequently has periods of either low flow or no flow

The model converged well with actual conditions at the site as indicated by

- Convergence with observed hydraulic conductivities and groundwater flow rate and direction It indicates that the advective transport rates of the model are similar to actual conditions

- Simulation of the observed sporadic nature of the contaminant concentrations The sporadic nature indicates that the source is intermittent, as the groundwater table rises, it contacts the residual DNAPL in the subsurface soil which results in some partitioning to the groundwater

- Accurate prediction of the effects of the French Drain and the extraction well on the hydrologic system at the site

In general, the results of the model indicated that.

- Contaminant concentrations are always overpredicted by the model. The implications of this are: (1) estimated exposure concentrations are conservative because they bound observed concentrations, (2) alternate source locations and conditions (such as a source located somewhere outside the plane of the model, or a source with a different release mechanism such as diffusion from fractures in bedrock) are indirectly accounted for by the model, a different source is unlikely to result in higher predicted concentrations, (3) spreading of a source caused by degradation and subsequent generation of a contaminant along a

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flowpath is also accounted for by the model because the estimated concentrations are much higher than actually observed, (4) predictive simulations overestimate contaminant concentrations because they are based on the same concepts as the calibrated model, and (5) if the model was more realistic, the simulated concentrations would be smaller and more consistent with observed data, which would translate into smaller concentrations under the predictive simulations

- The model simulates relatively well the oscillatory behavior observed in actual concentrations This supports the concept that the source periodically releases solutes and that the timing is related to seasonal variations in climatic conditions.

- The model accurately predicts the effects of the French Drain and the extraction well The rise in simulated 1,1-DCE and 1,1,1-TCA concentrations in Figures B-27 and B-25, respectively, that occur around 1992 is caused by simulating the operation of the French Drain which started construction in November 1991 and finished in April 1992 The rise in concentrations is caused by the increased hydraulic gradient resulting from the installation and operation of the French Drain which pulls groundwater more rapidly towards Well 0487 The simulated concentrations begin decreasing around 1993 when the extraction well started operating The gradients are reduced when the extraction well is simulated because it pulls groundwater away from Well 0487 The observed concentrations vary in the same manner The similarity between the model and observed variations in concentrations leads to the conclusion that the observed variations are caused by the installation and operation of the French Drain and extraction well That the model simulates this behavior underscores the conclusion that the model is an accurate and adequate representation of site conditions The spiking effect caused by the French Drain is observed in all contaminants.

Sensitivity analyses were completed for porosity, decay rate, adsorption, and hydraulic conductivity. The sensitivity shown for adsorption decreased with time as the effect of the decay rate increased on the contaminant concentrations. The analysis for porosity also indicated an overriding effect of decay as time progressed Hydraulic conductivity was consistently the most sensitive parameter chosen for the analyses and should affect transport rates and dispersion. Therefore the hierarchy of sensitivity for the parameters chosen for the analyses is

Hydraulic Conductivity > > > > Decay > > Porosity and Adsorption

Because the model converged well with observed hydraulic conductivities, it was assumed that the model was calibrated well with the actual hydrologic system

The computer simulation code TARGET_2DU (Dames & Moore 1985) was used to simulate contaminant transport in the subsurface at OU-1 TARGET_2DU is a vertically-oriented, finite difference model that can simulate variably saturated conditions This model was selected due to the variability of the saturated zone at OU-1, and because it has been successfully applied at other Superfund sites to support final CADs/RODs Detailed assumptions and uncertainties associated with the model are included in Appendix B The model will be available for public use in 1995

In examining the results of the modeling effort, PCE, TCE, 1,1-DCE, 1,1,1-TCA, and CCl_4 were selected as contaminants at the site A list of the peak concentrations, predicted for the contaminants at the French Drain and Woman Creek for each alternative is found in Table 4-1

For the No Action Alternative, concentrations rise and then remain constant for the remainder of the modeling period For the Institutional Controls with the French Drain Alternative, the peak concentrations occur at the beginning of the model They continue to decrease with time For the remediation alternatives, Alternatives 2 through 5, concentrations rise for a short time then decrease for the remainder of the modeled period

The three conceptual models were also used to estimate residual risk levels associated with the remedial action alternatives proposed in this section

4 2 3 <u>Residual Risk Assessment</u>

The residual risk assessment, presented in Appendix C, documents the approach and calculations used to estimate risks associated with the proposed alternatives. To select the most appropriate pathways and contaminants, the results of the OU-1 PHE were reviewed.

Groundwater modeling was performed to estimate the contaminant concentrations in groundwater, using the three conceptual models for OU-1. The results were then compared to contaminant-specific PRGs for OU-1. Using these results from groundwater modeling, noncarcinogenic hazard indices and carcinogenic risks were calculated. The results indicate that none of the calculated noncarcinogenic hazard indices approach 1 and that the maximum calculated carcinogenic risk, 1.2E-05, is for the No Action scenario. The acceptable carcinogenic risk range is 10^{-4} to 10^{-6}. Noncarcinogenic hazards greater than 1 can indicate a potential for adverse effects to human health. The carcinogenic risks and noncarcinogenic hazards for each alternative are listed in Table 4-1.

4.3 Detailed Analysis of Alternatives

The detailed analysis of alternatives evaluates the two threshold and five balancing criteria for each alternative. The analysis is conducted at a level of detail that builds on the information presented in Section 3 and is sufficient to provide an understanding of each alternative. Any uncertainties associated with the evaluation are also identified in the detailed analysis. Key trade-offs, with respect to the criteria, are identified for the alternatives. According to the CMS/FS guidance, the results of the detailed analysis are designed to provide the basis for identifying a preferred alternative for the remedial action.

Assumptions used in performing the detailed analysis of alternatives include the following:

- **DNAPLs are potentially present in the subsurface soil at IHSS 119.1 based on the results of the Phase III RFI/RI report. If present, it is assumed that they are primarily in residual form and in small quantities.**

- **Groundwater monitoring proposed under each alternative will include sampling and analysis at the French Drain sump and potentially a new performance monitoring system at OU-1. The locations would be sampled semiannually and analyzed for both organic and inorganic contaminants.**

- **A soil gas survey will be conducted prior to initiating any of the proposed treatment actions to more accurately define areas at OU-1 that require treatment. For purposes of the detailed analysis a 100 ft x 100 ft x 20 ft area located at the drum storage at IHSS 119.1 is used for the treatment area.**

Table 4-1.
Predicted Peak Contaminant Concentrations and Human Health Risks

Alternative	Performance Monitoring Location	
	Downgradient of French Drain	Upgradient of Woman Creek[a]
Alternative 0· No Action		
Predicted Peak Concentrations, $\mu g/\ell$[b,c]		
PCE	10	5 7E-02
TCE	1,050	44
1,1-DCE	0 22	3 1E-06
1,1,1-TCA	38	1 0E-01
CCl_4	1 8	7 7E-04
Carcinogenic Risk[d]		
Resident	1 2E-05	3 3E-08
Worker	9 2E-12	3 1E-15
Noncarcinogenic Hazard Index[e]		
Resident	0 14	2 4E-04
Worker	1 1E-08	2 5E-11
Alternative 1 Institutional Controls with the French Drain		
Predicted Peak Concentrations, $\mu g/\ell$[b,c]		
PCE	2 0	3 1E-02
TCE	420	23
1,1-DCE	1 8E-03	1 4E-07
1,1,1-TCA	5 2	4 8E-02
CCl_4	0 12	2 3E-04
Carcinogenic Risk[d]		
Resident	3 3E-07	3 5E-09
Worker	6 1E-14	2 4E-16
Noncarcinogenic Hazard Index[e]		
Resident	2 9E-03	2 3E-05
Worker	3 0E-10	1 8E-12

Table 4-1.
(Continued)

Alternative	Performance Monitoring Location	
	Downgradient of	Upgradient of
Predicted Peak Concentrations, $\mu g/\ell$[b,c]		
PCE	6 5	3 2E-02
TCE	820	31
1,1-DCE	0 22	3 1E-06
1,1,1-TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk[d]		
Resident	6 7E-07	1 2E-08
Worker	9 8E-14	1 0E-15
Noncarcinogenic Hazard Index[e]		
Resident	5 6E-03	8 2E-05
Worker	5 0E-10	6 5E-12
Alternative 3: Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement		
Predicted Peak Concentrations, $\mu g/\ell$[b c]		
PCE	6 5	3 2E-02
TCE	820	31
1,1-DCE	0 22	3 1E-06
1,1,1-TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk[d]		
Resident	6 7E-07	1 2E-08
Worker	9 8E-14	1 0E-15
Noncarcinogenic Hazard Index[e]		
Resident	5 6E-03	8 2E-05
Worker	5 0E-10	6 5E-12

Table 4-1.
(Continued)

Alternative	Performance Monitoring Location	
	Downgradient of	Upgradient of
Alternative 4: Hot Air Injection with Mechanical Mixing		
Predicted Peak Concentrations, $\mu g/\ell^{b\ c}$		
PCE	6 5	3 2E-02
TCE	820	31
1,1-DCE	0 22	3 1E-06
1,1,1-TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk[d]		
Resident	6 7E-07	1 2E-08
Worker	9 8E-14	1 0E-15
Noncarcinogenic Hazard Index[e]		
Resident	5 6E-03	8 2E-05
Worker	5 0E-10	6 5E-12
Alternative 5. Soil Excavation with Groundwater Pumping		
Predicted Peak Concentrations, $\mu g/\ell^{b,c}$		
PCE	6 5	3 2E-02
TCE	820	31
1,1-DCE	0 22	3 1E-06
1,1,1-TCA	23	4 8E-02
CCl_4	1 8	7 7E-06
Carcinogenic Risk[d]		
Resident	6 7E-07	1 2E-08
Worker	9 8E-14	1 0E-15
Noncarcinogenic Hazard Index[e]		
Resident	5 6E-03	8.2E-05
Worker	5.0E-10	6 5E-12

[a] Actual peak concentrations should be less than modeled concentrations since operation of the French Drain was not included in the groundwater model under remediation scenarios

[b] Predicted by groundwater model TARGET_2DU (Dames & Moore 1985)

[c] PRGs are PCE 5 $\mu g/\ell$, TCE 5 $\mu g/\ell$, 1,1-DCE 7 $\mu g/\ell$, 1,1,1-TCA 200 $\mu g/\ell$, and CCl_4 1 $\mu g/\ell$

[d] Acceptable risk range is 10^{-4} to 10^{-6} per the NCP

[e] Hazard index greater than 1 indicates a potential for adverse human health effects

In the comparative analysis, a qualitative sensitivity analysis is performed to assess the major assumptions which, if incorrect, could significantly impact the results of the detailed analysis of the alternatives

This section documents the detailed analysis of the proposed alternatives in the following subsections

- Alternative 0 No Action
- Alternative 1 Institutional Controls with the French Drain
- Alternative 2 Groundwater Pumping and Soil Vapor Extraction
- Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement
- Alternative 4 Hot Air Injection with Mechanical Mixing
- Alternative 5 Soil Excavation with Groundwater Pumping

4 3 1 Alternative 0. No Action

The evaluation of the two threshold and five balancing criteria for Alternative 0 No Action is summarized in the following subsections

4 3 1 1 Overall Protection of Human Health and the Environment

The degree of protection for human health and the environment is not increased from the current conditions under the No Action Alternative. Similarly, the exposure potential is not decreased by the alternative. It relies on natural degradation processes such as dispersion, volatilization, and biodegradation to gradually reduce contaminant concentrations so the time for the site to undergo full remediation by natural degradation is difficult to predict.

Chemical specific ARARs are currently not in compliance with the State groundwater standards,

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according to groundwater monitoring results Under the No Action Alternative, the site would remain noncompliant with the State's Basic Groundwater Standards (5 CCR 1002-8, 3 11.5), according to modelled conditions In addition, the RCRA CAP criteria for controlling contamination is not satisfied by the alternative This alternative may provide long-term effectiveness primarily because the natural degradation processes are essentially irreversible There are conditions that can exist, however, that allow the byproduct or endproduct of a degradation process to be more hazardous to the environment and human health than the original contaminant In addition, conditions at the site may allow some of the degradation process to reverse or remain in flux

Groundwater modeling indicates that the carcinogenic risk at the downgradient side of the French Drain is below the acceptable risk range of 10^{-4} to 10^{-6} The carcinogenic risk at the alluvium of Woman Creek is within the acceptable risk range The noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health Because the current site conditions do not change, there are no increases in potential risks to the public, workers, or the environment under the No Action Alternative It is assumed that current health and safety practices will continue to protect workers and visitors to the site

4 3 1 2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs, chemical-specific, action-specific, and location-specific, are evaluated for each alternative. The following sections evaluate the key ARARs specific to this alternative.

Chemical-Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002-8,3.11.5) are currently exceeded beneath OU-1. Specific chemical concentrations which exceed standards are CCl_4, 1,2-DCA, 1,1-DCE, 1,2,-DCE(cis), DCE, 1,1,1-TCA, and TCE

Review of the groundwater modeling results of the chemicals present beneath OU-1 from 1969 to 2029, and the hydrogeological conditions, indicate that the peak concentrations of contaminants probably would not comply with the State Basic Standards for Groundwater at the French Drain Peak concentrations of contaminants at Woman Creek, except for TCE, probably would comply with the State Basic Standards for Groundwater Results of the modeling also indicate that the concentrations of TCE at the French Drain may exceed the State Groundwater Standards beyond the year 2029, the limit of the groundwater model The results of the model reflect the high solubility of TCE in water and a steady-state modelled flow of groundwater conditions Assumptions of the model include a continuous source of groundwater contamination without the French Drain operating nor implementation of any other remediation technology Explanation of the model and further discussions of the results of modeling are in Appendix B

Action-Specific ARARs

Since contaminants would be left in place at the IHSSs at OU-1, a plan to monitor contaminants would be required at the time of closure A RCRA performance monitoring system would be implemented with this alternative for 30 years or more Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007-3, 264 93-264 98) Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002-8, 3.11.5) The state groundwater standards for the contaminants are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants, except for selenium

Corrective action would only be monitoring for as long as necessary to achieve the state groundwater standards at the selected point of compliance. Maintenance and monitoring of constituents would be required to be conducted for more than 30 years, based on modeling results The performance monitoring system would operate until there is no exceedances of groundwater standards for three consecutive years. The post-closure period would be determined by the time it takes for natural degradation and dispersion of contaminants Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment. Such a determination is not likely, since this alternative would not meet RAOs In addition, a point of compliance for the performance monitoring systems would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the ground water protection standard (Subpart F)

There would not be any air emissions associated with this alternative therefore the RCRA and air pollution control program regulations are not ARARs

Location-Specific ARARs

Alternative 0 would comply with the laws and regulations specific to wetlands and threatened and endangered or species of special concern When the French Drain is decommissioned, the wetland and riparian habitat may temporarily decrease in size The anticipated long-term effect is a net gain in wetland acreage The CDOW will be consulted for advice on mitigation measures to lessen the effects of the French Drain decommissioning

4 3 1 3 Long-Term Effectiveness and Permanence

The No Action Alternative involves groundwater monitoring for 30 years This alternative should not provide additional protection for human health, the environment, and ecological receptors because operation of the French Drain, which currently appears to be effective in capturing contaminated groundwater, would be discontinued under this alternative.

Groundwater modeling indicates that the No Action Alternative's carcinogenic risks at the French Drain and Woman Creek are within or below the acceptable risk range of 10^{-4} to 10^{-6}. The noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

The alternative does not address treatment of the source nor does it control the source The French Drain would not be operational and there is a possibility that contaminated groundwater may migrate from OU-1 Five-year reviews would be required to determine the effectiveness of this alternative until the contaminant concentrations are consistently below the PRGs and the agencies agree that the site is not a cause for concern

4 3 1 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

The No Action Alternative will not satisfy the NCP preference for treatment as a principal element of an alternative It does not treat groundwater and subsurface soil nor does it control the primary contaminant source Similarly, no wastes are created as a result of this alternative except for wastes created during well installation such as decontamination water and drill cuttings

The No Action Alternative reduces the toxicity, mobility, or volume of contaminants only through natural degradative processes such as volatilization The remediation time for natural degradation may be long even with low initial contaminant concentrations, however it is assumed for this alternative that groundwater monitoring will be required for at least 30 years

4 3 1 5 Short-Term Effectiveness

The No Action Alternative does not offer any additional protection for human health and the environment. Because no remedial actions are implemented, there are no additional short-term risks to the local community, workers, ecological receptors, or the environment. Existing health and safety procedures at the site are assumed to offer effective protection for workers and visitors. Adherence to appropriate health and safety measures will be required for as long as monitoring activities are continued at OU-1

4 3 1 6 Implementability

The No Action Alternative is easily implemented because its only component is long-term groundwater monitoring and the installation of a performance monitoring system It should not be limited by the availability of services and materials nor are there any significant technical or administrative difficulties associated with this alternative

Normally, natural degradative processes are irreversible and result in compounds that are less hazardous than the original compounds There are conditions that can exist, however, that allow the byproduct or endproduct of a degradative process to be more hazardous to the environment and human health than the original contaminant In addition, conditions at the site may allow some of the degradative process to reverse or remain in flux

4 3 1 7 Cost

Capital costs associated with the No Action Alternative include the completion of four groundwater monitoring wells, and post-closure costs consist of groundwater monitoring for 30 years There are no O&M costs anticipated for this alternative Total capital cost of this alternative is $63,800, and the post-closure expenditures total $1,740,400 The total cost for this alternative is $1,804,200 A detailed cost estimate is included in Appendix A

4 3.2 Alternative 1: Institutional Controls with the French Drain

The evaluation of the two threshold and five balancing criteria for Alternative 1· Institutional Controls with the French Drain is summarized in the following subsections

4.3.2.1 Overall Protection of Human Health and the Environment

Alternative 1 will be protective of human health and the environment assuming that the institutional controls are properly implemented, the French Drain and Building 891 water treatment system continue operation, and the site is not abandoned during the institutional control period The potential for exposure is reduced by removing contaminated groundwater at the French Drain Other institutional controls may include restrictions on well construction, well installation, zoning, and property transfers

The French Drain would capture contaminated groundwater for treatment thereby preventing potential downgradient migration of contaminants The alternative does not involve significant disturbance of the site so short-term risks will be minimized for workers and the environment It is assumed that standard health and safety procedures will be sufficient to protect on-site workers and visitors Compliance with action-specific ARARs can be achieved with this alternative as the area of disturbance is minimal for decommissioning the French Drain

Chemical-specific ARARs can be met using the French Drain and institutional controls Modeling indicates that State groundwater standards (the PRGs) would be met, with the possible exception of TCE, at Woman Creek and the French Drain Natural degradation is expected to be a factor in long-term effectiveness and compliance with the ARARs because of the low contaminant concentrations at IHSS 119.1 The institutional controls are also a factor in determining the long-term effectiveness of this alternative

Alternative 1 meets the RCRA CAP criteria for attaining groundwater cleanup standards for all of the contaminants, with the possible exception of TCE TCE concentrations at the French Drain do not meet the groundwater PRGs during the modeling time frame and may not meet them until the source of contamination is depleted.

Carcinogenic risks at the French Drain and Woman Creek are below the acceptable range of 10^{-4} to 10^{-6}. The noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

In Alternative 1, DNAPL contamination is controlled by passive containment and collection of groundwater rather than active remediation This type of action is usually well-suited to sites, such as OU-1, that have low aquifer transmissivity, low projected groundwater use, and low initial contaminant concentrations

Reduction in contaminant concentrations at the primary contaminant source and in groundwater should occur over time The actual remediation time is dependent on the locations and volumes of the DNAPL contamination which are not certain at this time Therefore, groundwater monitoring will be used to determine when the primary contaminant source is no longer considered an issue

4 3 2 2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs, chemical-specific, action-specific, and location-specific, were evaluated for this alternative The following sections discuss the key ARARs specific to this alternative

Chemical-Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002-8,3 11 5) are currently exceeded at OU-1 contaminants which exceed the standards are PCE, TCE, 1,1-DCE, 1,2-DCA, 1,2-DCE(cis), CCl_4, and 1,1,1-TCA

Concentrations at the French Drain and Woman Creek were modeled to determine if Alternative 1 would comply with the ARARs. Review of the groundwater modeling results from 1969-2029 indicates that in all probability the concentrations of contaminants will be reduced to below the Basic Standards for Groundwater (5 CCR 1002-8, 3.11.5). According to the modeling results TCE, CCl_4, DCE, 1,1-DCE, and 1,1,1-TCA would comply with the state groundwater standards by the year 2010 at the Woman Creek location. In addition, the organic contaminant concentrations would likely comply with the State Basic Standards for Groundwater at the French Drain Although the peak concentrations of TCE remain above the TCE groundwater standard, according to the modeling results, the model conservatively assumes an infinite source Peak concentrations of TCE would in all probability be collected by the French Drain and treatment system and be reduced with time to below the groundwater standard Assumptions of the model and discussion of results are in Appendix B

Action-Specific ARARs

The French Drain will collect contaminated groundwater for treatment for as long as is necessary to consistently achieve the State groundwater standards However, some contamination may be left due to the uncertainty of the location and volume of the contaminants, the sporadic nature of groundwater movement, and the climatic conditions at OU-1

Compliance with 6 CCR 1007-3, 264 90 and 264 101 of the State RCRA program is required at OU-1 Since some contaminants would be left in place, a plan to monitor contaminants would be required at the time of closure A RCRA performance monitoring system would be implemented with this alternative for as long as is necessary to demonstrate compliance with the state groundwater standards at the selected point of compliance Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007-3, 264 93-264 98) A post-closure period of 30 years would be initiated with CDPHE The State Basic Standards for Groundwater (5 CCR 1002-8, 3 11 5) are identified as the monitoring levels since the RCRA regulations do not have the organic contaminants listed in the groundwater protection standards of 40 CFR 264.94.

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance. Maintenance and monitoring of constituents is required until the performance monitoring system indicates no exceedances of the groundwater standards for three consecutive years. The period to achieve compliance depends on the effectiveness of the water treatment system as well as natural degradation. Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment In addition, a point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F)

Other action-specific ARARS, such as the Colorado Water Quality Control Act effluent limitations for the water treatment system, would be complied with during operation of the system

The State air pollution regulations and RCRA hazardous air pollutant standards would not be an ARAR for this alternative since there are not technologies or facilities which could be a source of emissions

Location-Specific ARARs

Alternative 1 would undergo a significant disruption when the French Drain is scheduled for decommissioning Decommissioning the French Drain will temporarily disturb wetlands and riparian areas around the drain The short-term effect of the decommission may be a loss of wetland acreage but the long-term effect is expected to be a net gain in wetland acreage Mitigation measures will be used to minimize the impacts and to comply with regulations.on wetland protection and threatened and endangered or species of special concern.

4 3 2 3 Long-Term Effectiveness and Permanence

Under this alternative, the French Drain removes contaminated groundwater migrating from IHSS 119.1, the area south of Building 881, and the western portion of IHSS 119.2 It is expected that natural degradation will be a significant factor in ensuring long-term effectiveness for this alternative because of the low contaminant concentrations. Groundwater monitoring will be conducted at the site until the contaminant concentrations are consistently below the PRGs and the agencies agree that the site is no longer a cause for concern. For the purposes of this detailed analysis, the period for groundwater monitoring is 30 years. Every 5 years a review will be conducted at the site to determine the alternative's effectiveness and degree of permanence

Human health risks may be reduced at the site by restricting access to wells at the site and prohibiting construction in the area The alternative can provide some long-term protection for human health and the environment provided the institutional controls remain in place Carcinogenic risks at the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} The noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

The French Drain passively collects groundwater rather than actively remediating the site The theory behind the alternative is that groundwater containment should adequately protect human health and the environment The theory is corroborated for the contaminants by the groundwater model, with the possible exception of TCE, and the human health risk calculations The model indicates that groundwater should meet the PRGs for the contaminants at Woman Creek with the possible exception of TCE Because of the uncertainty regarding the location and volume of the primary contaminant source, groundwater collection and treatment should continue until the groundwater consistently meets the PRGs to increase the degree of permanence achieved by the alternative

Wastes generated as a result of this alternative will be managed according to applicable regulations Waste types include spent GAC and regenerant solutions from ion-exchange resins Regenerant solution will be treated in the Building 891 water treatment system by pH neutralization and evaporation in Building 374 The spent GAC will be sent offsite for regeneration There are no significant risks associated with handling the ion-exchange resins or shipping the spent GAC

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4 3.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 1 does not actively remediate the primary source of contamination However, operation of the French Drain will reduce the mobility and volume of contaminants in groundwater at OU-1 contaminant toxicity will be reduced when the groundwater is treated by UV/Peroxide in the Building 891 water treatment system

The Building 891 treatment system currently operates with high removal efficiencies for all of the contaminants except for CCl_4 It is expected that the GAC unit from OU-2 will be added to the Building 891 water treatment system and this modification will make it possible for the system to effectively treat CCl_4 Wastes generated from this alternative include regenerant solution from ion-exchange resins and spent GAC which is sent offsite for regeneration The regenerant solution is transferred to the Building 891 water treatment system for pH neutralization and sent to Building 374 for evaporation

contaminant removal through groundwater extraction is irreversible, however contamination in soil at IHSS 119 1 may continue to contaminate groundwater through infiltration Degradation and/or removal of the contaminants should eventually be achieved but may require an extended period of time

4 3 2 5 Short-Term Effectiveness

Protection of human health and the environment should not increase under this alternative because it does not change the processes already in place at the site. The components of Alternative 1, institutional controls and operation of the French Drain, should not incur additional risks to the public, on-site workers, ecological receptors, or the environment. Existing safety measures used for permanent workers and visitors should offer effective and reliable protection at OU-1 Adherence to appropriate health and safety measures will be required for as long as monitoring activities are continued at OU-1.

The impact at Woman Creek is minimal and does not represent a departure from the current impacts under the IM/IRA The groundwater model indicates that surface water standards for Woman Creek should be met for all of the contaminants with the possible exception of TCE However, risk-based calculations indicate that the carcinogenic risk and noncarcinogenic hazard are below the acceptable limits

4 3 2 6 Implementability

Alternative 1 should not limit the options for future remediation if it is deemed necessary It is easily implemented because the only addition to current site conditions is the implementation of institutional controls The benefits of the current operations should not be significantly increased

The reliability of the French Drain and Building 891 water treatment system is well documented in the IM/IRA reports The planned addition of a GAC unit to the Building 891 water treatment system to remove CCl_4 does not present any significant difficulties since the GAC unit exists onsite and is readily available Groundwater monitoring will continue until the groundwater consistently remains below the PRGs and the agencies agree that the site is no longer a cause for concern For the purposes of the detailed analysis, a 30-year period of monitoring is assumed for the site

Implementability of this alternative is not limited by the availability of services and materials associated with this alternative Institutional controls proposed under this alternative, such as deed or well restrictions, could be implemented with no significant administrative problems

4 3 2.7 Cost

Capital costs associated with Alternative 1 include the installation of four groundwater monitoring wells, the O&M costs include operation of the Building 891 water treatment system for 30 years, and the post-closure costs consist groundwater monitoring for 30 years. Total

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capital cost for this alternative is $63,800, the total O&M cost is $5,761,200, and the total post-closure cost is $1,740,400 The total cost of this alternative is $7,565,400 A detailed cost estimate for this alternative is included in Appendix A

4 3 3 Alternative 2 Groundwater Pumping and Soil Vapor Extraction

The evaluation of the two threshold and five balancing criteria for Alternative 2 Groundwater Pumping and Soil Vapor Extraction is summarized in the following subsections

4 3 3 1 Overall Protection of Human Health and the Environment

Alternative 2 should be protective of human health and the environment because it extracts and remediates contaminated groundwater and soil vapor The exposure potential at the site is reduced by remediating the primary contaminant source and reducing contaminant concentrations to the PRGs SVE and groundwater extraction will decrease contaminant mobility and volume The French Drain will capture contaminated groundwater and prevent downgradient migration of contaminants for 10 years after remediation is completed

The RCRA CAP criteria for controlling contamination sources should be satisfied by the components of this alternative It should also meet the RCRA CAP criteria for attaining cleanup standards for all of the contaminants except possibly TCE Groundwater modeling indicates that the contaminant concentrations, except perhaps TCE, should be below the PRGs at the downgradient side of the French Drain and the alluvium of Woman Creek

Woman Creek is an intermittent stream which requires protection for ecological receptors under various regulatory programs. Chemical-specific ARARs for OU-1 should be met by groundwater extraction and SVE, based on results of groundwater monitoring Woman Creek surface water standards should be met for human and ecological receptors

Alternative 2 is easily implemented because of the availability and mobility of SVE systems.

The degree of permanence depends on the degree to which the primary contaminant source is remediated by the SVE system Fractured bedrock and low aquifer transmissivity may not be amenable to rapid and complete remediation of DNAPL sources In addition, the locations of DNAPL sources are not well-known For SVE and groundwater extraction to completely remediate DNAPL, the well should be located within or near the DNAPL source Otherwise, the extraction rate depends on the passive partitioning capability of the compound to groundwater

This alternative would remediate the primary contaminant source at IHSS 119 1 Carcinogenic risks at the French Drain and Woman Creek are currently below the acceptable risk range of 10^{-4} to 10^{-6}, therefore implementation of this alternative should lower the risk range well below 1 in 1,000,000 Noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

The implementation phase of Alternative 2 should be completed in 4 years depending on the soil properties, contaminant concentrations, carbon type, and volumes of contaminated subsurface soil and groundwater During implementation, there should be no additional short-term risks to the public Potential risks to on-site workers include exposure to contaminants in contaminated groundwater and soil vapor and safety hazards associated with drilling and construction activities Risks will be minimized through standard health and safety practices

4 3 3 2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs, chemical-specific, action-specific, and location-specific, are evaluated for each alternative. The following sections evaluate the key ARARs specific to this alternative.

Chemical-Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002-8,3.11.5) are currently exceeded beneath OU-1. Specific

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chemical concentrations which exceed standards are PCE, 1,2-DCA, 1,1-DCE, 1,2,-DCE(cis), CCl_4, 1,1,1-TCA, and TCE

Organic chemical concentrations have been modeled to reflect remediation activities at OU-1 using groundwater monitoring results and the knowledge of hydrogeological conditions The results of groundwater modeling of the chemicals indicate that Alternative 2 would comply with Basic Standards for Groundwater 10 years after implementation of remediation, assuming the French Drain is in place The French Drain location would achieve the State Basic Standards after the 10th year, with the exception of TCE, according to the modeling results However the steady-state model assumes the source of contamination remains during the period of remediation contaminants at the location of Woman Creek would comply with the State Groundwater Standards sooner than 10 years after remediation Assumptions of the model and results of the model are discussed in Appendix B

Action-Specific ARARs

Some contaminants would be left in place at the IHSSs (other than 119.1) within OU-1 The sources at IHSS 119 would be remediated to reduce contaminant concentrations Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions

Compliance with 6 CCR 1007-3, 264 90 and 264 101 of the State RCRA program is required at OU-1 Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition, will depend upon the selection of a point of compliance location by EPA, CDPHE, and DOE.

A plan to monitor contaminants would be required for the post-closure period A RCRA performance monitoring system would be implemented with this alternative and would probably be needed for 10 years after remediation according to a review of modeling results Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007-3, 264 93-264.98) Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002-8, 3 11 5) The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants, except for selenium

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time is approved by CDPHE According to the results of the modeling, the time period for requiring monitoring could be 10 years after source remediation, however an initial post-closure period of 30 years would be initiated with CDPHE Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F)

Other action-specific ARARS, such as the Colorado Water Quality Control Act effluent limitations for the water treatment system, would be complied with during operation of the system

The SVE system may be considered to be a temporary RCRA unit because the it treats hazardous waste constituents. Therefore the requirements of Subpart S (6 CCR 1007-3, Subsection 264 553) are applicable. In addition, any pre-filters, HEPA filters, and GAC used to remove VOCs in the off-gas treatment system should comply with the following provisions:

- Identification of hazardous waste (Part 261)
- Air emission standards for process vents (Subsection 264 1033)
- Air emission standards for equipment leaks (Subsections 264 1052, 264.1054 and 264 1057)
- Land disposal restrictions (Part 268)

It is anticipated that the operation and mobilization/demobilization of the SVE treatment unit and treatment residuals should comply with the applicable requirements of RCRA, and CHWA

The Colorado Solid Waste Regulations (6 CCR 1007-2) are an ARAR for disposal of any residual materials that are not hazardous waste If solid waste disposal is necessary, it should be in accordance with the regulations

Installation of additional extraction and monitoring wells should be in accordance with the Colorado Water Well and Pump Installation Regulations (2 CCR 402-2)

Location-Specific ARARs

Alternative 2 should comply with laws and regulations regarding wetlands and threatened and endangered or special concern species There may be a short-term impact to wetlands from decommissioning the French Drain but the anticipated long-term effect is an increase in wetland areas Mitigation measures will be used to minimize effects of the alternative on wetland habitat in and near OU-1 The CDOW will be consulted, prior to disturbing wetland habitat, to implement adequate mitigation measures for protection of Preble's meadow jumping mouse

4 3.3 3 Long-Term Effectiveness and Permanence

The primary contaminant source at IHSS 119.1 should be remediated under Alternative 2 The French Drain will continue to capture any contaminated groundwater still migrating from IHSS 119.1, after the SVE unit is removed. Groundwater modeling indicates that the groundwater should achieve the State groundwater standards after 10 years. However, the French Drain would operate until the groundwater meets PRGs Natural degradation, in addition to the SVE unit, will be a factor in ensuring long-term effectiveness A 5-year review of the site is required to determine if the most effective remedy is still being used at OU-1

In general, SVE and groundwater extraction are proven technologies for remediating contaminated sites However, the degree of permanence after remediation will depend on the extent of DNAPL contamination outside of IHSS 119 1 The geology of OU-1 may not be amenable to rapid and complete remediation of DNAPL contamination The soil has a low permeability and may develop preferential vapor channeling or short-circuiting A cap, such as a geotextile fabric, will be placed around each SVE well to minimize the tendency for short-circuiting The location of DNAPL at the site is still uncertain and, to ensure complete remediation, the SVE and groundwater wells should be located within or near the source Otherwise, the extraction rate will strictly depend on the contaminant's partition coefficient

Alternative 2 should provide long-term protection for potential human receptors by minimizing the human health risk associated with contaminated groundwater The calculated carcinogenic risks for the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} Noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

4 3 3 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 2 satisfies the NCP preference for treatment as a principal element of an alternative. Groundwater extraction and SVE should reduce the volume and mobility of contaminants in groundwater and the unsaturated zone, respectively. Groundwater extraction and SVE will reduce the volume by physically removing the contaminants. Removing the contaminants will also reduce their mobility by preventing potential migration.

Extracted groundwater will be treated in the Building 891 water treatment system using UV/

H_2O_2 and ion-exchange processes. UV/H_2O_2 is a destructive treatment process and will decrease the contaminant toxicity. During ion-exchange resin regeneration, the toxicity will be decreased because the regenerant will be treated to destroy the contaminants. contaminant toxicity will also be reduced as the GAC from the SVE process is regenerated offsite

Wastes generated as a result of this alternative will be managed according to applicable regulations Types of wastes include spent GAC from the off-gas treatment system and Building 891 water treatment system, liquid from the SVE vapor/liquid separator, regenerant solution from ion-exchange resins in the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water The spent GAC will be shipped offsite for regeneration and regenerant solution will be sent to Building 374 for evaporation The decontamination water and liquid from the SVE liquid/vapor separator will be sent through the Building 891 water treatment system There are no significant human health or environmental risks associated with handling the ion-exchange resins and shipping the spent GAC

4.3 3 5 <u>Short-Term Effectiveness</u>

Short-term effectiveness will be achieved through the SVE and groundwater extraction system operations Potential short-term impacts on the environment include minor disturbances to subsurface soil and displacement or loss of vegetation during well installation activities The decommission of the French Drain may temporarily decrease wetland acreage but it is expected that the long-term effect will be an increase in the number of wetland acres.

Short-term risks to the public are minimal for Alternative 2 Risks to workers during remediation include potential exposures to contaminants in extracted groundwater or soil vapor and safety hazards associated with drilling and other construction activities. Risks to workers will be minimized through standard construction health and safety procedures

4 3 3.6 Implementability

Alternative 2 is easily implemented because SVE and groundwater extraction are commonly used technologies that do not require unique or unusual equipment The implementability of this alternative should not be limited by the availability of services and materials nor should there be significant administrative difficulties The combination of low contaminant concentrations and soil permeability may make it more difficult to implement the alternative An SVE treatability study at OU-2 has been discontinued with a recommendation to not use SVE at the site

The ability to perform future remedial actions, if any, should not be limited by using SVE and groundwater extraction A performance monitoring program will monitor the concentration of contaminants for 13 years or more after completion of SVE Vapor and radiological monitoring programs will be implemented during construction and remediation

Vapor extraction wells can be installed using standard drilling techniques and construction materials Operation of the SVE system should not require highly specialized personnel or training A vapor monitoring program will be conducted at portals near the wells and the GAC units to determine the SVE system's efficiency and approximate replacement rates for the GAC

4.3 3 7 Cost

Costs for Alternative 2 include costs of the following items.

- Soil gas survey (approximately 100 probes)
- Three groundwater extraction wells (6-inch diameter, 20-foot depth)
- 36 vapor extraction wells (4-inch diameter, 20-foot depth)
- Three vapor extraction systems with blowers and filters
- Activated carbon adsorption system (2 vessels containing 1,500 pounds each)
- Associated piping, pumps, and instrumentation
- Four groundwater monitoring wells (6-inch diameter, 20-foot depth)
- Operation of the building 891 water treatment system
- Groundwater monitoring

The total capital cost for Alternative 2 is $925,600 The total O&M cost is $5,287,700 assuming operation of the Building 891 treatment system during the four-year SVE treatment period, and 10 years following completion of SVE The total post-closure cost of this alternative is $833,300 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is $7,046,600 A detailed cost estimate is included in Appendix A

4 3 4 Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement

The evaluation of the two threshold and five balancing criteria for Alternative 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement is summarized in the following sections

4 3.4.1 Overall Protection of Human Health and the Environment

Alternative 3 protects human health and the environment by removing DNAPLs from groundwater and remediating the subsurface soil in-situ The potential for exposure is reduced by remediating the primary contaminant source and reducing contaminant concentrations in groundwater to the PRGs SVE and groundwater extraction will reduce contaminant mobility and volume

The RCRA CAP criteria for controlling contamination sources will be satisfied by the components of this alternative It will also meet the RCRA CAP criteria for attaining cleanup standards for all of the contaminants, except possibly TCE Groundwater modeling indicates that the peak contaminant concentrations, except perhaps TCE, would achieve PRGs at Woman Creek Peak PCE, TCE, and CCl_4 concentrations are above the PRGs at the French Drain but the groundwater model does not account for the operation of the French Drain after the alternative is implemented. The French Drain should still be collecting groundwater at the time of the peak concentrations

Chemical-specific ARARs should be met by using SVE and groundwater extraction 10 years after implementation of these technologies Woman Creek is an intermittent stream which is a concern to the ecological receptors Surface water standards established for ecological receptors should be met at Woman Creek

Protection of human health and the environment will be achieved by removal of the source to the extent practicable The removal after remediation will depend on the location of the source of contamination For SVE and groundwater extraction to completely remediate DNAPL sources, the wells must be located near or in the DNAPL source Otherwise, the extraction rate depends on the passive partitioning capability of the compound The geology of OU-1 may also not be amenable to rapid and complete remediation of DNAPL contamination Factors that can be controlled such as groundwater and vapor extraction rates will be optimized to increase the degree of remediation possible at the site

Groundwater should be protected downgradient of and within the OU-1 boundaries The French Drain will capture groundwater for at least 10 years following completion of remediation before being decommissioned Because models are based on assumptions about a site, groundwater monitoring will be performed for an additional 3 years to ensure that contaminant concentrations remain consistently below the PRGs.

RF heating may have an adverse effect on the subsurface soil due to the high temperatures required by the in situ process While the elevated temperatures will increase the removal efficiency of the contaminants, some subsurface and surface biota may not be able to withstand the sustained high temperatures It is expected that the majority of biota will be able to repopulate itself within a reasonable amount of time

Alternative 3 can perhaps be implemented with few administrative difficulties because SVE and groundwater extraction are well-known processes with documented performances. However, an SVE treatability study at OU-2 has been discontinued because of low contaminant concentrations at the site. RF heating is an innovative technology which could cause some dislocation of fauna and destruction of flora The areas currently targeted for this technology are a distance from the riparian habitat of Preble's meadow-jumping mouse

Because Alternative 3 should remediate the primary contaminant source at IHSS 119.1, modeling shows that the carcinogenic risks at the French Drain and Woman Creek should be below the acceptable risk range of 10^{-4} to 10^{-6} The noncarcinogenic hazards associated with this alternative at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

The implementation of SVE with thermal enhancement should be completed within 3 years During implementation there are no unacceptable short-term risks to the public, although there may be some risks to flora and fauna at the site There may also be potential risks to on-site workers from exposure to contaminated water or soil vapor in addition to safety hazards associated with drilling, construction activities, and operating the RF heating elements Risks will be minimized through standard health and safety practices

4 3 4 2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs, chemical-specific, action-specific, and location-specific, are evaluated for each alternative The following sections evaluate the key ARARs specific to this alternative

Chemical-Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002-8,3 11.5) are currently exceeded beneath OU-1 Specific chemical concentrations which exceed standards are PCE, 1,2-DCA, 1,1-DCE, 1,2,-DCE(cis), CCl_4, 1,1,1-TCA, and TCE.

Organic chemical concentrations have been modeled to reflect remediation activities at OU-1 using groundwater monitoring results and the knowledge of hydrogeological conditions The

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results of groundwater modeling of the chemicals indicate that Alternative 3 would comply with Basic Standards for Groundwater 10 years after implementation of remediation, assuming the French Drain is in place The French Drain location would achieve the State Basic Standards after the 10th year, with the exception of TCE, according to the modeling results. However the steady-state model assumes the source of contamination remains during the period of remediation contaminants at the location of Woman Creek would comply with the State Groundwater Standards sooner than 10 years after remediation Assumptions of the model and results of the model are discussed in Appendix B

Action-Specific ARARs

The action-specific ARARs associated with Alternative 3 are the same as presented in Alternative 2 Compliance with RCRA requirements for identification, storage, and disposal of hazardous waste and organic air emissions and leaks should be achieved Compliance with other action-specific ARARs is anticipated to be similar to the compliance discussed under Alternative 2.

Some contaminants would be left in place at the IHSSs (other than 119 1) within OU-1 The sources at IHSS 119 would be remediated to reduce contaminant concentrations Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions

Compliance with 6 CCR 1007-3, 264.90 and 264 101 of the State RCRA program is required at OU-1 Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition, will depend upon the selection of a point of compliance location by EPA, CDPHE, and DOE

A plan to monitor contaminants would be required for the post-closure period. A RCRA performance monitoring system would be implemented with this alternative and would probably be needed for 10 years after remediation based on modeling results Monitoring of the organic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007-3, 264 93-264 98) Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002-8, 3 11 5) The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants except for selenium

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time is approved by CDPHE. According to the results of the modeling, the time period for requiring monitoring could be 10 years after source remediation, however an initial post-closure period of 30 years would be initiated with CDPHE Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F)

Other action-specific ARARS, such as the Colorado Water Quality Control Act effluent limitations for the water treatment system, would be complied with during operation of the system.

Location-Specific ARARs

Assuming additional extraction wells are placed away from the French Drain and Pond C-1, destruction of riparian vegetation and fauna during thermal enhancement should be minimal Compliance with DOE wetland protection regulations and the State's law concerning non-game species should be achieved if this alternative is implemented. Should it be necessary, riparian

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habitat will be replaced if it is destroyed by RF heating.

Impacts from decommissioning the French Drain may result in a short-term loss of wetlands However, it is anticipated that the net effect of the decommissioning should be a long-term gain in wetland acreage

4 3 4 3 Long-Term Effectiveness and Permanence

Alternative 3 should remediate the primary contaminant source at IHSS 119 1 The French Drain and extraction wells will extract contaminated groundwater for 10 years after implementation of the SVE and RF heating Because models are based on assumptions about a site, an additional 3 years of groundwater monitoring will be used to ensure long-term effectiveness It is assumed that the low initial contaminant concentrations will be a factor in ensuring long-term effectiveness A 5-year review of the site will be conducted to determine the effectiveness of the alternative

Alternative 3 may provide a high degree of permanence because thermal-enhanced SVE should remove more residual contaminants trapped within the subsurface soil at OU-1 than normal SVE operation However, the degree of permanence after remediation will depend on the exact location of the source of contaminants The locations of DNAPL are not well-defined and, for SVE and groundwater extraction to completely remediate a site, the wells must be located near or in the DNAPL Otherwise, the process depends on the passive partitioning capability of the contaminant. In addition, the geology of OU-1 may not be amenable to rapid and complete remediation of DNAPL contamination The soil has a low permeability and may develop preferential vapor channeling or short-circuiting To minimize the tendency for short-circuiting, a cap such as a geotextile fabric will be placed around each SVE well.

Long-term protection for human and ecological receptors should begin shortly after the alternative is implemented The calculated carcinogenic risks at the French Drain and Woman Creek, after implementation of this alternative, are below the acceptable risk range of 10^{-4} to 10^{-}

[6]. The noncarcinogenic hazards associated with this alternative at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health A 5-year review will be conducted to determine the continued effectiveness of this alternative

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include liquid from the SVE liquid/vapor separator, spent GAC from the off-gas treatment system and Building 891 water treatment system, regenerants solution from ion-exchange resins in the Building 891 water treatment system, and wastes associated with well installations such as drill cuttings and decontamination water. The SVE liquid/vapor separator waste and the decontamination water can be sent to Building 891 The regenerant solution from the ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation The spent GAC will be sent offsite for regeneration There are no significant risks associated with handling the resins or shipping the spent GAC

4 3 4 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 3 satisfies the NCP preference for treatment as a principal element of the alternative The volume and mobility of the DNAPLs are reduced through groundwater extraction and thermally-enhanced SVE Physically removing the contaminants will reduce their mobility by preventing additional migration

Extracted groundwater and waste from the SVE liquid/vapor separator will be treated at Building 891 by UV/Peroxide and ion-exchange processes UV/H_2O_2 is a destructive water treatment process and results in decreased toxicity Spent GAC from the SVE off-gas treatment system will be regenerated offsite resulting in an additional reduction in toxicity

Contaminated materials generated as a result of this alternative include GAC from the off-gas treatment system and Building 891 water treatment system, liquid from the SVE liquid/vapor separator, regenerants solution from ion-exchange resins in the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water The regenerants solution from ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation. The liquid from the SVE separator and decontamination water will be sent to Building 891 for treatment The spent GAC will be shipped offsite for treatment There are no significant risks associated with handling the regenerant solution or shipping the spent GAC

4 3 4 5 Short-Term Effectiveness

Protection of human health and the environment should begin shortly after implementing Alternative 3 Potential short-term impacts on the environment include disturbance to the subsurface soil and displacement or loss of vegetation during construction activities The RF heating may adversely affect some subsurface biota due to high soil temperatures but it is anticipated that the biota will repopulate within a reasonable amount of time Decommissioning the French Drain may result in a short-term loss of wetlands but it is anticipated that the net effect of the decommission should be a gain in wetland acreage

Potential short-term impacts to the public are minimal under Alternative 3 Potential risks to workers during remediation activities include exposure to contaminants in extracted groundwater or soil vapor There may be safety hazards associated with drilling and other construction activities as well as with the operation of the RF heating devices Risks to workers will be minimized through standard health and safety practices

4 3 4.6 Implementability

Alternative 3 can be readily implemented SVE and groundwater extraction are proven and commonly-used technologies that do not require unique or unusual equipment Although RF heating is a less common variation of the SVE process, it is available through specialized vendors The implementability of Alternative 3 should not be limited by the availability of services and materials nor should there be significant administrative difficulties Because of the low soil permeability and contaminant concentrations, there may be technical difficulties in implementing a SVE system A treatability study at OU-2 indicated that SVE was not a good option for that site

The ability to conduct future remedial actions, if necessary, should not be limited by implementation of thermally-enhanced SVE and groundwater extraction Groundwater monitoring will track potential movement of contaminants for at least 13 years Vapor and radiological monitoring will be conducted during the construction and remediation

Vapor extraction wells will be installed using standard drilling techniques and construction materials Operation of the basic SVE system should not require highly specialized personnel or training, however operation of the RF heating antennae may require special training or assistance from the vendor The RF antennae can be installed in one or more of the vapor extraction wells and moved from one well to another as required by the treatment process RF heating does not produce treatment residual waste

A vapor monitoring program, conducted at the wells and GAC units, will monitor the SVE system's efficiency and determine replacement rates for the GAC units Spent GAC from the off-gas treatment system and the Building 891 water treatment system will be sent offsite for regeneration Ion-exchange resins from the Building 891 water treatment system will be regenerated onsite and the regenerants solution pH neutralized and sent to Building 374 for evaporation Liquid from the SVE liquid/vapor separator and decontamination water will be sent to the Building 891 water treatment system

4 3.4.7 Cost

Costs for Alternative 3 include the following items

- Soil gas survey (approximately 100 probes)
- Three groundwater extraction wells (6-inch diameter, 20-foot depth)
- 36 vapor extraction wells (4-inch diameter, 20-foot depth)
- Four groundwater monitoring wells (6-inch diameter, 20-foot depth)
- Three vapor extraction systems with blowers, filters, and other appurtenances

- GAC system (two skid-mounted units containing 1,500 pounds of GAC each)
- RF heating unit
- Associated piping, pumps, and instrumentation
- Operation of the building 891 water treatment system
- Groundwater monitoring

The total capital cost of Alternative 3 is $1,843,600 The total O&M cost is $4,798,200 assuming operation of the building 891 treatment system during the two-year SVE treatment period, and for 10 years following SVE The total post-closure cost for this alternative is $918,700 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is $7,560,500 A detailed cost estimate is included in Appendix A

4 3 5 Alternative 4 Hot Air Injection with Mechanical Mixing

The evaluation of the two threshold and five balancing criteria for Alternative 4 Hot Air Injection with Mechanical Mixing is summarized in the following subsections

4.3.5.1 Overall Protection of Human Health and the Environment

Alternative 4 protects human health and the environment by removing DNAPL contaminants from subsurface soil and, if possible, groundwater at IHSS 119 1 The exposure potential is reduced by decreasing the volume of contaminants through groundwater extraction and remediation of the primary contaminant source. The French Drain and extraction wells will decrease contaminant mobility by capturing contaminated groundwater and preventing downgradient migration of contaminants

The RCRA CAP criteria for controlling contamination sources will be satisfied by the components of this alternative It will also meet the RCRA CAP criteria for attaining cleanup standards for all of the contaminants except possibly TCE. Groundwater modeling indicates that the peak contaminant concentrations at Woman Creek, except perhaps TCE, will be below the PRGs According to the model, TCE, PCE, and CCl_4 may not meet the PRGs at the French

Drain, however the model does not include the French Drain which should be operating to reduce peak concentrations

Alternative 4 should meet key ARARs at the French Drain and Woman Creek The intermittent stream status of Woman Creek, is a concern to ecological receptors Surface water standards established for ecological receptors should be met at Woman Creek

Hot air injection may have an adverse effect on the soil at OU-1 due to the high soil temperatures that are reached during operation While the elevated temperatures may increase the effectiveness of the alternative, they may be harmful to some subsurface biota in the short term It is expected that the biota will repopulate itself in a reasonable amount of time

Alternative 4 should provide permanence by remediating the primary contaminant area at IHSS 119 1 and reducing long-term risks to human health and the environment The degree of permanence achieved at the site depends on the extent that the primary contaminant area is remediated Uncertainties regarding the nature and extent of the DNAPL sources may limit the degree of permanence achieved by Alternative 4

Because this alternative should remediate the source at IHSS 119 1, groundwater modeling indicates that carcinogenic risk levels at the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} Noncarcinogenic hazard indices for the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

This alternative should be completed in approximately 1 year depending on the actual volumes of contaminated soil and groundwater, contaminant concentrations, and mobilization time. There should be no additional short-term risks to the public during implementation. Potential health risks to on-site workers occur from exposure to contaminants in groundwater and soil vapor and safety hazards associated with construction activities, hot air injection, and operation of the mechanical mixer tool Risks will be minimized through standard health and safety practices

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4.3.5.2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs, chemical-specific, action-specific, and location-specific, are evaluated for each alternative. The following sections evaluate the key ARARs specific to this alternative

The designation of ARARs for this alternative is the same as presented in Alternative 3 Alternative 4 should comply with chemical-specific, action-specific, and location-specific ARARs

Chemical-Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002-8,3 11 5) are currently exceeded beneath OU-1 Specific chemical concentrations which exceed standards are PCE, 1,2-DCA, 1,1-DCE, 1,2,-DCE(cis), CCl_4, 1,1,1-TCA, and TCE

Organic chemical concentrations have been modeled to reflect remediation activities at OU-1 using groundwater monitoring results and the knowledge of hydrogeological conditions The results of groundwater modeling of the chemicals indicate that Alternative 4 would comply with Basic Standards for Groundwater 10 years after implementation of remediation, assuming the French Drain is in place. The French Drain location would achieve the State Basic Standards after the 10th year, with the exception of TCE, according to the modeling results However the steady-state model assumes the source of contamination remains during the period of remediation contaminants at the location of Woman Creek would comply with the State Groundwater Standards sooner than 10 years after remediation Assumptions of the model and results of the model are discussed in Appendix B.

Action-Specific ARARs

Alternative 4, similar to Alternative 3, may enhance the volume of contaminants that can be

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extracted from the soil. Vapor monitoring will be used to determine the effectiveness of the system and to ensure that breakthrough does not occur in the GAC systems

Some contaminants would be left in place at the IHSSs (other than 119 1) within OU-1 The sources at IHSS 119 would be remediated to reduce contaminant concentrations Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions

Compliance with 6 CCR 1007-3, 264 90 and 264 101 of the State RCRA program is required at OU-1 Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition, will depend upon the selection of a point of compliance location by EPA, CDPHE, and DOE

A plan to monitor contaminants would be required for the post-closure period A RCRA performance monitoring system would be implemented with this alternative and would probably be needed for 13 years or more after remediation according to the modeling results Monitoring of the organic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007-3, 264 93-264 98) Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002-8, 3 11.5). The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants, except for selenium.

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time is approved by CDPHE. According to the results of the modeling, the time period for requiring monitoring could be as short as 13 years after source remediation, however an initial post-closure period of 30 years would be initiated with CDPHE. Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment. The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F)

Other action-specific ARARS, such as the Colorado Water Quality Control Act effluent limitations for the water treatment system, would be complied with during operation of the system Other action-specific ARARs should be complied with in a manner similar to Alternative 3

Location-Specific ARARs

It is assumed that mechanical mixing, hot air injection, and extraction well installation will not be completed in the riparian habitat near the French Drain and Pond C-1 Riparian habitat will be replaced if it is inadvertently destroyed by the hot air from the mechanical mixer It is anticipated that compliance with DOE and Colorado regulations concerning wetlands and nongame species should be achieved with the implementation of this alternative

4 3 5.3 Long-Term Effectiveness and Permanence

Alternative 4 should protect human health and the environment by removing contaminated groundwater and remediating contaminated soil at IHSS 119 1. The French Drain will extract and treat contaminated groundwater at IHSS 119.1 until the groundwater is reduced below the PRGs. Groundwater modeling indicates that the groundwater should be free from DNAPL contamination within 10 years. Because groundwater models are based on assumptions about a site, however, three additional years of monitoring and operation of the French Drain will be conducted to ensure that the groundwater remains below the PRGs The additional monitoring and collection should provide long-term effectiveness and minimize the risk to human health and

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the environment The low contaminant concentrations and natural degradation should also be a factor in providing long-term effectiveness

The carcinogenic risks from IHSS 119 1 at the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} primarily because the DNAPL contamination is remediated at IHSS 119 1 Noncarcinogenic hazard indices at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

The mechanical mixer-hot air injection process should provide a large degree of permanence if the primary contaminant source is fully remediated The process maximizes the chance for full remediation by providing a homogenous mixture, high airflow through the soil, and an increased soil permeability for ease of removing contaminants Uncertainties regarding the nature and extent of the DNAPL contamination may limit the permanence of this alternative A 5-year review of the alternative will be used to determine the degree of remediation achieved by the mechanical mixer-hot air injection process

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include liquid from a SVE liquid/vapor separator, spent GAC from the off-gas treatment system and Building 891 water treatment system, regenerant solution from ion-exchange resins in the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water The liquid/vapor separator waste and the decontamination water can be sent to Building 891. The regenerant solution from the ion-exchange resins will be pH neutralized and sent to Building 374 for evaporation The spent GAC will be sent offsite for regeneration. There are no significant risks associated with handling the regenerant solution and shipping the spent GAC

4 3.5 4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 4 should satisfy the NCP preference for treatment as a principal element of an alternative. Removing DNAPLs from the subsurface soil and groundwater will effectively reduce the mobility and volume of contaminants at IHSS 119.1 The mechanical mixer-hot air injection process should increase the soil permeability and volatilization rate thereby increasing the volume of contaminants that can be removed from the subsurface soil Groundwater extraction will reduce the contaminant volume in groundwater and the French Drain will prevent potential migration of the contaminants outside of OU-1 Remediating the subsurface soil and groundwater will reduce contaminant mobility by preventing potential downgradient migration

Extracted groundwater and waste from the liquid/vapor separator will be treated by UV/H_2O_2, ion-exchange, and GAC processes in the Building 891 water treatment system UV/H_2O_2 is a destructive treatment process and will result in decreased contaminant toxicity GAC from the off-gas treatment system will be regenerated offsite resulting in reduced contaminant toxicity

Wastes generated as a result of this alternative will be managed in compliance with applicable regulations The wastes include liquid from a liquid/vapor separator, spent GAC from the off-gas treatment system and Building 891 water treatment system, regenerant solution from ion-exchange resins in the Building 891 water treatment system, and wastes associated with well installation such as drill cuttings and decontamination water

4 3 5 5 Short-Term Effectiveness

Protection of human health and the environment should begin shortly after implementing Alternative 4 Short-term impacts on the environment include soil disturbance and displacement or loss of vegetation during remedial activities The hot air injection and mechanical mixing may affect some subsurface biota due to the high temperatures that are reached during operation, but it is expected that the biota will repopulate itself within a reasonable amount of time

Groundwater modeling for Alternative 4 indicates that the peak concentrations at Woman Creek are below the surface water standards. The actual peak concentrations should be less than the modeled concentrations because the model assumed that the French Drain would be decommissioned when the alternative was implemented Ecological receptors may be more affected by Woman Creek's intermittent stream status than by the contaminant concentrations

Potential short-term impacts to the public are minimal under this alternative Potential risks to workers during remediation include exposure to contaminants in extracted groundwater and soil vapor Workers may also be exposed to health and safety hazards associated with the operation of the mechanical mixer Mixing the soil may increase the risks associated with operating heavy equipment because of the increased possibility of unstable soil The risks will be minimized through standard health and safety practices

4 3 5 6 Implementability

Although the technology is not as common as other applicable technologies, equipment for hot air injection and mechanical mixing is available from specialized vendors Alternative 4 should not have any significant administrative difficulties, unless the hot air injection and mechanical mixing are conducted in the riparian habitat areas along Woman Creek

The technology may be difficult to implement due to the instability of the claystone soil found at OU-1 Safety hazards may occur during remediation because the mixing may increase the possibility for slope failures by decreasing the soil's cohesive properties Also, the treatment zone may become completely mixed, saturated, and soft as the remediation progresses Installing the necessary dewatering and monitoring wells into the treatment zone may be difficult if a drill rig cannot be driven onto the soil

4 3.5.7 Cost

Costs for Alternative 4 include the following items:

- Soil gas survey (approximately 100 probes)
- Four groundwater monitoring wells
- Mechanical mixing unit (including off-gas treatment)
- Associated piping, pumps, and instrumentation
- Operation of the building 891 water treatment system

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- Groundwater monitoring

The total capital cost for Alternative 4 is $1,781,400 The total O&M cost is $3,113,000 including operation of the Building 891 treatment system for 10 years following the completion of remediation The total post-closure cost is $1,120,700 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is $6,015,100 A detailed cost estimate is included in Appendix A

4 3 6 Alternative 5 Soil Excavation with Groundwater Pumping

The evaluation of the two threshold and five balancing criteria for Alternative 5 Soil Excavation with Groundwater Pumping is summarized in the following subsections

4 3 6 1 Overall Protection of Human Health and the Environment

Alternative 5 will be protective of human health and the environment by using a combination of soil excavation, groundwater extraction, and treatment of contaminated soil and groundwater The exposure potential is reduced at the site by decreasing the contaminant concentrations through groundwater extraction and removal of the primary contaminant source. The French Drain will capture contaminated groundwater and prevent downgradient migration of contaminants

The RCRA CAP standard for controlling contamination sources will be satisfied by the components of Alternative 5. Alternative 5 will also meet the RCRA CAP standard for attaining cleanup standards for all of the contaminants with the possible exception of TCE Groundwater modeling indicates that the peak contaminant concentrations, except perhaps TCE, will be below the PRGs at Woman Creek PCE, TCE, and CCl_4 may not meet the PRGs at the French Drain but the groundwater model assumed that the French Drain operation would be discontinued when Alternative 5 is implemented

The soil excavation and groundwater extraction of Alternative 5 should allow OU-1 to meet chemical-specific ARARs at the French Drain and Woman Creek. Woman Creek, as an intermittent stream, is a concern for ecological receptors. Surface water standards should also be met at Woman Creek for both human and ecological receptors Alternative 5 will provide long-term effectiveness because it removes the source of contamination, offers a high degree of permanence, and should be an effective method for removing DNAPLs from the site The degree of permanence is dependent on the extent to which the sources in IHSS 119 1 are remediated Uncertainties regarding the actual nature and extent of the DNAPL sources may limit the degree of permanence achieved by Alternative 5

Alternative 5 may have a significant impact on the environment due to the large excavation, soil storage, and transportation requirements Excavating the source area will adversely impact the flora, fauna, and subsurface biota of the area It is anticipated that proper mitigation and reclamation measures will minimize long-term effects from this alternative However, if the Preble's meadow jumping mouse becomes a Federally protected Endangered/Threatened species, the consultation process with U S Fish and Wildlife may require additional unanticipated measures

The carcinogenic risk levels associated with DNAPLs at the French Drain and Woman Creek under this alternative are lower than the acceptable risk range of 10^{-4} to 10^{-6} because the primary source of contamination is removed through excavation and the contaminant groundwater plume is captured by the French Drain The noncarcinogenic hazards associated with the alternative at the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

It is anticipated that treatment of contaminated soils should be completed within 1 to 2 years of implementation depending on the contaminant concentrations, subsurface soil volume, and the capacity of the thermal desorption unit. During implementation, there is a potential for risk to the public due to contaminated fugitive dust generated during the excavation, transportation, and storage of large volumes of subsurface soil. Risks to the public should be minimized by using dust suppressants, i e , water, to suppress the fugitive dust during transport and the construction of a roof or other cover for the storage areas. Potential risks to workers may occur from exposure to contaminants in groundwater, soil, and fugitive dust Workers may encounter safety hazards associated with operating excavation/backfill equipment and the thermal desorption unit Risks to workers will be minimized through standard health and safety practices

4.3 6.2 Compliance With Applicable or Relevant and Appropriate Requirements

Three types of ARARs, chemical-specific, action-specific, and location-specific, are evaluated for each alternative The following sections evaluate the key ARARs specific to this alternative

The ARARs associated with this alternative are very similar to those presented and discussed for Alternatives 3 and 4. Alternative 5 should comply with chemical-specific, location-specific, and action-specific ARARs

Chemical-Specific ARARs

The results of groundwater monitoring from 1989-1994 indicate that the State Basic Standards for Groundwater (5 CCR 1002-8,3 11 5) are currently exceeded beneath OU-1 Specific chemical concentrations which exceed standards are PCE, 1,2-DCA, 1,1-DCE, 1,2-DCE(cis), CCl_4, 1,1,1-TCA, and TCE

Organic chemical concentrations have been modeled to reflect remediation activities at OU-1 using groundwater monitoring results and the knowledge of hydrogeological conditions The results of groundwater modeling of the chemicals indicate that Alternative 5 would comply with Basic Standards for Groundwater 10 years after implementation of remediation, assuming the French Drain is in place The French Drain location would achieve the State Basic Standards after the 10th year, with the exception of TCE, according to the modeling results. However the steady-state model assumes the source of contamination remains during the period of remediation contaminants at the location of Woman Creek would comply with the State

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Groundwater Standards sooner than 10 years after remediation Assumptions of the model and results of the model are discussed in Appendix B

Action-Specific ARARs

Some contaminants would be left in place at the IHSSs (other than 119 1) within OU-1 The sources at IHSS 119 would be remediated to reduce contaminant concentrations Collection of the mobile contaminants in groundwater at the French Drain and subsequent treatment of contaminants in the water treatment system would continue for as long as is necessary to achieve the State groundwater standards There is a potential for some contaminants to be left in place at some of the IHSSs since groundwater movement is sporadic and subject to climatic conditions

Compliance with 6 CCR 1007-3, 264 90 and 264 101 of the State RCRA program is required at OU-1 Compliance with either the RCRA definition of point of compliance or the State groundwater regulatory definition, will depend upon the selection of a point of compliance location by EPA, CDPHE, and DOE

A groundwater monitoring plan would be required for the post-closure period A RCRA performance monitoring system would be implemented with this alternative and would probably be needed for 13 years or more Monitoring of the organic and inorganic constituents would be conducted in accordance with Subpart F of the State RCRA regulations (6 CCR 1007-3, 264 93-264 98) Monitoring would be conducted until it is determined that the contaminants are in compliance with the State Basic Standards for Groundwater (5 CCR 1002-8, 3 11.5) The state groundwater standards are selected for monitoring since the RCRA regulations do not have protection standards for the contaminants, except for selenium

Corrective action would be conducted as long as necessary to achieve the state groundwater standards at the selected point of compliance Maintenance and monitoring of constituents is required to be conducted for 30 years unless the performance monitoring system indicates no exceedances of groundwater standards for three consecutive years and a shortened period of time is approved by CDPHE According to the results of the modeling, the required monitoring period is 10 years after source remediation, however an initial post-closure period of 30 years would be initiated with CDPHE Implementation of this alternative would require a determination by CDPHE that the corrective action is protective of human health and the environment The point of compliance for the performance monitoring system would need to be selected to demonstrate compliance with the RCRA corrective action requirements and the groundwater protection standard (Subpart F)

Subsurface soils at OU-1 contain listed hazardous wastes, and are potentially regulated under Subtitle C of RCRA Delisting of the treated soils at OU-1 is a potential option as the treated soil should meet the RCRA delisting requirements in *A Guide to Delisting of RCRA Wastes for Superfund Remedial Responses* (OSWER # 9347 3-09FS) Delisting of the treated soils would allow disposal of the soils on-site The delisting process can require two years of agency review and approval

Site-specific treatability study data may become available from other OUs in the future Data provided by the supplier of the thermal desorption unit shows that treatment of similar wastes has resulted in constituent levels below the delisting criteria, the Maximum Allowable Concentrations (MACs) The constituents found in the subsurface soil that are listed wastes are

- carbon tetrachloride
- tetrachloroethene
- 1,1,1-trichloroethane
- trichloroethene
- toluene
- xylenes

The treated soil should pose no significant threat to groundwater and would be fully protective of human health and the environment

Verification testing in all likelihood would need to be performed after treatment to confirm delisting levels The verification testing would include analysis for total and TCLP leachate concentrations Verification testing would be performed using the appropriate QA/QC procedures

It is possible that EPA's proposed definition and treatment standards for hazardous soil could be promulgated prior to the final CAD/ROD It is anticipated that this alternative should meet any changes to the definition and treatment standards for hazardous soil Other action-specific ARARS, such as the Colorado Water Quality Control Act effluent limitations and stormwater regulations should be complied with during the remedial activities The State's air pollution regulations should not be an ARAR since there are no technologies or facilities at OU-1 which could be a source of emissions

Location-Specific ARARs

Dewatering will involve placing a PVC pipe from the excavation to the French Drain Although the construction area involved in the activity would be small, there may be a short-term impact to riparian and wetland areas around the French Drain Mitigation measures will be used to minimize the disruption, however any destroyed riparian areas will be replaced or created according to DOE wetland regulations

Alternative 5 may result in adverse effects to threatened and endangered species or species of special concern at the site Mitigation measures will be discussed with the CDOW to minimize habitat disruption and to comply with regulations for species such as the Preble's meadow-jumping mouse Should the mouse become a Federally protected species, consultation with the U S Fish and Wildlife Service will be initiated to comply with Section 7 of the Endangered Species Act.

4.3 6 3 Long-Term Effectiveness and Permanence

The excavation to bedrock and dewatering components of Alternative 5 will significantly reduce potential risks to human health and the environment by removing contaminated groundwater and subsurface soil The French Drain and Building 891 water treatment system will continue to extract and treat contaminated groundwater until concentrations at the IHSS are reduced below the PRGs Groundwater modeling indicates that the contaminated groundwater should be removed after 10 years Because groundwater models are based on assumptions rather than known quantities at a site, an additional 3 years of monitoring will be conducted to achieve the groundwater PRGs

The carcinogenic risks for the French Drain and Woman Creek are below the acceptable risk range of 10^{-4} to 10^{-6} because the contaminated soil and groundwater are removed from the treatment area The noncarcinogenic hazard indices associated with the French Drain and Woman Creek do not indicate a potential for adverse effects to human health

Following treatment of the primary contaminant source, contaminated groundwater within OU-1 may continue to migrate away from IHSS 119 1 Modeling indicates that, because of the French Drain and the source removal, groundwater should meet PRGs for the contaminants at Woman Creek thereby providing long-term effectiveness and minimizing human health risks Alternative 5 should provide a high degree of permanence if the sources at IHSS 119 1 are fully remediated Uncertainties regarding the nature and extent of the DNAPL sources may limit the degree of permanence achieved by the alternative A 5-year review should be conducted to determine the effectiveness of this alternative

To further provide long-term protection and minimize human health risk, excavated soil will be managed according to applicable regulations and treated to below LDR standards or levels of concern Disposal will be at a permitted TSD facility with the possibility of on-site disposal, if approved by CDPHE through the petition process There should be no significant risks associated with handling nonradioactive treated soil.

4 3.6.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 5 satisfies the NCP preference for treatment as a principal element of an alternative.

It should effectively and irreversibly reduce the mobility and volume of contaminants in OU-1 by removing the primary source of contaminants from the subsurface and groundwater Excavating an estimated 17,500 cubic yards of soil within the treatment zone will reduce the volume of contaminants in subsurface soil in both the saturated and unsaturated zones Removing the source of the contaminants will also reduce contaminant mobility by preventing potential migration Dewatering the treatment area of an estimated 80,000 gallons of groundwater will reduce the contaminant volume and mobility

Treating the contaminated soil will reduce the contaminant volume and toxicity in the soil prior to disposal at a properly permitted TSD facility or potentially onsite In addition, extracted groundwater will be treated using the UV/H_2O_2, ion-exchange, and GAC processes in the Building 891 water treatment system UV/H_2O_2 is a destructive and irreversible process and will decrease contaminant toxicity

Wastes generated as a result of this alternative include regenerant solution from ion-exchange resins and GAC from the Building 891 water treatment system, treated soil, and wastes from well installation such as drill cuttings and decontamination water The secondary wastes produced during treatment and the processes used to treat these wastes include.

- Regeneration of the ion-exchange resins resulting in a solution that will be treated at the Building 374 Evaporator
- Spent GAC that will be sent offsite for regeneration
- Decontamination water that will be sent to Building 891 for treatment by the UV/H_2O_2 and ion-exchange processes
- The treated soil and wastes such as drill cuttings will be managed according to applicable regulations before being transported to a permitted TSD facility.

There should be no significant risks associated with handling the wastes or shipping nonradioactive treated soil

4 3 6 5 Short-Term Effectiveness

Protection of human health and the environment should begin shortly after the excavation is completed for Alternative 5 However, the alternative may have significant short-term impacts on human health and the environment such as potential worker and public health exposure to fugitive dust created during the excavation, transportation, and storage of excavated soil Additional short-term effects include the displacement or destruction of vegetation

Alternative 5 will have a significant short-term impact on the immediate environment due to the large excavation and material transportation requirements. Excavating the contaminant source area will adversely impact the site flora, fauna, and subsurface biota Mitigation measures will be used to minimize the impact.

During implementation of Alternative 5, there may be a risk to the public due to potentially-contaminated dust generated during the excavation, transportation, and storage of large quantities of surficial and subsurface soil Management of the soil will comply with 40 CFR Part 122.26, Part 264, and DOE orders Stormwater controls would be employed to reduce runoff at the site Methods such as creating a three-sided building with a roof or other cover for storage areas to minimize fugitive dust will assist in minimizing exposure risks. There may be potential risks to workers from exposure to contaminants in groundwater, soil, or fugitive dust. Workers may also encounter safety hazards associated with operating excavation/backfill equipment and the thermal desorption unit Risks to workers will be minimized through standard health and safety practices

Although surface soils are being administratively addressed under OU-2, radionuclides are a short-term effectiveness concern under this alternative due to the potential for exposure to both on-site and off-site receptors from fugitive dust Excavation activities would increase the resuspension of radionuclides in surface soils, thereby increasing off-site exposure point source terms as well as the flux of contaminants to Woman Creek.

Groundwater modeling for Alternative 5 indicates that the peak concentrations at Woman Creek are below the PRGs at OU-1 for all of the contaminants except TCE The actual peak concentrations should be less than the modeled concentrations because the model assumed that the French Drain will be decommissioned when the alternative is implemented Therefore, ecological receptors at Woman Creek should not be affected by OU-1 groundwater contaminants under this alternative Woman Creek is an intermittent stream which may have a greater effect on ecological receptors because of a lack of water than the peak contaminant concentrations

4 3 6 6 Implementability

Alternative 5 will not limit the use of future remedial actions at the site if they are deemed necessary In addition, thermal desorption is a proven soil remediation technology that should not involve administrative difficulties. Alternative 5 should not be limited by the availability of services and materials There may be significant technical or administrative difficulties if Preble's meadow-jumping mouse is designated a Federally protected Threatened/Endangered species Such a designation would require consultation under Section 7 of the Endangered Species Act Protection of human health and the environment should begin shortly after the excavation is complete

It is anticipated that 3 months will be required to mobilize and demobilize the thermal desorption unit Standard equipment will be used for excavating the contaminated soil at IHSS 119 1 A large storage area may be required for stockpiling and treating the excavated soil but it is expected that sufficient space will be available adjacent to the excavation area The Treated soil may be delisted as a hazardous waste to allow onsite disposition However, the process of delisting could require two years. In addition, for offsite disposal, the number of TSD facilities that will accept the subsurface soil may be limited if it contains radioactive material.

Air monitoring will be required during the operation of the thermal desorption unit and radiological monitoring will be conducted throughout the remediation Groundwater monitoring will be conducted for 13 years after remediation is complete to achieve the groundwater PRGs

4 3 6 7 Cost

Costs for Alternative 5 include the following items

- Construction of a staging area
- Use of conventional soil excavation and backfill equipment
- Four new groundwater monitoring wells
- Operation and mobilization/demobilization of a thermal desorption unit
- Disposal of nonradioactive treated soil at a permitted TSD facility
- Operation of the building 891 treatment system
- Groundwater monitoring

The total capital cost for Alternative 5 is $9,034,500 The total O&M cost is $3,113,000 including operation of the Building 891 treatment system for 10 years following the completion of excavation The total post-closure cost is $1,122,100 including groundwater monitoring for 13 years following completion of remediation The total cost of this alternative is $13,269,600 A detailed cost estimate is included in Appendix A

4 4 Comparative Analysis of Alternatives

This section presents the comparative analysis of alternatives in relation to the specific RCRA/CERCLA evaluation criteria The results of the detailed analysis of alternatives is summarized in Table 4-2 This information is used to compare alternatives in the following subsections

4 4 1 Overall Protection of Human Health and the Environment

The overall protection of human health and the environment is highest with Alternative 1 because of its low overall risk to human health and the environment while providing irreversible groundwater extraction and treatment. Alternative 1 should result in no significant change in protection of human health and the environment. Alternatives 2, 3, and 4 currently offer the same verifiable protection as Alternative 1 because the locations of DNAPL sources are

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unknown Alternative 5 provides irreversible treatment and the largest reduction in exposure potential within the shortest time However, it also has the greatest adverse effects to the environment and workers

Alternatives 2, 3, 4, and 5 reduce the exposure potential by remediating the source of contamination Alternative 1 reduces the exposure potential by containing the source of contamination and limiting access to the site Attaining groundwater cleanup standards, a RCRA CAP criteria, is also met by Alternatives 1 through 5 Alternative 0 neither meets this criteria nor reduces the exposure potential at the site

Alternative 1 provides the least overall environmental effects of the alternatives because it maintains the current operations at the site and provides containment of the source Alternatives 2 and 3 do not substantially affect the environment but the permanence of SVE depends on knowing the locations of the DNAPL sources which are not well-defined at OU-1 Alternatives 3 and 4 affect the environment more than Alternative 2 because of the RF heating units and the mechanical mixer, respectively Alternative 5 provides the greatest short-term disruption of the environment and the most permanent solution Alternative 0 offers the least permanent solution and greatest long-term concern to the environment

The calculated noncarcinogenic hazards do not indicate a potential for adverse human health effects The carcinogenic risks were below the acceptable risk range of 10^{-4} to 10^{-6} for the alternatives except for Alternative 0 Alternative 0 had a carcinogenic risk of 1 2E-05 for an onsite resident. Other risks to the public are minimal with the exception of potential fugitive dust created under Alternative 5 by the excavation, transportation, and storage of potentially-contaminated soil

The overall risks to workers at the site include potential exposure to contaminants through groundwater extraction for Alternatives 1, 2, 3, 4, and 5 Workers may be exposed to contaminant vapors for Alternatives 2, 3, 4, and 5. However, calculated carcinogenic and noncarcinogenic effects for workers were below the acceptable risk range for all of these alternatives Alternatives 3, 4, and 5 may expose workers to safety hazards from operating equipment associated with the alternatives In addition, Alternative 4 may present safety hazards from potential destabilization of the soil and Alternative 5 may present hazards associated with fugitive dust

Alternative 1 is currently meeting the RAOs for the site Remediation should take less than 2 years for Alternatives 4 and 5 Alternative 3 should remediate the site within 3 years while Alternative 2 is estimated to be 5 years The remediation time for Alternative 0 is difficult to predict but it is assumed that groundwater monitoring will continue for 30 years

4 4 2 Compliance with Applicable or Relevant and Appropriate Requirements

Alternatives 1-5 would comply with the majority of chemical-specific, action-specific, and location specific ARARs The possible exception is the peak concentration of one contaminant, TCE, which could possibly be above the chemical-specific ARAR, the Colorado Basic Standards for Groundwater The duration and concentration of the peak is dependent on the alternative and location of the downgradient measured point These observations are based on a review of modeling results It is also possible that the predicted peak concentrations are over estimated and that Alternatives 1-5 or some of these alternatives would not exceed the state groundwater standards Alternative 0 is predicted, and in all likelihood, would not meet the state groundwater standards

Groundwater modeling results have been used to assist in determining ARAR compliance. The two locations used in the simulations of contaminant concentrations are the downgradient side of the french drain and the alluvium at Woman Creek Assumptions of the model include availability of a contamination source, even for remediation alternatives, through the period 1969-2029 In addition, the solubility of TCE in water is relatively high in comparison to the other chemicals used in the model Other modeled steady-state flow factors are discussed in Appendix B

The differences in predicted peak concentrations among the alternatives are summarized as follows Alternative 0· peak concentrations of organics do not comply with the state groundwater standards at the french drain and peak concentrations of the organics, except for TCE, might comply with the state groundwater standards at the Woman Creek location after a period of thirty or more years Alternative 1 peak concentrations of organics would probably comply with the state groundwater standards, except for TCE, sometime after 2010 at the French Drain location and peak concentrations of organics (including TCE) would probably comply with the state groundwater standards at approximately year 2010 at the Woman Creek location Alternatives 2-5 peak concentrations of organics would comply with the state groundwater standards, with the possible exception of TCE, ten years after remediation is completed at the French Drain Peak concentrations of organics would comply with the state groundwater standards within ten years, and probably sooner, of completed remediation at the Woman Creek location

Compliance with the action-specific ARARs are slightly different among the alternatives Although all the alternatives would be required to comply with the RCRA corrective action and groundwater protection standard, the period of time required to complete corrective action would vary among the alternatives In addition, CDPHE is required to determine that the selected compliance point and alternative would be protective of human health and the environment This determination could vary from Alternative 1 to Alternatives 2-5

The proposed groundwater performance monitoring system would be initiated for thirty years in accordance with the RCRA post-closure requirements. However, once the monitoring system indicates no exceedances of groundwater standards for 3 consecutive years, the period of compliance monitoring may be reduced with the approval of CDPHE Although the period of monitoring is dependent on the selected point to demonstrate compliance, it can be stated that the compliance period would be long for Alternative 0 as compared to Alternative 1 and that the compliance period for Alternative 1 would be relatively long compared to Alternatives 2-5 The monitoring differences would correlate to the differences in time to achieve the State groundwater standards, i.e. Alternative 0 may require 30 or more years of monitoring, Alternative 1 may require 16 years of monitoring , and Alternatives 2-5 may require 10 years or less of monitoring

The other major difference among the alternatives in complying with the action-specific ARARs, is the air pollution controls required on the vapor extraction systems Alternatives 2-4 would require compliance with the hazardous organic emission controls under RCRA regulations as well as the State's air pollution control Regulation 7 Alternatives 0 and 1 would not require such compliance as these alternatives do not involve organic compound air emissions

Compliance with location-specific ARARs is one of the major differences among the treatment technology alternatives The alternative that would require the most mitigation measures in order to comply with the State law on non-game species and DOE's regulation on wetlands protection is Alternative 5 This alternative would require placement of a pipeline from IHSS 119 1 to the French Drain Alternatives 2, 3, and 4 are not anticipated to disrupt wetland areas with the treatment technologies proposed, however if some areas are disturbed in the implementation of the technology, then compliance with the law and regulations to protect wetland and non-game species would be required All alternatives, including No Action, could disturb a small area of wetlands for a very short time (two to three days) during decommissioning of the French Drain. Mitigation measures would be implemented to minimize the disturbance and comply with the wetland and species protection requirements

If the Preble's meadow-jumping mouse becomes Federally protected as a Threatened/Endangered species, then the compliance requirement for Alternative 5 could be much more elaborate Consultation with U S Fish and Wildlife Service would be required and a biological assessment might need to be prepared

4 4 3 Long-term Effectiveness and Permanence

Alternative 5 offers the most permanent protection of human health and the environment because the primary contaminant source is physically removed and treated Alternatives 2, 3, and 4 offer some protection because the source is remediated to the extent possible by the technologies The degree of permanence depends on the extent that the wells are located next to a DNAPL source If the wells miss the DNAPL sources, the extraction rate is dependent on the passive partitioning capability of the contaminants Alternatives 3 and 4 may be more protective than Alternative 2 because they increase volatilization and provide more reduction in the contaminant concentrations Alternative 1 offers the same protection of human health and the environment as the current conditions because it does not significantly change the current procedures at the site Alternative 0 offers less protection than is currently available at the site because it decommissions the French Drain which is removing contaminated groundwater In addition, it does not contain, remediate, or remove the primary source of contamination

Five-year reviews will be conducted for all of the alternatives until contaminant concentrations are consistently below the PRGs and the agencies agree that the site is not a cause for concern In addition, all of the alternatives require groundwater monitoring to evaluate the site conditions

Carcinogenic risks and noncarcinogenic hazards are below the acceptable limits for all of the alternatives with the exception of Alternative 0 It indicates a carcinogenic risk for an on-site resident of 1 $2x10^{-5}$ at the French Drain which is within the acceptable range of 10^{-4} to 10^{-6} The carcinogenic risk is 3 $3x10^{-8}$ at Woman Creek under this alternative

Alternative 5 provides the best long-term effectiveness and permanence of the alternatives because it removes and treats the contamination Alternatives 4, 3, and 2 provide similar permanence and effectiveness; they differ by increasing volatilization capabilities However, the effectiveness of SVE is dependent on locating the wells near the DNAPL sources and the source locations are currently ill-defined Alternative 1 provides some permanence and effectiveness for the site because it removes and treats groundwater. Alternative 0 provides no permanence nor long-term effectiveness except through natural degradation.

4 4 4 <u>Reduction of Toxicity, Mobility, and Volume Through Treatment</u>

Alternatives 2, 3, 4, and 5 actively remediate the primary source of contamination thereby satisfying the NCP preference for treatment as a principal element of the alternative Alternatives 2, 3, and 4 use SVE or a variation of it while Alternative 5 uses excavation and thermal desorption Alternative 1 does not actively remediate the primary source of contamination, however it controls it by containing and extracting the contaminated groundwater Extracted groundwater is then treated in the Building 891 water treatment system Alternative 0 does not remediate nor control the primary source of contamination It relies on natural degradation to restore the site

Alternative 5 provides a greater reduction of TMV than Alternatives 2, 3, or 4 because it removes as well as remediates the primary source of contamination Alternative 5 provides ex-situ treatment and disposal of the subsurface soil whereas Alternatives 2, 3, and 4 provide in-situ treatment of the subsurface soil Groundwater is removed, treated, and disposed of for Alternatives 1, 2, 3, 4, and 5

Alternatives 2, 3, and 4 vary according to the enhancement used with SVE Alternative 2 uses normal SVE, Alternative 3 uses thermally-enhanced SVE, and Alternative 4 provides thermally-enhanced SVE with a mixing action to provide greater soil permeability Because Alternative 4 increases the soil permeability through homogenous mixing, it creates a more hospitable environment for contaminant volatilization than Alternatives 2 or 3. Similarly, Alternative 3 will provide more reduction in volume and mobility than Alternative 2 because it provides a better environment for contaminant volatilization.

An irreversible reduction in contaminant toxicity is provided by Alternatives 2, 3, and 4 through the use of an off-gas treatment system, such as a GAC unit, for treatment of contaminated soil vapors Thermal desorption provides a similar reduction in contaminant soil toxicity for Alternative 5. Alternatives 1 through 5 will equally and irreversibly reduce contaminant groundwater toxicity by using the UV/H_2O_2 and ion-exchange processes in Building 891.

Alternative 0 reduces contaminant toxicity through natural degradation

Wastes generated for Alternatives 2, 3, 4, and 5 are similar They include spent GAC and regenerant solution from ion-exchange resins in the Building 891 water treatment system, drill cuttings and decontamination water from well installation, and liquid from the SVE liquid/vapor separator Alternatives 2, 3, and 4 will have additional quantities of spent GAC because of the off-gas treatment system for the extracted soil vapors Treated soil is an additional waste that will have to be managed and disposed of for Alternative 5 Alternative 1 produces wastes associated with the UV/H_2O_2 and ion-exchange processes in building 891 and installation of wells Alternative 0 produces wastes associated only with well installation

Alternative 5 is ranked first for reduction in toxicity, mobility, and volume of the contaminants Alternatives 4, 3, and 2 are ranked second, third, and fourth, respectively, because of their capabilities for extracting contaminated vapors from the soil matrix at IHSS 119 1 Alternative 1 is ranked fifth because it controls the primary source of contamination but does not reduce contaminant soil toxicity, mobility, and volume It also has a higher possibility than Alternatives 2, 3, and 4 of reverting to the current condition once the remediation is considered complete Alternative 0 is ranked last because it neither remediates nor controls contamination at OU-1

4 4 5 Short-term Effectiveness

An increase in the protection of human health and the environment is achieved shortly after implementing Alternatives 2, 3, 4, and 5. Alternative 1 provides the same protection of human health and the environment that is currently available at the site Alternative 0 decreases the current protection of human health and the environment because it will decommission the French Drain and allow potentially-contaminated groundwater to migrate from the site.

