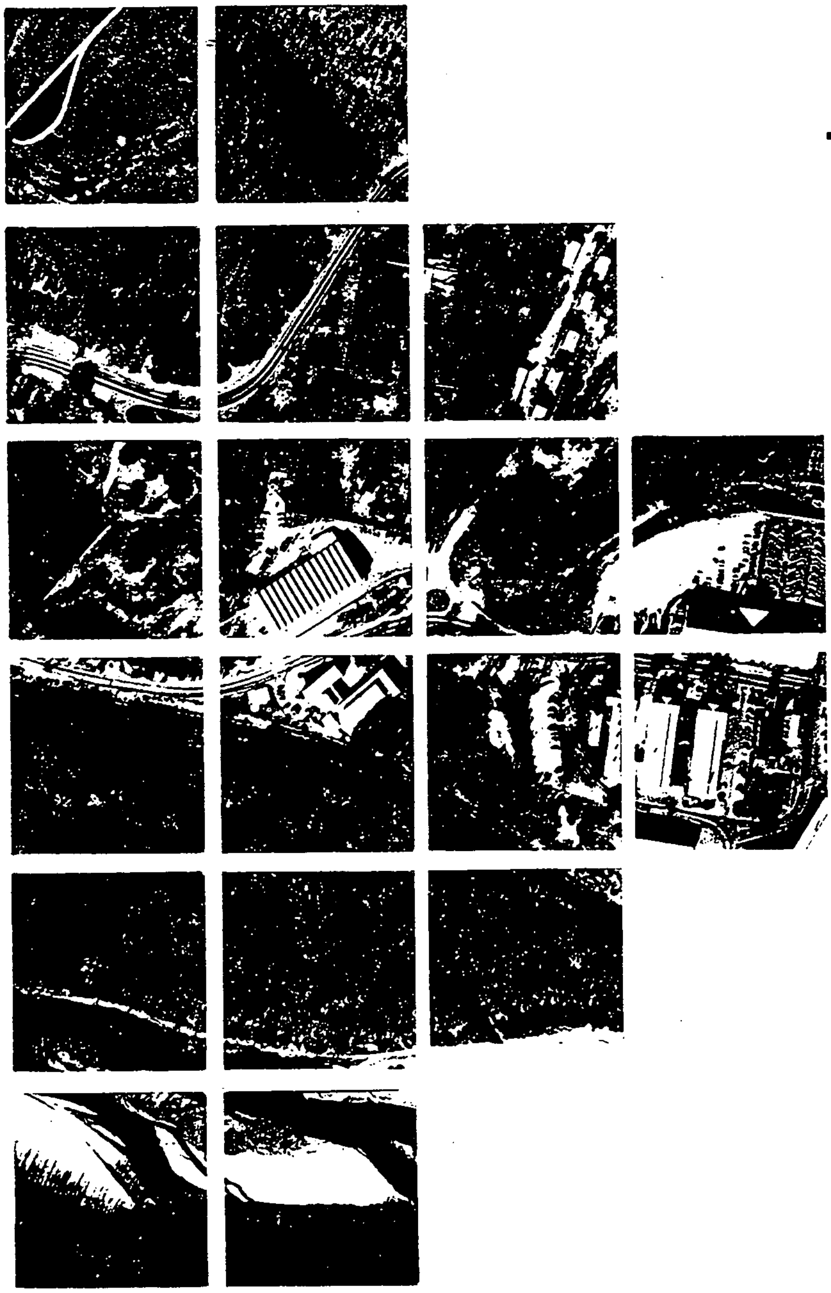
Draft Final

REMEDIAL INVESTIGATION REPORT
DRY CLEANING FACILITIES AREA (DCFA-RI)

Fort Riley, Kansas

4/6/95 Fed Ex

VOLUME I - REPORT



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LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Army Environmental Center (formerly USATHAMA)
AKAL	Alternate Kansas Action Level
AKNL	Alternate Kansas Notification Level
AMSL	Above Mean Sea Level
AR	Army Regulation
ARAR	Applicable or Relevant and Appropriate Requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BCF	Bioconcentration Factor
BEHP	Bis(2-ethylhexyl)phthalate
bgs	Below Ground Surface
Bldg.	Building
BLRA	Baseline Risk Assessment
BOD	Biochemical Oxygen Demand
BRAC	Base Realignment and Closure
BTEX	Benzene, Toluene, Ethylbenzene, and Xylenes
CAL	Corrective Action Level (RCRA)
CBD	Comprehensive Basic Documents
CEMRD	United States Army Corps of Engineers, Missouri River Division
CEMRK	U.S. Army Corps of Engineers, Missouri River Division, Kansas City District
CEMRO	United States Army Corps of Engineers, Omaha Division
CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CHPPM	Center for Health Policy and Preventive Medicine (formerly USAEHA)
CIF	Clothing Issue Facility
CLP	Contract Laboratory Program
cm^2	Centimeter Squared
cm/sec	Centimeters per Second
COD	Chemical Oxygen Demand
COE	Corps of Engineers
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CWA	Clean Water Act
DA	United States Department of the Army
DCE	Dichloroethylene
DCF	Dry Cleaning Facility
DCF"_"	Dry Cleaning Facility "Monitoring Well ID Number"
DCFA	Dry Cleaning Facilities Area
DCFSB"_"	Dry Cleaning Facility Soil Boring "Location ID Number"
DCFSD"_"	Dry Cleaning Facility Sediment "Sample Location Number"
DCFSSW"_"	Dry Cleaning Facility Sanitary Sewer "Sample Location Number"
DCFSTW"_"	Dry Cleaning Facility Storm Sewer "Sample Location Number"

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

DCFSW"_"	Dry Cleaning Facility Surface Water "Sample Location Number"
DCFUST"_"	Dry Cleaning Facility Underground Storage Tank "Sample Location Number"
DEH	Directorate of Engineering and Housing
DF	Dilution Factor
DNAPL	Dense Non-Aqueous Phase Liquid
DoD	Department of Defense
DQO	Data Quality Objective
ECD	Electron Capture Detection
EEQ	Ecological Effects Quotient
Elev.	Elevation
EPACML	U.S. EPA Composite Model for Landfill
EPS	Electromagnetic Profiling System
ER-L	Effects Range - Low
ER-M	Effects Range - Medium
FEMA	Federal Emergency Management Agency
FFA	Federal Facilities Agreement
FID	Flame Ionization Detector
FS	Feasibility Study
Ft.	Feet
GC	Gas Chromatography
GC/MS	Gas Chromatography/Mass Spectroscopy
g/m^2	Gram per Meter Squared
g/mole	Gram per Mole
gpm	Gallons per Minute
HADR	Historical and Architectural Documentation Reports
HEAST	Health Effects Assessment Summary Table
HRS	Hazard Ranking System
IAG	Interagency Agreement
IFI	Initial Field Investigation
IRIS	Integrated Risk Information System
KAL	Kansas Action Level
KAR	Kansas Administrative Regulations
KDHE	Kansas Department of Health and Environment
KDWP	Kansas Department of Wildlife Protection
kg	Kilogram
kg/g	Kilogram per Gram
kg/m^3	Kilogram per Meter Cubed
KGS	Kansas Geological Survey
KNL	Kansas Notification Level

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

l	Liter
LBA	Louis Berger & Associates, Inc.
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
LOAEL	Lowest-Observed-Adverse-Effect-Level
Ls.	Limestone
m	Meter
m/s	Meter per Second
Mbr.	Member
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
MECL	Methylene Chloride
mg	Milligram
mg/cm^2	Milligram per Centimeter Squared
mg/m^3	Milligram per Meter Cubed
mg/kg	Milligram per Kilogram
mg/l	Milligram per Liter
MH	Manhole
MRD	Missouri River Division Laboratory
MS	Mass Spectroscopy
msl	Mean Sea Level
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NA	Not Analyzed
NAAQS	National Ambient Air Quality Standard
NAp	Not Applicable
NAv	Not Available
NCP	National Contingency Plan
ND	Not Detected (Above Method Detection Limits)
NDA	No Data Available
NEPA	National Environmental Policy Act
No.	Number
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-Observed-Adverse-Effect-Level
NOEL	No-Observed-Effect-Level
NPL	National Priorities List
NS	Not Sampled
NS&T	National Status and Trends
NT	Not Tested
NYSDEC	New York State Department of Environmental Conservation

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

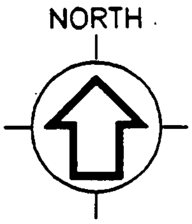
OP-FTIR	Open Path Fourier Transform Infrared Spectroscopy
OSHA	Occupational Safety and Health Administration
PA	Preliminary Assessment
PAH	Polynuclear Aromatic Hydrocarbon
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PA/SI	Preliminary Assessment/Site Investigation
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethylene (Perchloroethylene)
PEF	Particulate Emission Factor
PQL	Practical Quantitation Limit
PSF	Pesticide Storage Facility
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
QCSR	Quality Control Summary Report
RAGS	EPA Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RME	Reasonable Maximum Exposure
RPD	Relative Percent Difference
SA	Site Assessment
SAP	Sampling and Analysis Plan
SAS	Special Analytical Services
SCM	Site Conceptual Model
SFL	Southwest Funston Landfill
Sh.	Shale
SI	Site Investigation
SQL	Sample Quantitation Limit
SVE	Soil-Vapor Extraction
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
TBC	To Be Considered
TCE	Trichloroethylene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

THM	Trihalomethane
TIC	Tentatively Identified Compound
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TRPH	Total Recoverable Petroleum Hydrocarbons
TSC	EPA Technical Support Center
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
μg/kg	Micrograms per Kilogram
μg/l	Micrograms per Liter
UKN	Unknown
μm	Micrometer
U.S. ACOE	United States Army Corps of Engineers
USAEHA	United States Army Environmental Hygiene Agency
USATHAMA	United States Army Toxic and Hazardous Materials Agency
USCERL	U.S. Army Construction Engineering Research Laboratories
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UST	Underground Storage Tank
VOC	Volatile Organic Compound

LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS



EXISTING FEATURES

— SS —	Sanitary Sewer Line
— ST —	Storm Sewer Line
— G —	Gas Line
— W —	Water Line
— T —	Telephone Line
— P —	Power Line
CIP	Cast Iron Pipe
●	Manhole
■	Catch Basin
— —1050— —	Topographic Contour
TRIBUTARY E	Stream
⬅	Groundwater Flow Direction
⇦	Surface Water Flow Pathway
═══	Railroad Track
—x———x—	Fence
━━━	Curb With Gutter

ABBREVIATIONS

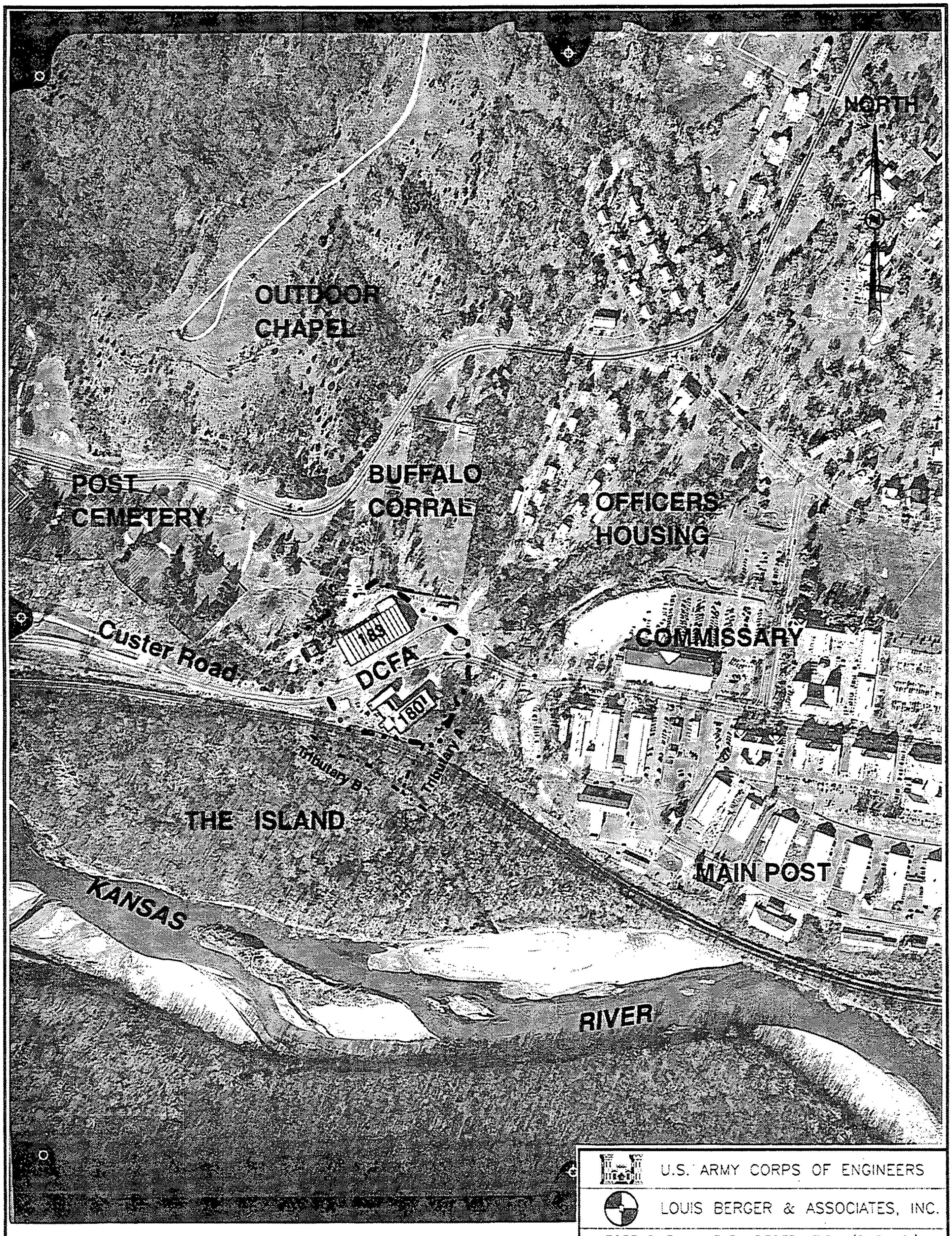
PCE = TETRACHLOROETHYLENE
FID = FLAME IONIZATION DETECTOR
TCE = TRICHLOROETHYLENE
MECL = METHYLENE CHLORIDE
DCE = 1,2 DICHLOROETHYLENE

SAMPLING DATA

● 23	SOIL GAS SAMPLE LOCATION
1.7 ● 102	PCE CONCENTRATION OR FID CONCENTRATION (ug/l) SOIL GAS SAMPLE NUMBER
—10—	PCE CONCENTRATION CONTOUR
——1——	TOTAL FID CONCENTRATION CONTOUR
—1045—	POTENTIOMETRIC CONTOUR
DCFSB-15 ●	SHALLOW SOIL BORING, IDENTIFICATION
DCF UST-2 ⊙	UST BORING
DCFSW01/ DCFSD01 ▲	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION
DCFSD-05 △	SURFACE WATER SAMPLE LOCATION
DCFSW-05 ▼	SEDIMENT SAMPLE LOCATION
DCFSSW-05 ▲	SURFACE SOIL SAMPLE LOCATION (0-1' DEPTH Unless Otherwise Noted)
DCFSW24 ○	SEEP SAMPLE LOCATION
DCF93-09 1044.28 ⌖	GROUNDWATER MONITORING WELL IDENTIFICATION GROUNDWATER LEVEL ELEVATION FT (MSL DATUM)
DCF94ES-2B	PILOT TEST STUDY WELL
DCFSSW05 ☐	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW05 ○	STORM SEWER WATER SAMPLE LOCATION
D1	AIR MONITORING LOCATION

SCALE IN FEET
1" = 50'

SCALE IN FEET
1" = 100'



Source: USACE; 11/15/84

U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

DCFA AND ENVIRONS PHOTO

SCALE:	DATE:	
1"=400'	MARCH 1995	FIG. ES-2

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CHAPTER 1
INTRODUCTION

Louis Berger & Associates, Inc. (LBA) has prepared this Draft Final Remedial Investigation (RI) report as part of the Remedial Investigation/Feasibility Study (RI/FS) for the Dry Cleaning Facilities Area (DCFA) at Fort Riley, Kansas. This investigation was performed under contract DACA41-92-D-0001 with the U.S. Army Corps of Engineers, Missouri River Division, Kansas City District in support of the Fort Riley, Directorate of Environment and Safety, Installation Restoration Program.

Pursuant to Section 105 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Fort Riley was proposed for inclusion on the National Priority List (NPL) on July 14, 1989. The Final NPL listing, published in the Federal Register August 30, 1990, assigned Fort Riley a Hazard Ranking System (HRS) score of 33.79. An HRS of 28.5 or higher is needed for inclusion on the NPL. Two other sites at Fort Riley, the Southwest Funston Landfill (SFL) and the Pesticide Storage Facility (PSF), were aggregated as one site by the U.S. EPA to develop the HRS score and are the subjects of separate RI/FS efforts.

Prior the finalization of the NPL listing, the Department of the Army (DA) - Fort Riley, the U.S. Environmental Protection Agency (U.S. EPA) Region VII, and the State of Kansas Department of Health and Environment (KDHE), negotiated a Federal Facility Agreement (FFA), Docket No. VII-90-F-0015 (U.S. EPA, 1991c). This agreement, also referred to as the Interagency Agreement (IAG) was signed by the Army in August 1990 and by U.S. EPA Region VII and KDHE in February 1991, and became effective on June 28, 1991. The IAG specifies the work to be performed and provides the procedural framework for its execution.

In addition to requiring the performance of Remedial Investigation/Feasibility Studies (RI/FS) at the SFL and PSF sites, the IAG required the DA to conduct a Site Assessment to identify potential areas of contamination at Fort Riley. The inactive dry cleaning facility was specifically identified to be included in this study based on reports of the disposal of still bottom residues from the solvent distillation process on to the ground behind Building 180 prior to 1980.

Planning documents for the former DCF Preliminary Assessment/Site Investigation (PA/SI) (as a single-site study) were prepared and reviewed in the summer and fall of 1991. Field investigations for the PA/SI occurred in February through July 1992. In September 1992, a "Working Draft" of the PA/SI report prepared for internal Army review, was issued and shared with U.S. EPA Region VII and KDHE. Because the data from the PA/SI clearly indicated the need for further investigation, the parties to the IAG agreed in October 1992 to proceed with the performance of a RI/FS without revising the PA/SI. Therefore, the Working Draft form of the PA/SI report was finalized with comment and allowed to serve as the documentation for the PA/SI.

Additional field investigations designed to better define and focus RI/FS activities occurred in the fall and winter of 1992. Detailed planning documents were then developed and finalized in July 1993. Quarterly monitoring of the groundwater monitoring wells installed during the PA/SI continued throughout this period. Full RI field activities were scheduled to begin in August 1993; however, a change in contractors performing the work delayed the work by approximately three months.

This RI report describes the activities performed and presents the results of the investigation. In addition, it includes a Baseline Risk Assessment (BLRA), which evaluates the site's impact on human health and the environment for current and likely future site uses. The RI provides a data base for the FS to develop and evaluate applicable remedial alternatives compatible with the remedial action objectives. FS activities are being performed and reported separately.

The RI was conducted in accordance with the approved Comprehensive Basic Documents for Investigations (CEMRK, 1993f), Quality Assurance Project Plan (CEMRK, 1993g), and revised Sampling and Analysis Plan (CEMRK, 1993h). Approved deviations from these plans are documented in Technical Memorandums in Appendix A. The work completed complies with requirements of the Federal Facility Agreement. The work performed and the format of the RI report are in accordance with the U.S. EPA Guidance Document for Conducting Remedial Investigations and Feasibility Studies (U.S. EPA, 1988a).

The DCFA covers approximately 7 acres at the southwest corner of the Main Post. Figure 1-1 shows the general location, and Figure 1-2 shows the DCFA and its boundaries. For the purposes of this RI report, the "DCFA," "Study Area," and "Site" are defined as follows:

- ***DCFA***: Area of current and former laundry and dry cleaning operations and related facilities;
- ***Study Area***: DCFA and the limits of other areas associated with the RI (i.e., Tributaries A and B and The Island); and
- ***Site***: As used in this RI, "site" is the same as the DCFA.

1.1 Purpose and Scope

The purpose of the DCFA RI is to identify the source or sources of contaminants, delineate the lateral and vertical extent of contamination, and provide data that enable evaluation of feasible remedial alternatives. This information will address the IAG requirements (U.S. EPA, 1991c), which include the following:

- Perform an RI of the DCFA sufficient to determine the nature and extent of the threat to the public health or welfare or the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants at the DCFA;
- Establish FS requirements for the DCFA sufficient to select site-specific remedial alternatives;
- Expedite the clean-up process; and
- Facilitate cooperation, exchange of information, and participation between the DA, KDHE, and U.S. EPA with regard to the selected remedial alternative action.

The scope of work consisted of a review of previous investigations; installation of soil borings and groundwater monitoring wells; and analysis of surface and subsurface soils, sediments, surface water, and groundwater. The scope of work also included evaluation of the data, fate and transport of chemicals in the environment and a Baseline Risk Assessment.