All of the alternatives will affect the environment when the French Drain is decommissioned The short-term effect may be a loss of wetland acreage but the expected long-term effect is a net gain in wetland acreage. Adverse short-term effects to the environment are greatest with

Alternative 5 because of the soil excavation and transportation. It may adversely affect flora, fauna, and biota at the excavation and along the transportation route depending on the mitigation measures used to minimize fugitive dust Alternative 4 may adversely affect the environment because of the soil mixing However, it should not affect the environment beyond the immediate treatment area unless it interrupts a major hydrogeological channel or major soil destabilization occurs Alternative 3 may adversely affect the environment because of the high temperatures that are reached by the RF heating Depending on the mitigation measures used, the flora and fauna of the area could be affected by a change in soil horizon or biota Alternative 2 may affect the immediate environment with minor disturbances to the subsurface soil and some vegetative loss during the installation of the SVE system and monitoring wells. Depending on the types of institutional controls that are selected, Alternative 1 may have the same minimal effects to the environment as Alternative 0 Alternative 0 is expected to affect the environment through the French Drain decommission and monitoring well installation Ecological receptors at Woman Creek should not be significantly affected by the alternatives, except for Alternative 5

Groundwater modeling indicates that the contaminant concentrations at points directly upgradient of Woman Creek meet the surface water standards with the possible exception of TCE The actual concentrations for Alternatives 1 through 5 should be less than the modeled concentrations because the model assumed that the French Drain would be immediately decommissioned rather than 10 years after remediation as suggested within the alternatives

Alternative 5 will affect human health by creating fugitive dust from the excavation, transportation, and storage of subsurface soil. Mitigation measures will be used to minimize the dust. Short-term effects on human health are minimal for Alternatives 1, 2, 3, and 4 There should be no additional short-term effects on human health for Alternative 0.

Alternatives 2, 3, 4, and 5 may affect workers through exposure to contaminants in groundwater, soil vapor, and operation of the remediation and well installation equipment Alternative 5 will also affect workers by creating fugitive dust during excavation, transportation,

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and storage of contaminated soil Alternative 4 may create an additional hazard for workers by decreasing the stability of the soil matrix Alternative 1 has the potential to affect workers only through exposure to contaminants in groundwater Because there is no source control or remediation for Alternative 0, there should be no additional risks to workers

The short-term risks are expected to be greatest for Alternatives 5, 4, and 3 Alternative 2 should have minimal risks and Alternative 0 and 1 should have no additional risks

4 4 6 Implementability

None of the alternatives should limit future remediation if it is deemed necessary by the regulatory agencies In addition, Alternatives 0-4 are not expected to have administrative difficulties before the alternatives can be implemented at the site. Alternative 5 may require additional lead time for agency approvals in either a RCRA delisting process or Endangered Species Act consultation process

Groundwater monitoring is required for all of the alternatives as long as the contaminant concentrations are above the PRGs and the agencies believe there is a cause for concern at the site Vapor monitoring will be conducted for Alternatives 2, 3, and 4 to optimize the SVE system and determine replacement rates for the GAC units Vapor and radiological monitoring will be conducted for Alternative 5 to indicate health risks to workers

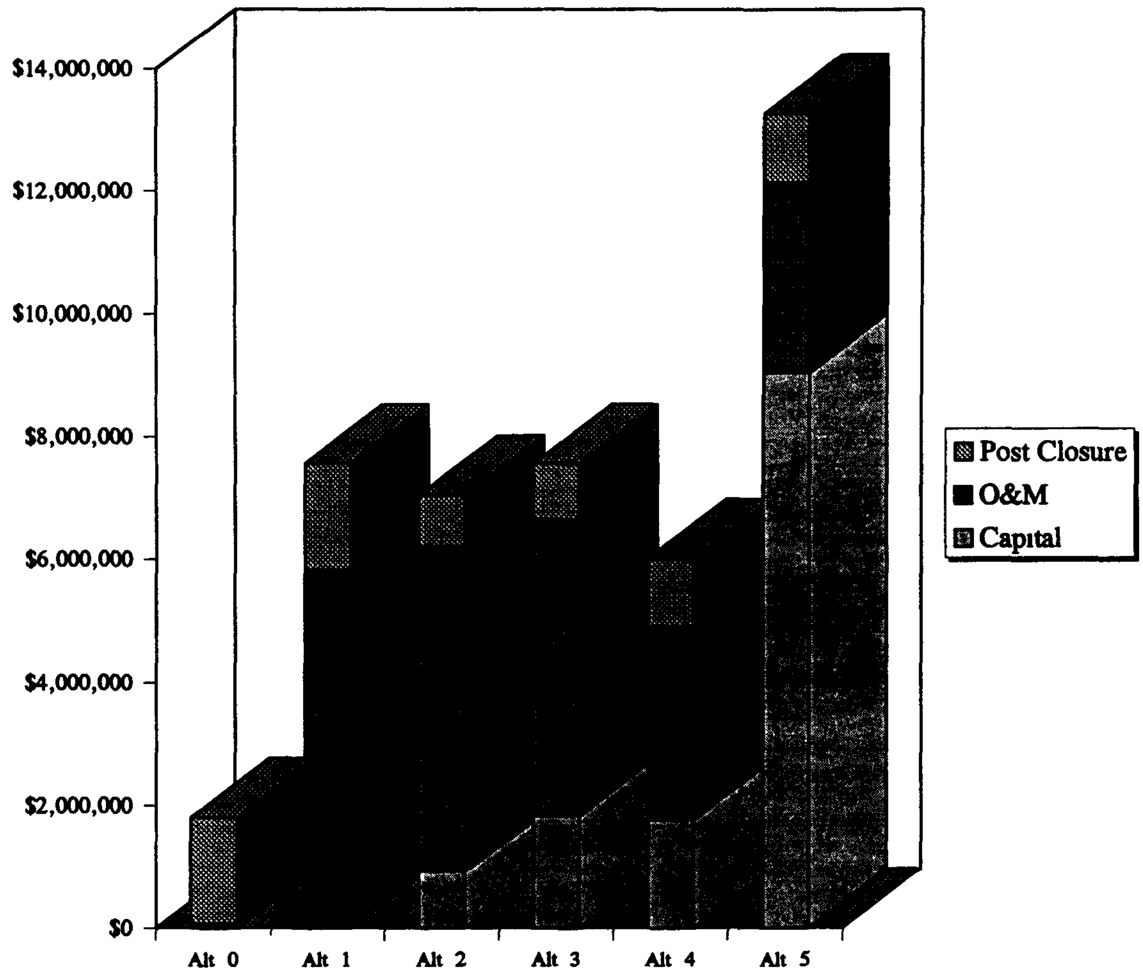
There may be technical problems with Alternatives 2, 3, and 4. For SVE and groundwater extraction to be effective, the wells should be located near or in the DNAPL source Otherwise, the technology is dependent on the passive partitioning capability and rate of the compound In addition, the mechanical mixer in Alternative 4 homogenizes the soil which can decrease the cohesiveness of the soil. The decreased cohesion may result in instability, slumping, and decreased traction for getting to the site and installing groundwater monitoring and extraction wells Alternative 4 may also require special training to operate the mixing equipment because of the proprietary technology. Alternative 3 may require special training from the vendor on operation of the RF antennae before it can be implemented

Alternatives 0 and 1 can be implemented immediately while the remaining alternatives may require 6 months before they can begin treatment of the primary contaminant source. Alternative 3 is available through specialized vendors and Alternative 4 is a proprietary treatment, the lead time necessary before treatment can begin for these alternatives may be longer than the original estimation

Because of the lack of lead time necessary for implementation, Alternatives 0 and 1 are expected to be the easiest to implement of the alternatives Alternative 0 can be implemented immediately once it is approved, however, it is not expected to be easily approved because of the nature of the site Alternatives 2 and 5 should be easily implemented but may require a six-month lead time Alternatives 3 and 4 may require specialized training and additional lead time to procure the equipment from vendors Alternative 5 could require substantial time to implement because of two facts 1) If the Preble's meadow-jumping mouse becomes Federally protected, the consultation process under the Endangered Species Act will be required. The process could require a biological assessment in addition to mitigation measures 2) Soils which are treated could be delisted under RCRA for onsite disposal The delisting process could require two years for agency review and approval

4 4 7 Cost

The total costs for the alternatives are listed in Figure 4-1. Alternative 5 has the largest cost primarily because of the large volume of soil that would require excavation, treatment, and disposal The costs for Alternatives 1 and 3 are comparable Alternative 2's cost was less than Alternatives 5, 1, and 3. Alternative 4 has higher capital costs but due to the higher O&M cost of SVE, Alternative 2 has a higher total cost than Alternative 4. Alternative 0 was the least expensive because it involved only the installation of monitoring wells and the associated monitoring activities



Cost Element	Alt 0	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5
Capital	$63,800	$63,800	$925,600	$1,843,600	$1,781,400	$9,034,500
O&M	$0	$5,761,200	$5,287,700	$4,798,200	$3,113,000	$3,113,000
Post Closure	$1,740,400	$1,740,400	$833,300	$918,700	$1,120,700	$1,122,100
Total Cost	$1,804,200	$7,565,400	$7,046,600	$7,560,500	$6,015,100	$13,269,600

Note Costs represent 1995 dollars at 5% discount rate

Figure 4-1. Summary of Remedial Action Alternative Costs

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APPENDIX A

ALTERNATIVE COST ESTIMATES

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Table A-1. Alternative 0: No Action

Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit: Mat'l	Equip.	Labor	Sub-contract	Source	Bare Costs: Mat'l	Equip.	Labor	Sub-contract	Total Costs
Direct Capital Costs													
Drill Monitoring Wells	Drill & Case 4 wells, 6"diam & 20'dept	4	ea				$10,000 00	Prof Judgement	$0	$0	$0	$40,000	$40,000
Field Personnel	Surveyor	8	hr			$50 00		Prof Judgement	$0	$0	$400	$0	$400
	Health & Safety	8	hr			$65 00		Prof Judgement	$0	$0	$520	$0	$520
	Geologist	40	hr			$55 00		Prof Judgement	$0	$0	$2,200	$0	$2,200
Subtotal Direct Capital Costs									$0	$0	$3,120	$40,000	$43,120
Indirect Capital Costs													
Misc Labor & Materials	10% of direct labor & $1 50 in materials cost for each direct labor hour							Facil Eng 009	$84	$0	$312	$0	$396
Permits	5% of direct materials, equipment, & labor							Prof Judgement	$0	$0	$156	$0	$156
Construction Management	10% of direct materials, equipment, & labor							Prof Judgement	$0	$0	$312	$0	$312
Project Management	10% of direct materials, equipment, & labor							EG&G Cost Est	$0	$0	$312	$0	$312
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor							Facil Eng 009	$0	$0	$789	$0	$789
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$4,000	$4,000
Subtotal Indirect Capital Costs									$84	$0	$1,881	$4,000	$5,965
Contingency	30% of direct and indirect capital costs							Facil Eng 009	$25	$0	$1,500	$13,200	$14,726
Total Capital Costs									$109	$0	$6,502	$57,200	$63,811
Annual O&M Direct Costs													
Subtotal O&M Direct Costs									$0	$0	$0	$0	$0
Total O&M Costs									$0	$0	$0	$0	$0
Annual Post Closure Direct Costs													
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
Analytical Work	Sample Analysis for VOCs & Inorganics	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400
Subtotal Post Closure Direct Costs									$0	$0	$0	$75,400	$75,400
Annual Post Closure Indirect Costs													
Project Management	10% of post closure direct materials, equipment, & labor costs							EG&G Cost Est	$0	$0	$0	$0	$0
Subcontractor Fee	10% of post closure subcontractor costs							Facil Eng 009	$0	$0	$0	$7,540	$7,540
Subtotal Post Closure Indirect Costs									$0	$0	$0	$7,540	$7,540
Contingency	30% of total post closure direct and inderect costs							Facil. Eng 009	$0	$0	$0	$24,882	$24,882
Total Annual Post Closure Costs									$0	$0	$0	$107,822	$107,822

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit				Source	Bare Costs				Total Costs
				Mat'l	Equip.	Labor	Sub-contract		Mat'l	Equip.	Labor	Sub-contract	
Total Post Closure Costs (30 yrs @ 5% discount rate)									$0	$0	$0	$1,740,363	$1,740,363

Total Cost Of Alternative		$109	$0	$6,502	$1,797,563	$1,804,174

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Table A-2. Alternative 1: Institutional Controls With the French Drain

Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit Mat'l	Bare Costs Per Unit Equip.	Bare Costs Per Unit Labor	Bare Costs Per Unit Sub-contract	Source	Bare Costs Mat'l	Bare Costs Equip.	Bare Costs Labor	Bare Costs Sub-contract	Total Costs
Direct Capital Costs													
Drill Monitoring Wells	Drill & Case 4 wells, 6"diam & 20'depth	4	ea				$10,000 00	Prof Judgement	$0	$0	$0	$40,000	$40,000
Field Personnel	Surveyor	8	hr			$50 00		Prof Judgement	$0	$0	$400	$0	$400
	Health & Safety	8	hr			$65 00		Prof Judgement	$0	$0	$520	$0	$520
	Geologist	40	hr			$55 00		Prof Judgement	$0	$0	$2,200	$0	$2,200
Subtotal Direct Capital Costs									$0	$0	$3,120	$40,000	$43,120
Indirect Capital Costs													
Misc Labor & Materials	10% of direct labor & $1 50 in materials cost for each direct labor hour							Facil Eng 009	$84	$0	$312	$0	$396
Permits	5% of direct materials, equipment, & labor							Prof Judgement	$0	$0	$156	$0	$156
Construction Management	10% of direct materials, equipment, & labor							Prof Judgement	$0	$0	$312	$0	$312
Project Management	10% of direct materials, equipment, & labor							EG&G Cost Est	$0	$0	$312	$0	$312
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor							Facil Eng 009	$0	$0	$789	$0	$789
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$4,000	$4,000
Subtotal Indirect Capital Costs									$84	$0	$1,881	$4,000	$5,965
Contingency	30% of direct and indirect capital costs							Facil Eng 009	$25	$0	$1,500	$13,200	$14,726
Total Capital Costs									$109	$0	$6,502	$57,200	$63,811

Activity	Resource Description	Qty.	Unit	Mat'l	Equip.	Labor	Sub-contract	Source	Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual O&M Direct Costs													
Groundwater Treatment	Building 891 Water Treatment System	1	yr				$249,600 00	(1)	$0	$0	$0	$249,600	$249,600
Subtotal O&M Direct Costs									$0	$0	$0	$249,600	$249,600
Annual O&M Indirect Costs													
Misc Labor & Materials	10% of direct labor & $1 50 in material cost for each direct labor hour							Facil Eng 009	$0	$0	$0	$0	$0
Project Management	10% of direct materials, equipment, & labor costs							EG&G Cost Est	$0	$0	$0	$0	$0
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor costs							Facil Eng 009	$0	$0	$0	$0	$0
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$24,960	$24,960
Subtotal O&M Indirect Costs									$0	$0	$0	$24,960	$24,960
Contingency	30% of total direct and indirect O&M costs							Facil Eng 009	$0	$0	$0	$82,368	$82,368
Total Annual O&M Cost									$0	$0	$0	$356,928	$356,928
Total O&M Costs (30 yrs @ 5% discount rate)									$0	$0	$0	$5,761,201	$5,761,201

Activity	Resource Description	Qty.	Unit	Mat'l	Equip.	Labor	Sub-contract	Source	Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual Post Closure Direct Costs													
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
Analytical Work	Sample Analysis for VOCs & Inorganics	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit Mat'l	Bare Costs Per Unit Equip.	Bare Costs Per Unit Labor	Bare Costs Per Unit Sub-contract	Source	Bare Costs Mat'l	Bare Costs Equip.	Bare Costs Labor	Bare Costs Sub-contract	Total Costs
Subtotal Post Closure Direct Costs									$0	$0	$0	$75,400	$75,400
Annual Post Closure Indirect Costs													
Project Management	10% of post closure direct materials, equipment, & labor costs							EG&G Cost Est	$0	$0	$0	$0	$0
Subcontractor Fee	10% of post closure subcontractor costs							Facil Eng 009	$0	$0	$0	$7,540	$7,540
Subtotal Post Closure Indirect Costs									$0	$0	$0	$7,540	$7,540
Contingency	30% of total post closure direct and inderect costs							Facil Eng 009	$0	$0	$0	$24,882	$24,882
Total Annual Post Closure Costs									$0	$0	$0	$107,822	$107,822
Total Post Closure Costs (30 yrs @ 5% discount rate)									$0	$0	$0	$1,740,363	$1,740,363

Total Cost Of Alternative		$109	$0	$6,502	$7,558,764	$7,565,375

(1) Letter from Kim Ruger, Group 1 Closures, Building 080, to Zeke Houk, Group 1 Closures, Building 080 December 21, 1994

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Table A-3. Alternative 2: Groundwater Pumping With Soil Vapor Extraction

Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit: Mat'l	Bare Costs Per Unit: Equip.	Bare Costs Per Unit: Labor	Bare Costs Per Unit: Sub-contract	Source	Bare Costs: Mat'l	Bare Costs: Equip.	Bare Costs: Labor	Bare Costs: Sub-contract	Total Costs
Direct Capital Costs													
Soil Gas Survey	Geologist	120	hr			$55 00		Prof Judgement	$0	$0	$6,600	$0	$6,600
	Field Technician	80	hr			$35 00		Prof Judgement	$0	$0	$2,800	$0	$2,800
	Portable GC	2	wk		$1,000 00			Prof Judgement	$0	$2,000	$0	$0	$2,000
	Probes, Pump, and Misc Equipment	100	ea		$15 00			Prof Judgement	$0	$1,500	$0	$0	$1,500
Dewatering	Drill Extraction Wells, 6" diam, 20 ft depth	3	ea				$10,000 00	Prof Judgement	$0	$0	$0	$30,000	$30,000
	10 gpm submersible pumps	3	ea		$300 00			Vendor Quote	$0	$900	$0	$0	$900
	PVC Piping to French Drain Sump, 2 5"	600	lf	$1 70		$2 19		Means Ref	$1,020	$0	$1,314	$0	$2,334
SVE System	Drill & Install Casing for Vapor Extraction Wells, 4"diam & 20' depth	36	ea				$10,000 00	Prof Judgement	$0	$0	$0	$360,000	$360,000
	Vapor Extraction System	3	ea				$5,280 00	Vendor Quote	$0	$0	$0	$15,840	$15,840
	4" PVC Piping Including Fittings	600	lf	$3 41		$2 77		Means Ref	$2,046	$0	$1,662	$0	$3,708
	6" PVC	40	lf	$5 25		$2 81		Means Ref	$210	$0	$112	$0	$322
	4" Butterfly Valves, PVC	42	ea	$300 00		$50 00		Vendor Quote	$12,600	$0	$2,100	$0	$14,700
	Manholes	36	ea				$1,500 00	Vendor Quote	$0	$0	$0	$54,000	$54,000
	Vacuum Gagues	36	ea				$150 00	Vendor Quote	$0	$0	$0	$5,400	$5,400
	Flow Element/Local Indicator	6	ea				$2,000 00	Vendor Quote	$0	$0	$0	$12,000	$12,000
	Shed Housing SVE Pumps & Carbon Adsorption Equipment	320	sq ft				$25 00	Prof Judgement	$0	$0	$0	$8,000	$8,000
	Electric Heater	1	ea		$350 00			Vendor Quote	$0	$350	$0	$0	$350
	Geotextile Liner (10,000 ft^2)	1	ls	$1,650 00	$575 00	$368 00		Vendor Quote/Means	$1,650	$575	$368	$0	$2,593
Installation of Equipment	Installation - Mechanical & Electrical	96	hrs			$35 00		Prof Judgement	$0	$0	$3,360	$0	$3,360
	Materials	1	ls	$400 00				Prof Judgement	$400	$0	$0	$0	$400
Off-gas Treatment	Carbon Adsorption System	2	ea		$5,218 00			Vendor Quote	$0	$10,436	$0	$0	$10,436
	Initial Granular Activated Carbon (3,000 lbs)	1	ls	$3,240 00				Vendor Quote	$3,240	$0	$0	$0	$3,240
Drill Monitoring Wells	Drill & Case 4 wells, 6"diam & 20'depth	4	ea				$10,000 00	Prof Judgement	$0	$0	$0	$40,000	$40,000
Additional Field Personnel	Surveyor	80	hr			$50 00		Prof Judgement	$0	$0	$4,000	$0	$4,000
	Health & Safety/Rad Monitoring	80	hr			$65 00		EGG Rad Eng	$0	$0	$5,200	$0	$5,200
	Maintenance of Rad Monitoring Equip	10	hr			$55 00		EGG Rad Eng	$0	$0	$550	$0	$550
	Geologist	24	hr			$55 00		Prof Judgement	$0	$0	$1,320	$0	$1,320
SVE Well Closure (1)	Labor	400	hr			$35 00		Prof Judgement	$0	$0	$10,903	$0	$10,903
	Bentonite Grout Wells	9 30	CY	$54 00				Vendor Quote	$391	$0	$0	$0	$391
Subtotal Direct Capital Costs									$21,557	$15,761	$40,290	$525,240	$602,848
Indirect Capital Costs													
Eng , Design & Inspection	15% of direct materials, equipment, & labor							Facil Eng 009	$3,234	$2,364	$6,043	$0	$11,641
Misc Labor & Materials	10% of direct labor & $1 50 in materials cost for each direct labor hour							Facil Eng 009	$780	$0	$4,029	$0	$4,809
Permits	5% of direct materials, equipment, & labor							Prof Judgement	$1,078	$788	$2,014	$0	$3,880
Construction Management	10% of direct materials, equipment, & labor							Prof Judgement	$2,156	$1,576	$4,029	$0	$7,761

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit Mat'l	Bare Costs Per Unit Equip.	Bare Costs Per Unit Labor	Bare Costs Per Unit Sub-contract	Source	Bare Costs Mat'l	Bare Costs Equip.	Bare Costs Labor	Bare Costs Sub-contract	Total Costs
Project Management	10% of direct materials, equipment, & labor + ED&I							EG&G Cost Est.	$2,479	$1,813	$4,633	$0	$8,925
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor							Facil Eng 009	$5,454	$3,988	$10,193	$0	$19,635
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$52,524	$52,524
Subtotal Indirect Capital Costs									$15,180	$10,528	$30,942	$52,524	$109,175
Contingency	30% of direct and indirect capital costs							Facil Eng 009	$11,021	$7,887	$21,370	$173,329	$213,607
Total Capital Costs									$47,758	$34,176	$92,602	$751,093	$925,629

Activity	Resource Description	Qty.	Unit	Mat'l	Equip.	Labor	Sub-contract	Source	Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual O&M Direct Costs													
Operations	Replacement Granular Activated Carbon	12,000	lb	$1 08		$1 25		Vendor Quote	$12,960	$0	$15,000	$0	$27,960
	Transportation of Spent GAC	4	loads				$2,700 00	Vendor Quote	$0	$0	$0	$10,800	$10,800
	Disposal of Granular Activated Carbon	12,000	lb				$0 34	Vendor Quote	$0	$0	$0	$4,080	$4,080
	Electrical Costs of Vacuum Pumps	36	wk	$47 00				Prof Judgement	$1,692	$0	$0	$0	$1,692
	Electrical Costs of Heater	24	wks	$23 63				Prof Judgement	$567	$0	$0	$0	$567
	Confirmatory Sampling	80	ea				$150 00	Prof Judgement	$0	$0	$0	$12,000	$12,000
	Groundwater Treatment @ Building 891 Treat. System	1	yr				$249,600 00	(2)	$0	$0	$0	$249,600	$249,600
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
	Sample Analysis for VOCs & Inorganics	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400
	Collect & Analyze Vapor Samples	12	ea				$1,000 00	Prof Judgement	$0	$0	$0	$12,000	$12,000
Maintenance	Labor	192	hr			$35 00		Prof Judgement	$0	$0	$6,720	$0	$6,720
	Materials & Parts	12	mo	$200 00				Prof Judgement	$2,400	$0	$0	$0	$2,400
Personnel	Operator	2,080	hr			$35 00		Prof Judgement	$0	$0	$72,800	$0	$72,800
	H&S	96	hr			$65 00		Prof Judgement	$0	$0	$6,240	$0	$6,240
	Geologist	192	hr			$55 00		Prof Judgement	$0	$0	$10,560	$0	$10,560
Subtotal O&M Direct Costs									$17,619	$0	$111,320	$363,880	$492,819
Annual O&M Indirect Costs													
Misc Labor & Materials	10% of direct labor & $1 50 in material cost for each direct labor hour							Facil Eng 009	$3,840	$0	$11,132	$0	$14,972
Project Management	10% of direct materials, equipment, & labor costs							EG&G Cost Est.	$1,762	$0	$11,132	$0	$12,894
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor costs							Facil Eng 009	$4,458	$0	$28,164	$0	$32,622
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$36,388	$36,388
Subtotal O&M Indirect Costs									$10,060	$0	$50,428	$36,388	$96,875
Contingency	30% of total direct and indirect O&M costs							Facil Eng 009	$8,304	$0	$48,524	$120,080	$176,908
Total Annual O&M Cost									$35,982	$0	$210,272	$520,348	$766,603
Total O&M Costs (expenditures occure in yrs 1-5 @ 5% discount rate) (3)									$127,591	$0	$745,615	$4,414,454	$5,287,660

Activity	Resource Description	Qty.	Unit	Mat'l	Equip.	Labor	Sub-contract	Source	Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual Post Closure Direct Costs													
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
Analytical Work	Sample Analysis for VOCs & Inorganics	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400
Subtotal Post Closure Direct Costs									$0	$0	$0	$75,400	$75,400

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit Mat'l	Equip.	Labor	Sub-contract	Source	Bare Costs Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual Post Closure Indirect Costs								EG&G Cost Est.	$0	$0	$0	$0	$0
Project Management	10% of post closure direct materials, equipment, & labor costs							Facil Eng 009	$0	$0	$0	$7,540	$7,540
Subcontractor Fee	10% of post closure subcontractor costs								$0	$0	$0	$7,540	$7,540
Subtotal Post Closure Indirect Costs													
Contingency	30% of total post closure direct and inderect costs							Facil Eng 009	$0	$0	$0	$24,882	$24,882
Total Annual Post Closure Costs									$0	$0	$0	$107,822	$107,822
Total Post Closure Costs (4)									$0	$0	$0	$833,261	$833,261

Total Cost Of Alternative		$175,349	$34,176	$838,217	$5,998,808	$7,046,550

(1) Future capital cost that takes place upon completion of treatment. (yr 5 @ 5% discount rate - total cost is in 1994 dollars)

(2) Letter from Kim Ruger, Group 1 Closures, Building 080, to Zeke Houk, Group 1 Closures, Building 080 December 21, 1994

(3) It has been assumed for cost estimating purposes that the Building 891 water treatment system will continue to treat water captured by the French Drain for 10 years following the 4 year SVE period
The costs for operating the Building 891 treatment system during this time have been included in the total O&M Cost.

(4) It has been assumed post-closure groundwater monitoring occurs for 13 years following the completion of SVE operation

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Table A-4. Alternative 3: Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement

Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit: Mat'l	Bare Costs Per Unit: Equip.	Bare Costs Per Unit: Labor	Bare Costs Per Unit: Sub-contract	Source	Bare Costs: Mat'l	Bare Costs: Equip.	Bare Costs: Labor	Bare Costs: Sub-contract	Total Costs
Direct Capital Costs													
Soil Gas Survey	Geologist	120	hr			$55 00		Prof Judgement	$0	$0	$6,600	$0	$6,600
	Field Technician	80	hr			$35 00		Prof Judgement	$0	$0	$2,800	$0	$2,800
	Portable GC	2	wk		$1,000 00			Prof Judgement	$0	$2,000	$0	$0	$2,000
	Probes, Pump, and Misc Equipment	100	ea		$15 00			Prof Judgement	$0	$1,500	$0	$0	$1,500
Dewatering	Drill Extraction Wells, 6" diam, 20 ft depth	3	ea				$10,000 00	Prof Judgement	$0	$0	$0	$30,000	$30,000
	10 gpm submersible pumps	3	ea		$300 00			Vendor Quote	$0	$900	$0	$0	$900
	PVC Piping to French Drain Sump, 2 5"	600	lf	$1 70		$2 19		Means Ref	$1,020	$0	$1,314	$0	$2,334
SVE System	Drill & Install Casing for Vapor Extraction Wells, 4"diam & 20' depth	36	ea				$10,000 00	Prof Judgement	$0	$0	$0	$360,000	$360,000
	Vapor Extraction System	3	ea				$5,280 00	Vendor Quote	$0	$0	$0	$15,840	$15,840
	4" PVC Piping Including Fittings	600	lf	$3 41		$2 77		Means Ref	$2,046	$0	$1,662	$0	$3,708
	6" PVC	40	lf	$5 25		$2 81		Means Ref	$210	$0	$112	$0	$322
	4" Butterfly Valves, PVC	42	ea	$300 00		$50 00		Vendor Quote	$12,600	$0	$2,100	$0	$14,700
	Manholes	36	ea				$1,500 00	Vendor Quote	$0	$0	$0	$54,000	$54,000
	Vacuum Gagues	36	ea				$150 00	Vendor Quote	$0	$0	$0	$5,400	$5,400
	Flow Element/Local Indicator	6	ea				$2,000 00	Vendor Quote	$0	$0	$0	$12,000	$12,000
	Shed Housing SVE Pumps & Carbon Adsorption Equipment	320	sq ft				$25 00	Prof Judgement	$0	$0	$0	$8,000	$8,000
	Electric Heater	1	ea		$350 00			Vendor Quote	$0	$350	$0	$0	$350
	Geotextile Liner (10,000ft²)	1	ls	$1,650 00	$575 00	$368 00		Vendor Quote/Means	$1,650	$575	$368	$0	$2,593
RF Heating Unit	Setup, Startup, & Testing	1	ls				$80,000 00	Vendor Quote	$0	$0	$0	$80,000	$80,000
	Equipment Rental	56	wk				$10,000 00	Vendor Quote	$0	$0	$0	$560,000	$560,000
Installation of Equipment	Installation - Mechanical & Electrical	96	hrs			$35 00		Prof Judgement	$0	$0	$3,360	$0	$3,360
	Materials	1	ls	$400 00				Prof Judgement	$400	$0	$0	$0	$400
Off-gas Treatment	Carbon Adsorption System	2	ea		$5,218 00			Vendor Quote	$0	$10,436	$0	$0	$10,436
	Initial Granular Activated Carbon (3,000 lbs)	1	ls	$3,240 00				Vendor Quote	$3,240	$0	$0	$0	$3,240
Drill Monitoring Wells	Drill & Case 4 wells, 6"diam & 20'depth	4	ea				$10,000 00	Prof Judgement	$0	$0	$0	$40,000	$40,000
Additional Field Personnel	Surveyor	80	hr			$50 00		Prof Judgement	$0	$0	$4,000	$0	$4,000
	Health & Safety/Rad Monitoring	80	hr			$65 00		EGG Rad Eng	$0	$0	$5,200	$0	$5,200
	Maintenance of Rad Monitoring Equipment	10	hr			$55 00		EGG Rad Eng	$0	$0	$550	$0	$550
	Geologist	24	hr			$55 00		Prof Judgement	$0	$0	$1,320	$0	$1,320
Well Closure (1)	Labor	400	hr			$35 00		Prof Judgement	$0	$0	$12,050	$0	$12,050
	Bentonite Grout Wells	9 30	CY	$54 00				Vendor Quote	$432	$0	$0	$0	$432
Subtotal Direct Capital Costs									$21,598	$15,761	$41,436	$1,165,240	$1,244,035

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit: Mat'l	Equip.	Labor	Sub-contract	Source	Bare Costs: Mat'l	Equip.	Labor	Sub-contract	Total Costs
Indirect Capital Costs													
Eng , Design & Inspection	15% of direct materials, equipment, & labor							Facil Eng 009	$3,240	$2,364	$6,215	$0	$11,819
Misc Labor & Materials	10% of direct labor & $1 50 in materials cost for each direct labor hour							Facil Eng 009	$780	$0	$4,144	$0	$4,924
Permits	5% of direct materials, equipment, & labor							Prof Judgement	$1,080	$788	$2,072	$0	$3,940
Construction Management	10% of direct materials, equipment, & labor							Prof Judgement	$2,160	$1,576	$4,144	$0	$7,880
Project Management	10% of direct materials, equipment, & labor + ED&I							EG&G Cost Est.	$2,484	$1,813	$4,765	$0	$9,061
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor							Facil Eng 009	$5,464	$3,988	$10,483	$0	$19,935
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$116,524	$116,524
Subtotal Indirect Capital Costs									$15,208	$10,528	$31,823	$116,524	$174,083
Contingency	30% of direct and indirect capital costs							Facil Eng 009	$11,042	$7,887	$21,978	$384,529	$425,436
Total Capital Costs									$47,848	$34,176	$95,237	$1,666,293	$1,843,554

Activity	Resource Description	Qty.	Unit	Mat'l	Equip.	Labor	Sub-contract	Source	Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual O&M Direct Costs													
Operations	Replacement Granular Activated Carbon	12,000	lb	$1 08		$1 25		Vendor Quote	$12,960	$0	$15,000	$0	$27,960
	Transportation of Spent GAC	4	loads				$2,700 00	Vendor Quote	$0	$0	$0	$10,800	$10,800
	Disposal of Granular Activated Carbon	12,000	lb				$0 34	Vendor Quote	$0	$0	$0	$4,080	$4,080
	Electrical Costs of Vacuum Pumps	36	wk	$47 00				Prof Judgement	$1,692	$0	$0	$0	$1,692
	Electrical Costs of Heater	24	wks	$23 63				Prof Judgement	$567	$0	$0	$0	$567
	Electrical Costs of RF Unit (500 KW Unit)	1	yr				$117,600 00	Prof Judgement	$0	$0	$0	$117,600	$117,600
	Confirmatory Sampling	80	ea				$150 00	Prof Judgement	$0	$0	$0	$12,000	$12,000
	Groundwater Treatment @ Building 891 Treat. System	1	yr				$249,600 00	(2)	$0	$0	$0	$249,600	$249,600
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
	Sample Analysis for VOCs & Inorganics	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400
	Collect & Analyze Vapor Samples	12	ea				$1,000 00	Prof Judgement	$0	$0	$0	$12,000	$12,000
Maintenance	Labor	192	hr			$35 00		Prof Judgement	$0	$0	$6,720	$0	$6,720
	Materials & Parts	12	mo	$200 00				Prof Judgement	$2,400	$0	$0	$0	$2,400
Personnel	Operator	4,160	hr			$35 00		Prof Judgement	$0	$0	$145,600	$0	$145,600
	H&S	96	hr			$65 00		Prof Judgement	$0	$0	$6,240	$0	$6,240
	Geologist	192	hr			$55 00		Prof Judgement	$0	$0	$10,560	$0	$10,560
Subtotal O&M Direct Costs									$17,619	$0	$184,120	$481,480	$683,219
Annual O&M Indirect Costs													
Misc Labor & Materials	10% of direct labor & $1 50 in material cost for each direct labor hour							Facil Eng 009	$6,960	$0	$18,412	$0	$25,372
Project Management	10% of direct materials, equipment, & labor costs							EG&G Cost Est.	$1,762	$0	$18,412	$0	$20,174
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor costs							Facil Eng 009	$4,458	$0	$46,582	$0	$51,040
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$48,148	$48,148
Subtotal O&M Indirect Costs									$13,180	$0	$83,406	$48,148	$144,734
Contingency	30% of total direct and indirect O&M costs							Facil Eng 009	$9,240	$0	$80,258	$158,888	$248,386
Total Annual O&M Cost									$40,038	$0	$347,784	$688,516	$1,076,339

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit: Mat'l	Equip.	Labor	Sub-contract	Source	Bare Costs: Mat'l	Equip.	Labor	Sub-contract	Total Costs
Total O&M Costs (expenditures occurs in years 2-3 @ 5% discount rate) (3)									$74,447	$0	$646,674	$4,077,097	$4,798,218
Annual Post Closure Direct Costs													
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
Analytical Work	Sample Analysis for VOCs & Inorganics	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400
Subtotal Post Closure Direct Costs									$0	$0	$0	$75,400	$75,400
Annual Post Closure Indirect Costs													
Project Management	10% of post closure direct materials, equipment, & labor costs							EG&G Cost Est.	$0	$0	$0	$0	$0
Subcontractor Fee	10% of post closure subcontractor costs							Facil Eng 009	$0	$0	$0	$7,540	$7,540
Subtotal Post Closure Indirect Costs									$0	$0	$0	$7,540	$7,540
Contingency	30% of total post closure direct and indirect costs							Facil Eng 009	$0	$0	$0	$24,882	$24,882
Total Annual Post Closure Costs									$0	$0	$0	$107,822	$107,822
Total Post Closure Costs (4)									$0	$0	$0	$918,670	$918,670
Total Cost Of Alternative									$122,295	$34,176	$741,911	$6,662,060	$7,560,442

(1) Future capital cost that takes place upon completion of treatment. (yr 3 @ 5% discount rate - total cost is in 1994 dollars)

(2) Letter from Kim Ruger, Group 1 Closures, Building 080, to Zeke Houk, Group 1 Closures, Building 080 December 21, 1994

(3) It has been assumed for cost estimating purposes that the Building 891 water treatment system will continue to treat water captured by the French Drain for 10 years following the 2 year SVE period
The costs for operating the Building 891 treatment system during this time have been included in the total O&M Cost.

(4) It has been assumed that post-closure groundwater monitoring occurs for 13 years following the completion of SVE operation

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Table A-5. Alternative 4: Hot Air Injection with Mechanical Mixing

Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit Mat'l	Bare Costs Per Unit Equip.	Bare Costs Per Unit Labor	Bare Costs Per Unit Sub-contract	Source	Bare Costs Mat'l	Bare Costs Equip.	Bare Costs Labor	Bare Costs Sub-contract	Total Costs
Direct Capital Costs													
Soil Gas Survey	Geologist	120	hr			$55 00		Prof Judgement	$0	$0	$6,600	$0	$6,600
	Field Technician	80	hr			$35 00		Prof Judgement	$0	$0	$2,800	$0	$2,800
	Portable GC	2	wk		$1,000 00			Prof Judgement	$0	$2,000	$0	$0	$2,000
	Probes, Pump, and Misc Equipment	100	ea		$15 00			Prof Judgement	$0	$1,500	$0	$0	$1,500
Treatment of Soils	Mechanical Mixing Tool (1)	7,400	cy				$150 00	Vendor Quote	$0	$0	$0	$1,110,000	$1,110,000
Additional Field Personnel	Surveyor	80	hr			$50 00		Prof Judgement	$0	$0	$4,000	$0	$4,000
	Health & Safety/Rad Monitoring	480	hr			$65 00		EGG Rad Eng	$0	$0	$31,200	$0	$31,200
	Maintenance of Rad Monitoring Equip	60	hr			$55 00		EGG Rad Eng	$0	$0	$3,300	$0	$3,300
	Geologist	120	hr			$55 00		Prof Judgement	$0	$0	$6,600	$0	$6,600
Drill Monitoring Wells	Drill & Case 4 wells, 6"diam & 20'depth	4	ea				$10,000 00	Prof Judgement	$0	$0	$0	$40,000	$40,000
Extraction Well Closure	Labor	50	hr			$35 00		Prof Judgement	$0	$0	$1,584	$0	$1,584
	Bentonite Grout Wells	0 40	CY	$54 00				Vendor Quote	$20	$0	$0	$0	$20
Subtotal Direct Capital Costs									$20	$3,500	$56,084	$1,150,000	$1,209,603
Indirect Capital Costs													
Eng , Design & Inspection	15% of direct materials, equipment, & labor							Facil Eng 009	$3	$525	$8,413	$0	$8,940
Misc Labor & Materials	10% of direct labor & $1.50 in materials cost for each direct labor hour							Facil Eng 009	$279	$0	$5,608	$0	$5,887
Permits	5% of direct materials, equipment, & labor							Prof Judgement	$1	$175	$2,804	$0	$2,980
Construction Management	10% of direct materials, equipment, & labor							Prof Judgement	$2	$350	$5,608	$0	$5,960
Project Management	10% of direct materials, equipment, & labor + ED&I							EG&G Cost Est.	$2	$403	$6,450	$0	$6,854
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor							Facil Eng 009	$5	$886	$14,189	$0	$15,080
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$115,000	$115,000
Subtotal Indirect Capital Costs									$292	$2,338	$43,072	$115,000	$160,702
Contingency	30% of direct and indirect capital costs							Facil Eng 009	$93	$1,751	$29,747	$379,500	$411,092
Total Capital Costs									$405	$7,589	$128,903	$1,644,500	$1,781,397

Annual O&M Direct Costs													
Groundwater Treatment	Building 891 Water Treatment System	1	yr				$249,600 00	(2)	$0	$0	$0	$249,600	$249,600
Subtotal O&M Direct Costs									$0	$0	$0	$249,600	$249,600
Annual O&M Indirect Costs													
Misc Labor & Materials	10% of direct labor & $1 50 in material cost for each direct labor hour							Facil. Eng 009	$0	$0	$0	$0	$0
Project Management	10% of direct materials, equipment, & labor costs							EG&G Cost Est.	$0	$0	$0	$0	$0
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor costs							Facil Eng 009	$0	$0	$0	$0	$0
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$24,960	$24,960
Subtotal O&M Indirect Costs									$0	$0	$0	$24,960	$24,960

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit Mat'l	Equip.	Labor	Sub-contract	Source	Bare Costs Mat'l	Equip.	Labor	Sub-contract	Total Costs
Contingency	30% of total direct and indirect O&M costs							Facil Eng 009	$0	$0	$0	$82,368	$82,368
Total Annual O&M Cost									$0	$0	$0	$356,928	$356,928
Total O&M Costs (expenditure occures in years 1-11 @ 5% discount rate)									$0	$0	$0	$3,113,031	$3,113,031

Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit Mat'l	Equip.	Labor	Sub-contract	Source	Bare Costs Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual Post Closure Direct Costs													
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
Analytical Work	Sample Analysis for VOCs & Inorganics	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400
Subtotal Post Closure Direct Costs									$0	$0	$0	$75,400	$75,400
Annual Post Closure Indirect Costs													
Project Management	10% of post closure direct materials, equipment, & labor costs							EG&G Cost Est.	$0	$0	$0	$0	$0
Subcontractor Fee	10% of post closure subcontractor costs							Facil Eng 009	$0	$0	$0	$7,540	$7,540
Subtotal Post Closure Indirect Costs									$0	$0	$0	$7,540	$7,540
Contingency	30% of total post closure direct and inderect costs							Facil Eng 009	$0	$0	$0	$24,882	$24,882
Total Annual Post Closure Costs									$0	$0	$0	$107,822	$107,822
Total Post Closure Costs (13 years at 5% discount rate)									$0	$0	$0	$1,120,656	$1,120,656

		Mat'l	Equip.	Labor	Sub-contract	Total Costs
Total Cost Of Alternative		$405	$7,589	$128,903	$5,878,187	$6,015,085

(1) Cost includes vapor treatment and confirmatory samples

(2) Letter from Kim Ruger, Group 1 Closures, Building 080, to Zeke Houk, Group 1 Closures, Building 080 December 21, 1994

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Table A-6. Alternative 5: Soil Excavation With Groundwater Pumping

Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit: Mat'l	Bare Costs Per Unit: Equip.	Bare Costs Per Unit: Labor	Bare Costs Per Unit: Sub-contract	Source	Bare Costs: Mat'l	Bare Costs: Equip.	Bare Costs: Labor	Bare Costs: Sub-contract	Total Costs
Direct Capital Costs													
Construct Staging Area	Towed Sheepsfoot	404	CY		$0 70	$0 20		Means Ref	$0	$283	$81	$0	$364
	Base Course	1003	SY	$2 12	$0 29	$0 22		Means Ref	$2 126	$291	$221	$0	$2,638
	Reinforced Concrete Slab, 6" Thick	104	CY	$88.28	$9 09	$72 52		Means Ref	$9 181	$945	$7 542	$0	$17,669
	Submersible Sump Pump, 5 gpm	2	ea		$300 00			Vendor Quote	$0	$600	$0	$0	$600
	2" PVC Piping (including fittings)	200	lf	$1 44		$2 04		Means Ref	$288	$0	$408	$0	$696
Scrape Top Soil & Stockpile	Towed Scraper	376	CY		$3 45	$0 81		Means Ref	$0	$1,297	$305	$0	$1,602
Dust Control	Water Truck, 5,000 gal capacity	1,440	hr		$21 32	$25 00		Means Ref	$0	$30,701	$36,000	$0	$66,701
Excavate Soil, Haul to Staging Area	Dozer	19,692	CY		$2 91	$0 64		Means Ref	$0	$57,304	$12,603	$0	$69,907
	Backhoe	985	CY		$0 98	$0 37		Means Ref	$0	$965	$364	$0	$1,330
	Front End Loader	18,707	CY		$0 66	$0 35		Means Ref	$0	$12,347	$6,547	$0	$18,894
	Dump Trailer	19,692	CY		$1 15	$0 46		Means Ref	$0	$22,646	$9,058	$0	$31,704
Dewatering	20 gpm Suction Pumps	2	ea		$400 00			Vendor Quote	$0	$800	$0	$0	$800
	2 5" PVC Pipe (includes fittings)	200	lf	$1 70		$2 19		Means Ref	$340	$0	$438	$0	$778
	Corrugated Metal Pipe	12	lf	$4 15		$1 40		Means Ref	$50	$0	$17	$0	$67
	Pea Gravel	30	CY	$17 55				Means Ref	$527	$0	$0	$0	$527
Rad Screening of Soils	Health & Safety Specialist	1,440	hr			$65 00		EG&G Rad Eng	$0	$0	$93,600	$0	$93,600
	Monitoring Equipment Maintenance	180	hr			$55 00		EG&G Rad Eng	$0	$0	$9 900	$0	$9,900
Treatment of Excavated Soils	Thermal Desorption Unit	19,692	CY				$75 00	Vendor Quote	$0	$0	$0	$1,476,900	$1,476,900
	Thermal Desorption Unit Mobilization	1	ls				$4,000 00	Vendor Quote	$0	$0	$0	$4,000	$4,000
	Thermal Desorption Unit Demobilization	1	ls				$1,500 00	Vendor Quote	$0	$0	$0	$1,500	$1,500
	Wheel Mounted Front End Loader	39,384	CY		$0 66	$0 35		Means Ref	$0	$25,993	$13,784	$0	$39,778
Transportation/Disposal of Soil	Transportation to Disposal Facility (< 50 mi)	19,692	CY				$53 00	Vendor Quote	$0	$0	$0	$1,043,676	$1,043,676
	Disposal at Licensed Facility	19,692	CY				$123 00	Vendor Quote	$0	$0	$0	$2,422,116	$2,422,116
	Soil Samples	1,641	ea				$250 00	Prof Judgement	$0	$0	$0	$410,250	$410,250
Backfill Excavation	Pit-Run Fill/Gravel, 5 mi haul	19,692	CY	$3 57	$4 86	$1 83		Means Ref	$70,300	$95,703	$36,036	$0	$202,040
	Towed Sheepsfoot, 12" lifts	19,692	CY		$0 35	$0 09		Means Ref	$0	$6,892	$1,772	$0	$8,664
	Revegitation	3,388	SY	$0.22	$0 06	$0 06		Means Ref	$745	$203	$203	$0	$1,152
Drill Monitoring Wells	Drill & Case 4 wells, 6"diam & 20'depth	4	ea				$10,000 00	Prof Judgement	$0	$0	$0	$40,000	$40,000
Additional Field Personnel	Sr Geologist	110	hrs			$75 00		Prof Judgement	$0	$0	$8,250	$0	$8,250
	Surveyor	100	hrs			$50 00		Prof Judgement	$0	$0	$5,000	$0	$5,000
Confirmatory Sampling	Soil Samples From Excavation Site	25	ea				$250 00	Prof Judgement	$0	$0	$0	$6,250	$6,250
Subtotal Direct Capital Costs									$83,558	$256,971	$242,130	$5,404,692	$5,976,100
Indirect Capital Costs													
Engineering, Design & Inspection	15% of direct materials, equipment, & labor							Facil Eng 009	$12,534	$38,546	$36,320	$0	$87,399
Miscellaneous Labor & Materials	10% of direct labor & $1 50 in materials cost for each direct labor hour							Facil Eng 009	$8,403	$0	$24,213	$0	$32,616
Permits	5% of direct materials, equipment, & labor							Prof Judgement	$4,178	$12 849	$12 107	$0	$29,133

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Activity	Resource Description	Qty.	Unit	Bare Costs Per Unit: Mat'l	Equip.	Labor	Sub-contract	Source	Bare Costs: Mat'l	Equip.	Labor	Sub-contract	Total Costs
Construction Management	10% of direct materials, equipment, & labor							Prof Judgement	$8,356	$25,697	$24,213	$0	$58,266
Project Management	10% of direct materials, equipment, & labor + ED&I							EG&G Cost Est.	$9,609	$29,552	$27,845	$0	$67,006
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor							Facil Eng 009	$21,140	$65,014	$61,259	$0	$147,413
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$540,469	$540,469
Subtotal Indirect Capital Costs									$64,219	$171,656	$185,956	$540,469	$962,301
Contingency	30% of direct and indirect capital costs							Facil Eng 009	$44,333	$128,588	$128,426	$1,783,548	$2,084,895
Total Capital Costs									$192,110	$557,215	$556,512	$7,728,710	$9,034,547

Activity	Resource Description	Qty.	Unit	Mat'l	Equip.	Labor	Sub-contract	Source	Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual O&M Direct Costs													
Groundwater Treatment	Building 891 Water Treatment System	1	yr				$249,600 00	(1)	$0	$0	$0	$249,600	$249,600
Subtotal O&M Direct Costs									$0	$0	$0	$249,600	$249,600
Annual O&M Indirect Costs													
Misc. Labor & Materials	10% of direct labor & $1 50 in material cost for each direct labor hour							Facil Eng 009	$0	$0	$0	$0	$0
Project Management	10% of direct materials, equipment, & labor costs							EG&G Cost Est.	$0	$0	$0	$0	$0
Overhead, Profit & Bond	25 3% of direct materials, equipment, & labor costs							Facil Eng 009	$0	$0	$0	$0	$0
Subcontractor Fee	10% of subcontractor costs							Facil Eng 009	$0	$0	$0	$24,960	$24,960
Subtotal O&M Indirect Costs									$0	$0	$0	$24,960	$24,960
Contingency	30% of total direct and indirect O&M costs							Facil Eng. 009	$0	$0	$0	$82,368	$82,368
Total Annual O&M Cost									$0	$0	$0	$356,928	$356,928
Total O&M Costs (expenditure occures in years 1-11 @ 5% discount rate)									$0	$0	$0	$3,113,031	$3,113,031

Activity	Resource Description	Qty.	Unit	Mat'l	Equip.	Labor	Sub-contract	Source	Mat'l	Equip.	Labor	Sub-contract	Total Costs
Annual Post Closure Direct Costs													
Semiannual Sampling	Collect Groundwater Samples	12	ea				$1,500 00	Prof Judgement	$0	$0	$0	$18,000	$18,000
Groundwater Monitoring	Semiannual Groundwater Sampling	14	ea				$4,100 00	Vendor Quote	$0	$0	$0	$57,400	$57,400
Revegitation	10% of Excavated Area/yr	290	SY	$0 22	$0 06	$0 06		Means Ref	$64	$17	$17	$0	$99
Subtotal Post Closure Direct Costs									$64	$17	$17	$75,400	$75,499
Annual Post Closure Indirect Costs													
Project Management	10% of post closure direct materials, equipment, & labor costs							EG&G Cost Est.	$6	$2	$2	$0	$10
Subcontractor Fee	10% of post closure subcontractor costs							Facil Eng 009	$0	$0	$0	$7,540	$7,540
Subtotal Post Closure Indirect Costs									$6	$2	$2	$7,540	$7,550
Contingency	30% of total post closure direct and inderect costs							Facil Eng. 009	$21	$6	$6	$24,882	$24,915
Total Annual Post Closure Costs									$91	$25	$25	$107,822	$107,963
Total Post Closure Costs (13 years @ 5% discount rate)									$948	$259	$259	$1,120,656	$1,122,121

Total Cost Of Alternative		$193,058	$557,473	$556,771	$11,962,397	$13,269,700

(1) Letter from Kim Ruger, Group 1 Closures, Building 080, to Zeke Houk, Group 1 Closures Building 080 December 21, 1994

APPENDIX B

GROUNDWATER MODELING RESULTS

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APPENDIX B
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ACRONYMS

CCl_4	carbon tetrachloride
CMS/FS	Corrective Measures Study/Feasibility Study
COC	contaminant of concern
DCE	dichloroethene
DNAPL	dense non-aqueous phase liquid
DOE	U S Department of Energy
IHSS	Individual Hazardous Substance Site
OU-1	Operable Unit 1
PCE	perchloroethene (or tetrachloroethene)
RFI/RI	RCRA Facility Investigation/Remedial Investigation
TCA	trichloroethane
TCE	trichloroethene
VOC	volatile organic compound

B.1.0 INTRODUCTION

Appendix B presents the results of a subsurface solute transport model of the OU-1 site The purpose of the model is to provide a basis for residual risk calculations and design calculations for the feasibility study In this appendix, the following topics are discussed the hydrogeological conceptual model of the site, the framework of the corresponding numerical model, the results and predictions of the model, and a qualitative discussion of model uncertainty Tables and figures are included in the back of this appendix after the references

B.2.0 HYDROGEOLOGICAL CONCEPTUAL MODEL

The OU-1 conceptual model describes the primary processes that control the movement of solutes in the subsurface Such processes include groundwater flow rates and directions, solute release rates and timing, recharge and discharge rates, dispersion, degradation rates, and adsorption

The groundwater flow system beneath the hillside at OU-1 is described in detail in the Phase III RFI/RI (DOE 1994) The following description is limited to features at IHSS 119 1 that are incorporated into the flow and transport model of the site IHSS 119 1 is where most of the observed contamination at the site is located

Groundwater flow beneath the hillside occurs in shallow colluvial, alluvial, and bedrock units with most of the flow concentrated in the colluvium and alluvium (DOE 1994) Groundwater flow tends to be focussed in areas of thick colluvium which generally correspond to topographic features The thick colluvium is probably produced by deep bedrock weathering in the area The weathering is assumed to be caused by oxygenated water infiltrating the bedrock located beneath streambeds

Site data from Volume IV, Appendix A of the Phase III RFI/RI (DOE 1994) supports the theory that thick colluvium is found beneath streambeds The vertical section of the French Drain from Station 16+00 to 16+50 shows a thick band of colluvium beneath the drainage and the shear plane as conforming with the bedrock channel This shear plane may correspond to the depth of bedrock weathering Therefore, there may be a relationship between the depth of weathering and soil volume affected by slope instability

One hydrologic drainage that extends upslope into IHSS 119 1, illustrated in Figures 3-23 and 3-24 of the Phase III RFI/RI (DOE 1994), is where most of the groundwater in the vicinity of IHSS 119.1 flows Site data indicate that it has a thick band of colluvium Therefore, it is assumed that groundwater is generally channelized along hydrologic drainages.

Recharge and discharge vary in the short-term at the site primarily because of the low groundwater volume and its large dependence on rainfall events and infiltration However, an average rate of recharge or discharge can be calculated from infiltration equations and long-term precipitation averages from site data or records from the National Oceanic and Atmospheric Administration No site-specific calculations or field measurements of recharge or discharge are available

Recharge to groundwater is assumed to occur from interflow and bedrock flow from the Rocky Flats alluvium and is significantly affected by the low permeability of the colluvium and alluvium at the site Recharge is decreased during arid conditions and high rainfall events because of the lowered infiltration capacity and permeability of the soil Similarly, it is increased during spring and fall when the soil has a greater infiltration capacity

Groundwater discharge is assumed to occur due to the low permeability and moisture content of the soil and the low-flow conditions caused by the arid climate at the site It occurs as evapotranspiration and flow into Woman Creek (Fedors et al 1993a and 1993b) Flow into Woman Creek is indicated by calculated hydraulic gradients of the site and the theory that the groundwater follows topographic features

The primary source of contamination is assumed to be located in the subsurface soil at IHSS 119 1 During the 1960s and 1970s, drums containing volatile organic compounds (VOCs) were stored at IHSS 119 1 (DOE 1994) Probable releases from the drums may have resulted in a residual DNAPL in the subsurface soil The residual DNAPL phase has not been directly observed but is indicated by high concentrations of VOCs in the areas near Well 0487, Well 4387, Well 4787, and Well 5587. The drums are assumed to have started leaking their contents into the soil in 1970 although it is not specifically known at this time. The primary groundwater release mechanism is assumed to be dissolution of residual DNAPL assisted by infiltration

The transport of contaminants in groundwater is controlled by groundwater direction and flowrate. Other processes that affect contaminant fate and transport are hydrodynamic dispersion, degradation, and adsorption Hydrodynamic dispersion is simulated using dispersivity, groundwater velocity, and molecular diffusion Degradation rates and sorption properties for VOCs are discussed and reported the Phase III RFI/RI (DOE 1994)

B.3.0 MODEL FRAMEWORK

The computer simulation code TARGET_2DU (Dames & Moore 1985) was used to simulate contaminant transport in the subsurface TARGET_2DU is a vertically oriented, two-dimensional, finite difference model that can simulate variably saturated conditions For the purposes of this CMS/FS, TARGET_2DU was modified to simulate a source with a constant concentration

Because the model is two dimensional, it cannot simulate dispersion (spreading) transverse (perpendicular) to the model section Therefore, the modeled dispersion in the plane of the model will be greater than the actual dispersion Consequently, the model is conservative and will overestimate dispersion because it does not account for spreading of contaminants in transverse to the model plane

The model grid as shown in Figure B-1 is 296 horizontal cells by 170 vertical cells It has approximately 25,000 active cells The grid was designed to capture details of the bedrock/colluvium interface and topography, to accurately simulate the vadose zone, and to minimize errors caused by numerical dispersion The location of the section of the model is shown in Figures B-2 and B-3, and corresponds to the trough of thicker colluvium at IHSS 119 1

Two criteria are used to ensure minimal numerical dispersion the Peclet number and the Courant number The grid Peclet number is the ratio of grid spacing (length of a cell side) to dispersivity To minimize numerical dispersion, the Peclet number generally should be less than or equal to one For this model, dispersivity is much larger than cell lengths, so the Peclet number is much smaller than one. The grid Courant number is the ratio of time step interval to groundwater travel time across a cell. Similar to the Peclet number, the Courant number generally should be less than or equal to one. Because of low gradients and hydraulic conductivities and moderate sorption, the Courant number for this model is much smaller than one.

The distribution of boundary conditions and soil types are shown in Figures B-4 and B-5 Soil properties, degradation rates, and adsorption distribution coefficients for the COCs are listed in Tables B-1a and B-1b The degradation rates used in the model were the maximum values listed in the Phase III RFI/RI (DOE 1994) and they reflect the slowest anticipated degradation rates at the site

Figures B-7 through B-12 show the relationship between relative saturation, relative hydraulic conductivity, and pressure head as specified in the model Calculated relative hydraulic conductivity refers to values calculated by Fedors et al (1993b) using Van Genuchten's equations relating pressure head, relative saturation and relative hydraulic conductivity (Van Genuchten 1980) The curve for colluvium is based on site data (Fedors et al 1993b), as indicated in the figure The curves for bedrock and alluvium in the Woman Creek drainage are based on material #1 and material #2, respectively, in Table 3-1 of Fedors et al 1993a

Each soil type is assumed to be homogeneous within the type and heterogenous between types Therefore, heterogeneity in the model is limited to the colluvium, alluvium, and bedrock layers These lithologies have been identified and defined during the site characterization activities Fractures in the colluvium resulting from slope instability are assumed to be healed, so that fractures do not provide preferential flowpaths It is assumed that most instabilities do not occur unless initiated by human activities and that, if active, slumping probably occurs at an imperceptibly slow rate If these observations are correct, then discontinuities (fractures) caused by mass movements would heal quickly in the easily deformed colluvium This is supported by the lack of distinct features typically associated with slumping, i e , discontinuities such as tension cracks at the upslope end of a slump The lack of such features is assumed to be due to the slow rate of movement and to the characteristic deformability of colluvium

For the French Drain, a constant head cell of 5876 2 ft (1791.1 m) was set at the bottom of the drain to simulate flow to the drain, as shown in Figure B-5. The extraction well was simulated in the same manner, but with an elevation of 5910.2 ft (1801 4 m). These elevations were set slightly above the interface between bedrock and colluvium material based on the assumption that the French Drain and extraction well could not draw groundwater down to the interface If this happened, the saturated thickness would approach zero and the flow would decrease to zero Simulations using the French Drain and extraction well are discussed in detail in following sections

The bottom of the model was selected to be somewhat lower than the elevation of Woman Creek which is considered to be the ultimate discharge point for groundwater at the site The French Drain is currently the assumed groundwater discharge point but was not included in the model to decrease the complexity of the site Because flow rates in the bedrock are much lower than those in the colluvium, the model is not very sensitive to the location of the colluvium-bedrock boundary

The primary contaminant source was simulated using a constant concentration boundary condition based on the assumption that a slow dissolution of residual DNAPL is the source of groundwater contamination The source cell shown in Figure B-5 is located at the interface between bedrock and colluvium material in the model where elevated concentrations of contaminants in groundwater have been observed Because the soil are fine-grained and have low permeability, the likelihood is small that there is a large, continuous, and mobile DNAPL present. In support of this conclusion, the following hypothetical cases are considered

- <u>Hypothetical Case 1</u> Large spill of DNAPL caused observed contamination Spill would spread over a large area because of the low-permeability soil DNAPL would penetrate only shallow soil due to spreading and reduced DNAPL source hydraulic head Large dissolved concentrations would be observed over a wide area relative to the spill location.

- <u>Hypothetical Case 2</u>. Small episodic spills of DNAPL caused the observed contamination. DNAPL would penetrate further into low-permeability soil than Case 1 However, penetration would be limited due to the source's low hydraulic head DNAPL would rapidly achieve residual saturation as source head is dissipated Large dissolved concentrations would be observed over a small area relative to the spill location

The descriptions in the hypothetical cases above are based on information presented by Cherry

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et al 1990 Case 2 is consistent with the large VOC concentrations observed in a limited area at IHSS 119 1 It is also consistent with how the site was used historically, i e , as a drum storage area rather than for activities in which solvents were actively used and spilled at the site Based on consideration of these two cases and on the measured concentrations at the hillside, the most reasonable situation is that the source in the subsurface is an immobile, residual DNAPL

Because soil instabilities have been documented at the OU-1 area (DOE 1994), the colluvium and bedrock involved in the movements is potentially fractured To flow into a fracture or pore, DNAPL must overcome the displacement pressure required to displace water (Cherry et al 1990) which is the wetting phase at the site Therefore, DNAPLs would be less susceptible to flow in fractures where water is present In addition as the fracture aperture decreases, more DNAPL head is required for flow to occur into the fracture The same principles apply to fine-grained soil as well DNAPL, if present at the site, would be found in larger fractures and more coarse-grained soil (Cherry et al 1990)

For significant DNAPL movement into fractures, the fractures must be interconnected or in direct connection with a large volume of DNAPL Fractures in claystone and siltstone are typically of small extent, few in number, and poorly connected Therefore, it is not likely that significant DNAPL movement into fractured bedrock has occurred at IHSS 119 1

Figure 5-10 of the Phase III RFI/RI (DOE 1994) shows the probable situation at OU-1 with regard to DNAPL, with the exception of (1) a pool of DNAPL in the colluvium and (2) movement into bedrock fractures The first exception, based on Case 2, is that the spill must have been small and episodic which would not have resulted in a large, mobile, saturated pool. The second exception, based on the previous discussion regarding DNAPL flow into fractures and pores, is that the DNAPL volume would have to be large to cause such a movement, otherwise the driving DNAPL head would not have overcome the displacement pressure In addition, the fractures would have to have been well-interconnected

Based, in part, on the oscillatory behavior of observed concentrations in wells at the site, the source is assumed to release solutes on a periodic basis, i.e., release occurs at the solubility limit for a DNAPL for six months of a year and does not occur the remaining six months Therefore, the source switches between an active and an inactive state This concept is also consistent with the probable configuration of the residual DNAPL Much of the DNAPL may be above the saturated zone during dry conditions, so that dissolution will not occur and there is no migration to groundwater As wetter conditions prevail however, dissolution of the residual DNAPL would occur as it contacts groundwater

B.4.0 CALIBRATION

The model was calibrated using steady-state flow for the time prior to the installation of the French Drain and transient flow from the time of the French Drain installation to the present The flow calibration is assumed to be conservative because the model always assumes flow occurs, whereas there are many areas and times of either no flow or low flow due to the arid climate (DOE 1994)

The calibration procedure was qualitative due to a limited number of wells for comparison This is a commonly accepted method of calibration, particularly when observation data is scarce, statistical measures and automated techniques require a moderate to extensive data set to produce meaningful and useful results For this study, several calibration targets were used to enhance model reliability such as water levels, calculated gradients, and COC concentrations Parameter values used in the model lie within measured or probable ranges

The primary goal in calibrating the flow portion of the model was to match the observed and calculated hydraulic gradients between Wells 4387 to 0487, 0487 to 4787, and 4787 to 5587 to determine if the model accurately simulates advective transport rates Tables B-2a through B-2c, which can be used for comparative purposes, lists observed and simulated gradients for these well pairs. As indicated in the tables, between Well 4387 and Well 0487 and between Well 0487 and Well 4787, the simulated hydraulic gradient is between the minimum and maximum calculated gradients based on site data Therefore, downgradient of the French Drain and between the source and Well 4787, the model accurately simulates average advective transport times Between Well 4787 and Well 5587, the simulated hydraulic gradient is smaller than the minimum calculated gradient based on site data

Between Well 4787 and Well 5587, the model simulates lower advective transport rates than the calculated rates that were based on site data. However, since the model overestimates the water level in Well 5587, the simulated gradient between Well 5587 and Woman Creek is likely higher than actual Thus, modeled COCs may be transported more rapidly than actual COCs between

Well 5587 and Woman Creek This would tend to offset the slower transport rate simulated between Well 4787 and Well 5587

One parameter that was the focus of the calibration is the areal discharge rate To achieve calibration, a net areal discharge of 2 96 in/yr from the water table was used A net recharge to groundwater yielded a simulated potentiometric surface aboveground which is not observed at the site The other focus of the flow calibration was determining the hydraulic conductivity of the various soil specified in the model The selected values lie within measured or probable ranges

A secondary goal of the flow calibration was to match simulated and observed water levels Figures B-13 through B-16 show simulated and observed hydrographs for Wells 0487, 4387, 4787, and 5587, respectively Although the model generally overestimates water levels, the overall hydraulic gradients, and therefore Darcian transport velocities, are comparable to those observed at the site

The flow mass balance provides a measure of how well the model is calibrated Discrepancies in the mass balance generally should be smaller than 5%, especially for groundwater flow, otherwise errors in the flow domain may adversely affect subsequent transport simulations As illustrated in Figure B-17, the percent discrepancy between simulated inflows and outflows ranges from about -17% to -4% Large changes in mass error are related to changes in hydraulic conditions, such as the simulation of extraction wells. During these changes in hydraulic conditions, different or new stresses will cause temporary and sometimes large changes in ground-water flow This typically causes the mass error to change As the flow domain begins to adjust to the new change, the mass error will decrease

Mass error is related to model size and complexity. In general, as models become larger or more complex, the mass error becomes larger. Larger models involve more calculations so that the net error, being a sort of sum over the active model cells, will tend to have a larger error For example, in a model having 10 constant head cells, the flows in and out of these cells depends on the head simulated adjacent to them Thus, the flow to or from each constant head cell can vary and result in some intrinsic mass error in flow caused by the numerical approximation and implementation of the simulation code Given the same number of closure criteria, similar models with twice as many constant head cells have generally the same or higher error than for a model with fewer constant head cells This is due to the summation over the constant head cells However, the larger model may converge just as well as the smaller one even though the error is larger

A similar effect is commonly observed for models with greater complexity A model with more variation in hydraulic conductivity, for example, will typically have greater error given similar closure criteria This is caused by the greater complexity in the interrelationships between model cells than between boundary conditions Even with a larger error, more complex models may be as well-converged as simple models due to the complex interrelationships between cells

Another commonly observed phenomenon is that subdomains within the model may be very well-converged, while other areas are moderately to poorly converged As long as the moderately to poorly converged parts are not in areas of specific interest, then the model generally can be considered converged adequately for practical purposes This is possible despite the appearance of poor convergence or mass balance

The minimum acceptable error depends on the model's size and complexity with a larger error being acceptable for larger or more complex models The OU-1 groundwater flow and transport model is large and somewhat complex. Therefore, the mass errors depicted in Figures B-17 are considered acceptable

Convergence of the model with regard to flow rate and direction was good, exhibiting monotonic behavior as indicated in Figure B-18. The figure shows the normalized sum of the absolute value of mass error over all active model cells for all time steps. To normalize the sum, each value was divided by the maximum absolute value of the sum so that all values range between zero and one. For transient flow calculations, the sum decreases from an initially large value for each time step, showing the monotonic convergence of the model at each time step. This results in the sawtooth pattern in Figure B-18 The initial flat part of the curve in Figure B-18 corresponds to the first part of the transient transport calculation when steady-state flow is specified Transient flow calculations start at about the 400th iteration where there is a spike in the sum

After calibrating the steady-state flow, transient transport simulations were done for each contaminant The same trial-and-error technique was used in calibrating the transport model The primary parameter changed during the transport calibration was the time that the source become active and inactive Simulation of a continuous, constant-concentration source resulted in excessively and unrealistically large concentrations at all observation points Priority in calibrating to Well 0487 was selected because it is closer than Well 4387 to points of demonstration which are located immediately downgradient of the French Drain and prior to discharge into Woman Creek Also, simulated concentrations that exceeded observed concentrations were preferred in the model to make it more conservative

Transport simulations started with the steady-state flow field, continued for 20 years, then incorporated the French Drain and extraction well, as shown in Figure B-6 Each transport simulation was calibrated in a manner similar to that used for the flow calibration Figures B-21 through B-30 show breakthrough curves for each of the COCs, with observed concentrations for comparison Three key components of the transport calibration are shown in these graphs.

- COC concentrations are always overpredicted by the model The implications of this are (1) estimated exposure concentrations are conservative because they bound observed concentrations, (2) alternate source locations and conditions (such as a source located somewhere outside the plane of the model, or a source with a different release mechanism such as diffusion from fractures in bedrock) are indirectly accounted for by the model; a different source is unlikely to result in higher predicted concentrations, (3) spreading of a source caused by degradation and subsequent generation of a COC along a flowpath is also accounted for by the model because the estimated concentrations are much higher than actually observed, (4) predictive simulations overestimate COC concentrations because they are based on the same concepts as the calibrated model, and (5) if the model was more realistic, the simulated concentrations would be smaller and more consistent with observed data, which would translate into smaller concentrations under the predictive simulations

- The model simulates relatively well the oscillatory behavior observed in actual concentrations This supports the concept that the source periodically releases solutes and that the timing is related to seasonal variations in climatic conditions

- The model accurately predicts the effects of the French Drain and the extraction well The rise in simulated 1,1-DCE and 1,1,1-TCA concentrations in Figures B-27 and B-25, respectively, that occur around 1992 is caused by simulating the operation of the French Drain which started construction in November 1991 and finished in April 1992 The rise in concentrations is caused by the increased hydraulic gradient resulting from the installation and operation of the French Drain which pulls groundwater more rapidly towards Well 0487 The simulated concentrations begin decreasing around 1993 when the extraction well started operating The gradients are reduced when the extraction well is simulated because it pulls groundwater away from Well 0487 The observed concentrations vary in the same manner The similarity between the model and observed variations in concentrations leads to the conclusion that the observed variations are caused by the installation and operation of the French Drain and extraction well That the model simulates this behavior underscores the conclusion that the model is an accurate and adequate representation of site conditions The spiking effect caused by the French Drain is observed in all COCs

The last component of the modeling addresses the issue of a mobile DNAPL Because the model provides a simple and plausible explanation for observed spikes in VOC concentrations and the existing site data do not suggest its presence, it is assumed that one does not exist

As with flow, the COC mass balance provides a measure of how well the model is converged Discrepancies in the mass balance should be smaller than 10%. The percent mass error for TCE, depicted in Figure B-19, is calculated by using the ratio of the mass error to the total solute mass in storage The change in relative error at about 1992 is caused by simulating the French Drain and in 1993 by the extraction well Percent error ranges from nearly 0 to 5 5%, which is acceptable for the model

The transport convergence is moderately good, exhibiting monotonic behavior as indicated in Figure B-20 The plotted sum value is calculated the same as the sum value for flow The spikes at larger iterations correspond to changes in boundary conditions, i.e., the simulation of the French Drain and extraction well This behavior mimics the observed behavior for mass error, and is caused by the same effects Some oscillatory behavior is observed, however, because the transport calculations rapidly converge at each time step This is typical for transport calculations The oscillatory behavior is caused largely by the size and complex nature of the model

B.5.0 RESULTS

This section presents a discussion of the results of the calibrated flow and transport model (often referred to as the baseline calibrated model). From the calibrated steady-state flow simulation illustrated in Figure B-31, groundwater flow rates and directions can be obtained Figures B-32 through B-34 show the effects of the French Drain and extraction well on groundwater flow The French Drain and extraction well both draw down the water table resulting in drawdown cones that extend upgradient into IHSS 119 1 As expected, the drawdown cones are asymmetrical due to the slope of the water table The effect of the French Drain and extraction well on COC transport was discussed in Section B 4 0

A water budget accounts for the flow into and out of the model domain Steady-state flow into the model domain is simulated to be about 2 09 ft^3/day (0 059 m^3/day) mostly from the Rocky Flats Alluvium Discharge from the model occurs as evapotranspiration and flow to Woman Creek Evapotranspiration is estimated to be 0 59 ft^3/day (0.017 m^3/day) and flow to Woman Creek is estimated at 1 76 ft^3/day per foot of creek bed (0 1635 m/day per m) Observed flow in Woman Creek is highly variable (DOE 1994), however the average for May 1990 and September 1990 is about 13 ft^3/day (0 368 m^3/day) with a range of 2 16 ft^3/day (0 061 m^3/day) to 23 76 ft^3/day (0 673 m^3/day) Because the model represents average long-term conditions and the observations are highly variable, the modeled flow is considered to be comparable to the observed conditions

Under transient conditions, simulated flow into the French Drain is about 0 0144 ft^3/day (4 078 x 10^{-4} m^3/day) per foot of drain and flow into the extraction well is about 0 173 ft^3/day (4 90 x 10^{-3} m^3/day) Measured flow into the French Drain represents flow from most of the site, making it difficult to compare the model and observed measurements, because of the large amount of flow that originates from the Building 881 footer drain However, measured flow into the drain is about 673 75 ft^3/day (19.08 m^3/day). Assuming that the distance over which the model represents groundwater flow as 1,435 ft (437 4 m), then the net simulated flow into the drain is 206.86 ft^3/day (5.86 m^3/day) For the extraction well, measured flows average

0 225 ft^3/day (6 37 x 10^{-3} m^3/day) which are very similar to that simulated by the model

Results of transport simulations for PCE are discussed in detail in the following paragraphs Results of other COC simulations will not be discussed because the compounds tend to behave similarly

The modeled PCE plume after 22 (pre-French Drain), 23, 26, and 28 years is shown in Figures B-35 through B-38 The plume moves downgradient slowly, at a rate of about 0 061 ft/day (0 0186 m/day) and appears to penetrate a small distance into the bedrock The majority of movement is in the colluvium due to higher groundwater flow rates Some migration in the vadose zone is also simulated corresponding to dispersion in soil moisture

After 24 years, the French Drain and extraction well have a significant effect on the plume as shown by Figures B-37 and B-38 and discussed in Section B 4 0 regarding calibration The extraction well pulls the plume back toward IHSS 119 1, and the French Drain captures the plume trapped between it and the extraction well

B.6.0 SENSITIVITY

Sensitivity analyses are used to assess the response of a model to changes in specific parameters Parameters that exhibit a large sensitivity or response are those for which small changes result in widely variable response Values for sensitive parameters in a calibrated model are generally considered to be more certain because there is only a small range in the parameter's values over which model calibration can be achieved

The method used in this study involved changing a parameter value in the calibrated flow and transport model, re-executing the model, and recording the response The variation in PCE concentration at the French Drain demonstration point was used to assess model response The parameters in the sensitivity analysis were selected based on their probable sensitivity The selected parameters were porosity, decay rates, adsorption, and hydraulic conductivity because each has the potential to directly affect transport rates and simulated concentrations

Other parameters were not selected because they are less likely to affect simulated concentrations For example, the density difference at the source for PCE is calculated to be 0 015%, which is far below the generally accepted criteria of 1% (Mackay et al 1985) used to assess the importance of density-coupled flow and transport. The density difference is calculated by assuming that 150 mg/L of a compound meant that the density ratio of the compound to water was 150 1,000,000 Therefore, the density difference is 0 015%

Table B-3 lists the changes in parameters that were made to assess model sensitivity Figures B-39 through B-46 illustrate the results of each simulation and the percent difference in concentration relative to the baseline calibrated model. Each parameter is discussed in the following paragraphs.