The scope of work also included integration (with the RI data) of the information gathered from the following activities:

- Sanitary sewer line repairs performed in May 1994;
- Air-monitoring studies performed during sewer line repair;
- Underground storage tank removal in July 1994; and
- Data resulting from implementation of the approved work plan for a soil vapor and groundwater extraction pilot study initiated in June 1994.

1.2 Background

This section presents the site description and site history and operations, based on a review of previous investigations.

1.2.1 Site Description

The Fort Riley Military Reservation is located just north of Junction City in northeast Kansas, approximately between latitudes 39°02′ and 39°18′ and longitudes 96°41′ and 96°58′. Fort Riley covers 101,058 acres, including portions of Riley and Geary Counties. The reservation was founded near the confluence of the Republican and Smoky Hill Rivers, which merge to form the Kansas River. The more widely developed areas of Fort Riley are in the southern portion of the reservation along the Republican and Kansas Rivers. As shown in Figure 1-1, the developed areas are divided into six cantonment areas: Main Post, Camp Forsyth, Camp Funston, Camp Whitside, Marshall Army Airfield, and Custer Hill.

For this report, the "Dry Cleaning Facilities Area" or DCFA will be defined as the area of current and former dry cleaning and laundry operations and related facilities. The approximately 7-acre site is situated on a rock promontory southwest of the Main Post and about 1,500 feet downstream from the confluence of the Smoky Hill and Republican Rivers. As shown in Figure 1-2, the DCFA consists of the northern and southern building complexes separated by Custer Road. The northern complex consists of a steam-generating plant (Building 184) and the current DCF (Building 183), a metal building and woodframe building, respectively. The southern complex consists of the former DCF (Building 180/181), a limestone/brick building currently used as a warehouse. Numerous buried utilities, including a gas main, water main, storm and sanitary sewer lines, telephone lines, and fiber-optics lines, run along Custer Road and across the site.

The surface around both complexes is mostly asphalt or concrete pavement with a small area of landscaped grass cover and crushed rock. The entire DCFA is isolated from the heavily populated areas, although both complexes are accessed by commercial and military vehicular traffic along Custer Road during business hours (0800 to 1600 hours).

A buffalo corral and open ground occupy the area immediately to the north. An officers' family housing complex is about 500 feet to the northeast; a commissary and veterinarian complex are about 2,000 feet to the east. The Union Pacific railroad is immediately to the south, and the Kansas River is about 1,000 feet to the south. Vacant land (formerly Mullins Park) is immediately to the west, and the Post cemetery is to the northwest (Figure 2-1).

There are 25 to 30 full-time employees at the current DCF and 20 employees at the Installation Property Book Office and Warehouse located in the former DCF. Approximately 75 people reside at the officers' family housing complex.

1.2.2 Site History and Operations

The former DCF (Building 180/181) commenced operations as early as 1915. Laundry operations began in Building 180 in 1915, and dry cleaning operations began in Building 181 in 1930. The two buildings were structurally connected in 1945. Laundry operations ceased at the southern complex in October 1983 and were transferred to the northern complex in Building 183. Table 1-1 provides a chronology of events associated with the DCFA.

Until 1966, the cleaning solution used was Stoddard solvent, a naphthalene-based fluid. Spills of the Stoddard solvent on the grounds behind Building 180/181 were reported in the Installation Assessment of Fort Riley, Kansas (USATHAMA, 1984). However, this possibility could not be verified in personal communications with former DCF employees. Since 1966, tetrachloroethylene (PCE) has been used.

Two dry cleaning machines are currently operating within Building 183. PCE is heated and sent to a cooling chamber on top of each machine. A series of coils within each cooling chamber circulates a constant flow of water used to cool the PCE. The coolant water enters and exits the cooling chamber without contacting the heated PCE.

The discharge lines for the coolant waters from each machine were directed to nearby floor drains within Building 183 until the drains were plugged with cement grout in the fall of 1993. The discharge lines from both dry cleaning machines were then rerouted to a service connection for the sanitary sewer line servicing the women's lavatory. This service connection is located in the northeast corner of Building 183.

Moisture consisting of PCE and water vapor is removed from garments during the dry cleaning process. These vapors are collected in the cooling chamber on top of each dry cleaning machine. After the vapors are cooled and condensed back into the liquid phase, the liquid flows to a separator where the water and PCE fractions are split. This separator is the size of a 1-pound coffee can. From this separator, the water drains into a 5-gallon bucket, which fills with the wastewater within 6 to 8 weeks.

Prior to October 1993, the 5-gallon bucket from each of the two dry cleaning machines had been emptied, when full, into a nearby floor drain (personal communication, DCF maintenance chief, 1993). Currently, the water is discharged into a lint collection vat for the commercial dryers, where it evaporates. Filters on the dry cleaning equipment are currently cleaned on a routine maintenance schedule, discarded in sealed drums, and disposed by the commercial company which provides the dry cleaning solvent and collects the used solvent for recycling and/or disposal.

In addition, potentially up to six spills (volumes ranging from 1 to 25 gallons) were reported to have occurred during the period from 1988 to 1993 in Building 183 (CEMRK, 1993d). These spills were reported, but no documentation of their occurrence was available. Some of these spills may have reached the floor drains, which are connected to a storm sewer that flows from Building 183 toward Building 180/181. The storm sewer eventually discharges into Tributary A, which is east of Building 180/181. Some of the spills onto the floor surfaces were reportedly contained with blankets and mattress covers. These materials were then cleaned by laundering. Laundering would have allowed diluted PCE to reach the sanitary sewer when washwater was discharged. The sanitary sewer in this area discharges to the Main Post sewage treatment plant.

The steam-generating plant, Building 184, is located approximately 80 feet west of the northwest corner of Building 183. A boiler heated by natural gas provides steam. The steam-generating plant is operated during laundry operations at Building 183 and during the night when the weather is cold. To prevent scaling on the boiler walls, blowdown water is released into the sanitary sewer at least once each day.

Water for the steam-generating plant is softened by sodium-based resin, which is recharged using sodium chloride. A large storage area for the saltwater solution is located at the back of the steam plant. In addition to sodium chloride, chemicals used at the steam plant are BL-1370, which contains 1-hydroxyethylidene-1, potassium hydroxide, and polymethacrylic acid; B120, which contains sodium sulfite; and CL-16, which contains citric acid and 1-diphosphoric acid.

BL-1370, B120, and CL-16 are commercially manufactured. BL-1370 and B-120 are boiler water treatment chemicals, and CL-16 is a resin cleaner. These chemicals are used to prevent scaling within boiler units and are discharged with the blowdown water to the sanitary sewer on a daily basis. A small supply of these chemicals is usually stored at the steam-generating plant.

1.2.3 Previous Investigations

Several investigations have been conducted within the DCFA. These have included investigations conducted by the Army Environmental Center (AEC), formerly the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA); the Center for Health Promotion and Preventive Medicine (CHPPM), formerly the U.S. Army Environmental Hygiene Agency (USAEHA); and the U.S. Army Corps of Engineers, Missouri River Division, Kansas City District (CEMRK). The findings are summarized below.

1.2.3.1 Installation Assessment of Fort Riley, Kansas (No. 341)

In December 1983, USATHAMA conducted an Installation Assessment of Fort Riley (USATHAMA, 1984). The purpose of the assessment was to assess past and current use of toxic and hazardous materials, as well as the potential for these substances to migrate off the installation. Other than record reviews and visual observations, there were no investigations (i.e., sampling and analysis) conducted as part of this assessment. This assessment reported that Stoddard solution was used as the dry cleaning solvent at the former DCF (Building 181). This assessment reported that this still residue was disposed of by pouring it on the ground behind the building. There were no records provided to support this statement.

1.2.3.2 Report: Results for Samples Submitted for Analysis, Former Dry Cleaning Facility, Fort Riley, Kansas

In June 1986, USAEHA (1986c) analyzed two soil samples for PCE. According to the Clothing Issue Facility Action Officer, the samples were collected from a grassy area along the west side of Building 181 just north of the old boiler room. No PCE was detected in either sample; the detection limit was 0.02 mg/kg. Sample collection procedures were not documented; however, the U.S. EPA's Report of RCRA Compliance Inspection (U.S. EPA, 1986) stated that the samples were collected within 4 to 5 inches of the ground surface.

1.2.3.3 Interim Final Report: Hazardous Waste Management Consultation No. 87-26-0190-89 Evaluation of Solid Waste Management Units, Fort Riley, Kansas

In 1988, USAEHA conducted an evaluation study of all solid waste management units (SWMUs) at Fort Riley. The USAEHA report stated that no evidence was observed outside Building 181 that would have indicated systematic spilling of dry cleaning solvent or sludge. The report also stated that the potential for solvent (PCE) release to the environment was low because PCE had not been detected at the site and recommended that no further sampling be conducted at the site.

1.2.3.4 Preliminary Assessment/Site Report for Preliminary Assessment/Site Investigation, Former Dry Cleaning Facility, Fort Riley, Kansas

A PA/SI was conducted to confirm the presence or absence of contamination at the site resulting from potential releases due to past waste management practices or from other types of releases in the vicinity of the former DCF. The PA/SI was completed for the former DCF in September 1992 (CEMRK, 1992a) with the preparation of a working draft document. Since the site obviously required additional characterization, this document was not finalized. Under the IAG, the Army agreed to conduct a Site Assessment (SA) to identify all potential and known areas where hazardous substances could have been released. As part of this SA, the former DCF was re-investigated.

Field activities and analytical testing conducted as part of the PA/SI included a soil gas survey, collection of soil samples from soil borings and monitoring well borings, collection of groundwater samples from the monitoring wells, and collection of sediment and surface water samples from the tributaries to the east (Tributary A) and southeast (Tributary B) of Building 180/181.

- **Soil Gas Survey Results**

A shallow soil gas survey was conducted in October 1991 to evaluate the presence or absence of Stoddard solvent, PCE, or other volatile organic compounds (VOCs) in the soils surrounding the site. Soil gas samples were collected at 49 locations (Figure 1-3). The sampling depth ranged from 3.5 to 6 feet below ground surface (bgs).

The highest PCE levels were found at the northeast corner of Building 180 (61 to 1,367 μg/l). More moderate levels extended westward to Building 181 and northward across Custer Road. A contour map of PCE concentrations is presented in Figure 1-4.

The highest levels of total VOCs as detected by flame ionization detection (FID) in soil gas were also found at the northeast corner of Building 180 (15 to 139 μg/l). Low levels extended westward beyond Building 181. An isopleth map of total FID VOCs is presented in Figure 1-5.

- **Soil Sampling Results**

Fifteen shallow soil borings were advanced to a depth of 15 feet bgs around the former DCF (Building 180/181) in March 1992 (Figure 1-6). Two soil samples from each boring were collected for chemical analysis of VOCs and semivolatile organic compounds (SVOCs). Soil samples were also collected from six monitoring well borings completed in April 1992 (DCF92-01 through DCF92-07) and analyzed for the same parameters. Soil samples were not collected for chemical analysis from monitoring well boring DCF92-07 due to its close proximity to monitoring well boring DCF92-04 (Figure 1-7).

Based on analytical results of the soil samples, PCE contamination was found to the northeast, east, and southeast of Building 180/181. Other VOCs detected include 1,1,2-trichloroethane, dibromochloromethane, carbon disulfide, and toluene. The horizontal extent of VOC contamination was not fully defined to the southeast of the site. The data also indicated that the vertical extent of VOC contamination in the areas east to southeast of the site extends from soils near the ground surface to the soil/bedrock interface.

SVOCs were detected in the soil to the northeast, east, and southeast of the former DCF. Compounds detected include benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, phenanthrene, pyrene, 2-methylnaphthalene, and bis(2-ethylhexyl)phthalate. The extent of contamination of SVOCs is limited to shallow soils from 1 to 9 feet bgs.

The results for VOCs and SVOCs in soil samples from the shallow borings at different depths are presented in Figures 1-8 and 1-9, respectively. The results for VOCs and SVOCs in soil samples from the groundwater monitoring well borings are presented in Figures 1-10 and 1-11, respectively. Results of quantifiable detections for shallow soil borings and soil from monitoring well borings are tabulated in Tables 1-2 and 1-3, respectively.

- **Groundwater Sampling Results**

Groundwater samples were collected for analysis of VOCs and SVOCs from six of the site monitoring wells (DCF92-01 through DCF92-06; monitoring well DCF92-07, installed above the water table to check for perched water, was dry at the time of installation and has remained dry). Sampling was conducted on a quarterly basis to assess temporal fluctuations in groundwater quality. Initial groundwater sampling began in July 1992.

During the installation of monitoring well boring DCF92-04, a sheen was noticed on the water being recirculated during coring procedures. A Technical Memorandum noting this sheen is provided in Appendix A (dated 29 July 1992). A sample of this recirculated coring water was collected from the well and sent to the U.S. Army Corps of Engineers-Missouri River Division (CEMRK) Laboratory for analysis. This sample was analyzed by U.S. EPA Method 8015 (modified) for fuel identification ("fingerprint" analysis). The sample contained 243 μg/l of petroleum hydrocarbons identified as highly weathered gasoline or mineral spirits (Stoddard solvent) residues (Appendix I of CEMRK, 1992a). This result has been added to the positive detections for the groundwater samples collected during the initial sampling event of July 1992 (Table 1-4). Results of the initial groundwater sampling event and the subsequent quarterly sampling events are discussed below.

Groundwater Sampling Event—July 1992. Results of the groundwater analysis from the initial sampling event (July 1992) indicated the presence of chlorinated VOCs to the northeast, east, southeast, and west of the former DCF. VOCs detected included PCE, DCE, trichloroethylene (TCE), vinyl chloride, and dichloromethane. One SVOC (naphthalene) was detected in one sample (DCF92-04). Table 1-4 provides chemical detections for the groundwater samples.

PCE was detected in four of the six monitoring wells sampled at concentrations ranging from 9.3 to 660 μg/l. Detectable concentrations of DCE ranging from 5.0 to 69 μg/l were found in three samples. TCE was detected in samples DCF92-03 and DCF92-05 at concentrations of 6.8 and 33 μg/l, respectively. Vinyl chloride was detected in sample DCF92-04 at a concentration of 11 μg/l.

All wells downgradient from the existing and former DCF contain detectable concentrations of chlorinated VOCs. If present, free phase PCE and TCE having a density greater than water would tend to migrate downward until a less permeable zone is reached. However, in a dissolved state, PCE and TCE tend to move with groundwater. Based on this, the horizontal and vertical extent of contamination may not have been defined. An aerial view of positive results for VOCs in groundwater is presented in Figure 1-12.

Groundwater Sampling Event—November 1992. The monitoring wells at the DCF were re-sampled in November 1992 as part of the quarterly sampling program at the site. In addition to the VOCs and SVOCs, groundwater samples collected during the first quarterly sampling event (November 1992) were analyzed for total metals (iron, magnesium, and manganese) and inorganic compounds. The inorganic compounds included total suspended solids (TSS), ammonia, total organic carbon (TOC), hardness, alkalinity, total Kjeldahl nitrogen (TKN), chemical oxygen demand (COD), and biochemical oxygen demand (BOD). Data for total metals and inorganic compounds were collected to evaluate groundwater remedial technologies. Table 1-5 provides analytical results for the groundwater samples from this sampling event (November 1992).

The data indicated the presence of chlorinated VOCs to the northeast, east, southeast, and west of the former DCFA (Building 181). VOCs detected included PCE, TCE, DCE, and vinyl chloride. PCE was detected in four of the six monitoring wells sampled at concentrations ranging from 3.7 to 360 μg/l. TCE was detected in two samples (DCF92-03 and DCF92-05) at concentrations of 13 μg/l and 19 μg/l, respectively. DCE was detected in three samples (DCF92-03, DCF92-04, and DCF92-05) at concentrations ranging from 12 to 51 μg/l. Vinyl chloride was detected in one sample (DCF92-04) at a concentration of 6.8 μg/l. An aerial view of positive results for VOCs in groundwater is presented in Figure 1-13 for this sampling event.

SVOCs were detected in only one sample (DCF92-04). The SVOCs detected in this sample are as follows: 2,6-dinitrotoluene (12 μg/l), hexachloroethane (43 μg/l), N-nitrosodi-n-propylamine (38 μg/l), naphthalene (5.4 μg/l), and bis(2-ethylhexyl)phthalate (10 μg/l). The results for 2,6-dinitrotoluene, hexachloroethane, and N-nitrosodi-n-propylamine are estimated and may be biased high due to high surrogate recoveries.

Of the total metal and inorganic constituents analyzed, concentrations of total magnesium, hardness, alkalinity, TKN, and BOD remained consistent with background concentrations detected in the upgradient well (DCF92-01). Concentrations of total iron, total manganese, ammonia, and COD in sample DCF92-04 were above background concentrations. Concentrations of TSS exceeded background levels in two samples (DCF92-05 and DCF92-06). Concentrations of TOC were detected in only three samples (DCF92-03 through DCF92-05).

Groundwater Sampling Event—February 1993. Analytical results of the groundwater samples collected during the second quarterly groundwater sampling event (February 1993) indicate the presence of VOCs to the northeast, east, southeast, and west of the former DCFA. VOCs detected include PCE, TCE, DCE, and toluene. SVOCs were not detected in any samples. Concentrations of total metals (iron at 2,800 μg/l, magnesium at 33,000 μg/l, and manganese at 830 μg/l) detected in sample DCF92-04 remained consistent with the concentrations detected in this sample during the previous sampling event (November 1992). The analytical results for the groundwater samples from this sampling event (February 1993) are provided in Table 1-6.

PCE was detected in three groundwater samples (DCF92-02, DCF92-03, and DCF92-05) at concentrations ranging from 72 to 470 μg/l. Concentrations of DCE were detected in three groundwater samples (DCF92-03, DCF92-04, and DCF92-05) at concentrations ranging from 9.1 to 33 μg/l. TCE was detected in two samples (DCF92-03 and DCF92-05) at concentrations of 11 μg/l and 14 μg/l, respectively. Toluene was detected in sample DCF92-05 at a concentration of 26 μg/l. An aerial view of positive results for VOCs in groundwater is presented in Figure 1-14.

▶ Summary of Groundwater Results

Groundwater samples were collected for two quarters following an initial sampling event to assess temporal fluctuations in groundwater quality. A comparison of all results for VOCs and SVOCs detected during these three sampling events is presented in Table 1-7. The trends in VOC and SVOC data collected from these three events are discussed below.

VOCs detected in groundwater samples include PCE, TCE, DCE, vinyl chloride, dichloromethane, and toluene. These compounds were detected in the following samples: DCF92-02 (PCE), DCF92-03 (DCE, PCE, TCE, and dichloromethane), DCF92-04 (DCE, PCE, and vinyl chloride), and DCF92-05 (DCE, PCE, TCE, and toluene). Concentrations of PCE have increased 29 to 45 percent from initial results in sample DCF92-02. In sample DCF92-03, concentrations of DCE and TCE have remained consistent with initial results while PCE concentrations have increased 100 to 137 percent. In sample DCF92-04, concentrations of PCE have remained consistent while DCE concentrations have increased 380 to 600 percent from initial readings. Concentrations of contaminants in sample DCF92-05 have decreased from initial results as follows: DCE (26 to 52 percent), PCE (41 to 55 percent), and TCE (42 to 58 percent). Concentrations of vinyl chloride were detected in sample DCF92-04 only during the first two sampling events. Toluene was detected in sample DCF92-05 only during the last sampling event.

Concentrations of SVOCs were detected in sample DCF92-04 only during the first two sampling events. While naphthalene was detected in both sampling events, the initial (July 1992) and the first quarter (November 1992), other compounds were detected during the first quarter (November 1992) sampling event as indicated on Table 1-5.

▶ Surface Water and Sediment Sampling Results

Three surface water and three sediment samples were collected for chemical analysis of VOCs and SVOCs during the PA/SI. Analytical results indicated the presence of PCE in surface water and sediment samples, and pyrene in a sediment sample only. Based on the number and location of samples taken, the background surface water/sediment in Tributary A (DCFSW/SD-01) indicated no contamination entering the area. The downstream samples in Tributary A (DCFSW-02 and DCFSD-02) contained low levels of PCE (4.5 μg/l and 6.6 μg/kg, respectively). The most downstream sediment sample (DCFSD-03), collected in Tributary B, contained pyrene at 120 μg/kg. Based on the analytical results (Chapter 4), positive detections for the surface water and sediment samples are presented in Figure 1-15 and Table 1-8.

Two sewer sediment samples (DCFSD-05 and DCFSD-06) and one sewer water sample (DCFSW-05) were collected for analysis of VOCs and SVOCs during the first quarter groundwater sampling event in November 1992 (Figure 1-16). Samples DCFSD-05 and DCFSW-05 were collected from the storm sewer line running beneath the grate in the grassy area approximately 55 feet north-northeast of the northeast corner of Building 180.

Sample DCFSD-06 was collected from the sanitary sewer line in manhole (MH) 363B, approximately 20 feet northeast of the northeast corner of Building 180. Field observations of sample DCFSD-06 revealed that it consisted mainly of clothing fibers (lint). The lint was removed from the sewer line when a segment of the line was replaced in April 1994. Details of the sewer repair can be found in Section 3.3.1. Documentation of disposal of the lint can be found in Appendix F. MH 363B is part of an abandoned section of sewer line that connects with the sanitary sewer line running north-south from the current DCF (Building 183), past the former DCF (Building 181). According to utility maps, this abandoned section of sewer line previously connected with the sanitary sewer line, which flows south from the steam plant (Building 184) and turns east along the north side of Custer Road. Currently, this abandoned section receives backwash during times of high flow in the main (north-south) sanitary sewer line.