The results of the sensitivity analysis for adsorption are shown in Figures B-39 and B-40 The first figure shows the results of the two sensitivity cases and the baseline calibrated results for comparison. The second figure shows the percent difference in PCE concentration relative to the baseline calibrated model As time progresses, the sensitivity with respect to adsorption decreases In all cases, the shapes of the curves exhibit an exponential form, which is due to the inclusion of decay in the analyses

Changes in adsorption cause a constant shift in a breakthrough curve Such a shift will result in a bell-shaped difference curve, and, when overprinted with decay, the bell-shaped curve is also shifted in the vertical direction This explains the form of the curves for adsorption Greater adsorption results in smaller simulated concentrations Smaller adsorption results in larger simulated concentrations The sensitivity of adsorption decreases with time as decay begins to have a significant effect on COC concentrations In both cases, the concentrations approach, but never equal, the baseline concentrations due to the overriding effect of the decay rates

In the decay sensitivity analysis, decay was not simulated so the sensitivity increases with time as shown in Figures B-41 and B-42 If decay had been set to a value smaller than that in the baseline model, the opposite sensitivity would be observed The smallest differences occur for times less than 10 half-lives This is because smaller amounts of decay are simulated at shorter times

The porosity sensitivity, as shown in Figures B-43 and B-44, is similar in form to adsorption Changes in porosity result in slower or more rapid transport time and, when compounded with decay, the breakthrough curve is shifted laterally and vertically. Meaningful percent differences do not start until about 1973, when noticeable breakthrough begins Concentrations at the onset of the model represent extremely small values of concentration which may be due to numerical dispersion. The actual concentration is zero, but the modeled results, and hence the difference curve, are not zero at the onset This phenomenon affects most of the sensitivity results at the onset of the model

Changes in hydraulic conductivity affect transport rate and dispersion (Figures B-45 and B-46) Conceptually, two breakthrough curves for the same model, with only differing hydraulic conductivity, should result in similar breakthrough curves with varying vertical and horizontal offsets For the case in which hydraulic conductivity was decreased, the response was smaller because the change in conductivity was smaller relative to the baseline calibrated value Hydraulic conductivity is consistently the most sensitive parameter in the model

The order of greatest to least sensitivity of the parameters studied is

Kxx > > > Decay > Porosity and Adsorption

with hydraulic conductivity (Kxx) much more sensitive than the other parameters The results of the sensitivity analysis verify the theoretical analysis of the governing equations The analysis indicates that small changes in parameters result in large differences in concentration The model is considered robust because only a small range of values will give appropriate calibration

B.7.0 UNCERTAINTY

This section is a qualitative discussion of uncertainties associated with the model In general, uncertainties can be divided into two types The first type results from an incomplete knowledge of the system or processes. A real system can often be too complex or lack the necessary information to be completely understood or modeled without making simplifying assumptions Parts of the system or processes may also be omitted because they are thought to be less important than others The second type of uncertainty relates to the values assigned to input parameters used to describe the system or processes In reality, input parameters are not single values but vary over a range of possible values

Table B-4 lists specific model assumptions or uncertainty factors that could contribute to variations in model predictions The second column of the table gives the source of the uncertainty "Not simulated" means a particular transport or transformation process was not considered in the modeling "Measurement Error" indicates that there could be some unknown or unmeasured variability or heterogeneity in the corresponding property "Not Measured" indicates that the parameter has not been measured under site-specific conditions either in the field or in the laboratory In the third column, "Incorrect Flows" indicates that a different flow could result by a corresponding change in the parameter The fourth column lists the relative degree of uncertainty

The combination of parameters used in the model is not considered to be unique Other combinations of the parameters may yield a similar result However, the parameter values used generally lie within observed and accepted ranges, and therefore, the model is considered representative of site conditions

B.8.0 PREDICTIONS

For predictions in which the source is not remediated, the source is assumed to be large enough to provide an infinite supply of groundwater contamination In such simulations, the source concentration is held constant throughout the simulations For predictive simulations in which the source is remediated, the concentrations in a 200-foot area of colluvium around IHSS 119 1 are set to the appropriate water quality standard For alternatives in which the French Drain and extraction well are removed, the steady-state flow conditions used for the first part of the simulations are re-imposed based on the assumption that steady-state flow is rapidly re-established relative to the total time of simulation For all other predictions, steady-state flow is assumed to exist at the beginning of the predictive part of the simulation, i e the French Drain and extraction well are assumed to create an essentially steady-state condition by the time the predictive simulation starts

Two points of demonstration are used to show the results of the predictive simulations The first is located on the downgradient side of the French Drain, about halfway between the water table and the colluvium-bedrock interface (see Figure B-38) The second point is located immediately upgradient of Woman Creek in the alluvium

B 8 1 <u>No Action Scenario</u>

In Alternative 0, the French Drain and extraction well are removed but the source is not remediated Transport simulations beginning from 1996 and continuing through 2028 were done for each of the COCs Under this scenario, the plume continues to grow with time because the source remains in place providing a constant release Figures B-47 through B-56 show the variation of concentration with time at the French Drain and Woman Creek At the French Drain, the installation of the drain and extraction well cause a dip in concentrations. After the drain and well are removed, concentrations begin to recover and increase due to a continuing source and desorption At Woman Creek, similar results are obtained, however due to the longer travel distance and time, the features of the curves are more subdued, and the small dips in concentration are caused by changes in the flow system, such as the installation of the French Drain, upgradient (in groundwater) of Woman Creek

B 8 2 Institutional Controls With the French Drain Scenario

Under Alternative 1, the French Drain and extraction well remain in operation No remediation of the source takes place under this scenario Transport simulations beginning from 1998 and continuing through 2028 were done for each of the COCs Under this scenario, the plume is drawn to and captured by the extraction well and French Drain Figures B-57 through B-66 show the variation of concentration with time at the French Drain and Woman Creek At the French Drain, the installation of the drain and extraction well cause a dip in concentrations With the drain and well in place, concentrations peak for COCs with shorter half-lives Desorption provides a decreasing but undecayed source At Woman Creek, similar results are obtained, with differences caused by the longer travel distance

B 8 3 Remediation Scenarios

Under Alternatives 2, 3, 4, and 5, the French Drain and extraction well are removed, and the source is remediated Transport simulations beginning from 1998 and continuing through 2028 were done for each of the COCs For these simulations, a 200-foot strip of colluvium assumed to be remediated to the appropriate water quality standard Under this scenario, the plume that remains in place after the source is removed continues to move downgradient with time Figures B-67 through B-76 show the variation of concentration with time at the French Drain and Woman Creek At the French Drain, the installation of the drain and extraction well cause a dip in concentrations The curves exhibit behavior that is a combination of the other sets of alternatives, i.e. concentrations that rise briefly after the drain and well are removed but rapidly decrease due to source remediation At Woman Creek, similar results are obtained with differences caused by the longer travel distance

B.9.0 SUMMARY

A groundwater flow and contaminant transport model has been developed and calibrated for OU-1 The model was used to simulate and predict contaminant movement from IHSS 119 1 to the French Drain and Woman Creek The results of the model are used in characterizing the residual risk associated with each of the remediation alternatives

The model is considered to be conservative for the following reasons

- The model is two dimensional, therefore dispersion (spreading) transverse to the plane of the model is not simulated This causes an overestimation of the COC concentrations

- The flow calibration is conservative because the model always assumes groundwater flow occurs whereas there are many areas and times of either no flow or low flow due to the arid climate (DOE 1994)

- Concentrations are generally always overestimated by the model The implications are (1) estimated exposure concentrations are conservative because they bound observed concentrations, (2) alternate source locations and conditions (such as a source located somewhere outside the plane of the model, or a source with a different release mechanism such as diffusion) are indirectly accounted for by the model, i e , a different source is unlikely to result in higher predicted concentrations, (3) spreading of a source caused by degradation and subsequent generation of a VOC along a flowpath is also accounted for by the model because the estimated concentrations are much higher than actually observed, (4) predictive simulations overestimate VOC concentrations because they are based on the same concepts as the calibrated model, and (5) if the model were more realistic, the simulated concentrations would be smaller and more consistent with observed data which translates into smaller concentrations under the predictive simulations

The model is calibrated to average site conditions for flow and transport with adequate agreement between the model and observed conditions The model indicates a good mass balance and exhibits monotonic convergence which is indicative of accurate calculations. The model is considered adequate for predictive purposes and representative of site conditions for the following reasons

- The hydraulic gradients simulated in the model are generally within the range calculated using site data Therefore, advective transport rates are indicative of site conditions

- The model simulates relatively well the oscillatory behavior observed in actual concentrations This supports the concept that the source periodically releases solutes and that the release is likely related to seasonal variations in climatic conditions

- The model approximates the effects of the French Drain and the extraction well with moderate accuracy The rise in simulated DCE and TCA concentrations that occur around 1992 is caused by simulating the French Drain The rise in concentrations is caused by the increased hydraulic gradient resulting from the installation and operation of the French Drain The drain begins to pull groundwater towards Well 0487 The simulated concentrations and hydraulic gradient begin decreasing around 1993 when the model begins simulating the extraction well The extraction well pulls groundwater away from Well 0487 The observed concentrations vary in the same manner The similarity between the model and observed variations in concentrations leads to the conclusion that the observed variations are caused by the installation and operation of the French Drain and extraction well That the model simulates this behavior underscores the conclusion that the model is an accurate and adequate representation of site conditions The spiking effect caused by the French Drain is observed in all COCs

The last component of the modeling investigated the issue of a mobile DNAPL Because the model provides a simple and plausible explanation for observed spikes in VOC concentrations and existing site data do not suggest the presence of a mobile DNAPL, it is assumed that one does not exist

The order of greatest to least sensitivity of the parameters studied is

$$Kxx >>> Decay > Porosity\ and\ Adsorption,$$

with hydraulic conductivity (Kxx) being more sensitive than the other parameters The results of the sensitivity analysis verify the expectations from a theoretical analysis of the governing equations The analysis indicates that small changes in parameters result in large differences in concentration The model is considered robust because only a small range of values will give appropriate calibration

Three modeling scenarios were simulated representing different alternatives Predicted results for the No Action Alternative indicate that concentrations at the French Drain and Woman Creek will increase to peak concentrations within 30 years Predicted results for the Institutional Controls with the French Drain Alternative indicate that concentrations at the French Drain and Woman Creek will decrease with time Peak concentrations occur at the time of the alternative's implementation Predicted results for the remediation alternatives indicate that concentrations at the French Drain and Woman Creek will increase slightly then decrease with time Peak concentrations occur within 30 years

B.10.0 REFERENCES

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Table B-1a
Media-Specific Hydraulic Parameters Used in all Contaminant Simulations

Hydraulic Parameter	Units	Bedrock	Colluvium	Alluvium
Horizontal hydraulic conductivity	ft/d (m/d)	0 06 (018)	0 45 (137)	6 (1 829)
Vertical hydraulic conductivity	ft/d (m/d)	0 06 (018)	0 2 (061)	3 (914)
Specific storativity	1/ft (1/m)	1E-4 (3 3E-4)	1 5E-4 (4 9E-4)	3 5E-4 (1 1E-3)
Porosity	--	0 35	0 36	0 45
Density of clean groundwater	mg/L	1 0E+6	1 0E+6	1 0E+6
Bulk density ratio	--	1 81	1 5	1 65
Molecular dispersion	ft^2/d (m^2/d)	1E-4 (9 3E-6)	1E-4 (9 3E-6)	1E-4 (9 3E-6)
Longitudinal dispersivity	ft (m)	20 (6 096)	30 (9 144)	40 (12 192)
Transverse dispersivity	ft (m)	2 (6096)	10 (3 048)	10 (3 048)
Coefficient for Sr (psi)	1/ft (1/m)	0 24 (0 79)	5 58E-2 (0 18)	3 (9 8)
Coefficient for Sr (psi)	--	1 09	1 22	2 5
Coefficient for Sr (psi)	--	-0 826	-0 18	-0 6
Residual moisture content	--	0 25	0 59	0 1
Saturated moisture content	--	0 35	0 377	0 45
Coefficient for Kr (psi)	1/ft (1/m)	0 83 (2 72)	0 0148 (0486)	3 48 (11 42)
Coefficient for Kr (psi)	--	0 41	0 44	1 93
Coefficient for Kr (psi)	--	-3	-10	-3
Minimum Kr (psi)	--	0 1	0 1	0 1

Table B-1b
Contaminant-Specific Modeling Parameters

Contaminant	Distribution Coefficient (L/mg)	Half Life (days)	Source Concentration (mg/L)
Tetrachloroethene (PCE)	4 34E-7	730 5	150
Trichloroethene (TCE)	3 80E-7	1643 6	1100
1,1,1-Trichloroethane (TCA)	3 99E-7	546	1500
1,1-Dichloroethene (DCE)	3 08E-7	154	5500
Carbon tetrachloride (CCL_4)	4 50E-7	365 25	757

250

Table B-2a
Simulated and Observed Hydraulic Gradients

Well 4387				Well 0487				Water Level Difference[c]	
Date of Water Level[a]	Observed Water Level (ft)	Model Time[b] (days)	Simulated Water Level (ft)	Date of Water Level[a]	Observed Water Level (ft)	Model Time[b] (days)	Simulated Water Level (ft)	Observed (ft)	Simulated (ft)
6/10/89	5917 3	7480 10	5920 54	06/09/89	5902 0	7480 10	5904 76	15 3	15 7802
1/16/90	5916 6	7691 25	5920 54	01/16/90	5899 2	7691 25	5904 76	17 4	15 7802
4/13/90	5920 4	7782 56	5920 53	04/12/90	5905 7	7782 56	5904 75	14 7	15 7798
3/18/91	5917 0	8119 29	5920 53	03/18/91	5898 5	8119 29	5904 74	18 5	15 7896
6/11/91	5917 5	8210 60	5920 52	06/05/91	5901 1	8210 60	5904 74	16 4	15 7798
11/5/91	5916 3	8357 74	5920 52	11/05/91	5896 6	8357 74	5904 74	19 7	15 7798
4/1/92	5918 5	8492 06	5927 53	04/06/92	5901 8	8492 06	5911 51	16 7	16 0200
5/13/93	5917 3	8897 21	5917 25	05/14/93	5901 6	8897 21	5900 88	15 7	16 3701
						Average	Differences	16 8	15 88
						Maximum	Differences	19 7	16 3701
						Minimum	Differences	14 7	15 7798
						Average	Gradients[d]	0 133	0 126
						Maximum	Gradients[d]	0 156	0 130
						Minimum	Gradients[d]	0 117	0 125

[a] Date of measurement of observed water level
[b] Time of simulated water level
[c] Difference in water levels
[d] Gradients are calculated from water level differences (average, minimum and maximum) divided by the distance between Well 4387 and Well 0487 (126 ft)

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Table B-2b
Simulated and Observed Hydraulic Gradients

Well 0487				Well 4787				Water Level Difference[c]	
Date of Water Level[a]	Observed Water Level (ft)	Model Time[b] (days)	Simulated Water Level (ft)	Date of Water Level[a]	Observed Water Level (ft)	Model Time[b] (days)	Simulated Water Level (ft)	Observed (ft)	Simulated (ft)
06/09/89	5902 0	7480 10	5904 76	06/10/89	5877 3	7480 10	5880 11	24 7	24 6499
01/16/90	5899 2	7691 25	5904 76	01/16/90	5878 4	7691 25	5880 10	20 8	24 6597
04/12/90	5905 7	7782 56	5904 75	04/12/90	5876 4	7782 56	5880 10	29 3	24 6499
03/18/91	5898 5	8119 29	5904 74	04/01/91	DRY	8119 29	5880 09		24 6504
06/05/91	5901 1	8210 60	5904 74	06/05/91	5877 2	8210 60	5880 08	23 9	24 6601
11/05/91	5896 6	8357 74	5904 74	11/05/91	5875 0	8357 74	5880 08	21 6	24 6601
04/06/92	5901 8	8492 06	5911 51	04/06/92	DRY	8492 06	5878 96	–	32 5498
05/14/93	5901 6	8897 21	5900 88	No good match		8897 21	5872 18	–	28 6997
						Average	Differences	24 06	26 15
						Maximum	Differences	29 3	32 5498
						Minimum	Differences	20 8	24 6499
						Average	Gradients[d]	0 134	0 145
						Maximum	Gradients[d]	0 163	0 181
						Minimum	Gradients[d]	0 116	0 137

[a] Date of measurement of observed water level
[b] Time of simulated water level
[c] Difference in water levels
[d] Gradients are calculated from water level differences (average, minimum and maximum) divided by the distance between Well 0487 and Well 4787 (180 ft)

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Table B-2c
Simulated and Observed Hydraulic Gradients

Well 4787				Well 5587				Water Level Difference[c]	
Date of Water Level[a]	Observed Water Level (ft)	Model Time[b] (days)	Simulated Water Level (ft)	Date of Water Level[a]	Observed Water Level (ft)	Model Time[b] (days)	Simulated Water Level (ft)	Observed (ft)	Simulated (ft)
06/10/89	5877 3	7480 10	5880 11	06/01/89	5850 7	7480 10	5856 77	26 6	23 3399
01/16/90	5878 4	7691 25	5880 10	01/16/90	DRY	7691 25	5856 77		23 3301
04/12/90	5876 4	7782 56	5880 10	04/12/90	5853 5	7782 56	5856 77	22 9	23 3301
04/01/91	DRY	8119 29	5880 09	04/01/91	DRY	8119 29	5856 77		23 3198
06/05/91	5877 2	8210 60	5880 08	C6/05/91	5850 7	8210 60	5856 77	26 5	23 3101
11/05/91	5875 0	8357 74	5880 08	11/05/91	5850 6	8357 74	5856 77	24 4	23 3101
04/06/92	DRY	8492 06	5878 96	04/01/92	5853 6	8492 06	5858 49		20 4698
No good match		8897 21	5872 18	05/14/93	5850 9	8897 21	5855 63		16 5503
						Average	Differences	25 1	22 12
						Maximum	Differences	26 6	23 3399
						Minimum	Differences	22 9	16 5503
						Average	Gradients[d]	0 155	0 137
						Maximum	Gradients[d]	0 164	0 144
						Minimum	Gradients[d]	0 141	0 102

[a] Date of measurement of observed water level
[b] Time of simulated water level
[c] Difference in water levels
[d] Gradients are calculated from water level differences (average, minimum and maximum) divided by the distance between Well 4787 and Well 5587 (162 ft)

Table B-3
Parameters Analyzed in Sensitivity Analysis

Parameter	Units	Sensitivity Analysis		Baseline	
		Colluvium	Alluvium	Colluvium	Alluvium
Distribution coefficient (Kd)	L/mg	4 77	4 77	4 34	4 34
Distribution coefficient (Kd)	L/mg	3 906	3 906	4 34	4 34
Half life	days	0	0	370 5	370 5
Porosity	--	0 18	0 225	0 36	0 45
Horizontal hydraulic conductivity (Kxx)[1]	ft/day (m/day)	0 12 (0 037)	4 8 (1 463)	0 45 (0 137)	6 0 (1 829)
Horizontal hydraulic conductivity (Kxx)[1]	ft/day (m/day)	1 2 (0 366)	7 2 (2 195)	0 45 (0 137)	6 0 (1 829)

[1] The ratio of horizontal to vertical hydraulic conductivities was kept the same for the sensitivity analysis as it was for the baseline model runs

Table B-4
Model Assumptions and Uncertainty Factors

Model assumption or uncertainty factor	Cause of uncertainty or model error	Probable effect on model results	Relative degree of uncertainty
Two-dimensional model	Three-dimensional transport not simulated	Incorrect spatial distribution of concentrations and flows	Low Model adequately matches general trends in the horizontal behavior of the observed plume Model is conservative due to underestimation of spreading transverse to model plane
Porous media	Flow in fractures or other secondary porosity not simulated	Incorrect spatial distribution of concentrations and fluxes	Low Although slip subsurface failure planes have been mapped (DOE 1994), it is likely that such potential pathways have healed and are no longer permeable
Steady-state flow	Transient flow is not simulated for calibration	Incorrect spatial distribution of concentrations and flows	Low Contaminant transport and fluctuations in flow become less important over long periods of time The model is conservative in simulating continually saturated conditions where seasonal wetting and drying is known to occur
Material properties are homogeneous within a model layer	Heterogeneity within model layers	Incorrect spatial distribution of contaminants and flows	Low The primary hydrogeologic layers that affect transport are well characterized
Timing of release	Not well known	Incorrect spatial distribution of contaminants	Low Model is generally conservative Observed concentrations have generally reached a steady-state condition, suggesting that transport across the hillside has achieved steady state Therefore, knowledge of the timing of release is not required to predict future conditions
Nature of release	Processes other than dissolution are not modeled	Incorrect spatial distribution of contaminants	Low Model is conservative and bounds observed concentrations

Sorption	Linear sorption	Incorrect spatial distribution of contaminants	**Low** Organic carbon content of subsurface materials is low
Natural recharge and discharge rates	Not measured	Incorrect spatial distribution of contaminants and flows	**Moderate.** Model is sensitive to this parameter
Decay and transformation	Multi-component transport not simulated due to lack of site-specific data	Incorrect spatial distribution of contaminants	**Low** Model is conservative
Porosity	Measurement error	Incorrect spatial distribution of contaminants	**Low** Measurement error relatively small
Diffusion coefficient	Not measured	Incorrect spatial distribution of contaminants	**Low** Error is small and model is insensitive to this parameter
Dispersivity	Not measured	Incorrect spatial distribution of contaminants	**Moderate** Parameter is based on scale of site, this is a standard assumption
Size of source	Not measured	Incorrect spatial distribution of contaminants	**Low** Model has been assumed to be insensitive to source size (Fedors et al 1993)

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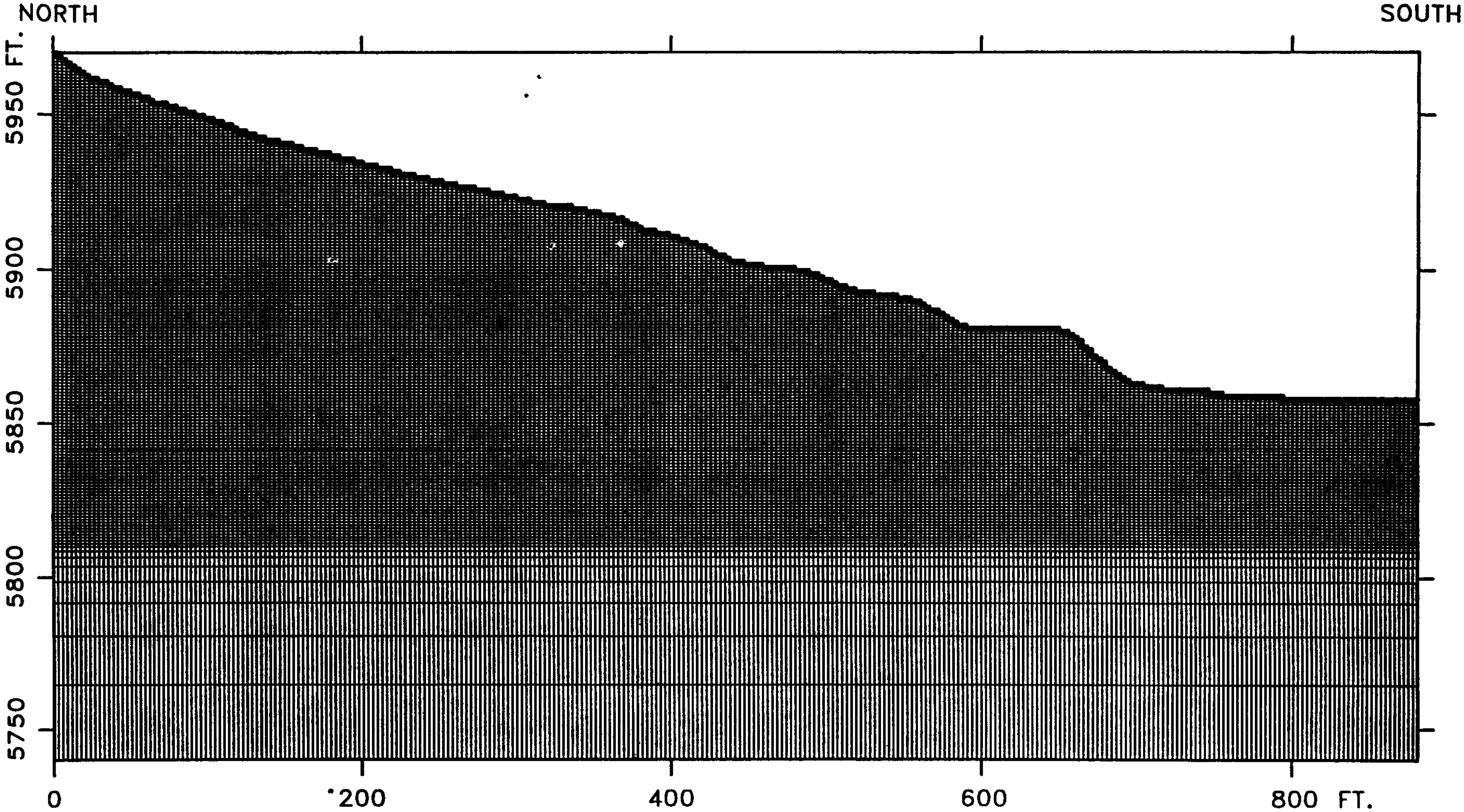
K\DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\MESHPLOT DWG



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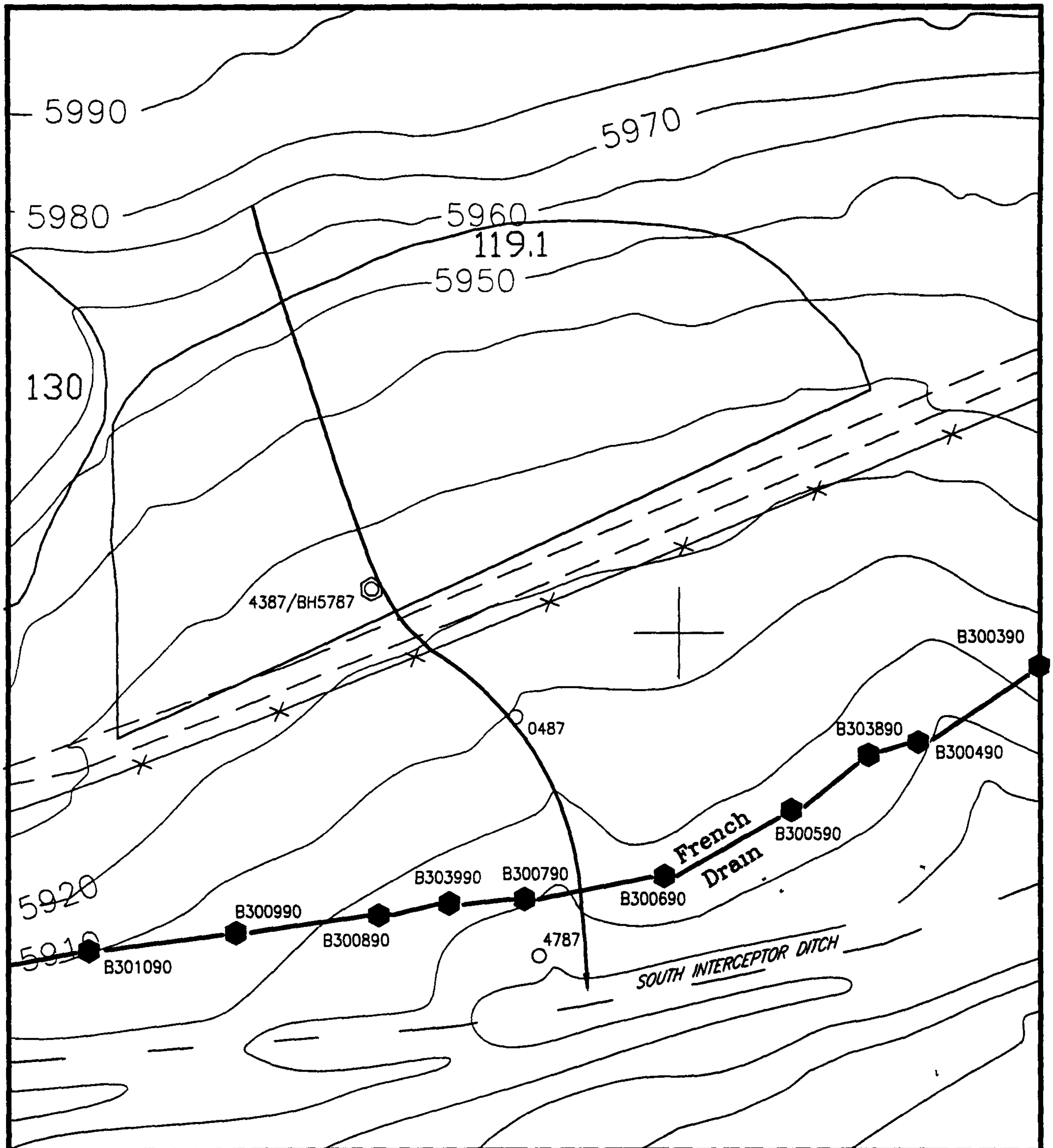
881 HILLSIDE AREA
OPERABLE UNIT NO 1

Model Discretization

Figure B-1



EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE

B301889 ALLUVIAL WELL

BH1587 BOREHOLE

B300390 FRENCH DRAIN BOREHOLES

CONTOUR INTERVAL = 10 FEET

N

0 50 100

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Location of Model Section in IHSS 119.1

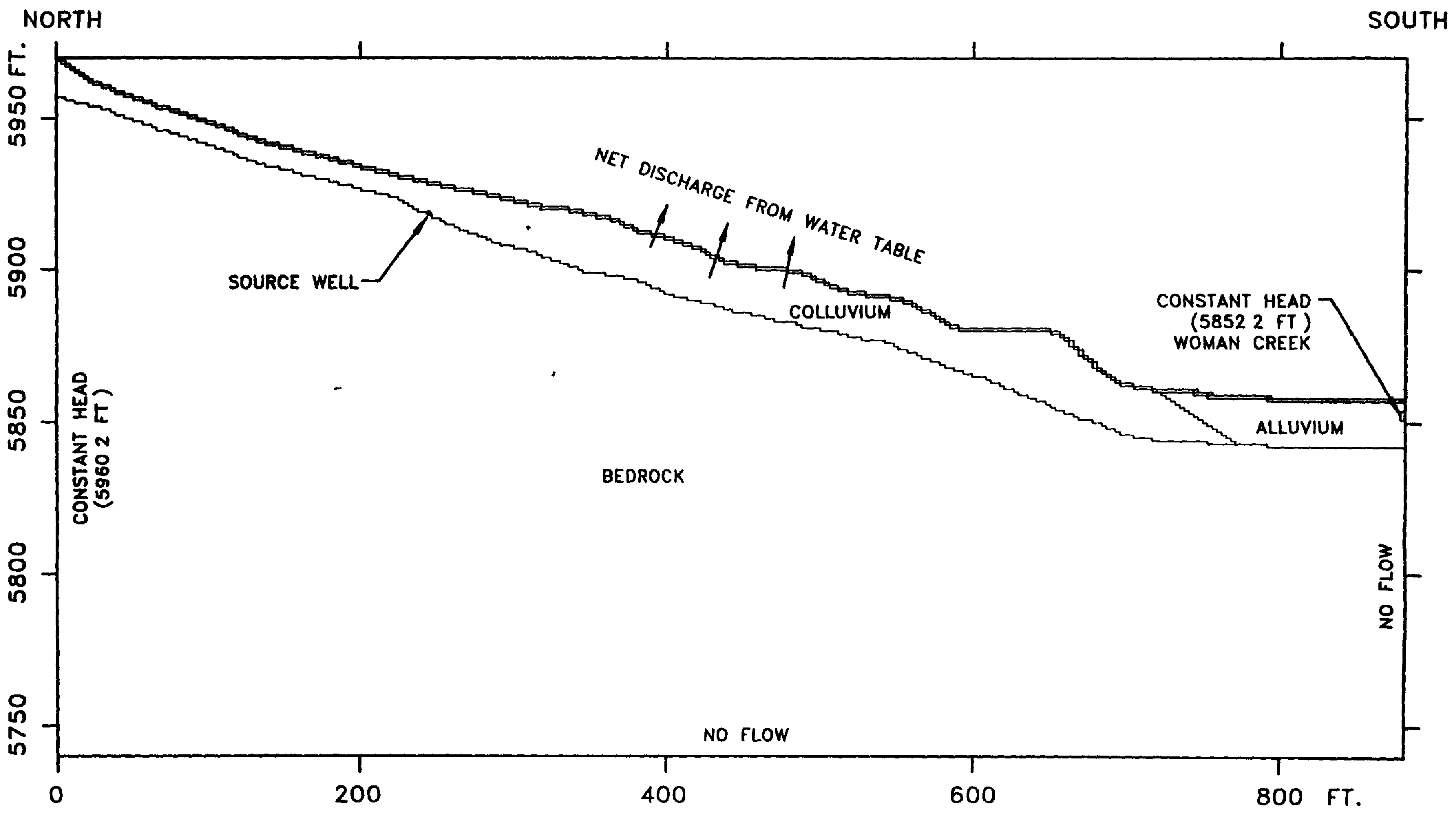
Figure B-3

K:\DESIGN\RCKYFLTS\HILL881\OU-1\IHSS-119.DWG

258

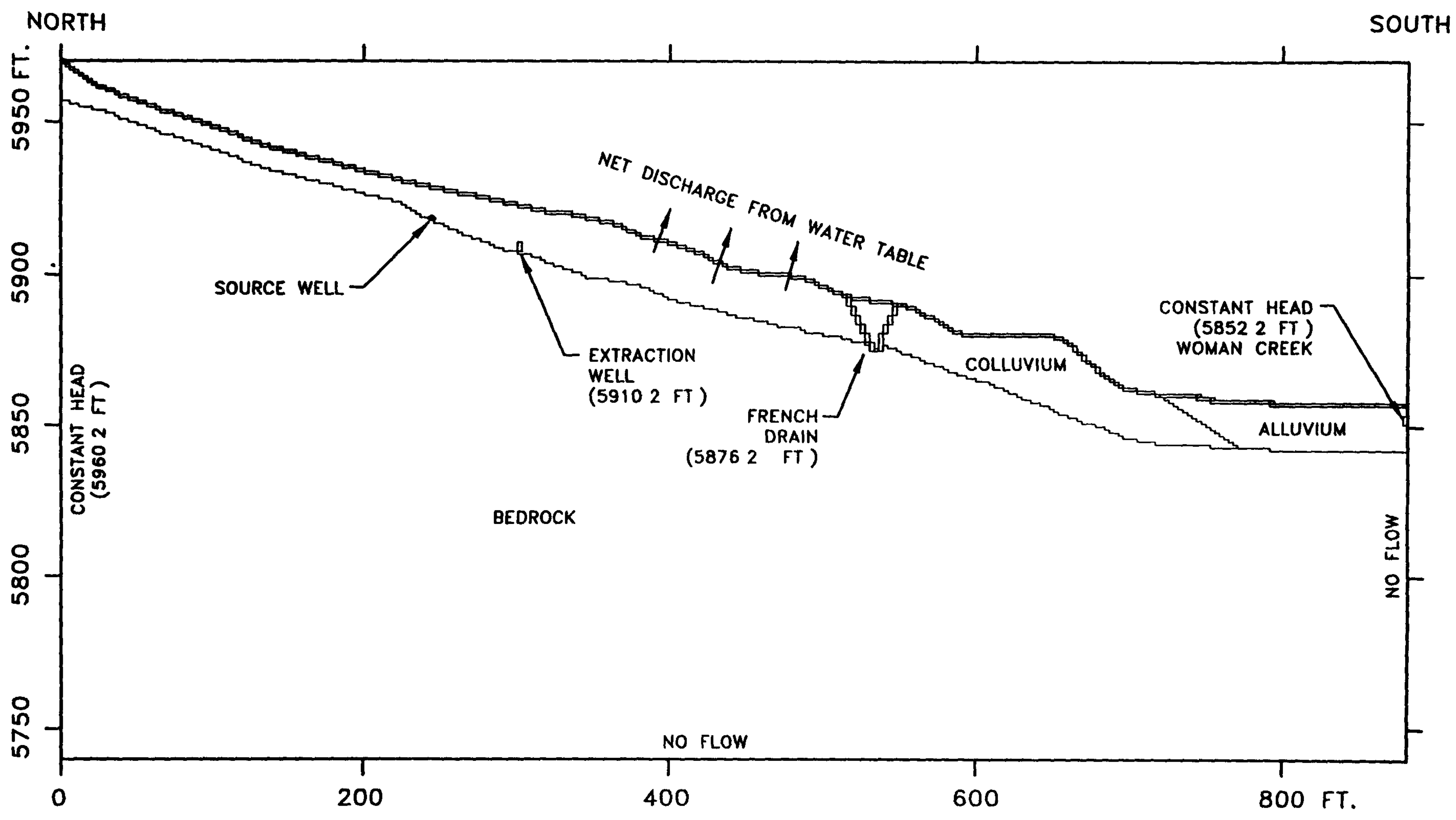
259

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\MDLBND92 DWG



U S DEPARTMENT OF ENERGY Rocky Flats Environmental Technology Site Golden, Colorado
881 HILLSIDE AREA OPERABLE UNIT NO 1 **Model Boundary Conditions Steady State** **Figure B-4**

K\DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\MDLBND94 DWG



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881 HILLSIDE AREA
OPERABLE UNIT NO 1

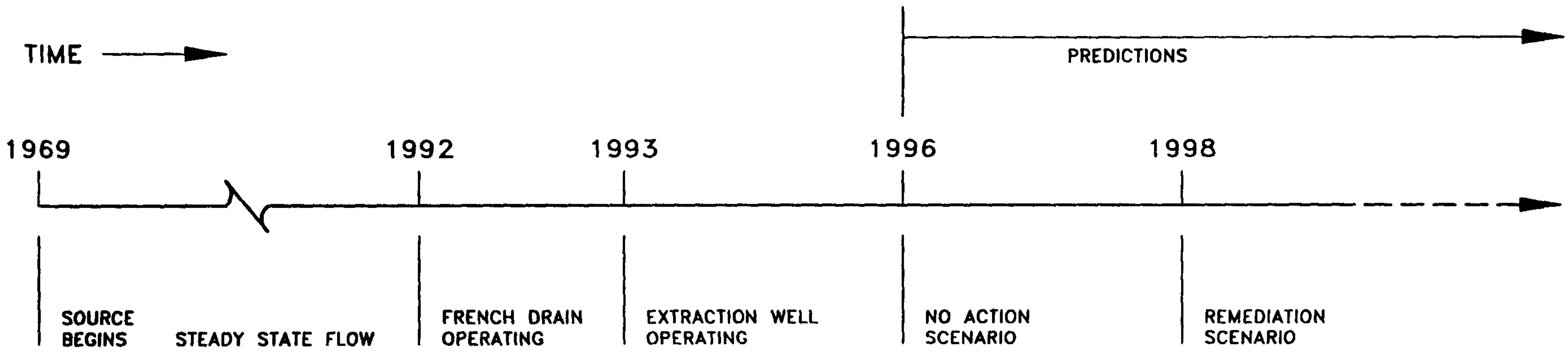
Model Boundary Conditions Transient

Figure B-5

260

261

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\TIMELINE.DWG



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881 HILLSIDE AREA
OPERABLE UNIT NO 1

Timeline

Figure B-6

262

Model vs Calculated Kr
Colluvium

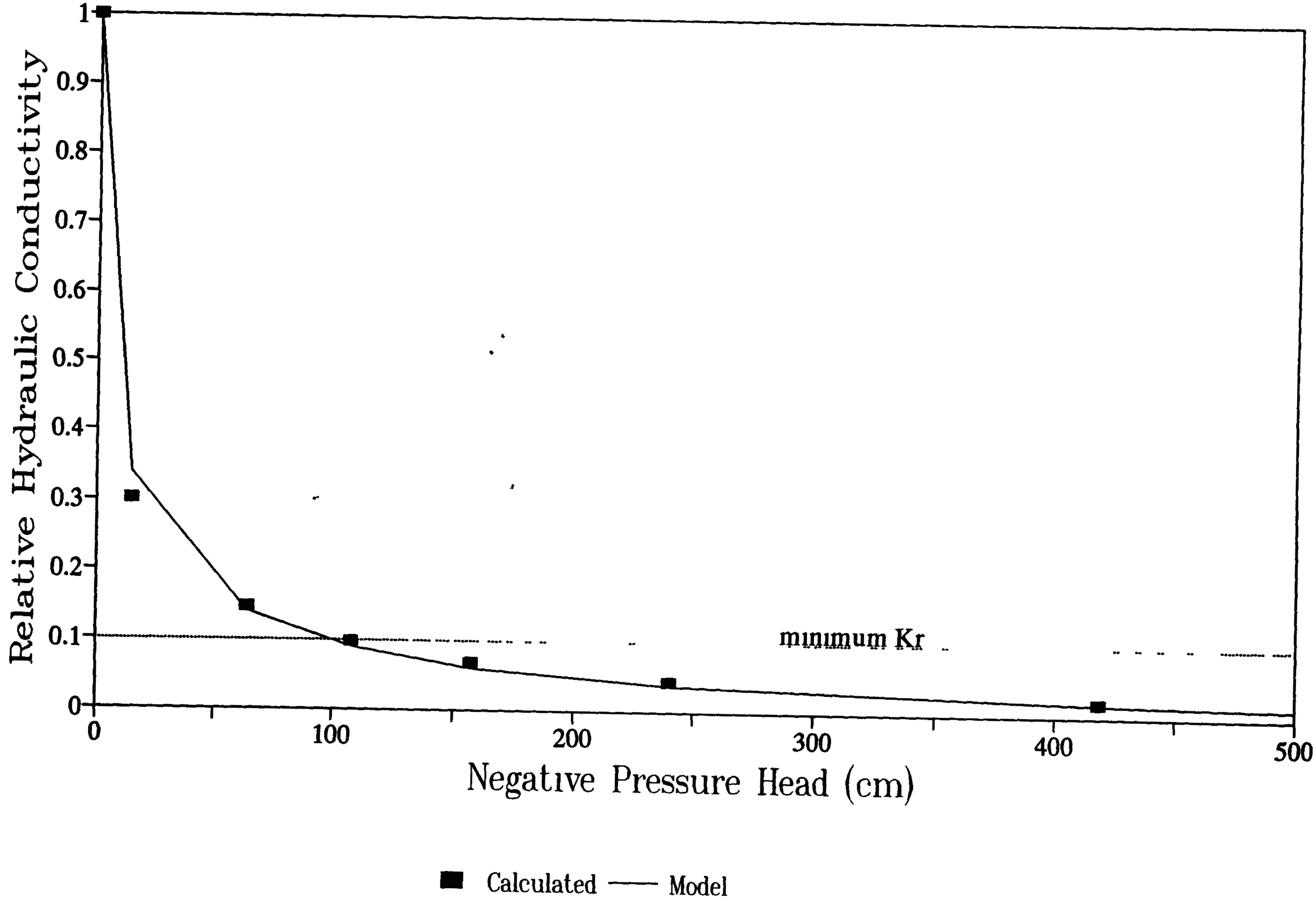


Figure B-7

263

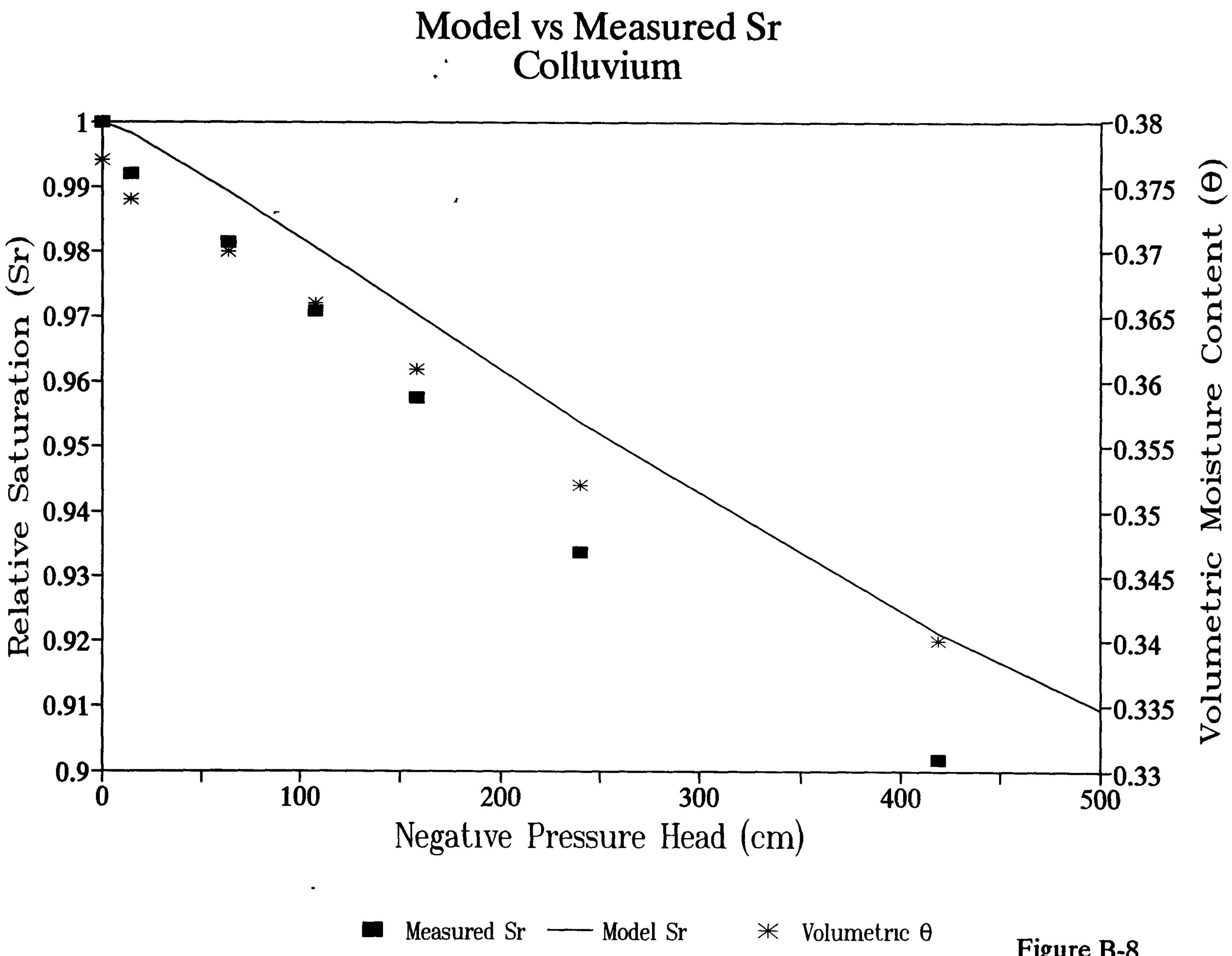


Figure B-8

264

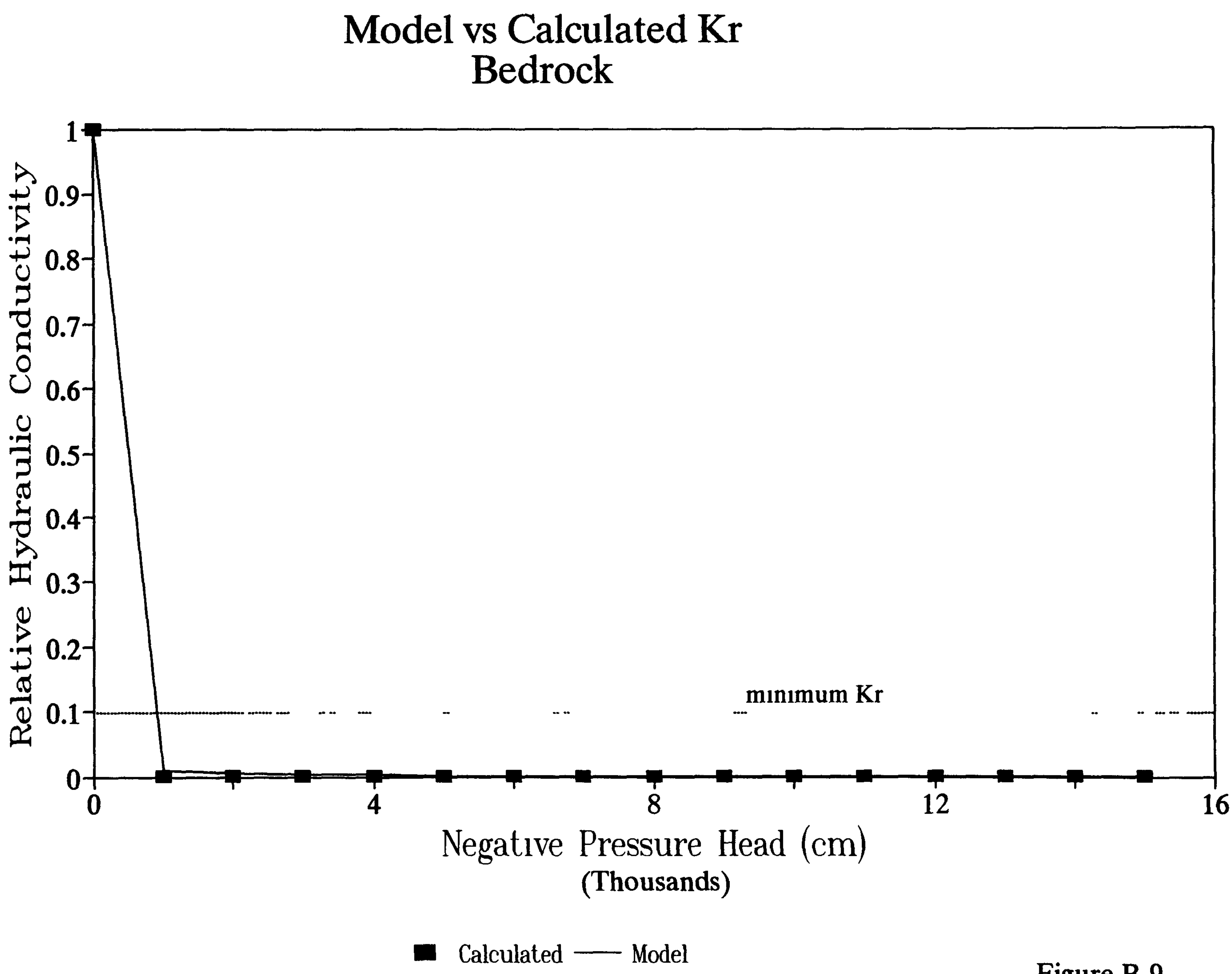


Figure B-9

Model vs Measured Sr
Bedrock

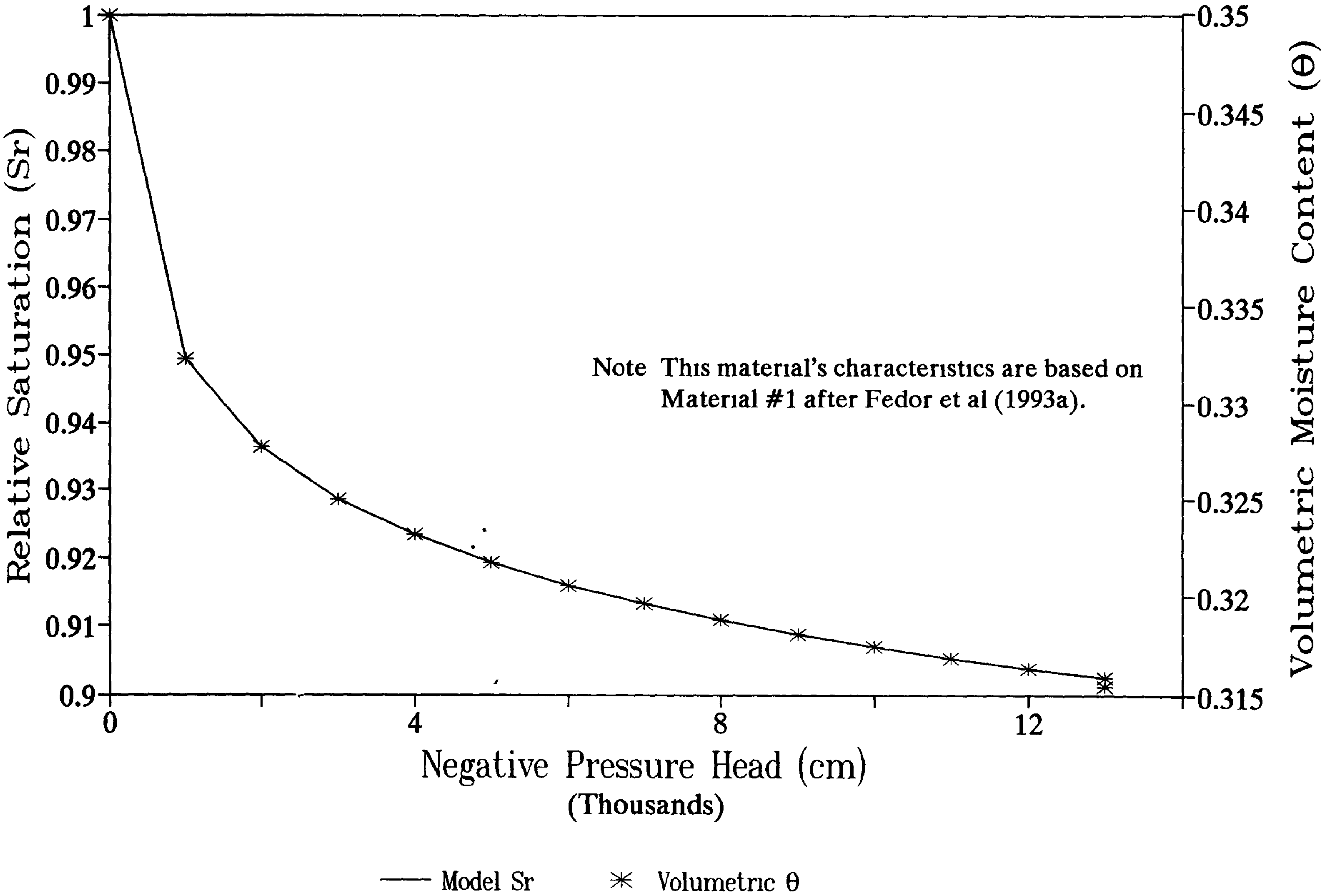


Figure B-10

Model vs Calculated Kr
Woman Creek Alluvium

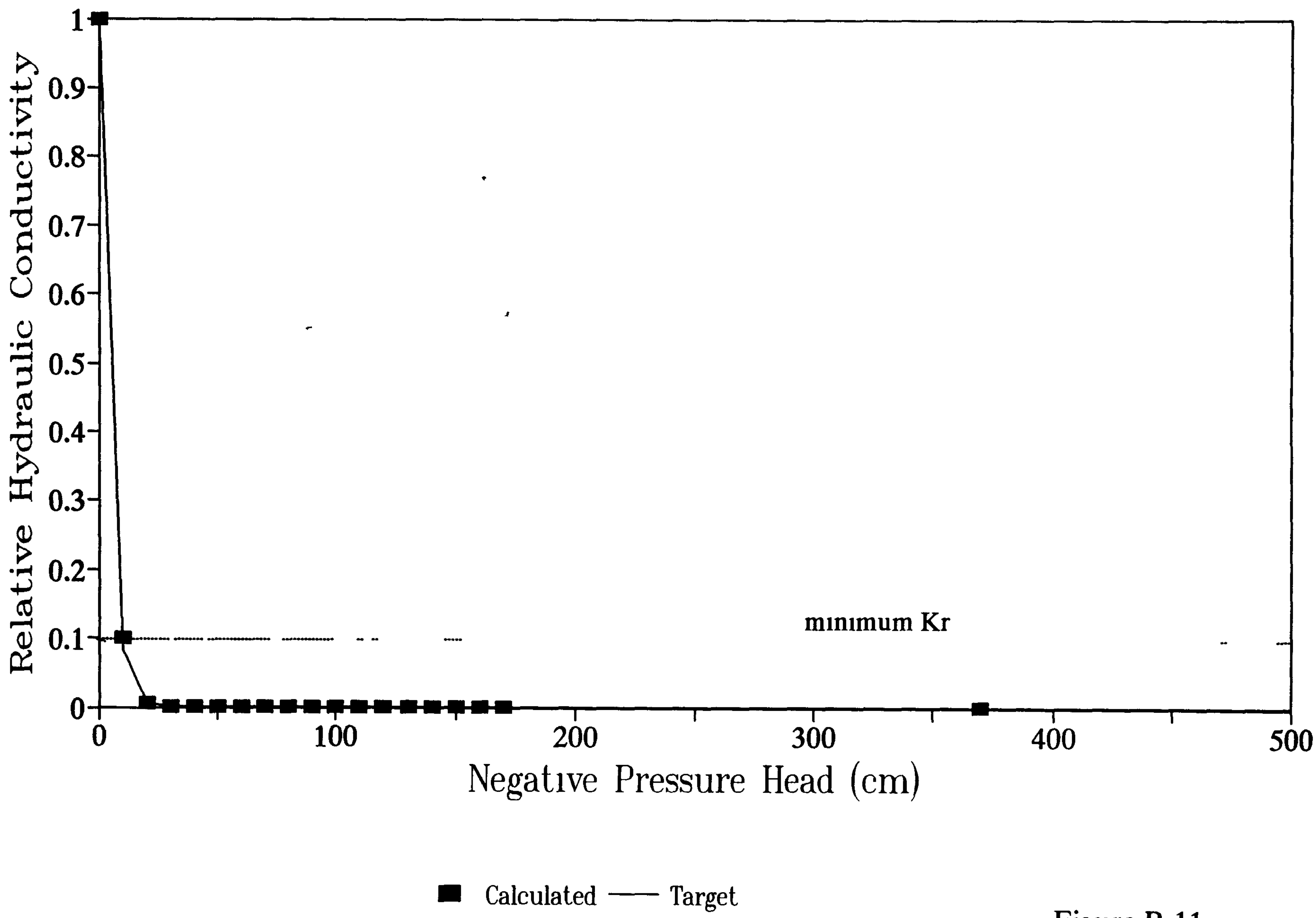


Figure B-11

267

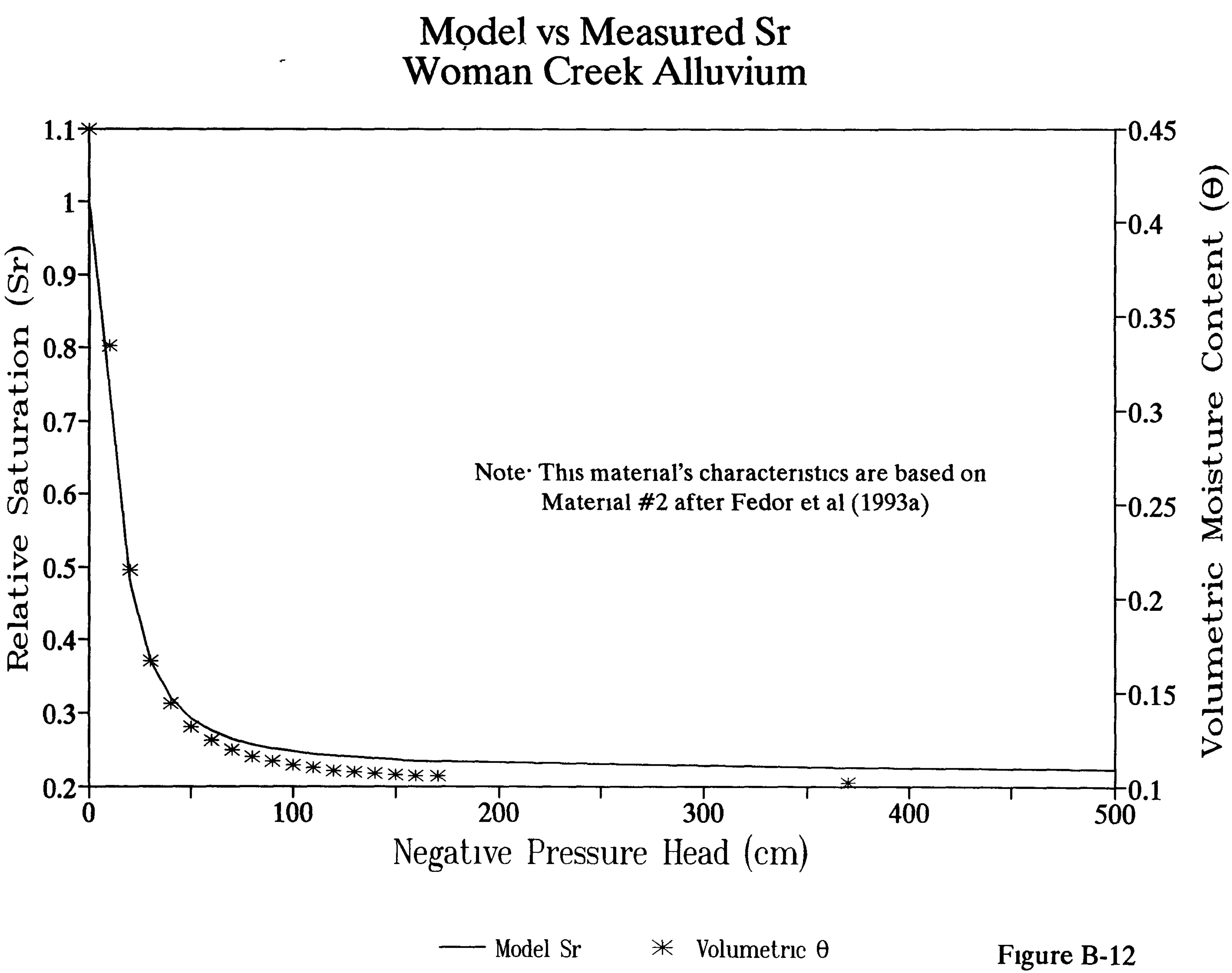


Figure B-12

268

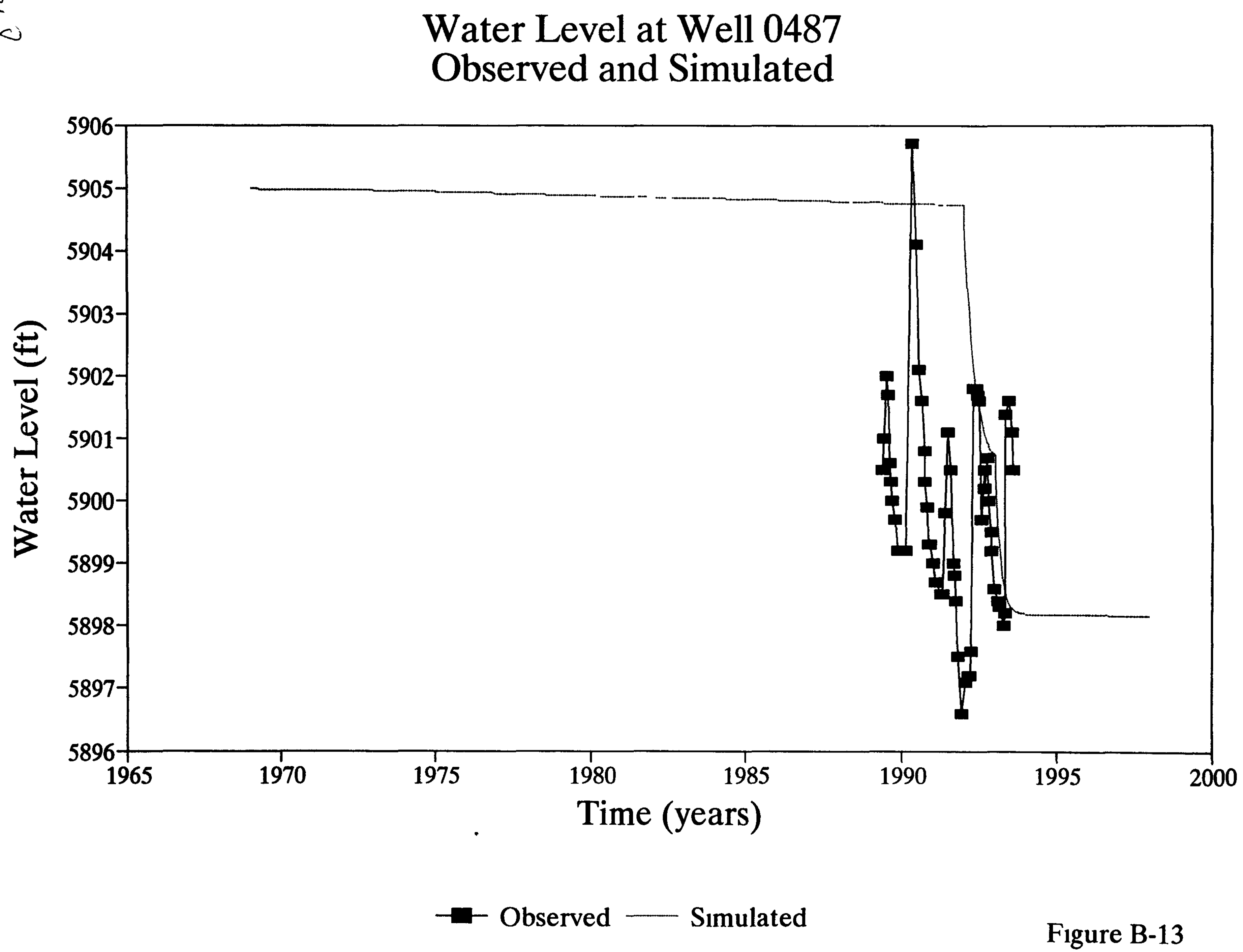


Figure B-13

269

Water Level at Well 4387
Observed and Simulated

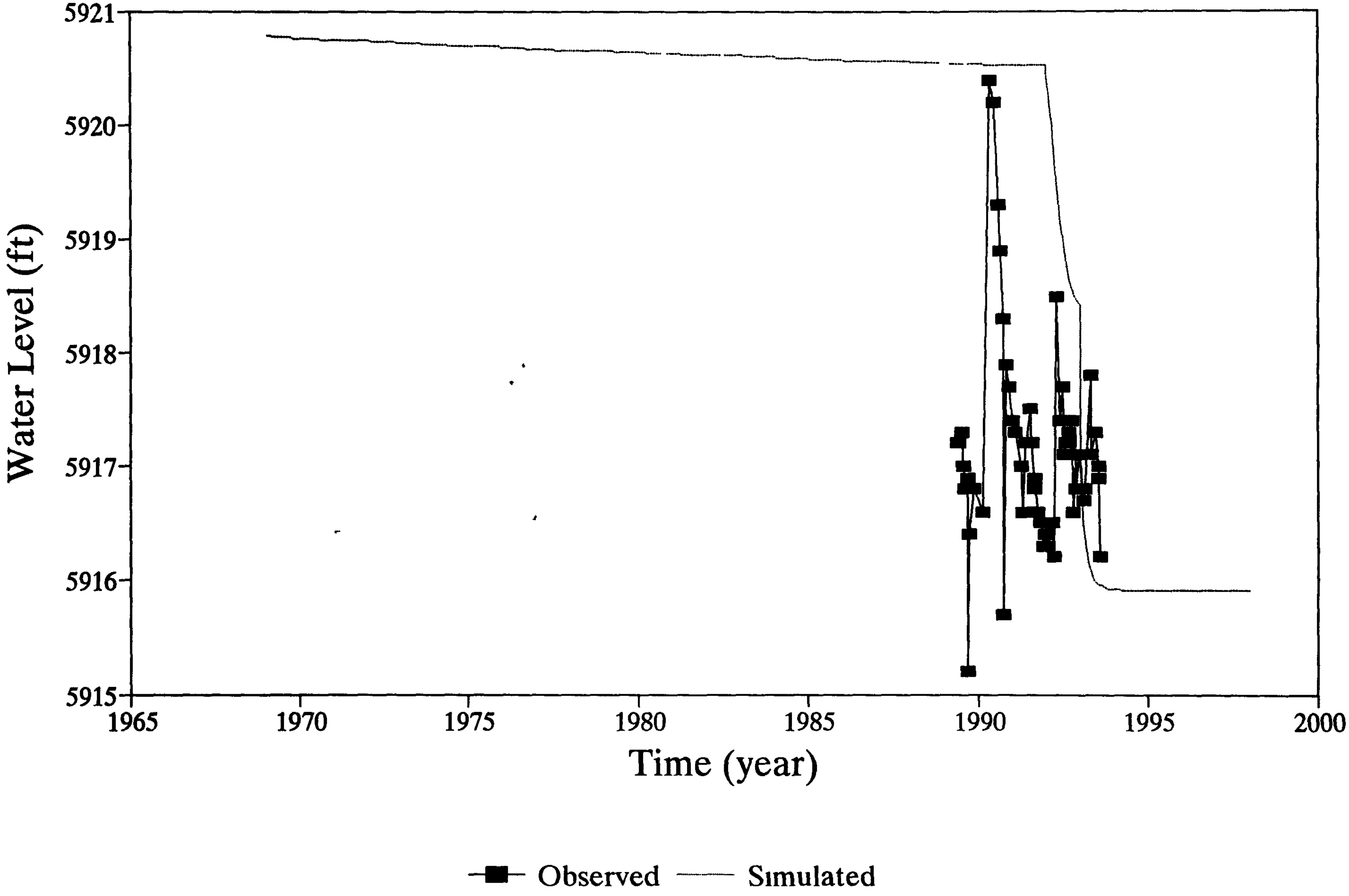


Figure B-14

210

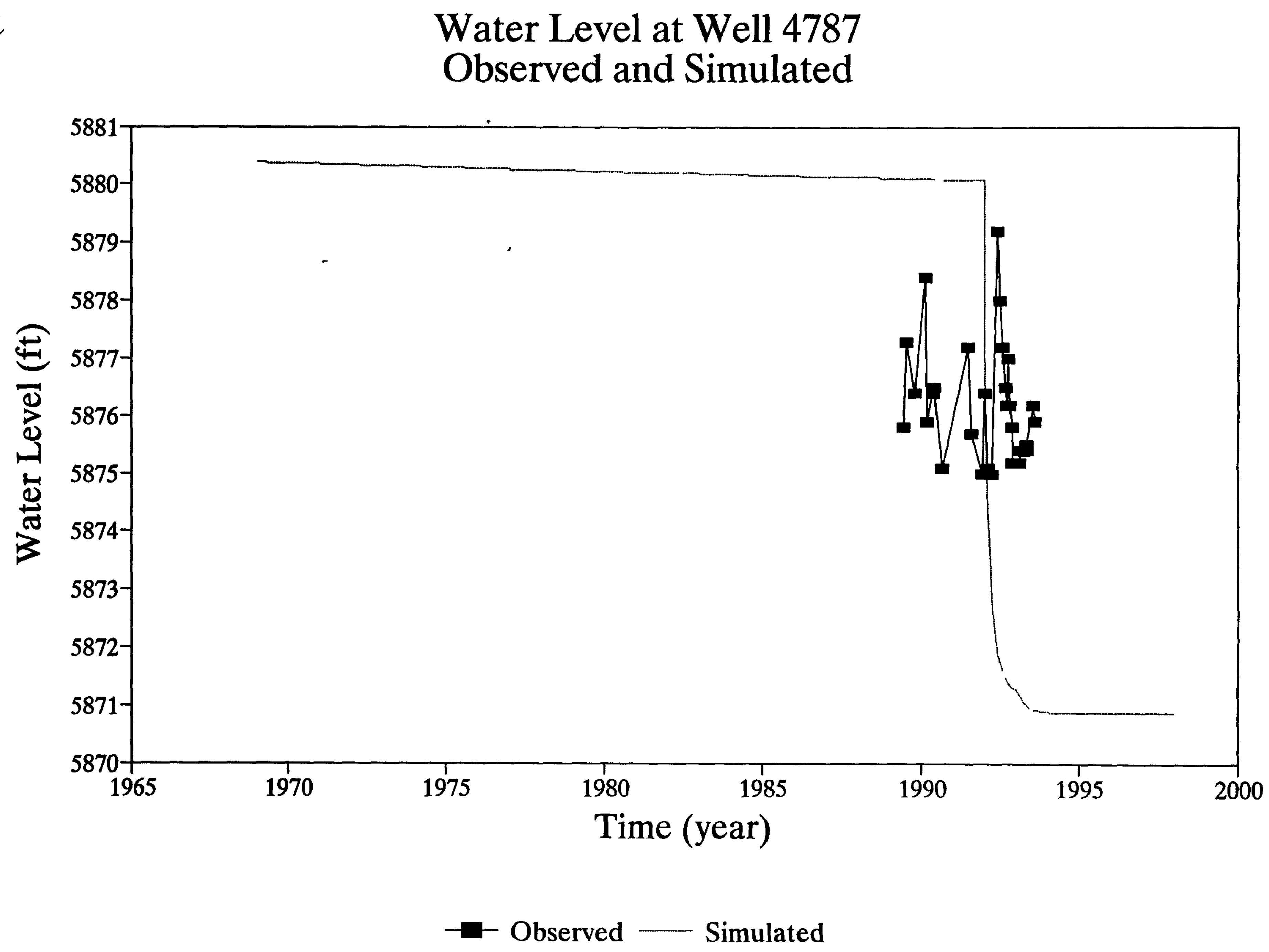


Figure B-15

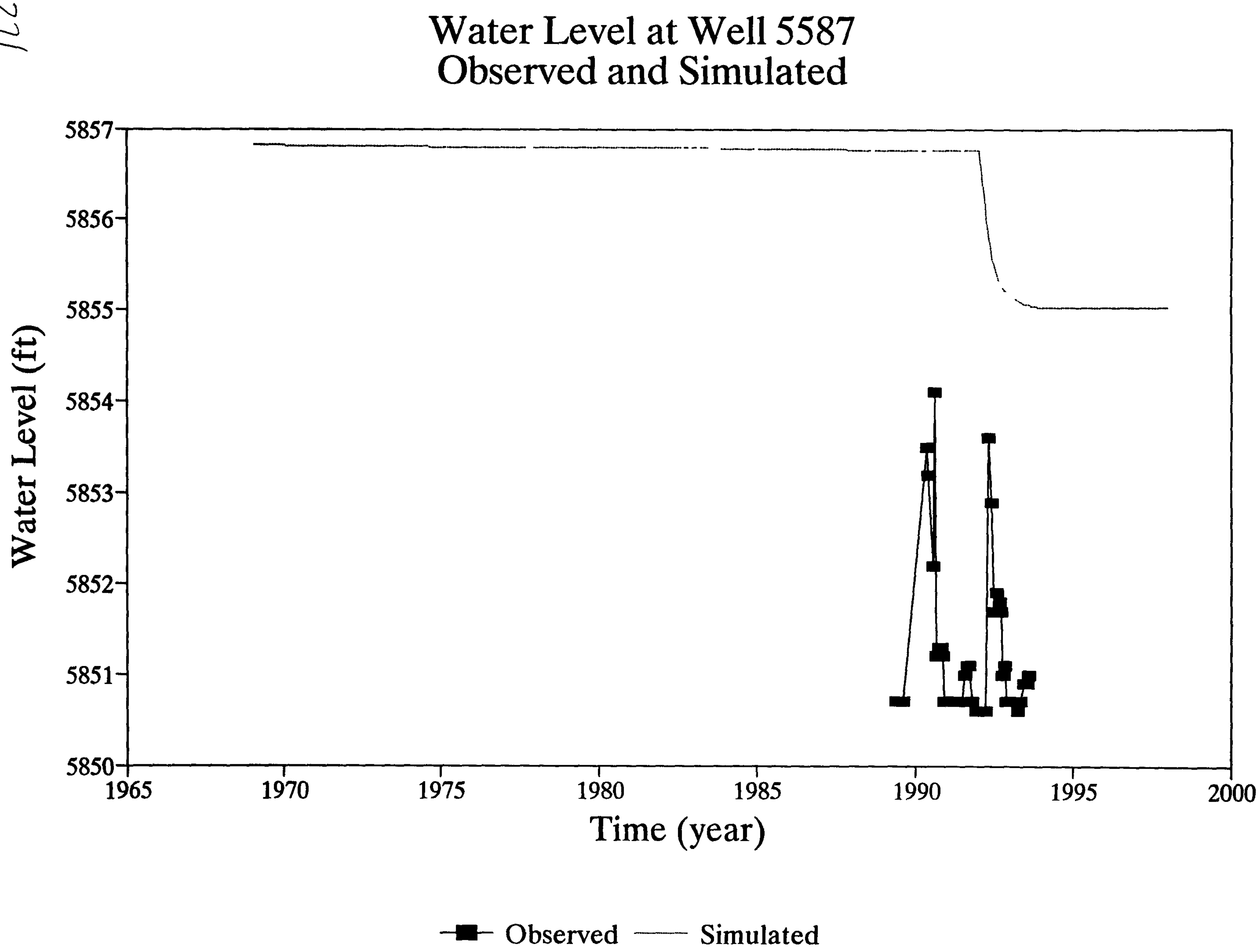

Water Level at Well 5587
Observed and Simulated
Water Level (ft)
5857
5856
5855
5854
5853
5852
5851
5850
1965
1970
1975
1980
1985
1990
1995
2000
Time (year)
Observed
Simulated

Figure B-16

272

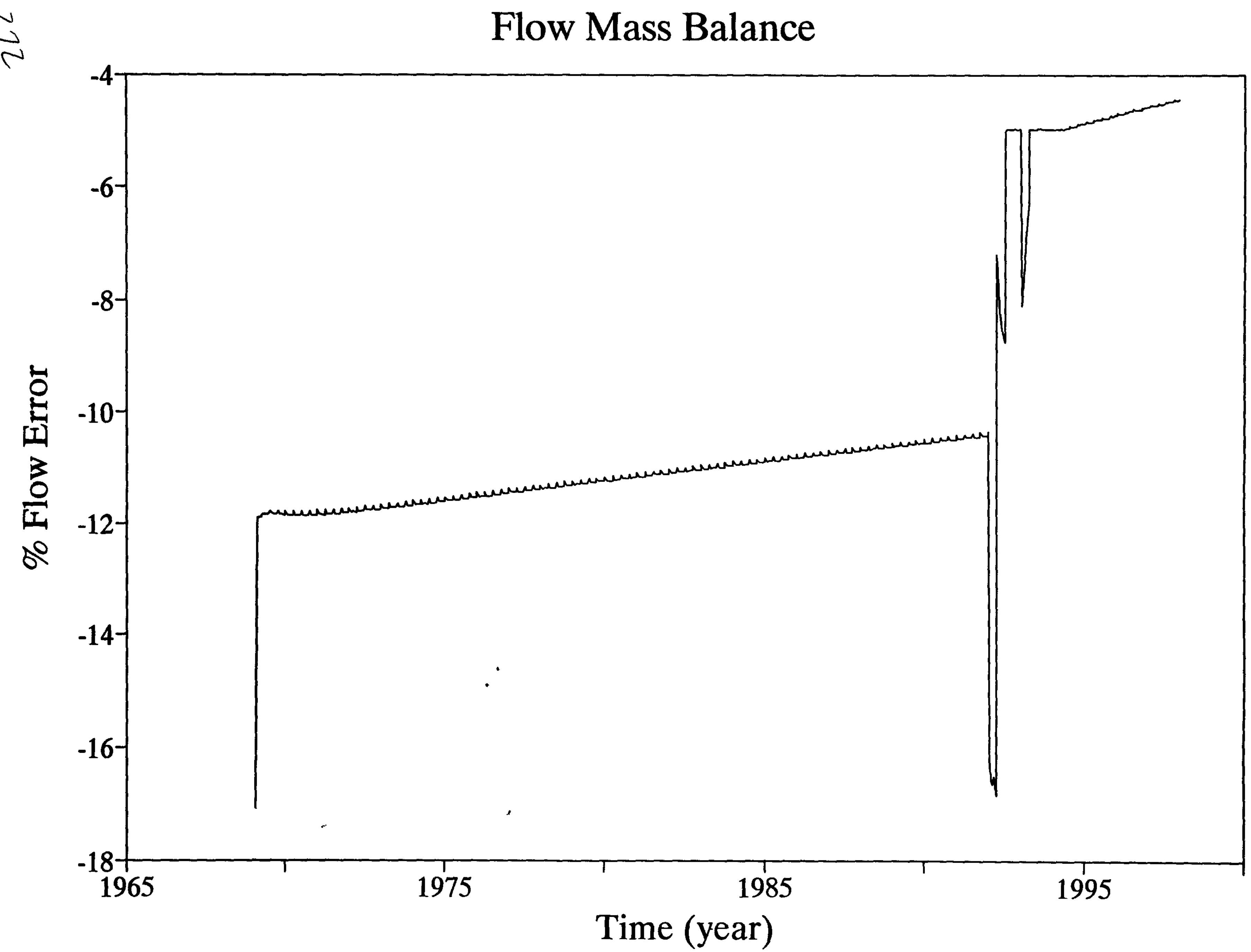


Figure B-17

273

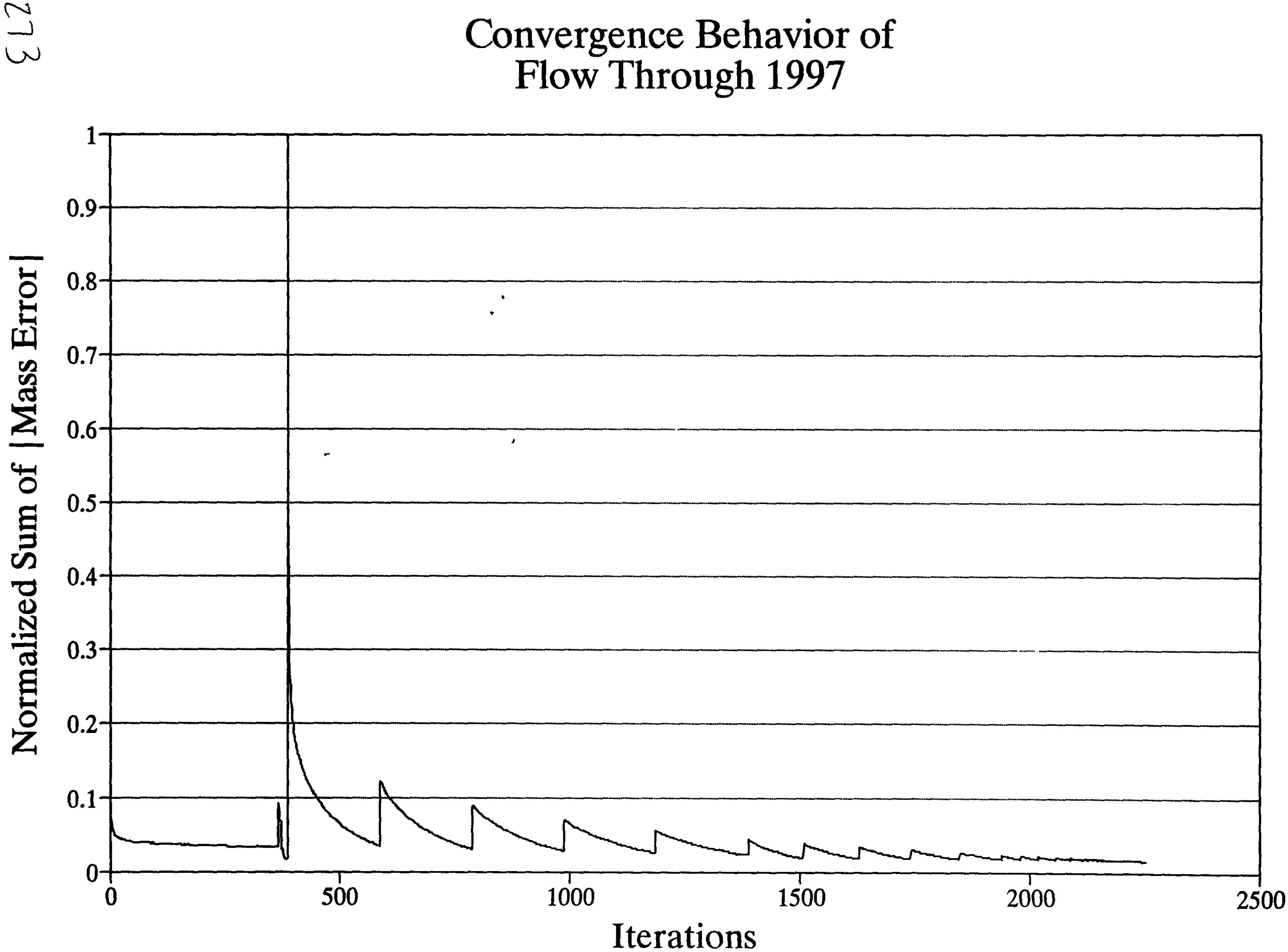


Figure B-18

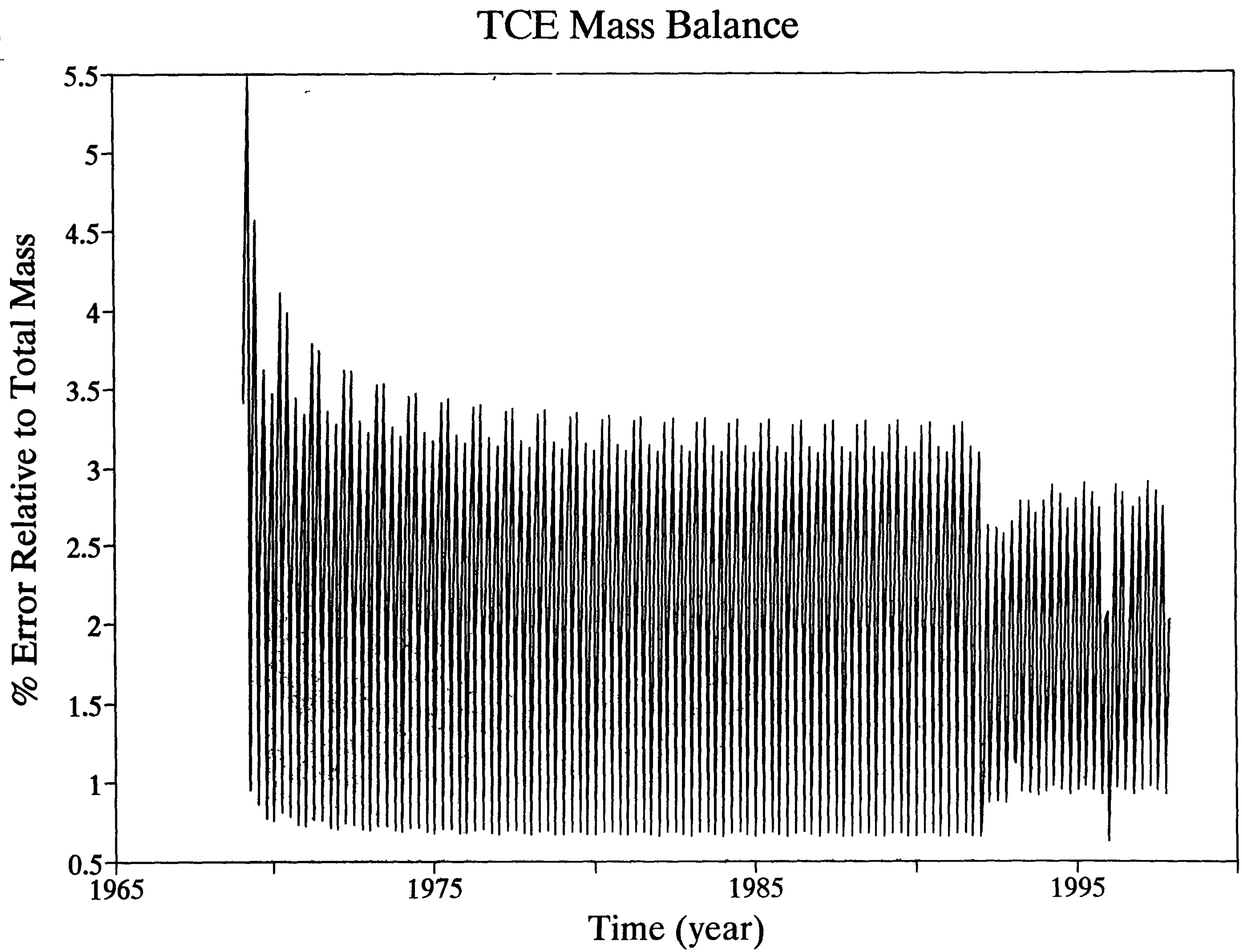

TCE Mass Balance
% Error Relative to Total Mass
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
1965
1975
1985
1995
Time (year)