Analytical results from the sewer sediment samples indicate the presence of VOCs and SVOCs. Sample DCFSD-05 contained the following concentrations of VOCs: DCE (total) at 42 μg/kg, dichloromethane at 22 μg/kg, PCE at 100 μg/kg, and TCE at 55 μg/kg. This sample also contained detectable concentrations of the following SVOCs: benzo(a)anthracene (140 μg/kg), chrysene (160 μg/kg), fluoranthene (210 μg/kg), pyrene (260 μg/kg), and bis(2-ethylhexyl)phthalate (1,900 μg/kg). Sample DCFSD-06, which was collected from the sanitary sewer line, contained the following concentrations of VOCs: DCE total (160,000 μg/kg), dichloromethane (26,000 μg/kg), PCE (470,000 μg/kg), and TCE (15,000 μg/kg). This sample also contained detectable concentrations of the following SVOCs: 4-methylphenol (5,800 μg/kg), butylbenzyl phthalate (11,000 μg/kg), and bis(2-ethylhexyl)phthalate (55,000 μg/kg). The positive detections of the sewer sediment samples (DCFSD-05 and DCFSD-06) are presented in Table 1-9.

The analytical results of sewer water sample DCFSW-05 indicate the presence of VOCs and SVOCs. This sample was collected from the storm water sewer line and contained the following concentrations of VOCs: bromodichloromethane (5.3 μg/kg), trichloromethane (4.4 μg/kg), dibromochloromethane (5.1 μg/kg), dichloromethane (5.6 μg/kg), and PCE (19 μg/kg). The only SVOC detected in this sample was bis(2-ethylhexyl)phthalate (13 μg/kg). The positive detections of the sewer water samples (DCFSW-05) are presented in Table 1-9.

1.3 Report Format

This report is presented in two volumes. Volume I consists of seven chapters, including this Introduction. Chapter 2, Environmental Setting, provides a description of natural and demographic characteristics of the site. Chapter 3, Study Area Investigation, describes the field work recently conducted in conjunction with the RI. Chapter 4, Nature and Extent of Contamination, reviews contaminants and describes the presence of these chemicals in the various media. Data on the fate and transport of contaminants via soil, surface water/sediment, groundwater, and air are presented in Chapter 5, Fate and Transport of Contaminants. The human health and ecological risks associated with conditions at the DCFA are evaluated in Chapter 6, Baseline Risk Assessment. Chapter 7, Summary and Conclusions, highlights the information from previous chapters. Appendices are presented in Volume II.

TABLE 1-1
CHRONOLOGY OF EVENTS ASSOCIATED WITH THE DCFA
Dry Cleaning Facilities Area
Fort Riley, Kansas

Date	Activity	Reports/ References
1914	Building 180 constructed (as Bldg 109, Stone)	CEMRK (1993d) Appendix, HADR; Real Property Records
1915	Laundry operations began in Building 180.	CEMRK (1993d)
1930	Building 181 constructed (as Bldg 213, Brick)	CEMRK (1993d) Appendix, HADR; Real Property Records
1931	Dry cleaning operations in Building 181.	Drawing "Layout of Dry Cleaning As Installed" dated January 1931
1940	Building 182 constructed (as Bldg 214, Stone), Inflammable Storage	HADR; Real Property Records; 1956 property listing
1941	Building 183 constructed (as Bldg 216T, Wood), Laundry Building 184 constructed (as Bldg 239), Laundry Boiler House	Real Property Records; 1956 Property listing HADR; 1956 property listing
1944	Building 180 burned (10 Sep 44)	Real Property Records
1944/45	"Solvent Used - Stoddard - Flash Point 300 - 400 F"	Drawing dated 1944/1945
1945	Building 181 reconstructed, 180 & 181 joined	Drawings dated 1945; Real Property Records
1966 (1971 ?)	Change from Stoddard to Tetrachloroethylene (PCE) as dry cleaning fluid. (Report & Interview differ on date.) Also, dry cleaning operations started in Building 180, Drums of PCE stored near single unit. (Unclear, but apparently dry cleaning ceased in 181 at this time.) Interviewee also reported that diatomaceous earth filter material was "broadcast" and used as "fill" behind the building along southwest slope & that contents of "muck tank" holding still bottoms, distillate residue & filter material discharged to the sanitary sewer. Manager also recalled 3 tanks on north side of Bldg 180 - held Stoddard but not PCE.	USATHAMA (1984) PA/SI (CEMRK 1992a) Appendix - Interview of Former Dry Cleaning Manager (1940-1971)
1974	Building 180 re-designated from Laundry/Steam Plant to Warehouse (but Dry Cleaning operations apparently continued)	Real Property Records
1979 - mid 80's	PCE delivered by tanker truck. Pumped through window north side of 181 into barrels near machines. Initially filter cartridges & sludge (1-2 gallons every 3 months) disposed of in dumpster - later (approx. 1983) disposed (off-post) through Property Disposal Office.	PA/SI (CEMRK 1992a) Appendix - Interview Former Manager (1971 - mid 1980's) RI/FS Work Plan (CEMRK 1993d) Appendix - Interview (same person)

TABLE 1-1 (CONTINUED)
CHRONOLOGY OF EVENTS ASSOCIATED WITH THE DCFA

Date	Activity	Reports/ References
October 1983	All dry cleaning (and laundry if this hadn't occurred previously) activities moved to Building 183. Buildings 180/181 becomes General Purpose Warehouse (Installation Consolidated Property Book Office).	USATHAMA (1984)
1984	U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) Installation Assessment reported still bottom residue was being dumped behind the building.	USATHAMA (1984)
1985	Contractor provides solvent supply and disposal/ recycling services	RI/FS Work Plan (CEMRK 1993d) Appendix -Interview
June 1986	Fort Riley collected and USAEHA analyzed (GC) two soil samples from the west side of Building 181. Results indicated no detections and no recommendations for further sampling were made.	Letter Report, USAEHA (1986)
1988	Evaluation of Solid Waste Management units on Fort Riley; included former Dry Cleaning Plant area. No observational evidence of systematic spilling of solvent or sludge.	USAEHA (1988)
August 1990	Fort Riley placed on National Priority List.	Federal Register 30 Aug 90
June 1991	Federal Facilities Agreement effective; requires site investigation of former Dry Cleaners	IAG, U.S. EPA (1991)
1991-1992	PA/SI Planning Draft Planning Documents, Sept.'91 Draft Final Planning Documents, Dec. '91 Revisions to Planning Documents, Jan '92 Draft Modified Planning Documents, May '92 Draft Final Mod Planning Documents, Sep '92	
1991-1992	PA/SI Field Work Soil Gas Survey, Oct 29 - Nov 2, '91 Soils Borings, Mar - Apr '92 Monitoring Well Installation, Apr '92 Monitoring Well Development, May - Jun '92 Groundwater Sampling, July '92 Exploratory Monitoring Well DCF92-07 installed (dry), Aug '92	
September 1992	Working Draft PA/SI is submitted. A decision was made to have EPA and KDHE review this document instead of extending the schedule for submission of a Draft. A meeting was held on 16 Oct 92, during which the project managers for the parties to the IAG decided that the Working Draft would be approved as Final with comments attached.	

TABLE 1-1 (CONTINUED)
CHRONOLOGY OF EVENTS ASSOCIATED WITH THE DCFA

Date	Activity	Reports/ References
1992 - 1993	Periodic groundwater sampling of six monitoring wells installed during the PA/SI. Nov, 92 Feb '93 May '93 Nov '93	QCSRs (CEMRK 1992b; 1993a,b.e)
February - April 1993	RI/FS Initial Field Investigations (IFI), Feb - Mar '93 Soil Gas Survey Sewer/Surface Water/Sediment Sampling Supplemental IFI Activities, Mar - Apr '93 Sewer Survey and Tracing Dry Cleaning Operations Sampling	Results reported in Draft Final RI/FS Work Plan, July 1993 (CEMRK, 1993d)
July 1993	Draft Final RI/FS Work Plan Submitted.	(CEMRK, 1993d)
October 1993	Revised Draft Final RI Sampling and Analysis Plan. (Result of change in Contractor performing work.)	(CEMRK, 1993h)
November - December 1993	RI field work. Soil Borings Surface Soil, Surface Water & Sediment Sampling	
December 1993	"Baseline" RI groundwater sampling including new RI monitoring wells.	QCSR (CEMRK, 1994e)
February 1994	Periodic groundwater sampling (PA/SI & RI wells, 1st Round after "Baseline")	QCSR (CEMRK, 1994f)
May 1994	Sewer line repair. A portion of sanitary sewer line was replaced between manholes 365 and 363 (portion of line serving 183 above 180/182) due to suspected leakage of the aged line.	
May 1994	Soil Sampling in conjunction with SVE Pilot Study	
April 1994 May 1994	USTs located. (Interview information about tanks unclear if removed or not. An electromagnetic survey performed by US Army Construction Engineers Laboratory [USCERL] revealed the presence of the tanks. Previous methods had been unsuccessful.) UST contents sampled	
July 1994	UST removal (2 removed, 1 abandoned in place due to depth & proximity to building foundation & utilities.	
May 1994	Soil Vapor and Groundwater Extraction Pilot Studies initiated near Building 180/181.	CEMRK (1994h)

TABLE 1-1 (CONTINUED)
CHRONOLOGY OF EVENTS ASSOCIATED WITH THE DCFA

Date	Activity	Reports/ References
June 1994	Installation of soil vapor and groundwater extraction wells. (Subsequent pumping tests performed on the groundwater wells proved extraction to be impractical due to extremely low yield rates therefore groundwater extraction pilot test terminated.	QCSR (CEMRK, 1994h)
June 1994	Periodic groundwater sampling (PA/SI & RI wells - 2nd round).	QCSR (CEMRK, 1994g)
June - July 1994	Supplemental Sewer (flow) Investigations	
August 1994	Monitoring Well DCF94-22 installed (driven well point) as a replacement for DCF94-11 which had gone dry.	
August 1994	Periodic groundwater sampling (PA/SI & RI wells - 3rd round)	QCSR (CEMRK, 1994i)
October 1994	UST area soil borings performed	
November 1994	Draft RI Report	
November - December 1994	Soil Vapor Extraction Pilot Test - 30-day test performed	
January 1995	Periodic groundwater sampling (PA/SI & RI wells - 4th round)	CEMRK (1995a)
January 1995	Additional surface water and sediment sampling.	CEMRK (1995b)
March 1995	Draft Final RI.	

Note:

HADR Historical and Architectural Documentation Reports for Fort Riley, Kansas, October 1993.

TABLE 1-2
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS
Dry Cleaning Facilities Area
Fort Riley, Kansas
1992 PA/SI

All results shown in μg/kg as dry weight unless otherwise noted.

Analyte/Depth or Interval (ft)		Tetra chloro ethylene	Tri chloro ethylene	Toluene	Carbon Disulfide	Dichloromethane	2-Methyl Naphthalene	Phenanthrene	bis(2-Ethylhexyl)phthalate
DCFSB01A	10	ND(4.7)	ND(4.7)	ND(7.8)	ND(4.7)	28	ND(160)	ND(160)	ND(400)
DCFSB01B	5	ND(3.2)	ND(3.2)	ND(5.3)	ND(3.2)	33	ND(140)	ND(140)	ND(330)
DCFSB02A	10	ND(3.4)	ND(3.4)	ND(5.6)	ND(3.4)	24	ND(150)	ND(150)	ND(370)
DCFSB02B	15	ND(3.5)	ND(3.5)	ND(5.8)	ND(3.5)	23	ND(160)	ND(160)	ND(390)
DCFSB02C	19	ND(3.4)	ND(3.4)	ND(5.7)	ND(3.4)	24	ND(150)	ND(150)	ND(380)
DCSB03A*	10	32	ND(3.5)	ND(5.8)	ND(3.5)	64B	ND(160)	ND(160)	ND(390)
DCSB03B*	15	ND(3.3)	ND(3.3)	ND(5.6)	ND(3.3)	79B	ND(150)	ND(150)	ND(380)
DCSB04A*	10	7.0	ND(3.3)	ND(5.5)	9.2	130	ND(140)	ND(140)	ND(350)
DCSB04B*	15	ND(3.4)	4.2	ND(5.6)	ND(3.4)	100	ND(150)	ND(150)	ND(370)
DCSB04C*	15	ND(3.4)	ND(3.4)	ND(5.8)	ND(3.4)	56	ND(150)	ND(150)	ND(380)
DCSB05A*	10	ND(3.5)	ND(3.5)	ND(5.8)	ND(3.5)	41	ND(160)	ND(160)	ND(390)
DCSB05B*	15	ND(3.5)	ND(3.5)	ND(5.8)	ND(3.5)	46	ND(160)	ND(160)	ND(390)

TABLE 1-2 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS

Analyte/Depth or Interval (ft)	Tetra chloro ethylene	Tri chloro ethylene	Toluene	Carbon Disulfide	Dichloromethane	2-Methyl Naphthalene	Phenanthrene	bis(2-Ethylhexyl)phthalate
DCSB06A* 10	ND(3.6)	ND(3.6)	ND(6.0)	ND(3.6)	39	ND(160)	ND(160)	ND(390)
DCSB06B* 15	ND(3.2)	ND(3.2)	ND(5.4)	ND(3.2)	37	ND(140)	ND(140)	ND(360)
DCSB07A* 10	29	ND(3.4)	ND(5.8)	ND(3.4)	36	ND(150)	ND(150)	380
DCSB07B* 15	3.7	ND(3.2)	ND(5.4)	ND(3.2)	27	ND(150)	ND(150)	460
DCSB08A* 5	ND(3.3)	ND(3.3)	ND(5.6)	ND(3.3)	33	ND(140)	ND(140)	ND(360)
DCSB08B* 8	ND(3.1)	ND(3.1)	ND(5.2)	ND(3.1)	27	ND(140)	ND(140)	ND(350)
DCFSB09A 10	ND(4.5)	ND(4.5)	ND(7.4)	ND(4.5)	27	ND(150)	ND(150)	ND(370)
DCFSB09B 15	ND(3.1)	ND(3.1)	ND(5.2)	ND(3.1)	22	ND(140)	ND(140)	ND(360)
DCFSB10A 10	ND(3.8)	ND(3.8)	ND(6.4)	ND(3.8)	23	ND(170)	ND(170)	ND(430)
DCFSB10B 15	ND(3.6)	ND(3.6)	ND(6.0)	ND(3.6)	25	ND(160)	ND(160)	ND(400)
DCFSB11A 10	ND(3.4)	ND(3.4)	ND(5.6)	ND(3.4)	25B	ND(160)	ND(160)	ND(410)
DCFSB11B 15	ND(4.4)	ND(4.4)	ND(7.4)	ND(4.4)	124	ND(140)	ND(140)	ND(360)
DCFSB12A 10	ND(3.3)	ND(3.3)	ND(5.4)	ND(3.3)	48B	ND(150)	ND(150)	ND(370)
DCFSB12B 15	ND(3.3)	ND(3.3)	ND(5.5)	ND(3.3)	51B	ND(150)	ND(150)	ND(370)
DCFSB13A 10	180	ND(3.1)	5.9	ND(3.1)	98	ND(140)	ND(140)	ND(350)
DCFSB13B 15	960	ND(14)	31	ND(14)	180	220	290	ND(360)

TABLE 1-2 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS

Analyte/Depth or Interval (ft)	Tetra chloro ethylene	Tri chloro ethylene	Toluene	Carbon Disulfide	Dichloromethane	2-Methyl Naphthalene	Phenanthrene	bis(2-Ethylhexyl)phthalate
DCFSB14A 10	5.5	ND(3.6)	ND(6.0)	ND(3.6)	37	ND(140)	ND(140)	ND(350)
DCFSB14B 15	ND(3.2)	ND(3.2)	ND(5.2)	ND(3.2)	93	ND(170)	ND(170)	ND(430)
DCFSB15A 10	ND(3.7)	ND(3.7)	ND(6.2)	ND(3.7)	40	ND(160)	ND(160)	ND(410)
DCFSB15B 15	ND(3.6)	ND(3.6)	ND(6.0)	ND(3.6)	49	ND(160)	ND(160)	ND(400)

Notes:

NA	Not Analyzed.
ND	Not Detected.
B	Compound detected in sample is less than 10 times the amount detected in the method blank. Result is estimated.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
*	Indicates identification code from CEMRK (1992b); soils taken from shallow borings where the F was not used as an identifier.

See Figure 1-8 or 1-9 for locations of soil borings.

Table adapted from CEMRK (1992b).

TABLE 1-3
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM MONITORING WELL BORINGS
Dry Cleaning Facilities Area
Fort Riley, Kansas
1992 PA/SI
Sampling March and April 1992

All results shown in μg/kg as dry weight unless otherwise noted.

Analyte/Depth or Interval (ft)		Tetra chloro ethylene	Toluene	Dichloro-methane	Phenan-threne	Benzo(a)-anthracene	Pyrene	Benzo(a)-pyrene	Chrysene	Fluor-anthene	bis(2-Ethylhexyl) phthalate
DCF92SB01A	1	ND(3.4)	ND(5.7)	68	ND(150)	ND(110)	110	ND(270)	ND(110)	ND(150)	ND(380)
DCF92SB01B	6	ND(3.4)	ND(5.8)	60	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF92SB01C	14	ND(3.2)	ND(5.4)	61	ND(160)	ND(120)	ND(120)	ND(270)	ND(120)	ND(160)	ND(390)
DCF92SB01D	UKN	ND(3.5)	ND(5.8)	56	ND(160)	ND(120)	ND(120)	ND(290)	ND(120)	ND(160)	ND(410)
DCF92SB01E	27	ND(3.3)	5.8	50	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF9202A	4	9.1	ND(5.0)	43	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF9202B	9	10	ND(5.6)	40	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF9202C	19	53	ND(5.8)	44	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF9202D	24	ND(3.1)	ND(5.1)	31	NA	NA	NA	NA	NA	NA	NA
DCF9202E	9	4.5	ND(5.6)	44	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
D9202E	29	ND(4.2)	ND(7.1)	35	ND(140)	ND(120)	ND(120)	ND(260)	ND(120)	ND(140)	ND(370)

TABLE 1-3 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM MONITORING WELL BORINGS

Analyte/Depth or Interval (ft)	Tetra chloro ethylene	Toluene	Dichloro-methane	Phenan-threne	Benzo(a)-anthracene	Pyrene	Benzo(a)-pyrene	Chrysene	Fluor-anthene	bis(2-Ethylhexyl) phthalate
DC9203A 4	110*	7.4*	34*	610	380	530	270	300	610	ND(380)
DC9203B 9	38*	ND(5.5)*	26*	ND(140)	ND(110)	ND(110)	ND(250)	ND(110)	ND(140)	ND(360)
DC9203C 14	15	ND(6.2)	30	ND(160)	ND(120)	ND(120)	ND(290)	ND(120)	ND(160)	ND(410)
DC9203D UKN	ND(3.4)	ND(5.8)	25	NA	NA	NA	NA	NA	NA	NA
DC9203E 24	ND(3.8)	ND(6.4)	37	ND(160)	ND(120)	ND(120)	ND(280)	ND(120)	ND(160)	ND(400)
DC9203F 29	7.2	ND(6.1)	32	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF92SB03E 35	44	ND(5.8)	25	ND(160)	ND(120)	ND(120)	ND(260)	ND(120)	ND(160)	ND(380)
DC92SB04A 3	ND(3.4)	ND(5.6)	89	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF92SB05A 9	ND(3.3)	ND(5.5)	26	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF92SB05B 10	ND(3.1)	ND(5.2)	22	ND(140)	ND(100)	ND(100)	ND(240)	ND(100)	ND(140)	ND(340)
DCF92SB05C 24	ND(3.2)	ND(5.4)	24	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF92SB05D UKN	ND(3.4)	ND(5.6)	65	NA	NA	NA	NA	NA	NA	NA
DCFSB05E 35	21	ND(7.1)	31	ND(180)	ND(120)	ND(120)	ND(300)	ND(120)	ND(180)	ND(430)

TABLE 1-3 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM MONITORING WELL BORINGS

Analyte/Depth or Interval (ft)	Tetra chloro ethylene	Toluene	Dichloro-methane	Phenan-threne	Benzo(a)-anthracene	Pyrene	Benzo(a)-pyrene	Chrysene	Fluor-anthene	bis(2-Ethylhexyl) phthalate
DCF9206A 4	ND(3.3)	ND(5.6)	37	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF9206B 9	ND(3.4)	ND(5.8)	46	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	2,400
DCF9206C 19	ND(3.1)	ND(5.2)	32	ND(140)	ND(100)	ND(100)	ND(240)	ND(100)	ND(140)	ND(340)
DCF9206D UKN	ND(4.1)	ND(6.9)	55	NA	NA	NA	NA	NA	NA	NA
DC92SB06E 28	ND(3.4)	ND(5.6)	50	ND(150)	ND9110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)

Notes:

UKN	Unknown.
NA	Not Analyzed.
ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
*	Re-analysis result reported. In original analysis of sample DCF9203A, 1,1,2-trichloroethane was detected at 8.6 μg/kg, and dibromochloromethane was detected at 190 μg/kg.