Figure B-19

275

Convergence Behavior of TCE Concentrations Through 1997

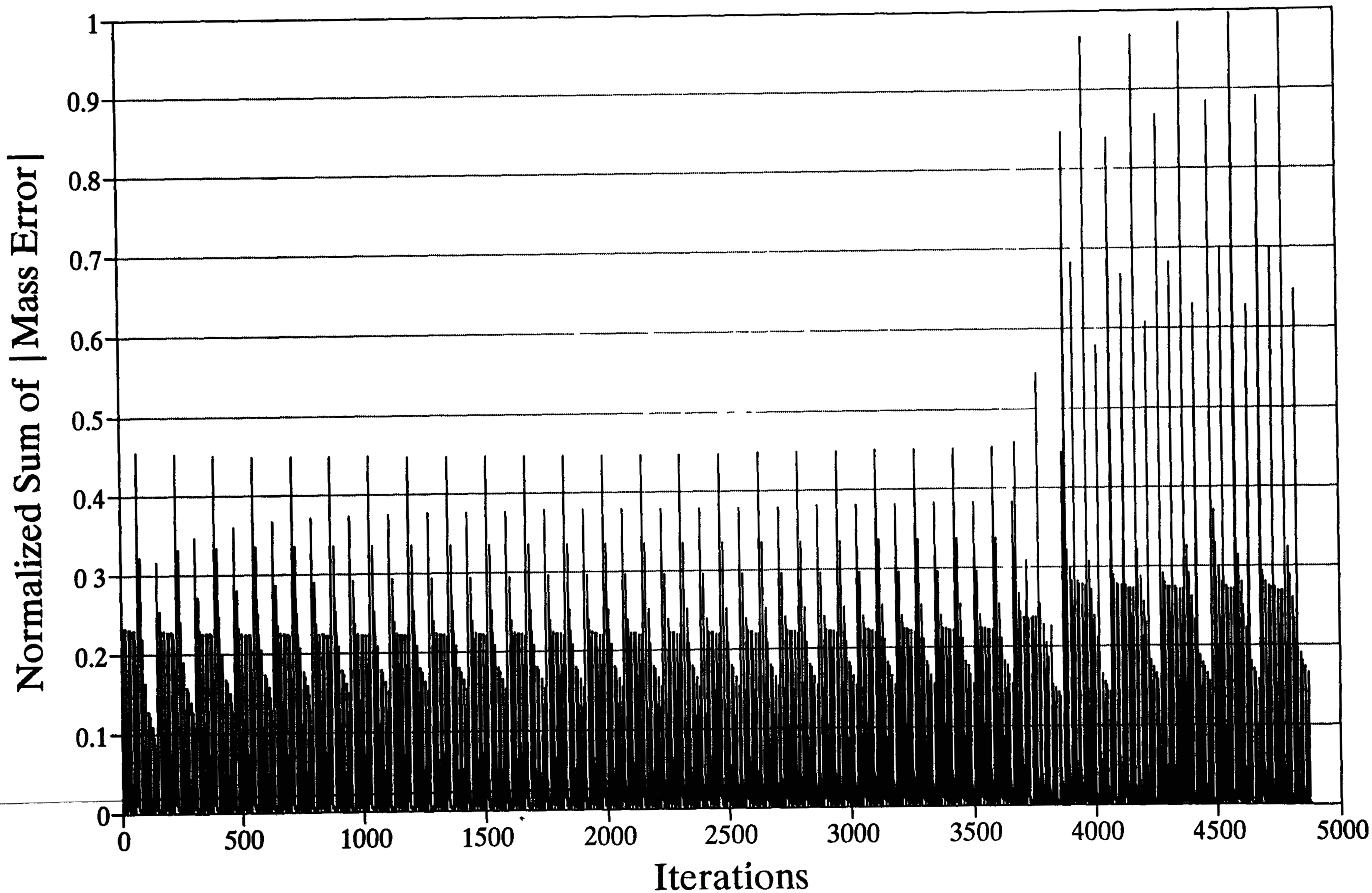


Figure B-20

276

PCE Calibration of Well 0487

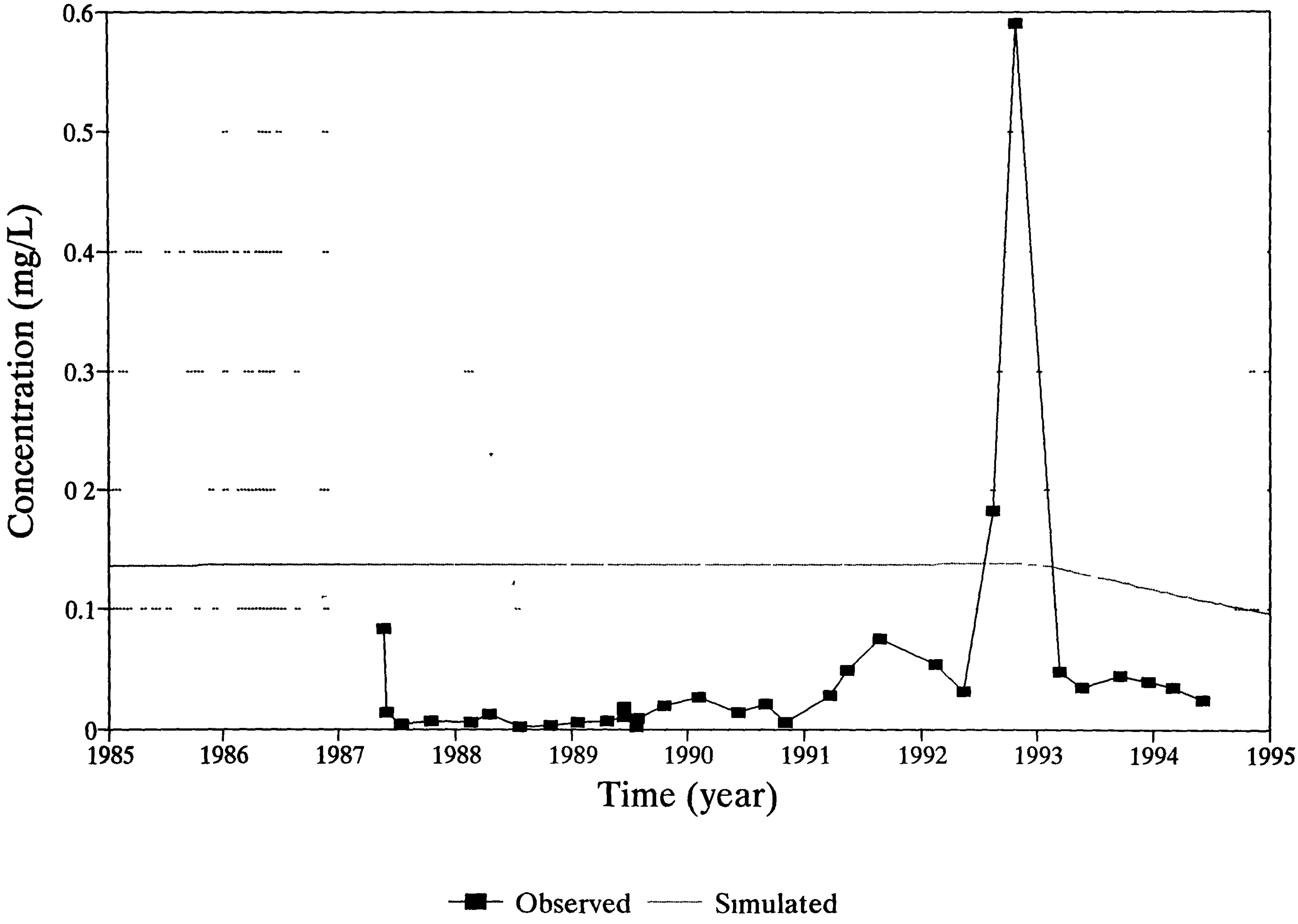


Figure B-21

PCE Calibration of Well 4387

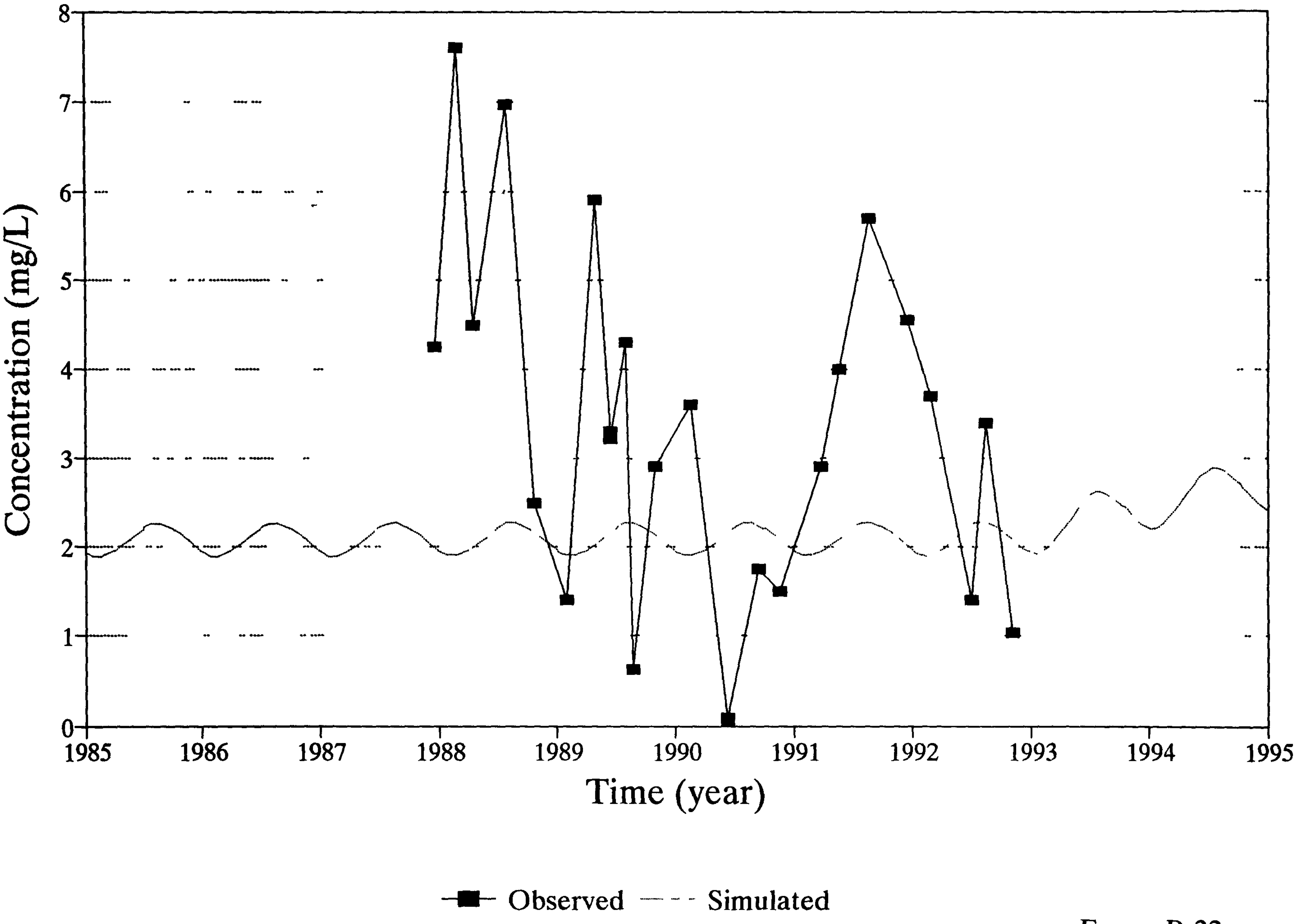


Figure B-22

TCE Calibration of Well 0487

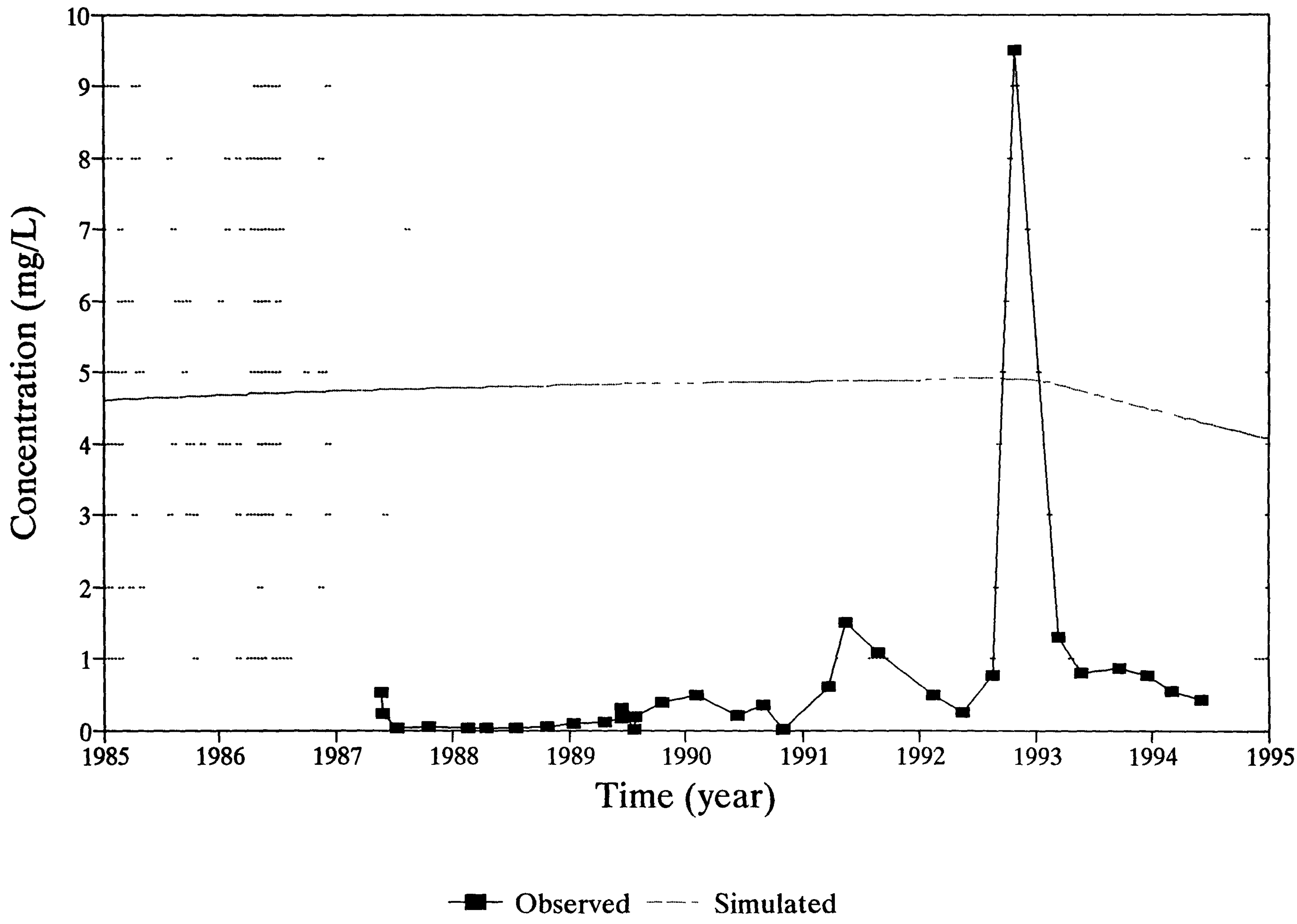


Figure B-23

082

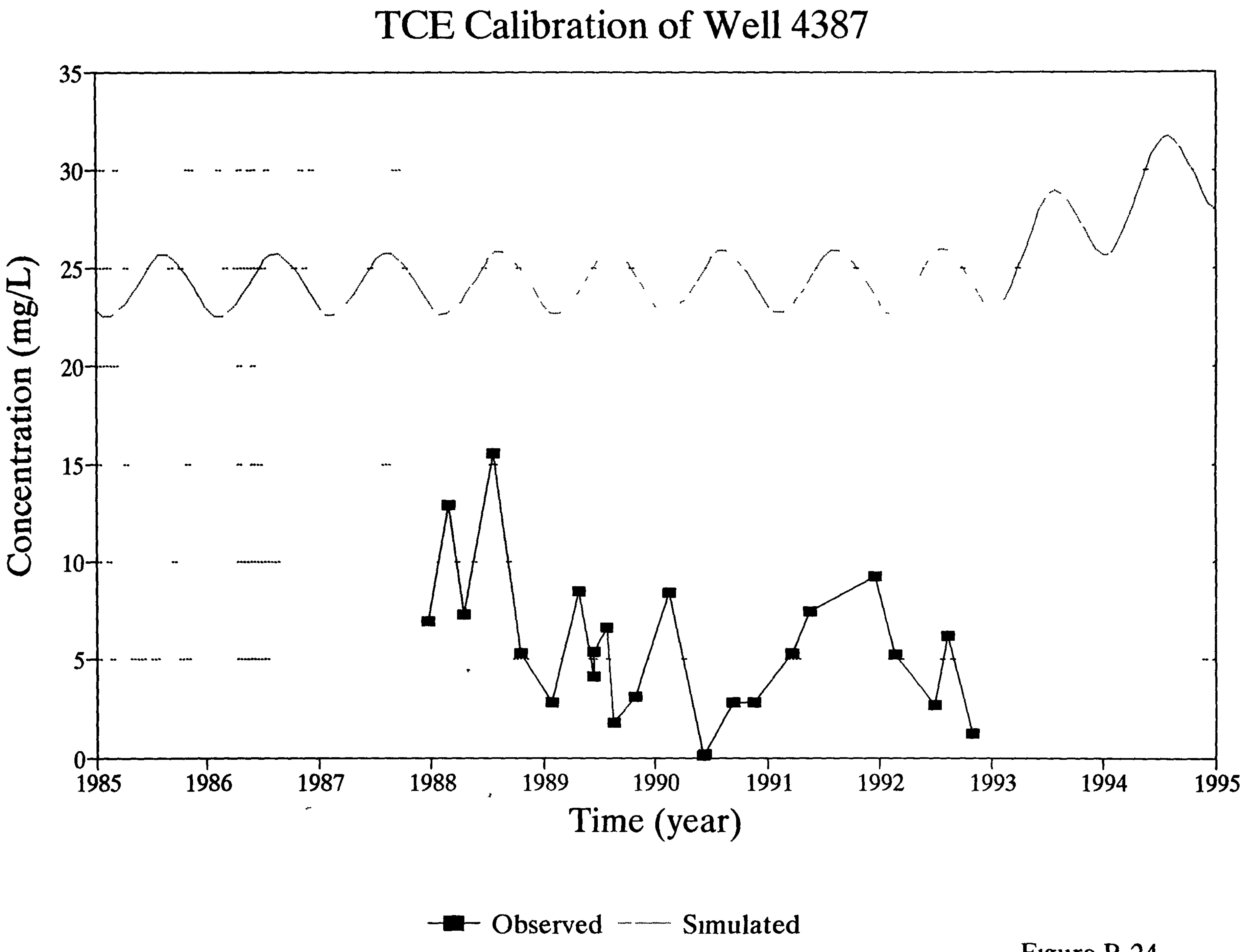


Figure B-24

182

1,1,1-TCA Calibration of Well 0487

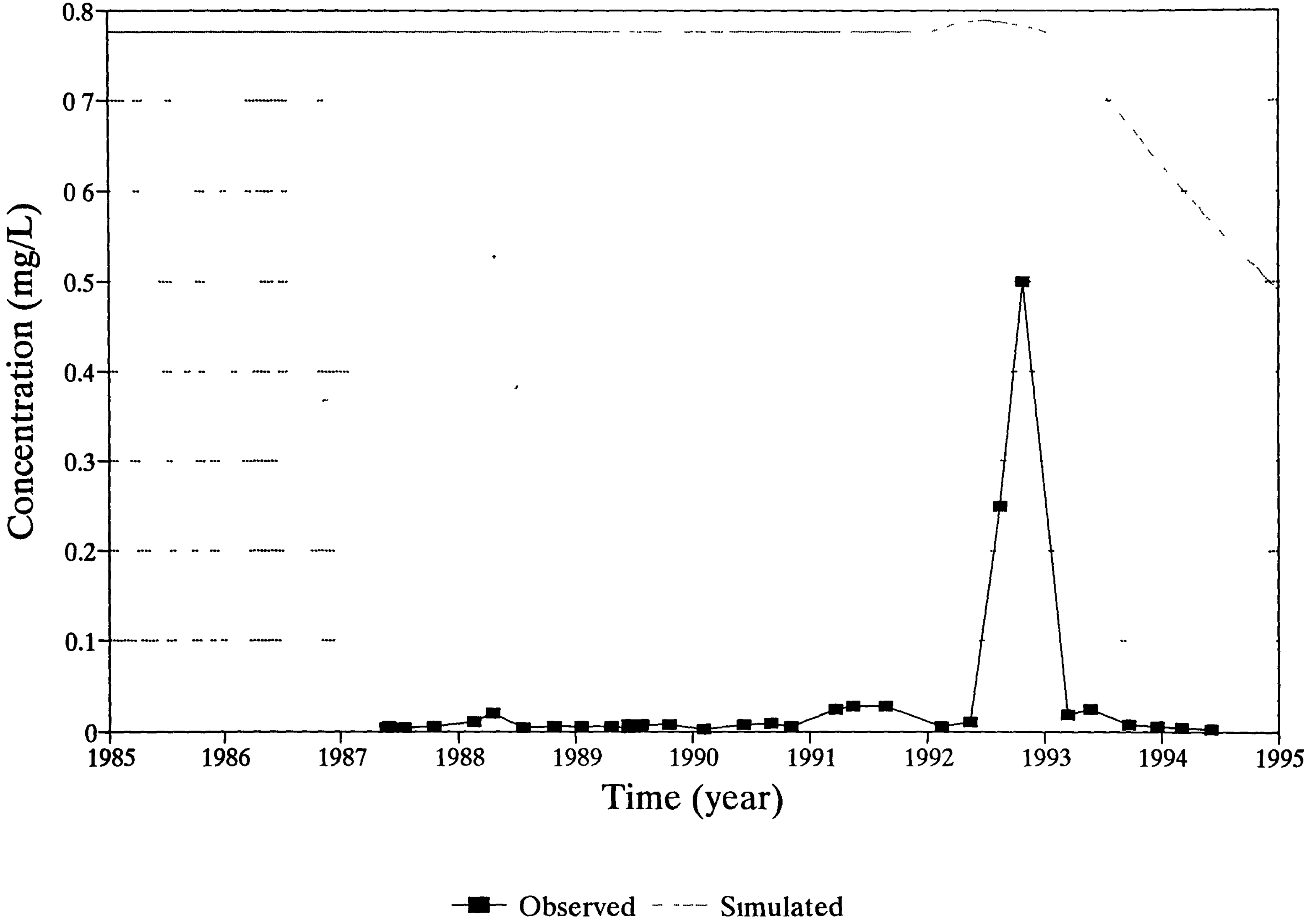


Figure B-25

282

1,1,1-TCA Calibration of Well 4387

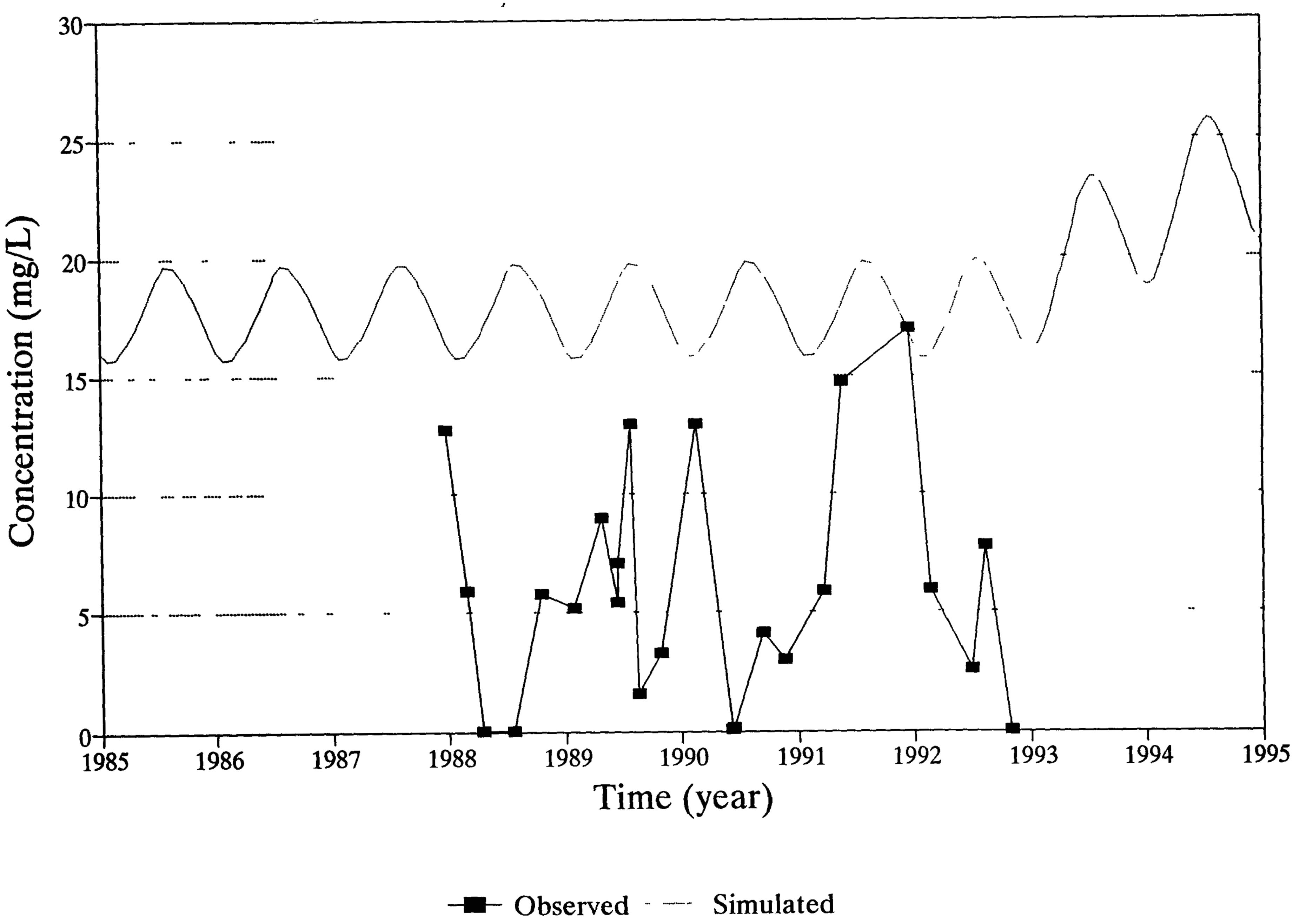


Figure B-26

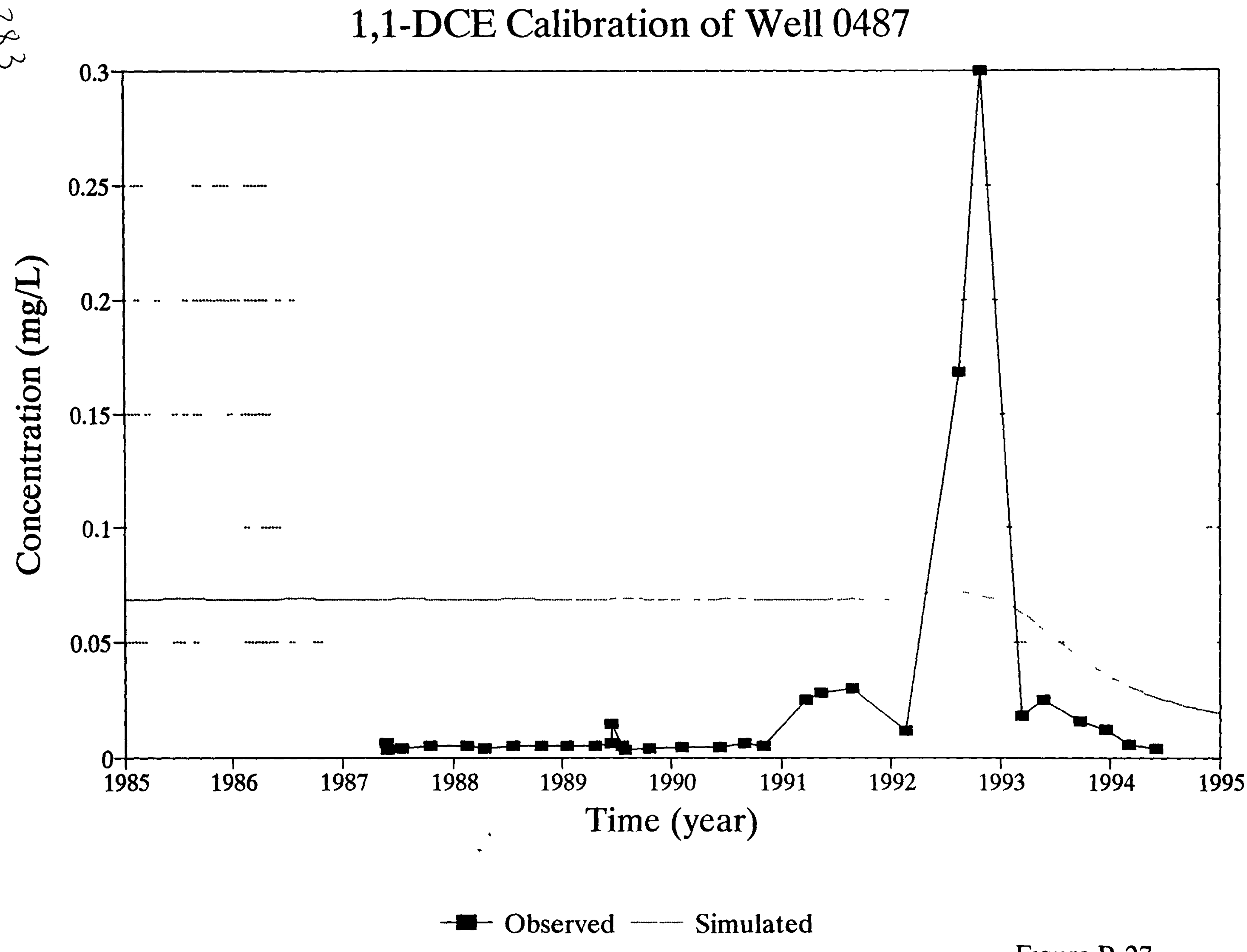


Figure B-27

283

284

1,1-DCE Calibration of Well 4387

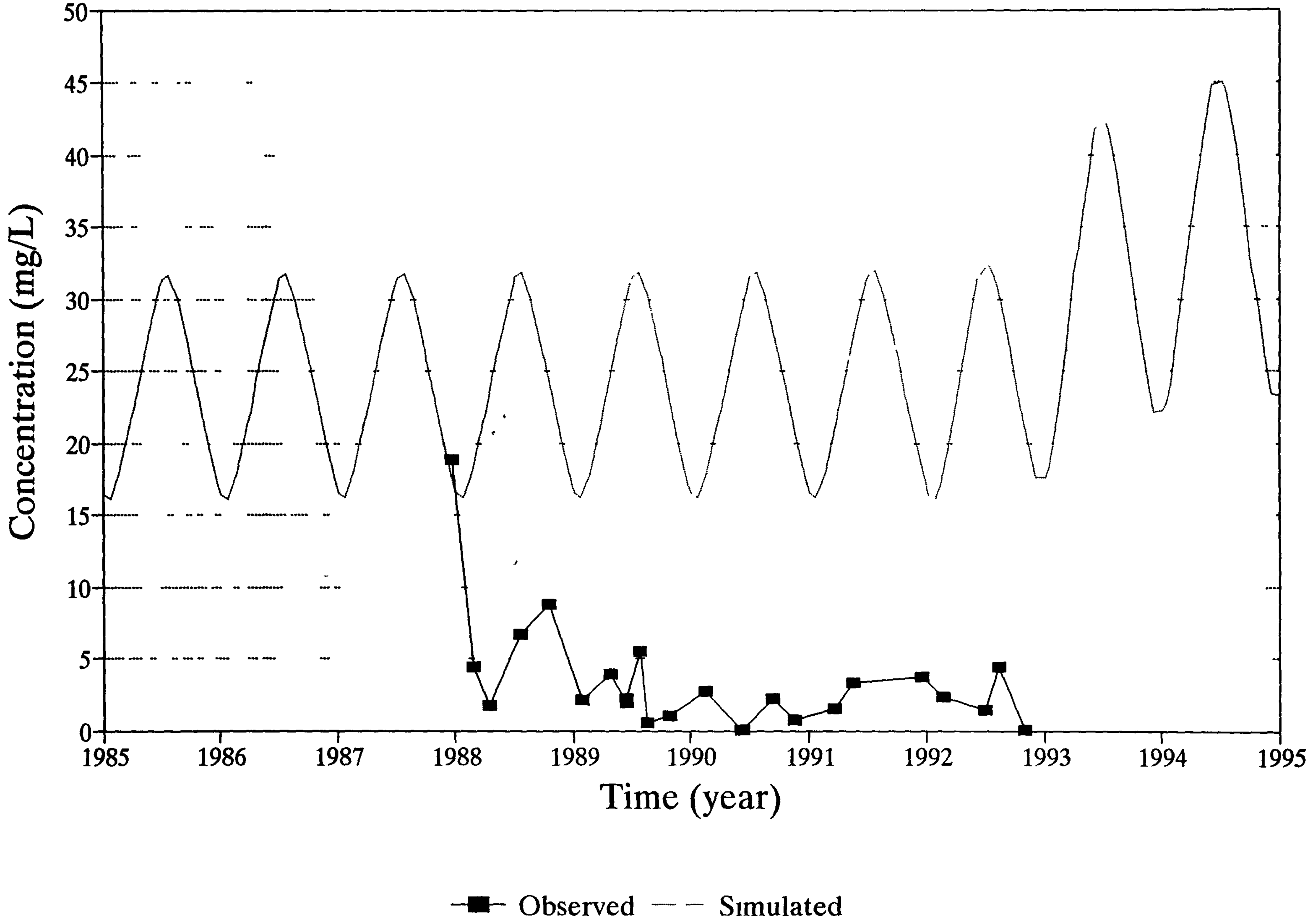


Figure B-28

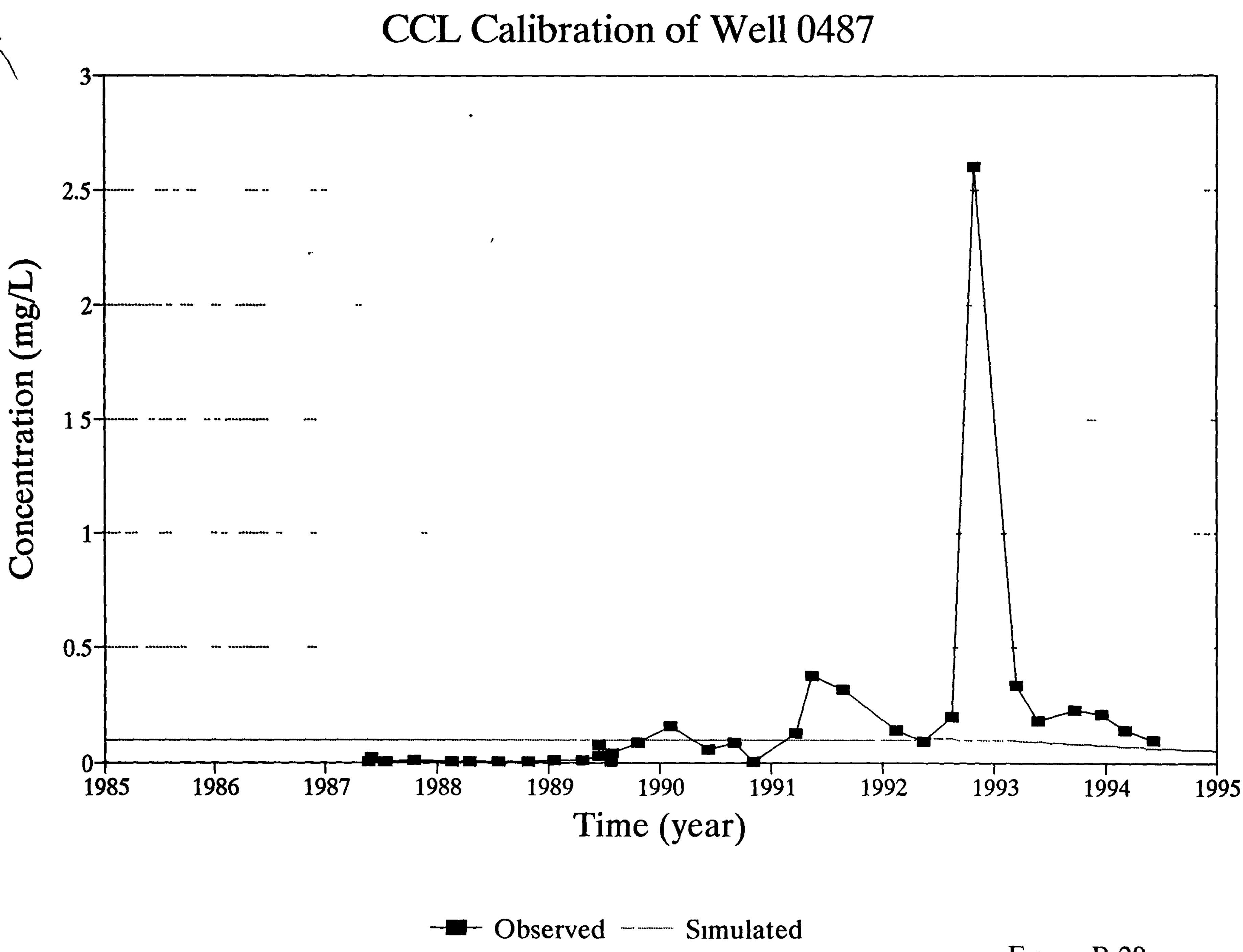


Figure B-29

285

982

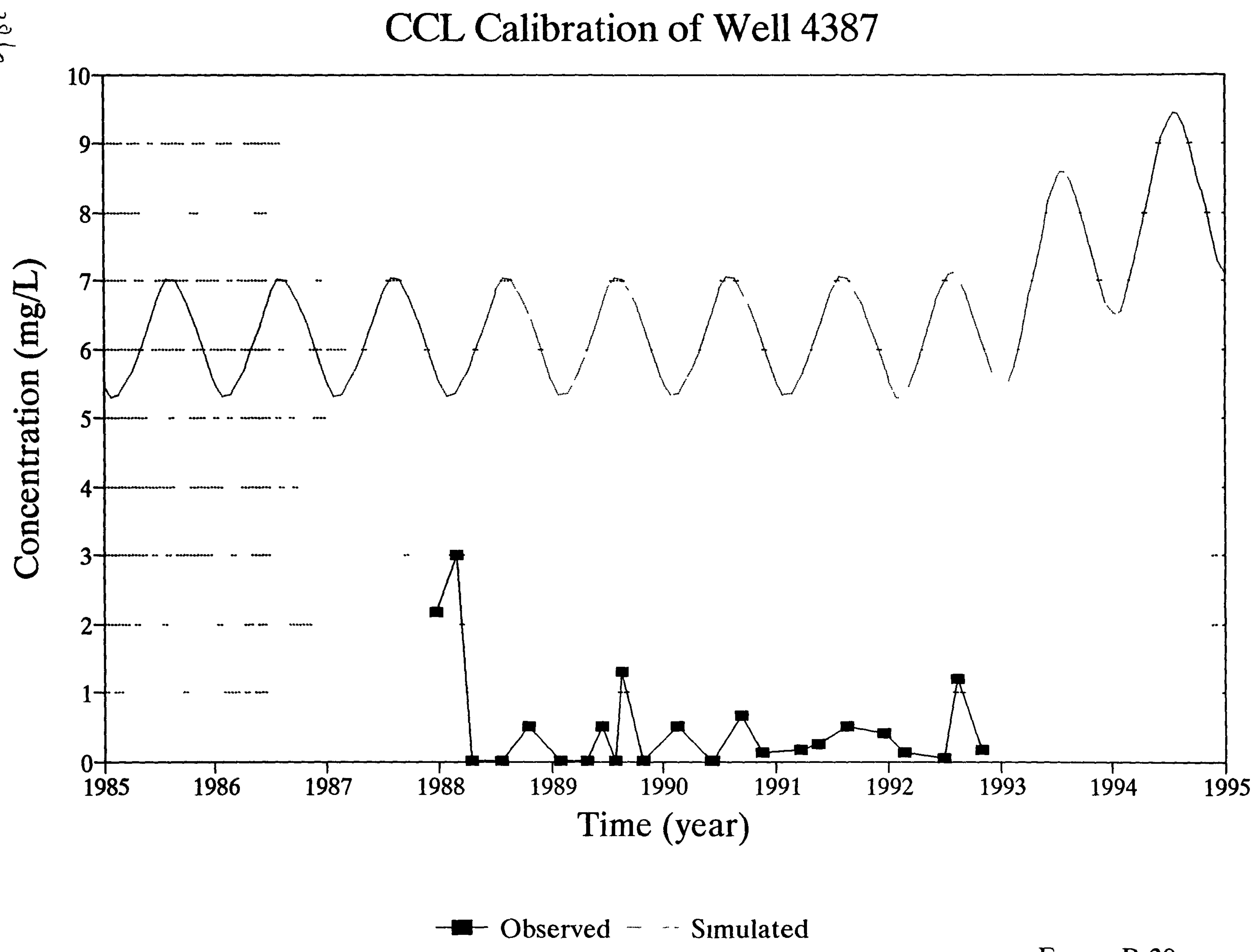
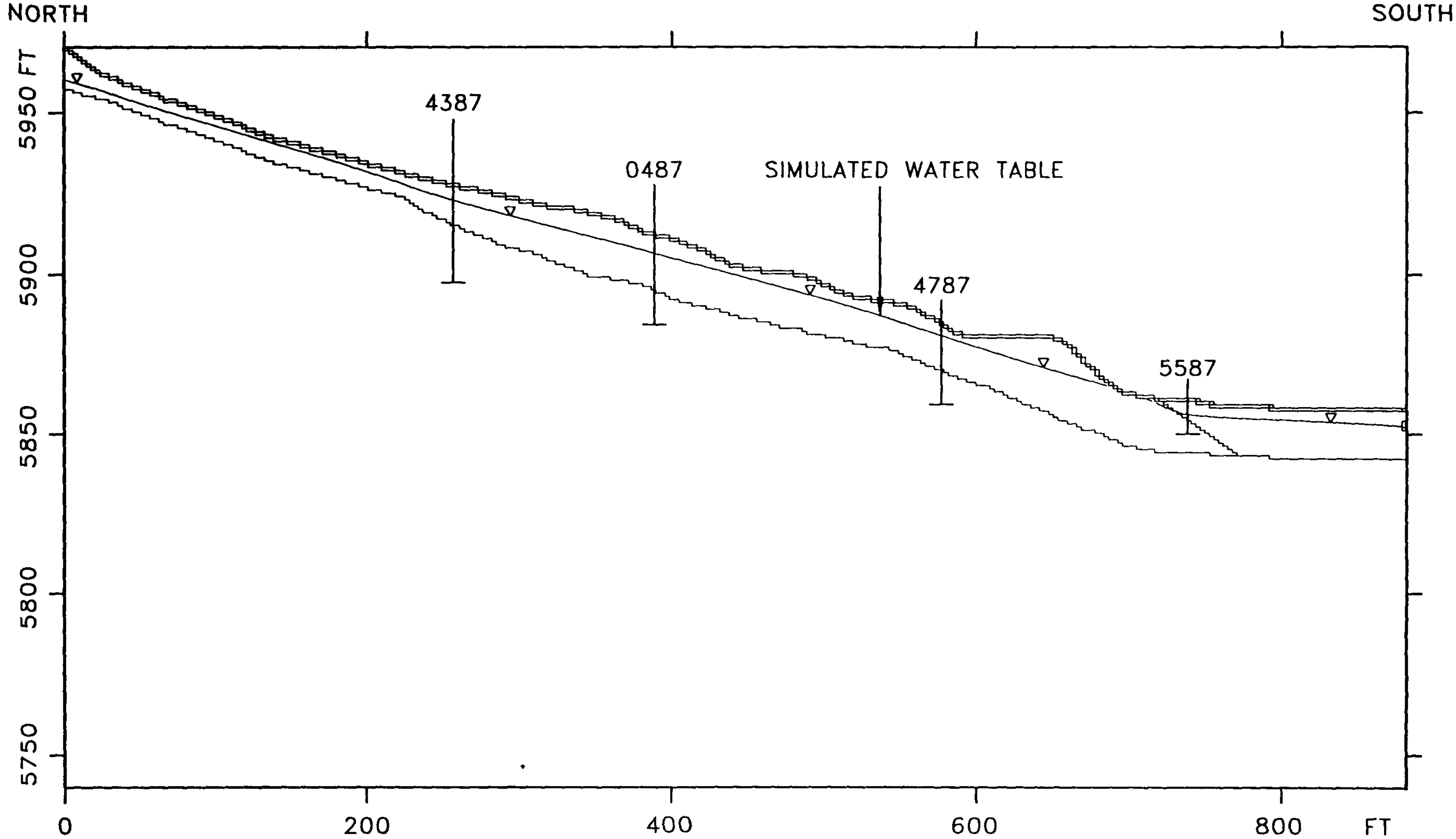


Figure B-30

287

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\WTSS DWG



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881 HILLSIDE AREA
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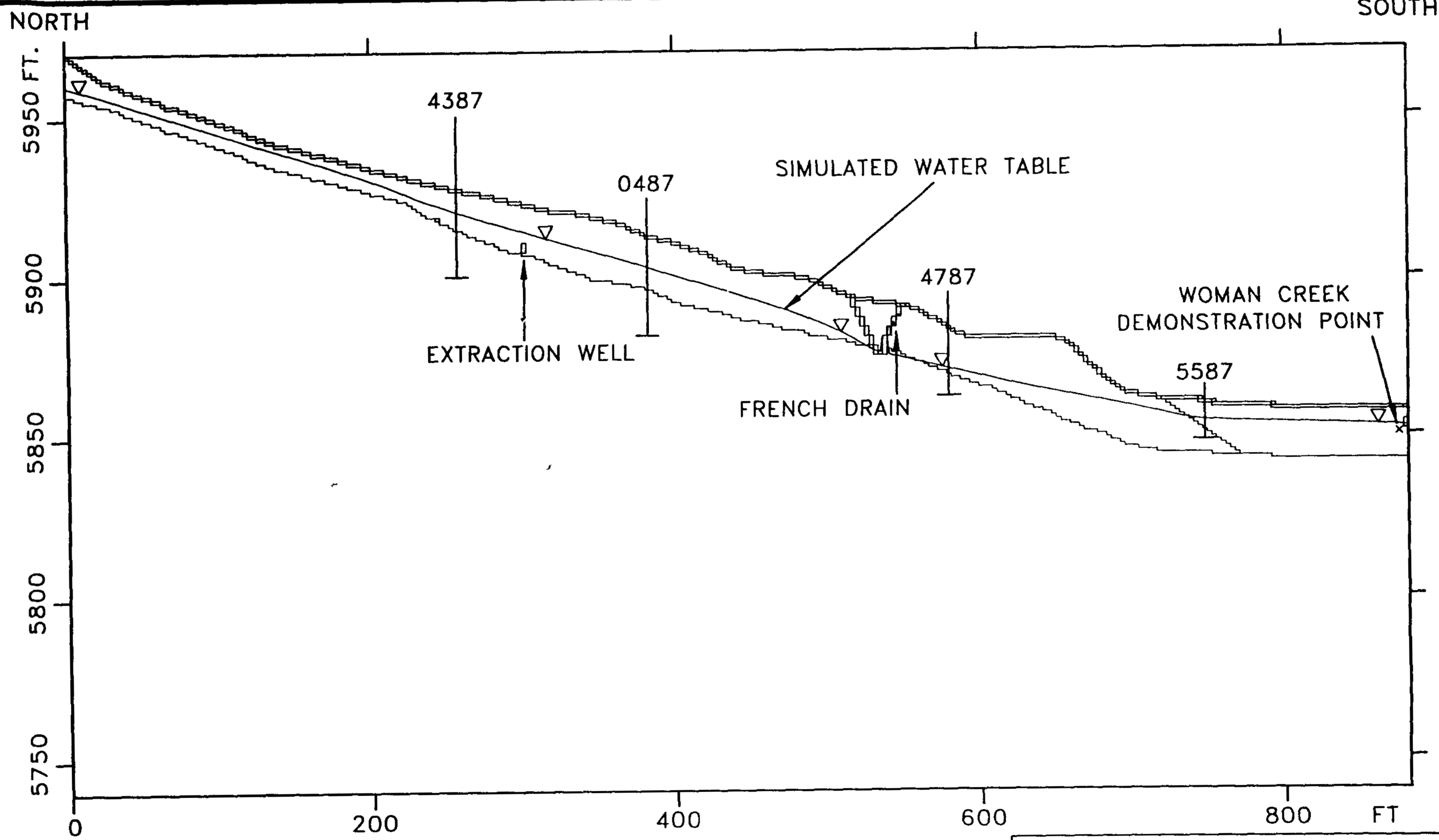
Simulated Water Table
Steady State

Figure B-31

882

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\WTDFD DWG



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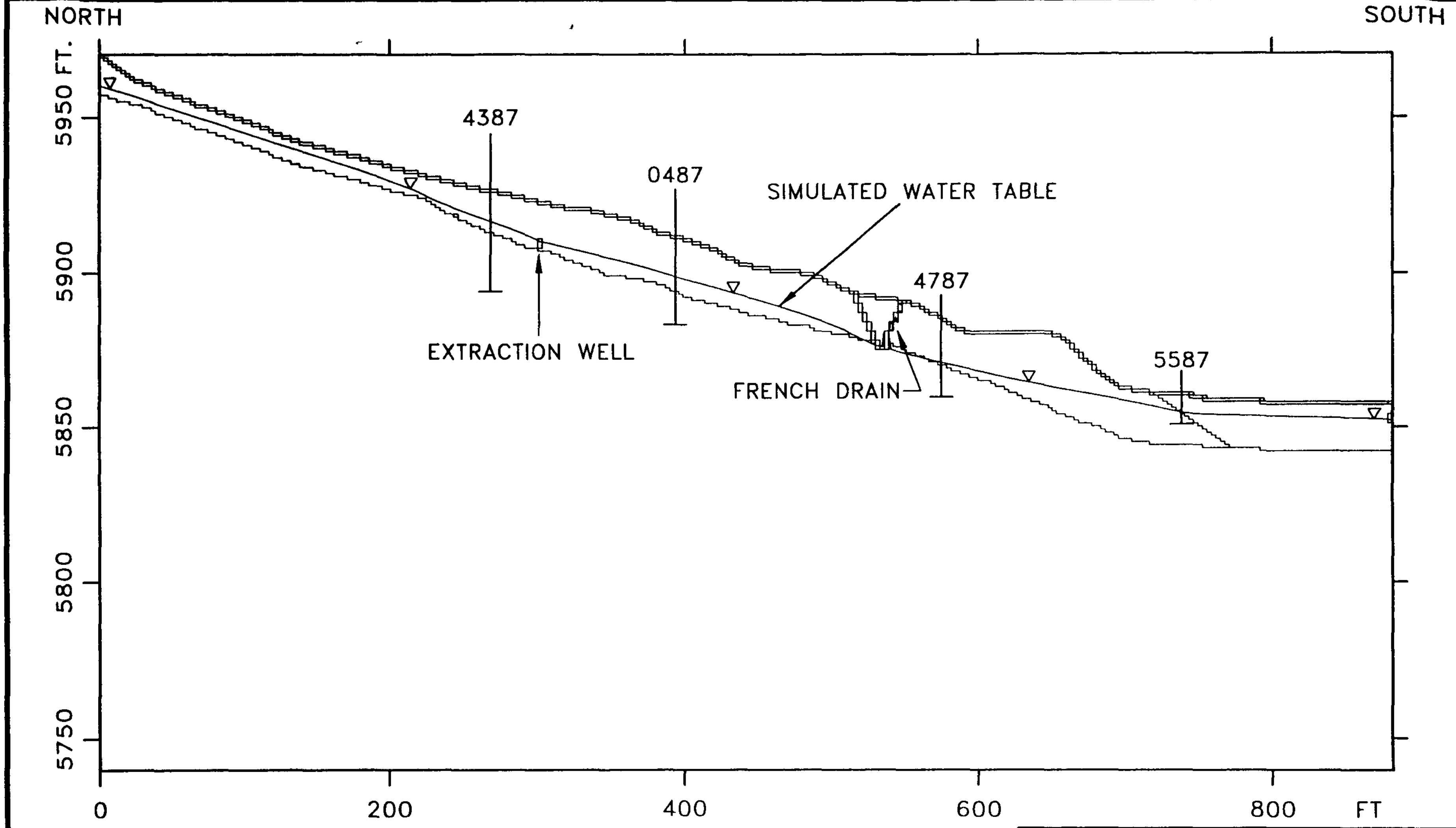
881 HILLSIDE AREA
OPERABLE UNIT NO 1

Simulated Water Table
Time = 8766 Days (1993)

Figure B-32

289

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\WTNOACT DWG



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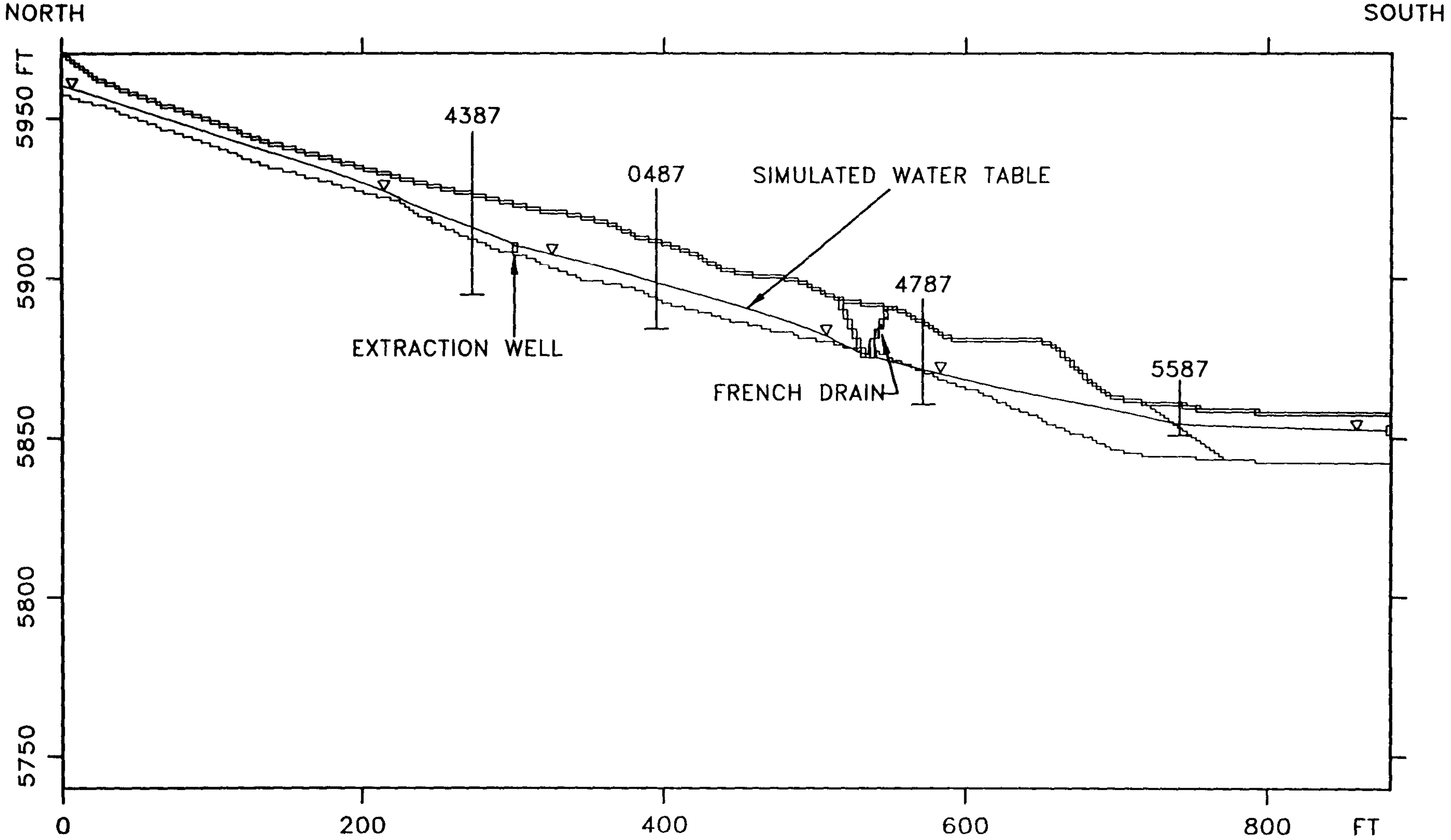
881 HILLSIDE AREA
OPERABLE UNIT NO 1

Simulated Water Table
Time = 9855 Days (1996)

Figure B-33

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\WTDFDW DWG



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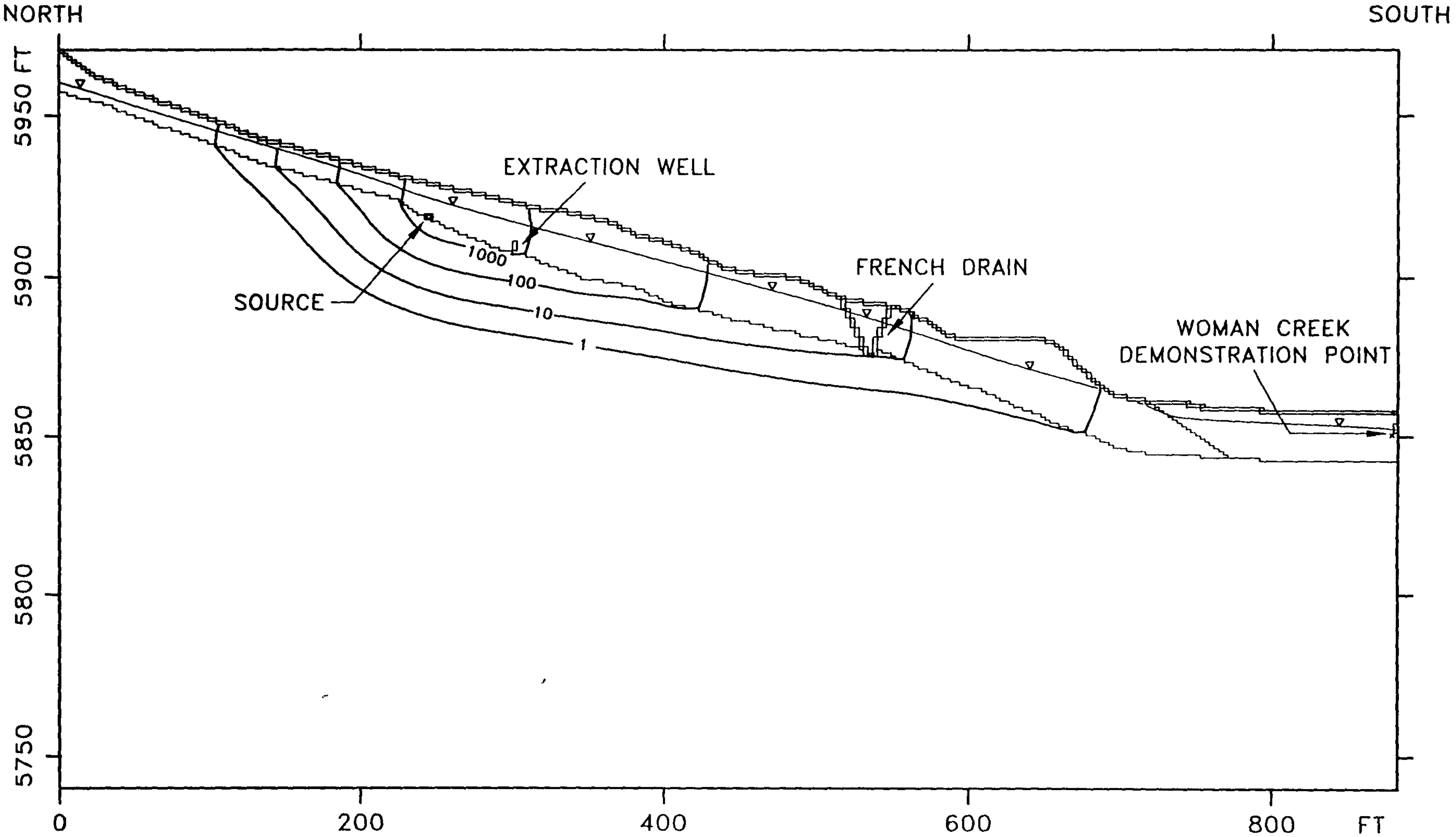
881 HILLSIDE AREA
OPERABLE UNIT NO 1

Simulated Water Table
Time = 10585 Days (1998)

Figure B-34

290

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\PCE01 DWG



NOTE Concentrations in ppb

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881 HILLSIDE AREA
OPERABLE UNIT NO 1

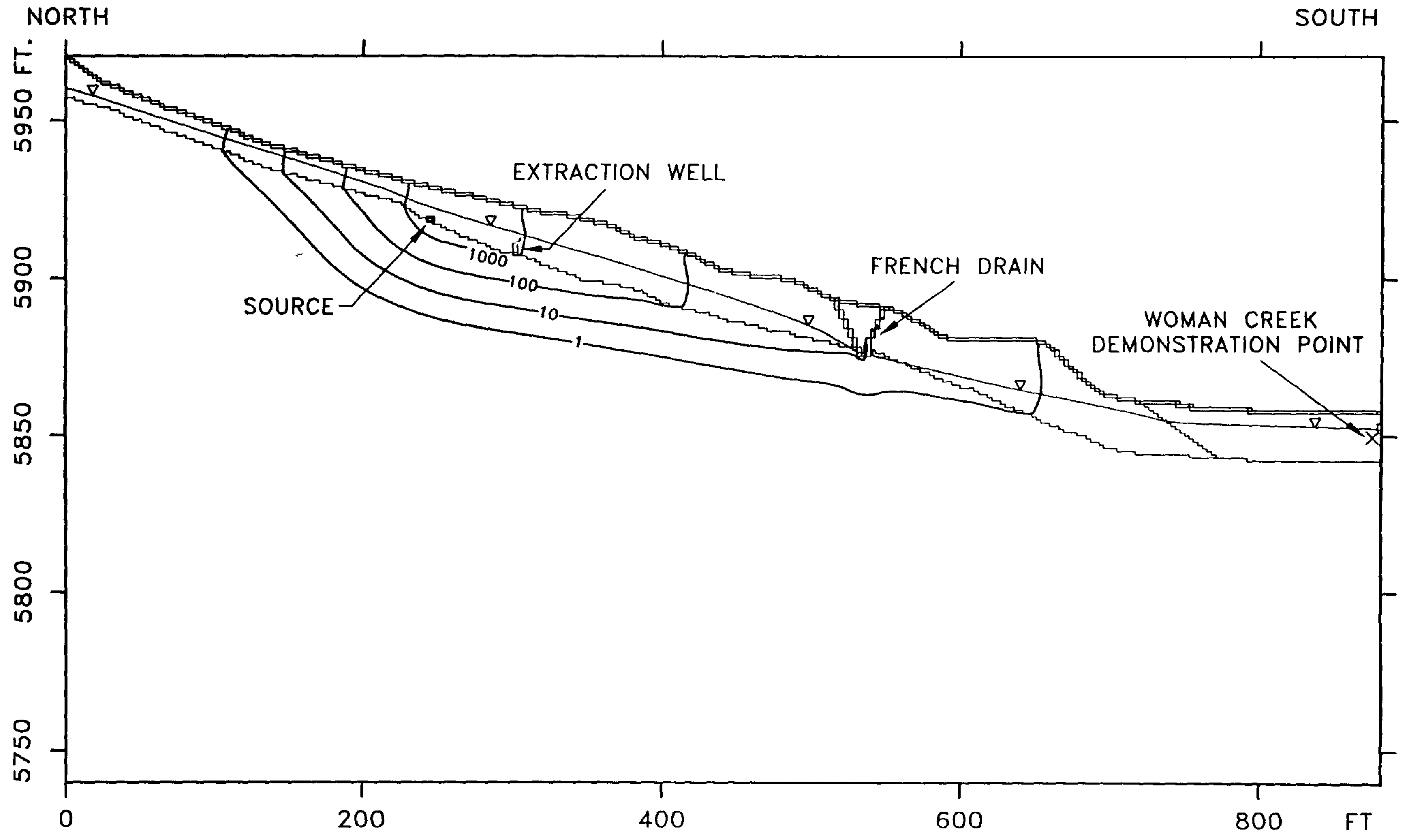
Concentration Contours Of PCE
Time = 8401 Days (1992)

Figure B-35

291

292

K \DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\PCE02 DWG



NOTE Concentrations in ppb

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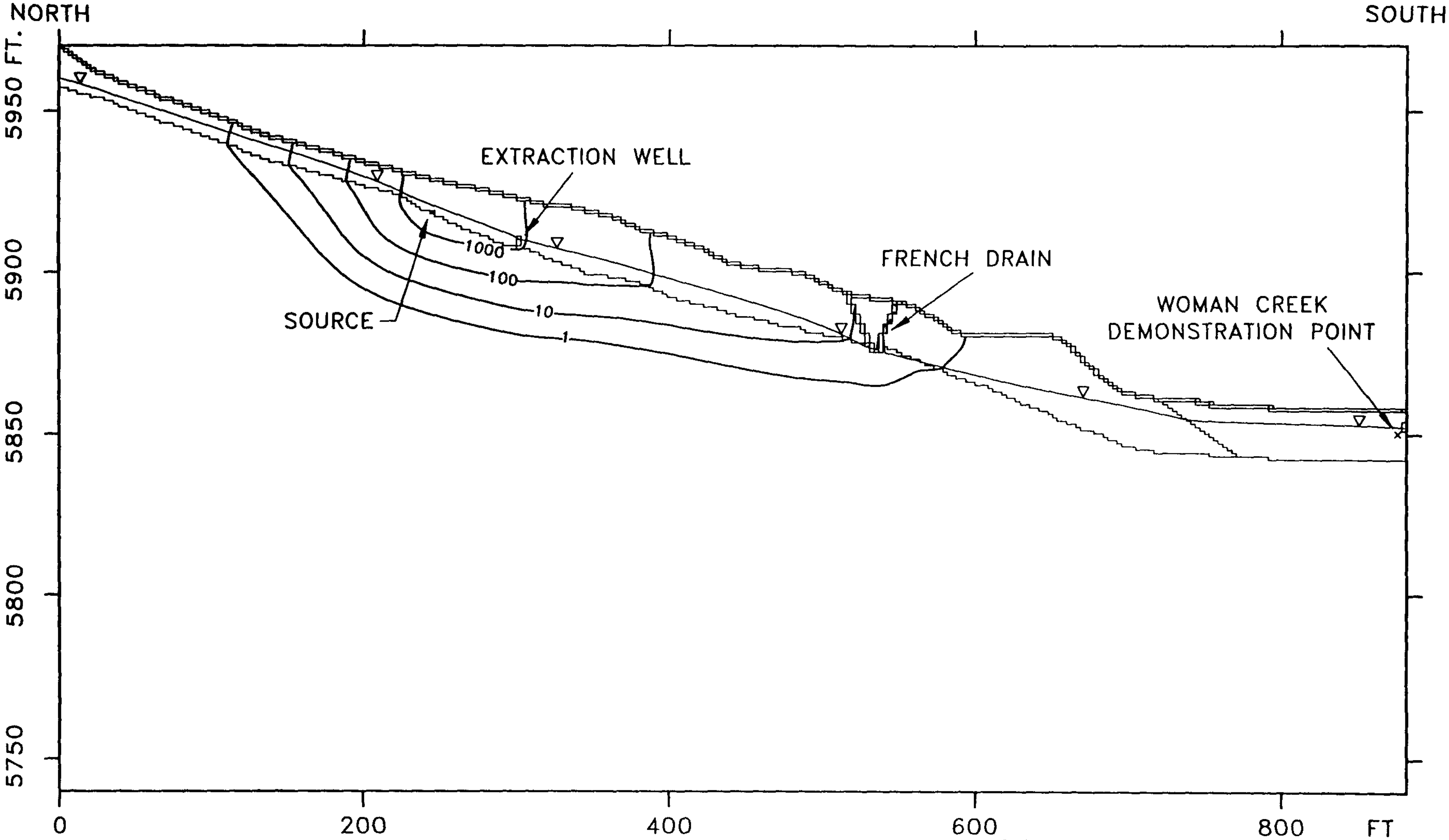
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

Concentration Contours Of PCE
Time = 8766 Days (1993)

Figure B-36

K\DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\PCE03 DWG



NOTE Concentrations in ppb

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Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

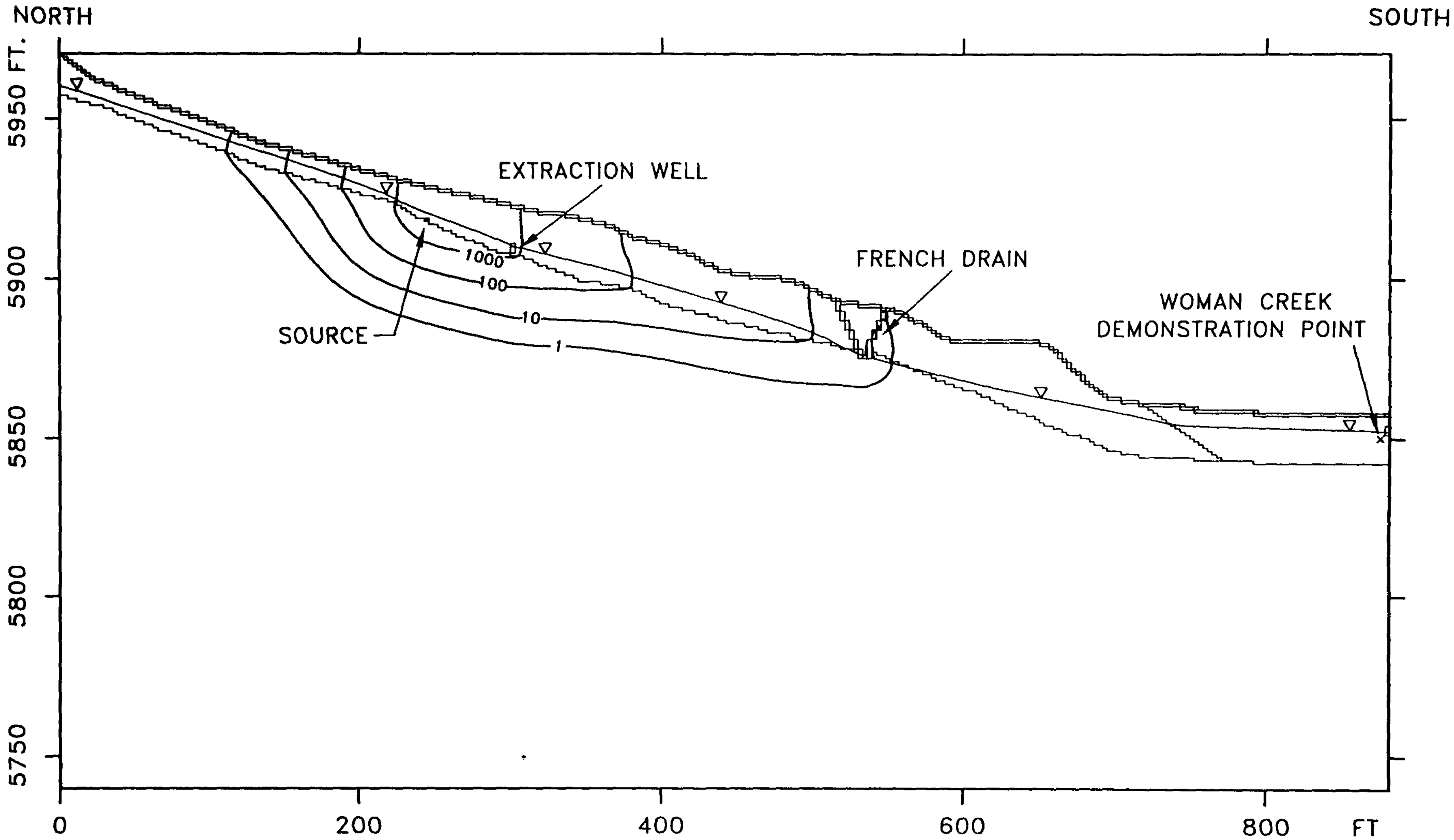
Concentration Contours Of PCE
Time = 9855 Days (1996)

Figure B-37

293

294

K\DESIGN\RCKYFLTS\HILL881\OU-1\GRAPHS\PCE04 DWG



NOTE Concentrations in ppb

U S DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

Concentration Contours Of PCE
Time = 10585 Days (1998)

Figure B-38

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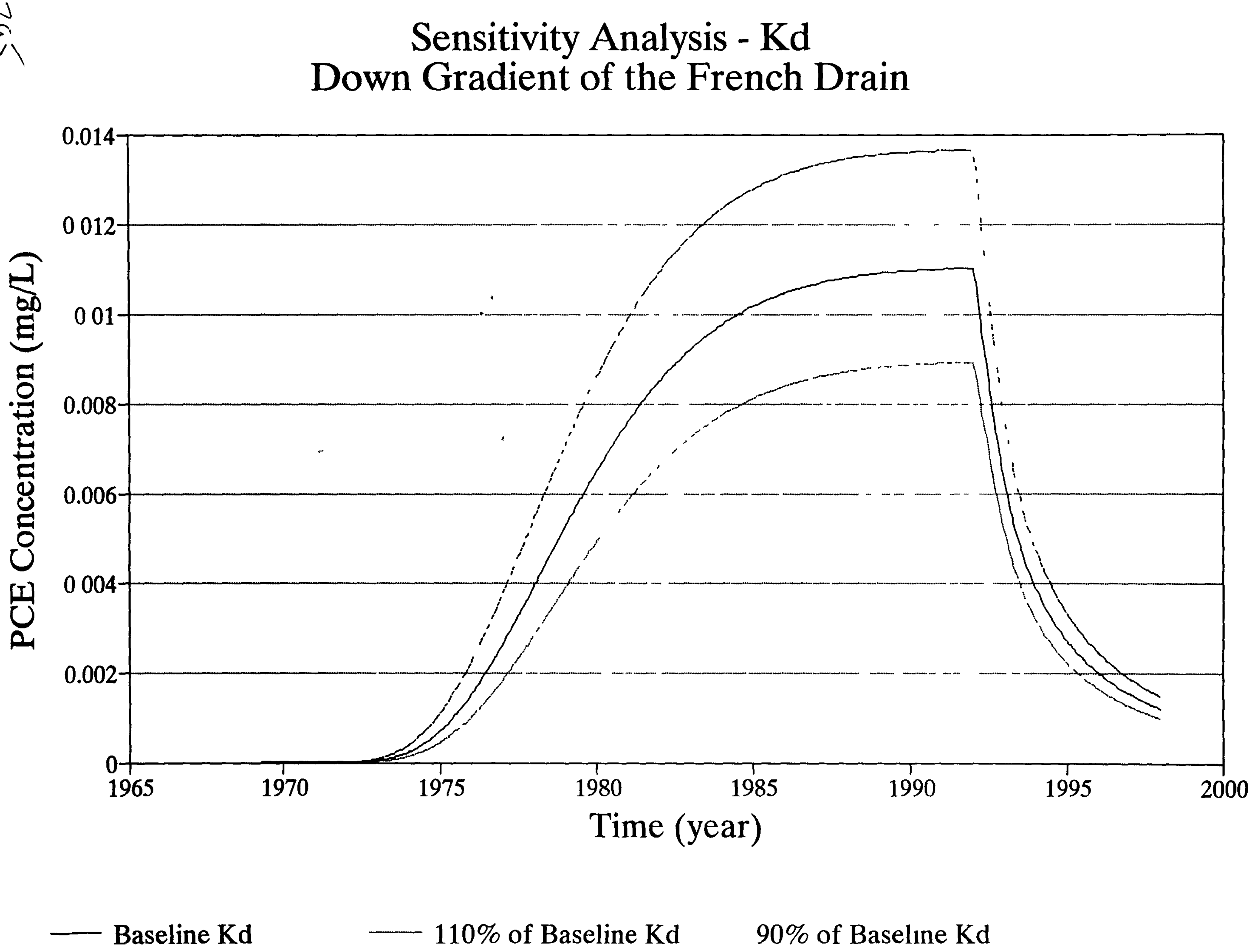

Figure B-39

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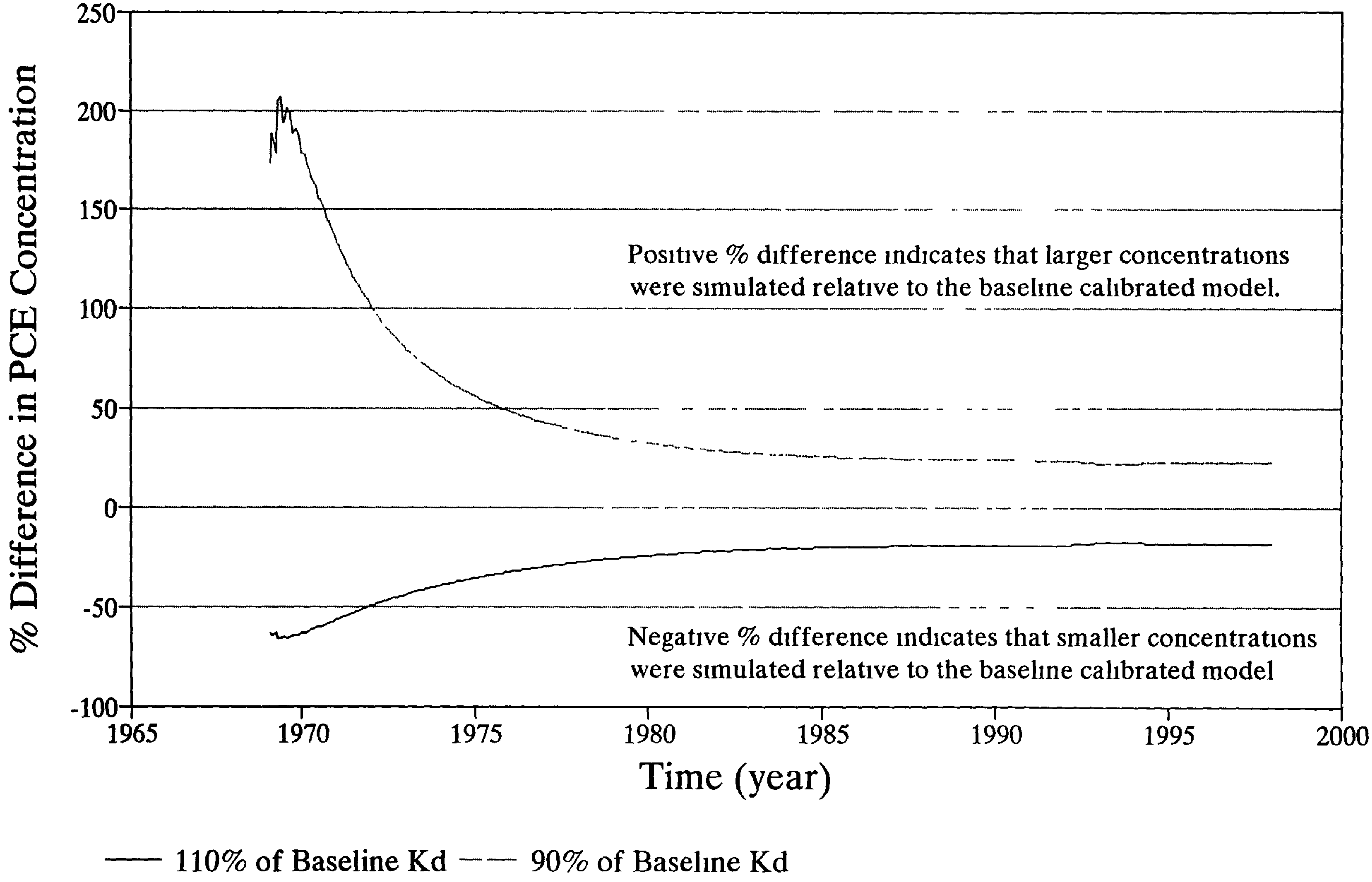
Sensitivity Analysis - Kd
Down Gradient of the French Drain



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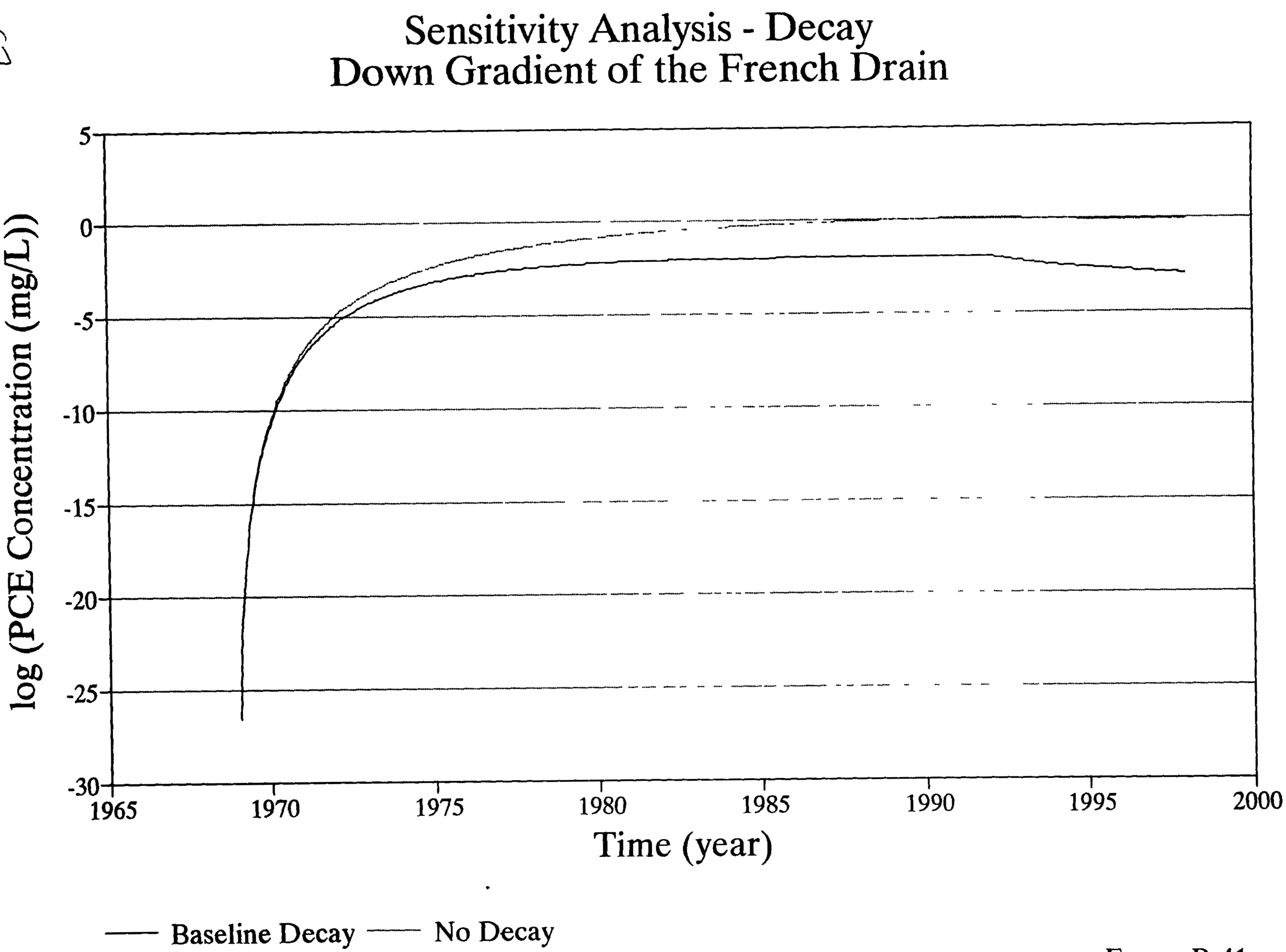

Figure B-41

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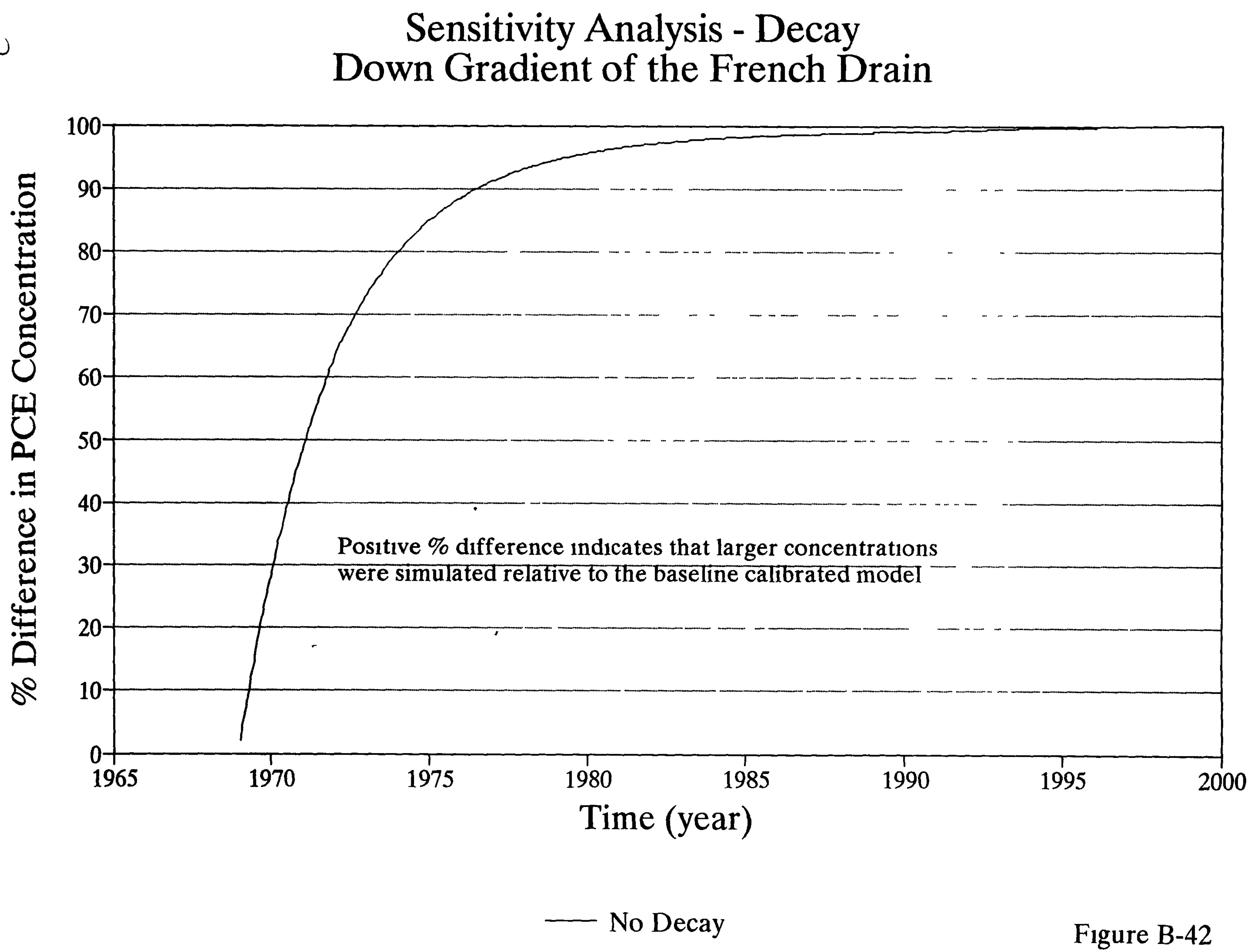

Figure B-42

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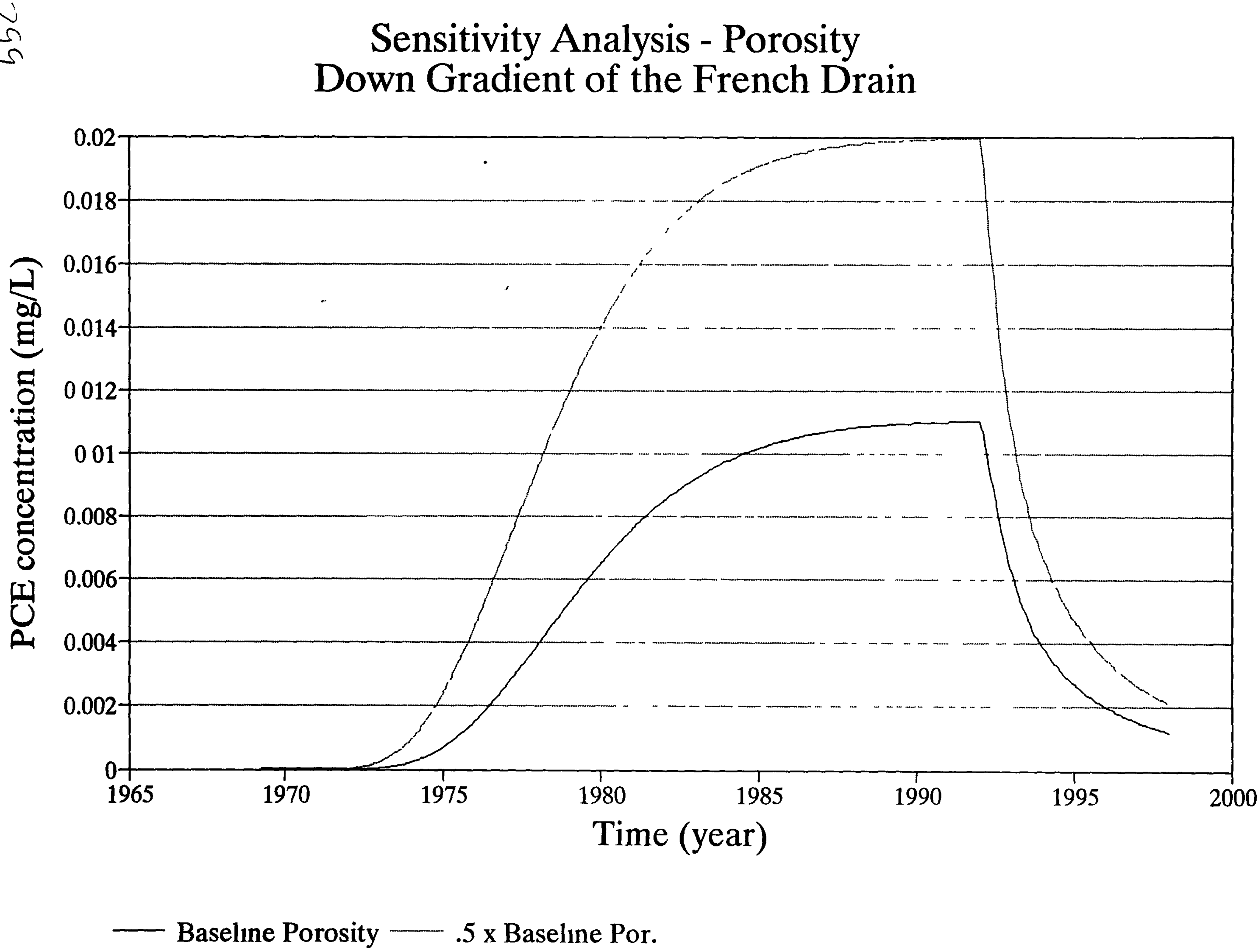

Figure B-43

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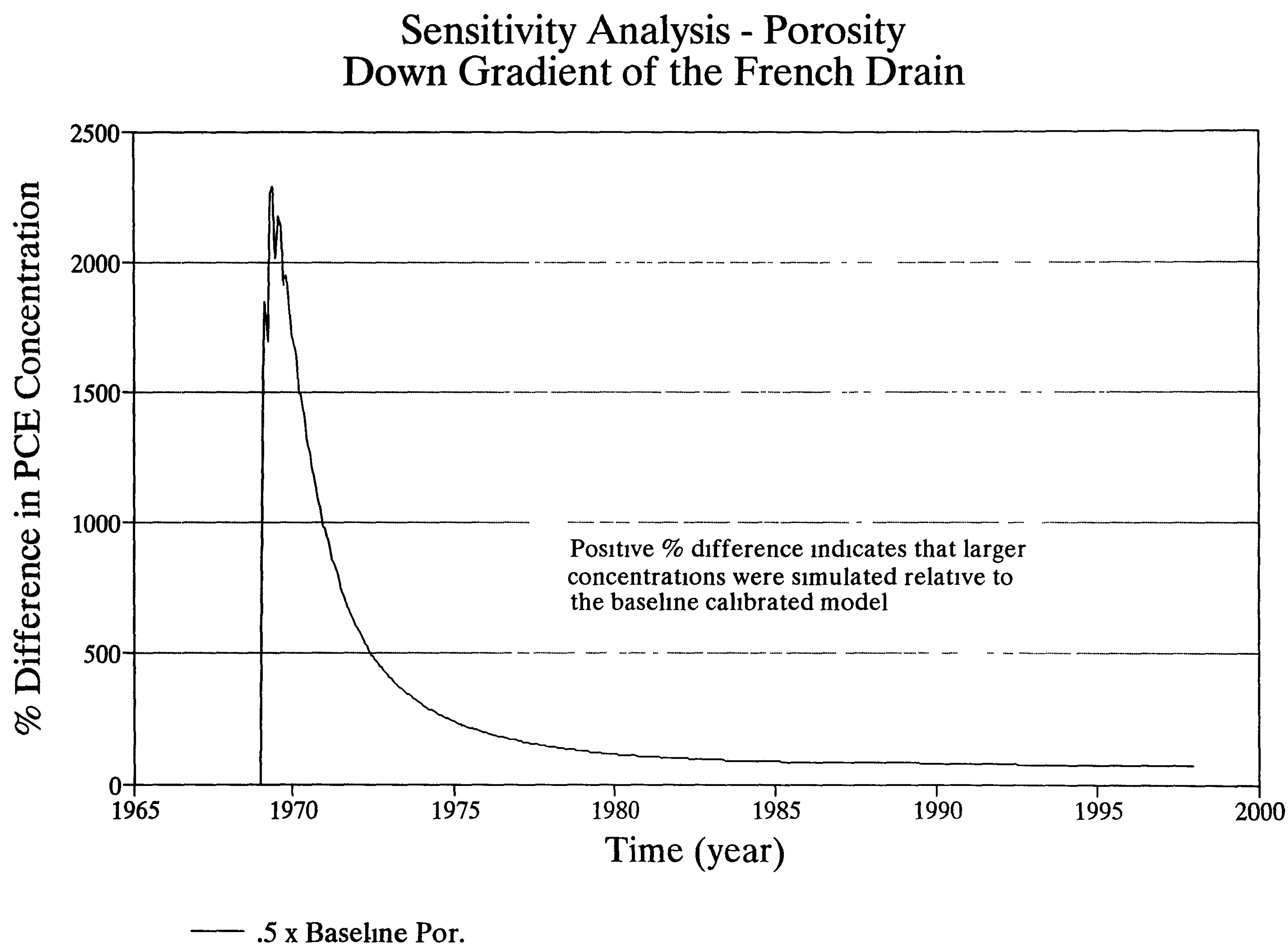

Figure B-44

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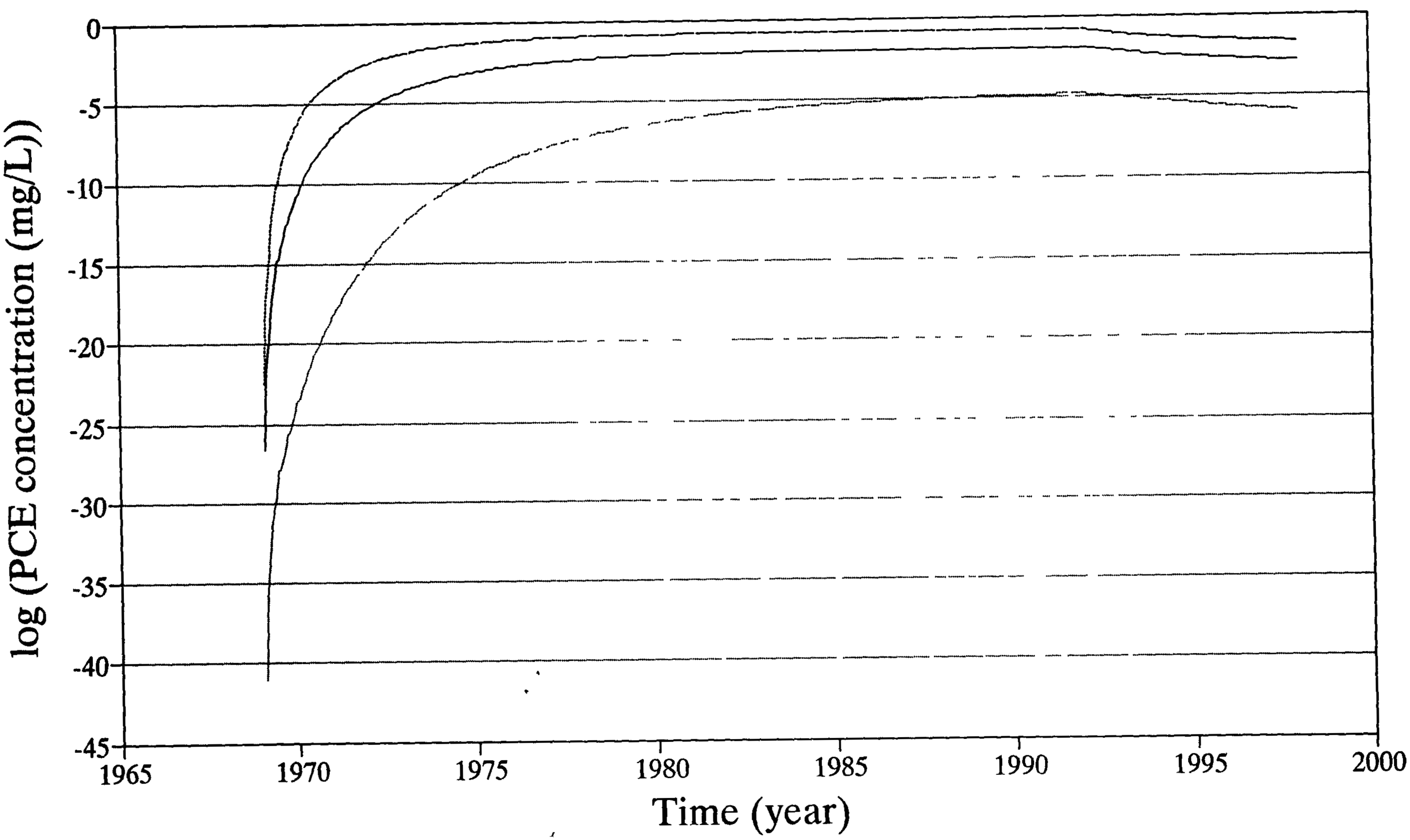
Sensitivity Analysis - Hydraulic Cond. Down Gradient of the French Drain