See Figure 1-10 or 1-11 for sample locations.

This table was adapted from CEMRK (1992c). The format has been modified to be consistent with other tables produced for this document.

TABLE 1-4
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
July 1992

All results shown in μg/l unless otherwise noted.

Parameter	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
VOLATILE ORGANICS:						
1,2-Dichloroethylene	ND (5.0J)	ND (5.0)	5.5	5.0	69	ND (5.0)
Tetrachloroethylene	ND (3.0J)	660	80	9.3	160	ND (3.0)
Trichloroethylene	ND (3.0J)	ND (3.0)	6.8	ND (3.0)	33	ND (3.0)
Vinyl Chloride	ND (2.0J)	ND (2.0)	ND (2.0)	11	ND (2.0)	ND (2.0)
Dichloromethane	5.0J	130B	13	ND (5.0)	14B	ND (5.0)
TOTAL FUEL HYDROCARBONS:	NA	NA	NA	243	NA	NA
SEMIVOLATILE ORGANICS:						
Naphthalene	ND (3.0J)	ND (3.0)	ND (3.0)	7.0	ND (3.0)	ND (3.0)
TPHC[1]	NA	NA		243	NA	NA

<u>Notes</u>:

NA	Not Analyzed.
ND	Not Detected.
( )	Number in parentheses indicate Sample Quantitation Limits, or SQLs.
B	Compound detected in sample result is less than 10 times the amount detected in the method blank. Result is estimated.
J	Sample quantitation is estimated.
[1]	Modified EPA 8015 for fuel identification; reported as highly weathered gasoline or mineral spirits (Stoddard solvent).

See Figure 1-12 for monitoring well locations.

This table was adapted from CEMRK (1992b). The format has been modified to be consistent with other tables produced for this document.

TABLE 1-5
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
November 1992

All results shown in µg/l unless otherwise noted.

Parameter	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
VOLATILE ORGANICS:						
1,2-Dichloroethylene (total)	ND (5.0)	ND (5.0)	12	35	51	ND (5.0)
Dichloromethane	ND (5.0)	5.4B	ND (5.0)	5.0B	ND (5.0)	ND (5.0)
Tetrachloroethylene	ND (3.0)	360	190	3.7	95	ND (3.0)
Trichloroethylene	ND (3.0)	ND (3.0)	13	ND (3.0)	19	ND (3.0)
Vinyl Chloride	ND (10)	ND (10)	ND (10)	6.8J	ND (10)	ND (10)
SEMIVOLATILE ORGANICS:						
2,6-Dinitrotoluene	ND (7.0)	ND (7.0)	ND (7.0)	12J	ND (7.0)	ND (7.0)
Hexachlorethane	ND (7.0)	ND (7.0)	ND (7.0)	43J	ND (7.0)	ND (7.0)
N-Nitrosodi-n-propylamine	ND (6.0)	ND (6.0)	ND (6.0)	38J	ND (6.0)	ND (6.0)
Naphthalene	ND (3.0)	ND (3.0)	ND (3.0)	5.4	ND (3.0)	ND (3.0)
bis(2-Ethylhexyl)phthalate	ND (10.0)	ND (10.0)	ND (10.0)	10	ND (10.0)	ND (10.0)
TOTAL RECOVERABLE METALS:						
Iron	170	120	ND (50.0)	2300	140	120
Magnesium	37,000	44,000	36,000	39,000	26,000	40,000
Manganese	36	34	34	990	33	34

TABLE 1-5 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Parameter	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
WET CHEMICAL INORGANICS (mg/l):						
Total Suspended Solids	5.0	2.0	1.0	5.0	8.0	8.0
Ammonia (N)	ND (0.10)	ND (0.10)	ND (0.10)	0.11	ND (0.10)	ND (0.10)
Total Organic Carbon	ND (2.0)	ND (2.0)	2.00	2.90	2.00	ND (2.0)
Hardness as $CaCO_3$	624.0	652.0	640.0	520.0	524.0	628.0
Alkalinity as $CaCO_3$	410.0	367.0	418.0	394.0	390.0	412.0
Total Kjeldahl Nitrogen	ND (1.0)J	ND (1.0)J	ND (1.0)J	ND (1.0)J	ND (1.0)J	ND (1.0)J
Chemical Oxygen Demand	ND (10.0)	ND (10.0)	ND (10.0)	11.3	ND (10.0)	ND (10.0)
Biochemical Oxygen Demand	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)	ND (10.0)

Notes:

ND Not Detected.
( ) Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
B Compound detected in sample result is less than 10 times the amount detected in the method blank. Result is estimated.
J Sample quantitation is estimated.
See Figure 1-13 for monitoring well locations.

This table was adapted from CEMRK (1993a). The format has been modified to be consistent with other tables produced for this document.

TABLE 1-6
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
February 1993

All results shown in μg/l unless otherwise noted.

Parameter	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
VOLATILE ORGANICS (METHOD 8260):						
1,2-Dichloroethylene (total)	ND (5.0)	ND (5.0)	9.1	24	33	ND (5.0)
Tetrachloroethylene	ND (2.5)	470	160	ND (2.5)	72	ND (2.5)
Toluene	ND (1.5)	ND (1.5)	ND (1.5)	ND (1.5)	26	ND (1.5)
Trichloroethylene	ND (1.0)	ND (1.0)	11	ND (1.0)	14	ND (1.0)
TOTAL RECOVERABLE METALS:						
Iron	NA	NA	NA	2,800	NA	NA
Magnesium	NA	NA	NA	33,000	NA	NA
Manganese	NA	NA	NA	830	NA	NA

Notes:

NA	Not Analyzed.
ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

See Figure 1-14 for monitoring well locations.

This table was adapted from CEMRK (1993b). The format has been modified to be consistent with other tables produced for this document.

TABLE 1-7
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
1992-1993

All results shown in μg/l unless otherwise noted.

Parameter	Sample Date	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
VOLATILE ORGANICS:							
1,2-Dichloroethylene (total)	7/15/92	ND(5.0)	ND(5.0)	5.5	5.0	69	ND(5.0)
	11/9/92	ND(5.0)	ND(5.0)	12	35	51	ND(5.0)
	2/4/93	ND(5.0)	ND(5.0)	9.1	24	33	ND(5.0)
Dichloromethane	7/15/92	5.0	130B	13.0	ND(5.0)	14.0B	ND(5.0)
	11/9/92	ND(5.0)	5.4B	ND(5.0)	5.0B	ND(5.0)	ND(10.0)
	2/4/93	ND(10.0)	ND(10.0)	ND(10.0)	ND(10.0)	ND(10.0)	ND(10.0)
Tetrachloroethylene	7/15/92	ND(3.0)	660	80	9.3	160	ND(3.0)
	11/9/92	ND(3.0)	360	190	3.7	95	ND(3.0)
	2/4/93	ND(2.5)	470	160	ND(2.5)	72	ND(2.5)
Toluene	7/15/92	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)
	11/9/92	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)
	2/4/93	ND(1.5)	ND(1.5)	ND(1.5)	ND(1.5)	26	ND(1.5)
Trichloroethylene	7/15/92	ND(3.0)	ND(3.0)	6.8	ND(3.0)	33	ND(3.0)
	11/9/92	ND(3.0)	ND(3.0)	13	ND(3.0)	19	ND(3.0)
	2/4/93	ND(1.0)	ND(1.0)	11	ND(1.0)	14	ND(1.0)
Vinyl Chloride	7/15/92	ND(2.0)	ND(2.0)	ND(2.0)	11	ND(2.0)	ND(2.0)
	11/9/92	ND(2.0)	ND(2.0)	ND(2.0)	12	ND(2.0)	ND(2.0)
	2/4/93	ND(2.0)	ND(2.0)	ND(2.0)	ND(2.0)	ND(2.0)	ND(2.0)

TABLE 1-7 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Parameter	Sample Date	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
SEMIVOLATILE ORGANICS:							
bis(2-Ethylhexyl)phthalate	7/15/92	ND(10.0)	ND(10.0)	ND(10.0)	ND(10.0)	ND(10.0)	ND(10.0)
	11/9/92	ND(10.0)	ND(10.0)	ND(10.0)	10	ND(10.0)	ND(10.0)
	2/4/93	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)
2,6-Dinitrotoluene	7/15/92	ND(7.0)	ND(7.0)	ND(7.0)	ND(7.0)	ND(7.0)	ND(7.0)
	11/9/92	ND(7.0)	ND(7.0)	ND(7.0)	12J	ND(7.0)	ND(7.0)
	2/4/93	ND(4.0)	ND(4.0)	ND(4.0)	ND(4.0)	ND(4.0)	ND(4.0)
Hexachloroethane	7/15/92	D(7.0)	ND(7.0)	ND(7.0)	ND(7.0)	ND(7.0)	ND(7.0)
	11/9/92	ND(7.0)	ND(7.0)	ND(7.0)	43J	ND(7.0)	ND(7.0)
	2/4/93	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)
Naphthalene	7/15/92	ND(3.0)	ND(3.0)	ND(3.0)	7.0	ND(3.0)	ND(3.0)
	11/9/92	ND(3.0)	ND(3.0)	ND(3.0)	5.4	ND(3.0)	ND(3.0)
	2/4/93	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)
N-Nitrosodi-n-propylamine	7/15/92	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)
	11/9/92	ND(6.0)	ND(6.0)	ND(6.0)	38J	ND(6.0)	ND(6.0)
	2/4/93	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)

Notes:

( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
B	Compound detected in sample is less than 10 times the amount detected in the method blank. Result is estimated.
J	Sample quantitation is estimated.

This table was adapted from CEMRK (1992b; 1993a,b,e). The format has been modified to be consistent with other tables produced for this document.

TABLE 1-8
SUMMARY OF CHEMICAL DETECTIONS FOR SEDIMENT AND SURFACE WATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
March 1992

All results shown in μg/kg unless otherwise noted.

Parameter	DCSD01	DCSD02	DCSD03	DCSW01[a]	DCSW02[a]	DCSW03[a]
VOLATILE ORGANICS:						
Dichloromethane	84B	80B	80B	22J	21J	20J
Tetrachloroethylene	ND(6.3)	6.6	ND(3.6)	ND(3.0)	4.5	ND(3.0)
SEMIVOLATILE ORGANICS:						
Pyrene	ND(780)	ND(120)	120	ND(3.0)	ND(3.0)	ND(3.0)

Notes:

ND	Not Detected.
B	Compound detected in sample result is less than 10 times the amount detected in the method blank. Result is estimated.
J	Sample quantitation is estimated.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
[a]	Results are in μg/l.

See Figure 1-15 for sample locations.

This table was adapted from CEMRK (1992a; 1993a,d). The format has been modified to be consistent with other tables produced for this document.

TABLE 1-9
SUMMARY OF CHEMICAL DETECTIONS FOR SEWER LINE SEDIMENT AND WATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
November 1992

All results shown in μg/kg unless otherwise noted.

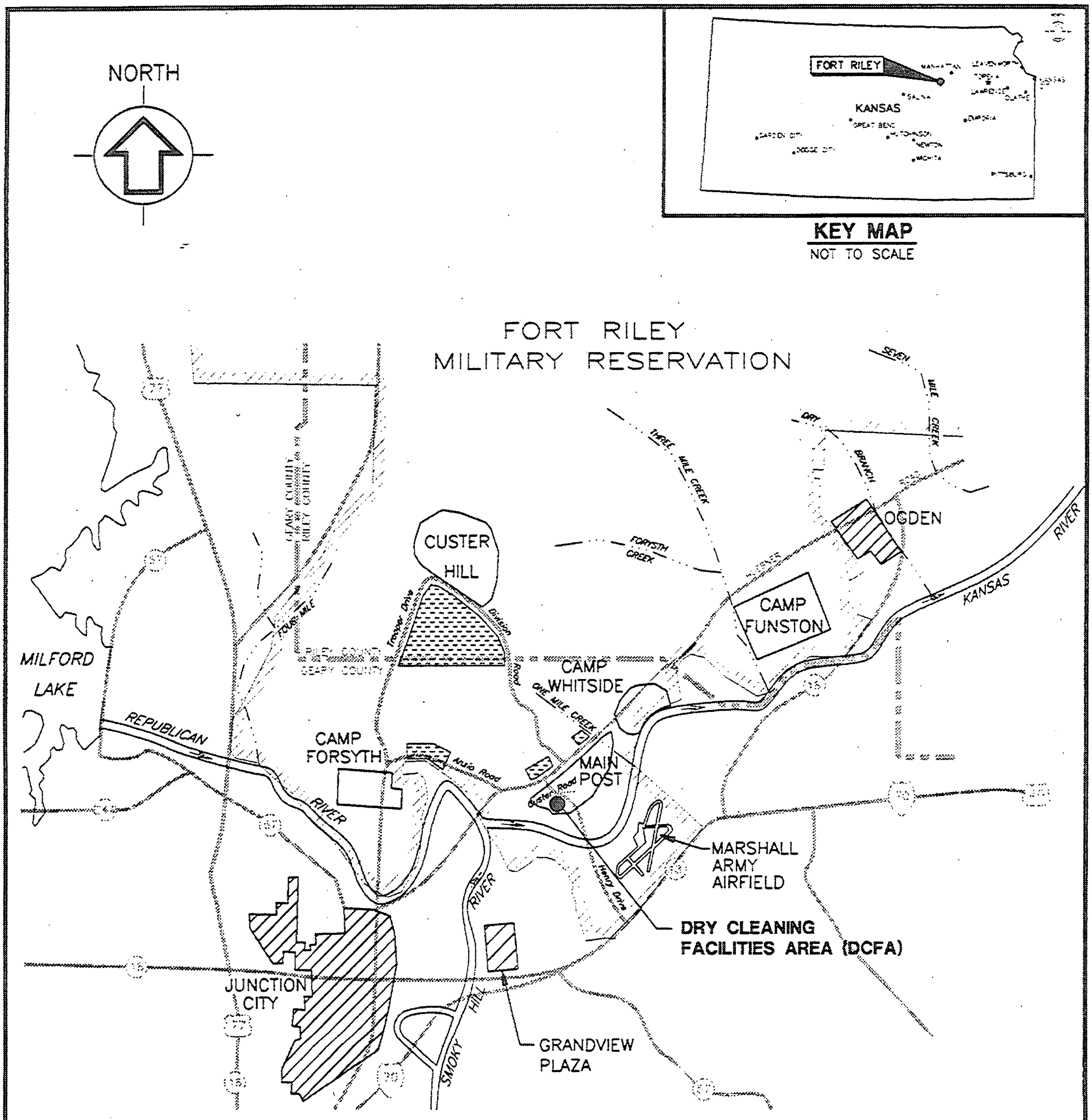
Parameter	DCFSD05	DCFSD06	DCFSW05[a]
VOLATILE ORGANICS:			
1,2-Dichloroethylene	42	160,000J	ND (5.0)
Bromodichloromethane	ND (6.3)	ND (10,000)	5.3
Dibromochloromethane	ND (6.3)	ND (10,000)	5.1
Dichloromethane (total)	22B	26,000J	5.6B
Tetrachloroethylene	100J	470,000J	19
Trichloroethylene	55	15,000J	ND (3.0)
Trichloromethane	ND (3.8)	ND (6,100)	4.4
SEMIVOLATILE ORGANICS:			
4-Methylphenol	100J	470,000J	ND (7.0)
Benzo(a)anthracene	140	ND (2,000)	ND (3.0)
bis(2-Ethylhexyl)phthalate	1,900	55,000	ND (10.0)
Butylbenzylphthalate	ND (460)	11,000	ND (10.0)
Chrysene	160	ND (2,000)	ND (3.0)
Fluoranthene	210	ND (2,700)	ND (4.0)
Pyrene	260	ND (2,000)	13

Notes:

ND	Not Detected.
B	Compound detected in sample result is less than 10 times the amount detected in the method blank. Result is estimated.
J	Sample quantitation is estimated.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
[a]	Results are in μg/l.

See Figure 1-16 for sample locations.

This table was adapted from CEMRK (1992b; 1993a). The format has been modified to be consistent with other tables produced for this document.



LEGEND:

▤	MILITARY HOUSING
☐	CANTONMENT AREA
▨	MUNICIPALITY
⊓	MILITARY RESERVATION BOUNDARY

0 1 2 4

SCALE IN MILES
1" = 2 MILES

NOTE:

BIG BLUE RIVER (NOT SHOWN) IS
APPROX. 8km TO THE NE OF MAIN POST

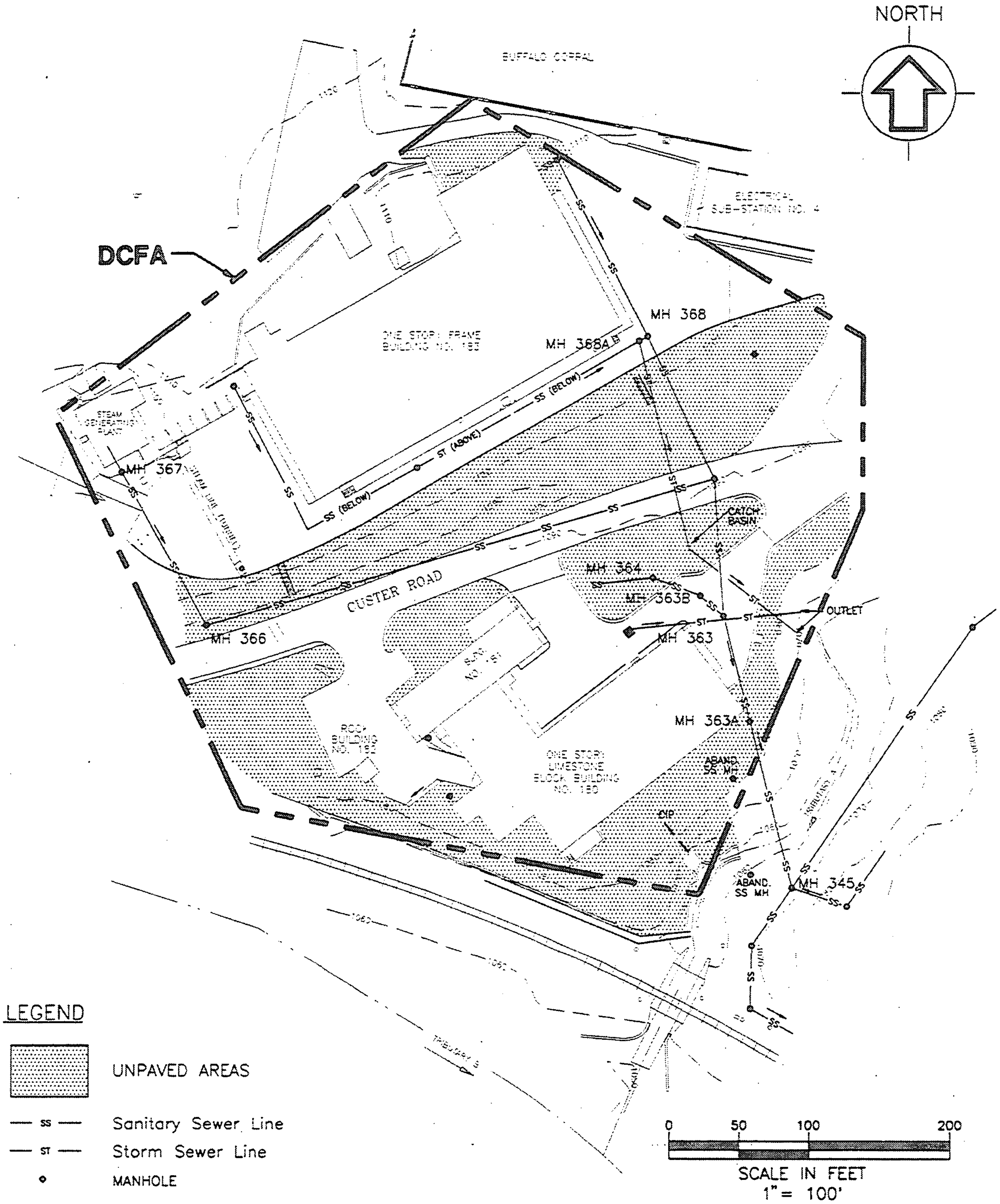
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

GENERAL VICINITY MAP

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-1



LEGEND

▨	UNPAVED AREAS
— SS —	Sanitary Sewer Line
— ST —	Storm Sewer Line
○	MANHOLE
■	Catch Basin (Grate)
CIP	Cast Iron Pipe

NOTE:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.

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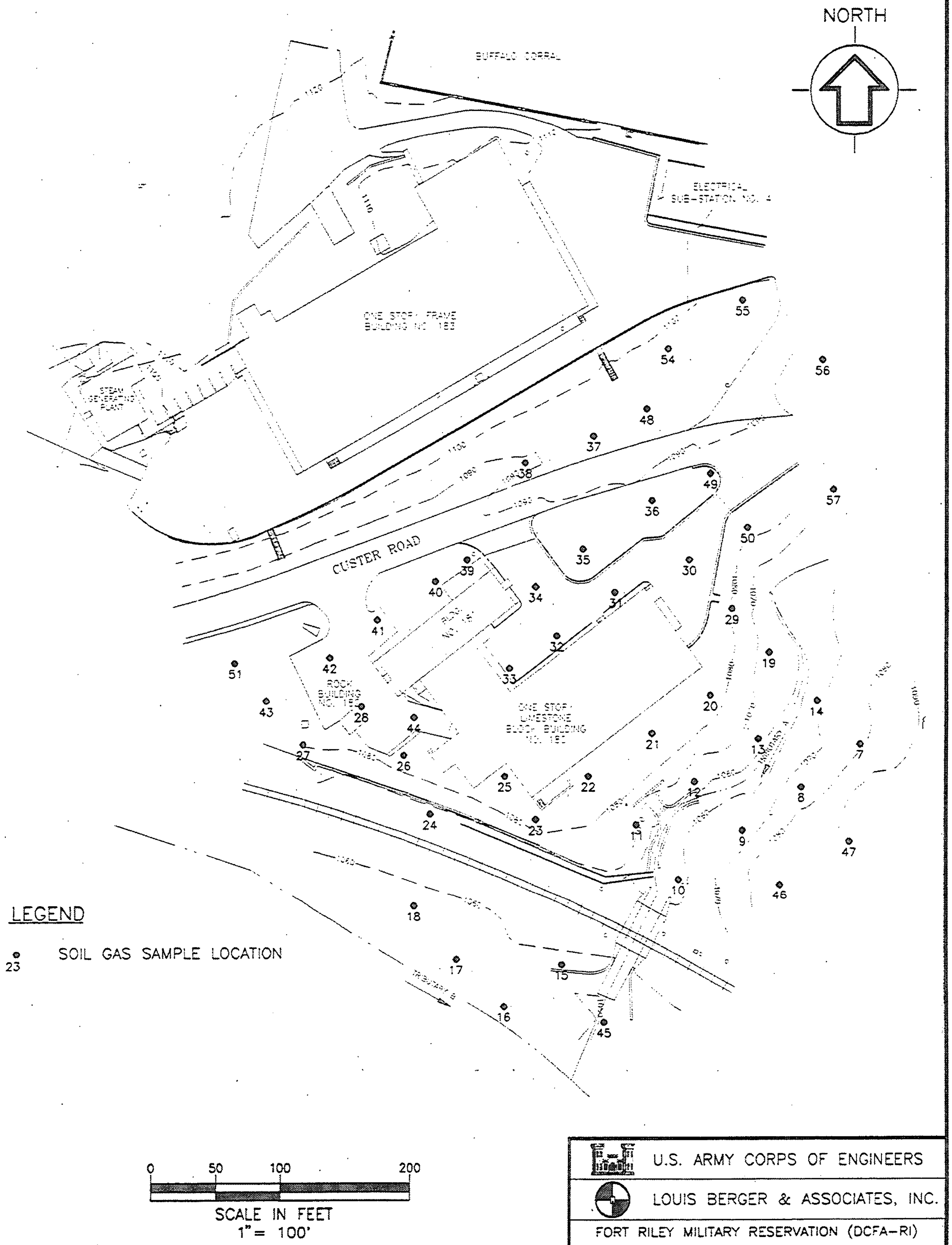
FORT RILEY MILITARY RESERVATION (DCFA–RI)

SITE MAP

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 1–2



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.

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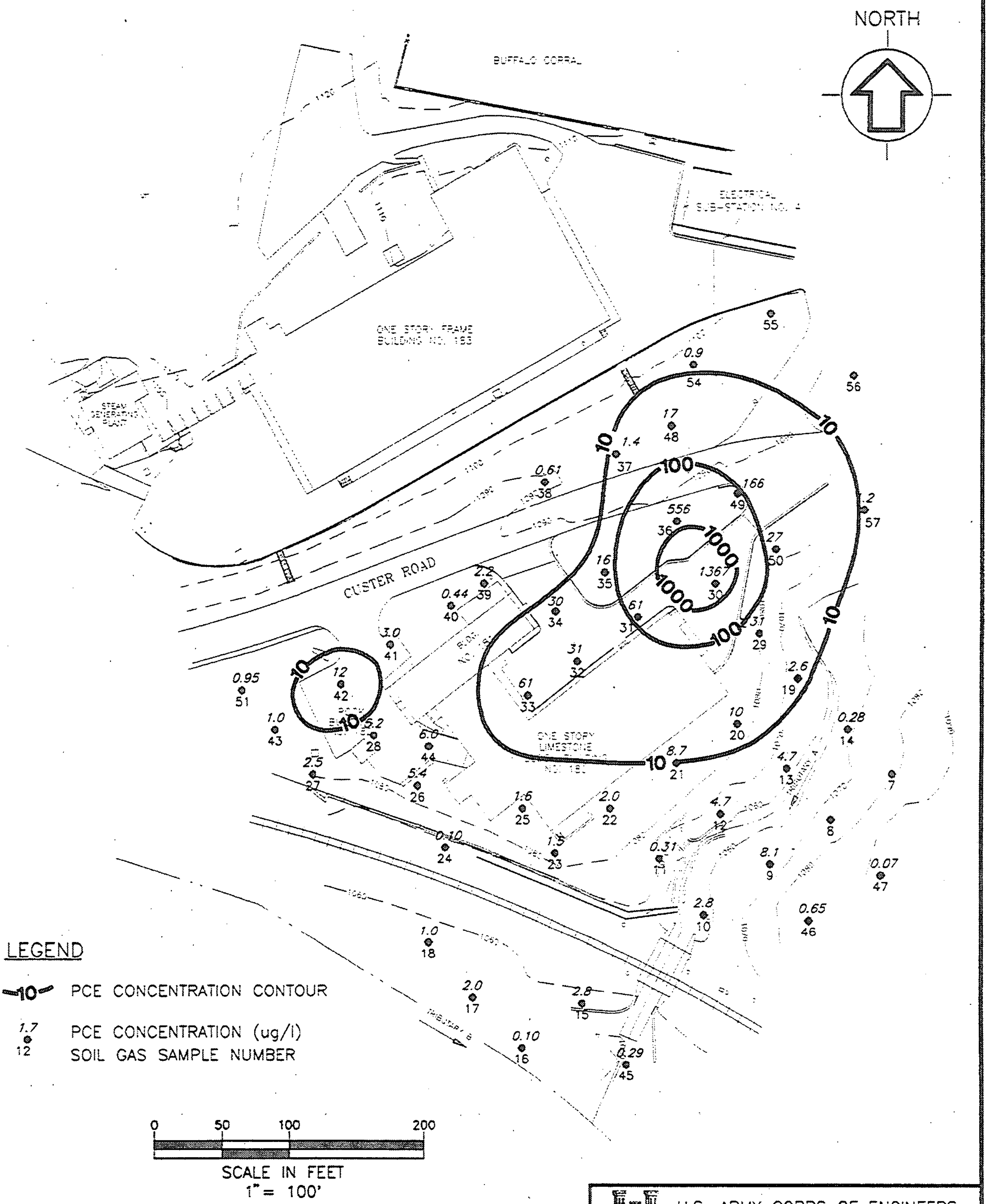
FORT RILEY MILITARY RESERVATION (DCFA-RI)

SOIL GAS SURVEY
LOCATION MAP, 10/91

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 1–3



LEGEND

—10— PCE CONCENTRATION CONTOUR

1.7 PCE CONCENTRATION (ug/l)
●
12 SOIL GAS SAMPLE NUMBER

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.
3. PCE CONCENTRATIONS BASED ON ANALYSIS OF SAMPLES USING GC/MS.

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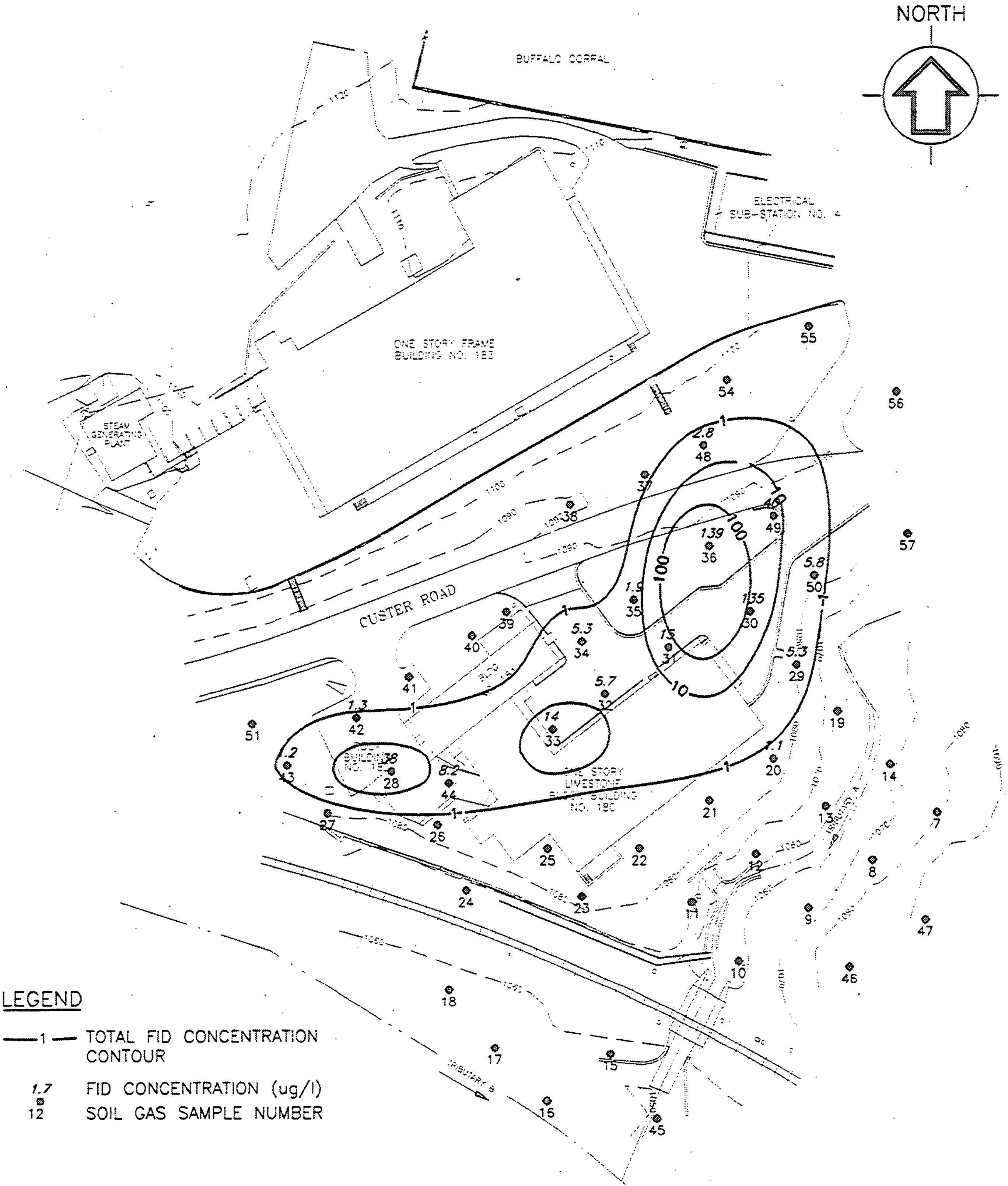
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE CONCENTRATIONS FROM SOIL GAS SURVEY, 10/91

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 1–4



LEGEND

—1— TOTAL FID CONCENTRATION CONTOUR

1.7 FID CONCENTRATION (ug/l)

12 SOIL GAS SAMPLE NUMBER

0 50 100 200

SCALE IN FEET
1" = 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.
3. FID CONCENTRATIONS INCLUDE TOTAL VOLATILE ORGANIC COMPOUNDS.

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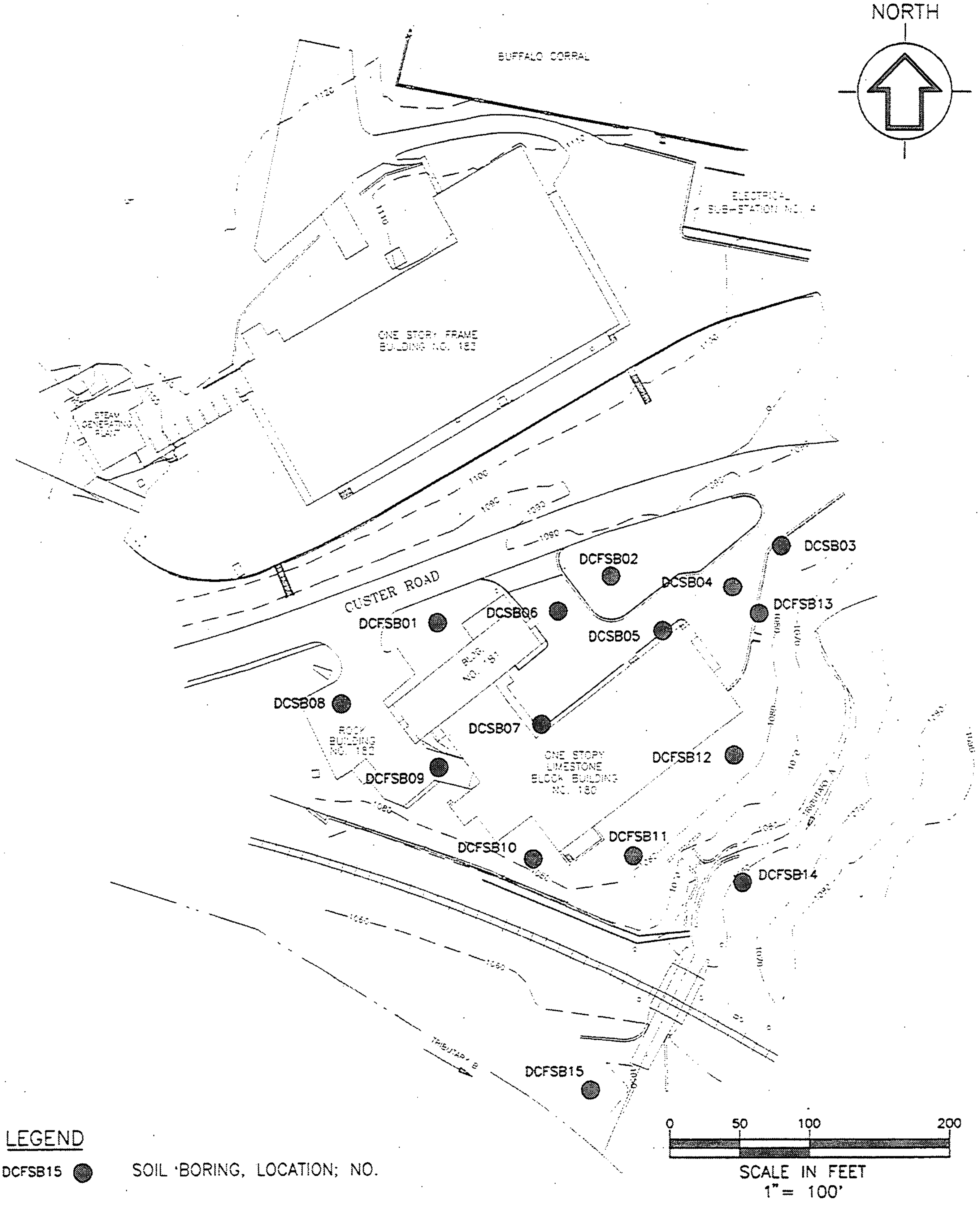
FORT RILEY MILITARY RESERVATION (DCFA–RI)

TOTAL VOC CONCENTRATIONS FROM SOIL GAS SURVEY, 10/91

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 1–5



LEGEND

DCFSB15 ● SOIL BORING, LOCATION; NO.

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.

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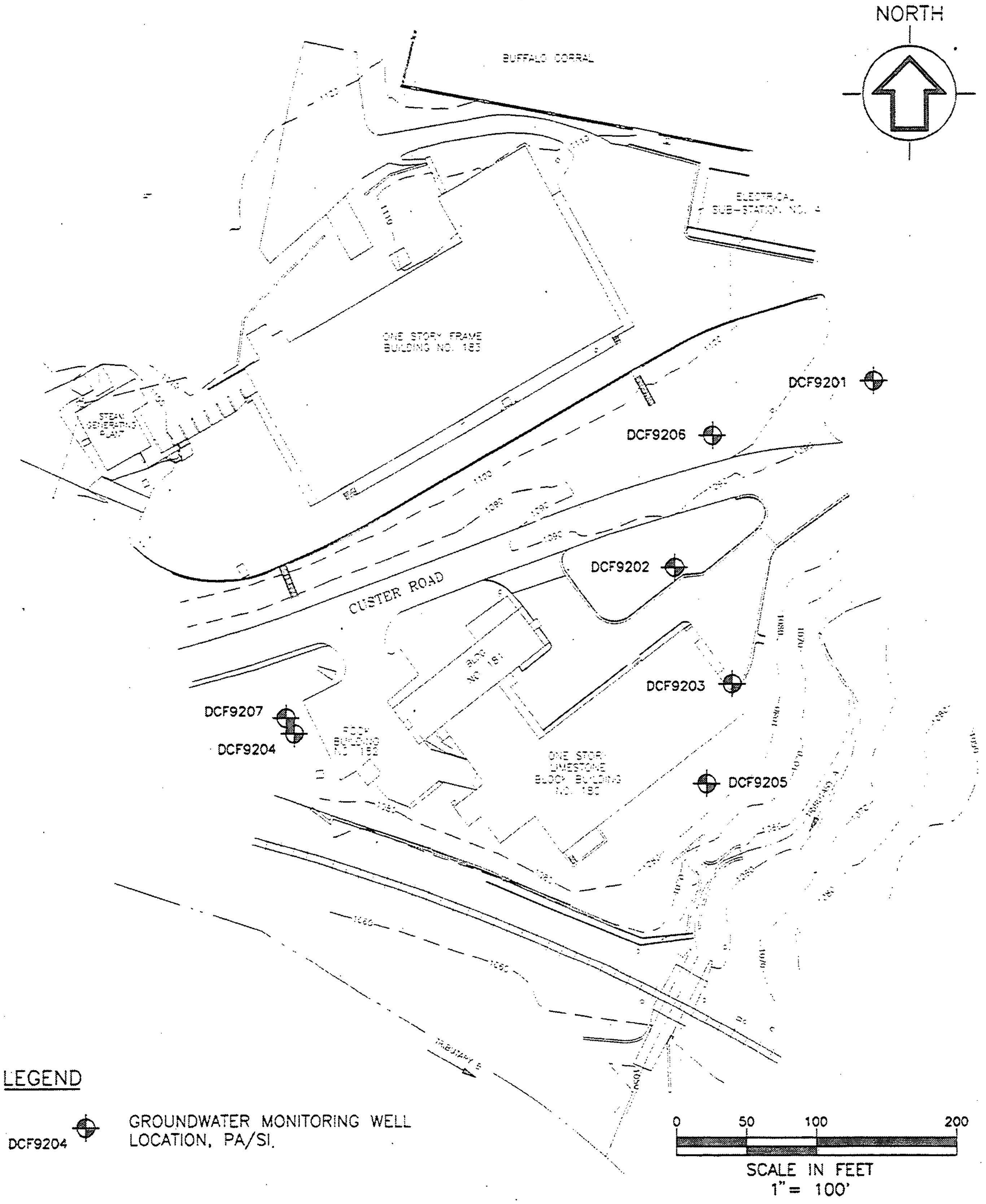
FORT RILEY MILITARY RESERVATION (DCFA–RI)

SHALLOW SOIL BORING
LOCATION MAP, 3/92

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 1–6

1—SSBLM/30MAR95



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.