—— Baseline Kxx —— Lower Kxx Higher Kxx

* See Table B-3

Figure B-45

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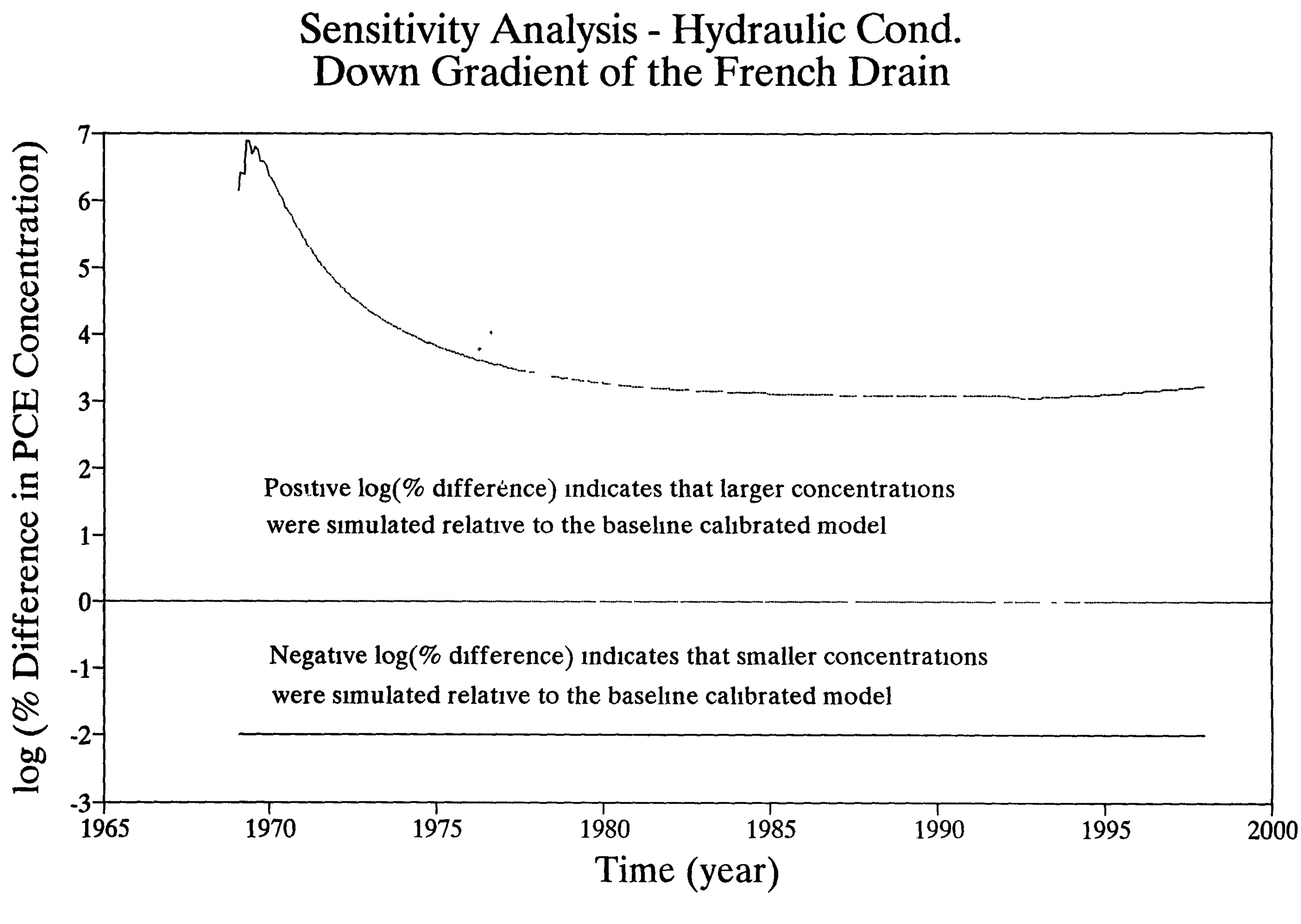

* See Table B-3

Figure B-46

303

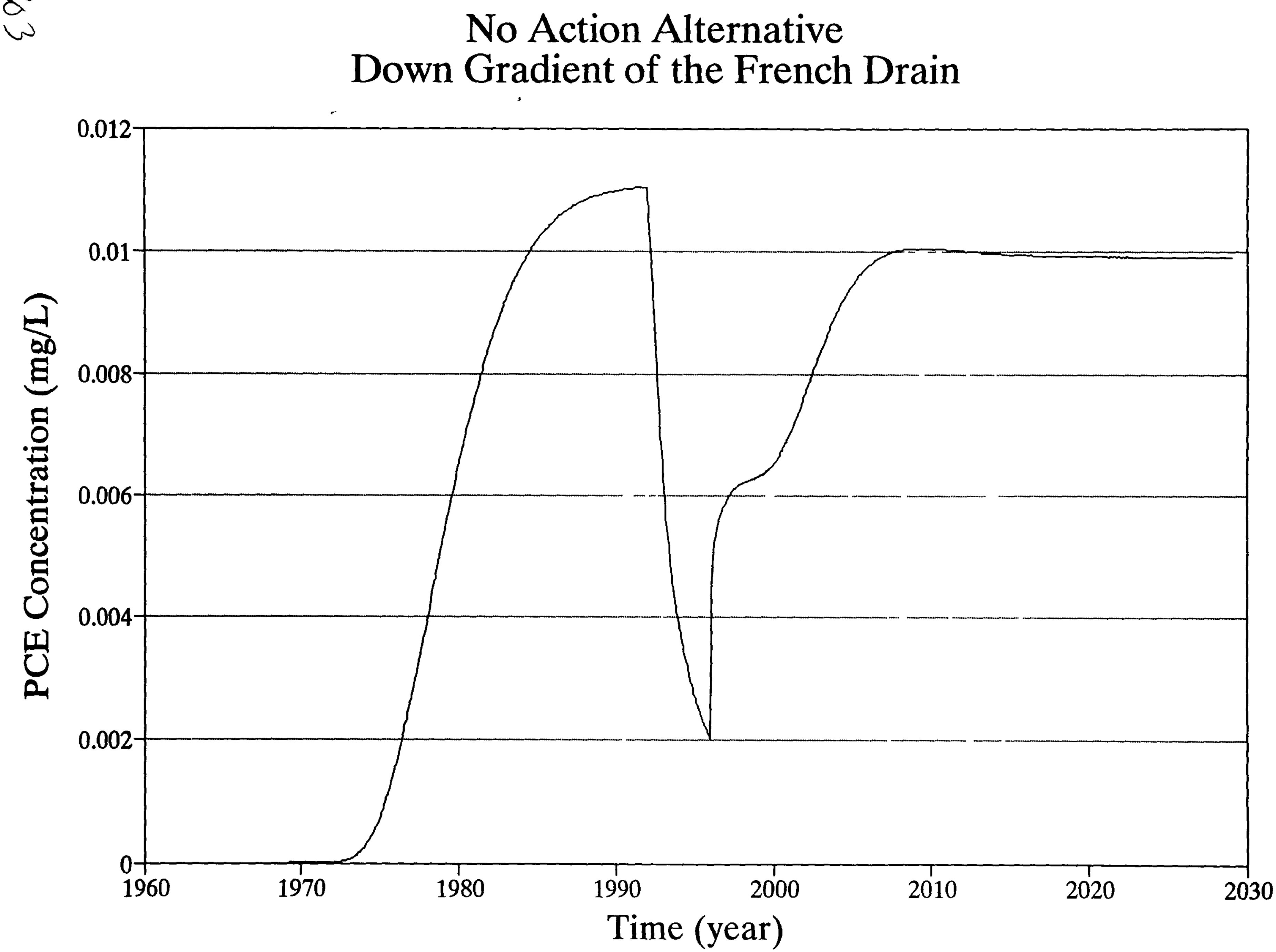

Figure B-47

No Action Alternative
Woman Creek

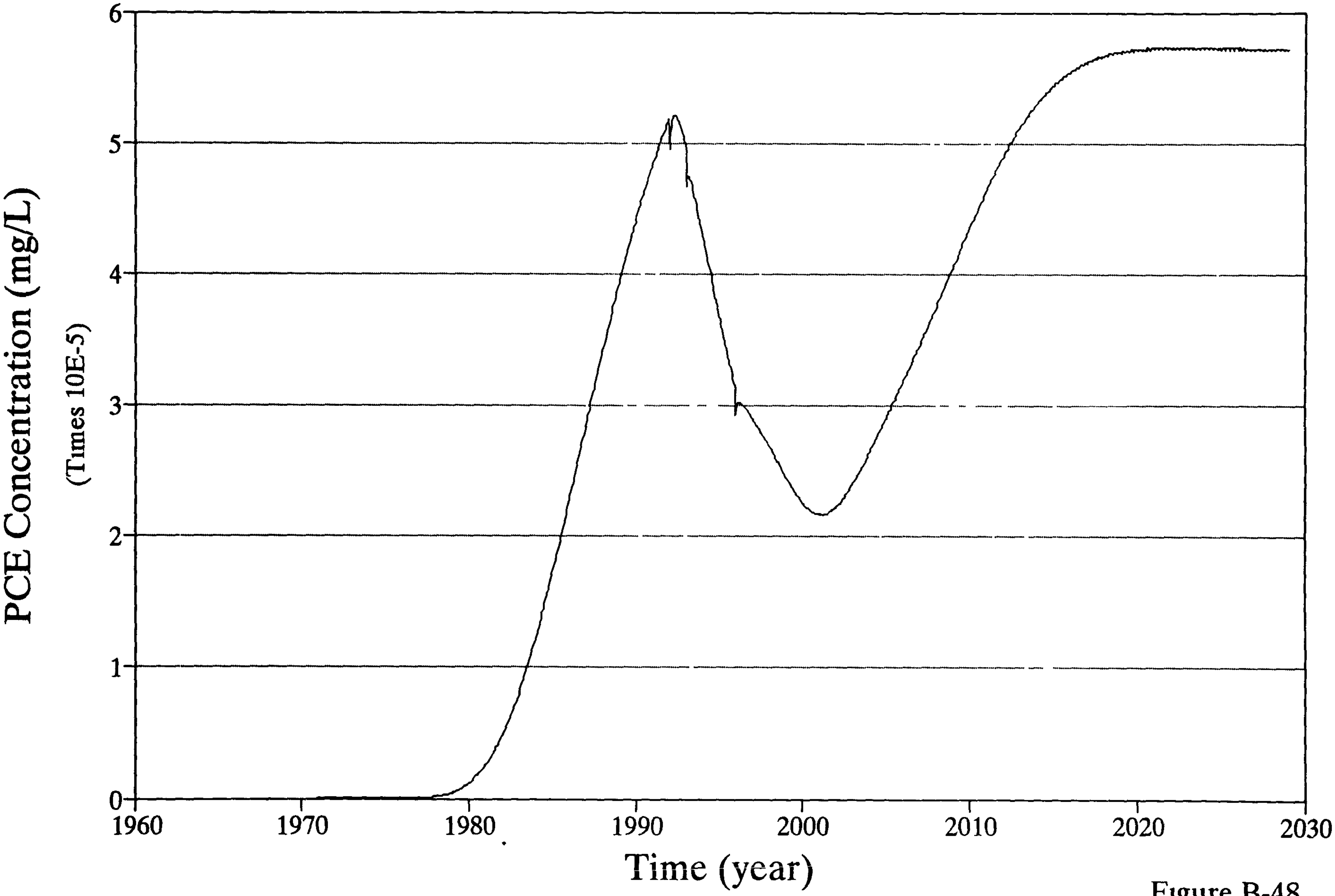

Figure B-48

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No Action Alternative
Down Gradient of the French Drain

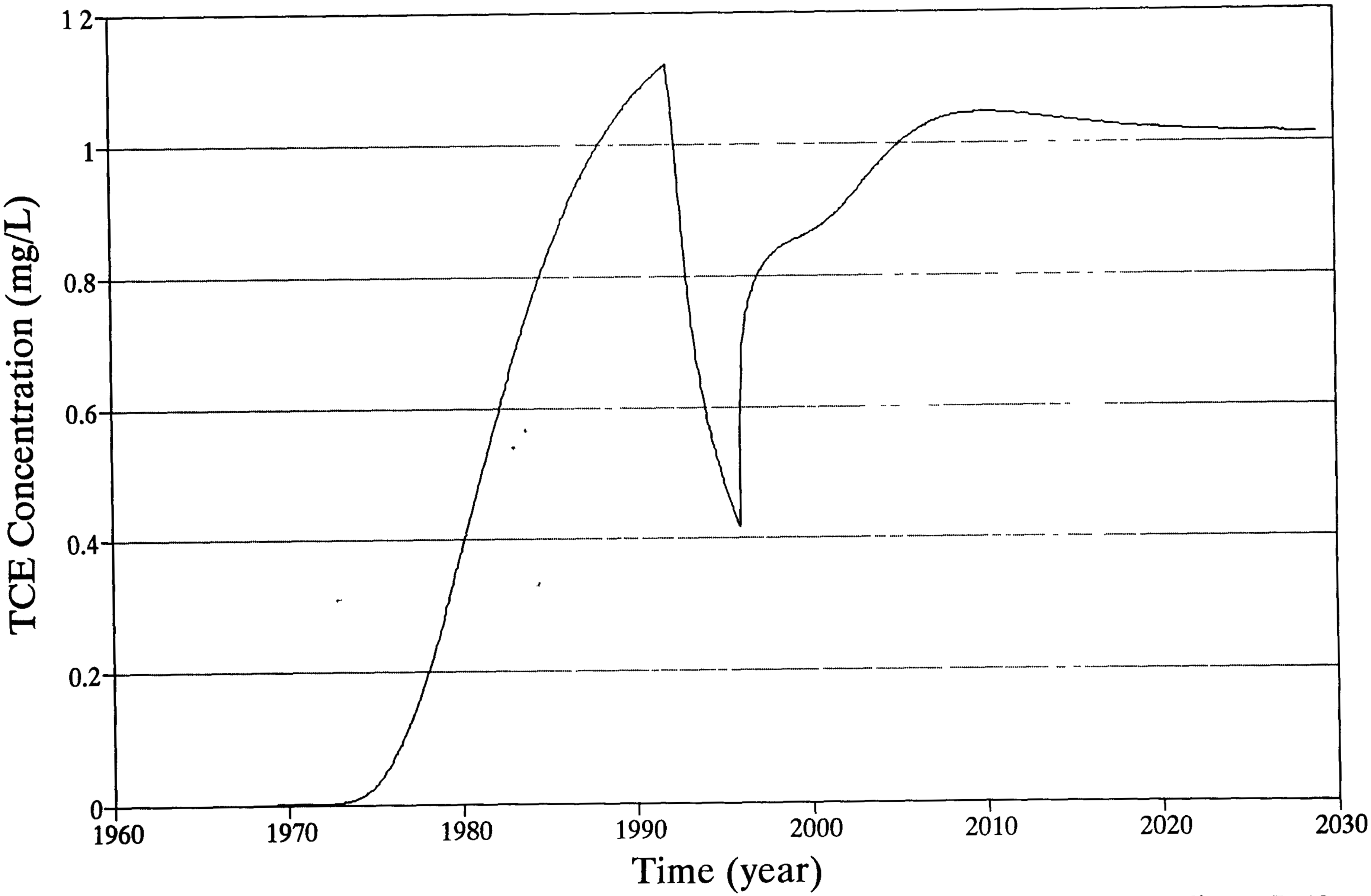

Figure B-49

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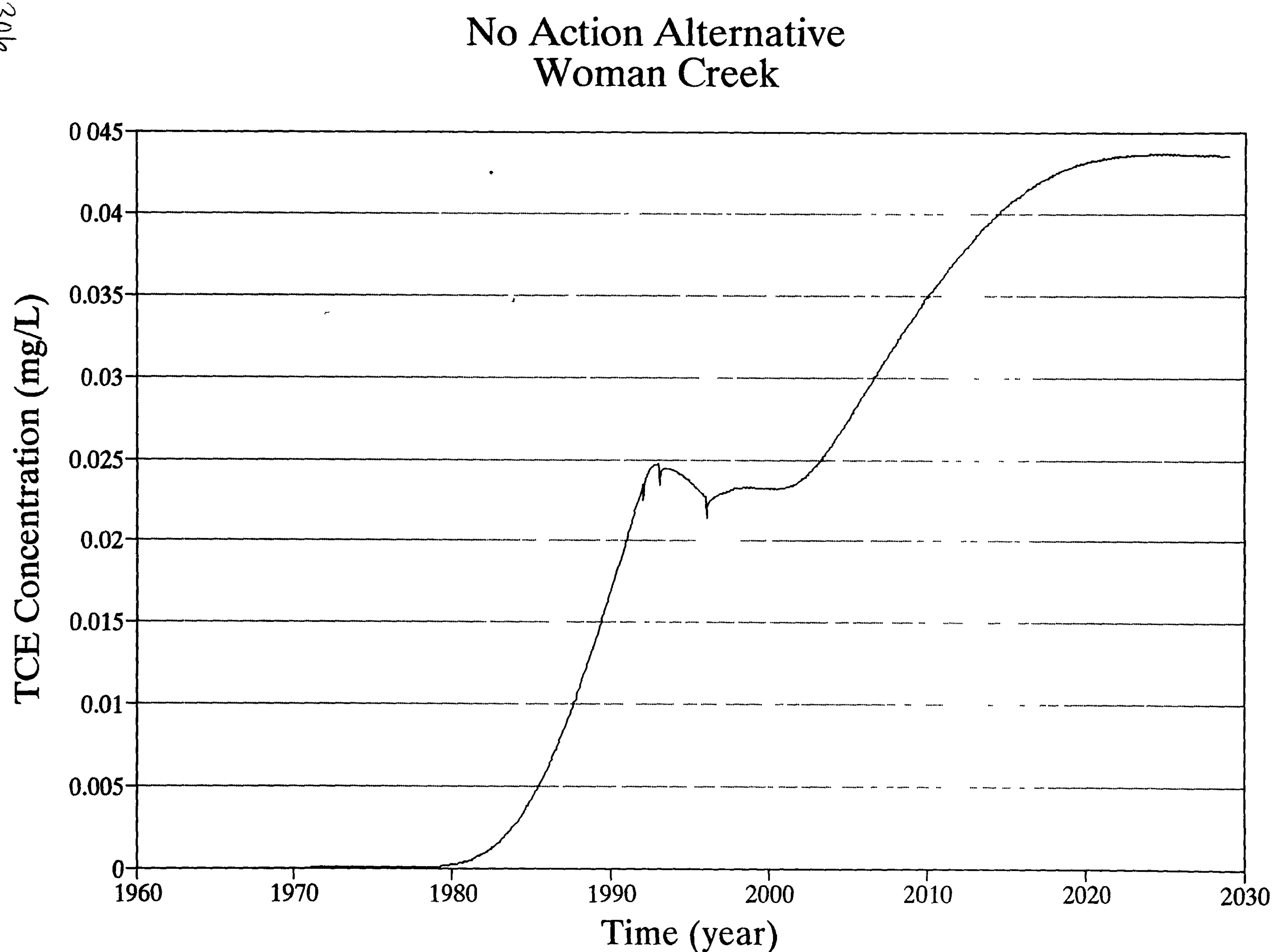

Figure B-50

307

No Action Alternative
Down Gradient of the French Drain

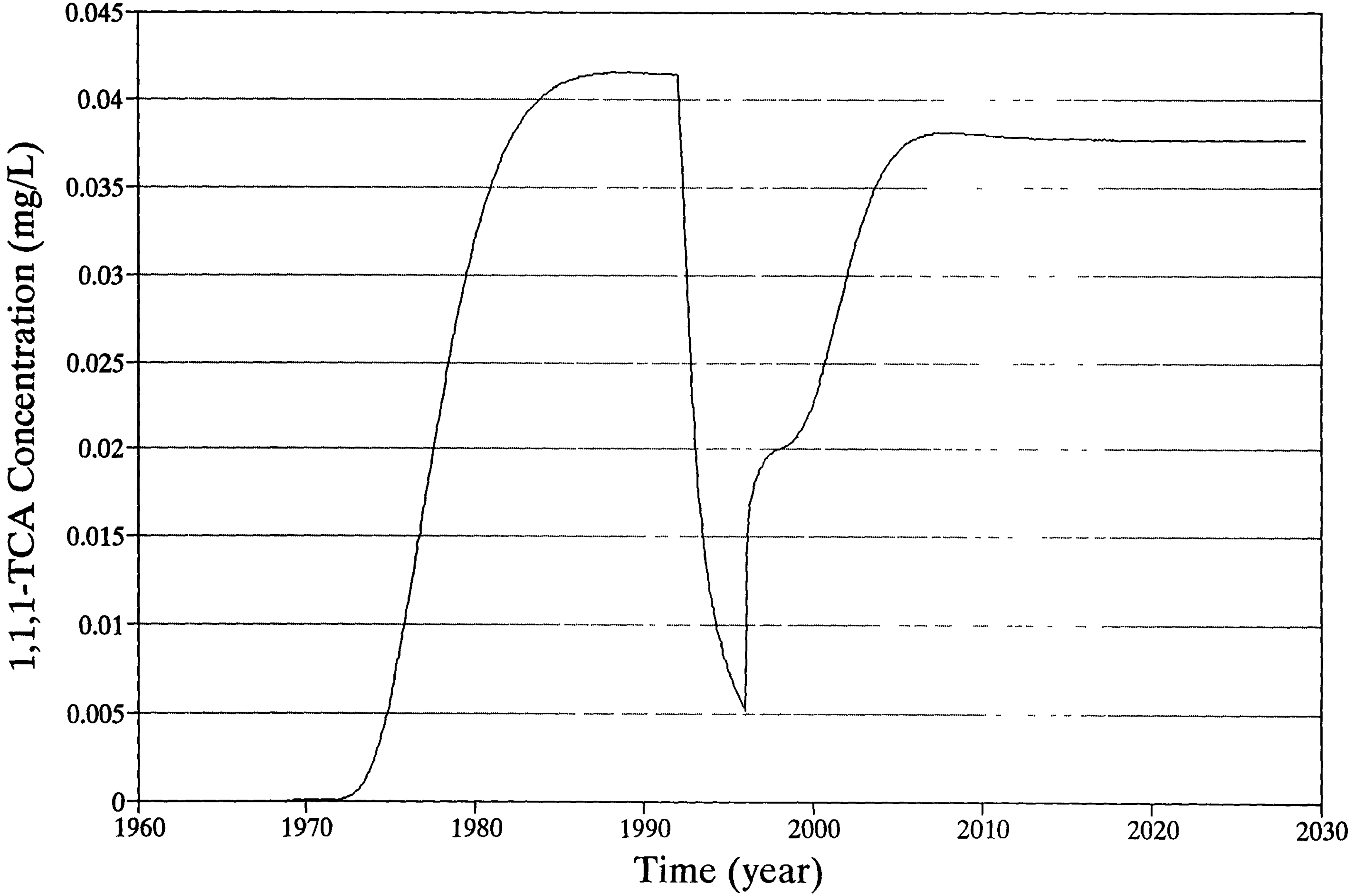

Figure B-51

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No Action Alternative
Woman Creek

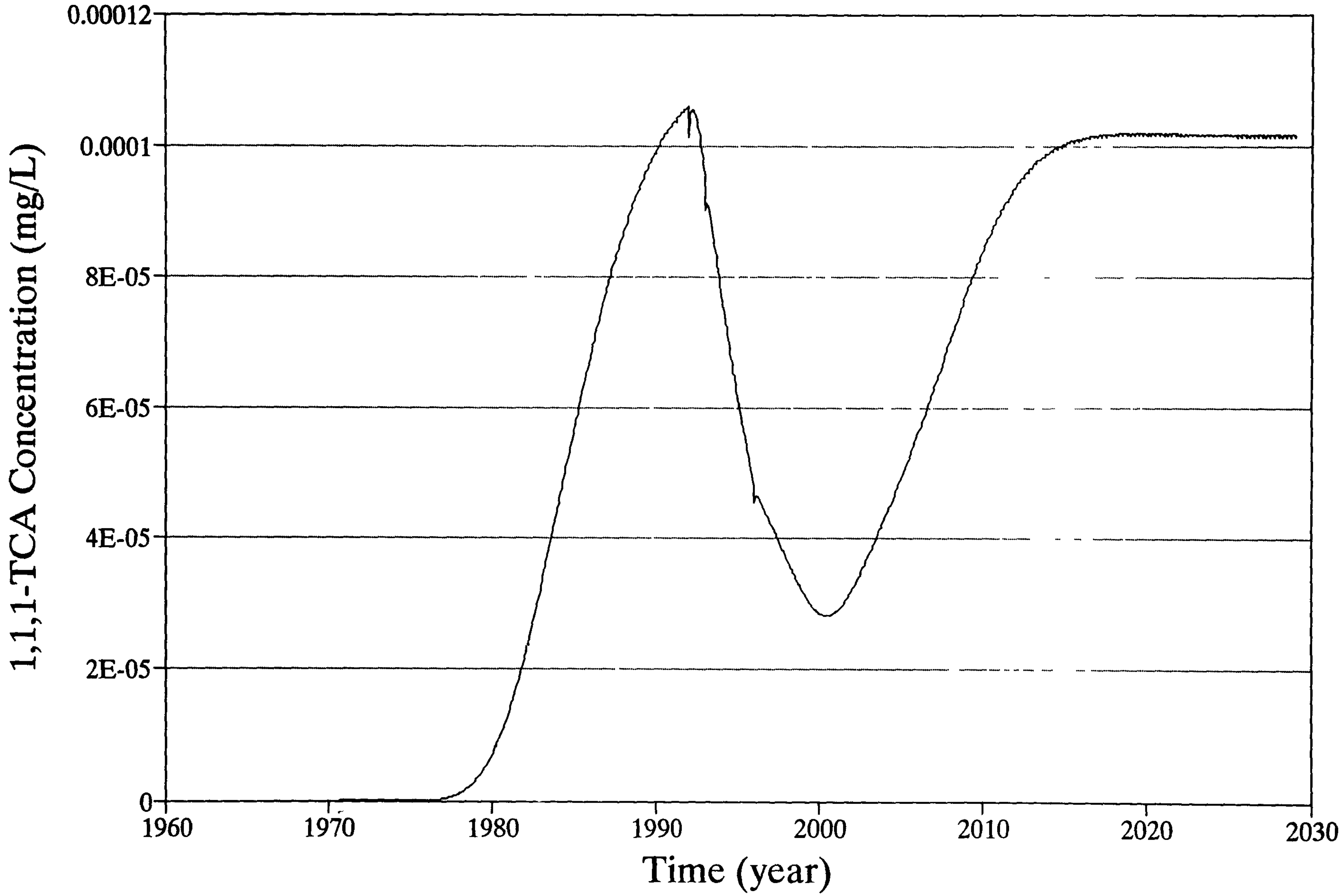

Figure B-52

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No Action Alternative
Down Gradient of the French Drain

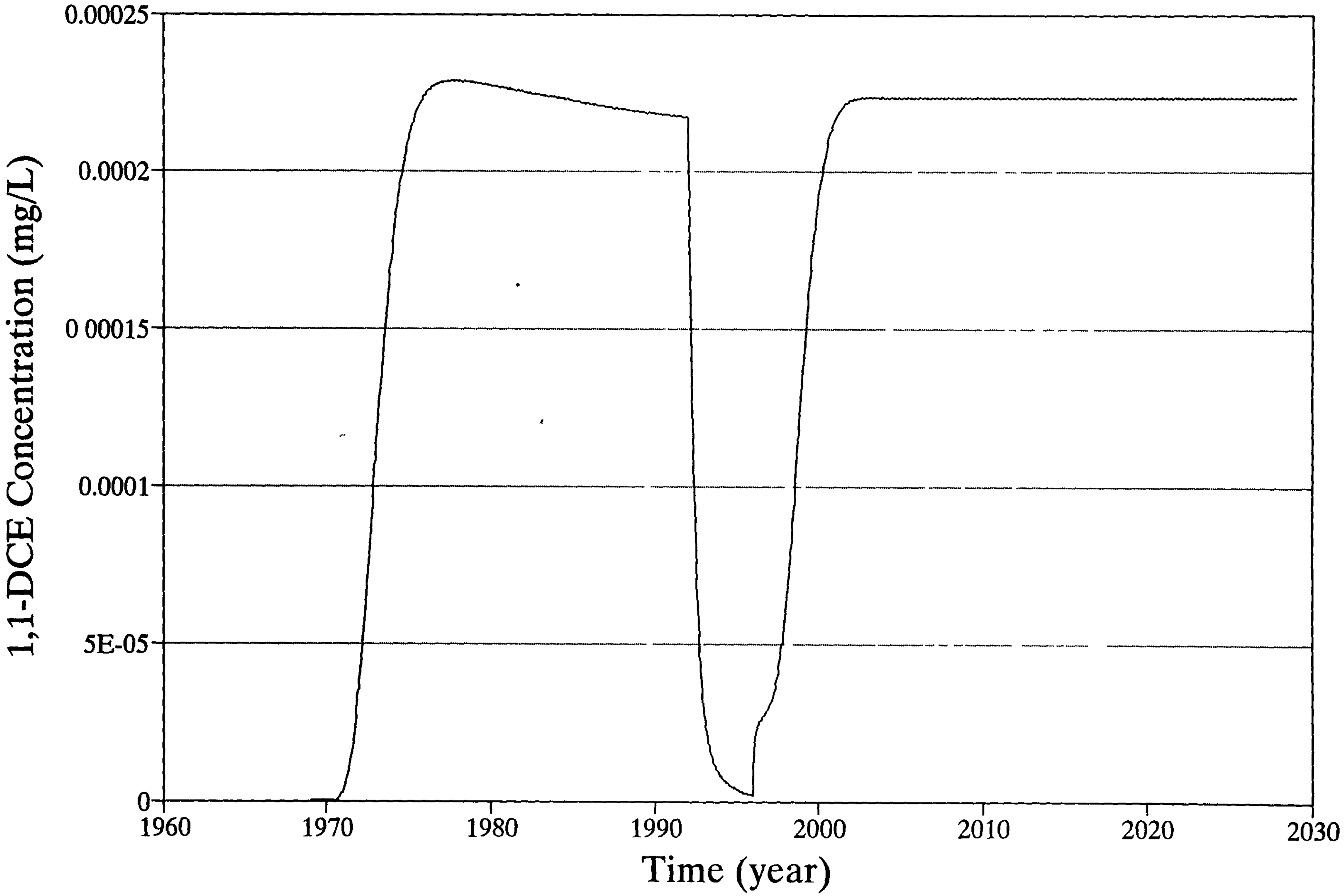

Figure B-53

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No Action Alternative
Woman Creek

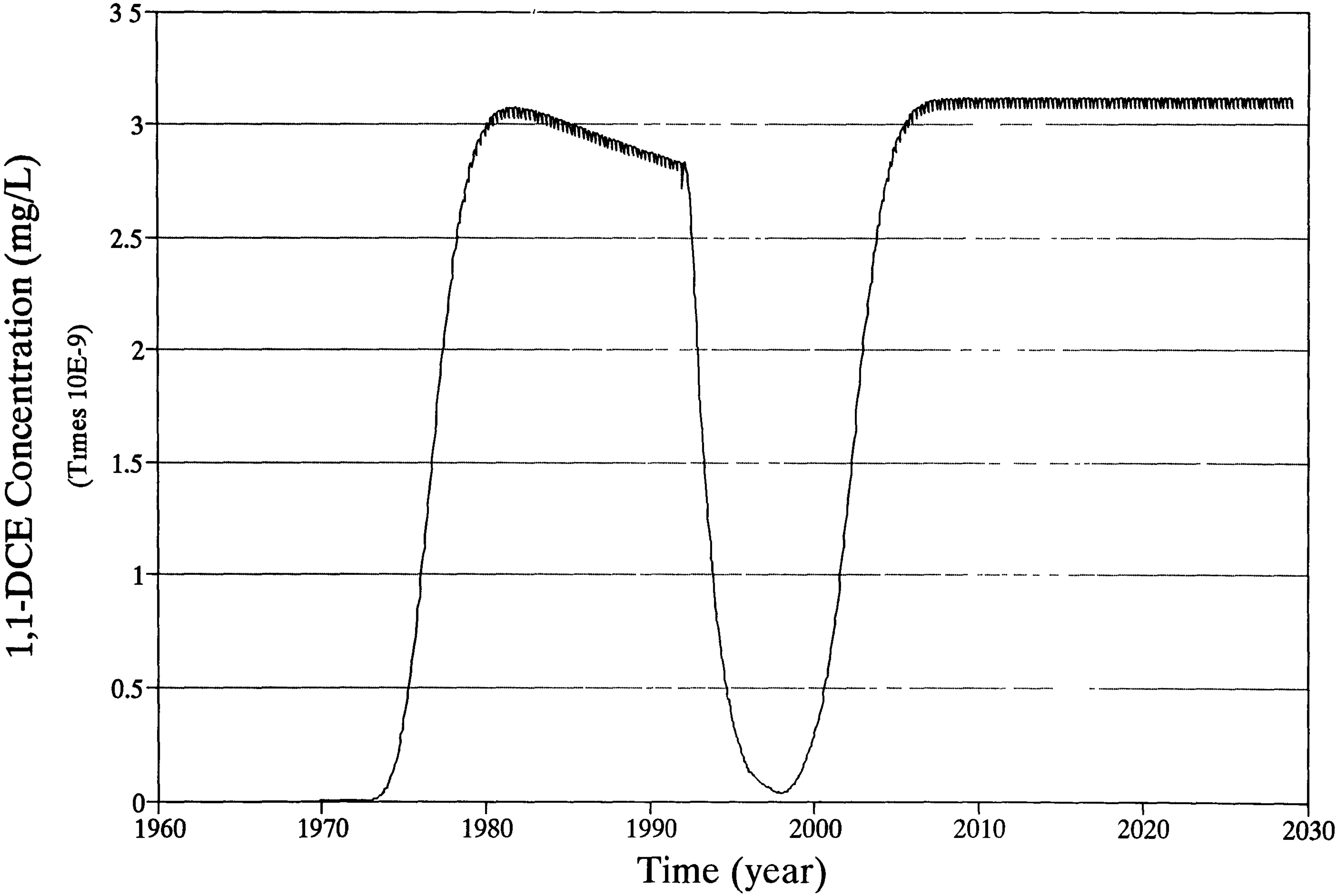

Figure B-54

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No Action Alternative
Down Gradient of the French Drain

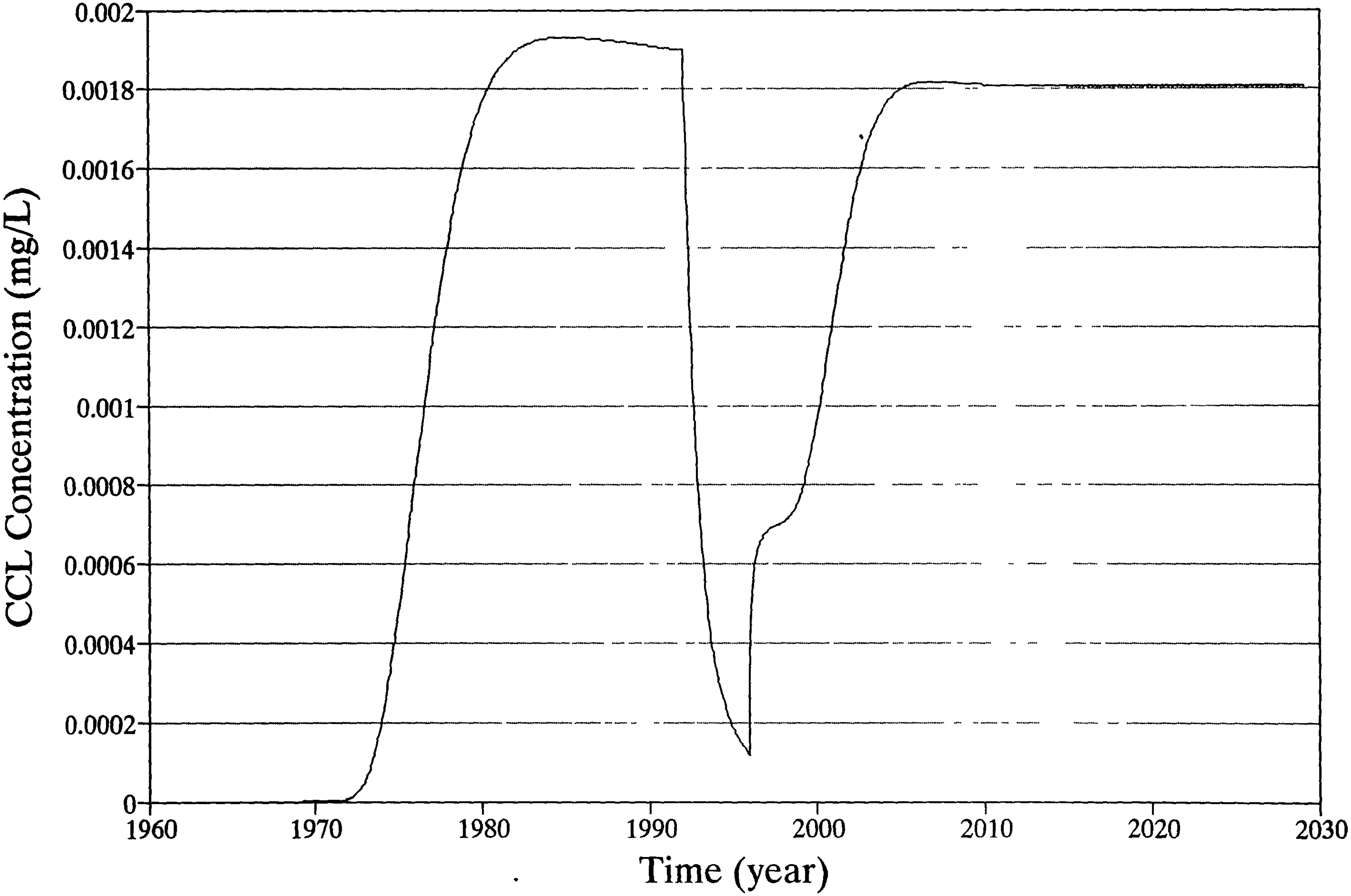

Figure B-55

No Action Alternative
Woman Creek

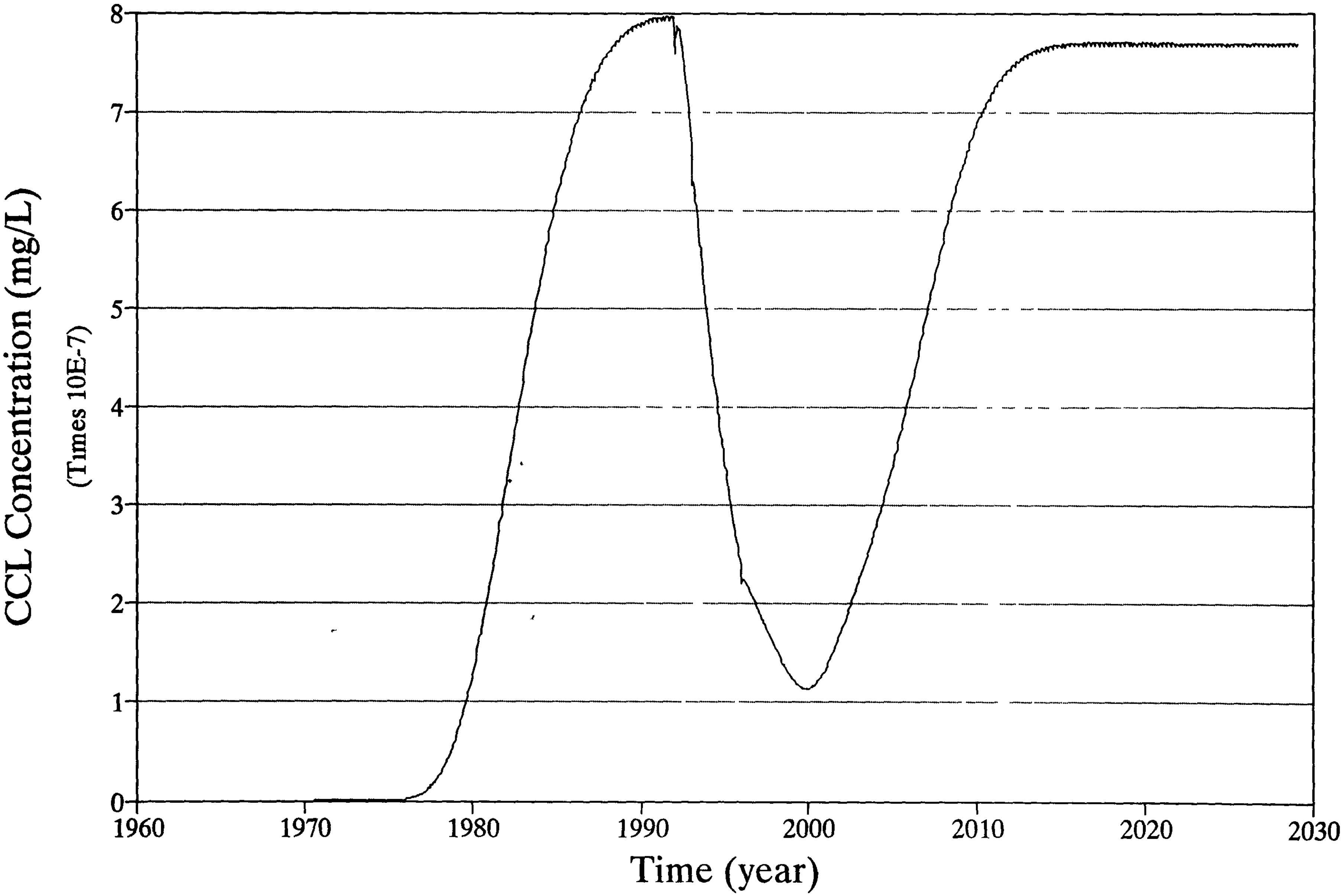

Figure B-56

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313

Institutional Control Alternative
Down Gradient of the French Drain

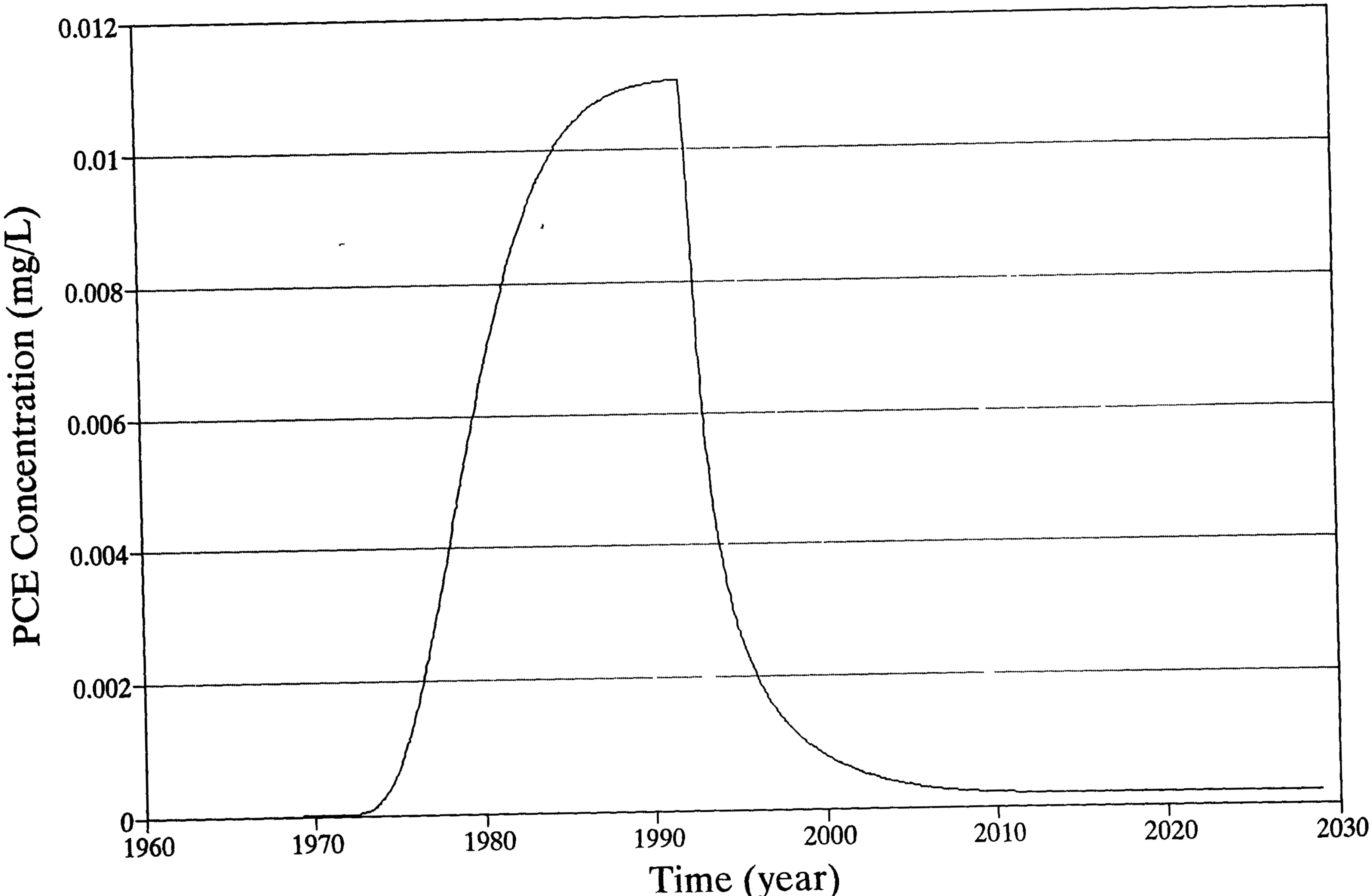

Figure B-57

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Institutional Control Alternative
Woman Creek

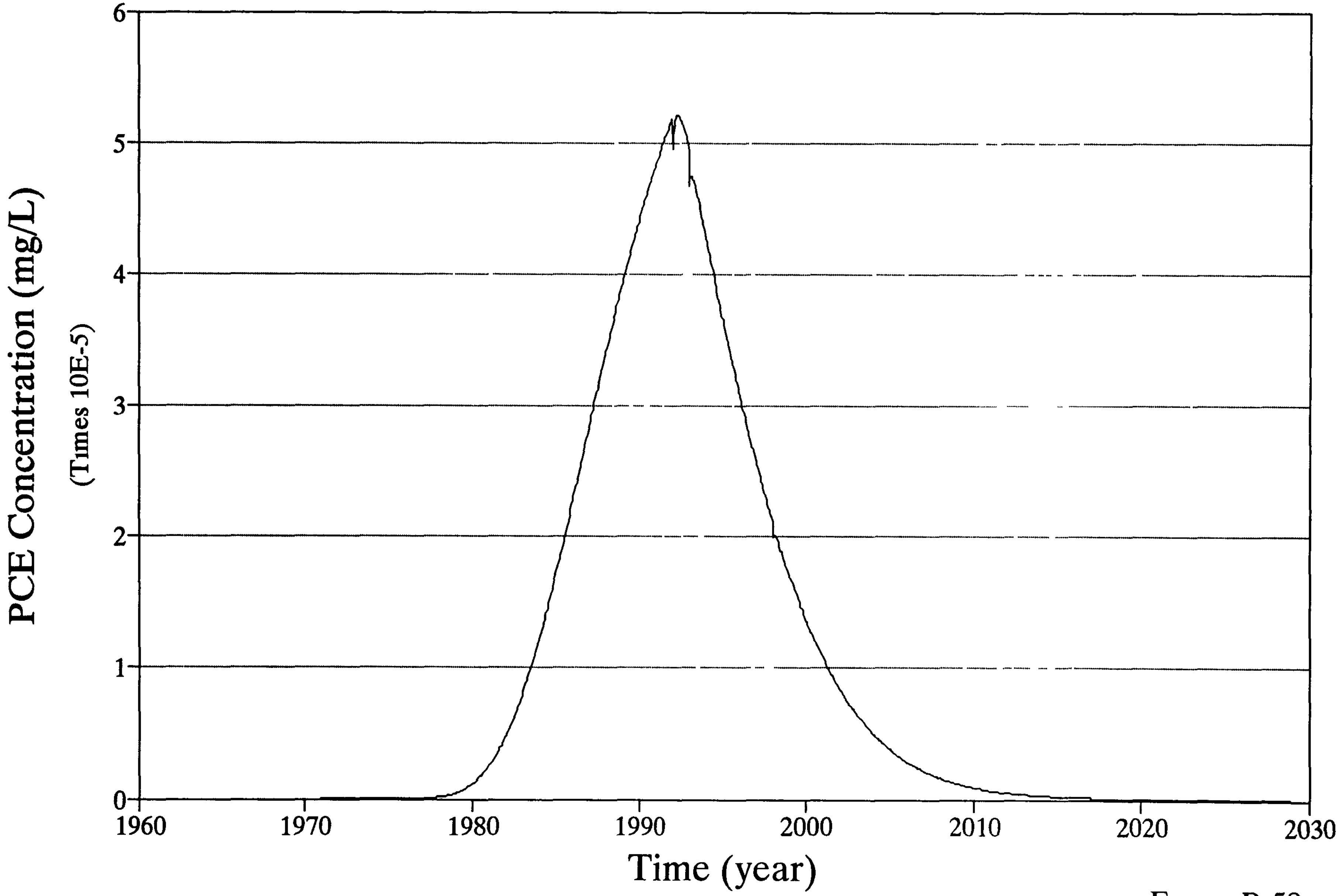

Figure B-58

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Institutional Control Alternative
Down Gradient of the French Drain

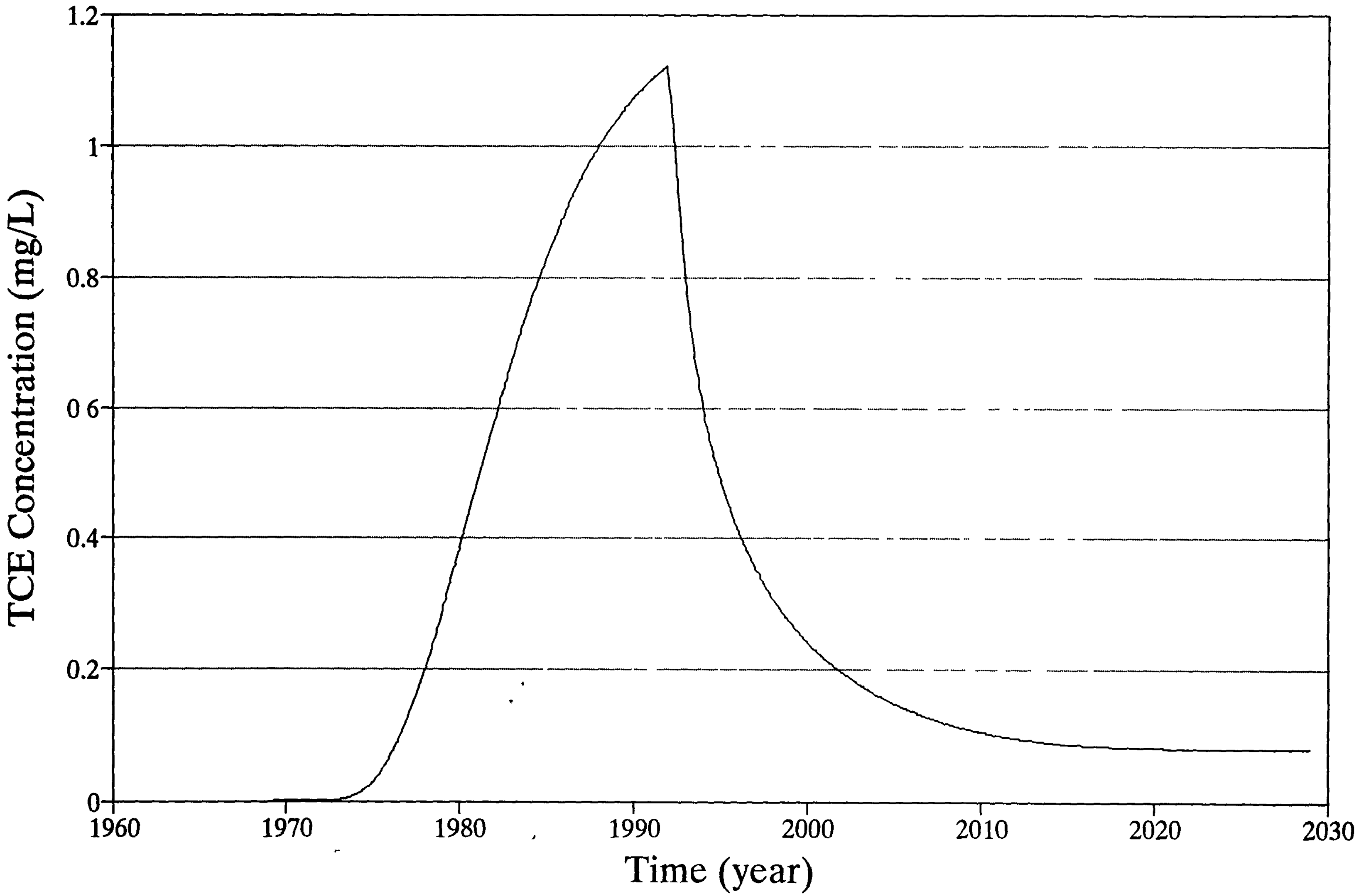

Figure B-59

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Institutional Control Alternative
Woman Creek

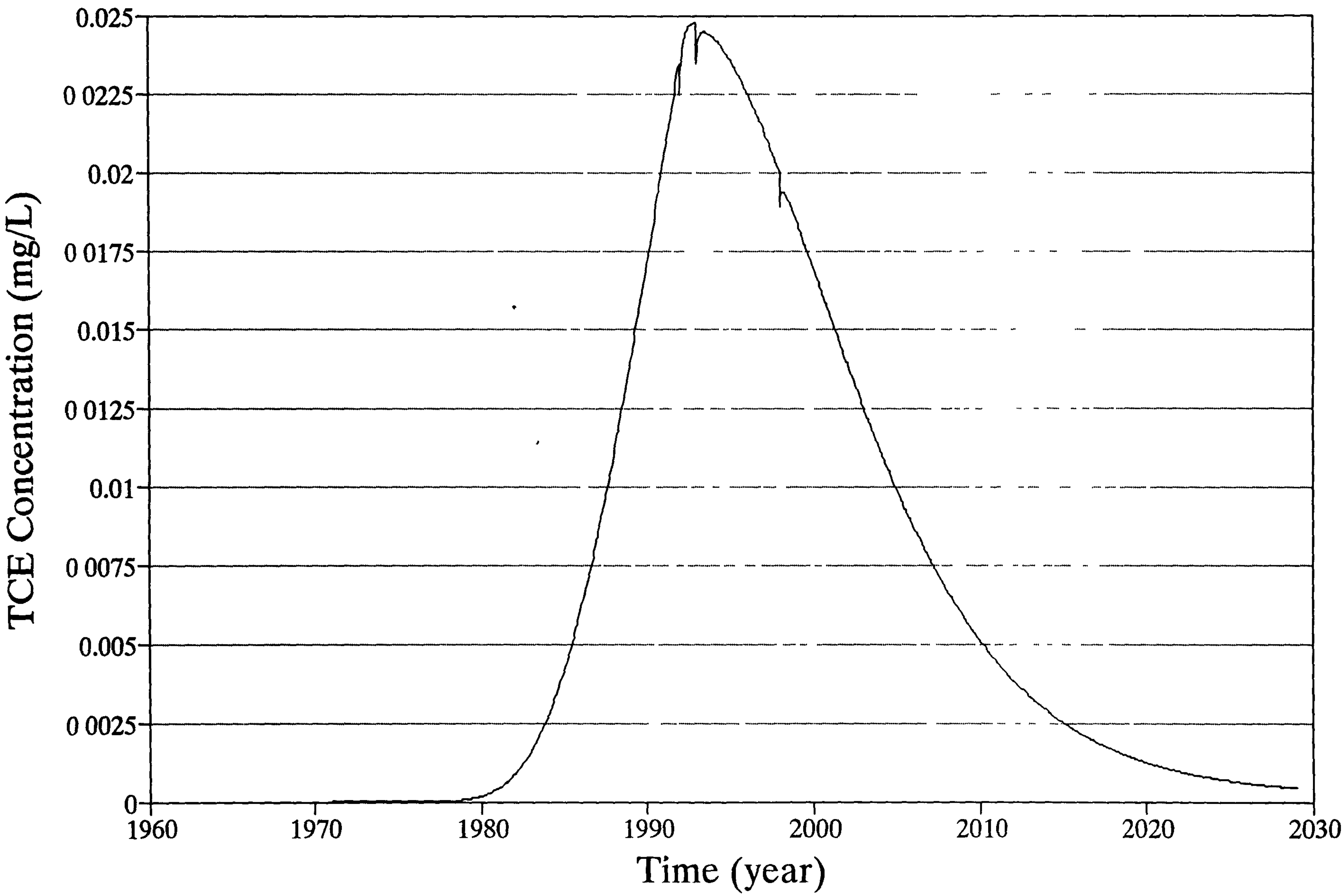

Figure B-60

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Institutional Control Alternative
Down Gradient of the French Drain

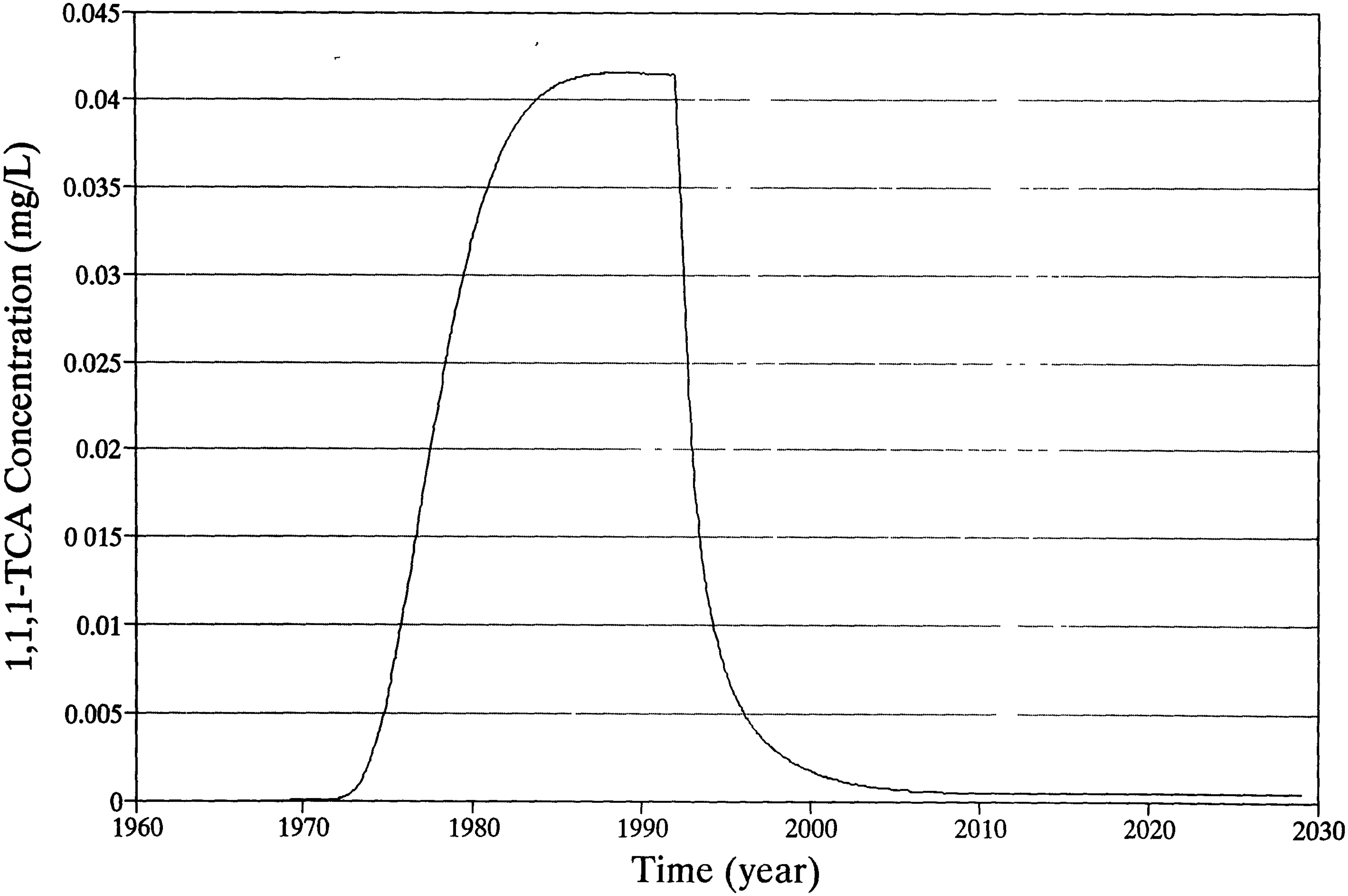

Figure B-61

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Institutional Control Alternative
Woman Creek

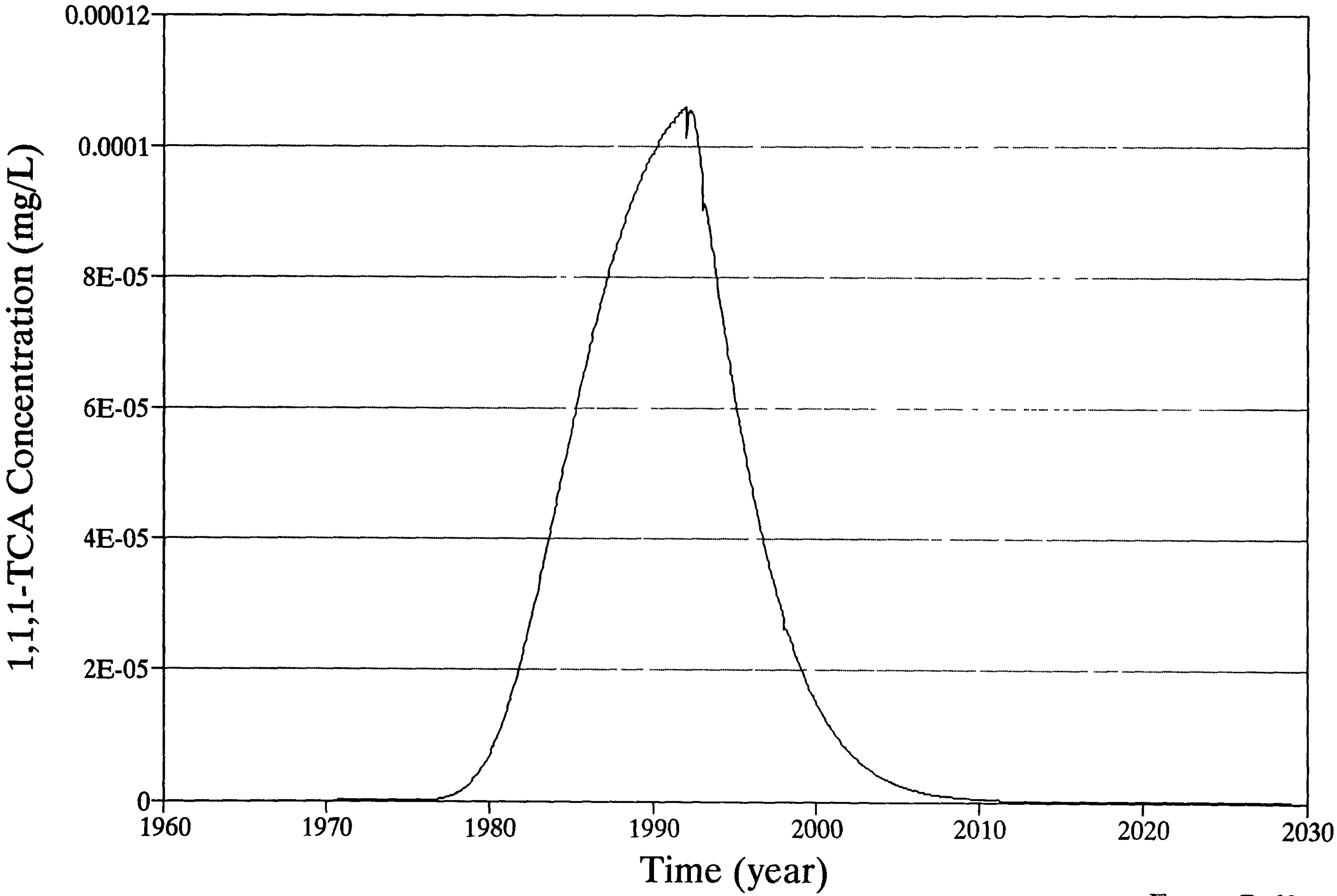

Figure B-62

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Institutional Control Alternative
Down Gradient of the French Drain

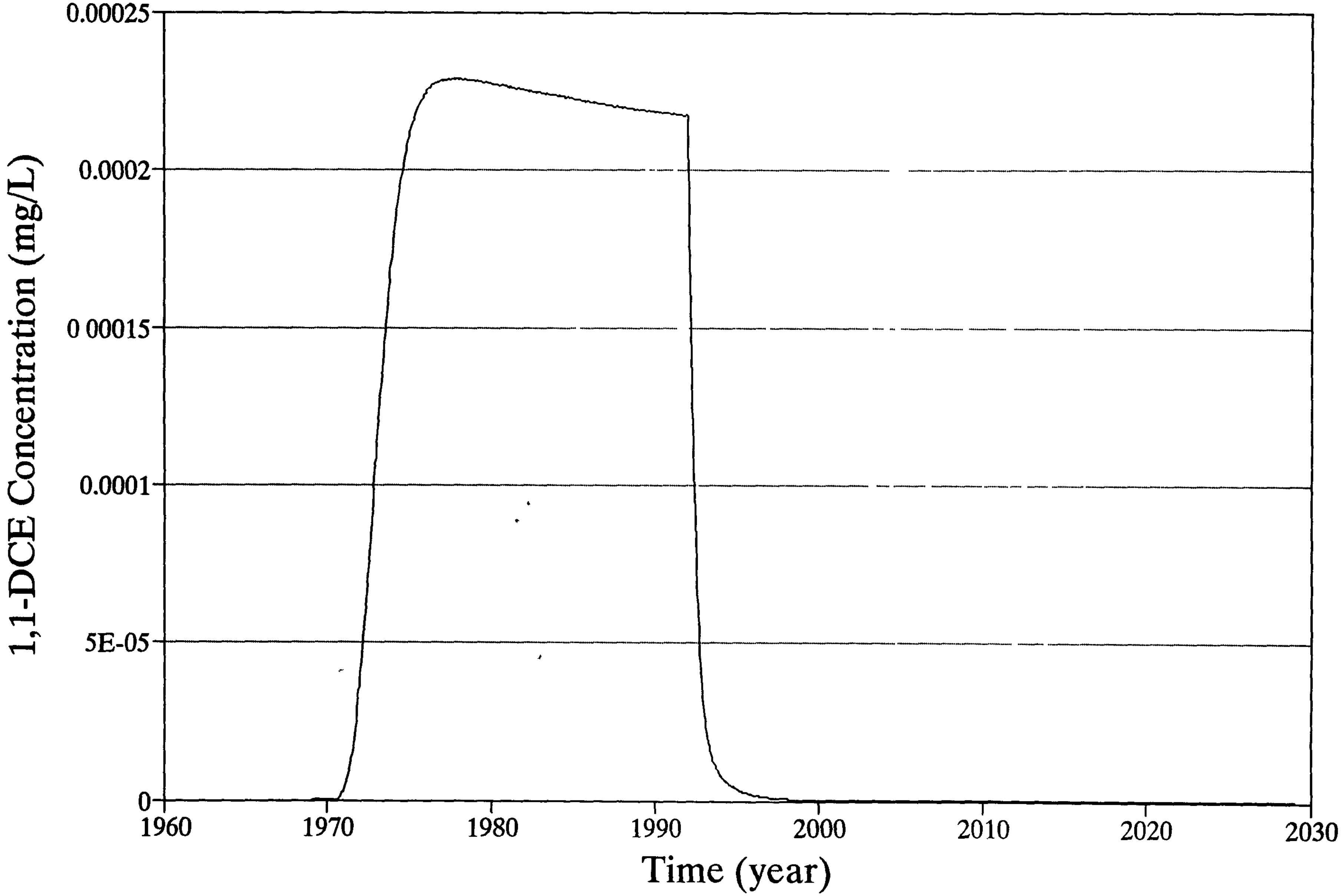

Figure B-63

Institutional Control Alternative
Woman Creek

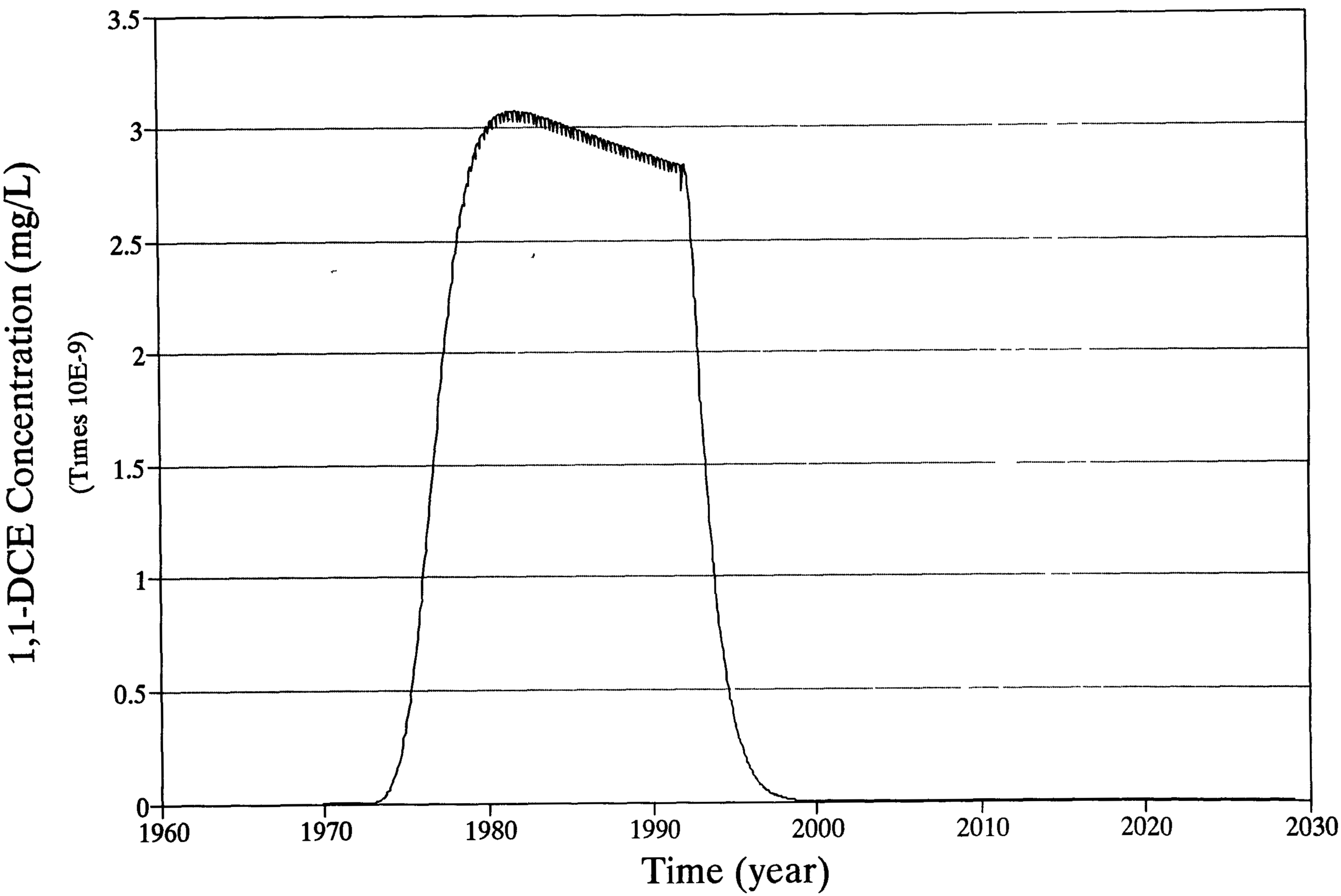

Figure B-64

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Institutional Control Alternative
Down Gradient of the French Drain

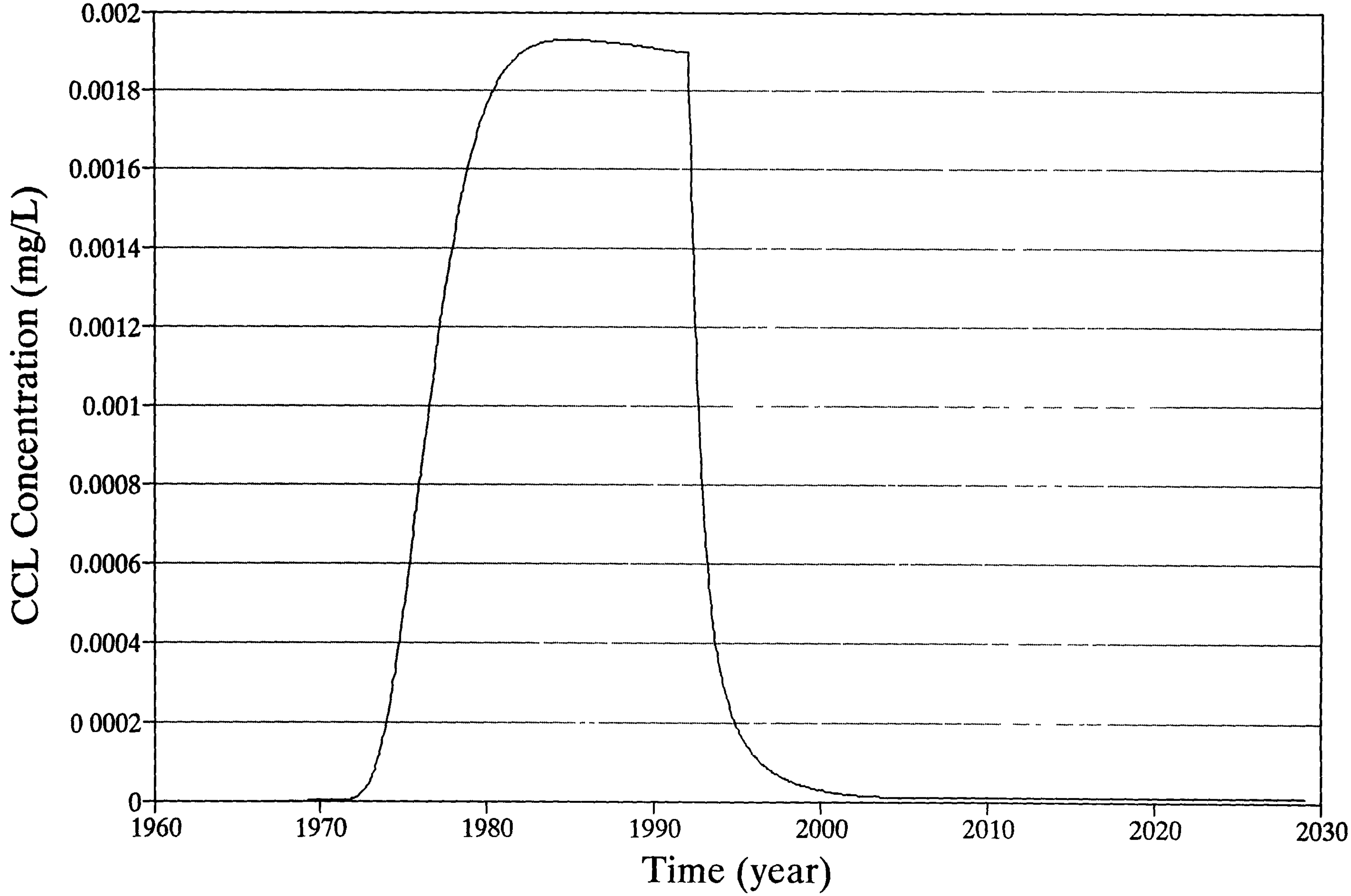

Figure B-65

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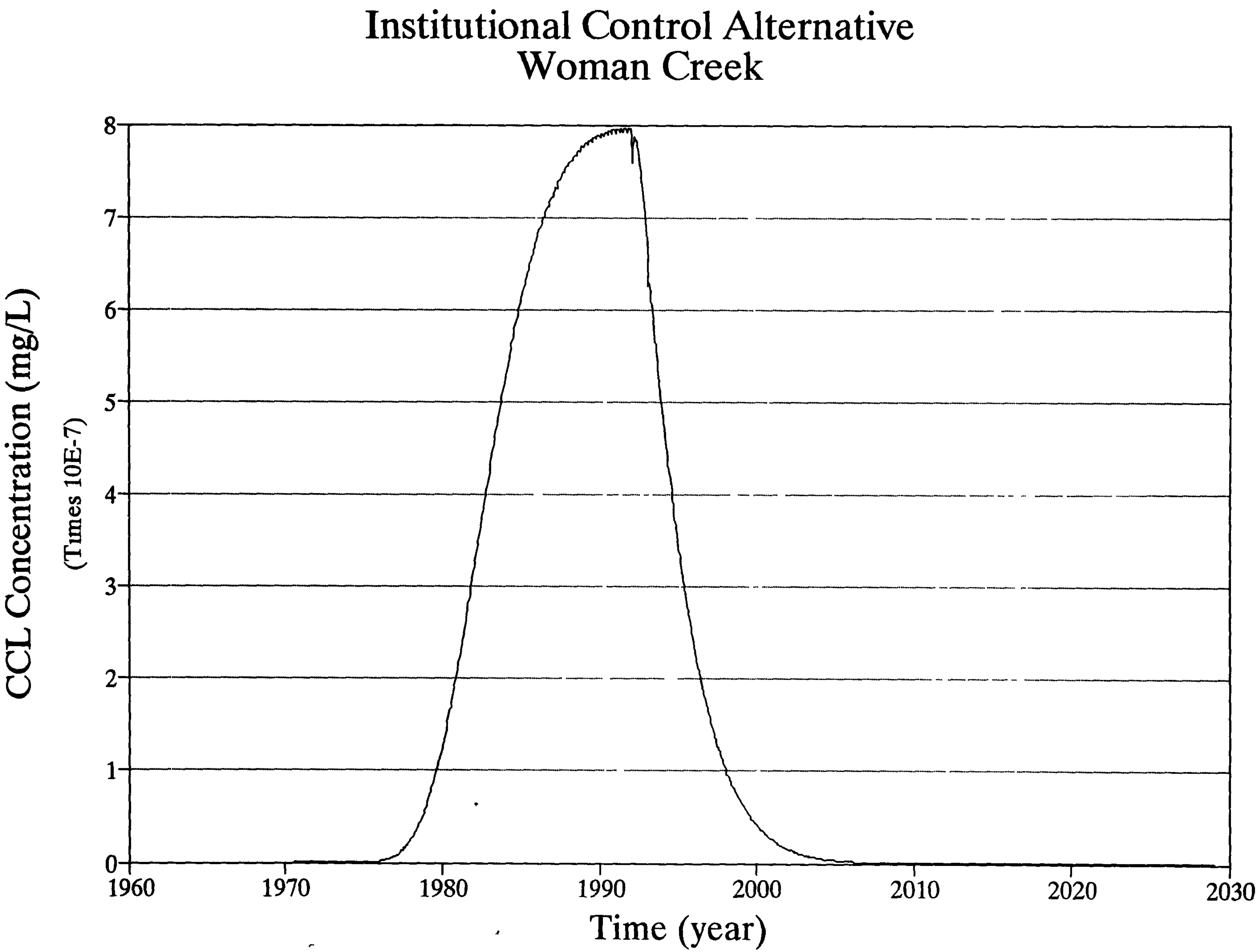

Figure B-66

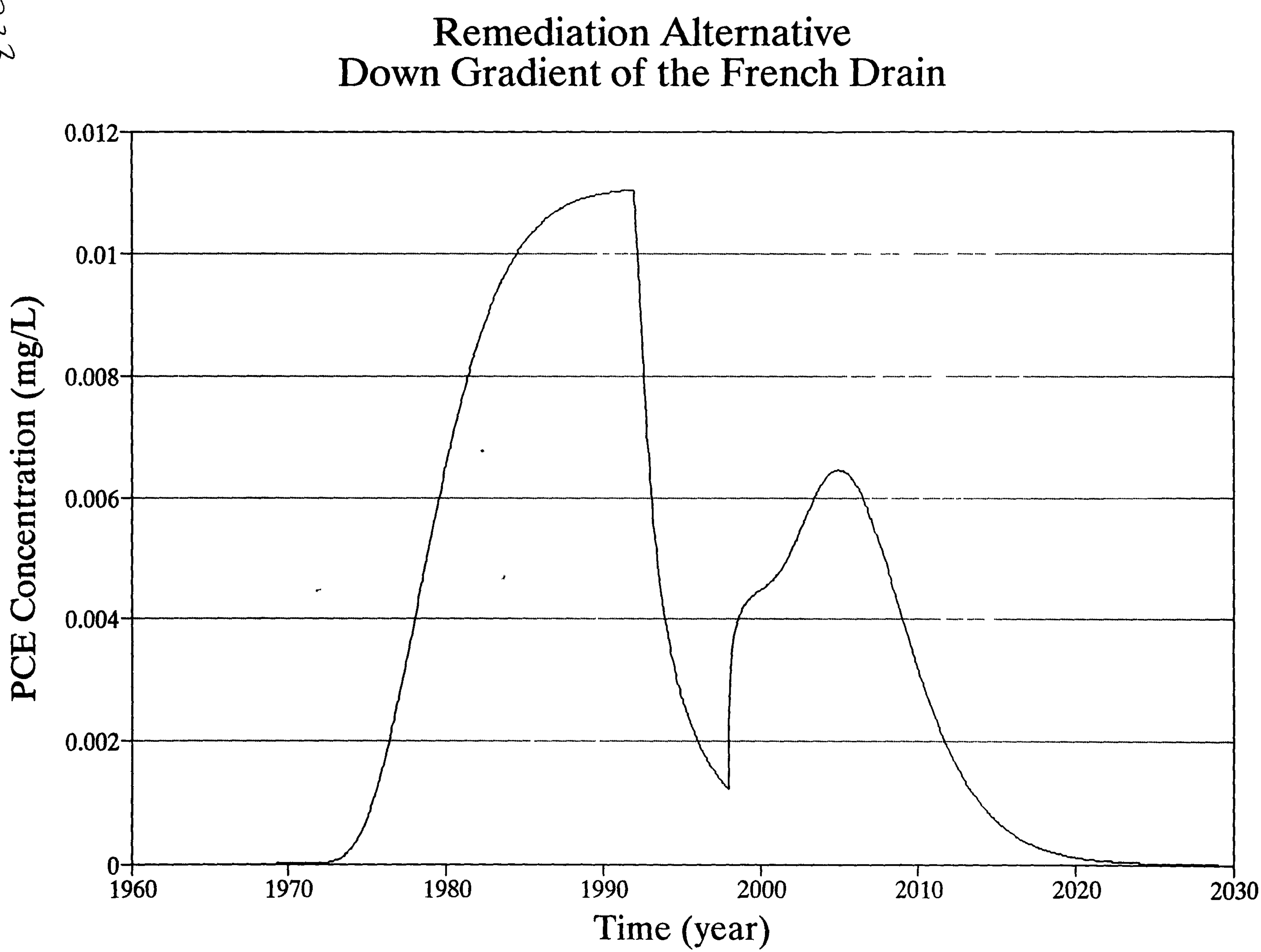
Remediation Alternative
Down Gradient of the French Drain
PCE Concentration (mg/L)
0.012
0.01
0.008
0.006
0.004
0.002
0
1960
1970
1980
1990
2000
2010
2020
2030
Time (year)

Figure B-67

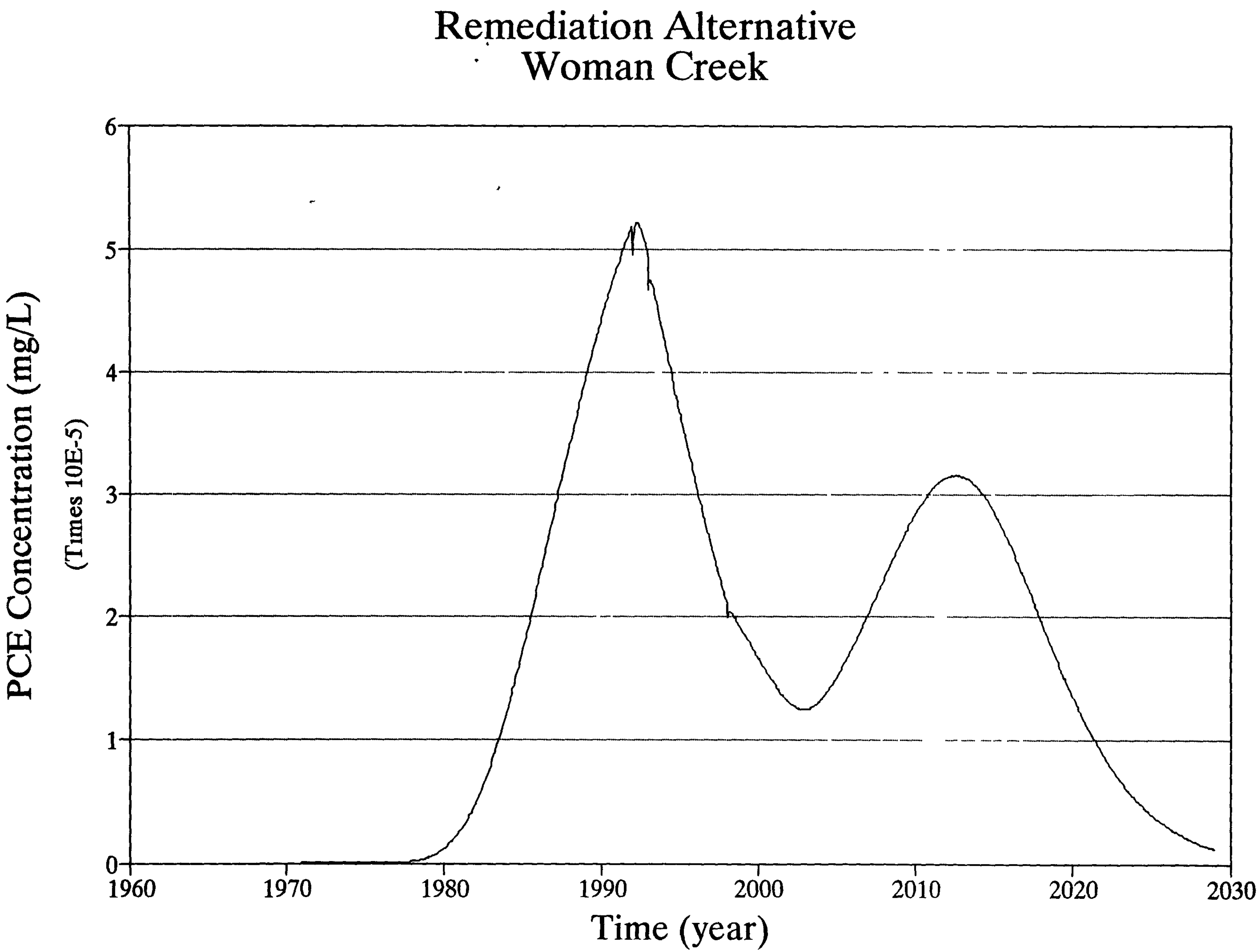

Figure B-68

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Remediation Alternative
Down Gradient of the French Drain