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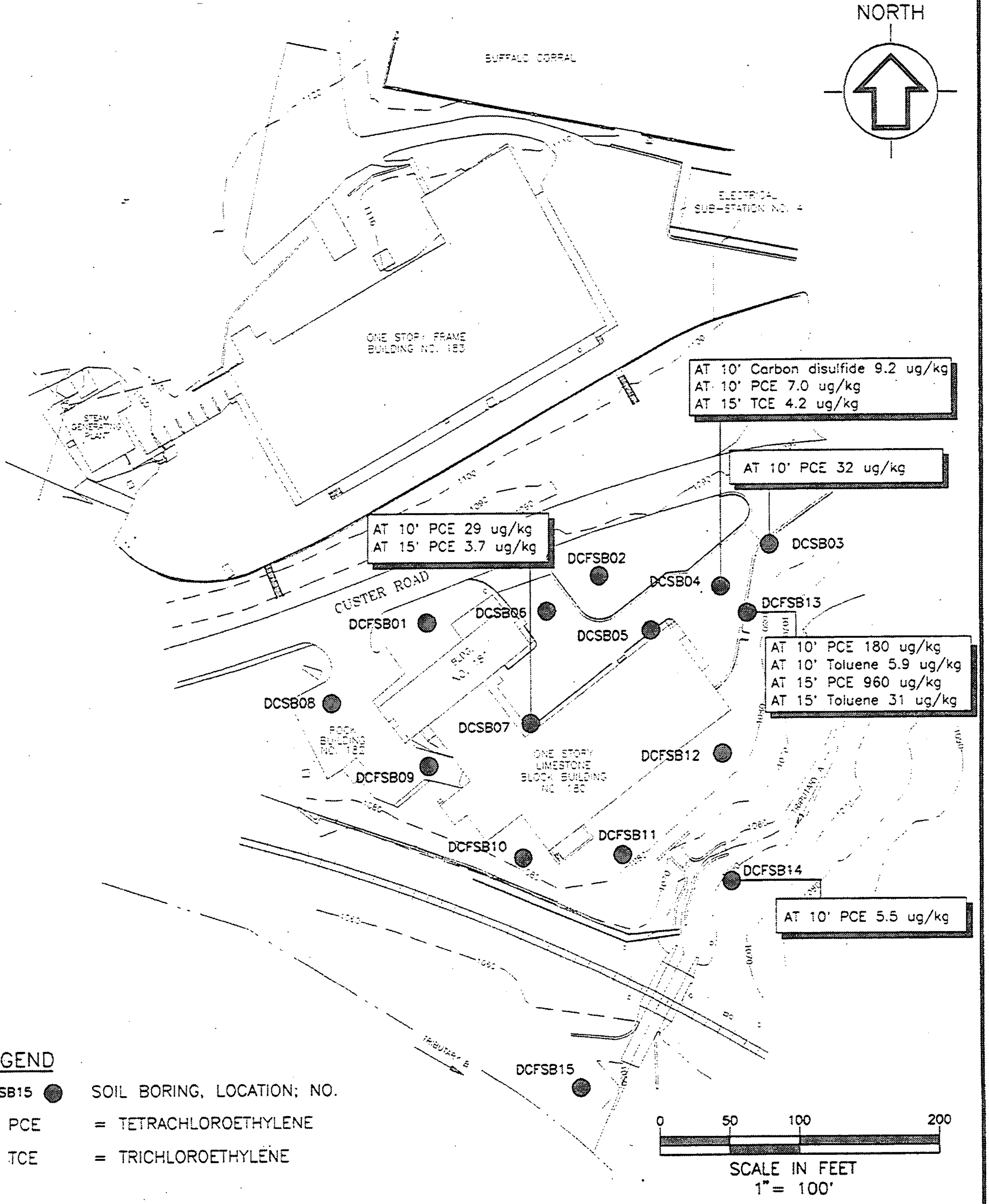
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER MONITORING WELL LOCATION MAP, 4/92

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-7



LEGEND

DCFSB15 ●	SOIL BORING, LOCATION; NO.

PCE = TETRACHLOROETHYLENE

TCE = TRICHLOROETHYLENE

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992b.
3. SEE TABLE 1-2 FOR ANALYTICAL RESULTS; DEPTHS OF BORINGS ARE INDICATED BY THE SUFFIX AND THE NUMBER ON TABLE 1-2. THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".
4. DICHLOROMETHANE NOT REPORTED HERE.

U.S. ARMY CORPS OF ENGINEERS

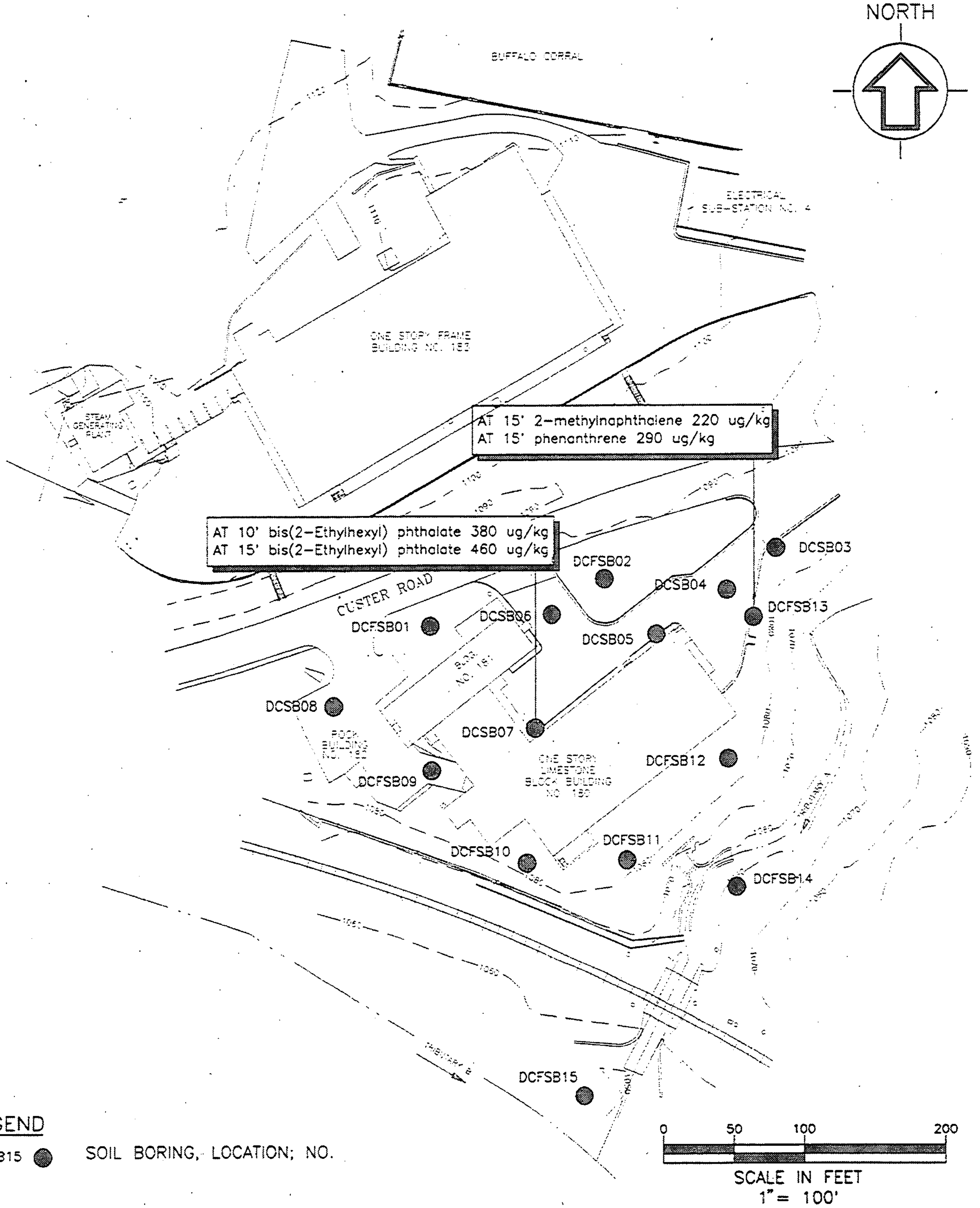
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

CHEMICAL DETECTIONS, VOC's FROM SOIL BORING SAMPLES, 4/92

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-8

1-CDVOC/30MAR95



AT 15' 2-methylnaphthalene 220 ug/kg
AT 15' phenanthrene 290 ug/kg

AT 10' bis(2-Ethylhexyl) phthalate 380 ug/kg
AT 15' bis(2-Ethylhexyl) phthalate 460 ug/kg

LEGEND

DCFSB15 ● SOIL BORING, LOCATION; NO.

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.
3. SEE TABLE 1-2 FOR ANALYTICAL RESULTS; DEPTHS OF BORINGS ARE INDICATED BY THE SUFFIX AND THE NUMBER ON TABLE 1-2. THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".

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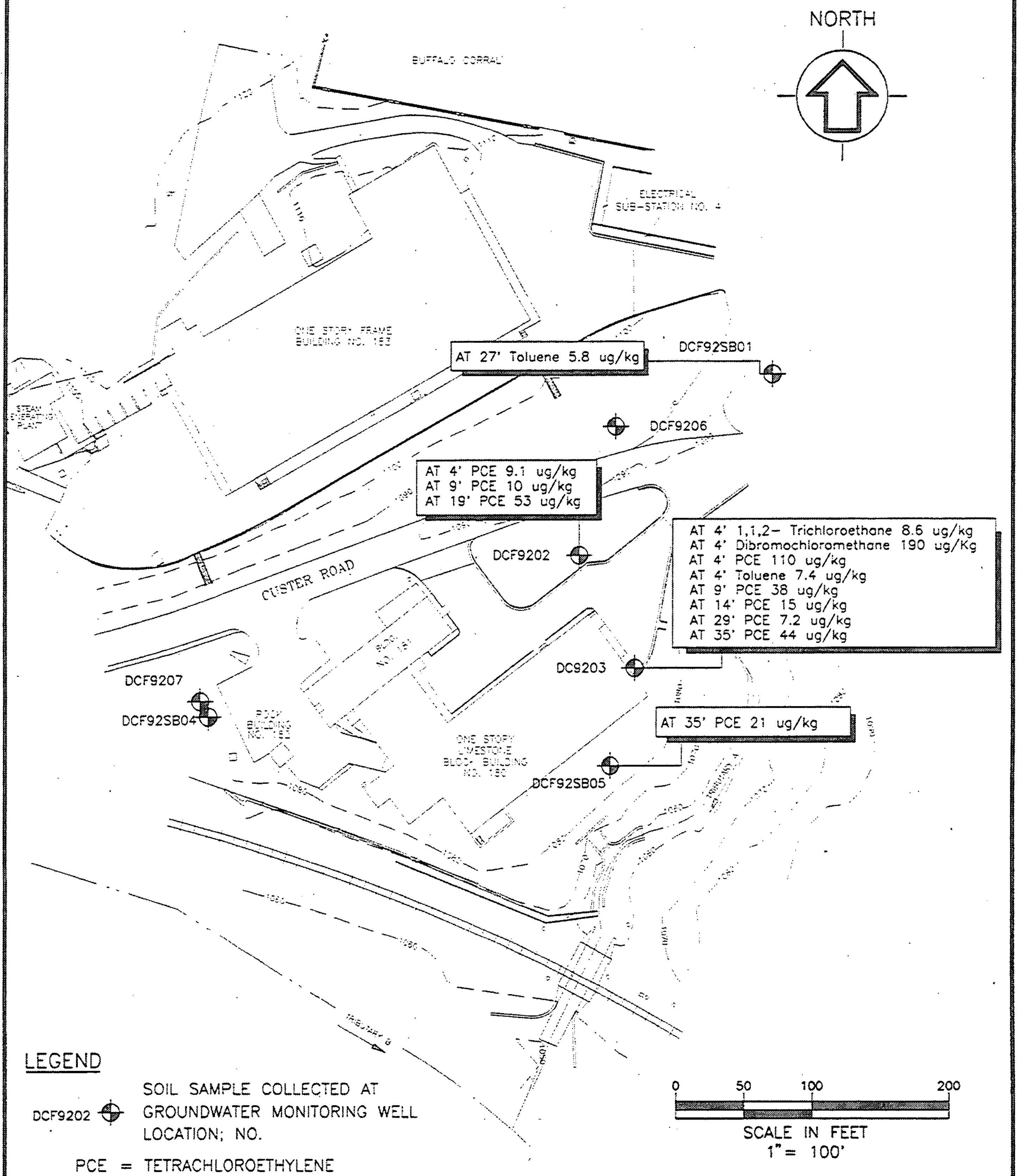
FORT RILEY MILITARY RESERVATION (DCFA-RI)

CHEMICAL DETECTIONS, SVOC's FROM SOIL BORING SAMPLES, 4/92

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-9



LEGEND

DCF9202 ⊕ SOIL SAMPLE COLLECTED AT GROUNDWATER MONITORING WELL LOCATION; NO.

PCE = TETRACHLOROETHYLENE

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992c.
3. SEE TABLE 1-3 FOR ANALYTICAL RESULTS; DEPTHS OF BORINGS ARE INDICATED BY THE SUFFIX AND THE NUMBER ON TABLE 1-3. THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".
4. DICHLOROMETHANE NOT REPORTED HERE.

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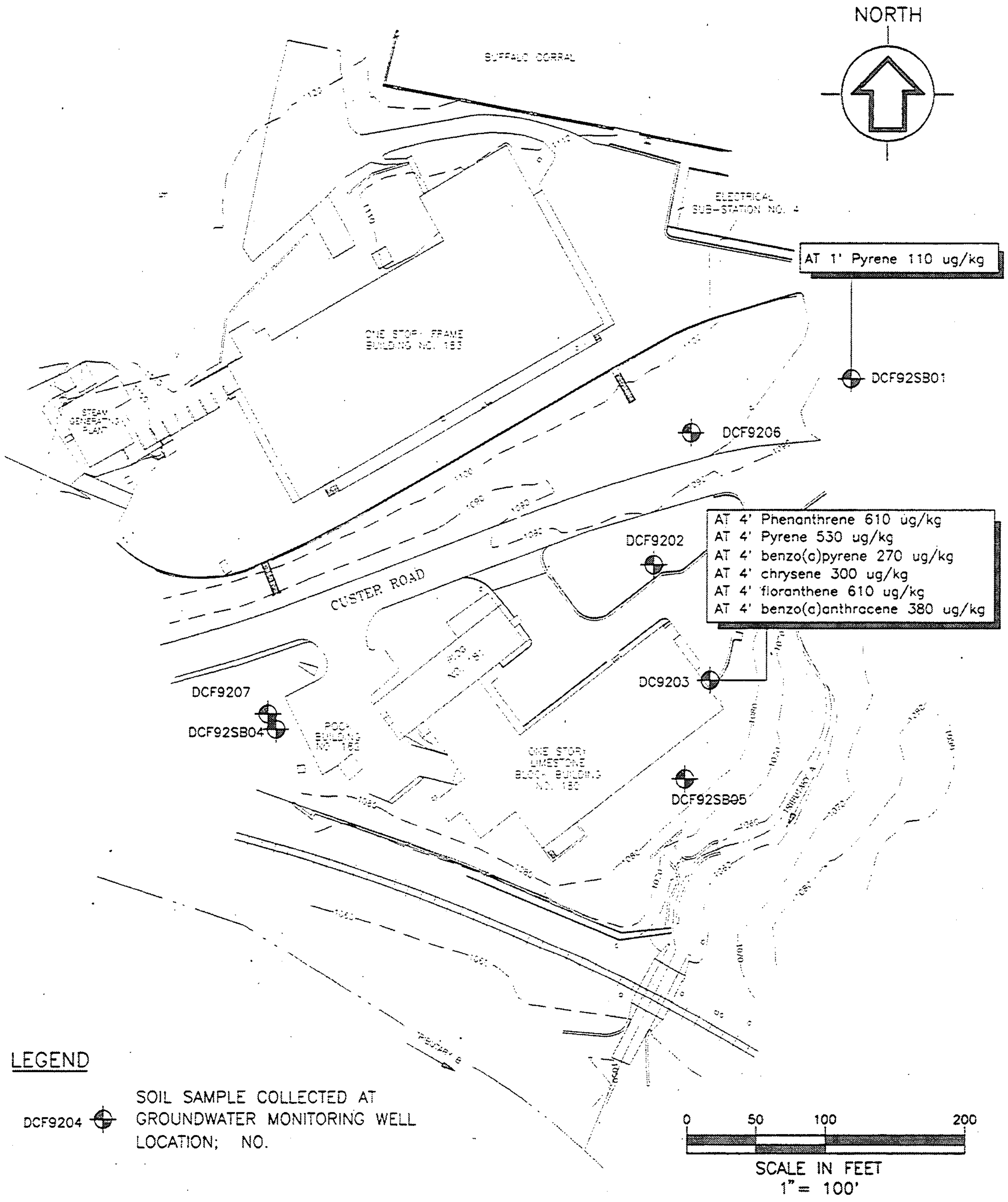
FORT RILEY MILITARY RESERVATION (DCFA-RI)

CHEMICAL DETECTIONS, VOC's IN SOILS FROM GROUNDWATER MONITORING WELLS, 4/92

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-10

I-VOCMWL/30MAR95



LEGEND

DCF9204 ⊕ SOIL SAMPLE COLLECTED AT GROUNDWATER MONITORING WELL LOCATION; NO.

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992c.
3. SEE TABLE 1–3 FOR ANALYTICAL RESULTS; DEPTHS OF BORINGS ARE INDICATED BY THE SUFFIX AND THE NUMBER ON TABLE 1–3. THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".

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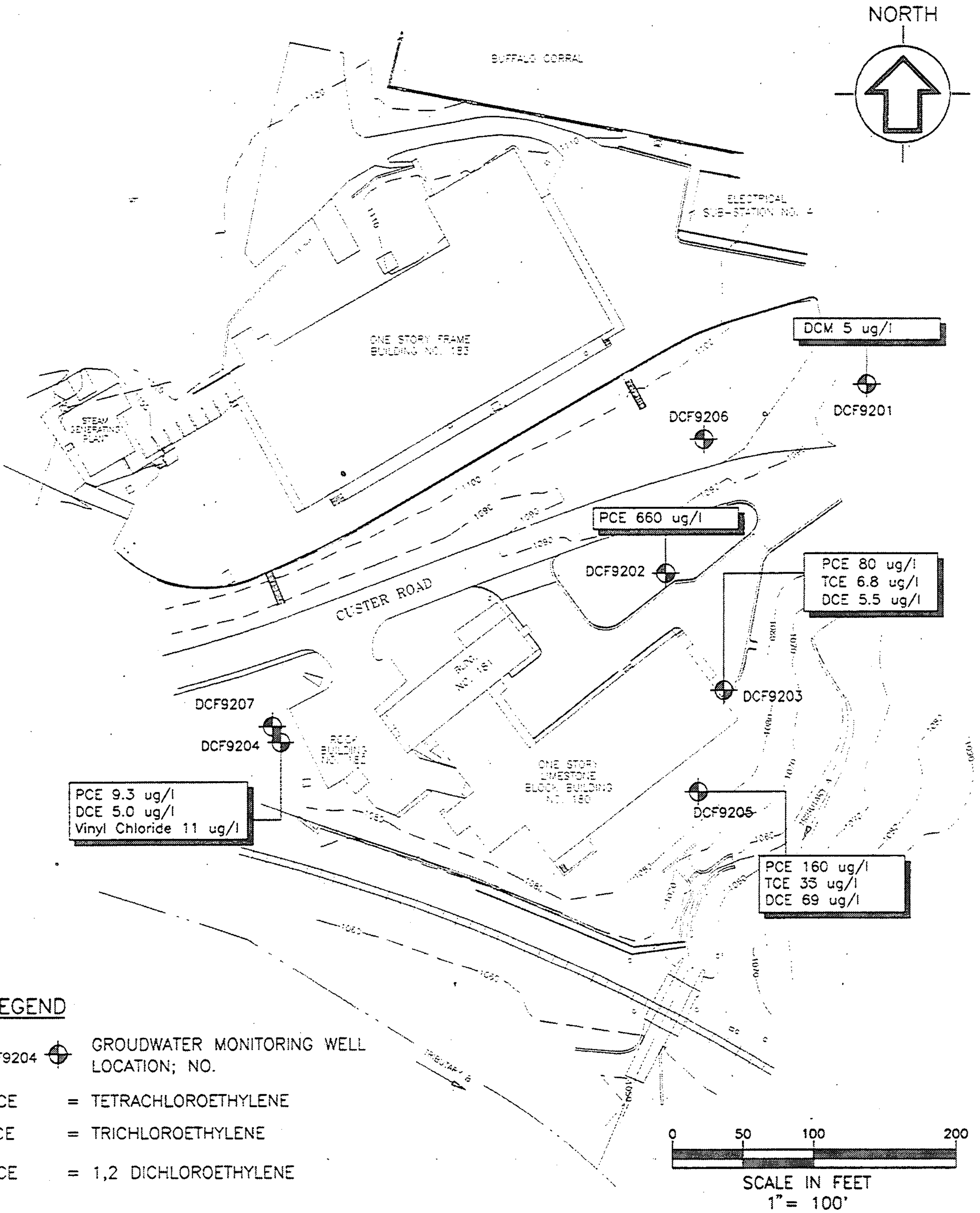
FORT RILEY MILITARY RESERVATION (DCFA–RI)

CHEMICAL DETECTIONS, SVOC's IN SOILS FROM GROUNDWATER MONITORING WELLS, PA/SI 4/92

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 1–11



LEGEND

DCF9204 ⊕ GROUNDWATER MONITORING WELL LOCATION; NO.

PCE = TETRACHLOROETHYLENE

TCE = TRICHLOROETHYLENE

DCE = 1,2 DICHLOROETHYLENE

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992b.
3. SEE TABLE 1-4 FOR ANALYTICAL RESULTS; THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".
4. DICHLOROMETHANE NOT REPORTED HERE.

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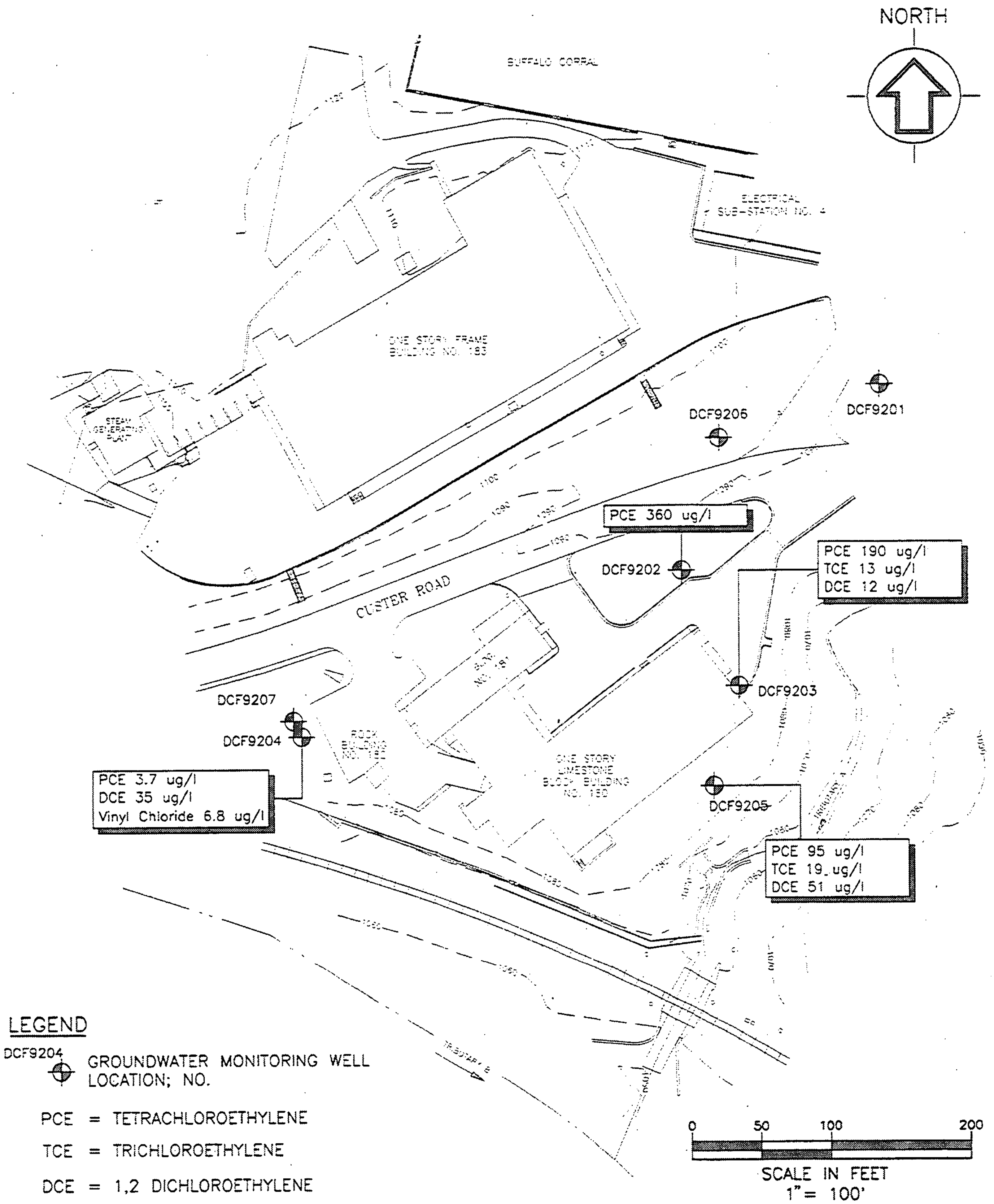
FORT RILEY MILITARY RESERVATION (DCFA-RI)

CHEMICAL DETECTIONS, VOC's IN GROUNDWATER - 7/92

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-12

1-VOCGW1/30MAR95



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER - CEMRK 1993a.
3. SEE TABLE 1-5 FOR ANALYTICAL RESULTS; THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".
4. DICHLOROMETHANE NOT REPORTED HERE.

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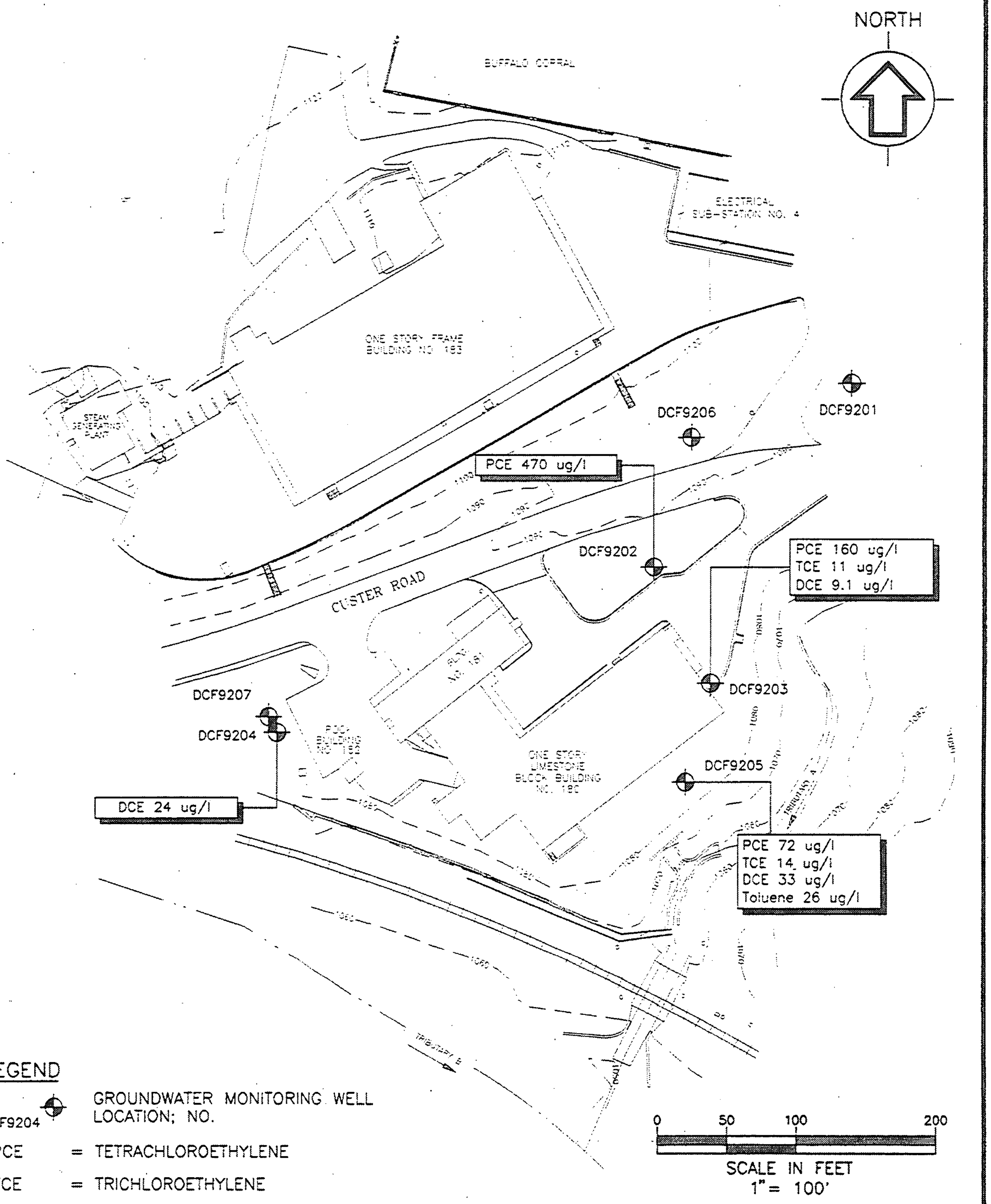
FORT RILEY MILITARY RESERVATION (DCFA-RI)

CHEMICAL DETECTIONS, VOC's IN GROUNDWATER - 11/92

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-13

VOCGW2/30MAR95



LEGEND

DCF9204 ⊕ GROUNDWATER MONITORING WELL LOCATION; NO.

PCE = TETRACHLOROETHYLENE

TCE = TRICHLOROETHYLENE

DCE = 1,2 DICHLOROETHYLENE

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993b.
3. SEE TABLE 1–6 FOR ANALYTICAL RESULTS; THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".

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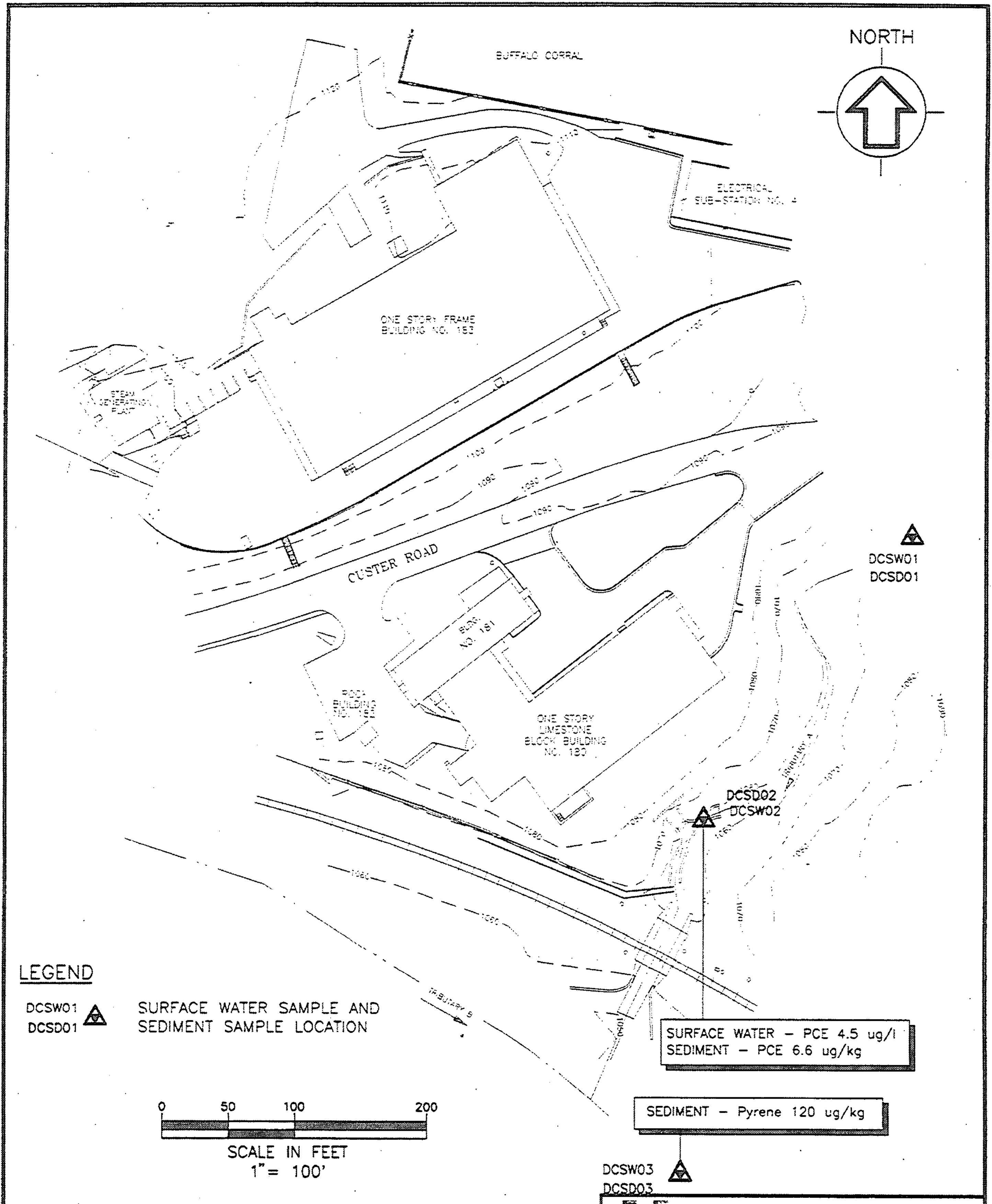
FORT RILEY MILITARY RESERVATION (DCFA–RI)

CHEMICAL DETECTIONS, VOC's IN GROUNDWATER – 2/93

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1–14



SURFACE WATER – PCE 4.5 ug/l
SEDIMENT – PCE 6.6 ug/kg

SEDIMENT – Pyrene 120 ug/kg

LEGEND

DCSW01 DCSD01 △	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992c, 1993c & 1993d.
3. SEE TABLE 1-8 FOR ANALYTICAL RESULTS; THIS FIGURE REPRESENTS DATA GREATER THAN "NON-DETECTS".
4. DICHLOROMETHANE NOT REPORTED HERE.

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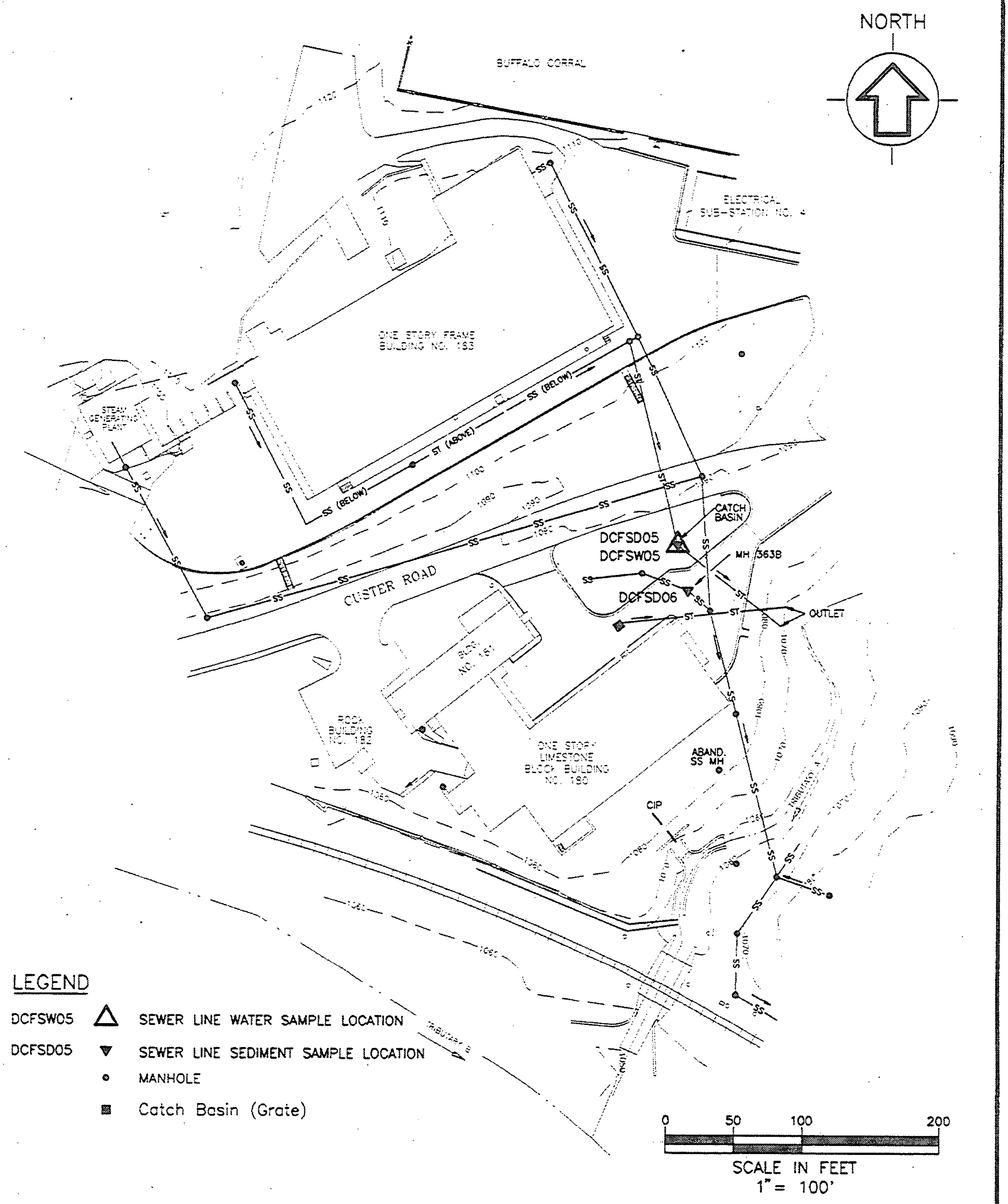
FORT RILEY MILITARY RESERVATION (DCFA-RI)

CHEMICAL DETECTIONS, SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATIONS - 3/92

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 1-15



NOTES:

1. SAMPLE DCFSD-06 WAS COLLECTED FROM WITHIN MH363B. DCFSD-05 AND DCFSW-05 WERE COLLECTED FROM WITHIN THE CATCH BASIN.
2. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
3. REFERENCE: AFTER – CEMRK 1992b & 1993c.
4. SEE TABLE 1-9 FOR ANALYTICAL RESULTS.

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FORT RILEY MILITARY RESERVATION (DCFA-RI)

SEWER LINE WATER AND SEWER LINE SEDIMENT SAMPLE LOCATIONS - 11/92

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 1-16

TABLE OF CONTENTS

CHAPTER 2
ENVIRONMENTAL SETTING

The environmental setting is described in terms of its physiography, climate, soils, geology, hydrology, hydrogeology, demographics, and ecological aspects. Ecological discussion includes human and biological factors for consideration in Chapter 6, Baseline Risk Assessment.

2.1 Physiography

Fort Riley lies within the Osage Plains section of the Central Lowlands physiographic province. The topography around Fort Riley consists of plains incised by steep drainage features. The surface elevation ranges from 1,025 to 1,356 feet above mean sea level.

Terrain on the installation varies from alluvial bottomlands along the Republican and Kansas Rivers on the southern boundary through the hilly to steep country in the central section, and into the high uplands or prairies toward the north (Figure 2-1).

The DCFA is located on a promontory approximately 1,500 feet downstream from the confluence of the Smoky Hill and Republican Rivers. A main thoroughfare, Custer Road, separates the existing and former DCFs that together cover about 7 acres. Topographically, the DCFA is at the mouth of a 140-acre drainage that at one time may have been a tributary to the Pumphouse Canyon drainage. The slopes on site and in the area are steep and range from 25 to 30 percent and greater. Topographic relief in the DCFA ranges from 320 to 340 meters (1,056 to 1,127 feet). However, the building complexes are on graded, level ground.

A buffalo corral and open ground occupy the area immediately to the north. An officer's family housing complex is located about 500 feet to the northeast; a commissary and veterinarian complex are about 2,000 feet to the east. The Union Pacific railroad is immediately to the south, and the Kansas River about 1,000 feet to the south. Vacant land (formerly Mullins Park) is immediately to the west, and the Post cemetery is to the northwest (Figure 2-1).

2.2 Climate

Fort Riley lies in a region of extremes in terms of temperature and precipitation. The annual precipitation ranges between 17 and 49 inches, and the temperature ranges between -32 degrees Fahrenheit (°F) and 115°F. Average annual precipitation is approximately 31 inches. The 24-hour rain event can exceed 3.5 inches (U.S. Air Force, 1993).

2.3 Soils

Soils were not specifically mapped and identified during this investigation. Near-surface materials encountered during field investigations, soil borings, and monitoring well installations were described. Descriptions of soils were obtained from a Soil Conservation Service publication (USDA, 1960).

Three soil types were identified for areas with terrain similar to that existing at the DCFA. Because of the fill areas, utility installations, and excavations for the buildings, field identification of these soil types within the DCFA was not attempted. The three soil types are the Monona, Sogn, and Riverwash, as described below. The Monona comprises fine, sandy loam on the east and north sides of the Kansas River. This description of fine, sandy silt is consistent with the materials encountered during installation of soil borings and groundwater monitoring wells.

The second soil type encountered in similar environments is the Sogn complex. These soils occupy narrow bands on slopes that vary from 15 to 40 percent, and are characterized by a dark grayish-brown silty clay loam at the surface horizon (depths of 7 to 18 inches) and by calcareous clay loams and soft shales that grade into bedrock.

The third soil type is the Riverwash soils, an accumulation of sandy alluvium that constitutes more of a land type than a soil. These materials exist south of the railroad in the area identified as "The Island." In general, the few unpaved areas associated with the DCFA consist of soils disturbed by utility installation and often consist of materials brought in from other locations. DCFA-specific soils information, both near-surface and at depth, is presented in Chapter 3.

2.4 Geology

Riley and Geary Counties (within which Fort Riley lies) are within the belt of outcropping Permian rocks that occur in east-central Kansas. Some older and younger rocks occur in Riley County, but overall, the principal rocks in the area are of Permian age. The geology of Riley and Geary Counties was first reported by Jewett (1941). The geologic information presented in this chapter is a compilation of data obtained from Jewett (1941), Moore (1951), Chelikowsky (1972), Zeller (1968), and Fader (1974), and field work conducted during this investigation. The following sections describe the regional geology followed by the site-specific geology.

2.4.1 Regional Geology

Based on review of the regional geologic history, Kansas lies within the central stable region of the North American continent where no seismic activity has occurred since Tertiary time (geologically, about 60 million years ago). Ages of rocks range from Precambrian to Quaternary; however, there is no one geographic location with all the units present. In Riley and Geary Counties, the predominant surface and subsurface rocks are of Permian age. These rocks are composed of alternating limestones and shales that slope gently to the west at approximately 15 feet per mile.

2.4.1.1 Stratigraphy

The regional stratigraphy and that of the DCFA is critical to an understanding of groundwater flow and of potential constituent migration pathways. The regional stratigraphic data presented are based on a literature review of Kansas Geological Survey Bulletins and geologic publications, and upon outcrops. The DCFA-specific data are based on the results of this investigation, including examination of rock cores (from borings and groundwater monitoring wells), and from outcrops.