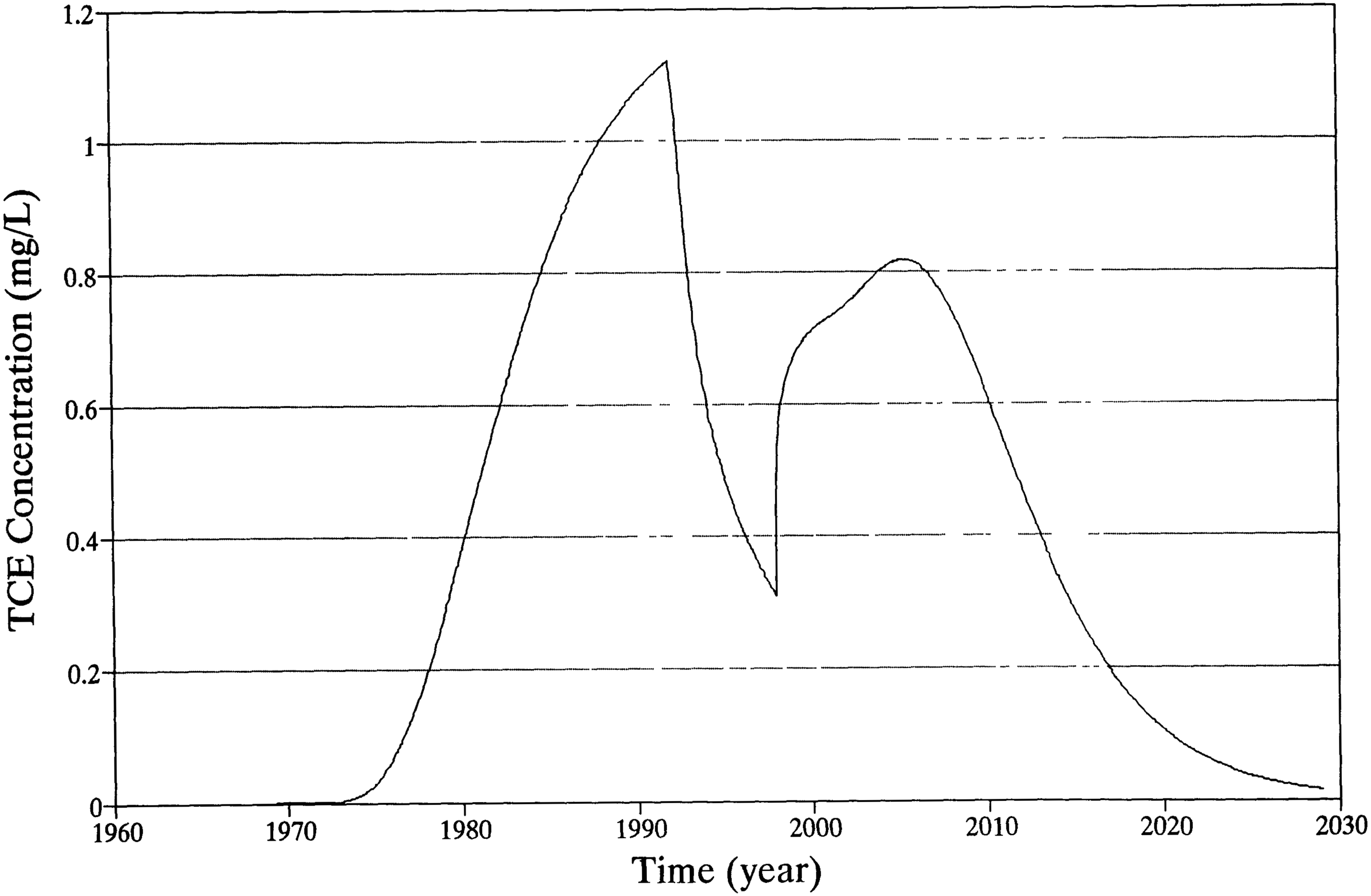

Figure B-69

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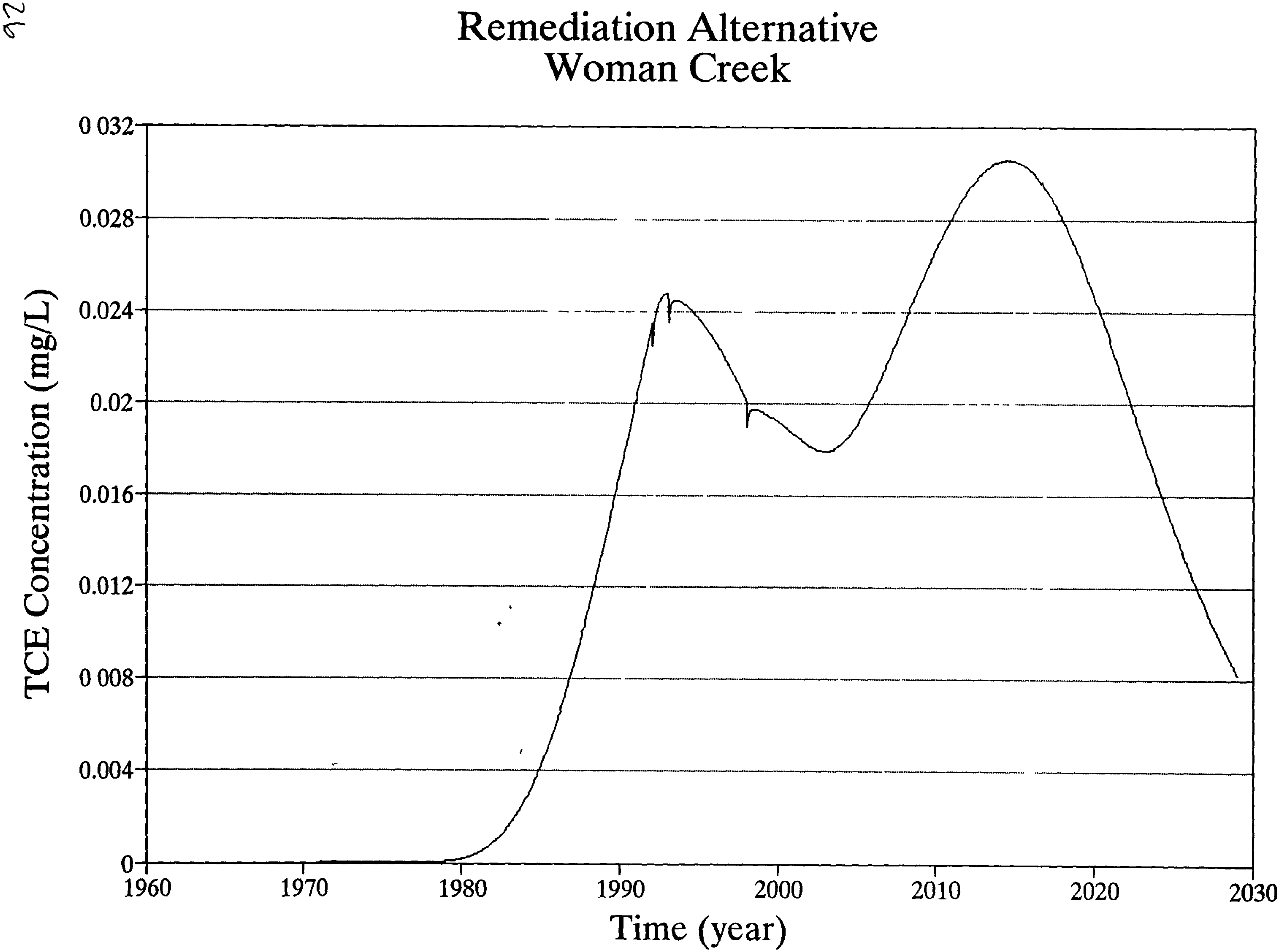

Figure B-70

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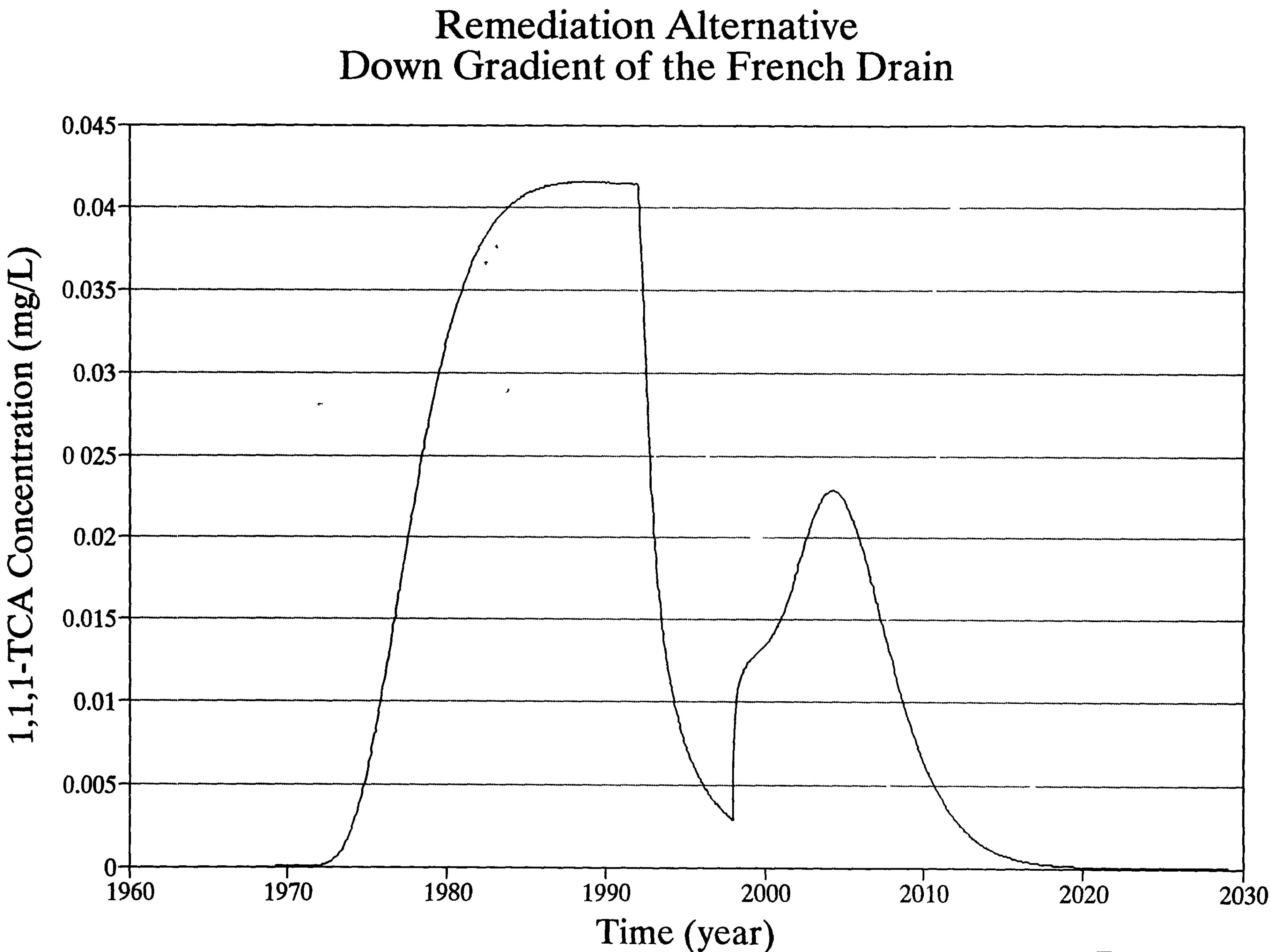

Figure B-71

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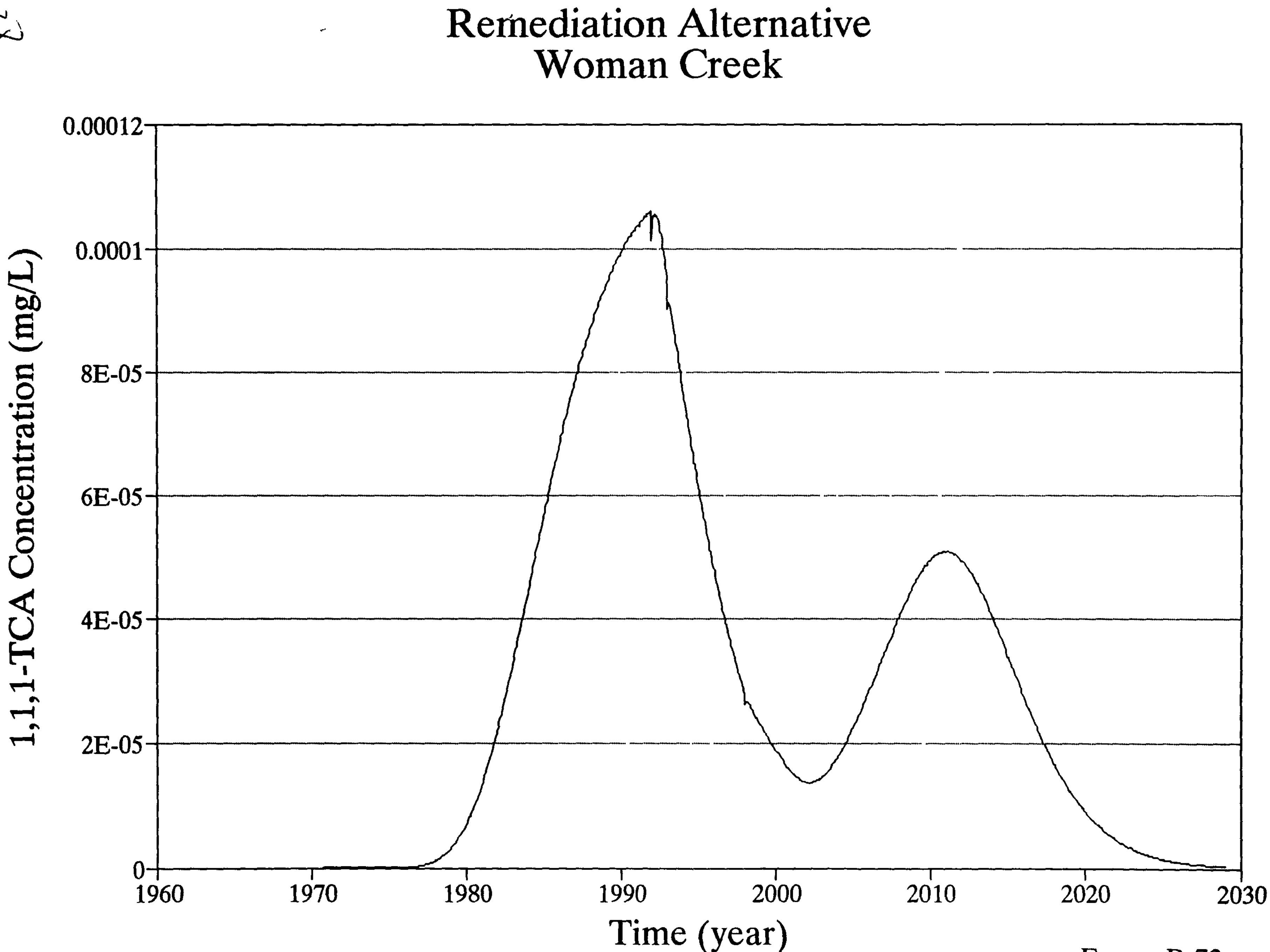

Figure B-72

Remediation Alternative
Down Gradient of the French Drain

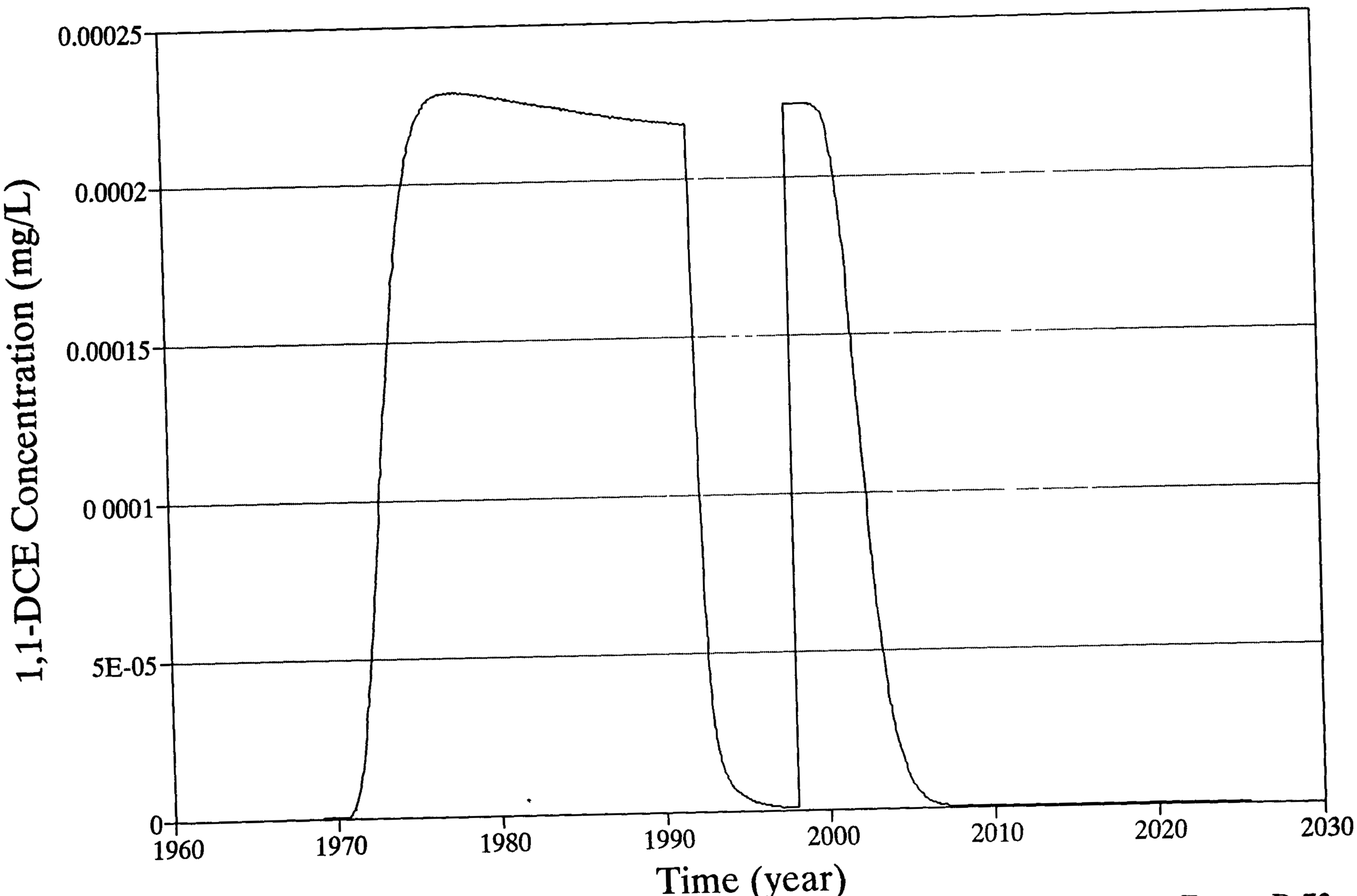

Figure B-73

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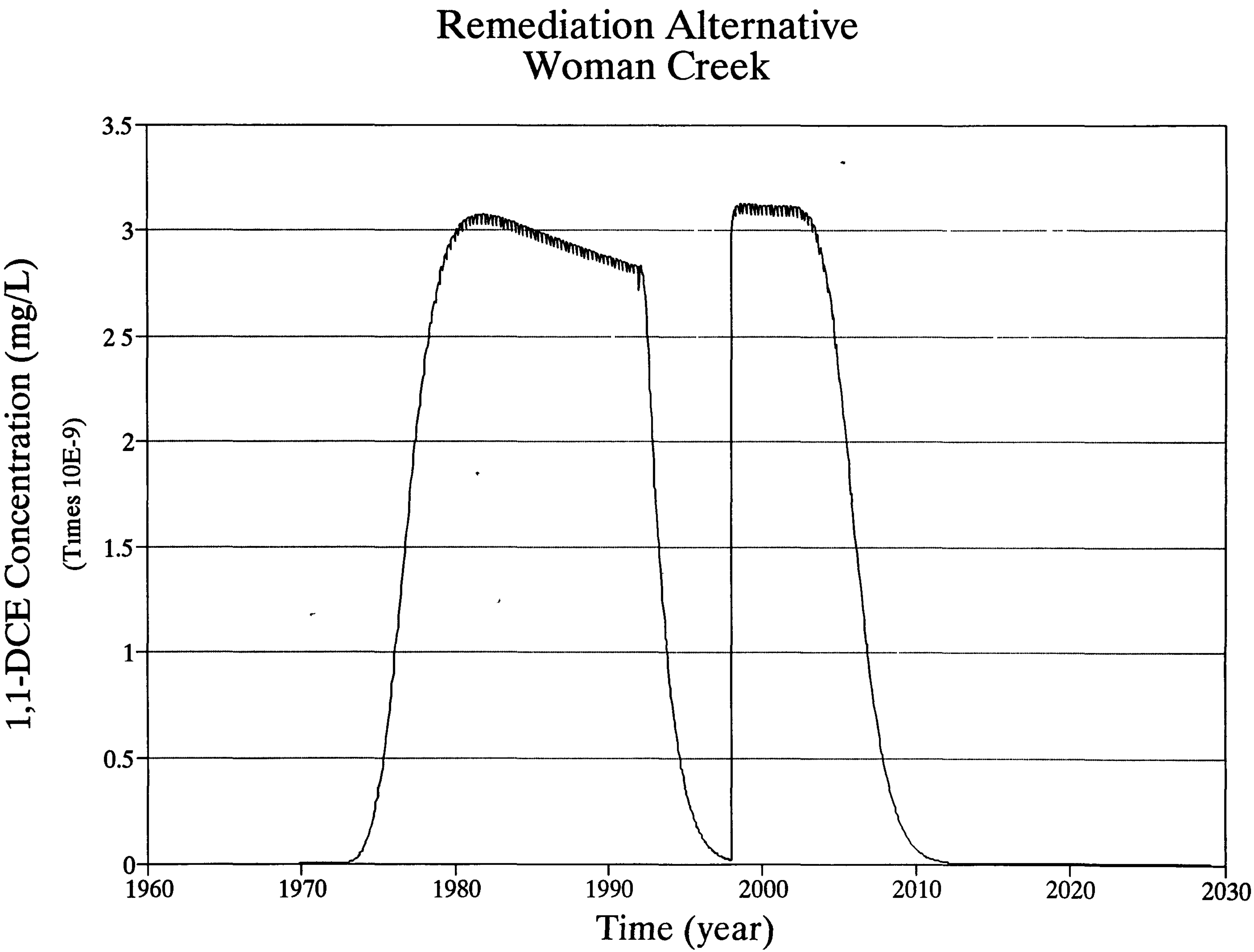
Remediation Alternative
Woman Creek
1,1-DCE Concentration (mg/L)
(Times 10E-9)
3.5
3
2 5
2
1.5
1
0.5
0
1960
1970
1980
1990
2000
2010
2020
2030
Time (year)

Figure B-74

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Remediation Alternative
Down Gradient of the French Drain

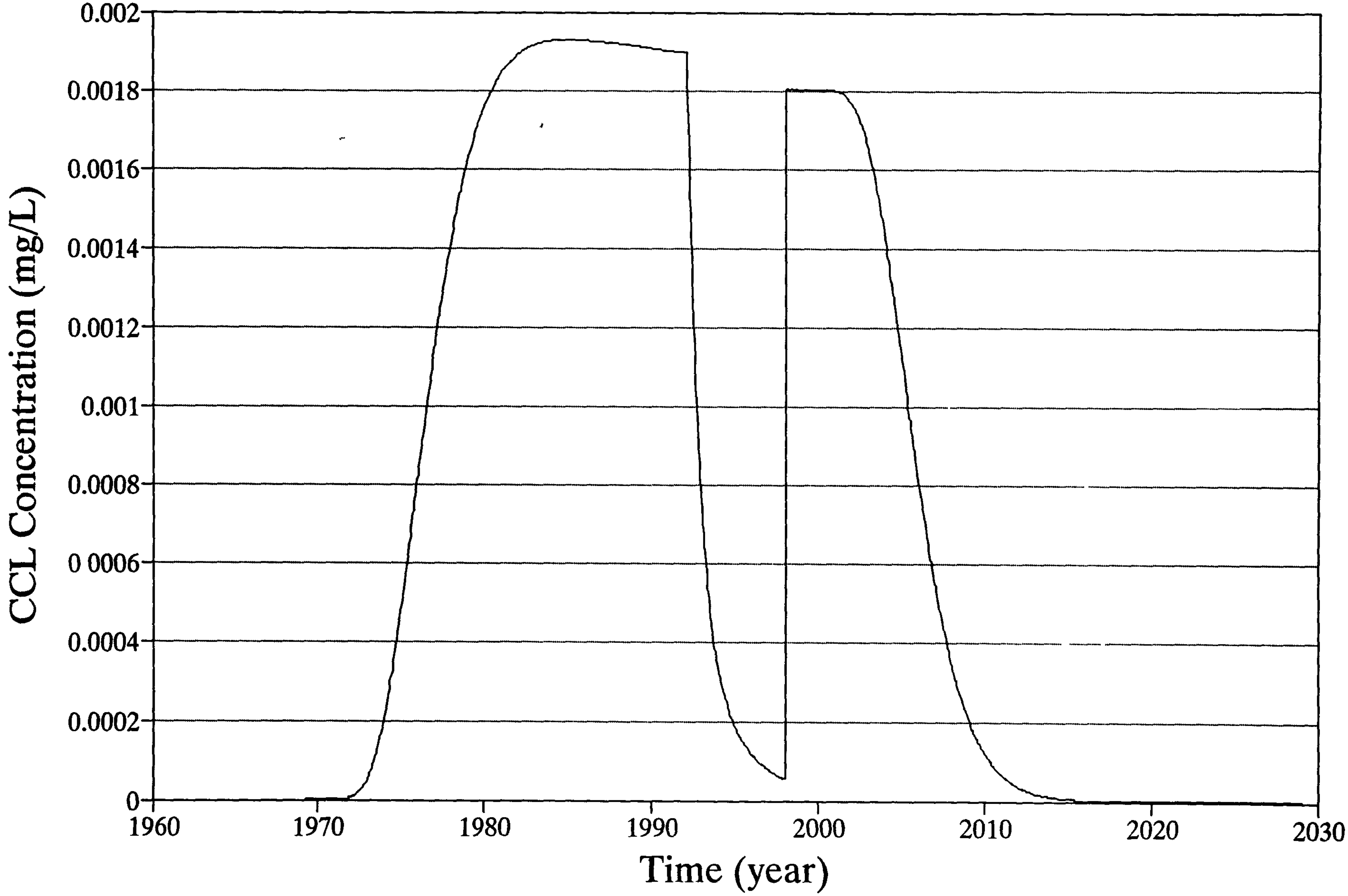

Figure B-75

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Remediation Alternative
Woman Creek

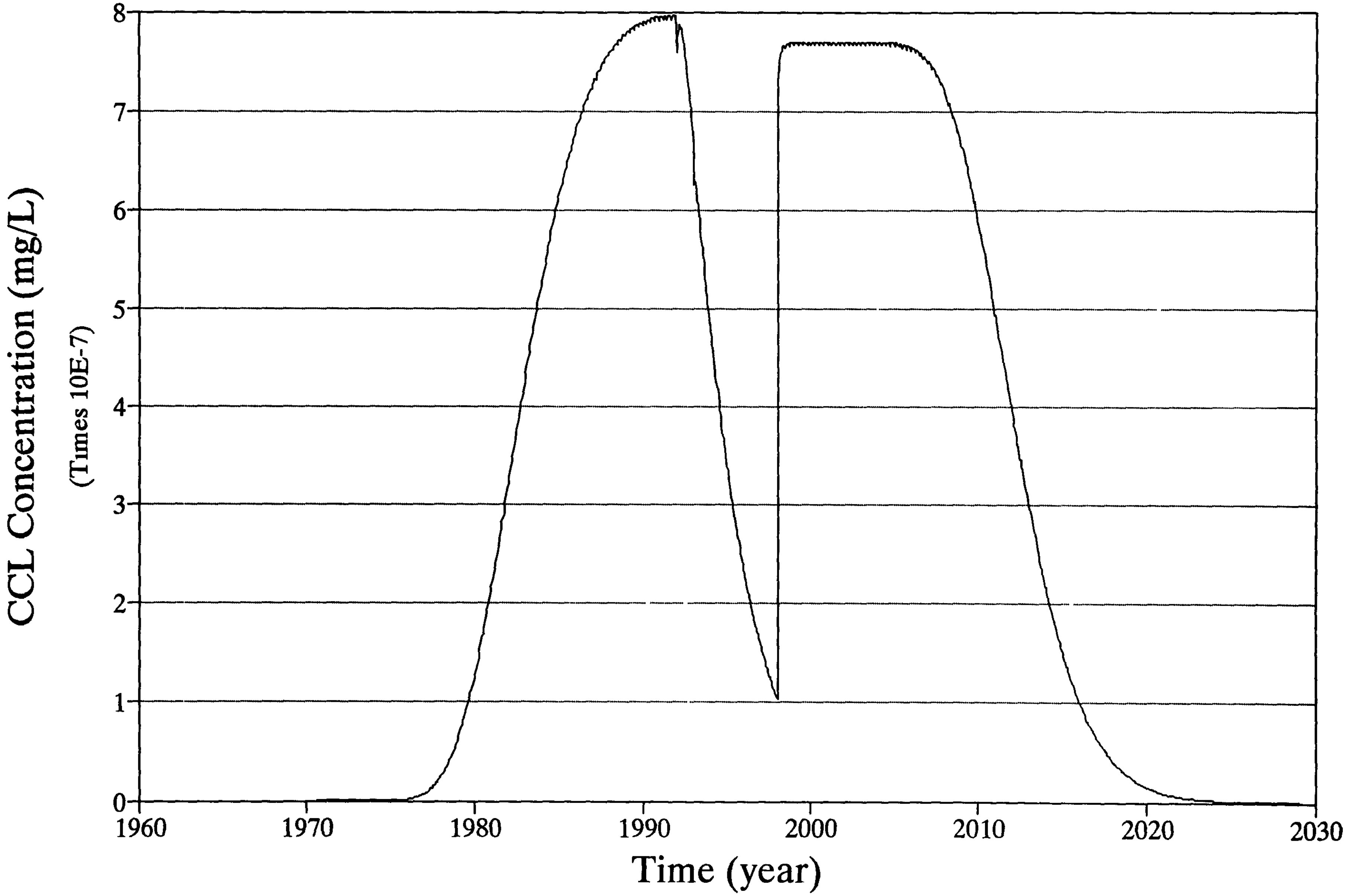

Figure B-76

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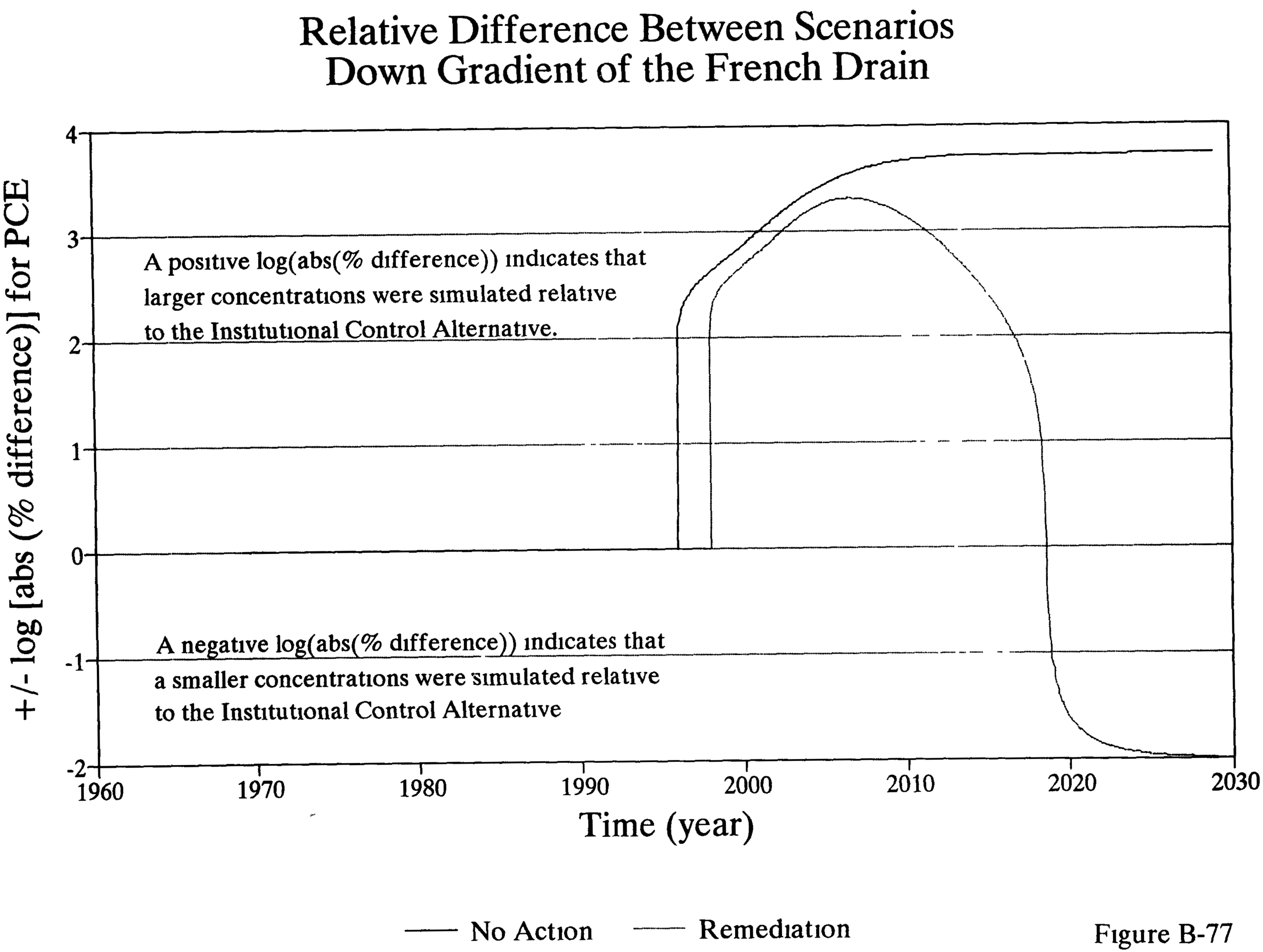

Figure B-77

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Relative Difference Between Scenarios
Woman Creek

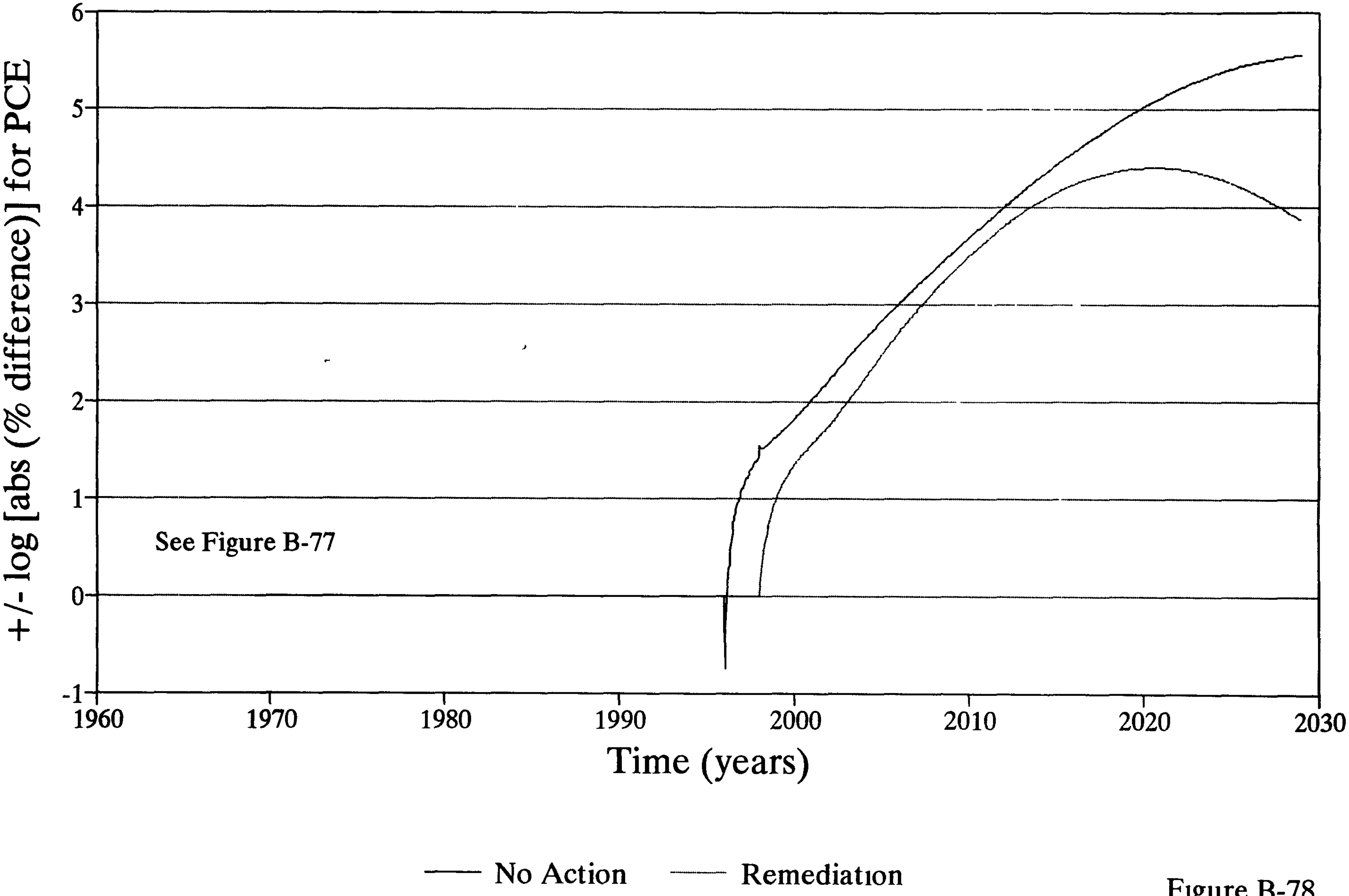

Figure B-78

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Relative Difference Between Scenarios Down Gradient of the French Drain

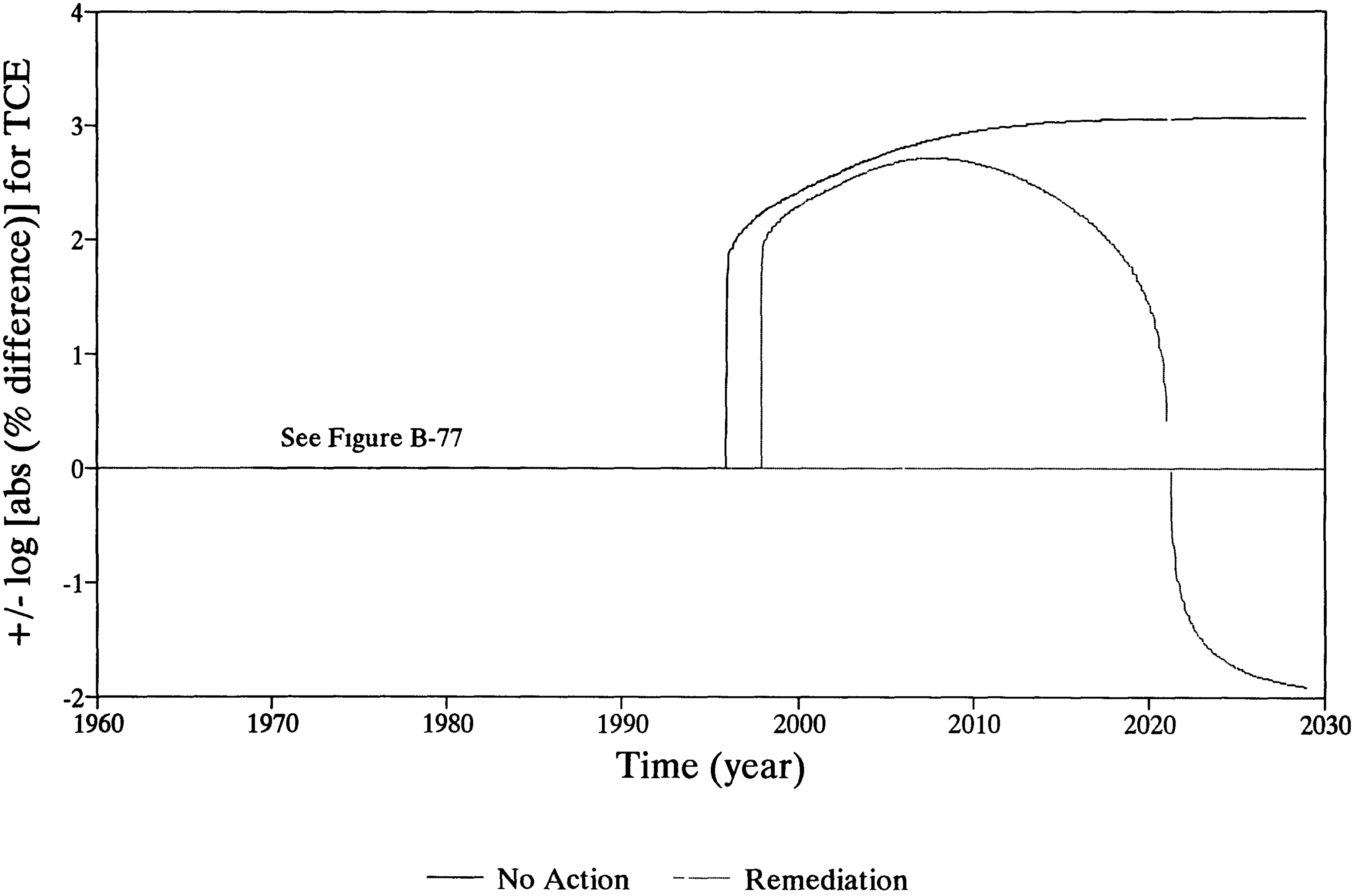

Figure B-79

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Relative Difference Between Scenarios
Woman Creek

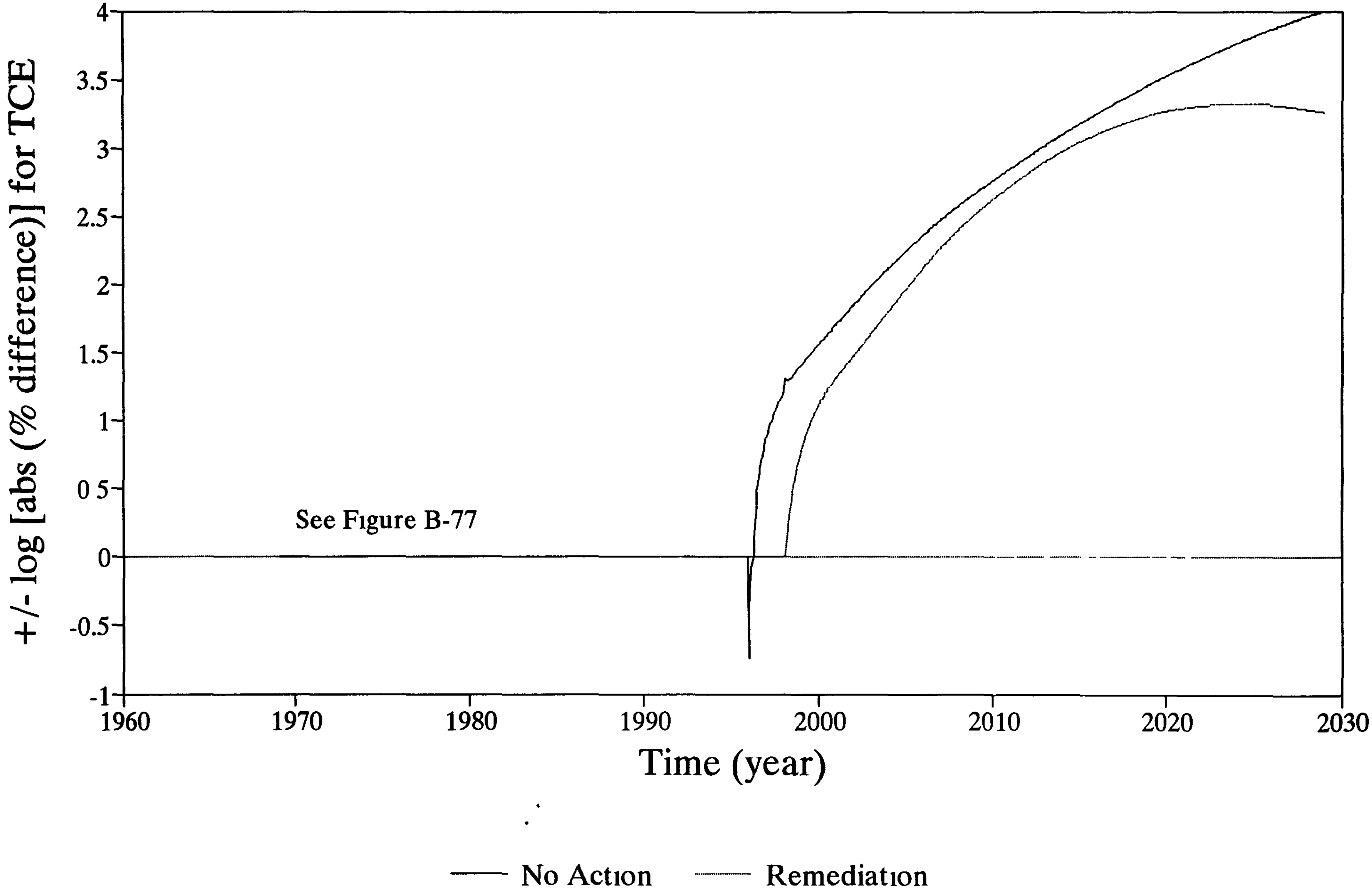

Figure B-80

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Relative Difference Between Scenarios Down Gradient of the French Drain

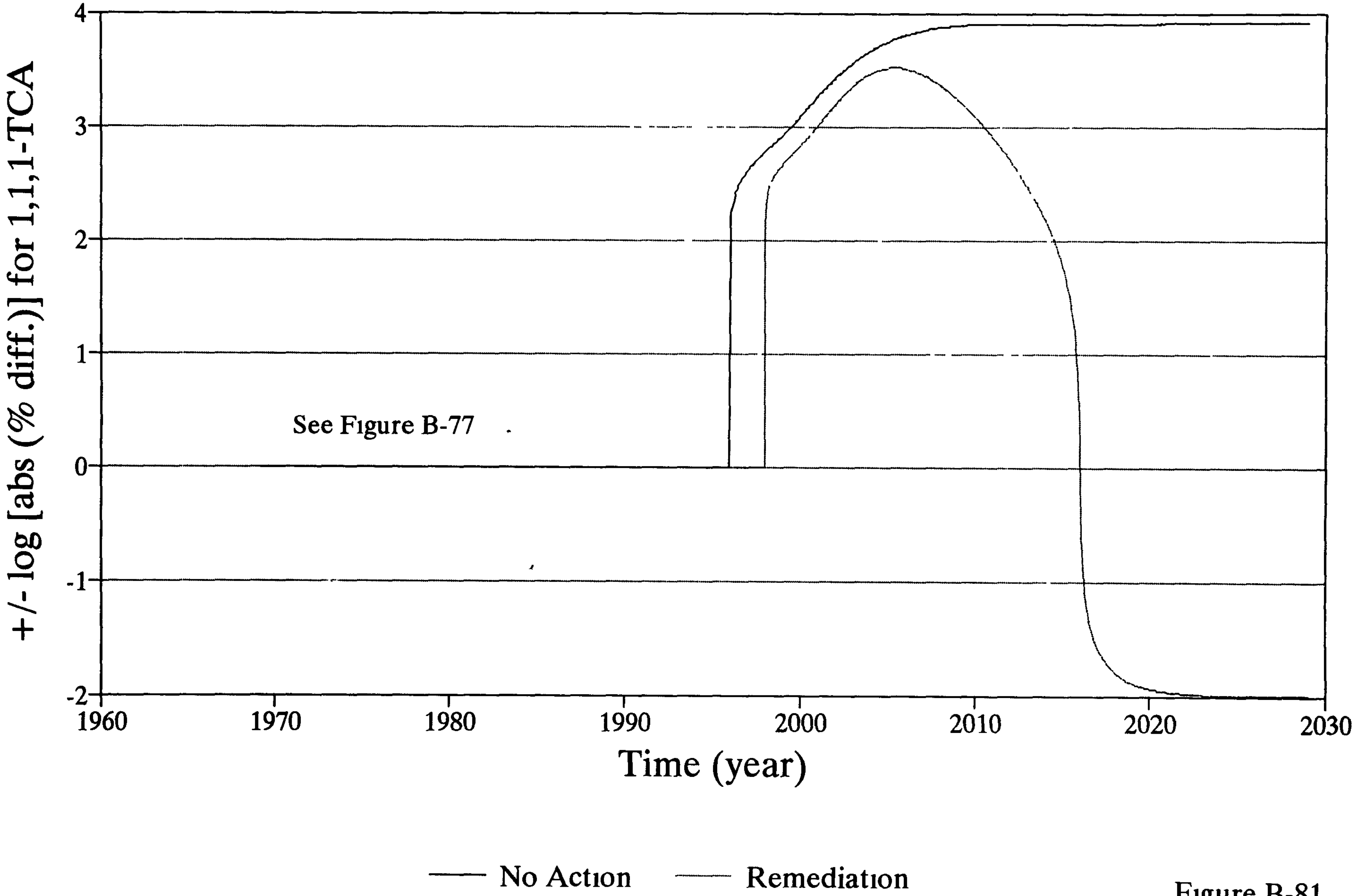

Figure B-81

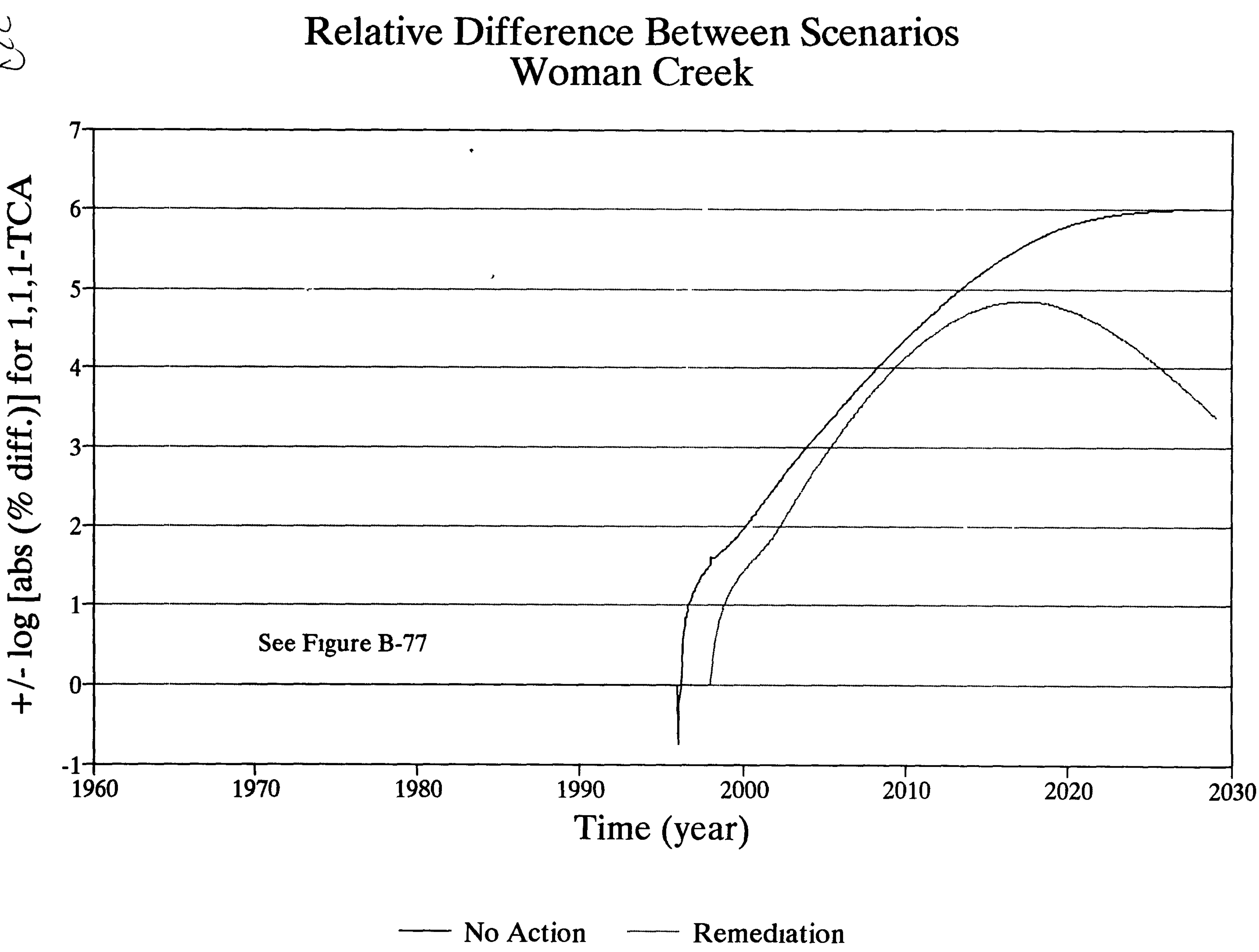

Figure B-82

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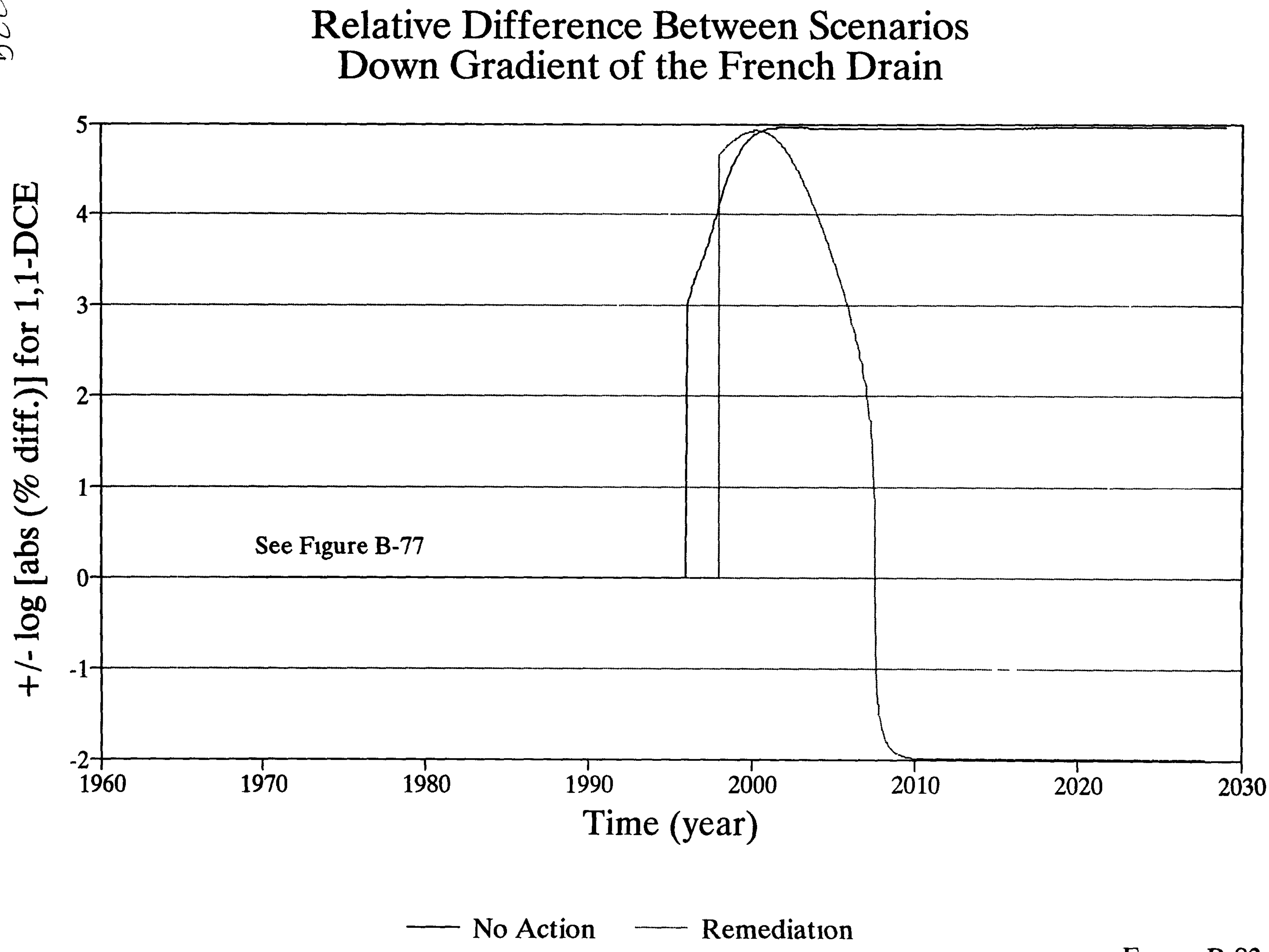

Figure B-83

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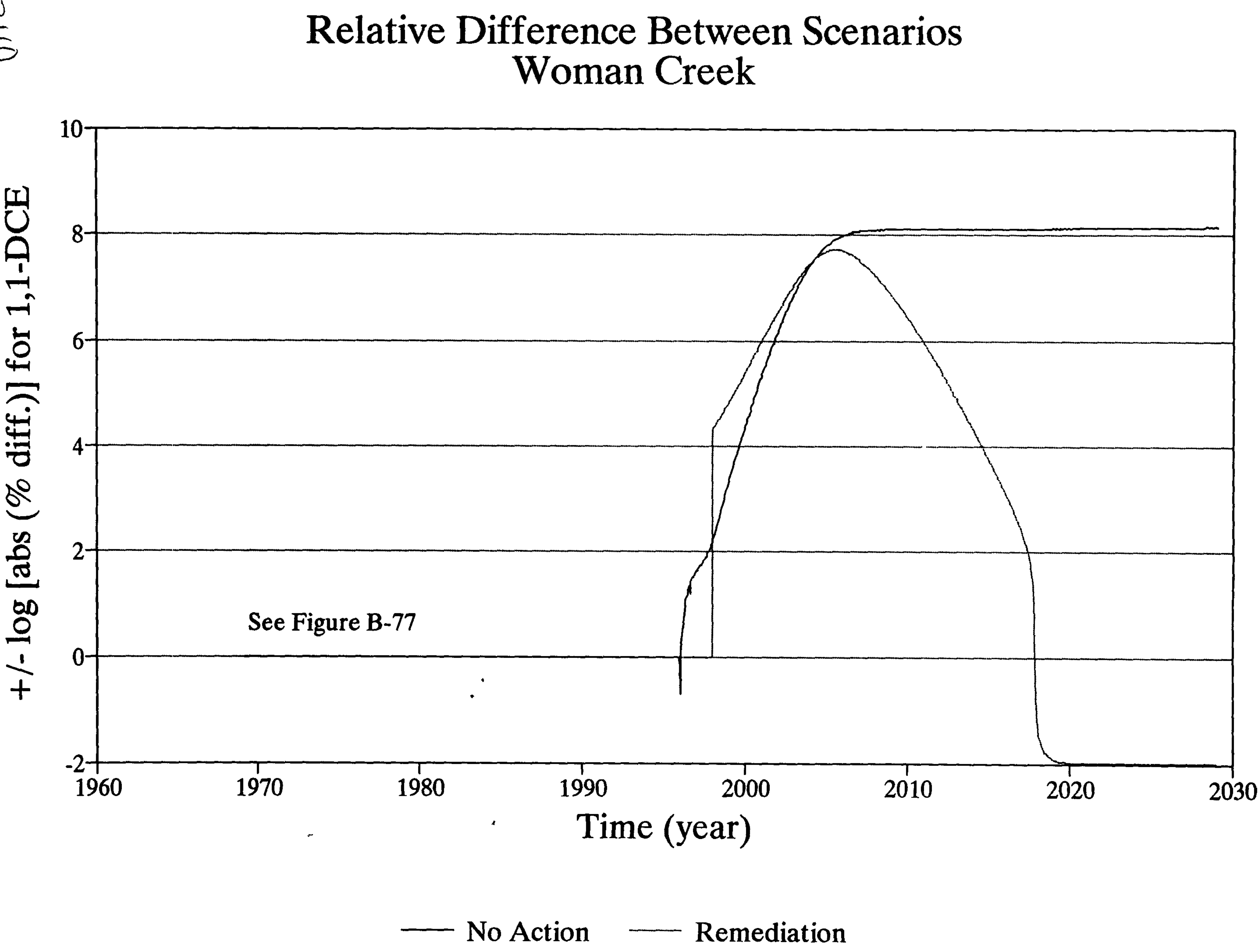

Figure B-84

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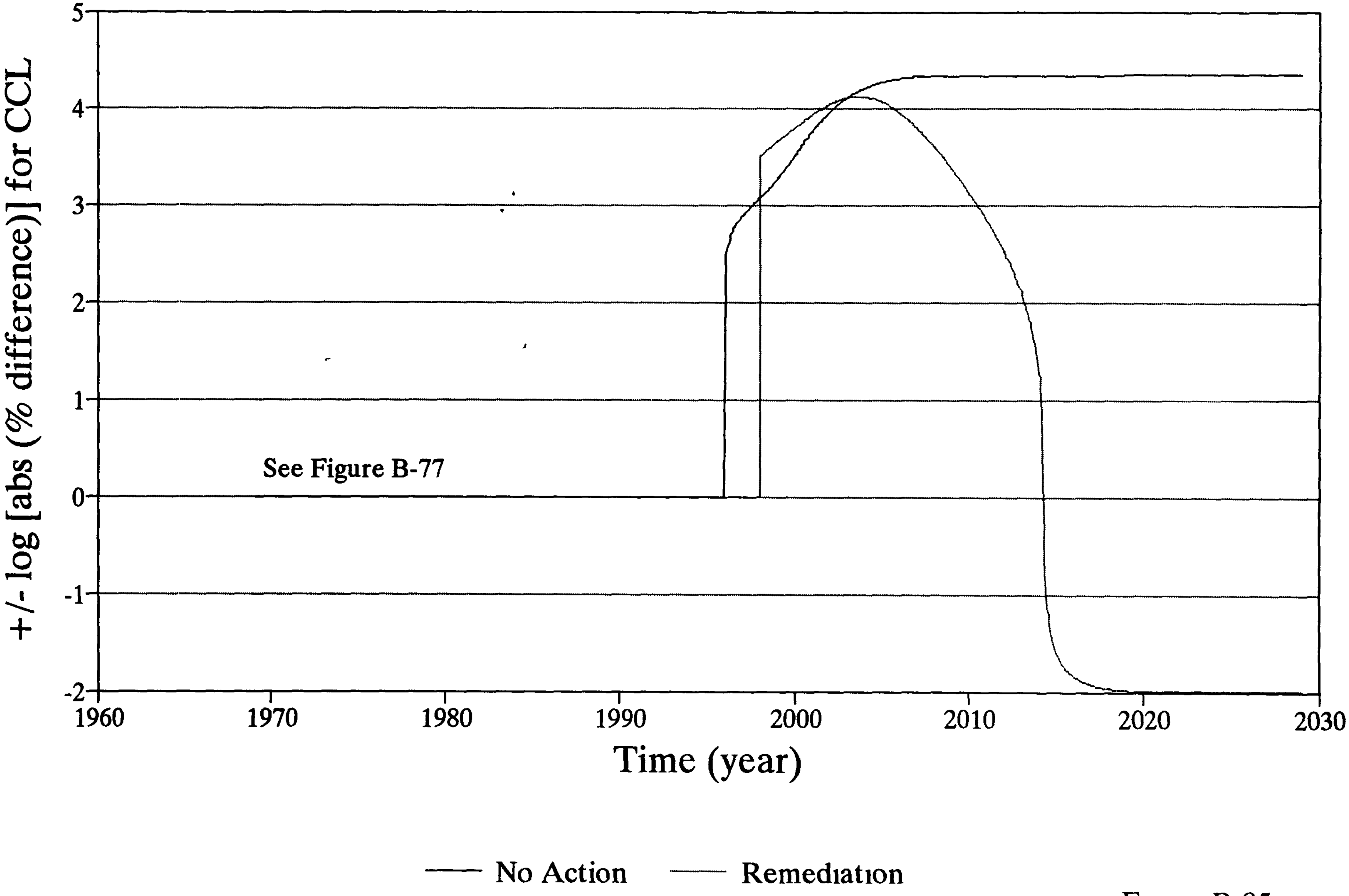
Relative Difference Between Scenarios Down Gradient of the French Drain



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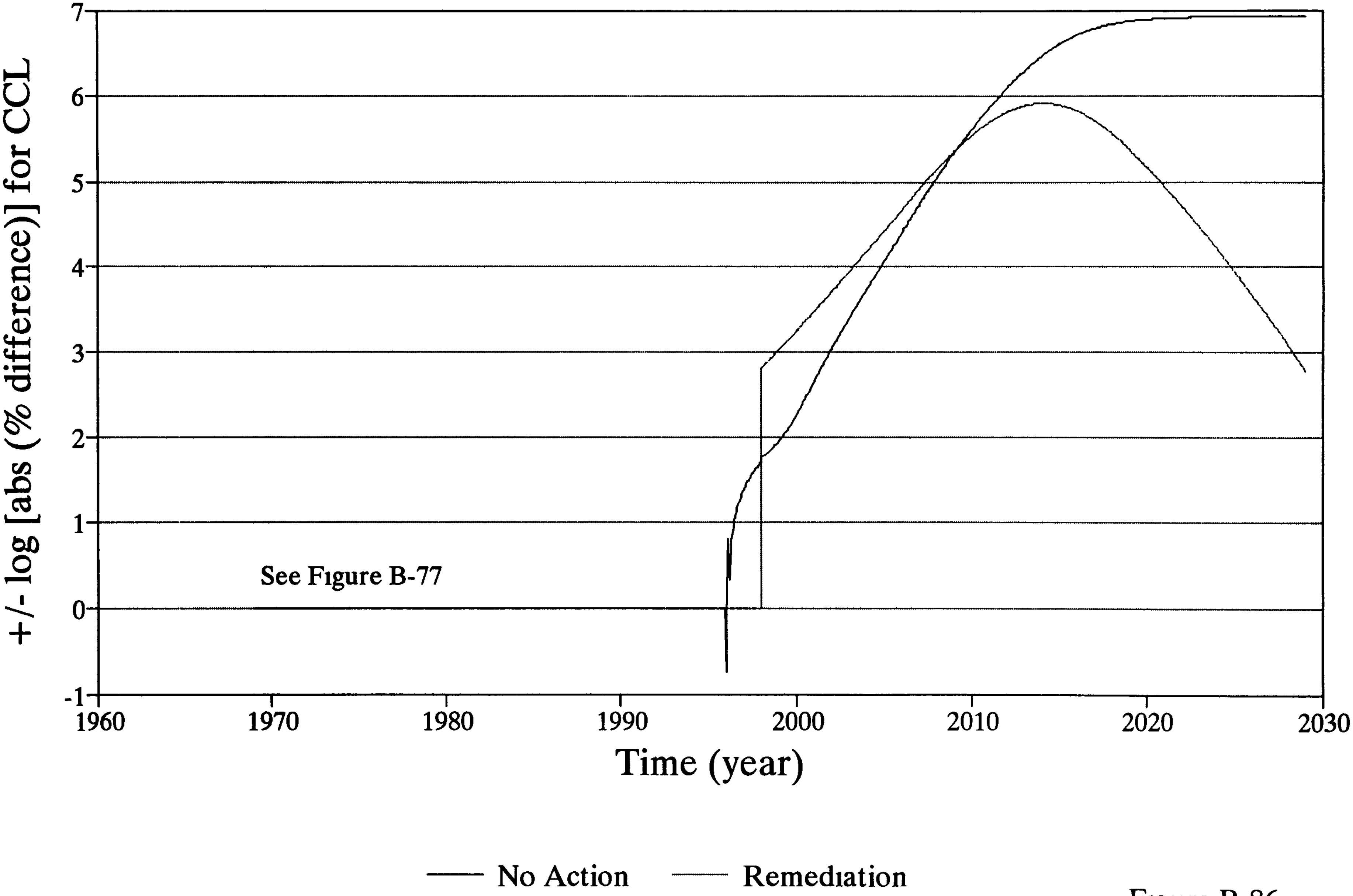
Relative Difference Between Scenarios
Woman Creek



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APPENDIX C

RESIDUAL RISK CALCULATIONS

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APPENDIX C
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LIST OF TABLES

ACRONYMS

1,1-DCE	1,1-dichloroethene
1,1,1-TCA	1,1,1-trichloroethane
ATSDR	Agency for Toxic Substances and Disease Registry
BRA	Baseline Risk Assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CCl_4	carbon tetrachloride
CNS	central nervous system
DOE	Department of Energy
EE	Ecological Evaluation
EPA	Environmental Protection Agency
FS	Feasibility Study
HI	hazard indices
HQ	hazard quotient
NOAEL	no observed adverse effect level
OU1	Operable Unit No 1
PCE	tetrachloroethene
PHE	Public Health Evaluation
PRG	preliminary remediation goal
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
SFs	slope factors
VOCs	volatile organic compounds

C.1.0 INTRODUCTION

The Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation (RFI/RI) at Operable Unit No 1 (OU1) 881 Hillside Area at the Rocky Flats Environmental Technology Site (RFETS) includes a Baseline Risk Assessment (BRA) The BRA is comprised of an Ecological Evaluation (EE) and a Public Health Evaluation (PHE) The results of the complete OU1 PHE are presented in Volume X, Appendix F of the Final Phase III RFI/RI, dated June 1994 [Department of Energy (DOE) 1994a]

This risk assessment performed for the OU1 Feasibility Study (FS) is intended to calculate and document the human health risks associated with OU1 assuming that specified remedial actions are incorporated at the site This risk assessment considered the dominating carcinogenic risks, noncarcinogenic hazards, associated contaminants, pathways, and receptors determined in the PHE and calculated risk based on contaminant levels at the site due to incorporation of specified remedial actions The three remedial action alternatives include no action, continued use of the french drain and extraction well (institutional controls), and remediating the contamination at the source (remediation)

C.2.0 EXPOSURE PATHWAYS, AND RECEPTORS OF CONCERN

This section discusses the potential release and transport of chemicals from OU1 This section also discusses the potential receptors of concern and the exposure pathways by which these receptors may be exposed to site contaminants

C 2 1 Exposure Pathways

An exposure pathway describes a specific environmental pathway that can expose an individual to contaminants that are onsite or originate from a site Five elements that must be present for an exposure pathway to be complete

- Source of chemicals
- Mechanism of chemical release
- Environmental transport medium
- Exposure point
- Human intake route

An incomplete pathway means that no human exposure can occur An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms, and receptors identified for that exposure pathway

An exposure route is the pathway through which a contaminant enters or impacts an organism There are four basic human exposure routes

- Dermal absorption through contact with soil, surface water, or groundwater
- Inhalation of volatile organic compounds (VOCs) or airborne particulates
- Ingestion of soil, surface water, groundwater or food
- External irradiation if radionuclides are present

As documented in the PHE, the pathways that dominated the human health risk are associated with groundwater contamination Therefore, the pathways considered in this risk assessment will only consider groundwater contamination associated with the potential remedial actions

C 2 2 Receptors of Concern

Receptors that were quantitatively evaluated in the PHE were

- Current offsite residents
- Future onsite residents
- Current onsite workers
- Future onsite workers
- Future onsite ecological researcher

Of these potential receptors, only the future onsite residents and the future onsite workers could be significantly exposed to contaminants in the groundwater These two receptors and potential scenarios are conservative since neither receptor could exposed until the RFETS has been released for unrestricted use The remaining receptors evaluated in the PHE do not have significant exposure to groundwater and, therefore, were not evaluated in this risk assessment

Although onsite residences are not consistent with future land-use plans, a hypothetical future onsite resident exposure scenario is evaluated in this risk assessment The future onsite resident is assumed to live within the OU1 study area boundary at the Woman Creek location To use the most conservative scenario for direct ingestion of groundwater, one of the future onsite resident scenarios assume that an adequate well water supply exists

A future onsite worker, assumed to be an office worker, is also quantitatively evaluated in this risk assessment The setting for the office worker is likely to have extensive paved areas and well-maintained landscaping It is assumed that municipal water would be supplied to the office building, and, therefore the future office worker will not directly access OU1 groundwater

C 2 2 1 Future Onsite Resident

Contaminants that volatilize from site groundwater and are released to indoor air through the house foundation represent a potentially complete inhalation pathway to future onsite residents Assuming that site groundwater is used within the household, inhalation of VOCs from indoor water use represents another potentially complete inhalation pathway Inhalation of outdoor VOCs is considered insignificant due to expected dispersal and dilution of the VOCs

Assuming that site groundwater will be used within the future onsite residential household, direct ingestion of groundwater contamination represents a potentially complete pathway Future onsite residents also could physically contact contaminated groundwater Therefore, dermal absorption of contaminants from contact with contaminated groundwater represents a potentially complete pathway

The location of the groundwater contamination for the future onsite resident is assumed to be Woman Creek

C 2 2 2 Future Onsite Office Worker

Since the municipal water, not groundwater, will be used in an office building, no direct exposure to groundwater is anticipated for the future onsite worker The only remaining exposure pathway is volatilization of contaminants from site groundwater and release to indoor air through the office building foundation. The inhalation pathway is then potentially complete for the future onsite office worker Similar to the future onsite resident scenario, the inhalation of outdoor VOCs is considered incomplete due to expected dispersal and dilution of the VOCs As with the future onsite resident the location of the contamination for the future onsite office worker is assumed to be Woman Creek

C.3.0 CONTAMINANTS OF CONCERN

This section identifies the contaminants of concern and the contaminant concentrations used in the risk calculations

C 3 1 Contaminants Identified

The OU1 PHE (DOE 1994a) identified the future onsite adult resident receptor as having the highest potential risk values for the following contaminants

- 1,1-Dichloroethene (1,1-DCE)
- Carbon tetrachloride (CCl_4)
- Tetrachloroethene, also known as perchloroethylene (PCE)

These risks were calculated assuming adequate groundwater present and available for receptor use The total risk values in the PHE for 1,1-DCE, CCL_4, and PCE respectively are 3 8E-2, 2 5E-3, and 1 1E-3, with the dominating pathway being ingestion of groundwater for all three contaminants

The contaminants with the highest calculated noncarcinogenic hazard indices (HI) in the PHE for the future onsite adult receptor assuming use of groundwater also include 1,1-DCE, CCL_4, and PCE In addition to these three contaminants, 1,1,1-trichloroethane (1,1,1-TCA), has an elevated HI These four contaminants also yielded the highest HIs for the future onsite residential child receptor and are of the same order of magnitude as the adult receptor

The three most dominating pathways for these contaminants are. ingestion of groundwater, inhalation of volatiles, and dermal contact with groundwater These pathways are all driven by groundwater contamination and, therefore, this risk assessment focuses on groundwater-associated pathways only Groundwater modeling results are used to derive concentrations of contamination in groundwater at Woman Creek By comparing initial modeling results with respective contaminant-specific preliminary remediation goals (PRGs) for RFETS (DOE 1994b), these contaminants were deemed appropriate to use in this risk calculation Detailed groundwater modeling results (refer to Appendix B) for these contaminants are used to calculate carcinogenic risk and noncarcinogenic HIs

C 3 2 Concentrations of Contaminants Identified

Groundwater modeling was used to calculate the expected contamination in groundwater at various locations downgradient of IHSS 119 1 The concentrations were modeled to include the specific remediation scenarios starting in 1969 and continuing in time steps The three scenarios were modeled out to the year 2029 Concentration averages were calculated for each contaminant at the French Drain and at Women Creek For the no action and institutional controls scenario, 30-year averages were calculated For the remediation scenario, concentration averages were taken beginning in 2008, after completion of remediation

The calculated groundwater concentrations were then used in the Johnson and Ettinger (1991) soil gas model which considers chemical-specific parameters such as Henry's law constant and air diffusion coefficients to calculate a vapor concentration inside a building, refer to the PHE for further details To calculate the concentration in indoor air from groundwater use, the conservatively modeled groundwater concentrations were multiplied by the volatilization fraction of 0 065 mg/m^3 air per mg/l water This conservative approach is consistent with Andelman (1990) and is discussed further in the PHE The concentrations of PCE and associated scenarios are summarized in Table C 3-1

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Table C.3-1
Contaminant Concentrations

Contaminant	French Drain			Woman Creek		
	Indoor Air Volatiles Diffusing through the Foundation (mg/m^3)	Groundwater (mg/L)	Indoor Air from Groundwater Use (mg/m^3)	Indoor Air Volatiles Diffusing through the Foundation (mg/m^3)	Groundwater (mg/L)	Indoor Air from Groundwater Use (mg/m^3)
No Action Scenario						
1,1-DCE	4 23E-10	2 21E-04	1 43E-05	5 28E-15	2 75E-09	1 79E-10
1,1,1-TCA	1 71E-07	3 61E-02	2 35E-03	3 85E-10	8 12E-05	5 28E-06
CCL_4	9 98E-10	1 72E-03	1 12E-04	3 52E-13	6 08E-07	3 95E-08
PCE	2 55E-09	9 49E-03	6 17E-04	1 23E-11	4 56E-05	2 97E-06
Institutional Controls Scenario						
1,1-DCE	6 18E-13	3 22E-07	2 09E-08	1 09E-17	5 67E-12	3 68E-13
1,1,1-TCA	4 64E-09	9 78E-04	6 36E-05	2 83E-11	5 97E-06	3 88E-07
CCL_4	1 02E-11	1 76E-05	1 15E-06	1 22E-14	2 10E-08	1 37E-09
PCE	4 64E-09	9 78E-04	6 36E-05	1 36E-12	5 05E-06	3 28E-07
Remediation Scenario						
1,1-DCE	8 79E-15	4 59E-09	2 98E-10	4 48E-17	2 34E-11	1 52E-12
1,1,1-TCA	7 65E-09	1 61E-03	1 05E-04	1 00E-10	2 11E-05	1 37E-06
CCL_4	1 77E-11	3 06E-05	1 99E-06	9 54E-14	1 65E-07	1 07E-08
PCE	2 38E-10	8 85E-04	5 75E-05	4 61E-12	1 71E-05	1 11E-06

C.4.0 EXPOSURE ASSESSMENT AND INTAKE EQUATIONS

Pathway-specific exposures or intakes are quantified through the use of intake equations, exposure parameters, and exposure concentrations Intake equations are pathway-specific, while exposure parameters and exposure concentrations are scenario-specific and pathway-specific Exposure concentrations for this risk assessment have been modeled using groundwater modeling techniques (Appendix B) The generalized intake equations associated with each pathway and the non-chemical specific parameters that are used in the equations are presented in this section

C 4 1 Ingestion of Water

Equation 1 was used to calculate direct ingestion, or intake, of contaminated water The ingestion rate was adjusted in accordance with the scenario

$$\text{Intake (mg/kg/day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT} \qquad (1)$$

where

CW	=	Chemical concentration in water (mg/liter)
IR	=	Ingestion rate (liter/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged, in days)

The chemical concentration in water is a modeled value and the modeling techniques are described in the PHE (DOE 1994a) Some parameters vary between adult and child receptors, such as ingestion rates, exposure durations, and body weights The adult and child ingestion rates are 2 liters and 1 liter per day, respectively Exposure frequency for residential receptors is 350 days/year The exposure durations for adult and child receptors are 30 and 6 years, respectively. The adult and child body weights are 70 and 15 kilograms, respectively The averaging time for a carcinogen is 25,550 days, or 70 years

C 4 2 Dermal Contact With Water

The future onsite resident is the only receptor that potentially can contact contaminated groundwater Equation 2 was used to calculate the absorbed dose, or intake, of the contaminant through the skin This equation calculates the actual absorbed dose, not the amount of chemical that comes in contact with the skin

$$\text{Absorbed Dose (mg/kg/day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT} \qquad (2)$$

where

CW	=	Chemical concentration in water (mg/liter)
SA	=	Skin surface area available for contact (cm^2)
PC	=	Chemical-specific dermal permeability constant (cm/hr)
ET	=	Exposure time (hours/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
CF	=	Volumetric conversion factor for water (1 liter/1000 cm^3)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged in days)

The chemical concentration in water is a modeled value as described in the PHE Some parameters vary between adult and child receptors, such as skin surface areas, exposure durations, and body weights The adult and child skin surface areas are 23,200 cm^2, and 9,180 cm^2, respectively The dermal permeability constants are chemical-specific and their origination is discussed in the PHE Adult and child exposure times for dermal contact with groundwater are 0 2 hours/day Exposure frequency for a residential adult and child is 350 days/year Adult and child exposure durations are 30 and 6 years, respectively The volumetric conversion factor for water is 0 001 liters/cm^3 Adult and child body weights are 70 and 15 kilograms, respectively The averaging time for a carcinogen is 25,550 days, or 70 years

C 4 3 Inhalation of Airborne Contaminants

Exposure scenarios involving the residential adult, residential child, and office worker include intake of airborne contaminants The contaminants are in the vapor phase and originate from groundwater contaminants volatilizing and diffusing through either a home foundation or office building foundation, as applicable Assuming well water is used within the home, the residential receptor can also inhale contaminants volatilized during in-home water use Dermal absorption of vapor-phase contaminants is considered to be a negligible portion of inhalation intakes and, therefore, is disregarded in accordance with Risk Assessment Guidance for Superfund (RAGS) Supplemental Guidance [Environmental Protection Agency (EPA) 1991a] Equation 3 was used to calculate inhalation intakes for residential and office worker receptors

$$\text{Intake (mg/kg/day)} = \frac{CA \times IR \times EF \times ED}{BW \times AT} \qquad (3)$$

where

CA	=	Contaminant concentration in air (mg/m^3)
IR	=	Inhalation rate (m^3/day)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
BW	=	Body weight (kg)
AT	=	Averaging time (period over which exposure is averaged in days)

Both residential and office worker receptors have the potential to inhale volatilized contamination that has diffused through the foundation of either a home or an office building, as applicable It is assumed that groundwater would not service onsite office buildings, therefore, only a residential receptor could inhale volatilized contamination due to indoor water use The chemical concentrations in indoor air (volatilized through a foundation and volatilized due to indoor water use) are modeled values as described in the PHE. Some parameters vary between the onsite office worker, adult and child receptors, such as inhalation rates, exposure frequencies, exposure durations, body weights, and averaging times The inhalation rate is 15 m^3/day for a residential adult (assuming indoor activities), and 20 m^3/day for both a residential child and office worker. The exposure frequency is 350 days/year for a residential adult and child, and 250 days/year for an office worker The exposure duration is 30 years for a residential adult, 6 years for a residential child, and 25 years for an office worker The body weight is 70 kilograms for a residential adult and office worker, and 15 kilograms for a residential child

C 4 4 Contaminant Intakes

The intake equations discussed use the nonchemical-specific parameters, chemical-specific parameters, chemical concentrations, and appropriate scenarios to calculate respective chemical intakes Tables C 4-1 through C 4-6 summarize the carcinogenic and noncarcinogenic intakes by scenario, receptor, and pathway

Table C.4-1
Carcinogenic Intakes, No Action Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water - Adult				
CCl_4	8 79E-11	2 02E-05	1 03E-06	9 86E-06
PCE	2 25E-10	1 11E-04	1 24E-05	5 43E-05
1,1-DCE	3 72E-11	2 59E-06	9 61E-08	1 26E-06
Future Onsite Office Worker				
CCl_4	6 98E-11	NAP	NAP	NAP
PCE	1 78E-10	NAP	NAP	NAP
1,1-DCE	2 96E-11	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water - Adult				
CCl_4	3 10E-14	7 14E-09	3 64E-10	3 48E-09
PCE	1 08E-12	5 36E-07	5 97E-08	2 61E-07
1,1-DCE	4 65E-16	3 23E-11	1 20E-12	1 58E-11
Future Onsite Office Worker				
CCl_4	2 46E-14	NAP	NAP	NAP
PCE	8 58E-13	NAP	NAP	NAP
1,1-DCE	3 69E-16	NAP	NAP	NAP

NAP = Not Applicable Pathway

Table C.4-2
Carcinogenic Intakes, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite resident With Water - Adult				
CCl_4	8 99E-13	2 07E-07	1 06E-08	1 01E-07
PCE	1 01E-11	5 01E-06	5 58E-07	2 44E-06
1,1-DCE	5 44E-14	3 78E-09	1 40E-10	1 84E-09
Future Onsite Office Worker				
CCl_4	7 14E-13	NAP	NAP	NAP
PCE	8 03E-12	NAP	NAP	NAP
1,1-DCE	4 32E-14	NAP	NAP	NAP
Woman Creek				
Future Onsite resident With Water - Adult				
CCl_4	1 07E-15	2 47E-10	1 26E-11	1 20E-10
PCE	1 20E-13	5 93E-08	6 60E-09	2 89E-08
1,1-DCE	9 57E-19	6 66E-14	2 47E-15	3 24E-14
Future Onsite Office Worker				
CCl_4	8 51E-16	NAP	NAP	NAP
PCE	9 49E-14	NAP	NAP	NAP
1,1-DCE	7 60E-19	NAP	NAP	NAP

NAP = Not Applicable Pathway

Table C.4-3
Carcinogenic Intakes, Remediation Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water - Adult				
CCl_4	1 56E-12	3 60E-07	1 84E-08	1 75E-07
PCE	2 10E-11	1 04E-05	1 16E-06	5 06E-06
1,1-DCE	7 74E-16	5 39E-11	2 00E-12	2 63E-11
Future Onsite Office Worker				
CCl_4	1 24E-12	NAP	NAP	NAP
PCE	1 66E-11	NAP	NAP	NAP
1,1-DCE	6 15E-16	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water - Adult				
CCl_4	8 40E-15	1 93E-09	9 87E-11	9 43E-10
PCE	4 06E-13	2 01E-07	2 24E-08	9 80E-08
1,1-DCE	3 94E-18	2 74E-13	1 02E-14	1 34E-13
Future Onsite Office Worker				
CCl_4	6 67E-15	NAP	NAP	NAP
PCE	3 22E-13	NAP	NAP	NAP
1,1-DCE	3 13E-18	NAP	NAP	NAP

NAP = Not Applicable Pathway

Table C.4-4
Noncarcinogenic Intakes, No Action Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water - Adult				
CCl_4	NA	5 90E-05	3 01E-06	NA
PCE	NA	3 25E-04	3 62E-05	NA
1,1-DCE	NA	7 55E-06	2 80E-07	NA
1,1,1-TCA	4 40E-08	1 24E-03	4 88E-05	6 03E-04
Future Onsite Resident With Water - Child				
CCl_4	NA	1 10E-04	4 45E-06	NA
PCE	NA	6 06E-04	5 34E-05	NA
1,1-DCE	NA	1 41E-05	4 14E-07	NA
1,1,1-TCA	2 19E-07	2 31E-03	7 21E-05	3 00E-03
Future Onsite Office Worker				
CCl_4	1 95E-10	NAP	NAP	NAP
PCE	4 99E-10	NAP	NAP	NAP
1,1-DCE	8 28E-11	NAP	NAP	NAP
1,1,1-TCA	3 35E-08	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water - Adult				
CCl_4	NA	2 08E-08	1 06E-09	NA
PCE	NA	1 56E-06	1 74E-07	NA
1,1-DCE	NA	9 43E-11	3 50E-12	NA
1,1,1-TCA	9 89E-11	2 78E-06	1 10E-07	1 36E-06
Future Onsite Resident With Water - Child				
CCl_4	NA	3 89E-08	1 57E-09	NA
PCE	NA	2 92E-06	2 57E-07	NA
1,1-DCE	NA	1 76E-10	5 17E-12	NA
1,1,1-TCA	4 92E-10	5 19E-06	1 62E-07	6 75E-06
Future Onsite Office Worker				
CCl_4	6 89E-14	NAP	NAP	NAP
PCE	2 40E-12	NAP	NAP	NAP
1,1-DCE	1 03E-15	NAP	NAP	NAP
1,1,1-TCA	7 54E-11	NAP	NAP	NAP

NA = Not Available
NAP = Not Applicable Pathway

Table C.4-5
Noncarcinogenic Intakes, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water - Adult				
CCl_4	NA	6 04E-07	3 08E-08	NA
PCE	NA	1 46E-05	1 63E-06	NA
1,1-DCE	NA	1 10E-08	4 10E-10	NA
1,1,1-TCA	1 19E-09	3 35E-05	1 32E-06	1 63e-05
Future Onsite Resident With Water - Child				
CCl_4	NA	1 13E-06	4 55E-08	NA
PCE	NA	2 73E-05	2 41E-06	NA
1,1-DCE	NA	2 06E-08	6 05E-10	NA
1,1,1-TCA	5 93E-09	6 25E-05	1 95E-06	8 13E-05
Future Onsite Office Worker				
CCl_4	2 00E-12	NAP	NAP	NAP
PCE	2 25E-11	NAP	NAP	NAP
1,1-DCE	1 21E-13	NAP	NAP	NAP
1,1,1-TCA	9 08E-10	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water - Adult				
CCl_4	NA	7 20E-10	3 67E-11	NA
PCE	NA	1 73E-07	1 93E-08	NA
1,1-DCE	NA	1 94E-13	7 21E-15	NA
1,1,1-TCA	7 28E-12	2 05E-07	8 07E-09	9 97E-08
Future Onsite Resident With Water - Child				
CCl_4	NA	1 34E-09	5 43E-11	NA
PCE	NA	3 23E-07	2 84E-08	NA
1,1-DCE	NA	3 62E-13	1 06E-14	NA
1,1,1-TCA	3 62E-11	3 82E-07	1 19E-08	4 96E-07
Future Onsite Office Worker				
CCl_4	2 38E-15	NAP	NAP	NAP
PCE	2 66E-13	NAP	NAP	NAP
1,1-DCE	2 13E-18	NAP	NAP	NAP
1,1,1-TCA	5 54E-12	NAP	NAP	NAP

NA = Not Available
NAP = Not Applicable Pathway

Table C.4-6
Noncarcinogenic Intakes, Remediation Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation (mg/kg/d)	Ingestion of Groundwater (mg/kg/d)	Dermal Contact with Groundwater (mg/kg/d)	Inhalation of Volatiles from Indoor use of Groundwater (mg/kg/d)
French Drain				
Future Onsite Resident With Water - Adult				
CCl_4	NA	1 05E-06	5 36E-08	NA
PCE	NA	3 03E-05	3 37E-06	NA
1,1-DCE	NA	1 57E-10	5 83E-12	NA
1,1,1-TCA	1 96E-09	5 53E-05	2 18E-06	2 69E-05
Future Onsite Resident With Water - Child				
CCl_4	NA	1 96E-06	7 91E-08	NA
PCE	NA	5 66E-05	4 98E-06	NA
1,1-DCE	NA	2 93E-10	8 61E-12	NA
1,1,1-TCA	9 78E-09	1 03E-04	3 22E-06	1 34e-04
Future Onsite Office Worker				
CCl_4	3 47E-12	NAP	NAP	NAP
PCE	4 66E-11	NAP	NAP	NAP
1,1-DCE	1 72E-15	NAP	NAP	NAP
1,1,1-TCA	1 50E-09	NAP	NAP	NAP
Woman Creek				
Future Onsite Resident With Water - Adult				
CCl_4	NA	5 64E-09	2 88E-10	NA
PCE	NA	5 86E-07	6 53E-08	NA
1,1-DCE	NA	8 00E-13	2 97E-14	NA
1,1,1-TCA	2 57E-11	7 23E-07	2 85E-08	3 53e-07
Future Onsite Resident With Water - Child				
CCl_4	NA	1 05E-08	4 25E-10	NA
PCE	NA	1 09E-06	9 64E-08	NA
1,1-DCE	NA	1 49E-12	4 39E-14	NA
1,1,1-TCA	1 28E-10	1 35E-06	4 21E-08	1 76E-06
Future Onsite Office Worker				
CCl_4	1 87E-14	NAP	NAP	NAP
PCE	9 01E-13	NAP	NAP	NAP
1,1-DCE	8 76E-18	NAP	NAP	NAP
1,1,1-TCA	1 96E-11	NAP	NAP	NAP

NA = Not Available
NAP = Not Applicable Pathway

C.5.0 TOXICITY ASSESSMENT

This section provides the toxicity constants used for risk characterization purposes and summarizes toxicological information Specific derivation of toxicity constants and respective sources is discussed in the PHE For this risk assessment, toxicity information is summarized for two categories of potential effects noncarcinogenic and carcinogenic effects These two categories were selected because of the slightly differing methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens Toxicity information is provided for the four contaminants of concern

- 1,1-DCE
- 1,1,1-TCA
- CCl_4
- PCE

Table C 5-1 also summarizes chemical-specific constants for each of these contaminants

C 5 1 <u>1,1-DCE</u>

Volatilization and subsequent photo-oxidation in the atmosphere are the primary transport and fate process for 1,1-DCE The available information also indicates that sorption, bio-accumulation, and degradation of 1,1-DCE are possible, albeit, at lower rates and are not of environmental significance

Studies on the general toxicity and possible carcinogenicity of 1,1-DCE are limited Oral LD50 of 1,1-DCE in rat is 1,500 mg/kg Exposure to high concentrations is often associated with disturbances of the central nervous system Chronic exposure to low doses of 1,1-DCE has been shown to produce hepatic and renal toxicity. However, 1,1-DCE does not produce embry-toxicity and teratogenic effects in experimental animals

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Table C.5-1.
Chemical Specific Constants

Analyte	Weight of Evidence	SF Ingestion (mg/kg-day) [1]	SF Inhalation (mg/kg-day) [1]	Target System	RfD Ingestion (mg/kg-day)	RfD Inhalation (mg/kg-day)	Dermal Permeability (cm/hr)
1,1-DCE	C	6 00E-01	1 75E-01	Hepatic	9 00E-03	NA	1 60E-02
1,1,1-TCA	D	NA	NA	CNS	9 00E-02	3 00E+00	1 70E-02
CCl_4	B2	1 30E-01	5 25E-02	Hepatic	7 00E-04	NA	2 20E-02
PCE	B2	5 20E-02	2 03E-03	Hepatic	1 00E-02	NA	4 80E-02

The results of the studies on the carcinogenic effects of 1,1-DCE are inconclusive However, 1,1-DCE has been shown to be mutagenic in several bacterial assays

For 1,1-DCE, the oral reference dose (RfD) is 9 00E-03 mg/kg-day and the oral and inhalation slope factors (SFs) are 6 00E-01 and 1 75E-01 $(mg/kg\text{-}day)^{-1}$, respectively (Table C 5 1)

C 5 2 <u>1,1,1-TCA</u>

1,1,1-TCA is used as a solvent for cleaning precision instruments, for metal degreasing, as aerosol propellants, as a pesticide, and in textile processing

1,1,1-TCA has a low toxicity profile (oral LD_{50} in rats is 11,000 mg/kg) Both in humans and animals, high concentrations of 1,1,1-TCA causes, disturbances of the central nervous system characterized by such symptoms as depression, imbalance in equilibrium and temporary reversible loss of coordination Other effects including cardiovascular effects such as hypotension, premature ventricular contractions, and arrhythmia have been reported Effects such as irritation of the skin, mucous membranes and eye as a result of exposure to 1,1,1-TCA has been reported (EPA, 1985)

Torkelson et al (1958) exposed groups of rats, rabbits, guinea pigs and monkeys to 1,1,1-TCA vapor at concentrations of 500, 1000, 2000, or 10,000 ppm From these studies, it was determined that the female guinea pig was the most sensitive species of those tested At 500 ppm, groups of eight male and eight female guinea pigs showed no evidence of adverse effects compared with unexposed and air-exposed controls after exposure for 7 hours/day, 5 days/week for 6 months Groups of five female guinea pigs exposed to 1000 ppm 1,1,1-TCA vapor 3 hours/day, 5 days/week for 3 months had fatty changes in the liver and statistically significant increased liver weights Thus, this study defined a NOAEL of 500 ppm (2730 mg/m^3) in guinea pigs

In a similar study, (Adams et al., 1950) groups of guinea pigs of 6-10 were exposed to

1,1,1-TCA (650 ppm) vapor 7 hours/day, 5 days week for 2 to 3 months These animals exhibited a slight depression in weight gain compared with both air-exposed and unexposed controls, thereby establishing a LOAEL of 650 ppm (3550 mg/m^3) in guinea pigs

On the basis of the existing inadequate animal data and absence of human carcinogenicity data, 1,1,1-TCA is not classifiable as to human carcinogenicity (EPA weight-of-evidence classification D) There are no reported human data and animal studies (one lifetime gavage, and one intermediate-term inhalation) have not demonstrated carcinogenicity Technical grade 1,1,1-TCA has been shown to be weakly mutagenic, although the contaminant 1,4-dioxane, a known animal carcinogen may be responsible for this response

C 5 3 <u>CCl_4</u>

CCl_4 is used in the preparation of refridgerants, aerosols and propellants, the preparation of chlorofluoromethanes, the production of semiconductors, dry cleaning operations, veterinary medicine, and organic synthesis It is also used as an agricultural fumigant, a solvent for fats, oils, and rubber, and an industrial extractant

The effects of CCl_4 were studied by Lamson and Minot (1928) in patients receiving CCl_4 and magnesium sulfate orally as a treatment for hookworms The authors reported the treatment of thousands of patients with a single dose of 2 5-15 ml of CCl_4 without any adverse effects One man was reported to have safely ingested 40 ml of CCl_4 However, an "extremely small" population of adults died after receiving 1 5 ml of CCl_4 and doses of 0 18-0 92 ml were reported to be fatal to children

The toxic effect of CCL_4 are potentiated by both the habitual and occasional ingestion of alcohol (EPA, 1991b) Pretreatment of laboratory animals with ethanol, methanol, or isopropanol increases the susceptibility of the liver to CCl_4 Protective effects against CCl_4-induced lipid peroxidation are exhibited by vitamin E, selenium and methionine Very obese or undernourished persons or those suffering from pulmonary diseases, gastric ulcers or a tendency to vomiting, liver or kidney diseases, diabetes or glandular disturbances, are especially sensitive to the toxic effect of CCl_4 (Von Oettingen, 1964)

Stewart et al (1961) reported the toxic effects of experimental exposure of human volunteers to CCl_4 vapor Healthy males 30-59 years of age, were exposed to concentrations of 63, 69 and 309 mg/m^3 of CCl_4 in an exposure chamber for 180 minutes at the two lower doses or 70 minutes at the highest dose One of six subjects exposed to the highest concentration experienced had an increased level of urinary urobilinogen 7 days after exposure In addition, two out of four subjects exposed to the highest concentration and monitored for serum iron showed a decrease within 48 hours after exposure

Little data are available concerning the teratogenic effects of CCl_4 Schwetz et al (1974) found CCl_4 to be slightly embryotoxic and to a certain degree retarded fetal development, when administered to rats at 300 or 1000 mg/ℓ for 7 hours/day on gestation days 6-15

Cases of chronic poisoning have been reported by Von Oettingen (1964) and others The clinical picture of chronic CCl_4 poisoning is much less characteristic than that of acute poisoning Patients suffering from this condition may complain of fatigue, lassitude, giddiness, anxiety and headache The suffer from paresthesia and muscular twitchings, and show increased reflex excitability. They may be moderately jaundiced, have a tendency to hypoglycemia and biopsy specimens of the liver may show fatty infiltration Patients complain of lack of appetite, nausea and occasionally of diarrhea In some instances, the blood pressure is lowered and is accompanied by pain in the cardiac region and mild anemia Other patients have developed pain in the kidney region, dysuria and slight nocturia, and have had urine containing small amounts of albumin and a few red blood cells Burning of the eyes and, in a few instances, blurred vision are frequent complaints of those exposed If these symptoms are not pronounced, or of long standing, recovery usually takes place upon discontinuation of the exposure if the proper treatment is received (Von Oettingen, 1964)

Reports on pathological changes in fatalities from CCl_4 poisoning are generally limited to findings in the liver and kidneys The brain and lungs may be edematous The intestines may be hyperemic and covered with numerous petechial hemorrhages and the spleen may be enlarged and hyperemic Occasionally the adrenal glands may show degenerative changes of the cortex and the hearth may undergo toxic myocarditis (Von Oettingen, 1964)

There have been three case reports of liver tumors developing after CCl_4 exposure Several studies of workers who may have used CCl_4 have suggested that these workers may have an excess risk of cancer CCl_4 has been classified by the EPA as a probable human carcinogen (EPA weight-of-evidence classification B2) based on carcinogenicity in rats, mice and hamsters, producing hepatocellular carcinomas in all three of these species (EPA, 1991c)

C 5 4 PCE

PCE has widespread use in the dry-cleaning and textile industries It is also used in the cold cleaning and vapor degreasing of metals, as a chemical intermediate in the synthesis of fluorocarbons, as a component of aerosol laundry treatment products, as a solvent for silicones, as the insulating fluid and cooling gas in electrical transformers, and in typewriter correction fluid PCE is not known to occur naturally, but contributes to water pollution through leaching from vinyl liners in asbestos-cement water pipelines and as wastewater from metal finishing, laundries, aluminum-forming, organic chemical/plastics manufacturing, and municipal treatment plants Air contamination is the result of emissions and vaporization losses from dry cleaning and industrial metal cleaning (ATSDR, 1992)

The effects discussed below are due to occupational exposure levels which are much higher than the expected environmental levels. Primarily, exposure occurs through inhalation of contaminated air or ingestion of contaminated water. PCE can cause lightheadedness, dizziness, euphoria, blindness, cardiac arrhythmias, hypotension, cyanosis, respiratory depression, pulmonary hemorrhages, and central nervous system (CNS) depression in acute dosages When chronically dosed, trigenial nerve impairment, liver injury, and chapped skin can occur PCE is metabolized and excreted very slowly. Individuals with diseases of the heart, liver, kidneys, and lungs are the most vulnerable to PCE poisoning It has also been known to cause jaundice in newborns from PCE excretion in the breast milk [Agency for Toxic Substances and Disease Registry (ATSDR), 1992]

Historically, few acute or chronic industrial toxicity problems have arisen from the use of this solvent, although researchers have reported both hepatotoxity and CNS effects Ingested or inhaled PCE is mostly excreted by the lungs The metabolism of PCE is very slow, a very low percentage is excreted in the urine as metabolites Currently no inhalation RfD is available for PCE Oral RfDs have been calculated based on research with rodents Primary effects associated with PCE exposure include liver and kidney damage and CNS depression The oral RfD for chronic exposures is 1E-2 mg/kg/day with an uncertainty factor of 1000 There is medium confidence in this RfD because no one study combined the features required for deriving a high confidence RfD Confidence in the principle study is low, because it lacked complete histopathological examination at the no observed adverse effect level (NOAEL), and corroborative studies on its teratogenic and reproductive impacts are lacking (EPA, 1994)

PCE is listed as a probable group B2 carcinogen in IRIS, has an oral SF of 5 20E-2, and an inhalation SF of 2 03E-3 This classification was based on studies performed on rodents, where inhalation produced both leukemia and tumors of the liver PCE is for the most part nonmutagenic and has not been shown to cause reproductive toxicity

C.6.0 RISK CHARACTERIZATION

Risk characterization involves estimating the magnitude of potential adverse effects, summarizing the nature of the threats to public health, and considering the nature and weight of evidence supporting these risk estimates and the degree of uncertainty surrounding the estimates Specifically, risk characterization involves combining the results of the exposure and toxicity assessments to provide numerical estimates of health risk These estimates are comparisons of exposure levels with appropriate RfDs or estimates of the lifetime cancer risk with a given intake

Generally, to quantify the health risks, the intakes are first calculated, as identified in Section C 4 0, for each applicable scenario The intakes were calculated from the concentrations discussed in Section C 3 2 and the methodology documented in RAGS (EPA, 1989) The specific intakes, calculated in Section C 4, were then compared to the applicable chemical-specific toxicological data presented in Section C 5, to determine the health risk

The health risks from the contaminants were calculated to determine potential carcinogenic and noncarcinogenic effects as discussed in Sections C 6-1 and C 6-2, respectively

C 6 1 Risk and Hazard Quotient Calculation

Potential carcinogenic risks are expressed as an estimated probability of an individual developing cancer from lifetime exposure to the carcinogen This probability is based on projected intakes and chemical-specific dose-response data called cancer slope factors (SFs) Cancer SFs and the estimated daily intake of a compound, averaged over a lifetime of exposure, is used to estimate the incremental risk that an individual exposed to that compound may develop cancer. Potential carcinogenic risks are estimated from the following equation

$$\text{Risk} = \text{Intake} \times \text{SF} \quad (4)$$

where

Risk	=	Potential lifetime excess cancer risk (unitless)
SF	=	Slope factor for chemicals $(mg/kg/day)^{-1}$
Intake	=	Chemical intake (mg/kg/day)

Potential health effects of chronic exposure to noncarcinogenic compounds is assessed by calculating a hazard quotient (HQ) which is derived by dividing the estimated daily intake by a chemical-specific RfD as shown in the following equation

$$HQ = Intake/RfD \quad (5)$$

where

HQ	=	Noncancer hazard quotient (unitless)
Intake	=	Chemical intake (mg/kg/day)
RfD	=	Reference dose (mg/kg/day)

A HQ greater than 1 0 indicates that exposure to that contaminant, (at the concentrations and for the duration and frequencies of exposure estimated in the exposure assessment), may cause adverse health effects in exposed populations However, the level of concern associated with exposure to noncarcinogenic compounds does not increase linearly as HQ values exceed 1 0 In other words, HQ values do not represent a probability or a percentage For example, an HQ of 10 does not indicate that adverse health effects are 10 times more likely to occur than an HQ value of 1 0, but that potential adverse health effects are of greater concern

C 6 2 Carcinogenic Effects

Carcinogenic risks from exposure to each contaminant were calculated and summed for a future onsite resident using groundwater, using public water, and for a future onsite office worker using public water The source of contamination considered (1) maintaining the current groundwater contamination level and removing the french drain and extraction well, (2) maintaining the current groundwater contamination level and continuing the french drain and extraction well operations, and (3) remediating the contamination source and removing the french drain and extraction well These receptors and scenarios considered contamination at the French Drain and at Woman Creek Tables C 6-1 through C 6-3 summarize the results of the risk calculations by scenario, receptor, and pathway

For all three scenarios, the highest carcinogenic risks at the French Drain and at Woman Creek are associated with the future onsite resident The risks for the future office worker are negligible (in the 10^{12} to 10^{-16} range)

The scenario that yielded the maximum calculated carcinogenic risks was the no action scenario The total calculated risk for the future onsite resident with this exposure is 1 17E-05 with the dominating pathway of ingestion of groundwater with a risk of 9 97E-06 (see Table C 6-1) The risk from the next dominant pathway, inhalation of volatiles from indoor use of groundwater, is 8 44E-07

The scenario with the next highest calculated carcinogenic risk assumed remediation of the contamination and discontinuing the operation of the french drain and extraction well The total calculated risk for the future on-site resident with this exposure is 6 69E-07 with the dominating pathway of ingestion of groundwater with a risk of 5 87E-07 (see Table C 6-3)

The institutional controls scenario has the lowest calculated carcinogenic risks The total calculated risk for the future on-site resident with this exposure is 3 31E-07 with the dominating pathway of ingestion of groundwater with a risk of 2 88E-07 (see Table C 6-2) In all three scenarios, PCE is responsible for the highest risks

C 6 3 Noncarcinogenic Effects

The receptors and pathways used to evaluate carcinogenic effects were also used to evaluate noncarcinogenic effects The HIs for each contaminant are the summed HQs for each exposure pathway If the HI exceeds unity there may be a concern for potential health effects and the exposure should be evaluated more closely. Tables C.6-4 through C 6-6 summarize the results of the HQ and HIs calculations by scenario, receptor, and pathway

The calculation of HQs and respective HIs did not yield a significant noncarcinogenic hazard (i e , did not approach unity) The highest HI is 2 59E-01 for a future onsite child resident and the no action scenario (see Table C 6 4) The dominating pathway for this receptor is ingestion of groundwater with a HQ of 1 57E-01 from CCl_4 The remaining HIs ranged from 1 40E-01 to 1 85E-12

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Table C.6-1
Carcinogenic Risks, No Action Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total Risks by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water - Adult						
CCl_4	4 57E-12	2 63E-06	1 34E-07	5 13E-07	3 28E-06	
PCE	4 56E-13	5 79E-06	6 45E-07	1 10E-07	6 55E-06	
1,1-DCE	6 52E-12	1 55E-06	5 77E-08	2 21E-07	1 83E-06	1 17E-05
Future Onsite Office Worker						
CCl_4	3 63E-12	NAP	NAP	NAP	3 63E-12	
PCE	3 62E-13	NAP	NAP	NAP	3 62E-13	
1,1-DCE	5 17E-12	NAP	NAP	NAP	5 17E-12	9 16E-12
Women Creek						
Future Onsite Resident With Water - Adult						
CCl_4	1 61E-15	9 28E-10	4 74E-11	1 81E-10	1 16E-09	
PCE	2 20E-15	2 79E-08	3 10E 09	5 30E-10	3 15E-08	
1,1-DCE	8 14E-17	1 94E-11	7 20E-13	2 76E-12	2 29E-11	3 27E-08
Future Onsite Office Worker						
CCl_4	1 28E-15	NAP	NAP	NAP	1 28E-15	
PCE	1 74E-15	NAP	NAP	NAP	1 74E-15	
1,1-DCE	6 46E-17	NAP	NAP	NAP	6 46E-17	3 09E-15

NAP = Not applicable pathway

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Table C.6-2
Carcinogenic Risks, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total Risks by Contaminant	Total Risks from All Contaminanants and Pathways
French Drain						
Future Onsite Resident With Water - Adult						
CCl_4	4 68E-14	2 69E-08	1 37E-09	5 25E-09	3 35E-08	
PCE	2 05E-14	2 61E-07	2 90E-08	4 96E-09	2 95E-07	
1,1-DCE	9 52E-15	2 27E-09	8 43E-11	3 23E-10	2 68E-09	3 31E-07
Future Onsite Office Worker						
CCl_4	3 71E-14	NAP	NAP	NAP	3 71E-14	
PCE	1 63E-14	NAP	NAP	NAP	1 63E-14	
1,1-DCE	7 56E-15	NAP	NAP	NAP	7 56E-15	6 10E-14
Women Creek						
Future Onsite Resident With Water - Adult						
CCl_4	5 57E-17	3 21E-11	1 64E-12	6 26E-12	4 00E-11	
PCE	2 43E-16	3 08E-09	3 43E-10	5 87E-11	3 48E-09	
1,1-DCE	1 67E-19	3 99E-14	1 48E-15	5 68E-15	4 71E-14	3 52E-09
Future Onsite Office Worker						
CCl_4	4 42E-17	NAP	NAP	NAP	4 42E-17	
PCE	1 93E-16	NAP	NAP	NAP	1 93E-16	
1,1-DCE	1 33E-19	NAP	NAP	NAP	1 33E-19	2 37E-16

NAP = Not applicable pathway

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Table C.6-3
Carcinogenic Risks, Remediation Scenario

Contaminants	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total Risks by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water - Adult						
CCl_4	8 13E-14	4 68E-08	2 39E-09	9 12E-09	5 83E-08	
PCE	4 26E-14	5 40E-07	6 02E-08	1 03E-08	6 11E-07	
1,1-DCE	1 36E-16	3 23E-11	1 20E-12	4 59E-12	3 81E-11	6 69E-07
Future Onsite Office Worker						
CCl_4	6 45E-14	NAP	NAP	NAP	6 45E-14	
PCE	3 38E-14	NAP	NAP	NAP	3 38E-14	
1,1-DCE	1 08E-16	NAP	NAP	NAP	1 08E-16	9 84E-14
Women Creek						
Future Onsite Resident With Water - Adult						
CCl_4	4 37E-16	2 51E-10	1 28E-11	4 90E-11	3 13E-10	
PCE	8 23E-16	1 05E-08	1 16E-09	1 99E-10	1 18E-08	
1,1-DCE	6 90E-19	1 65E-13	6 11E-15	2 34E-14	1 94E-13	1 21E-08
Future Onsite Office Worker						
CCl_4	3 47E-16	NAP	NAP	NAP	3 47E-16	
PCE	6 53E-16	NAP	NAP	NAP	6 53E-16	
1,1-DCE	5 48E-19	NAP	NAP	NAP	5 48E-19	1 00E-15

NAP = Not applicable pathway

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Table C.6-4
Noncarcinogenic HIs, No Action Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total HIs by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water - Adult						
CCl_4	NA	8.43E-02	4.30E-03	NA	8.86E-02	
PCE	NA	3.25E-02	3.62E-03	NA	3.61E-02	
1,1-DCE	NA	8.39E-04	3.12E-05	NA	8.70E-04	
1,1,1-TCA	1.47E-08	1.38E-02	5.42E-04	2.01E-04	1.45E-02	1.40E-01
Future Onsite Resident With Water - Child						
CCl_4	NA	1.57E-01	6.36E-03	NA	1.64E-01	
PCE	NA	6.06E-02	5.34E-03	NA	6.60E-02	
1,1-DCE	NA	1.57E-03	4.60E-05	NA	1.61E-03	
1,1,1-TCA	7.30E-08	2.57E-02	8.01E-04	1.00E-03	2.75E-02	2.59E-01
Future Onsite Office Worker						
CCl_4	NA	NAP	NAP	NAP	0.00E+00	
PCE	NA	NAP	NAP	NAP	0.00E+00	
1,1-DCE	NA	NAP	NAP	NAP	0.00E+00	
1,1,1-TCA	1.12E-08	NAP	NAP	NAP	1.12E-08	1.12E-08
Women Creek						
Future Onsite Resident With Water - Adult						
CCl_4	NA	2.97E-05	1.52E-06	NA	3.13E-05	
PCE	NA	1.56E-04	1.74E-05	NA	1.74E-04	
1,1-DCE	NA	1.05E-08	3.89E-10	NA	1.09E-08	
1,1,1-TCA	3.30E-11	3.09E-05	1.22E-06	4.52E-07	3.26E-05	2.38E-04
Future Onsite Resident With Water - Child						
CCl_4	NA	5.55E-05	2.24E-06	NA	5.78E-05	
PCE	NA	2.92E-04	2.57E-05	NA	3.17E-04	
1,1-DCE	NA	1.96E-08	5.75E-10	NA	2.01E-08	
1,1,1-TCA	1.64E-10	5.77E-05	1.80E-06	2.25E-06	6.18E-05	4.37E-04
Future Onsite Office Worker						
CCl_4	NA	NAP	NAP	NAP	0.00E+00	
PCE	NA	NAP	NAP	NAP	0.00E+00	
1,1-DCE	NA	NAP	NAP	NAP	0.00E+00	
1,1,1-TCA	2.51E-11	NAP	NAP	NAP	2.51E-11	2.51E-11

NA = Not available due to unavailability of toxicity constant
NAP = Not applicable pathway

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Table C.6-5
Noncarcinogenic HIs, Institutional Controls Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total HIs by Contaminant	Total Risks from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water - Adult						
CCl_4	NA	8 62E-04	4 40E-05	NA	9 06E-04	
PCE	NA	1 46E-03	1 63E-04	NA	1 63E-03	
1,1-DCE	NA	1 23E-06	4 55E-08	NA	1 27E-06	
1,1,1-TCA	3 97E-10	3 72E-04	1 47E-05	5 44E-08	3 92E-04	2 93E-03
Future Onsite Resident With Water - Child						
CCl_4	NA	1 61E-03	6 50E-05	NA	1 67E-03	
PCE	NA	2 73E-03	2 41E-04	NA	2 97E-03	
1,1-DCE	NA	2 29E-06	6 72E-08	NA	2 36E-06	
1,1,1-TCA	1 98E-09	6 95E-04	2 17E-05	2 71E-05	7 44E-04	5 39E-03
Future Onsite Office Worker						
CCl_4	NA	NAP	NAP	NAP	0	
PCE	NA	NAP	NAP	NAP	0	
1,1-DCE	NA	NAP	NAP	NAP	0	
1,1,1-TCA	3 03E-10	NAP	NAP	NAP	3 03E-10	3 03E-10
Women Creek						
Future Onsite Resident With Water - Adult						
CCl_4	NA	1 03E-06	5 25E-08	NA	1 08E-06	
PCE	NA	1 73E-05	1 93E-06	NA	1 92E-05	
1,1-DCE	NA	2 16E-11	8 01E-13	NA	2 24E-11	
1,1,1-TCA	2 43E-12	2 27E-06	8 97E-08	3 32E-08	2 40E-06	2 27E-05
Future Onsite Resident With Water - Child						
CCl_4	NA	1 92E-06	7 75E-08	NA	2 00E-06	
PCE	NA	3 23E-05	2 84E-06	NA	3 51E-05	
1,1-DCE	NA	4 03E -11	1 18E-12	NA	4 14E-11	
1,1,1-TCA	1 21E-11	4 24E-06	1 32E-07	1 65E-07	4 54E-06	4 17E-05
Future Onsite Office Worker						
CCl_4	NA	NAP	NAP	NAP	0	
PCE	NA	NAP	NAP	NAP	0	
1,1-DCE	NA	NAP	NAP	NAP	0	
1,1,1-TCA	1 85E12	NAP	NAP	NAP	1 85E-12	1 850E-12

NA = Not available due to unavailability of toxicity constant
NAP = Not applicable pathway

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Table C.6-6
Noncarcinogenic HIs, Remediation Scenario

Contaminant	Inhalation of Volatiles Diffusing Through Foundation	Ingestion of Groundwater	Dermal Contact with Groundwater	Inhalation of Volatiles from Indoor use of Groundwater	Total HIs by Contaminant	Total HIs from All Contaminants and Pathways
French Drain						
Future Onsite Resident With Water - Adult						
CCl_4	NA	1 50E-03	7 65E-05	NA	1 58E-03	
PCE	NA	3 03E-03	3 37E-04	NA	3 37E-03	
1,1-DCE	NA	1 75E-08	6 48E-10	NA	1 81E-08	
1,1,1-TCA	6 55E-10	6 14E-04	2 42E-05	8 98E-06	6 47E-04	5 59E-03
Future Onsite Resident With Water - Child						
CCl_4	NA	2 80E-03	1 13E-04	NA	2 91E-03	
PCE	NA	5 66E-03	4 98E-04	NA	6 15E-03	
1,1-DCE	NA	3 26E-08	9 57E-10	NA	3 35E-08	
1,1,1-TCA	3 26E-09	1 15E-03	3 58E-05	4 47E-05	1 23E-03	1 03E-02
Future Onsite Office Worker						
CCl4	NA	NAP	NAP	NAP	0 00E+00	
PCE	NA	NAP	NAP	NAP	0 00E+00	
1,1-DCE	NA	NAP	NAP	NAP	0 00E+00	
1,1,1-TCA	4 99E-10	NAP	NAP	NAP	4 99E-10	4 99E-10
Women Creek						
Future Onsite Resident With Water - Adult						
CCl_4	NA	8 06E-06	4 11E-07	NA	8 47E-06	
PCE	NA	5 86E-05	6 53E-06	NA	6 52E-05	
1,1-DCE	NA	8 89E-11	3 30E-12	NA	9 22E-11	
1,1,1-TCA	8 57E-12	8 04E-06	3 17E-07	1 18E-07	8 47E-06	8 21E-05
Future Onsite Resident With Water - Child						
CCl_4	NA	1 50E-05	6 08E-07	NA	1 57E-05	
PCE	NA	1 09E-04	9 64E-06	NA	1 19E-04	
1,1-DCE	NA	1 66E-10	4 87E-12	NA	1 71E-10	
1,1,1-TCA	4 27E-11	1 50E-05	4 68E-07	5 85E-07	1 61E-05	1 51E-04
Future Onsite Office Worker						
CCl_4	NA	NAP	NAP	NAP	0 00E+00	
PCE	NA	NAP	NAP	NAP	0 00E+00	
1,1-DCE	NA	NAP	NAP	NAP	0 00E+00	
1,1,1-TCA	6 53E-12	NAP	NAP	NAP	6 53E-12	6 53E-12

NA = Not available due to unavailability of toxicity constant
NAP = Not applicable pathway

C.7.0 UNCERTAINTY ANALYSIS

Uncertainty analysis is an important component of the risk assessment process. According to the EPA *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, point estimates of risk "do not fully convey the range of information considered and used in developing the assessment" (EPA, 1992). To provide information about the uncertainties associated with the risk assessment, uncertainties were identified during the PHE process (DOE, 1994a) and are presented in qualitative terms.

C.7.1 Sources of Uncertainty

There are four stages of analysis applied during the risk assessment process that can introduce uncertainties:

- Data Collection and Evaluation
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization

The uncertainty analysis characterizes the propagated uncertainty in public health risk assessments. These uncertainties are driven by uncertainty in the chemical monitoring data, the transport models used to estimate concentrations at receptor locations, receptor intake parameters, and the toxicity values used to characterize risk. Additionally, uncertainties are introduced in the risk assessment when exposures to several substances across multiple pathways are summed.

One approach to address the uncertainties is to use health-protective assumptions. Health-protective assumptions are those that systematically overstate the magnitude of health risks such that even with errors due to uncertainty in the methodology, actual health risks are expected to be less than those calculated. This process bounds the plausible upper limits of risk and facilitates an informed risk management decision.

C 7 1 1 Data Collection and Evaluation

Variability in observed concentrations is due to sampling design and implementation, laboratory analysis, seasonality, contaminant level variation, and natural variation

C 7 1 2 Exposure Assessment

The largest measure of uncertainty in the exposure assessment is associated with characterizing transport, dispersion, and transformation of COCs in the environment, establishing exposure settings, and deriving estimates of chronic intake The ultimate effect of this process is the generation of a range or distribution of estimates for intake at a given exposure point

C 7 1 3 Toxicity Assessment

Toxicity assessment is the process of characterizing the relationship between the dose or intake of a substance and the incidence of adverse effects in the exposed population Toxicity assessments evaluate results from studies with laboratory animals or from human epidemiological studies These evaluations are used to extrapolate high levels of exposure, where adverse effects are known to occur, to low levels of environmental exposures, where effects can only be predicted based on statistical probabilities The results of these extrapolations are used to establish quantitative indicators of toxicity

C 7 1 4 Risk Characterization

The last step in the risk assessment is risk characterization This is the process of integrating the results of the exposure and toxicity assessments (i.e., comparing the estimates of intake with appropriate toxicological measures to determine the likelihood of adverse effects in potentially exposed populations) Similarly, the propagated uncertainties defined throughout the uncertainty analysis process are combined and presented as part of the risk characterization to provide an overall uncertainty in the estimate of risk

C 7 2 Uncertainty in Human Intake Parameters

Inherent in the evaluation of modeled contaminant intake is the uncertainty in the values used to assign intakes Uncertainty parameters of intake (such as ingestion rate) as well as parameters of demographics (residence time, length of work day, etc) are evaluated quantitatively to the extent possible so that the uncertainty about the mean for those important variables is propagated through the analysis along with modeled concentrations and toxicity constants

The selection of probability distributions as inputs to exposure and risk models is conducted according to guidance set forth in the *Exposure Factors Handbook* (EFH) (EPA, 1990)

> "In general, the selection of a probability distribution to represent an input factor in the exposure models should be based upon any gathered information about that factor, theoretical arguments, and/or expert opinions A probability distribution can be ascertained for such information as the following general shape of the distribution, minimum, maximum, mode, mean, median, midrange, and other percentiles Available data on the probability distributions for each of the exposure factors discussed in this handbook have been presented in previous sections When distribution data are not available, distributions can be assigned using professional judgement "

Although the exact shape of many of the distributions is not known, the estimated distributions approximate the current state of knowledge about these variables much better than a single point estimate From the data presented in EFH, it may be seen that for each variable, a range of values exists In many cases, additional information such as central tendency values (e g , mean, median) and/or percentiles is provided Selection of a single point estimate from such data is a significant loss of information. In effect, a point estimate is a distribution in which a single value has a 100 percent chance of occurring, and all other values have no chance of occurring The data presented in EFH is capable of providing much more information than a single point estimate, particularly for the purpose of risk assessment

A further consideration is that exposure parameters may not be independent For example, there is typically a positive correlation between inhalation rate and body weight A range of values may be identified in the literature for this correlation These correlations range from moderate to moderately high

C 7 3 Qualitative Uncertainty Analysis

A qualitative uncertainty analysis can be used to estimate the impact of aspects of a risk assessment

The initial characterization that defines the risk assessment for a site involves many professional judgments and assumptions Definition of the physical setting, population characteristics, and selection of the chemicals included in the risk assessment are examples of areas for which a quantitative estimate of uncertainty cannot be achieved because of the inherent reliance on professional judgement

Assumptions and supporting rationale regarding these types of parameters, along with the potential impact on the uncertainty (i e , overestimation or underestimation of uncertainty), are described qualitatively above as part of the qualitative exposure assessment uncertainty analysis A qualitative uncertainty analysis is presented in Table 1

Table C.7-1
Selected Qualitative Uncertainty Factors

Uncertainty Factor	Effect of Uncertainty	Comment
Fate and Transport Estimation		
Assumed house volume and ventilation rate	May slightly overestimate or underestimate risk	The indoor concentration of soil gas penetrating the foundation depends on indoor ventilation
Soil-gas source term assumptions	May overestimate or underestimate risk	The heterogeneous sources were assumed to be homogeneous
Natural infiltration rate	May overestimate risk	A conservative value was used for this parameter
Moisture content	May overestimate or underestimate risk	This varies seasonally in the upper vadose zone and may be subject to measurement error
Water table fluctuations	May slightly overestimate or underestimate risk	The average value used is expected to be representative of the depth over the 25-year exposure period
Modeling of VOCs from soil gas through the foundation	May over estimate or underestimate risk	There may be DNAPLs in the vadose zone, however, conservative assumptions were used in the modeling from the saturated zone
Variability in annual meteorological data	May slightly overestimate or underestimate risk	Although a rigorous statistical analysis on annual variability was not conducted, the annual variability is less than approximately 1% in each category, resulting in less than approximately 5% from year to year
Exposure scenario assumptions	May overestimate risk	The likelihood of future onsite residential development is small If future residential use of this site does not occur, then the risk estimates calculated for future onsite residents are likely to overestimate the true risk associated with future use of this site
Exposure parameter assumptions	May overestimate risk	Assumptions regarding media intake, population characteristics, and exposure patterns may not characterize actual exposures
Exposure Estimation		
Exposure duration	May overestimate or underestimate risk	The assumption that an individual will work or reside at the site for 25 or 30 years is conservative Short-term exposures involve comparison to sub-chronic toxicity values, which are generally less restrictive than chronic values

Non chemical-specific constants (not dependent on chemical properties)	May overestimate risk	Conservative or upper bound values were used for all parameters incorporated into intake calculations
	Toxicological data	
Exclusion of some hypothetical pathways from the exposure scenarios	May underestimate risk	Exposure pathways were rigorously evaluated for each scenario and eliminated only if it was determined that they were either incomplete or negligible compared to other evaluated pathways
Permeability coefficients	May slightly overestimate or underestimate risk	EPA permeability coefficients were algorithmically predicted and have an uncertainty of approximately one order of magnitude
Use of cancer slope factors	May overestimate risk	Potencies are upper 95th percentile confidence limits Considered unlikely to underestimate true risk
Critical toxicity values derived primarily from animal studies	May overestimate or underestimate risk	Extrapolation from animal to humans may induce error due to differences in absorption, pharmacokinetics, target organs, enzymes, and population variability
Critical toxicity values derived primarily from high doses, most exposures are at low doses	May overestimate or underestimate risk	Assumes linear at low doses Tend to have conservative exposure assumptions
Critical toxicity values and classification of carcinogens	May overestimate or underestimate risk	Not all values represent the same degree of certainty All are subject to change as new evidence becomes available
Lack of inhalation slope factors	May underestimate risk	Carcinogenic COCs without inhalation slope factors, may or may not be carcinogenic through the inhalation pathway
Use of oral slope factors to evaluate dermal absorption	May overestimate or underestimate risk	Assumes that introduction to the blood stream through the skin acts similarly to absorption through the gut
Addition of risks across weight-of-evidence classifications	May overestimate risk	Addition of risks across weight-of-evidence classifications is extremely health conservative and potentially inappropriate
Lack of RfDs or RfCs	May underestimate risk	Inhalation RfDs or RfCs are not available from IRIS for some chemicals
Effect of absorption	May overestimate or underestimate risk	The assumption that absorption is equivalent across species is implicit in the derivation of the critical toxicity values Absorption may actually vary with chemical
Lack dermal absorption or direct action toxicity values	May slightly underestimate risk	The unavailability of consensus absorption values does not facilitate comparison of absorbed dose to toxicity constants based on administered dose

C.8.0 SUMMARY

These residual risk calculations discussed in this risk assessment were intended to develop a quantitative assessment of the risk associated with appropriate receptors and scenarios after specific remedial action alternatives have been implemented. Based on information from the PHE, the most conservative contamination, scenarios, receptors, and pathways, were evaluated. Concentrations of contaminants were modeled using groundwater modeling techniques and then receptor intakes were calculated. The intakes were combined with toxicological data in risk and HQ equations to calculate potential probabilities for carcinogenic risk and noncarcinogenic HQs. The carcinogenic risks and HQs were then summed by scenario to yield total potential carcinogenic and noncarcinogenic effects.

The maximum calculated carcinogenic risk is for the no action scenario. The total risk to the future onsite resident with groundwater is 1.17E-05.

The HIs calculated for the scenarios and receptors were not significant (i.e., did not approach unity). The maximum HI is 2.59E-01 for a future onsite child resident and the no action scenario.

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APPENDIX D

POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

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8702-8706) Further, it is not obvious that the preferred alternative, recommended in the OU-1 draft final CMS/FS report, would not achieve compliance with State Groundwater Standards Until a specific point of compliance is agreed upon, the EPA's assumption that a remedial action is necessary to achieve compliance under the State Groundwater Standards (which are different from the chemical-specific ARARs presented in the CMS/FS) is invalid DOE has suggested demonstrating compliance with certain performance monitoring points prior to selection of a remedy, while compliance at several locations is evaluated by the agencies and the public

Resolution.

As discussed in the meeting held on December 14, 1994, between DOE, EPA and CDPHE, the results of the revised CMS/FS report will be reviewed prior to selecting a preferred remedy for OU-1 The results of the revised detailed analysis of alternatives will be presented to both agencies and input will be solicited at that time for selecting an appropriate remedial action for preparation of the proposed plan for OU-1

Comment 3

The FS states that the preferred alternative for OU1 is institutional control without the french drain but with groundwater monitorings Under this strategy, chlorinated solvents in the subsurface will continue to contaminate groundwater until sources diminish through natural processes However, due to some uncertainty regarding the location and nature of the sources, it is difficult to determine with confidence how long institutional controls and groundwater monitoring will be required Modeling results presented in the FS indicate that concentrations at Woman Creek will continue to increase until the year 2369, or for 375 years into the future To ensure that Woman Creek is protected, it follows that groundwater monitoring will be required as long as concentrations increase, but only 30 years of monitoring is accounted for in the cost estimate for the preferred alternative

Response

Due to the impact of present worth analysis on cost estimates of monitoring periods extending beyond 30 years, EPA guidance recommends that costs occurring beyond thirty years be neglected in feasibility study cost analyses Specifically, the *Remedial Action Costing Procedures Manual* (EPA 1987) states on page 3-21 "Remedial action alternatives requiring perpetual care should not be costed beyond thirty years, for the purpose of feasibility analysis The present worth costs beyond this period become negligible and have little impact on the total present worth of an alternative " Also, *the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988) states on page 6-13 "In general, the period of performance for costing purposes should not exceed 30 years for the purpose of detailed analysis " In addition, 30-year monitoring periods are required under RCRA for closure actions that may impact groundwater (6 CCR 1007-3, 264 117) The costing of monitoring periods for thirty years does not limit the actual monitoring period, which would be extended if continued monitoring is required

Resolution:

As discussed in the meeting held on December 14, 1994, between DOE, EPA and CDPHE, the monitoring period described in the CMS/FS report will remain at 30 years as prescribed by guidance, except for remediation alternatives which may limit the amount of monitoring required

Comment 4:

The source removal remedial alternatives offer the possibility of removing source areas and potentially reducing the post-closure monitoring period and the potential for future corrective action Therefore, the time required to reach remedial action objectives (RAOs) is one of the major difference among the three general types of alternatives evaluated (monitoring, containment, and source removal followed by residual contaminant containment and monitoring) The FS must evaluate the time element in more detail before a remedial alternative is recommended The report must also provide more discussion about the uncertainty of the source extent and how this uncertainty affects the effectiveness of the source removal technologies These discussions must also consider the degree of confidence gained after the proposed soil gas study is conducted In addition, the FS must estimate the time it will take to reach a point when monitoring is no longer required for each alternative and incorporate these results into the comparative analysis The FS must also consider the uncertainty associated with the models when evaluating the effectiveness of the various strategies Finally, the FS should incorporate a sensitivity analysis into the model results to further evaluate the impact of subsurface contaminant uncertainty

Response.

Where possible, the elements of this comment will be included in the revised CMS/FS report In particular, more text will be added to the document discussing the uncertainties involved with each remedial action and with the source areas in general However, it is because of the large uncertainty associated with the source areas at OU-1 that it was not deemed appropriate to specify the monitoring periods required for each alternative Until data are available concerning the actual performance of a remedial action at OU-1, it is impossible to accurately predict the monitoring period required for any alternative, other than through standard guidance (i e , 30 years) In addition, it is believed that these time periods will not affect the selection of a preferred remedy, and therefore are not critical to the detailed analysis of alternatives

Uncertainties associated with the groundwater model will be discussed further in the revised CMS/FS A sensitivity analysis was suggested by DOE previously but could not be accomplished in the schedule provided Both EPA and CDPHE acknowledged this fact and agreed that it would not be presented in the draft final CMS/FS A sensitivity analysis will be initiated for the OU-1 CMS/FS and will be incorporated based on schedule constraints

Resolution:

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, the resolution to this comment is as stated in the response above

Comment 5:

Given the proximity of OU1 to Woman Creek, one of the primary functions of any remediation that occurs at OU1 should be to protect Woman Creek and the associated ecological receptors Therefore, protecting ecological receptors associated with Woman Creek must be an RAO for OU1

Response:

This issue will be discussed further through a special work group designated by DOE and the regulatory agencies to resolve specific comments However, this exposure route was not included in the RFI/RI report or the BRA and it is unclear why the EPA is raising the issue at this time

Resolution:

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, this comment will be resolved by including additional detail in the short-term effectiveness evaluation of each alternative concerning impacts to Woman Creek and other environmental receptors In addition, an RAO will be added to include protection of ecological receptors in Woman Creek

Comment 6:

It is uncertain whether Woman Creek and the associated ecological receptors will be protected under the proposed remedial alternative Throughout the FS, the text states that maximum contaminant levels (MCLs) need to be met only at Woman Creek to be protective It is not clear whether MCLs will protect ecological receptors associated with Woman creek The FS must be revised to illustrate how Woman Creek ecological receptors will be protected from OU1 contamination

Response.

See response to General Comment #5

Resolution:

See resolution to General Comment #5

Comment 7:

More detailed discussion about the proposed monitoring plan must be added to the FS, particularly since monitoring is one of the primary features of the preferred alternative and is common to all alternatives The alternatives that would suspend french drain operations but leave it in place (Alternatives 0 and 1) imply that monitoring will continue, and that the french drain will be reactivated only if monitoring results exceed predicted values The only locations for which predicted values are given in Appendix B are both down gradient of the french drain The text does not specify which monitoring wells correspond to these locations Regardless, by the time concentrations begin to exceed predicted values down gradient of the french drain, it may be too late for the french drain to be effective If a contamination front is detected below the french drain, it is probable that the contaminants have already spread throughout the length of the french drain Monitoring wells that will be used to trigger remedial decisions should be located above the portion of the french drain that intersects the expected contaminant flow path Currently, the closest well reported to have 9,500 micrograms per liter (μg/L) of trichloroethene (TCE), 2,600 μg/L of carbon tetrachloride, and 590 μg/L of tetrachloroethane (PCE) from a sample collected in late 1992 On the basis of these results, french drain operation should not be discontinued under any of the alternatives If future wells are planned for the area above the french drain, investigative methods should be used that will optimize the well location with respect to bedrock topography and the contaminant plume

Response:

The location of monitoring wells is typically not a component of the CMS/FS as it does not affect alternative development or the detailed analysis of alternatives This information is usually included in the PRAP/PP, CAD/ROD, or in a post-closure monitoring plan More information regarding the monitoring plan will be incorporated into the CMS/FS report at the agency's request, although DOE disagrees that the information is relevant to the remedy selection process Note that both regulatory agencies will have input to the monitoring plan through any of the documents mentioned above

Resolution.

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, the resolution to this comment is as stated in the response above

Comment 8:

There is no mention in this document of the buried gas transmission line that crosses OU1 in an east-west direction between 119 1 and the French Drain The existence of this feature could certainly impact some of the alternatives discussed in this document Additionally, since this line lies in the path of the migrating contaminated groundwater, an evaluation of how it might be affecting migration is needed

Response:

It is unclear how this comment could impact the remedial action alternatives presented in the CMS/FS report The line is a utility feature which will undoubtedly be reviewed during detailed design The purpose of the CMS/FS report is to evaluate conceptual approaches to remediation of OU-1 Details such as the transmission line do not impact the analysis, especially in the case where the line is not in the immediate vicinity of the treatment zone as is the case here In addition, evaluation of the transmission line as a potential route for contaminant migration is not within the scope or purpose of the CMS/FS report This issue should have been raised during the preparation of the RFI/RI report if EPA felt that it warranted significant attention

Resolution.

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, this comment will be resolved by including a reference to the gas transmission line wherever alternatives are presented that could potentially be impacted by the presence of the line

Comment 9.

This report fails to make use of all available and pertinent data, and this is especially critical in the ground water modeling that was performed Apparently only analytical data from 1990 through mid 1992 was used in the modeling, even though data from 1987 to the present is readily available for this purpose Nor were the soil gas survey results from December 1993 mentioned or presented, although a much older (pre-1987) soil gas survey was cited a few times in the text What happened to the cores and associated data that were proposed in the OU1 Treatability Study Work Plan, Soil Flushing, Biotreatment, and Radio Frequency Heating, September, 1992? That work plan was designed for the purpose of collecting site specific data to be used in evaluating alternatives for the OU1 CMS/FS and any data that was collected must be presented in this report

Response.

DOE believes it is appropriate to use the data set considered in the RFI/RI report for the groundwater model constructed for the OU-1 CMS/FS Groundwater monitoring data for the hillside is available to the present date and will continue to be available in the future However, the groundwater model must consider a data set that is static and cannot be updated continuously based on current monitoring programs The data set selected for the model is the most appropriate data set to use given its use in the RFI/RI report, to which results of the model are being compared Remedy selection is based on the results of the CMS/FS report, which in turn is based on the results of the RFI/RI report However, at the request of both agencies, the groundwater model has been revised to include data through 1994 It is assumed that this data will be sufficient to satisfy this comment

Note that the intent of the treatability study work plan was not to gather soil characterization data Rather the intent of the study was to gather soil samples for testing of various treatment technologies Unfortunately, soil samples recovered contained few if any detectable concentrations of contaminants even though they were taken from the most probable contaminant regions at IHSS 119 1 Data from the tests themselves were supposed to be used for evaluating alternatives Since the tests were not performed due to the unavailability of contaminated soils, the data are not available to include in the CMS/FS report

The CMS/FS report will be revised to reference both soil gas surveys The data was used indirectly in the CMS/FS during conceptualization of remedial action alternatives The text will be revised to include this information

Resolution:

As discussed in meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, the resolution to this comment is as stated in the response above

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General Comments

Comment 1.

General Lack of Response to Division Comments -- The Division finds that the DOE has in general failed to adequately respond to or resolve the vast majority of our comments and concerns in this draft CMS/FS report These concerns were discussed with DOE staff in several meetings and are documented in the Division's comments to TM 10 and TM 11 The DOE's failure to resolve these comments has resulted in the submittal of an incomplete and inadequate draft CMS/FS

Response

DOE has made every effort to adequately respond to comments received from both EPA and CDPHE Many of the concerns listed in the State's comments on the OU-1 CMS/FS have not been raised during the various working meetings held between DOE, EPA, and the State since January of this year Issues such as classification of IHSS 130 as a mixed waste landfill significantly impact the content of the OU-1 CMS/FS and should have been discussed during the identification of preliminary remediation goals and remedial action alternatives Additionally, technical input from both agencies received during working meetings has not been representative of written comments received after review of both TMs and the CMS/FS report For example, the State has commented heavily on the conceptual approach and parameters used to develop the OU-1 groundwater model This information was presented to both agencies through several meetings beginning in June of this year and continuing through July Both agencies were involved in reviewing the model as it was developed and at no time did either agency indicate a concern over the conceptual approach applied DOE is disappointed that the State has criticized DOE's approach to the consultive process, while continuing to limit the value of such meetings These disparities have hindered proper resolution of outstanding issues - issues which often times are not discussed early in the process due to the State's consistent submittal of comments on OU-1 documents much later than EPA comments

Resolution·

During the December 8 meeting between DOE, EPA, and CDPHE it was decided that regular meetings will be held to resolve outstanding issues on the OU-1 CMS/FS report These meetings will be instrumental in achieving a common forum through which all parties can come to agreement on specific items Resolution will be documented herein and incorporated into the revised CMS/FS report

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Comment 2:

<u>Role of the State and RCRA Correction Action in Remedy Selection</u> -- This Draft CMS/FS is entirely focused on CERCLA and the CERCLA process No attempt has been made to meet the State's RCRA/CHWA requirements Under the IAG, the State will make a Corrective Action Decision under RCRA/CHWA and the EPA will make a Remedial Action Decision under CERCLA The CMS/FS must be adequate to support both Agencies' decisions The IAG specifically requires that Feasibility Studies / Corrective Measures Studies comply with the requirements of CERCLA, RCRA, CHWA, and pertinent guidance and policy [paragraph 152] The Division has stated on many occasions, both formally and informally, that the CERCLA process is only a template and some modifications to the process will be necessary to meet RCRA/CHWA CMS requirements The DOE has repeatedly ignored these Division concerns

In this draft CMS/FS report, the DOE's position continues to be that consistency with CERCLA RI/FS guidance takes precedence over meeting RCRA/CHWA CMS needs and requirements The DOE's failure to address this issue has resulted in the submittal of a deficient CMS/FS document that does not meet the State's needs in making a corrective action decision for all IHSSs in OU-1 The DOE must fully recognize and meet all RCRA/CHWA requirements in the Final CMS/FS and, where necessary, deviate from CERCLA FS guidance to meet such requirements Consistency with CERCLA guidance is not sufficient justification for ignoring the Division's concerns and comments

Response

DOE disagrees with the State's comment that the draft final CMS/FS report is focused solely on CERCLA and the CERCLA process Comments further state that no attempt has been made to meet the State's RCRA/CHWA requirements CERCLA evaluation criteria duplicate RCRA evaluation criteria and include additional criteria which address community and state acceptance The State has acknowledged that Section 4 0 of the report was not reviewed This section represents the core of the CMS/FS and contains a detailed evaluation of both RCRA and CERCLA criteria DOE requests that the State specify what requirements are not being met under RCRA/CHWA, since the detailed analysis of alternatives includes discussions on RCRA standards, evaluation criteria, and source control measures Additional information regarding specific deficiencies is requested prior to responding to this comment For information purposes the following table lists the evaluation criteria considered under both CERCLA and RCRA guidance

National Contingency Plan, Evaluation Criteria 40 CFR 300.430 (e) (9) (iii)	RCRA Corrective Action Plan Guidance Evaluation Criteria OSWER Directive 9902.3-2A (May 1994)
Overall protection of human health and the environment	Protect human health and the environment
	Control the sources of releases[1]
Compliance with ARARs	Comply with any applicable standards for management of wastes
	Attain media cleanup standards set by the implementing agency
Long-term effectiveness and permanence	Long-term reliability and effectiveness
Reduction of toxicity, mobility, or volume through treatment	Reduction in the toxicity, mobility or volume of wastes
Short-term effectiveness	Short-term effectiveness
Implementability	Implementability
Cost	Cost
State acceptance	
Community acceptance	

[1]This criterion is addressed under the National Contingency Plan threshold criteria for Overall Protection of Human Health and the Environment This criterion is also directly related to the Long-Term Effectiveness and Permanence criteria

Resolution

During the December 8 meeting it was made clear that the State felt that the OU-1 CMS/FS report did not adequately address the RCRA CAP criteria in the detailed analysis of alternatives (DAA) The State suggested a separate working session to review the DAA, and to provide input into the presentation of Section 4 0 of the CMS/FS DOE agrees that this approach will resolve this comment and agrees to provide more information in the report on the RCRA CAP process and how it is integrated with the CERCLA process Summary tables in Section 4 0 of the report will be revised to include specific CAP criteria where the criteria differ from those evaluated under CERCLA For example, source control measures will be specifically discussed in the DAA to address this CAP criterion

Comment 3:

DOE Inappropriate Proposal for a CAMU -- The DOE has proposed as part of all remedial alternatives for OU-1, that the Division designate the 881 Hillside at RFETS as a corrective action management unit (CAMU) The DOE's sole intention in proposing this designation appears to be avoiding the active clean-up of the hillside The Division is bewildered by the DOE's apparent lack of understanding of the intent and substance of the CAMU regulations The intent of CAMU is to facilitate an effective and efficient remedy, not to avoid the need for active corrective action The Division finds the application of CAMU proposed by the DOE in this document to be inconsistent with the intent of the CAMU regulations and both the substantive and administrative requirements of CAMU

The Division is extremely disappointed that we were not consulted on this proposal or notified of the DOE's intention to apply CAMU at OU-1 prior to the submittal of this CMS/FS report Based on our evaluation of all information available under OU-1, the Division finds no basis for designating OU-1 a CAMU If the DOE can provide sufficient information supporting the appropriateness of a CAMU at OU-1, this information must be discussed and a CAMU designation agreed to by the Agencies prior to its inclusion in the Final CMS/FS

Response:

DOE has proposed use of the Subpart S hazardous waste requirements as a possible means of achieving "an effective and efficient remedy" for OU-1 The information on the Corrective Action Management Unit (CAMU) rule that DOE has access to is the Commission's proceedings on adopting the rule and the rule itself (6 CCR 1007-3, 264 552) The CAMU approach to OU-1 was proposed in this draft final CMS/FS for review and discussion with the State, as is required under the CAMU rule If the State does not agree that the CMS/FS report is the proper forum for discussing the CAMU concept at OU-1, then DOE requests that the State suggest an appropriate forum for this discussion within the confines of the IAG

Resolution:

During the meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, it was agreed that the CAMU language will be removed from the CMS/FS report CDPHE agreed that an IHSS by IHSS evaluation is not required for alternative development as long as each source area and IHSS is identified in the OU-1 CMS/FS and dispositioned in terms of remedial actions The CAMU concept was proposed to retain an OU-wide approach to alternative analysis at OU-1 Based on the State's revised position on the IHSS by IHSS evaluation issue, the CAMU language will be removed

Comment 4:

Information Necessary to Support a Corrective Action Decision -- This comment was originally made to TM 11 and has not been resolved to the Division's satisfaction in the Draft CMS/FS The draft CMS/FS does not contain sufficient information to support a CAD for all of the IHSSs in OU-1 The Division will not consider the Final CMS/FS to be complete until all IHSSs and/or source areas in OU-1 are sufficiently addressed This draft CMS/FS only addresses contamination at IHSS 119 1, at a minimum the group of IHSSs south of Building 881, IHSS 130, and IHSS 119 2 must also be evaluated

This concern was raised in the Division's comments to the draft TM 11 and clarified in a meeting with DOE and EG&G staff The DOE formally responded to this concern on September 30, 1994, almost a month after releasing the draft CMS/FS The Division finds the DOE response to this comment inappropriate, inaccurate and inconsistent with both the IAG and the risk screening approach that all parties agreed to

The evaluation of each IHSS is consistent with the CERCLA process and has been recognized by the EPA as necessary and appropriate for all OUs at RFETS Regardless of CERCLA guidance, the Division requires the CMS/FS contain sufficient information to fully support a corrective action decision by the Division under RCRA/CHWA for each IHSS and/or source area in OU-1

The DOE disagreement with the Division's application of the risk screening approach is concerning This screening methodology was agreed to by all parties, including the DOE

The development of remedial action alternatives must start at the IHSS and/or source level Corrective measures must be selected for each IHSS and/or source area that are fully protective and meet all appropriate RAOs and PRGs The number and range of alternatives evaluated for each IHSS and/or source area may be limited by the scope and complexity of contamination and availability of treatment options Alternatives selected for each IHSS should then be combined to form a range of remedial action alternatives for the operable unit When appropriate, IHSSs with similar effective alternatives can be combined to achieve economies of scale Alternatives developed at the operable unit level must provide the range of alternatives prescribed in EPA guidance

The Division recognizes that it may not be efficient to address all contamination strictly through IHSSs, in some instances it may be more efficient to address an area of contamination as a source area independent of the IHSSs This does not mean that each IHSS does not need to be addressed

The DOE statement, in response to this comment under TM 11, that the groundwater contamination at the eastern edge of the operable unit has not been "definitively" tied to any one IHSS is correct but totally misleading As reported in the OU-1 RFI/RI Report, this contamination was in fact attributed by the DOE to multiple IHSSs, although not "definitively" To definitively tie the contamination on the eastern edge of OU-1 to IHSS 119 2 and/or the 903 Pad would require additional, largely unnecessary characterization field work Regardless of the source of contamination near IHSS 119 2 it must be addressed in the OU-1 CMS/FS

Response:

The meetings referenced in this comment were held during the preparation of the OU-1 CMS/FS report Both regulatory agencies have repeatedly denied DOE's informal requests to extend the schedule for preparation of the CMS/FS report Many of the comments received on the OU-1 CMS/FS are based on

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unresolved issues from the OU-1 RFI/RI report The State must recognize that many of these issues impact the CMS/FS directly and therefore impact its schedule Because both agencies have repeatedly insisted that the CMS/FS report be produced prior to resolution of these issues, agreements made between the agencies and DOE may not be represented in the draft final CMS/FS

In addition, as stated in the response to comments received on TM 11, DOE does not agree that individual IHSSs should be examined for remedial action alternatives The IAG states that the CERCLA RI/FS guidance should be used as the template for conducting OU CMS/FSs The IAG also establishes the OU concept and recognizes the need for evaluating remedial actions at the OU level The OU concept is particularly suited to the circumstances of OU-1, where unspecified sources of groundwater contamination have resulted in OU-wide contamination at various levels The OU-1 RFI/RI document also does not support an IHSS by IHSS evaluation If the State feels that IHSSs should be evaluated individually for overall protection to human health and the environment, then the State should initiate these evaluations through the RFI/RI process and not the CMS/FS process The BRA results must at some point be used by the State to determine if further action is warranted at a site, or in this case, at an IHSS It is inappropriate for the State to request that the CMS/FS be used as a vehicle to identify no action decisions prior to conducting a detailed analysis

DOE requests that the State provide additional guidance on the value of evaluating each IHSS and source area independently in the OU-1 CMS/FS report As the last paragraph of this comment suggests, " the contamination near IHSS 119 1 must be addressed regardless of its source " DOE does not believe that the groundwater medium beneath OU-1, which represents the highest potential risk to viable receptors, can be evaluated on the basis of individual IHSSs DOE has proposed alternatives that remediate both the most contaminated areas of OU-1 groundwater, as well as the OU as a whole These alternatives adequately represent potential remedial action strategies at this OU To address this comment, the revised CMS/FS will contain additional information regarding each IHSSs status in terms of each alternative

Resolution

During the December 8 meeting, the State voiced the concern that the public may not be able to follow the decision process if individual IHSSs are not specifically discussed in the OU-1 CMS/FS report DOE suggested that IHSSs be discussed early in the report to identify specific source areas These source areas will then be addressed separately and evaluated for remedial action The discussion on IHSSs and how they are addressed by the source area approach will be included in future documents (such as the Proposed Remedial Action Plan/Proposed Plan) as well The State concluded that individual alternative analyses are not required for each IHSS as long as each IHSS is included in the initial discussion of source areas Also see resolution to General Comment #4

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Comment 5:

RCRA/CHWA Criteria for the Evaluation of Final Corrective Measure Alternatives -- The Division will use the RCRA corrective action evaluation criteria presented in the latest version of the RCRA Corrective Action Plan (OSWER Directive 9902 3-2A, May 1994), a guidance document produced by EPA for implementation of RCRA corrective action, as guidance in evaluating remedial action alternatives These standards reflect the major technical components of remedies including cleanup of releases, source control and management of wastes that are generated by remedial activities

The specific standards as set out in the RCRA CAP guidance include 1) protect human health and the environment, 2) Attain media cleanup standards set by the implementing agency, 3) Control the source of release so as to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment, 4) Comply with any applicable standards for management of wastes, 5) Other factors Other factors include five general factors that will be considered as appropriate by the Division in selecting a remedy that meets the four standards above The five general factors include a Long-term reliability and effectiveness, b Reduction in the toxicity, mobility or volume of waste, c Short-term effectiveness, d implementability, and e Cost

RCRA/CHWA corrective action remedies must meet the above listed standards Therefore, the Final CMS/FS must provide detailed documentation of how the potential remedy will comply with each of the Five RCRA CAP standards

Response

DOE believes that the five criteria of EPA's RCRA Corrective Action Plan (OSWER Directive 9902 3-2A, pp 63-67) and the nine criteria of the National Contingency Plan (NCP) in 40 CFR 300 430(e)(9) are essentially identical (see Table in response to General Comment #2) It is DOE's understanding that EPA has strived over the last seven years to provide guidance that can be consistently implemented at various sites with the same contaminants under the two sets of regulations The overall objective of the two acts is the same in situations of contaminant releases and agency selection of remedies Specific differences would seem to point to additional criteria in the NCP regulations such as community acceptance It is emphasized that the RCRA Corrective Action Plan is a guidance as is the CERCLA RI/FS guidance

The State asserts that RCRA/CHWA corrective action remedies must meet the listed standards, and suggests that the CMS/FS provide detailed documentation of how the potential remedy will comply with each of the standards It is DOE's position that in fact the referenced "standards" are not standards but evaluation criteria These criteria are evaluated in the detailed analysis of alternatives presented in Section 4 0 of the CMS/FS report Until the State has reviewed this section of the document, it is inappropriate to assume that the RCRA CAP evaluation criteria are not included

Resolution. See Resolution to General Comment #2

Comment 6·

<u>Effectiveness of Remedial Action/Corrective Action to Protect the Environment</u> -- This comment was originally made to TM 11 and has not been resolved to the Division's satisfaction in the Draft CMS/FS

The general assumption that remedial actions at OU-1 that are protective of human health will adequately protect ecological receptors and environmental resources at OU-1 is not appropriate in the CMS/FS report The effectiveness of each alternative to protect the environment must be evaluated The DOE response to this comment under TM 11, that it is not necessary to consider environmental protectiveness in the OU-1 CMS/FS because the OU-1 BRA EE did not identify any significant hazards to ecological receptors, is not an acceptable response

The BRA EE finds that many of the contaminants evaluated in the BRA EE are toxic to ecological receptors at concentrations found at OU-1, but that because of the limited extent of contamination, no adverse ecological impacts occur The assumption that contamination is limited and no adverse ecological impacts will occur is not valid under all of the OU-1 CMS/FS remedial alternatives - specifically, those alternatives which allow contamination to continue to migrate uncontrolled could invalidate this assumption The effectiveness of all remedial alternatives to protect the environment must be fully addressed in the Final CMS/FS

Response

The assumption that remedial actions at OU-1 that are protective of human health will be protective of ecological receptors is based on the results of the OU-1 RFI/RI report The results of the which indicate that there is no current <u>or future</u> significant risk to these receptors The effectiveness of each alternative to protect the environment is evaluated in the detailed analysis of alternatives (Section 4 0) This section was not reviewed by the State and therefore the comment that this evaluation was not conducted may be premature

The State concludes that " the assumption that contamination is limited and no adverse ecological impacts will occur is not valid under all of the OU-1 CMS/FS remedial alternatives " due to the potential for contaminant migration This assumption is based on the RFI/RI surface soil evaluation and is not related to groundwater contamination which is the focus of the CMS/FS report The groundwater medium was not identified as a potential source of future risk to ecological receptors and therefore the assumption is valid, unless the State has identified future risks to ecological receptors from groundwater contaminants that are not identified in the OU-1 RFI/RI report

Resolution:

During the meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, it was agreed that the resolution to this comment will be present a more thorough analysis of short-term impacts to the environment under the Detailed Analysis criterion of Short-Term Effectiveness

Comment 7:

Incomplete and Inaccurate Identification of ARARs -- The Division has commented on several occasions regarding specific deficiencies in the identification of ARARs for OU-1 The Division has expressed major concerns with the DOE's identification and determination of ARARs under TM 10 The majority of the Division's comments and concerns regarding ARARs have not been adequately addressed and remain unresolved in this draft CMS/FS In comments to TM 11, the Division deferred ARARs comments in hope that several outstanding issues could be resolved through the ARARs Working Group Unfortunately, the DOE has chosen to proceed at an extremely slow pace under the ARARs working group and the group has yet to entertain substantive ARARs discussions

The Division's general comments on specific potential ARARs are presented below Additional ARARs comments are also included in the Division's specific comments All ARARs issues must be resolved in the Final CMS/FS before the Division will consider the document to be complete

a) State Groundwater Standards -- The DOE has failed to present any valid argument to support its claim that the State groundwater standards are not ARARs This document states that "groundwater standards are not addressed ARARs because the classifications requiring those standards have not been applied consistently throughout the State and thus fail the NCP criteria of 'general applicability' in 40 CFR 300 400 (g) (4) " This argument, much like the last two arguments against the application of State groundwater standards as ARARs, is simply incorrect Contrary to this argument, the phrase "general applicability" has nothing to do with whether or not standards have been applied consistently The preamble to the NCP explains that "of general applicability" means "that potential State ARARs must be applicable to all remedial situations described in the requirement, not just CERCLA sites " Consistent with the preamble's explanation, State groundwater standards are applicable to all situations, not just CERCLA sites and, therefore, are "of general applicability " Moreover, no "classifications" exist for organics, rather, the standards for organics apply statewide regardless of classification Therefore, the claim that "the classifications requiring those standards have not been applied consistently" makes no sense

b) RCRA/CHWA Subpart F Groundwater Protection -- RCRA/CHWA groundwater protection standards were identified in the Division's comments to TM 10 as potential chemical specific ARARs They have not been included in the draft CMS/FS These standards must be identified as potential ARARs in the Final CMS/FS

c) Doctrine of Sovereign Immunity -- The DOE, in response to Division and EPA comments on sovereign immunity, has stated that it has removed such language from the text of the CMS/FS, but that questions regarding sovereign immunity may still be discussed during ARARs working group meetings The Division and EPA positions' on sovereign immunity appear to be clearly presented, however if the DOE has any remaining questions at OU-1, they must be raised under this CMS/FS Report

d) Surface Water Standards -- State surface water standards were identified in the Division's comments to TM 10 as potential chemical specific ARARs They have not been included in the draft CMS/FS These standards must be identified as potential ARARs in the Final CMS/FS

e) Closure of French Drain -- The requirements for the final closure of the french drain must be identified as ARARs and included in the detailed analysis of alternatives

f) Radioactive, Hazardous and Mixed Waste Landfill Requirements -- The Division considers IHSS 130 to be a mixed-hazardous waste landfill which must be closed in accordance with all applicable landfill regulatory requirements Therefore, the DOE must identify all ARARs and TBC associated with landfills in this CMS/FS This determination is based on the documented disposal of radioactive waste in the IHSS, the known or suspected disposal of hazardous waste debris associated with the OPWL in the IHSS, and the detection of hazardous waste constituents in groundwater monitoring wells directly downgradient of the IHSS This landfill is located on an unstable hillside, is not capped and has no controls in place to prevent future release or exposure to hazardous constituents or radionuclides Regardless of the current risk associated with IHSS 130, the DOE must meet all appropriate regulatory criteria for landfills The DOE must identify all ARARs relevant to solid, radioactive, hazardous and mixed waste landfills

Response

DOE disagrees with the statement that the identification of ARARs in the OU-1 CMS/FS is incomplete The State may disagree with the selection of ARARs, however, the identification of ARARs in the CMS/FS and in TMs 10 and 11 was performed according to guidance and regulations (40 CFR 300 430(b)(9), (d)(3), (e)(2), and (e)(9) During the review of TM 11, the State emphasized that action-specific ARARs were being reviewed and comments would follow shortly These comments were never received and therefore State comments were not available prior to preparation of the CMS/FS report The following responses are applicable to other portions of this comment

a DOE has carefully reviewed the State's position and the regulations concerning the State's Basic Standards for Ground Water (5 CCR 1002-8,3 11 5) DOE has determined that the State's basic standards are potential ARARs for all contaminants except radionuclides The CMS/FS will be revised to reflect this potential ARAR at OU-1

b The RCRA groundwater protection standards (6 CCR 1007-3,264, Subpart F) were briefly mentioned in the detailed analysis of alternatives in the CMS/FS The CMS/FS will be revised to clarify that the RCRA groundwater protection standards are potential chemical-specific ARARs and that the process of establishing groundwater protection standards at the point of compliance is part of the selection of a protective remedy under RCRA and CERCLA The RCRA groundwater protection standards are maximum contaminant levels, background levels, or alternate concentration levels as approved by the Director (6 CCR 1007-3, 264 94) It is noted that MCLs were used in the CMS/FS as the potential chemical-specific ARARs and thus used to identify PRGs

c This comment is noted DOE believes that the proper forum for further discussion of sovereign immunity is the ARARs working group

d Although the State identified the Colorado surface water quality standards as potential chemical-specific ARARs earlier in the CMS/FS process, surface water has not been one of the media investigated at OU-1 The RFI/RI identifies soil and groundwater as the media of concern within the boundaries of OU-1 Information presented in the RFI/RI on the water quality of Woman Creek and the South Interceptor Ditch is from OU-5 and other locations e Clarification of this comment is required in order to respond to the comment The french drain collects ground water and to our knowledge is not a waste unit DOE is unfamiliar with specific requirements applicable to "closure" of a french drain DOE requests that the State provide specific references to support the comment

f The identification of IHSS 130 as a mixed waste landfill is the first comment from the State on this subject since the initial preparation of the CMS/FS report The RFI/RI report did not identify this issue, and the comment was never raised by the State DOE requests that the State specify its requirements for determining what areas are considered mixed waste landfills at the RFETS, and what regulatory basis is being used for these designations

Resolution

This comment is being resolved through the ARARs working group Comments a b , and d are resolved as stated in the responses above, however Comments e and f could not be subtantiated by the Division in terms of providing regulatory justification for the comments Closure requirements or performance standards are not available for the French Drain Likewise, the Division could not justify the position that IHSS 130 is a mixed waste landfill The CMS/FS report will be revised as appropriate to clarify the text

Comment 8.

Point of Compliance with Preliminary Remediation Goals -- The DOE has incorrectly determined Women Creek as the point of compliance for protectiveness and ARARs requirements at OU-1 State groundwater standards are applicable to all groundwater in OU-1 The point of compliance for groundwater PRGs at OU-1 is therefore anywhere that groundwater is present at OU-1 That is, they both must be met The correct point of compliance must be incorporated into this report and utilized in the development and screening of alternatives Once a remedy is selected, a new point of compliance for remedy effectiveness will be chosen and specifically delineated

Response

Woman Creek has not been selected as a point of compliance in the draft final CMS/FS report DOE's position on this issue is that the point of compliance should be discussed in working meetings with the agencies The meetings held in July 1994, with representatives from both agencies, concerned groundwater monitoring and covered the subject of point of compliance These discussions were focused on the RCRA requirements found in 6 CCR 1003-7, 264 95 and the State's groundwater regulations in 5 CCR 1002-8, 3-11 6 The RCRA requirements specify the following

> The point of compliance is a vertical surface located at the hydraulically downgradient limit of the waste management area that extends down into the uppermost aquifer underlying the regulated unit, where the "waste management area" is
>
> - the limit projected in the horizontal plane of the area on which waste will be placed during the active life of a regulated unit,
> - and includes horizontal space taken up by any liner, dike, or other barrier designed to contain waste in a regulated unit, or
> - if the facility contains more than one regulated unit, the waste management area is described by an imaginary line circumscribing the several regulated units
>
> Whereas the State's requirements specify that for contamination identified and reported on or before September 30, 1992, the point of compliance for the statewide standards shall be at whichever of the following locations is closest to the contamination source
>
> - the site boundary, or
> - the hydrologically downgradient limit of the area in which contamination exists when identified

The State's comment defining the point of compliance as " anywhere that groundwater is present at OU-1 " appears to be inconsistent with both sets of regulations DOE requests clarification as to the basis for the State's assertion that the point of compliance has no relation to site boundaries, and that the point of compliance should be arbitrarily set in the CMS/FS, only to be revised once a remedy is selected

Resolution:

Resolution to this comment is pending separate discussions concerning point of compliance issues

Comment 9:

Selection of Preliminary Remediation Goals -- The DOE has selected State MCLs as PRGs for OU-1 in this draft CMS/FS While the division considers State and Federal MCLs to be potential ARARs for OU-1, the Division does not find that State MCLs are necessarily the appropriate PRGs for all contaminants for either IHSS 119 1 or the OU Sufficient documentation supporting how and why the DOE selected State MCLs as PRGs for OU-1 is not included in the CMS/FS Report The rationale for selecting State MCLs over risk based PRGs or other ARARs is not included in the draft CMS/FS PRGs should be the lower of chemical specific ARARs or risk-based PRGs that exceed background and appropriate PQLs Compliance with ARARs and protection of human health and the environment are two distinct CERCLA requirements for remedies PRG selection must be correctly implemented and fully documented in the Final CMS/FS

Response

PRGs were established by following the NCP (40 CFR 300 430 (e)(2)(i)) and RCRA CAP guidelines (pgs 49 and 50) DOE does not agree that groundwater PRGs should be set at the lowest possible value available, regardless of the practicality of remediating to this value This is particularly true in the case of OU-1, where groundwater is marginally available and does not present a realistic source of usable drinking water This comment will be addressed further under the forum of the ARARs working group Justification for selection of State MCLs was provided during the working meetings held between DOE, EPA, and the State in January of this year, and is included in TM 10 At the request of both agencies much of the material presented in the TMs was not included in the OU-1 CMS/FS to limit duplication of material If this approach is no longer desired by the agencies, then DOE will include the material from both TMs in the revised CMS/FS report

Resolution·

During the meeting held on December 14, 1994 between DOE, EPA and CDPHE it was agreed that State groundwater standards will be identified as potential chemical-specific ARARs for OU-1 Groundwater PRGs will therefore be based on these standards Risk-based PRGs will not be presented in the final CMS/FS report It is assumed that State groundwater standards are considered protective by the State and therefore risk-based PRGs are not required for groundwater This is consistent with the NCP that specifies that chemical-specific ARARs are generally appropriate when available Risk-based values are typically only necessary when chemical-specific ARARs are not available, or are otherwise not sufficient to protect human health and the environment

Comment 10·

Development of Preliminary Remediation Goals -- The Division does not find that the PRGs developed in section 2 3 of this draft CMS/FS adequately address all of the RAOs presented in Section 2 2 or the additional RAOs required in the Division's specific comments The State MCLs selected by the DOE as PRGs for groundwater fail to meet the groundwater RAO as identified in this draft CMS/FS report No PRGs have been developed to ensure protection of groundwater from degradation by subsurface soil contamination under the subsurface soil RAO PRGs must be developed that ensure all RAOs are obtained at OU-1 This includes the complete and accurate identification of all chemical specific ARARs

Response

DOE requests clarification of this comment Specifically, the comment states that State MCLs fail to meet the groundwater RAO listed in the draft final CMS/FS report, then goes on to state that no PRGs have been developed to ensure that protection of groundwater from degradation by subsurface soil contamination under the subsurface soil RAO DOE requests clarification as to which RAOs the State is referring to in regard to the MCLs MCLs are presented as PRGs for groundwater and are not intended to target the subsurface soil medium

In addition, subsurface soil PRGs cannot be established unless there exists a clear source of subsurface soil contamination to groundwater Repeated efforts to obtain samples from the IHSS 119 1 area, that contain possible contaminant sources, have indicated that there are no clear source areas identifiable at the IHSS, and therefore no sources for which PRGs can be established and measurably achieved With regard to ARARs, identification of chemical-specific ARARs is discussed in the responses to General Comments #7 and #9, and will be addressed through the ARARs working group It is important to note here that not all RAOs necessarily require quantified PRGs

Resolution.

Based on the meeting held on December 8, 1994, this comment will be resolved by revising the subsurface soil RAO included in the CMS/FS report to state the following "Prevent migration of contaminants from subsurface soils to groundwater that would result in ground water contamination in excess of groundwater ARARs for OU-1 contaminants "

Comment 11.

<u>Risk Based PRG Calculation Methodology</u> -- The Division specifically raised several concerns with the calculation of risk based PRGs in comments to TM 10 The DOE has failed to adequately address many of these comments Many of these issues remain unresolved from the Final Phase III RFI/RI Report The Division approved the Revised Final Phase III RFI/RI Report, Rocky Flats Plant 881 Hillside, OU1, June, 1994 <u>contingent upon DOE's revisions on a limited number of issues</u> These issues cannot simply be addressed by discussing them in the Phase III RFI/RI report comment-response section The Division has not been convinced by DOE's arguments, and expects compliance with our requests

The Division's major issues included an adequate quantitative assessment of external irradiation both OU-wide and at the source, a good qualitative assessment of toxicity of PAHs and PCBs and also of those chemicals for which there are not as yet any EPA toxicity factors, calculation of intake values for all those chemicals for which there are as yet no EPA toxicity factors, an assessment of surface soil exposure to the construction worker receptor, and a more objective presentation of the risks As of yet, the Division has not seen any revisions Therefore, DOE's contention that absolutely no changes will be made in the PRG documents or methodology because similar methodologies were used in the RI/RFI document is premature The Division is particularly concerned by the DOE's refusal to calculate external exposure to radiation by a future resident This calculation is supported both by RAGS (Part B, p 35) and by ICRP 26 and 30

Response.

The concerns listed in this comment do not apply to the OU-1 CMS/FS report They are primarily RFI/RI issues as stated in the comment and do not affect alternative development In addition, the State has requested throughout the comment document that the OU-1 CMS/FS report not include any reference to the surface soil medium DOE seeks clarification as to why the concerns listed in this comment are presented here, in light of the State's comments regarding this medium Although the State is particularly concerned about external exposure to radiation by a future resident, DOE requests clarification of how this will affect the evaluation of remedial action alternatives for groundwater at OU-1

Resolution·

Based on the meeting held on December 8, 1994, between DOE, EPA and CDPHE, this comment is not relevant to the OU-1 CMS/FS report, and is therefore noted but does not require a revision to the document

Comment 12:

Failure to Consider ALL Contaminants -- This comment was raised in the Division's comments to TM 10 and TM 11 It has not been fully addressed by the DOE and remains a deficiency in this draft CMS/FS report

The Division, under its corrective action authority, will consider all hazardous constituents found at OU-1 in making a corrective action decision Therefore, the CMS must include all contaminants and cannot be limited to only the BRA COCs The BRA COC screen was developed to focus the BRA risk evaluation on risk drivers This screen does not preclude non-COCs from being present at levels above risk based concern or that need management and monitoring This is evident in Table 5-2 of the draft CMS/FS where many non-COCs are shown to be present at OU-1 at concentrations above risk based PRGs As stated by the Division in previous comments, the Division requires that all contaminants identified at OU-1 be included and fully evaluated in the OU-1 CMS/FS

Response

The table referenced in this comment is unknown In addition, DOE requests clarification on the State's position that all contaminants identified at OU-1 be fully evaluated It is unclear in this comment how a contaminant is "evaluated" The focus of the CMS/FS report is to evaluate remedial action alternatives using specific COCs as indicators to determine the effectiveness of each alternative The CMS/FS report will be revised to specify that the complete list of contaminants are potential COCs, although the alternative evaluation process will remain unchanged

The revised groundwater model will evaluate all of the organic contaminants identified inthe OU-1 BRA In addition, TCE will be modeled since it appears in concentrations similar to other identified BRA COCs Other contaminants, which appear at much lower concentrations in OU-1, will be qualitatively evaluated in the revised CMS/FS report This approach should meet the intent of this comment while preserving the integrity of the existing groundwater model

Resolution:

This comment will be addressed by the revised groundwater model, which now includes all of the BRA organic COCs as well as TCE Other contaminants will be evaluated qualitatively but occur at much lower concentrations throughout the site, and are adequately represented by the modeled COCs

Comment 13:

Subsurface Soils Preliminary Remediation Goals -- The DOE has repeatedly failed to respond to the Division's concerns that subsurface soil contamination is not being adequately addressed in the CMS/FS The DOE continues to claim that subsurface soils were found not to present unacceptable risk in the BRA, and thus do not require consideration This is not correct, subsurface soils were indirectly evaluated in the BRA through groundwater pathways, many of which were found to present elevated risks

Regardless of the BRA, hazardous constituents are present in the subsurface soils within OU-1 and must be evaluated in the RCRA/CHWA Corrective Measures Study and subsequent Corrective Action Decision Therefore, subsurface soils must be considered along with groundwater in developing RAOs and PRGs RAOs and PRGs for subsurface soils must be based on risk, protection of groundwater and ARARs

Response

DOE requests clarification from the State as to how subsurface soil PRGs can be developed based on risk, protection of groundwater, and ARARs, when no direct risks have been identified in the BRA, and chemical-specific ARARs currently do not exist for this medium The State has repeatedly suggested that PRGs be developed for subsurface soils without providing guidance as to what is being requested

Additionally, given the wide variability in partitioning values found at OU-1, PRGs cannot be reliably calculated for subsurface soils based on these values DOE therefore requests that the State clarify whether it is asking for PRGs based on ingestion of subsurface soil, or on contaminant transport to groundwater If the latter is the primary concern, then this issue should have been raised as an RFI/RI issue It is unclear why the State is continuing to question RFI/RI issues in this document inappropriately

Resolution:

Based on the meetings held on December 8 and December 14, 1994, between DOE, EPA and CDPHE, subsurface soil PRGs will not be calculated directly The subsurface soil RAO included in the OU-1 CMS/FS report will be revised as discussed in the response to General Comment # 11

Comment 14:

Inadequate Documentation of Remedial Action Alternative Development and Screening Process -- The Division does not find the documentation and supporting rationale for the development and screening of remedial action alternatives as presented in TM 11 and the draft CMS/FS to be adequate The Division commented on the development and screening of alternatives in several specific comments to TM 11 The DOE has failed to resolve these comments or address the Division's concerns

The DOE has on several instances chosen to cite CERCLA guidance as a rationale for not addressing the Division's concerns This is not adequate All of the Division's comments must be fully resolved to the Division's satisfaction and integrated into the CMS/FS The CMS/FS must include a thorough documentation of the remedy development and selection process, including appropriate supporting rationale It is not appropriate to reference the DRAFT TM 11 for this documentation

Response

The draft TM 11 document was incorporated by reference in the OU-1 CMS/FS report as agreed to by DOE, EPA, and the State during various working meetings At the request of both regulatory agencies this was done in order to limit the duplication of material found in the TMs and the CMS/FS report If desired, the final CMS/FS report will include all of the material originally presented in the TMs, although each document will still be available in the administrative record

CERCLA guidance has been cited where necessary to justify the amount of detail included in the CMS/FS report, and/or to explain how specific concepts are applied in the CMS/FS process DOE has attempted to satisfactorily address the State's concerns while maintaining the intent of RCRA and CERCLA cleanup guidelines which specify evaluating various criteria to determine both the feasibility and necessity of initiating remedial actions The State's position to date has been that remedial action is warranted at OU-1 regardless of the results of the detailed analysis of alternatives DOE fundamentally disagrees with this approach and has therefore cited guidance where necessary to maintain an appropriate and accepted methodology for remedy selection

Resolution:

The revised CMS/FS report will not reference the draft TM 11 document The report will provide information regarding both RCRA and CERCLA remedy selection processes and will incorporate State comments as appropriate

4Z1

Comment 15:

Impacts of Decommissioning of the French Drain -- Several of the alternatives presented in this document, including the DOE preferred alternative, recommend the decommissioning of the french drain The text in several sections discusses decommissioning the french drain by breaching the drain with a backhoe It does not appear that the decommissioning of the drain was considered in modeling of contaminant migration down gradient of the drain Specifically, any breach in the drain would become a preferential pathway for transport to Women Creek Contaminated groundwater collected in the "decommissioned" drain would essentially be discharging directly to Women Creek as surface water This pathway must be considered in modeling the impact of decommissioning the drain

The current modeling assumes that if the french drain were decommissioned, contamination would eventually reach Women Creek via continued migration of the contaminant plume down gradient of the drain The fate of contaminated groundwater collected within the french drain after decommissioning must be considered in modeling the impact of such alternatives

Additionally, the eventual final closure of the french drain raises many issues that have yet to be considered including potential decontamination methods, closure performance standards and potential post-closure care requirements for the drain The Division strongly recommends that the DOE fully consider these issues in evaluating the role of the french drain in remedial alternatives at OU-1

Response

Decommissioning of the drain was not considered in modeling of contaminant migration downgradient of the drain As discussed in the response to General Comment #1, this issue was not raised during the various meetings held with both regulatory agencies to discuss the conceptual approach applied to modeling OU-1 Additionally, it is unclear 1) how decommissioning of the drain would result in direct discharge to surface water, and 2) how the State wishes this pathway to be considered in modeling the impact of decommissioning the drain DOE therefore requests clarification as to what type of modeling the State is suggesting for the french drain

The State's comments regarding decontamination methods for the french drain are likewise unclear DOE is unaware of any regulatory provisions for decontaminating this type of unit, for closure performance standards, or potential post-closure care requirements DOE requests clarification as to what State requirements are being referenced, and how these requirements affect selection of a preferred remedy at OU-1

Resolution.

Resolution of this comment is pending information from the State concerning decontamination requirements, closure performance standards, and potential post-closure care requirements for the drain

Comment 16:

Role of Institutional and Engineering Controls -- NCP explains that institutional controls shall not substitute for active response measures as the remedy unless such active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives (300 430 (a) (1) (iii)) Clearly not the case here In any event, the use of institutional controls to limit exposure at the site does not alleviate the requirement to meet, or waive all ARARs

Response

DOE agrees with the statement on the use of institutional controls DOE requests clarification of the State's position given the State's acknowledgment that it has not reviewed the detailed analysis of alternatives, and therefore has not examined the analysis of the RCRA and CERCLA evaluation criteria (i e , trade-offs) for each proposed remedial action DOE also requests that the State specify why institutional controls are not appropriate for OU-1 DOE agrees that the use of institutional controls do not alleviate the requirement to meet, or waive all ARARs, and does not present this view in the CMS/FS report

Resolution.

This comment does not require resolution

Comment 17:

Regulatory Requirements for IHSS 130 Radioactive Site - 800 Area -- Recent groundwater monitoring data for the three monitoring wells directly down gradient of IHSS 130 (36391, 36691, 37191) show the presence of hazardous constituents not detected during the Phase III RFI/RI sampling The date from two of these wells over the time frame utilized in the RFI/RI (1990 to mid 1992) were limited to only a single sampling event The newer 1993 monitoring data may confirm the HRR report that hazardous waste associated with the OPWL were disposed of at this IHSS and are potentially leaching from this IHSS into the groundwater As a result, the Division is currently reviewing this monitoring well data to determine if IHSS 130 is a potential hazardous waste landfill, as well as a radioactive waste landfill As such, the Division requires that remedial action alternatives be developed for this landfill that are protective of human health and the environment, and meet all the appropriate regulatory requirements

Response.

DOE disagrees with the assumption that IHSS 130 should be considered a mixed waste landfill DOE requests that the State provide justification as to why this IHSS falls into this regulatory classification DOE also disagrees with the State's position given that it is still trying to determine whether IHSS 130 is a potential hazardous waste landfill based on downgradient groundwater data This comment represents a significant departure from the approach to alternative development presented to the agencies since January of this year Raising such an issue after preparation of the draft final CMS/FS limits the value of the consultive process that has been occurring to date between DOE and the regulatory agencies The State has criticized DOE for its approach to negotiating issues, however, it appears as if the discourse which occurs during CMS/FS working meetings is not being considered in written comments Since January of this year the focus of the OU-1 CMS/FS has been on groundwater remediation This approach is supported by the RFI/RI report and the BRA in particular DOE's position is that it is inappropriate to target units for remediation which have not been identified as risk contributors at the site and do not exceed existing ARARs

Resolution.

During the meeting held on December 14, 1994, between DOE, EPA, and CDPHE, the State revised its position that IHSS 130 is considered a mixed waste landfill The State is currently reviewing its approach to classifying this IHSS

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Comment 18·

Use of All Available Data -- The modeling and analysis of groundwater data in this report must use all available field data Groundwater monitoring data for the hillside is available from 1987 to the present Limiting this report to groundwater data from 1990 to mid 1992 is not appropriate Additionally, there is no mention of the December 1993 soil gas survey conducted at IHSS 119 1 The Division requires that all available field data be used in the Final CMS/FS It is important to note that the RFI/RI was performed using data gathered at a finite point in time (1990 to mid 1992) Inclusion of any new, pertinent data into the development of the final CMS/FS is essential in order to help ensure an accurate CMS/FS Therefore, as new information is obtained and evaluated, further field work at OU-1 may be required prior to a remedy selection

Response

DOE believes it is appropriate to use the data set considered in the RFI/RI report for the groundwater model constructed for the OU-1 CMS/FS Groundwater monitoring data for the hillside is available to the present date and will continue to be available in the future The data set selected for the model is the most appropriate data set to use given its use in the RFI/RI report, to which results of the model are being compared However, at the request of both agencies, the groundwater model has been revised to include data through 1994 It is assumed that this data will be sufficient to satisfy this comment

DOE disagrees with the State's position that as new information is obtained and evaluated, further field work at OU-1 may be required prior to remedy selection Remedy selection is based on the results of the CMS/FS report, which in turn is based on the results of the RFI/RI report DOE believes that the State is inappropriately suggesting continued RFI/RI characterization, while continuing to request that the CMS/FS be conducted regardless of unresolved characterization issues

The CMS/FS report will be revised to reference all soil gas surveys The data was used indirectly in the CMS/FS during conceptualization of remedial action alternatives The text will be revised to include this information

Resolution.

This comment will be resolved as discussed in the response presented above

Comment 19:

Detailed Analysis of Alternatives -- As documented in the Division's comments, the DOE has made many fundamental mistakes in the CMS/FS process, including selection of ARARs and PRGs, and the development of alternatives The number and degree of these mistakes have forced the Division to conclude that the underlying basis for the detailed analysis of alternatives and the preferred alternative presented in this draft CMS/FS are fatally flawed and without basis The Division requires that, after the ARARs, PRGs, development of alternatives and all other underlying errors in this report are corrected, the detailed analysis of alternatives and DOE preferred remedy by reworked

The detailed analysis of alternatives must include detailed documentation of how the potential remedy will comply with each of the five standards for evaluation of a final corrective measure alternative presented in the RCRA Corrective Action Plan (OSWER Directive 9902 3-2), as well as the nine CERCLA criteria Specifically, the Division requires the reworked detailed analysis of alternatives to include how the sources of releases will be controlled, and to comply with any applicable standards for management of wastes as evaluation criteria

The Division has not specifically commented on section 4 0 Detailed Analysis of Alternatives, of this draft CMS/FS The Division finds that based on the number and significance of the unresolved issues, the evaluation of section 4 is not warranted at this time This should not be construed as concurrence by the Division on anything contained in Section 4 of the draft CMS/FS

Response:

DOE does not agree that "mistakes" were made in the CMS/FS process at OU-1 Many of the issues raised by the State have failed to point to specific deficiencies in the CMS/FS report and instead are general statements that are not supported by clear examples In many cases, issues presented are opinions of the State which have not necessarily been identified by the EPA as deficiencies Several comments received from the State suggest that the document does not include an analysis of the RCRA "standards" Because the State did not evaluate the detailed analysis of alternatives where these criteria are evaluated, DOE does not believe these comments are warranted The table included in the response to General Comment #2 delineates how the RCRA evaluation criteria compare to the CERCLA evaluation criteria which are included in the detailed analysis of alternatives The State has suggested in several comments that the RCRA criteria have not been considered As shown in the table included in the response to General Comment #2, CERCLA and RCRA evaluation criteria are similar and are discussed at length in Section 4 0 of the CMS/FS report

Resolution.

During the meeting held on December 14, 1994, between DOE, EPA and CDPHE, the State revised its position that the OU-1 CMS/FS report does not contain sufficient information regarding the RCRA CAP evaluation criteria, with the exception that source control measures are not adequately discussed under alternatives that do not attempt to remediate the source of contamination at IHSS 119 1 The revised CMS/FS report will include more a detailed discussion concerning source control measures under each alternative

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Comment 20:

Failure to Adequately Consider Risk in Evaluating Alternatives -- In the CMS/FS document, DOE based its decision on whether remediation alternatives protected human health solely on the modeled predictions of the fate and transport of one chemical, PCE They did not discuss CC14, 1,1,-DCE, or any other hazardous constituents This is unacceptable RAGS Part B states that all chemicals with risks greater than $1x10^{6}$ "should remain on the list of chemicals of potential concern for that medium" (RAGS part B p 16) A remediation decision based on only one chemical does not consider the cumulative risks from all chemicals in a particular media In this case, the remediation decision does not even consider the risks from CC14 and 1,1-DCE, both of which are more toxic and present in higher concentrations at OU1 than PCE Moreover, HQs were not even calculated for inhalation exposure (see Tables C 6-4, 5 & 6) because no inhalation RfD was available for PCE

If DOE had done a toxicity assessment on this chemical it would have been apparent that there is no evidence that this chemical causes local respiratory tract irrigation, so that it would be appropriate to do route-route extrapolation on the oral toxicity factor for this chemical As it is, DOE did not even evaluate the single chemical it assessed in the CMS/FS for noncarcinogenic effects by the inhalation route of exposure

Response

The revised OU-1 CMS/FS will include each BRA COC in the risk evaluation for each alternative, with the addition of TCE due to its presence in unusually high concentrations at OU-1 Results from the groundwater model will be examined for each of these COCs and will be incorporated in the appropriate residual risk discussions

The residual risk for the residential receptor will be documented consistent with the methodology presented in Appendix C An inhalation reference dose for PCE was not available in IRIS, HEAST, or ECAO The issue of a RfD for PCE will be deferred to ECAO for additional guidance prior to revision of the CMS/FS report

Resolution

The resolution to this comment is as stated in the response above

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Comment 21

Groundwater Modeling -- This model is a first attempt to describe a complex system and as such tends to raise as many or more questions than it answers about the conceptualization of the source locations and inclusion of decay products The concept of a single flow line within a preferential channel may not adequately describe the flow system between the chosen calibration wells Slumping is an active process on the hillside and may interrupt what appears to be a bedrock low channel Current top of bedrock information may not be detailed enough to define a single flow path accurately, therefore this model represents a theoretical flow path with a gradient similar to flow paths that may exist on the hillside Only one conceptualization of the source was considered, a residual DNAPL located in one cell at the bedrock/alluvium interface Alternate source conceptualizations such as diffusion into the pore waters of the bedrock between fractures were not mentioned The model shows a fair amount or contaminant moving through the bedrock portion of the model so a source within bedrock could be important Discussion of the choices made in the model conceptualization is an important element in model documentation

Contaminant calibrations were apparently performed with less than the full suite of available data and not all contaminants in the PCE decay chain were considered The source and location of each succeeding contaminant becomes dispersed from the transport of its parent product Such complex linkage of contaminant models becomes too difficult for a transport model dealing with one product at a time Recognition of this complexity would indicate this model is not "conservative"

The English/Metric conflict is not yet resolved in this country Data in this report is presented in metric units but the model is run in English units and the conversions are not presented The best option seems to be to present both to facilitate review of the model

Response

Specific issues in this comment are addressed in the following bullets

The concept of a single flow line within a preferential channel is based on the hydrogeologic conditions and hydrogeologic conceptual model presented in the RFI/RI report, and on fundamental techniques for developing and applying a numerical model Data from the RFI/RI report reveal limited saturated conditions at OU-1, indicating that flow directions are restricted laterally The data also indicate that flow is down the hillside, consistent with porous-media flow and typical hillslope hydrology The alignment of the modeled flowpath corresponds to the suspected source area beneath IHSS 119 1, and the groundwater flow direction coincident with the bedrock channel, consistent witht the Phase III RFI/RI Therefore, the model represents the most credible flowpath from IHSS 119 1 to Woman Creek As such, the modeled flowpath is the "shortest" flowpath in terms of distance and travel time Other flowpaths would represent "longer", less conservative, flowpaths

With regard to slumping, the "interruption" referred to the comment may have little to no effect on groundwater flow direction and magnitude The geologic cross-section produced as part of the Phase III RFI/RI from geologic mapping during the construction of the french drain does not indicate that discontinuities caused by mass movement of colluvium "interupt" the bedrock channel which is represented in the model (refer to Volume IV Appendix A of the Phase III RFI/RI figure showing the vertical section of the french drain from station 16+00 to 16+50) The section actually shows the "shear plane" as conforming with the bedrock channel (in the section the "shear plane" is also referred to as a "potential shear plane", and a "discontinuous shear plane")

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The source represented in the model is that presented in the Phase III RFI/RI as the most credible based on data collect during the RFI/RI Since the model over estimates all COC concentrations, larger sources (in terms of size) due to spreading caused by decay, or alternate sources are accounted for indirectly by the model Consider also the possibility of three sources for groundwater contamination a source above the water table, a source at the bedrock/colluvium interface, and a source in the bedrock For a source above the water table, the contaminant could not dissolve freely into groundwater A constant source at the bedrock/colluvium interface could dissolve indefinitely into groundwater A source in the bedrock could also dissolve into groundwater but would migrate at a slower rate than the source at the bedrock/colluvium interface Thus, a constant source at the bedrock/colluvium interface represents a conservative scenario Diffusion as a release mechanism would result in much smaller releases of COCs because it typically occurs at rates much lower than groundwater flow Further discussion of conservatism and sources is contained on responses to specific comments

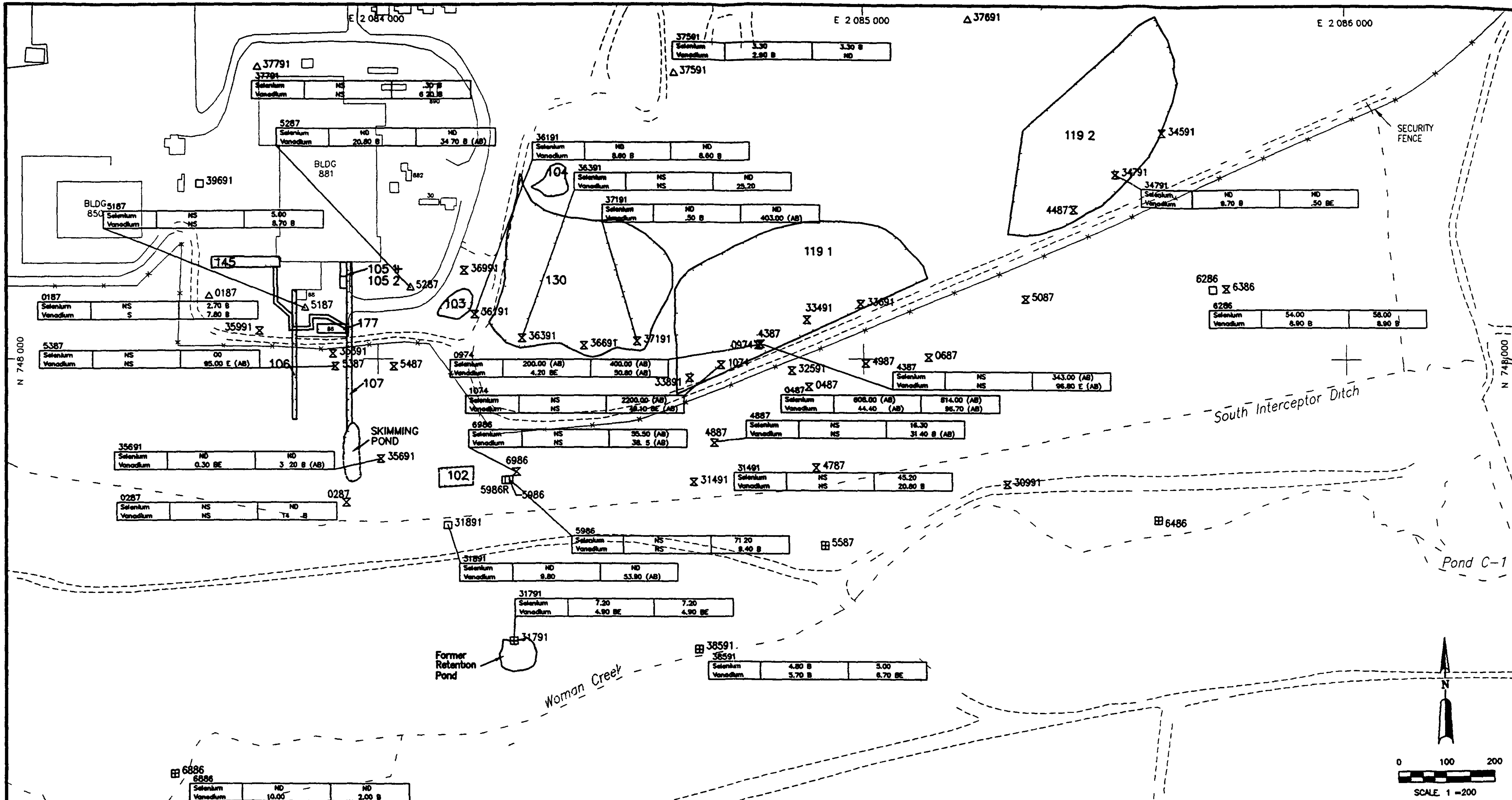
Movement of a solute in bedrock does not indicate source in bedrock No data gap with regard to bedrock was identified in the Phase III RFI/RI report Therefore, no bedrock source was simulated in the modeling

With regard to the issue of conservatism, the model is conservative in two aspects The simulated groundwater flow is conservative because the model always assumes flow occurs, whereas there are many areas and times of no flow (or low flow) due to dry conditions The overall hydraulic gradients, and therefore Darcian velocities, are comparable to those observed at the site Model predictions are conservative because they consistently over predict COC concentrations TCE has been included as a COC in the model predictions

The COCs modeled are consistent with the COCs identified in the Phase III RFI/RI baseline risk assessment, and discussed with the agencies on May 23, 1994 This meeting included DOE's explanation of exactly how the model was to be constructed All parties participated in the discussion The model was developed in accordance with these discussions as well as with the active participation of CDPHE and EPA representatives during the various informal working meetings that occurred during the modeling process The function of the model in the FS is to provide a predictive tool to facilitate the selection of a remedial alternative

Resolution:

The resolution of the topics covered in this comment is discussed in more detail in the response and resolution of specific comments



EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN

- △ ROCKY FLATS ALLUVIUM
- ⧗ COLLUVIUM
- ⊞ VALLEY FILL ALLUVIUM
- □ WEATHERED CLAYSTONE/ SANDSTONE
- ND NOT DETECTED
- E ESTIMATED VALUE
- B REPORTED VALUE <CONTRACT REQUIRED DETECTION LIMIT AND >INSTRUMENT DECTION LIMIT
- (AB) ABOVE BACKGROUND CONCENTRATION
- NS NOT SAMPLED

Well 38591	1st QTR 1992	1986 2 d QTR 1992
Selenium	4.80 B	5.00
Vanadium	5.70 B	6.70 BE
Analyt	Concentration ug/l	Histori al M mum

BACKGROUND UPPER TOLERANCE
S le m 80 ug/l
V d m 29 7 g/l

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Selenium and Vanadium Concentrations Detected in Upper Hydrostratigraphic Unit Groundwater

Figure 1-5

TAKEN FROM JUNE 1994 OU1 FINAL PHASE III RFI/RI REPORT

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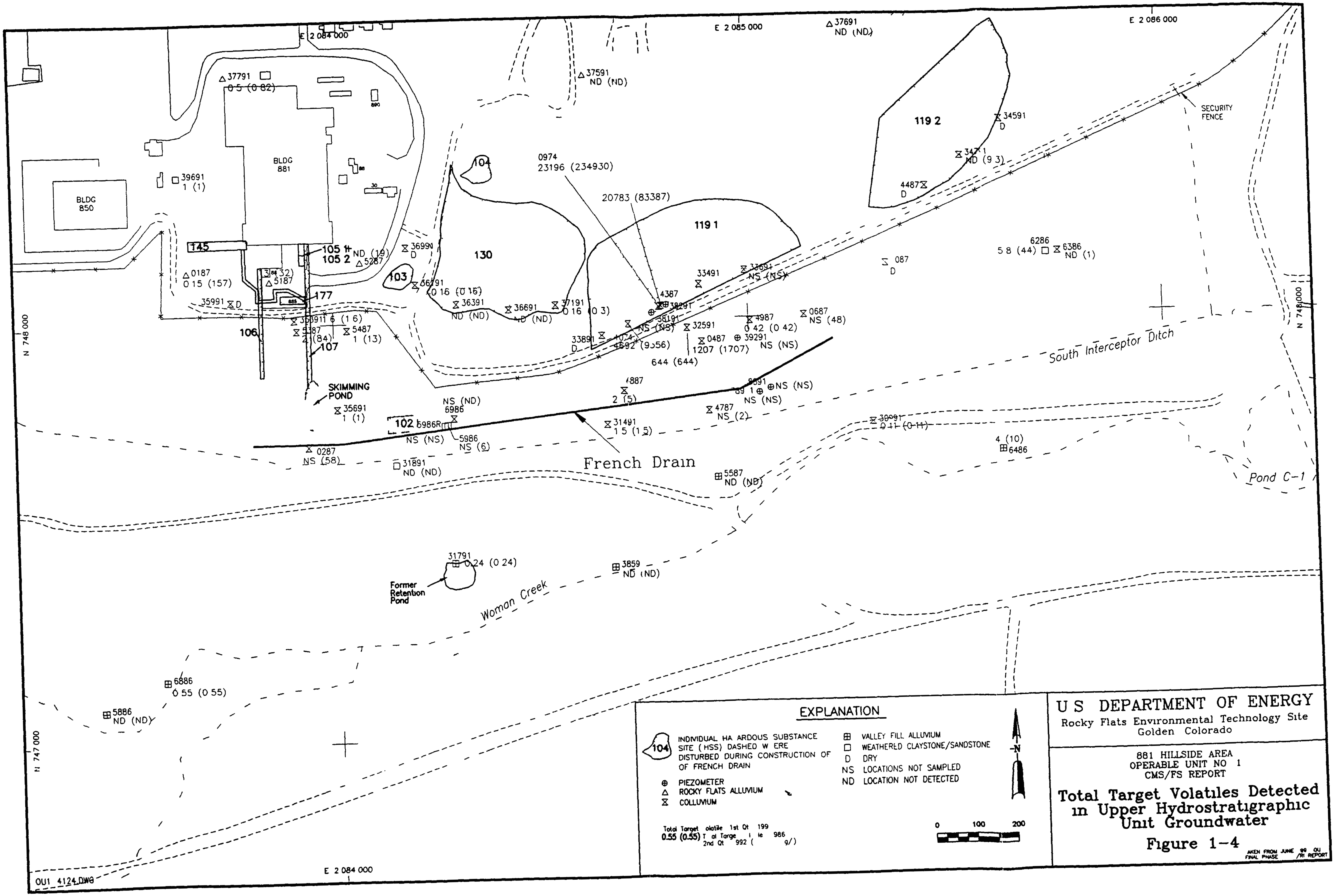

BLDG 850
BLDG 881
145
105 1
105 2
106
107
177
103
104
130
119 1
119 2
102
SKIMMING POND
French Drain
South Interceptor Ditch
Woman Creek
Former Retention Pond
Pond C-1
SECURITY FENCE
0974
23196 (234930)
20783 (83387)
N 748 000
N 747 000
E 2 084 000
E 2 085 000
E 2 086 000
EXPLANATION
INDIVIDUAL HA ARDOUS SUBSTANCE SITE (HSS) DASHED W ERE DISTURBED DURING CONSTRUCTION OF OF FRENCH DRAIN
PIEZOMETER
ROCKY FLATS ALLUVIUM
COLLUVIUM
VALLEY FILL ALLUVIUM
WEATHERED CLAYSTONE/SANDSTONE
D DRY
NS LOCATIONS NOT SAMPLED
ND LOCATION NOT DETECTED
0
100
200
N
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Total Target Volatiles Detected in Upper Hydrostratigraphic Unit Groundwater
Figure 1-4
OU1 4124.DWG

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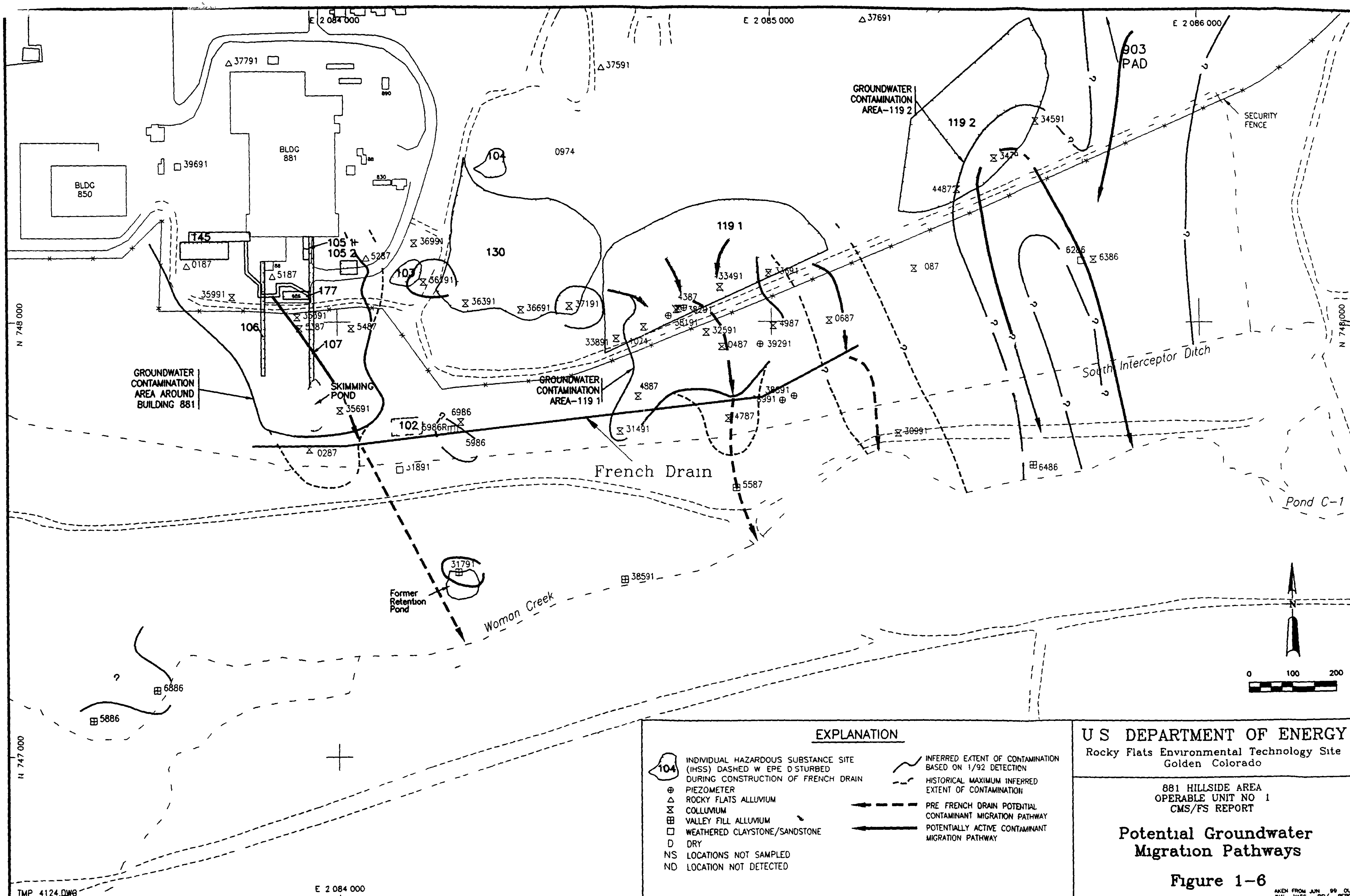

EXPLANATION

- INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) DASHED W ERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
- ⊕ PIEZOMETER
- △ ROCKY FLATS ALLUVIUM
- ⧖ COLLUVIUM
- ⊞ VALLEY FILL ALLUVIUM
- □ WEATHERED CLAYSTONE/SANDSTONE
- D DRY
- NS LOCATIONS NOT SAMPLED
- ND LOCATION NOT DETECTED
- INFERRED EXTENT OF CONTAMINATION BASED ON 1/92 DETECTION
- HISTORICAL MAXIMUM INFERRED EXTENT OF CONTAMINATION
- PRE FRENCH DRAIN POTENTIAL CONTAMINANT MIGRATION PATHWAY
- POTENTIALLY ACTIVE CONTAMINANT MIGRATION PATHWAY

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Potential Groundwater Migration Pathways

Figure 1-6

TAKEN FROM JUN 99 OU FINAL HASC RFI/ REPORT

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
N Ac ion	None	Not ppl bl	Req ired for on dera on by NCP	Pot lly ppl bl a omparison g other GRA
I on l C rol	A ces R tric ion	Leg l R tn u on La d Use	Re tri on presen and f ture se and/ p rch se f l d lud a i uch as g nd deed i	P ally ppl cabl f co trolli g se f l nd wh b m y be c tam d
Cont inm	Horizo tal S bsurface Flow Control	S bs rf Drain	Gra ty dn llec on y tem wh b sed red cc g oundw e fl w d/or collec fo eatm	Pot lly appl bl in l des po b lity f modifying g f h drain y tem for d g med
		Gro Curt	Grou lumn are injected ally h so l i lose pro m ty f each other form impern bl w ll	W ld not bute add onal con nm bec se f ting l w hydra l condu v ty
		Slurry Walls	A il/be on or cem g ou wall f rmed by backfilli g tre hed ar has l wer perm b l ty than so l	No impl me ble bec f hill d tabil ty m tre hi g m y le d to l mp g f so ls
		Shee Pil g	S eel form wh h ar d en th g ou d d j i ed form barri wh h impermeabl g ndwa er	Very d ff l implem d to pro im y f bedrock widely ed or accep ed lean ps
		Cry g Barri	A cc f ground frozen to redu permeab lity thu limiting th mobility f co taminan thr gh th ar	O ly ppli bl as sho term meas re to on l th migra on f tami ants through an area
	Vertical S bsurfac Flow Co trol	Gro Injectio	G ou jected in horizo tal p ttern be th rfa soils to lim rtic l migration f VOCs from groundw ter	Not pplica l f remed tion f VOCs gro ndwa fractured bedrock
		Block D pl em	I no s f gro forms perm te barri aro d w wh l d plac g waste pward to block p thw y	Not ppl c bl fo contr l f VOC th re l fr m latiliza f gro dwate o taminants n f in frac red bedrock
R mo al	Ex on	L d / Ex / Dozer	T /wheel m ed h les omm ly used e ca m larg amou f il an pera an d pth	P ally ppl bl f ca f u fac and bs rf l
	D C trol	D S ppre a	Van y th i and ural compo d wh h ar prayed urf soil redu f g d m (g w)	Po i lly pl bl red d mi dun g remed u f perable
		Temporary Stru tures	L gh eas ly tru ed tructures sed dun g remed ion th provid protec ion from the ffec f wind and rain	Not feas bl i se f areal t f am io and o con dered necessary for l w l vel f ontam a io
D pos l	O S D posal	Engineered On S te D posal F ility	O d po l f l ty designed on i pec fic was for gl perable un or for th ure te	Po ally ppl bl for torag f am a ed so l re id l which re l from th tre tme f so l
	Off S te Disposal	Perm ted Off S te D posal Facility	E i g fac l ty which perm ed cep perabl pe fic waste or remedial action was tr atm re d als	Pot lly pl bl for orag f on ami ed so l or re id l which re l from th e tme f ls

Double lines surrounding process option or technology denote options tha were screened out from further considera ion on the basi of technical implementabil ty pplicabil ty or feas bil ty

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I itial Screeni g of Technologies and Process Options f Subsurface Soils

FIGURE 2 3

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GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
I S Tre m	B ological	B oremed tion	Destroy organ through microb al d gradation several m hods are il ble for tre tm f VOC	F a b lity lim ed for tre g VOC in ls du t ry low degrad ion ra e and diff l y proc o l
	Chemical	Ch mi al Ox da on/ Red tion	Breakdow f VOC g hemical which are typically trod ed t th bsurfac je w ll	Diff cul pply beca se f onc m inj c ing dd on l hem cal i t th bsurf wh h m y l i h f rm ion f hazardo reac p od
	Phy ical	So l Fl hing	Aq eo fl hing g are for ed hro gh so l jec w ll wh h fl h co am nan m collec on y m	P en lly ppl bl for rem ing rga mpo d fr m s l lth gh fl hing gen would ll eq re tre tm t/d pos l
		V trific on	Electrical l m l g process th d troy mos orga cs wh l i g th tami an s l d glassy m trix	Appl c bil ty lim ed by tab l y f h ll d l no ppropri f l w le l f l tami on
		RF/Ohm Heating	Rad frequ cy or hm nergy pplied i lectrodes he urr ding l promoting l liza f VOC	Pote ally appli abl for th treatm f VOC tami ted bsurface l
		Vapo Extraction	A um ppl ed to bsurface soil to l ilize rga cs and rem inorgan th are in th po phase	Pot lly appli bl f h treatme f VOC ontam ed bsurfac so l
		Ho Air/S am Stripping w th Mechani al Mi ing	Hot team i jected bel w urfac l to forc orga contami a th urface for pture and treatmen	Pot lly ppli bl f the treatme f VOC tami ted bsurfac i l
Ex S Tre tm	B ological	Bioremediation	Destroy o gan through microb al d grada se eral m thods are ail bl for biorm ed VOC	Pote ally ppli ble f treati g e ted il alth gh m y be lim ted by low degradation ra for om VOC
		Land Applic tion	Appli ation f thin l yer f was er a area t promote ural b od grada m y lud add f t	Not impl m bl bec use f po l rad lid am so l wh h wo ld be pr ad dun g tre tm
	Chem al	Ultra l Phot ly w/ Ch m al Oxid on	UV rad ppl ed to as dizi g ga mpo d ing an u xid zi g g) th reby d oy g th m	P ally ppl bl for de troyi g VOC i ex ed soils man arom ea ons are UV (free rad cal) talyzed
		S l Extractio	R r oval f organ ompound from so l by m ss tran f organ l wh h then c llec ed a d ed	Limited f as b lity f em ing VOC from soil with l w tami an e tra sol would ll req tm t/d po al
	Physical	So l Washing	A an ty f lean i g g an be u ed wash soil f gan tami an so ls an be repla ed fter treatm	Potentially ppl bl f rem ing rga mpo nd from s l alth gl wash g gen wo ld ll eq re tre tm t/d po l
		Stab liza o / Solid f c on	Bi di g gents are mixed w th contam ed soil i e ther b ch or con uou proces tabilize/sol d fy contaminan	N ppropri for ery l w lev l f tamin e pec lly for tamin ts h ar re d ly l lized
		Incineration	Destruc on f organic through oxidation and/or pyroly Various method are a l bl (rotary k l flu d zed bed)	Pote ally ppl bl for treatme f hlor ted organics urfac so l al hough m y n re h arge l l
	Thermal	Thermal Desorption	Orga c are latilized f om soil through th add on f l t aly m y be sed to hanc process	Poten ally pl bl for treatm f hlori ted organ cs i urfac so l lthough may no rea h arget l l
		V trification	Electrical soil m lting process th de troy mos organ cs while containing other contaminants solid, glassy matrix	N ppli bl f tre tme f exc ted s ils inc impractical f low l ls of ontami on i urated media

Doubl l nes surrounding proces option or technology de ote options tha were screened ou from further consideration on the bas f technical implementabil ty pplicability or feas bil ty

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FIGURE 2 3 (Cont)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
N A tion	None	Not ppli ble	Req ired f onsidera on by the N ion l Oil d Hazard S bstances Con g ncy Plan	P te lly appl bl a baseline g n which othe GRAs/ l m a be ompared d g de led an ly
	Mon toring	Grou dwa Mon toring	Mon ori g f g oundwate i operabl n du g and f er remed ion a part f in n l o l pe od as oc ed w th th N A o al m	P te lly ppli bl f mon ori g pe ific g ndw e d n
I on l Co trols	A cess R tri tio	Leg l Restri tion on W ll Plac m	Perm re tric ion on presen and f pla me f pote l g ndw te extrac on wells	Po ally ppl bl for roll g ac grou dw e es and/ posure to COC
		Leg l Re tric ion Land Use	R tri on pre a d f ture se and/or purchase f land i l d action uch as zoning and deed re tri ti	Pot lly ppl bl for ontroll g s f l d ffe ed by ontamin t d g oundw er zones
C ainm	Horizontal S bsurface Flow Control	S bsurface Drain	Cra ty dri c llec sy tem whi h sed red ec gro ndw er fl w a d/or collec for treatm	P al y appl bl in ludes pos bility f modifying u g tr nch drain sy tem for use d g remed i
		Grou Curtain	Grou column are injected ert cally to be so l in lose pro im ty f ach other form an imperme bl w ll	Would ot b add onal con inm bec se f i g l w hydra l onduc vity
		Slurry Walls	A soil/be onite or c me grou wall f rmed by backfilli g trenched are has l w perme bil ty than ls	Not impl.m abl bec se f hills de tabil ty con rns trenchi g m y l ad to slump g f so l
		Shee Piling	S eel form wh h ar dri en i he gro d a d j ed form barri wh h impermeabl t gro dw	Very d ff l implem du to pr im ty f bedrock wid ly ed or cc p ed lean ps
		Cry g Barri	i ection f g und fr zen t red permeab lity h lim g th m b lity f co taminants thro gh th ar	O ly ppli bl a sh t rm measure l th m gra f ami an thro gh an area
	V rti al S b urfac Flow Co l	Grou I jection	(ro injected i horizo tal pattern be e th rf ls t lim rti al migratio f VOC from g ou dw	N ppli bl f emed f VOCs gro ndw t frac ured bedrock
		Block D placem	I no f g ou forms perimete barrier arou d as whil e d plac g waste pwards block pathw y	N ppl l fo o trol f VOC th re l fr m latilizatio f groundwater contaminants no fo se in fra tured bedrock

Doubl l nes surrounding proces option or technology denote options th were screened ou from further onsideration on the basis of technical implementabil ty pplic bil y or feas bil ty

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I itial Scree i g of Tech ologies a d Process Opti ns for Groundwate

FIGURF 2-4

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
R m val	Pas Remo al	S bs rface Drains	Gra ty dn collec on sy tem which sed edirec g oundwa er fl w and/or collec for e tme	Pot n lly pplic ble includes po bility of modifying g f h drain sys em for se d g med
	A Removal	Horizontal and/or V rti al Extrac on W ll or S mps	Sy ms on g f wells n talled he rti lly or horizon lly th ar sed llect/recharg g oundw er	Po ally ppl abl for rem ing con ami ted w te f tre m for d ert g groundw fl w or fi l w g loc li ed w t tabl
I S T e tm	B ological	B oremed tion	Destroy organics thro gh microb al degrad m thanotrop proce pe f to bl rm ed l	Pot lly ppli ble for in tre tm f ga mpo d groundw er how e d grad on prod m y be r re harmful than origi al ontaminan
	Chemical	P lymeriza on	C ly jec ed in groundw ter uses polymeriza io f organ mon mers forming g l lik no mobil mass	C ta be wee reagen and grou dwa er tu lly ly h d red by th form tion f th g l lik mass
		Chem cal O id tion	Breakdow f organic u ing hem cal wh h are typ ally trod ced th bsurfa ject w ll or by drill g direc ly th edg or w th o tam pl m	D ff cul pply beca se f concern er injec ing add on l hem cal i the s bs rf which m y re l th form ion f hazardou d on prod
	Phy c l	Air Sparging	Pressurized air i injected bel w or w thi contami ted groundwater plume to c use i tu tripping of VOCs	Not applic bl for in tu treatmen f VOC in groundw ter OU 1 du to presence of bedrock and low perme bility air b bbles would fl w pr ferentially through fra ture thereby ding o tact with DNAPL sources
		Vapor Extraction	Ind ed g pres ure bo a urated zone c llec l li ed contami an f tm	Po en lly ppl bl for removal f VOC from grou dwater or f i porti g other techn l g (g air parg g)
		Perm bl Treatm Bed	A f ed bed ta i g treatm re n pl ced d w grad en f gro ndwa er plum w er in	P lly ppl bl f in tre tm f rga mpo nd g dw (includ g VOC in dose zon) how e lim ted by hydrogeology and ex ence f Fran h Drai
		I S tu Ad orptio w/W ll (proprietary proc)	Adsorp on f organic contaminan groundwater through th se f propr tary re i bead pl ed g w ll	Pot ally ppl abl for in e tm f ga ic mpound groundw ter (includ g VOCs dose zon) bu no impl me tabl due l w hydra l c nduc ty and ariably s urated med um

Double lines surrounding process option or technology denote options th were screened ou from further onsideration on the basi f technical implementabil ty applicability or feas bility

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Initial Screening of Tech olog es and Process Options for Groundwat

FIGURE 2-4 (C t)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	DESCRIPTION	SCREENING COMMENT
Ex S Tre tm	B ologic l	Bio med ion	Destroy organ cs through m crob l degrad on n d anotrop proce pecific to blorin ed sol	Poten ially ppl ble for tre tm f organ compounds groundwa er howe er d grad on prod m y be more harmful than orig l co tam
	Chemic l	Sol en Extrac ion	Rem al f orga cs by m transfer organ l wh h m lly sol bl w h th g l sol (w)	Not f as bl f gr ndwa er w h l w VOC onc tra sol e wo ld ll req re tre m t/d pos l
		Ultra iol Phot ly w th Ch m al Ox d o	UV rad on ppl d to a dizi g gan mpo d g anou id zi g g th reby d y g h m	Poten ally ppl bl f destroying organ ompo d tracted g ndw e m y n d mod f ion f e g UV/pe x d tre tm sy m
	Physical	Gamm Irrad at	I a echnol gy whi h dec mpose gan ompou d by destroy g th h mi al bond us g gamm rrad	Not wid ly do m ed se in th tre tm f organic wa l ot fe bl fo l w am an l l
		Act ted Carbon or Carbonaceou Adsorbe	Extracted groundw te pas ed thro gh ted arbo which adsorbs mos f th organ taminan	Potentially appl bl for rem ing organ ompound from tracted gro dw ter arbon could be d posed f or reg nera ed
		A Strippi g	W er prayed through p ked we des gned incr se urfac are to air ra th reby prom ti g l lizatio	Poten ally ppl bl for remo g l il organ c compounds from extracted gro ndwa
		Membrane Processes	Applica on f an osmo pressure forces con ami an flow through sem perm ble membran gain d ff	Not directly ppl abl for treatme f VOC in gro d water more omm ly used rem part l es
		E apora on	Concentra on method sed to dri ff sol nt from an aqueous waste tream ing man mad and/or tural mean	Not applicabl as stand alone treatme technology more often u d as pre treatm tep for process
		Freeze Cry talliza ion	M thod f rem ing d ss l ed org peci by freezi g th pporti g m tn and cry t llizi g th sol for para	O ly feas bl f q eou was tream where organ con aminan tr on are bo 3 7 % by we gh
	Thermal	Inc eratio	Destructi f rgan thro gh mbu w th yg ing thermal and/or taly proc p	G erally n ppl bl f l q d tre tm l w tamin trat l ls
		Plasm Arc Discharg	Pyroly f organic by h gh empera ur plasm ind ed through lectri al d scharg to arrier gas	Poten ally ppl bl for destru f refra ory organ c i extracted gro dw er
		Catalyti Oxid tion	C taly all ws l w mperature th rm l d grad on f halogen ted hydrocarbons to arbo dio de w ter and hydrogen hlorid Als d troy on hal ge ated VOC formi g wa e and carbon d id	Pot ally ppli bl f tre tm f gro dw te or air Can prod ac d ff gas

Double l nes surrounding process option or technology denot options th were screened ou from further consideration on the basis f technical implementability applic bility or feas bil ty

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I itial Screeni g of Tech ologies and Process Options for Groundwate

FICURE 2-4 (C nt)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
N Acuo	None	Not appl c bl	M y not achieve remedial action objectu es although req ired for considerat on by NCP	Diff cult t mpl ment f p bl c concern s high regarding te cond u ns	Very Low Cap tal Very Low O & M
Instit u al Contr ls	Access Re trict s	Legal R trictions on Land Use	Effectu e for contr l f present and future use f land which is aff cted by remed al actions	Diff culty in obtaining ecessary legal estri tions may educe impl mentab l ty	Low Cap tal V ry Low O & M
Containme t	Hori tal S bsurface Fl w Control	S bsurf ce Drain	Effectu e for contami g re d al DNAPL ource if bounded by bedrock l yer (n fracture)	Read ly mpl m tabl t bedrock afterward more diff cult	Moderate Cap tal Low O & M
Remo al	E ca au	Loade / Exca ator / Do er	Effectu fo ca aung soils and sl dges l ss than 30 feet deep	Readily mpl mentabl use comm road b lding and constructio equipm nt	Low Cap tal Moderate O & M
	Dust Control	Dust Suppressants	Moderately effectu e for red cing surface d st generation depending type f s ppressant	Read ly implementable although certain ppressants may be cons dered hazardous	Low Cap tal Moderate O & M
D sposal	O S te Di posal	Engineered On S te D sposal Fac l ty	Effective in containing treated or es dual wastes assuming the facility s des gned pr pe ly	D ff cult to mpl ment because of permit equirements and administrati e concerns	V ry High Cap tal High O & M
	Off S te D posal	P rmitted Off S te Disposal Fac l ty	Effectu e in containing treated or res dual wastes if proper fac lity s availabl	R adily impl me tabl f wastes other than TRU or mixed (rad acu e/hazardous)	Moderate Cap tal Very Low O & M
In S tu Treatme t	B l g cal	B oremedi uo	Effectu e in treati g o ganics b t diff cult to monitor progres during in tu treatme t may result in res dual which equire furthe treatme t	Req ir s tens tre tabil ty w k to determine viab l ty of microb al growth	Mod rate C p tal Moderate O & M
	Physical	S il Flushing	Effectiveness limited by site hydrol gy D ff cult to ensure uniform treatme t and fl shing agent reco ery	D ff cult to mpl ment d to p efere ce against inje ting add tio al chemical to the s bsurface	Mod rate Cap tal Moderate O & M
		RF/Ohmic Heati g	Effectu e in treating pper soil layers in s tu to prevent migrat o of contaminant	Readily mpleme table uses commonly available gricultural engineering equipment	Low Cap tal Moderate O & M
		Vapor E tractio	Effectu e in removing organics from sub urface so ls to carrie gas which may require treatme t	Readily mpl mentable alth gh may be limited by low rad us of influe ce	Low Cap tal Moderate O & M
		Hot Air/Steam Stripping w th Mechanical Mixing	Effectu e in removing organics from so ls t carrier gas for treatment	Implementabil ty may be limited by hillside stabil ty and history of slumping	Moderate Cap tal High O & M

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Evaluation of Process Options for Subsurface Soils

FIGURE 2 5

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GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
E Sтu T eatme t	B log cal	B oremed u	Eff ctive ı treatı g organ cs but may poss bly result n res duals wh ch requ e furthe treatme t	Requ s e tens e tre tab l ty work to determ e viabıl ty f m crob al growth	Moderate Cap tal Moderate O & M
	Chemical	Ultr olet Photolys s w/Ch m cal Oxidation	Effective method for destroyı g some organ compounds depend g on UV lamp used y tem	Impl me tab l ty will depend dat m thod ch sen to accompany UV process	H gh Capital H gh O & M
		S l e t E tractio	Eff t e removı g olatile and no olatile organ c compounds from so ls altho gh spe t solve t will equı e tre tme t or disposal	Moderately d ff cult to mpleme t elatı e t othe s tu treatme t pt s	H gh Cap tal Moderate O & M
	Phys cal	So l Washı g	Effectı e for removal f organı and norganic co taminants se eral washı g agents ail ble	Impl me table techn logy wh ch s based o commonly used ore mining technologies	H gh Cap tal Moderate O & M
	Thermal	Incineration	Effective ı destroying or removing organ c contaminants to le els n the l w ppm range	Implementable technology which has been used e tens ely for treating organic	H gh Cap tal H gh O & M
		Thermal Desorption	Effectı e for removing olatile and semı olatil compounds from soil require off gas treatment	Impl me table technol gy wh ch has bee used tens ely fo treat g organ c	H gh Cap tal H gh O & M

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Evaluation of Process Options
for Subsurface Soils

FIGURE 2-5 (Cont.)

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
No Action	None	Not Applicable	May not achieve remedial action objective although required for consideration by NCP	Difficult to implement if public concern is high regarding site conditions	Very Low Capital Very Low O & M
	Monitoring	Groundwater Monitoring	Effective in monitoring site conditions or with No Action alternative as an institutional control	Readily implementable depending remedial alternative selected	Low Capital Low O & M
Institutional Controls	Access Restrictions	Legal Restrictions on Well Placement	Effective for control of present and future access to groundwater	Difficulty in obtaining necessary legal restrictions may reduce implementability	Low Capital Very Low O & M
		Legal Restrictions on Land Use	Effective for control of present and future use of land which is affected by remedial actions	Difficulty in obtaining necessary legal restrictions may reduce implementability	Low Capital Very Low O & M
Containment	Horizontal Subsurface Flow Control	Subsurface Drains	Effective diverting flow of groundwater around targeted areas to limit the mobility of contaminants	May be difficult to implement upgradient of plume due to proximity of building	Moderate Capital Low O & M
Removal	Passive Removal	Subsurface Drains	Effective in collecting groundwater if the system is designed appropriately for site conditions	Modification of existing french drain would be readily implementable if required	Moderate Capital Very Low O & M
	Active Removal	Horizontal and/or Vertical Extraction Wells or Sumps	Effective in diverting, collecting, or recharging groundwater when gradient is relatively flat	Readily implementable based on existing site conditions if few wells are installed	Low Capital Low O & M

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Evaluation of Process Options for Groundwater

FIGURE 2-6

GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
In Situ Treatment	Biological	Bioremediation	Effective in treating organics but difficult to monitor progress during in situ treatment may result in residuals which require further treatment	Requires extensive treatability work to determine viability of microbial growth f[illegible] existing site specific conditions	Moderate Capital Moderate O & M
	Physical	Vapor Extraction	Moderately effective in moving VOCs from saturated soil although limited by nature of contamination	Would require the use of extraction wells to temporarily depress the water table	Low Capital Moderate O & M
Ex Situ Treatment	Biological	Bioremediation	Effective in treating organics but may possibly result in residuals which require further treatment	Readily implementable if all contaminants can be degraded under similar conditions	Moderate Capital Moderate O & M
	Chemical	Ultraviolet Photolysis with Chemical Oxidation	Effective and proven method of destroying organic contaminants in extracted groundwater	UV treatment system already exists on site and may be used w/o significant modification	High Capital High O & M
	Physical	Activated Carbon or Carbonaceous Adsorbents	Effective if used as a final polishing step in groundwater treatment system	Readily implementable as this is a common technology supported by many vendors	Moderate Capital Moderate O & M
		Air Stripping	Effective removing VOCs and some SVOC from extracted groundwater in large volume	Readily implementable as this is a common technology supported by many vendors	Low Capital Moderate O & M
	Thermal	Plasma Arc Discharge	Effective in destroying organics including refractory halogenated compounds	Treatability studies required to optimize energy level and treatment times for RFETS	High Capital Moderate O & M
		Catalytic Oxidation	Effective in destroying organics including refractory halogenated compounds	Treatability studies required to determine catalyst temperature and residence time	High Capital Moderate O & M

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Evaluation of Process Options for Groundwater

FIGURE 2-6 (Cont.)

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GENERAL RESPONSE ACTION	PROCESS OPTION	PROPOSED REMEDIAL ACTION ALTERNATIVES					
		0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Hot Air Injection with Mechanical Mixing	Soil Excavation with Groundwater Pumping
AREA ADDRESSED =>		N/A	All IHSSs	IHSS 119 1	IHSS 119 1	IHSS 119 1	IHSS 119 1
No action	Groundwater monitoring	✓	✓	✓	✓	✓	✓
Institutional controls	Legal restrictions on land use		✓				
	Legal restrictions on well placement		✓				
Containment	Subsurface drains (existing French Drain)		✓	✓	✓	✓	✓
	Environmental isolation enclosure (optional)						✓
Removal	Subsurface drains (existing French Drain)		✓	✓	✓	✓	✓
	Horizontal and/or vertical extraction wells or sumps		✓	✓	✓	✓	✓
	Loader/dozer/excavator						✓
Disposal	Permitted off site disposal facility						✓
In situ treatment	RF/ohmic heating				✓		
	Soil vapor extraction			✓	✓		
	Hot air/steam stripping with mechanical mixing					✓	
Ex situ treatment	Ultraviolet photolysis with chemical oxidation		✓	✓	✓	✓	✓

Figure 3-1 Development of Remedial Action Alternatives

Table 4 2
Summary of Detailed Analysis of Alternatives

RCRA CAP Standards/ CERCLA Evaluation Criteria	ALTERNATIVE 0 No Action	ALTERNATIVE 1 Institutional Controls with the French Drain	ALTERNATIVE 2 Groundwater Pumping and Soil Vapor Extraction	ALTERNATIVE 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement	ALTERNATIVE 4 Hot Air Injection with Mechanical Mixing	ALTERNATIVE 5 Soil Excavation with Groundwater Pumping
Overall Protectiveness						
Human Health Protection (including source control measures)	Carcinogenic risk at French Drain for on site adult residents 1 in 10 000 Noncarcinogenic effects are below concern at the French Drain and Woman Creek. Sources in IHSS OU 1 not controlled	Human health will be protected through source containment Carcinogenic risks are below 1 in 1 000 000 at the French Drain and Woman Creek. Noncarcinogenic effects are below concern Sources OU 1 controlled but not remediated	Human health will be protected through source remediation and reduced exposure potential Carcinogenic risks are below 1 in 1 000 000 at the French Drain and Woman Creek. Noncarcinogenic effects are below concern	Human health will be protected through source remediation and reduced exposure potential Carcinogenic risks are below 1 in 1 000 000 at the French Drain and Woman Creek Noncarcinogenic effects are below concern	Human health will be protected through source remediation and reduced exposure potential Carcinogenic risks are below 1 in 1 000 000 at the French Drain and Woman Creek. Noncarcinogenic effects are below concern	Human health will be protected through source remediation and reduced exposure potential Carcinogenic risks are below 1 in 1 000 000 at the French Drain and Woman Creek. Noncarcinogenic effects are below concern
Environmental Protection	Least permanent solution Minimal effects to the environment include French Drain decommissioning and potential groundwater migration Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	No changes from current processes used at the site Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	No significant effects to the environment. Degree of protection depends on placing wells near DNAPL sources Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	Possible subsurface biota disruption due to RF heating Degree of protection depends on placing wells near DNAPL sources Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek	Hot air injection and mechanical mixing may have adverse effects on surface and subsurface soil conditions including destabilization of the hillside Transport modeling indicate that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	Excavation transportation, and storage requirements may significantly impact environment Fugitive dust created by excavation and transportation may be concern Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.
Compliance With ARARs						
Ability to Meet ARARs	Key ARARs may not be met. Transport modeling indicates that peak concentrations could exceed groundwater PRGs for TCE PCE and CCl4 at the French Drain and TCE at Woman Creek.	Key ARARs should be met. Transport modeling indicates that predicted peak concentrations should remain below groundwater PRG at Woman Creek and the French Drain with the possible exception of TCE at the French Drain	Key ARARs should be met. Transport modeling indicates that predicted peak concentrations should remain below groundwater PRGs at Woman Creek and the French Drain with the possible exception of TCE at the French Drain Note that the French Drain will operation until peak concentrations fall below PRGs at the drain	Key ARARs should be met. Transport modeling indicates that predicted peak concentrations should remain below groundwater PRGs at Woman Creek and the French Drain with the possible exception of TCE at the French Drain Note that the French Drain will in operation until peak concentrations fall below PRGs at the drain	Key ARARs should be met Transport modeling indicates that predicted peak concentrations should remain below groundwater PRGs at Woman Creek and the French Drain with the possible exception of TCE at the French Drain Note that the French Drain will in operation until peak concentrations fall below PRGs at the drain	Key ARARs should be met Transport modeling indicates that predicted peak concentrations should remain below groundwater PRGs at Woman Creek and the French Drain with the possible exception of TCE at the French Drain Note that the French Drain will in operation until peak concentrations fall below PRGs at the drain.
Long Term Effectiveness and Permanence						
Magnitude of Residual Risk	Slightly increased risk because of the French Drain decommission and potential groundwater migration.	No significant change from existing risk.	Residual risk reduced through COC reduction Residual risk slightly less than Alternative 1 due to remediation of COC source	Residual risk reduced through COC reduction Residual risk less than Alternative 2 because of the thermal enhancement	Residual risk reduced through COC reduction Residual risk less than Alternatives 2 and 3 because of the expected increase in contaminant removal	Residual risk reduced through COC reduction Residual risk less than the other alternatives due to removal and treatment of COC source
Adequacy and Reliability of Controls	No controls used to protect human health or the environment.	Institutional controls used to protect human health. French Drain should prevent COC migration beyond OU 1	COCs should be controlled through source remediation. Reliability depends on placing wells near DNAPL source However residuals may reduce long term effectiveness	Contaminants should be controlled through source remediation However COC residuals may reduce effectiveness of long-term control Reliability depends on placing wells near DNAPL source Control would be slightly more effective than for Alternative 2 because of thermal enhancement although technology is considered innovative	Contaminants should be controlled through source remediation However COC residuals may reduce effectiveness of long term control Reliability depends on placing wells near DNAPL source Control may be slightly more effective than for Alternatives 2 and 3 because of increased soil permeability Treatment uses proprietary/innovative technology	Contaminants should be controlled through source removal Controls should be significantly more effective than those under other remedial alternatives because entire area is excavated and treated
Need for 5 Year Review	5 year review will be conducted	5 year review will be conducted	5 year review will be conducted	5 year review will be conducted	5 year review will be conducted	5 year review will be conducted

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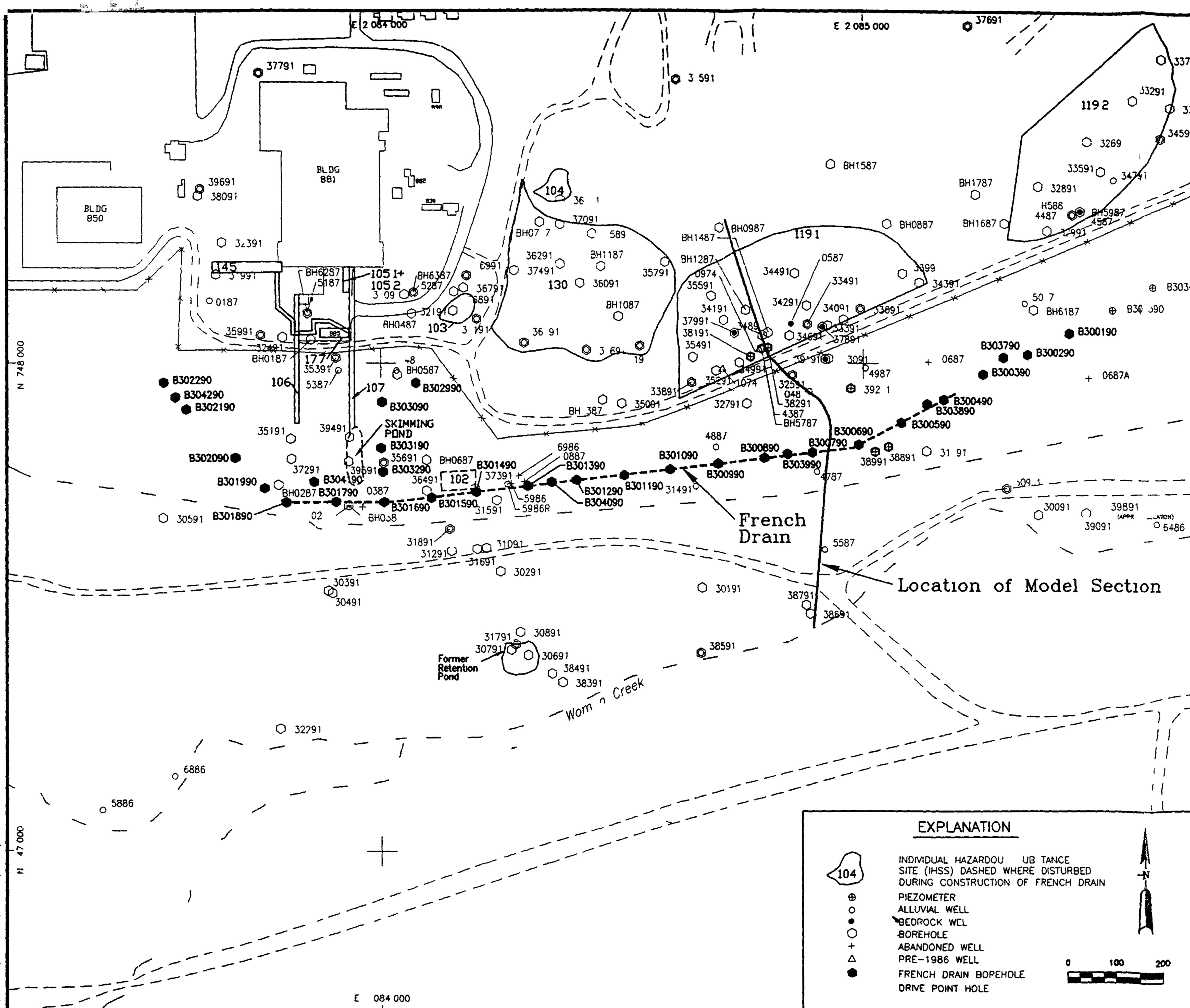
Table 4 2
(Contnued)

RCRA CAP Standards/ CERCLA Evaluati n Crit ria	ALTERNATIVE 0 N Action	ALTERNATIVE 1 Inst t tional Controls w th the French Drai	ALTERNATIVE 2 Groundw te Pump ng and Soil Vapo Extraction	ALTERNATIVE 3 Groundw te Pump ng nd Soil V po Extraction w th Thermal Enhancem t	ALTERNATIVE 4 H t Ai Injection with Mechanical Mixing	ALTERNATIVE 5 Soil E ca tio with G dw te Pumping
Reduction f T xicity M bility V l me Th ough Treatm nt						
Treatme t Process Used	None	E tracted groundwater treated by UV/peroxide on-e change and GAC processes	SVE s p en technol gy for so l emed ation Extracted so l apo treat d w th GAC Extracted groundwater treated by UV/pero ide on-exchange and GAC processes	RF heating s an nn atı e techn logy E tracted so l apor treated with GAC Extracted groundwater treated by UV/peroxide on-e change and GAC processes	H t air injectio w th s tu mechani al mixing s prop etary technology E tracted so l vapo treated with GAC Extracted grou dwater treated by UV/pe o de io e change and GAC processes	Exc ated so l treated w th thermal desorpt on whi h s a pro e so l remediation technol gy Off gas treated by GAC Extracted groundwater treated by UV/pero de on-e change p ocess and GAC proce ses
Amount Destroyed or Treated	None	Small q antities of COCs would be treated due to low groundwater concentrat ons and e traction rate	Treatment area of 100 ft x 100 ft x 20 ft SVE may not completely remo e COCs due to low so l permeab l ty l w COC concentra ons and uncertain location of DNAPL	Treatme t area of 100 ft x 100 ft x 20 ft. G eater q antity of COCs may be remo ed from so l and treated than for Alternati e 2 du to thermal enhancement.	Treatment area of 100 ft 100 ft 20 ft Greater q antity of COCs may be remo ed from o l than for Alternati es 2 and 3 due to increased so l permeabil ty from mixing de ce	Treatment area f 100 ft 100 ft x 20 ft. COC remo ed by xca ation and subsequent so l treatment by thermal desorption G oundwater remo ed and treated by Buildi g 891 water treatment system.
Reduction of Toxicity Mobil ty or Volume	None	French Drai should reduce mobil ty and olume of COCs Toxicity reduced through UV/peroxide GAC and on-e change processes	SVE and groundwater extraction will reduce olume and mob l ty of COCs T xicity s reduced through GAC UV/peroxide and on e change processes	Reduction of COC volume and mobility in soil may be sl ghtly more effecti e than for Alternati e 2 due to increased olatil zation Groundwater COC volume and mob l ty decreased by e tract on T xic ty red ced through GAC UV/peroxide and on-e change processes	Reduction of COC olume and mobility in soil may be sl ghtly more effective than for Altern ti es 2 and 3 due to increased olatili ation and soil permeab l ty Groundwate COC olume and mob l ty decreased by xtraction Toxicity ed ced thr ugh GAC UV/peroxide and -e change processes	Excavation will educe COC soil volume and mob l ty Dewatering may reduce groundwate mobil ty and lume Toxic ty w ll be reduced through GAC UV/peroxide and g neratio of the process s
Irre ers ble T eatment	Natural degradation may be irre ers ble depending on en ironment. Reactions may create more toxic daughter compounds from parent compounds	Irrevers ble contami ant removal Howe er DNAPL-contaminated soil may conti ue to act as a source	Irre ers ble contami ant removal Howe e DNAPLs in soil may contin e to act as source	Irre ers ble contaminant remo al Howe e DNAPL-contaminated so l may continue to act as source	Irre ers ble cont minant remo al Howe er DNAPL-contaminated s il may continue to act as so rce	Irre ers ble contami ant remo al assuming all DNAPL sources are remo ed
Type and Quantity of Residuals Remaining after T eatment	COC concentrations in so l and groundwater remain unchanged e cept for natural degradation	Res dual concentrations of COCs may remain in subsurface soil and groundwater Creates wastes from GAC and on-exchange processes in Bu lding 891 wate treatment system.	Low concentrations of COCs may remain in soil and groundwater Generated wastes are GAC from SVE and on-exchange regeneration l q d plus GAC from Bu ld ng 891 wate treatment ystem	Low concentrations of COCs may emain in so l and groundwate Generated wastes are GAC from SVE and on-e change regeneration liqu d plus GAC from Building 891 water treatment system.	Low concentration of COCs may remain in so l and groundwater Generated wastes are GAC from off gas treatment system and on-exchange regeneration l qu d plus GAC from Building 891 wate treatment system	Low concentration of COCs may remain in groundwater Generated wastes include GAC and on-e change regen ration l q d from Building 891 water treatment system GAC from thermal desorption system, and treated soil
Statutory Preference for Treatment	Does not satisfy preference for treatment	Satisfies preference for treatment.	Satisf es preference for treatment.	Satisf es preference for treatment.	Satisf es preference for treatment.	Satisfies preference for treatment.
Sh rt Term Effecti eness						
Commun ty Protect on	No short-term risks to the publ c	No increas short term risks to the publ c	No s gn ficant ncrease ı pote t al risks to the publ c	No signif cant increase pote t al risks to the publ c	No s gnificant incr ase n potential risks to the public	Potential ri ks to publ c due to fug ti e dust generated during e cavation transportation and storage of so l
Worke Protection	No short-term risks to workers	No increase in short term risks to workers	Potential r sks from exposure to COCs in groundwater or so l apor and safety hazards associated with drilling and construction	Potential risks from exposure to COCs in groundwate or soil apo and safety hazards associated w th drilling construction, and operation of RF heating	Pote tial ri ks f m exposure t COCs in groundwate or so l apor and safety hazards associated w th operating the mixer	Potential risks f m exposur to COCs in groundwate soil apo and f g ti e dust and safety hazards associated w th operating exca ating eq pment and thermal desorptio unit.

Table 4-2
(Continued)

RCRA CAP Standards/ CERCLA Evaluation Criteria	ALTERNATIVE 0 No Action	ALTERNATIVE 1 Institutional Controls with the French Drain	ALTERNATIVE 2 Groundwater Pumping and Soil Vapor Extraction	ALTERNATIVE 3 Groundwater Pumping and Soil Vapor Extraction with Thermal Enhancement	ALTERNATIVE 4 Hot Air Injection with Mechanical Mixing	ALTERNATIVE 5 Soil Excavation with Groundwater Pumping
Environmental Impacts	Decommissioning of the French Drain may result in decreased wetland and riparian areas in the short-term. Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	Environmental impacts are minimal. Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	Minor impacts to soil including limited loss of vegetation. Decommission of French Drain may result in short term loss of wetlands and riparian areas. Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek	Minor loss of vegetation. Insitu heating may affect subsurface biota in the treatment area. Short term loss of wetlands and riparian areas from French Drain decommission. Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	Loss of vegetation. Significant impact on environment in the treatment area due to mixing and insitu heating. Soil stability may be decreased. Short term loss of wetlands and riparian areas from French Drain decommission. Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek.	Significant environmental impact due to excavation and regrading. Short term loss of wetlands and riparian areas from French Drain decommission. Transport modeling indicates that predicted peak concentrations should remain below State and Federal surface water standards at Woman Creek
Implementability						
Ability to Construct and Operate	Not applicable	Access control should not be difficult to implement nor should operation of French Drain and water treatment processes be difficult to continue	Vendors should be able to help with design. Wells must be located near DNAPL source for effective treatment. Does not require specialized training to operate	Vendors should be able to help with design. Wells must be located near DNAPL source for effective treatment. Special training may be needed to operate the RF heating	Specialized training may be needed to operate the equipment. May be difficult to install future wells due to unconsolidated soil	Excavation can be implemented using standard equipment. Potential radionuclide contamination in subsurface soil may limit soil disposal options
Ease of Doing More Action if Needed	Will not limit the ability to perform future remedial actions	Will not limit the ability to perform future remedial actions	Will not limit the ability to perform future remedial actions	Will not limit the ability to perform future remedial actions	Will not limit the ability to perform future remedial actions	Will not limit the ability to perform future remedial actions
Ability to Monitor Effectiveness	Groundwater monitoring programs should track movement of COCs	Groundwater monitoring programs should track movement of COC	Groundwater and vapor monitoring programs should determine effectiveness	Groundwater and vapor monitoring programs should determine effectiveness	Groundwater and vapor monitoring programs should determine effectiveness	Groundwater and vapor monitoring programs should determine effectiveness. Radiological monitoring program will determine ease of soil disposal and protect workers
Ability to Obtain Permits/Coordination with Agencies	Anticipate local opposition	No problems anticipated	No problems anticipated	No problems anticipated	No problems anticipated	Potential radionuclide contamination in subsurface soil may limit soil disposal options
Availability of Services and Capacities	None required	No additional services required	Services readily available. System can be designed to meet requirements	Services readily available. System can be designed to meet requirements	Should be readily available	Services readily available
Availability of Equipment, Specialists and Materials	None required	None required	Readily available	Readily available through specialized vendors	Should be available although technology is proprietary	Readily available
Availability of Technologies	None required	None required	Readily available	Available but technology is considered innovative	Technology is proprietary	Readily available
Cost						
Present Worth (1995) Cost	$1 804,200	$7,565 400	$7 046 600	$7,560,500	$6 015 100	$13,269 600

K \DESIGN\RCKYFLTS\HILL881\OU 1\LOC MSEC DWG



U S DEPARTMENT OF ENERGY

Rocky Flats Environmental Technology Site
Gold n Colo ado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

Location of Model Section

Figure B-2

Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls with the French Drain	2 Groundwater Pumping and Soil Vapor Extraction	3 Groundwater Pumping and SVE with Thermal Enhancement	4 Steam Injection with Mechanical Mixing	5 Soil Excavation and Groundwater Removal with Sump Pumps
Resource Conservation and Recovery Act (RCRA)	42 USC Secs 6901 6987						
A Criteria for Classification of Solid Waste Disposal Facilities and Practices	40 CFR Part 257	NA	NA	A[2]	A	A[2]	A[2]
B Hazardous Waste Management Systems General	40 CFR Part 260	R/Y	R/Y	A[2]/Y	A /Y	A[2]/Y	A /Y
C Identification and Listing of Hazardous Wastes	40 CFR Part 261	R/Y	R/Y	A[2]/Y	A[2]/Y	A /Y	A[2]/Y
D Proposed Definition of Hazardous Waste to Exclude Environmental Media[1] 58FR48156	40 CFR Parts 260 and 261 Secs 261 4 261 42 and Part 268	C/Y[1]	C/Y[1]	C/Y[1]	C/Y[1]	C/Y[1]	C/Y[1]
E Standards Applicable to Generators of Hazardous Waste	40 CFR Part 262	R/Y	R/Y	A[2]/Y	A[2]/Y	A[2]/Y	A[2]/Y
F Releases from Solid Waste Management Units	40 CFR Part 264 Subpart F	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y
G Closure and Post Closure	40 CFR Part 264 Subpart G and Secs 264 600 et seq	R/Y	R/Y	A/Y	A/Y	A/Y	A/Y
H Use and Management of Containers	40 CFR Part 264 Subpart I	NA	NA	A/Y	A/Y	A/Y	A/Y
I Landfills	40 CFR Part 264 Subpart N	NA	NA	NA	NA	NA	NA
J Miscellaneous Units	40 CFR Part 264 Subpart X	NA	NA	R/Y	R/Y	R/Y	R/Y
K Air Emission Standards for Process Vents	40 CFR Secs 264 1032 and 264 1033 Subpart AA	NA	NA	A/Y	A/Y	A/Y	A/Y
L Air Emission Standards for Equipment Leaks	40 CFR Secs 264 1056 and 264 1057 Subpart BB	NA	NA	A/Y	A/Y	A/Y	A/Y
M Proposed Air Emission Standards for Storage Units	40 CFR Sec 264 1083 Subpart CC	NA	NA	C/Y[3]	C/Y[3]	C/Y[3]	C/Y[3]
N Temporary Unit	40 CFR Sec 264 553 Subpart S	NA	NA	A/Y	A/Y	A/Y	A/Y

1 Assumes requirements of 261 42 could be met acceptable risk range 10 10⁻⁶ and lev ls in so l and groundwater do not pose human health hazard or environmental hazard
2 Appl es to new treatment system
3 May apply f concentrati of organ c tank exceed 500 ppm

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Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard, Requirement, Criteria, or Limitation	Citation	0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Steam Injection with Mechanical Mixing	Soil Excavation and Groundwater Removal with Sump Pumps
O Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities	40 CFR Part 265	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y
P Interim Status Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities	40 CFR Part 267	NA	NA	NA	NA	NA	NA
Q Land Disposal Restrictions	40 CFR Part 268	NA	NA	A[4]/Y	A[4]/Y	A[4]/Y	A[4]/Y
Toxic Substances Control Act	15 USC Secs 2601 2629						
A PCB Requirements	40 CFR Part 761	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
Clean Water Act	33 USC Secs 1251 1376						
A Discharge of Effluent FFCA CWA 90 1 NPDES Federal Facility Compliance Agreement	40 CFR Sec 125 100 40 CFR Sec 122 41	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
B Toxic Pollutant Effluent Standards	40 CFR Part 129	NA	A/Y	A/Y	A/Y	A/Y	A/Y
C Discharge of Stormwater	40 CFR Sec 122 21 40 CFR Sec 122 26	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
Atomic Energy Act	42 USC Secs 2011 et seq						
A Radiation Protection and Radioactive Waste Management	10 CFR Secs 20 1301 and 20 1302 Subpart D and Sec 20 2001 et seq Subpart K	NA	NA	NA	NA	NA	A/Y
B Performance Objectives in Licensing for Land Disposal of Radioactive Waste	10 CFR Part 61 Subpart C	C[5]/Y	C[5]/Y	C[5]/Y	C[5]/Y	C[5]/Y	C[5]/Y

4 Applies to residuals of treatment system such as spent carbon, HEPA filters or ion exchange resins
5 Considered for impacts to groundwater

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Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls with the French Drain	2 Groundwater Pumping and Soil Vapor Extraction	3 Groundwater Pumping and SVE with Thermal Enhancement	4 Steam Injection with Mechanical Mixing	5 Soil Excavation and Groundwater Removal with Sump Pumps
Clean Air Act	42 USC Secs 7401 7642						
A Prevention of Significant Deterioration Requirements	40 CFR Part 52	NA	NA	NA	NA	NA	NA
B National Emission Standards for Hazardous Air Pollutants	40 CFR Part 61	NA	NA	R/Y	R/Y	R/Y	R/Y
Safe Drinking Water Act							
Underground Injection Control Program Class V Wells	40 CFR Secs 146 5 and 146 52 Subpart F	NA	NA	NA	NA	R/Y	NA
DOE Orders							
General Environmental Protection Program	5400 1	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y
Environmental Compliance Issue Coordination	5400 2A	NA	NA	NA	NA	NA	NA
Radiation Protection of the Public and Environment	5400 5	NA	NA	NA	NA	NA	C/Y
Environment Safety and Health Programs for DOE Operations	5480 1B	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y
Radioactive Waste Management	5820 2A	NA	NA	NA	NA	NA	C/Y
Hazardous and Radioactive Mixed Hazardous Waste Management	5480 3	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y
Environmental Protection Safety and Health Protection Standards	5480 4	C/Y	C/Y	C/Y	C/Y	C/Y	C/Y

Endnotes

A– Applicable
R= Relevant and Appropriate
NA= Not an ARAR
C= Considered
Y= in compliance or can be in compliance
N= not in compliance/standard exceeded

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Table D 2
Potential State
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls with French Drain	2 Groundwater Pumping and Soil Vapor Extraction	3 Groundwater Pumping and SVE with Thermal Enhancement	4 Steam Injection with Mechanical Mixing	5 Soil Excavation and Groundwater Removal with Sump Pumps
Colorado Hazardous Waste Act and State Hazardous Waste Siting Act	CRS § 25 15 101 et seq 25 15 200 et seq 25 15 301 et seq						
Hazardous Waste Management Regulations Identification and Listing of Hazardous Waste	6 CCR 1007 3 Part 261	R/Y	R/Y	A[1]/Y	A[1]/Y	A[1]/Y	A[1]/Y
Standards Applicable to Generators of Hazardous Waste	6 CCR 1007 3 Part 262	R/Y	R/Y	A[1]/Y	A[1]/Y	A[1]/Y	A[1]/Y
Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities	6 CCR 1007 3 Part 264	R/Y	R/Y	A[1]/Y	A[1]/Y	A[1]/Y	A[1]/Y
Temporary Units	6 CCR 1007 3 Sec 264 553	NA	NA	A/Y	A/Y	A/Y	A/Y
Interim Status Standards for Owners and Operators of Hazardous Waste Treatment Storage and Disposal Facilities	6 CCR 1007 3 Part 265	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y
Interim Status Corrective Action Orders	6 CCR 1007 3 Sec 265 5	R/Y	R/Y	R/Y	R/Y	R/Y	A/Y
Land Disposal Restrictions	6 CCR 1007 3 Part 268	NA	NA	A /Y	A[2]/Y	A /Y	A /Y
Colorado Solid Waste Disposal Sites and Facilities Act	CRS § 30-20 100 5 et seq						
Colorado Solid Waste Disposal Sites and Facilities Regulations	6 CCR 1007 2 Secs 2 1 15 2 5 5 and 2 5 7	NA	NA	A[2]	A[2]	A[2]	A
Colorado Water Quality Control Act	CRS 24-4-103(3) and (8)						
A Effluent Limitations	5 CCR 1002 Sec 10 1 4	NA	C/Y	C/Y	C/Y	C/Y	C/Y
B Basic Standards and Methodologies for Surface Water Quality	5 CCR 1002 8 Secs 3 1 0 et seq	R/N	R/Y	R/Y	R/Y	R/Y	R/Y
C Classifications and Water Quality Standards for Groundwater and Basic Standards	6 CCR 1007 3 5 CCR 1002 8 3 11 5 3 11 8	R/N	R/Y[3]	R/Y[3]	R/Y[3]	R/Y[3]	R/Y[3]

1 Appl es to new treatme t system
2 Appl s to residuals of treatment system such as spent carbon, HEPA f lter or on e change
3 P ss bl e ception of TCE based on pred cted model g esults

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Table D 2
Potential State
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria, or Limitation	Citation	0 No Action	1 Institutional Controls with French Drain	2 Groundwater Pumping and Soil Vapor Extraction	3 Groundwater Pumping and SVE with Thermal Enhancement	4 Steam Injection with Mechanical Mixing	5 Soil Excavation and Groundwater Removal with Sump Pumps
Colorado Air Pollution Prevention Control Act, as amended	CRS 25 7 112						
Colorado Air Pollution Control Regulations Air Pollutant Emission Notice Requirements	5 CCR 1001 5 Regulation 3 Subpart A	NA	NA	NA	NA	NA	NA
State Construction Permits	5 CCR 1001 5 Regulation 3 Subpart B	NA	NA	NA	NA[4]	NA[4]	NA[4]
Operating Permit Program	5 CCR 1001 5 Regulation 3 Subpart C	NA	NA	NA[4]	NA[4]	NA[4]	NA[4]
Control of Emissions Volatile Organic Compound	Regulation 7 General Provisions	NA	NA[5]	R/Y	R/Y	R/Y	R/Y
Soil Erosion Dust Blowing Act	CRS 35 72 101 et seq	NA	NA	R/Y	R/Y	R/Y	R/Y
Act to Establish Power and Duties of Board of Health Department of Health	CRS § 25 1 107 25 1 108 and 25 11 104	NA	NA	NA	NA	NA	NA
Colorado Rules and Regulations Pertaining to Radiation Control	See below						
A Radioactive Material Other than Source Material	6 CCR 1007 1 1 Part III RH 3 3 1 Schedule A	NA[6]	NA[6]	NA[6]	NA	NA[6]	A/Y
B Standards for Protection Against Radiation	6 CCR 1007 1 Part IV RH 4 2 1-4 2 2 3	NA[6]	NA[6]	NA[6]	NA[6]	NA[6]	A/Y
Colorado Noise Abatement Statute	CRS 25 12 101 et seq	NA	NA	A/Y	A/Y	A/Y	A/Y
Storage Tank Facility Owner/Operator Guidance Documents	Colorado Department of Health December 1992[1]	NA	NA	NA	NA	NA	NA
State Engineers Authorities							
Colorado Water Well & Pump Installation Regulations	CRS 37 91 101 112 2CRR402 2	NA	NA	C/Y	C/Y	C/Y	C/Y

4 Construction requirements do not apply to treatment alternative source (without cons deration of other sources) although ome chemicals could trigger a requirement for an operating permit, substanti e requireme ts are found in R gulation 7 for RACT
5 Minimal so l d sturbance french drai remains i place
6 Assumes no action that would newly d sturb rocks or so l

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Table D 3
Potential Federal and State
Location Specific ARARs and TBCs for Proposed Remedial Action Alternatives

Standard Requirement, Criteria, or Limitation	Citation	0	1	2	3	4	5
		No Action	Institutional Controls with the French Drain	Groundwater Pumping and Soil Vapor Extraction	Groundwater Pumping and SVE with Thermal Enhancement	Steam Injection with Mechanical Mixing	Soil Excavation and Groundwater Removal with Sump Pumps
Resource Conservation and Recovery Act (RCRA)	42 USC Secs 6901 et seq						
General Facility Standards Location Standard Floodplain	40 CFR Part 264 Subpart B 264 18(b)	NA	NA	NA	NA	NA	NA
Endangered Species Act	16 USC Secs 1531 1544						
Interagency Cooperation Endangered and Threatened Wildlife and Plants	50 CFR Part 402 50 CFR Part 17	NA	NA	NA	NA	NA	NA
National Historic Preservation Act	16 USC Secs 470 et seq						
Protection of Historic and Cultural Properties	36 CFR Part 800	NA	NA	NA	NA	NA	NA
Historic Sites, Buildings, and Antiquities Acts	16 USC Secs 461 467						
National Natural Landmarks Program	36 CFR Part 62	NA	NA	NA	NA	NA	NA
Archaeological Resources Protection Act	16 USC Secs 470aa 11						
Protection of Archaeological Resources Uniform Regulations	36 CFR Part 296	NA	NA	NA	NA	NA	NA
Preservation of American Antiquities Act Preservation of American Antiquities	16 USC Secs 431-433 43 CFR Part 3	NA	NA	NA	NA	NA	NA
Executive Orders							
Executive Order on Floodplain Management Compliance with Floodplain/Wetlands Environmental Review Requirements	Executive Order No 11988 10 CFR Part 1022	NA	NA	NA	NA	NA	NA
Executive Order on Protection of Wetlands Compliance with Floodplain/Wetlands Environmental Review Requirements	Executive Order No 11990 10 CFR Part 1022	A/Y	A/Y	A/Y	A/Y	A/Y	A/Y
State Requirements							
Historical Prehistorical and Archaeological Resources Act	CRS 24-65 1 104 CRS 24-65 1 201 202 and 302	NA	NA	NA	NA	NA	NA
State Register of Historic Places Act	CRS 24-80-401 et seq CRS 24-80 1 101 et seq	NA	NA	NA	NA	NA	NA
Non game Endangered or Threatened Species Conservation Act	CRS 33 2 101 et seq	R/Y	R/Y	R/Y	R/Y	R/Y	R/Y

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