The limestone and shale units underlying most of the region in which Fort Riley lies encompasses two groups of rocks within the Wolfcamp Series of the Permian System: the Chase and Council Grove Groups (Table 2-1). Within these two groups, four basic rock types occur with minor variation: limestone, flinty or cherty limestone, gray shales, and variegated shales with red, green, brown, purple, and yellow shades. The published descriptions of the formations are derived from a geologic study of outcrops that provide direct correlation between the various units. Figure 2-2 provides the stratigraphic sequence characteristic of rock units for Riley and Geary Counties (Zeller, 1968). Those units, outcropping or drilled, within the DCFA, are noted in the margin of the figure.

Younger deposits in the form of glacial materials occur regionally in the northeastern part of Kansas and extend into the northeastern part of Riley County. There are no known glacial deposits in the Geary County area except for the windblown loess deposits, which range from 2 to 8 feet in thickness.

Other regional deposits are the sand and gravel associated with the major river valleys. These include the valleys of the Republican, Kansas, Big Blue, and Smoky Hill Rivers. These rivers surround Fort Riley on three sides, and the sands and gravels of the Republican River serve as the major aquifer for water supply wells at Fort Riley. Figure 1-1 shows the relationship of Fort Riley with respect to these major rivers, with the exception of the Big Blue River, which is approximately 8 kilometers (km) to the northeast of the Fort Riley boundary.

2.4.1.2 Structure

Structurally, two anticlines trend northeast-southwest across the region: the Nemaha and Abilene anticlines. The southern part of the axis of the Nemaha anticline is about 15 miles east of Fort Riley. In terms of structural characteristics (Chelikowsky, 1972), this regional joint pattern is reflected in the Fort Riley limestone north of the DCFA and in the Funston limestone south of the DCFA, and consists of two sets of vertical joints at approximately right angles to each other. Figure 2-3 shows the orientation of these joints, either of which may be dominant in the area.

2.4.2 Site-Specific Geology

The geologic units of interest with regard to the DCFA include the Havensville shale and the Threemile limestone of the Chase Group, and the Speiser shale, Funston limestone, Blue Rapids shale, Crouse limestone, Easly Creek shale, and Bader limestone of the Council Grove Group (Table 2-1). The unconsolidated materials overlying these rock units consist of clays, silts, sands, and fill material.

Geologic data for rock units at the site have been obtained from borehole DCF93-18. Rock coring at this well borehole began in the Havensville shale (the first rock encountered at this location) and terminated in the Bader limestone. The Havensville shale, the overlying Shroyer limestone, and the underlying Threemile limestone constitute the members of the Wreford limestone formation of the Chase Group. The rock units below this (as noted above) are part of the Council Grove Group (Figures 2-2 and 2-4). Figure 2-4 is a generalized block diagram of the site showing the relationship between various rock units.

2.4.2.1 Stratigraphy in the DCFA

The stratigraphic units encountered in the DCFA are alternately shales, beginning with the Havensville shale, and limestones. Outcrops of the Havensville shale and the Threemile limestone occur north of the steam plant (Building 184), and outcrops of the Speiser shale and Funston limestone occur above and below Custer Road, respectively.

The shales tend to be cohesive, with minimal horizontal and vertical fractures. Although gray predominates, the shales are variegated in color—maroon and green-gray are the most common. These colorations are indicative of depositional environments that received exposure to atmospheric conditions.

The stratigraphic units listed below were encountered in drilling and coring operations conducted during the RI. The thicknesses of the units encountered in the DCFA are listed in Table 2-1.

- ***Havensville shale.*** Because of the presence of gray calcareous shales that constitute this unit, it is often difficult to distinguish as a shale unit. In addition to the calcareous shales, thin limestone beds alternate with the shales; some of these contain chert. The Havensville lies between the Shroyer and Threemile limestones, which are both very cherty; therefore, some chert within this unit may be anticipated.

- ***Threemile limestone.*** The material immediately below the Havensville shale is the Threemile limestone, which is a cherty limestone having a more massive and less cherty middle layer. The basal portion of the unit is vuggy.

- ***Speiser shale.*** Part of the Council Grove Group, this shale is varicolored with shades of green, gray, and red. It is difficult to distinguish this shale from many of the other varicolored shales that occur above and below. The core from this formation was observed to be tight, with potential permeability primarily along bedding planes between shale and limestone beds. The Speiser is about 16 feet thick in the DCFA.

- ***Funston limestone.*** The Funston limestone is found as a light gray to very light gray limestone with an olive green shale break in the upper few feet. It is vuggy to very vuggy in the lower half, such that recovery during coring resulted in collection of rock fragments. This unit outcrops below Building 180, just above the railroad. In the outcrop, the vuggy nature causes it to resemble an old, dirty, dried-out sponge. An elevation taken on the outcrop corresponds well with the elevation of this limestone as determined from the coring of DCF93-18: 1077.80 feet versus 1078.93 feet, respectively.

- ***Blue Rapids shale.*** Although a pale olive-gray unit typifies the upper part of the Blue Rapids, it is another of the varicolored shales containing shades of blue-green, maroon, and brown. It is a very tight cohesive shale about 19 feet thick at the site.

- ***Crouse limestone.*** The Crouse limestone consists of two limestone units separated by shale. The upper limestone, about 4 feet thick, is characterized by a gray, shaley, vuggy limestone that grades downward into a gray fissile calcareous shale. The shale is about 8 feet thick before grading downward to more of a limestone with small isolated vugs.

- ***Easly Creek shale.*** In the DCFA, the upper portion of the Easly Creek starts out as a grayish-black shale with minor thin limestone stringers. This combination grades downward into a wavy pattern of shale and limestone that is very cohesive. Variegated shales are present at depth with an approximately 8-foot-thick layer of predominantly crystalline anhydrite. This anhydrite varies from being relatively pure to containing bands of dark greenish-gray shale with fibrous gypsum layers.

- ***Bader limestone.*** Similar to the Crouse limestone, the Bader limestone consists of two limestone units separated by a shale unit. Overall, the Bader is about 23 feet thick at DCF93-18. The upper limestone unit is about 4 feet thick and is referred to as the "Middleburg member." The middle shale member, Hooser shale, is about 10 feet thick and is underlain by the Eiss limestone member, which is about 9 feet thick. Although identified as a limestone, the Eiss has a prominent shale parting. Core recovery in this formation was generally 100 percent, and the rock material was so cohesive that the core had to be broken to fit into the core box.

As-built drawings, geologic logs, geophysical logs, and well development for groundwater monitoring wells are provided in Appendix B. Photographs of rock cores are provided in Appendix E.

2.4.2.2 Site Geologic Structure

The only structure to be noted within the DCFA is the jointing in the Funston limestone below the railroad tracks. This jointing is nearly at right angles and is dominant at this location. The presence of similar structure in overlying and underlying rock units is not known. These units are shales that, as observed in cores, tend to be more cohesive such that jointing is less likely. Figure 2-5 represents a north-south cross-section through the site that shows the relationship of the geologic units to the alluvium of the river. This section is essentially along the strike of the bedrock units.

2.5 Hydrology

The hydrology is described in both a regional and a site-specific setting. Both settings influence the site in different ways. The regional hydrology has effects on the groundwater at the site, whereas the site-specific hydrology affects both surface water and groundwater at the site. The site drainage basin is a part of the regional system. Figure 2-1 shows the drainage basin area for Tributary A.

2.5.1 Regional Hydrology

The regional hydrology is dominated by three major rivers in the vicinity of the site: the Republican, Smoky Hill, and Kansas Rivers. The DCFA is located approximately 800 feet north of the Kansas River. The Kansas River changes its position in the floodplain periodically. The Republican River is located west of Fort Riley and is controlled by Milford Dam. The river flows southeasterly and joins the Smoky Hill River near Junction City. The junction of these two rivers forms the Kansas River.

A Federal Emergency Management Agency (FEMA) Flood Insurance Study (FEMA, 1988) lists the following flood elevations above mean sea level (m.s.l.) for the Kansas River: 10 year = 1,058 feet; 50 year = 1,067 feet; and 100 year = 1,070.5 feet. Figure 2-6 shows a cross-section through the study area and the estimated 10-year, 50-year and 100-year flood elevations. A stage-discharge curve was also prepared using USGS and FEMA data and is included as Figure 2-7. The USGS data is based on the U.S. Geological Survey Water Resource Data, 1993, for gaging station No. 06879100 located on the Henry Road Bridge next to Marshall Army Air Field, approximately 5,100 feet downstream of the DCFA. A plan view of the limits of the 10-year, 50-year and 100-year flood elevations near the DCFA is shown on Figure 2-8. Based on these data, Buildings 180, 181, 182, 183, and 184 would not be affected by a 10, 50, or 100 year flood, as their elevations range from approximately 1,082 to 1,110 feet M.S.L. In addition, these data also show that the Island would be inundated under all three flood events, including the 10-year flood.

High water stages in the Kansas River occur from the last part of February through the first part of June. The lowest river stages occur from late October through January. Prior to the construction of Milford Reservoir and Tuttle Creek Reservoir, major flooding occurred approximately every 8 to 10 years, with a three- to five-day duration. The average annual flow in the Kansas River from 1964 to 1992 at the Henry Street Bridge gaging station is 2,436 cubic feet per second (cfs) (USGS, 1992). The gage height fluctuated between 10 and 24 feet during this period. Between 1978 and 1988 the river stage fluctuated from 3.7 feet (elevation 1038.4 M.S.L.) to 17.0 feet (elevation 1051.7 feet m.s.l.).

As a result of river stage fluctuations, the groundwater in the alluvial deposits adjacent to the river also fluctuate. Although the groundwater levels in the alluvium are generally higher than the river stage, this relationship can reverse during flood events on the river. During the flood of 1993, water levels in the water supply production wells for Fort Riley rose 15 to 18 feet above average (personal communication, Fort Riley Water Treatment plant manager, 1994). These increased levels were in direct response to the higher stage levels in the river. When a spike or peak on the graph shows for the river but not for the alluvium, it is generally a result of releases from Milford Dam following a precipitation event. These releases pass quickly through the stretch of river opposite the site and do not affect the groundwater level in wells. Whenever river levels are above groundwater levels, recharge to the alluvium and underlying bedrock occurs.

2.5.2 Site Hydrology

The site is well drained. Almost all of the DCFA is paved and sloped such that surface runoff is channeled to open ditches or to a storm drainage system that discharges into Tributary A. Tributary A drains an area of approximately 140 acres inclusive of the DCFA (Figure 2-1). Tributary A is well incised into the soils and bedrock at the site. The bottom elevation of Tributary A, based on topographic maps, ranges from 1,050 to 1,060 feet.

Tributary A is an ephemeral stream. During periods of flow, Tributary A could recharge the groundwater in the immediate area and the alluvial materials on The Island.

South of the DCFA, Tributary A enters a stream known as Tributary B. Tributary B tends to be dry upstream of its confluence with Tributary A and downstream of the confluence when no flow exists in Tributary A. Groundwater recharge would also occur from Tributary B.

2.6 Hydrogeology

The hydrogeologic setting is discussed in terms of site-specific conditions. Although there are bedrock aquifers in bedrock of the upper Chase Group, there are no regionally recognized bedrock aquifers identified beneath the site influencing or contributing to groundwater conditions. Alluvial aquifers do occur regionally along the Kansas River. Three geologic materials are identified:

- Unconsolidated materials consisting of clays, silts, and sands;
- Limestones of the Crouse formation; and
- Alluvial materials south of and between the DCFA and the Kansas River beneath The Island.

The unconsolidated materials occur in a small area east of Building 180/181 where the bedrock units have eroded, including the upper Crouse limestone. In other areas of the site, the Crouse Limestone Formation is intact. A detailed discussion of this area of the site is provided in Chapter 3.

2.6.1 Recharge

Recharge to groundwater in the water-bearing materials beneath the site occurs by direct infiltration of precipitation, by infiltration from streams, and by manmade structures. Direct infiltration of precipitation is limited by the large area of the site covered with buildings and other impermeable material, such as concrete and asphalt. Recharge from streamflow occurs when there is flow in Tributary A, and when the level of the Kansas River is higher than adjacent levels in the groundwater.

2.6.2 Movement

Groundwater movement beneath the site in the bedrock and unconsolidated materials is to the south and southwest toward the alluvial materials of The Island. The groundwater flow in the alluvium beneath The Island is in the same direction as, and parallel to, the Kansas River. Based on the groundwater monitoring wells completed in the upper Crouse limestone beneath the site, groundwater movement in this bedrock unit would also be to the south-southwest. Because these shallow rock units subcrop beneath the Kansas River, movement can also be to the north-northeast during high river levels.

2.6.3 Discharge

Groundwater discharge from materials beneath the site will be to the alluvial materials beneath The Island and, ultimately, to the Kansas River when the river water levels are lower than the groundwater levels in the alluvium.

2.7 Demographics and Land Use

Three population groups are closely associated with the DCFA:

- The employees of the respective buildings;
- The patrons of services provided at those buildings; and
- The residents of the officers' quarters northeast of the DCFA.

There are 25 to 30 full-time employees at the current DCF (Building 183) and 20 employees at the former DCF (Buildings 180 and 181). Approximately 75 persons reside at the officers' family housing complex. Base personnel are present at the current DCF and former DCF on a regular basis between 0800 and 1600 hours. The commissary and other services farther east also receive traffic during these hours and are, in part, responsible for most of the vehicular traffic through this area. The population groups are addressed in greater detail in Chapter 6, Baseline Risk Assessment.

Land use has remained constant from the 1900s to the present for dry cleaning and laundry operations. The current laundry facility was built during World War II, but combined laundry and dry cleaning activities did not occur in this building until 1985. At that time, the old facility, Building 180/181, was shut down, and both activities were performed in Building 183.

Two former structures that existed in the historic past are worthy of mention: the Kansas Power and Light substation was located west of Building 180/181, and a railroad was located along what is now Custer Road. Historic land use also included two former structures within the DCFA. These were a railroad along what is now Custer Road, and a power substation that was located west of Building 180/181.

Because no known discharges of potential contaminants are specifically associated with the railroad, no sampling was conducted for that purpose alone. Potential contaminants that might be associated with railroad ties are also associated with asphalt paving, which is ubiquitous within the DCFA.

Given that the DCF exists within the designated historical area of Fort Riley, it is highly unlikely that the site will be used for other than light industrial activities, even if the current DCF were closed. Additional data on demographics and land use is presented in Chapter 6.

2.8 Ecology

The site can be divided into four basic habitat types: highly disturbed or commercial, wooded upland, wooded riverine, and river aquatic. Figure 2-9 shows the location of these habitats within the DCFA and The Island.

Highly Disturbed or Commercial. The commercial portion of the site includes the dry cleaning facility and associated structures. This area consists of three buildings, parking lots associated with the buildings, and lawn areas around the parking lots and buildings. To the south, buildings and associated structures border the Union Pacific Railroad right-of-way. The area slopes steeply to the south and drops approximately 30 feet to the tracks below. Vegetation along this bank is typical of that found in a disturbed old field, consisting mainly of grasses and low shrubs. Continuing across the tracks to the south lies the area known as The Island.

Immediately south of the inhabited area, comprising a portion of the floodplain of the Kansas River, is an area known as The Island. This is an area of approximately 40 acres and is bordered to the north by the Union Pacific railroad track. The Island lies entirely within the 10-year floodplain and was completely inundated during the 1993 floods of the Kansas River.

Wooded Upland. A small section of wooded upland area is located southeast of Building 180 and is bounded on the north by Custer Road. It grades into The Island to the south and as a definable characteristic, is bounded on the southern margin by the Union Pacific Railroad right-of-way. This area is the immediate watershed for the tributary and receives stormwater runoff from the DCFA, the officers' housing complex, and the western portion of the Main Post. This feature covers approximately 0.5 hectacres. Vegetation in this area is composed of redbud *(Cercis canadensis)*, dogwoods *(Cornus sp.)*, and hackberry *(Celtis occidentalis)* with vinaceous species in the herb layer, such as greenbriar *(Smilax sp.)*, Virginia creeper *(Panthinocissis quinquefoliia)*, and shrubby species including gooseberry *(Ribes missouriense)*.

Wooded Riverine. The Island is a 40-acre area that lies in the 10-year floodplain of the Kansas River. The Island is composed of a sandy substrate that was, at one time, a depositional sand bar in the Kansas River. The land mass is being extended to the east in the vicinity of the Tributary A delta by additional sand deposition.

The Island is characteristic of a wooded riverine habitat. The ground cover is sparse over the area and, where found at all, consists mainly of low shrubs or short grasses. The sandy soil is frequently exposed. Much of The Island's current understory development is a result of the modifications made to the area by the 1993 flood. The area is characterized by snags of tree limbs and river debris that have been populated with vinaceous species such as greenbriar *(Smilax sp.)*. The vegetative cover consists of three basic layers: understory/sapling, mid-canopy, and canopy. Trees range from sapling size to diameters up to 3 feet. Because this area is subject to periodic flooding and resultant modification, the forest is not expected to reach a stable climax condition.

Forest composition, from field survey data collected by Fort Riley personnel, includes a canopy layer composed of silver maple *(Acer saccarinum)*, eastern cottonwood *(Populus deltoides)*, sycamore *(Platanus occidentalis)*, hackberry *(Celtis occidentalis)*, and red ash *(Fraxinus pennsylvanica)*. The mid-canopy is typically composed of hackberry *(Celtis occidentalis)*, red mulberry *(Morus rubra)*, and box-elder *(Acer negundo)*.

River Aquatic. The Kansas River flows south of the site formed by the confluence of the Smoky Hill River and the Republican River in the immediate vicinity of The Island. The Republican River flows from its origins, in the vicinity of Limon, Colorado, to the east some 500 miles and drains approximately 25,840 square miles (Jewett, 1941). It is dammed approximately 4 miles to the west of The Island and forms Milford Lake, one of the largest reservoirs in Kansas. Water flowing through the dam system is controlled by the U.S. Army Corps of Engineers.

The Smoky Hill River intersects the Republican River from the south. This is a major west-east drainage whose ultimate origins derive from the vicinity of Kit Carson, Colorado. It flows east for approximately 310 miles and drains approximately 20,480 square miles (Jewett, 1941).

Rivers are at or near grade in the vicinity of Fort Riley and are characterized by wide stream valleys with deep meanders and oxbow lakes. In the embedded vicinity of The Island, water depth ranges to approximately 10 feet in the main channel.

Water velocity is not high during normal water periods, and water is generally turbid due to silts and organic material. Aquatic plants are probably limited to algae in the area with no emergent or submergent vascular plant species noted in the vicinity of the site. River substrates are characteristically of sand and silt.

2.8.1 Vegetation

The vegetation throughout The Island consists of large overstory trees and understory plant species commonly found in similar northern riverine/floodplain forest habitat-type across the eastern half of the United States. The large overstory tree species in this area include, but are not limited to, eastern cottonwood *(Populus deltoides)*, American sycamore (*Platanus occidentalis*), box-elder (*Acer negundo),* common hackberry (*Celtis occidentalls*), and dogwood (*Cornus spp.*) (CEMRK, 1993d). An understory of vegetation consists of a wide variety of plants, grasses, bushes, and small trees. The predominant plant species of the understory include gooseberry (*Ribes spp.*), eastern redbud (*Cercis- canadensis*), roughleaf dogwood (*Cornus drummondii*), greenbrier (*Smilax spp.*), black raspberry (*Rubus occidentalis*), poison ivy (*Toxicodendron radicans*), Virginia creeper (*Parthenocissus quinquefolia*), and vigorous overstory seedling regeneration.

The oak-hickory habitat type occurs along the upper slopes and upper reaches of certain streams and riverine areas. In general, the oak-hickory forest is dominated by bur oak (*Quercus macrocarpa*), northern red oak (*Quercus rubra*), chinquapin oaks (*Quercus muhlenbergii*), American elm (*Ulmus americana*), and red mulberry (*Morus rubra*) on the upper slopes, and black walnut (*Juglans nigra*), black willow (*Salix nigra*), hickories (*Carya spp.*), honey-locust (*Gleditsia triacanthos*), and green ash (*Fraxinus pennsylvanica*) on the lower slopes and along the streams in the western portion of the installation.

There are no known occurrences of any threatened or endangered plant species in the vicinity of The Island or the site.

2.8.2 Wildlife

Vertebrate wildlife for this area are characteristic for the region of Eastern Kansas. Species expected for the region were compiled from various sources and then compared with the available habitat. The actual diversity found on site can only be ascertained from field sampling over seasonal changes and over a period of years. Surrounding land use, local climate conditions, and temporal climate fluctuations coupled with reproductive cycling, immigration, and emigration are only a few of the factors contributing to the area's actual vertebrate biodiversity. In the case of migratory species, wildlife populations may fluctuate from year to year or demonstrate long-term trends unrelated to local ecology. Such effects can be observed locally despite the fact that the causative agents may be removed by great distances. Examples include declines in bird populations due to loss of wintering habitat in Central and South America.

With these understandings, a listing of vertebrate species was compiled to describe species expected to occur in the site vicinity. The lists were originally based on the coarse distribution of vertebrate species and were later refined to include species that may be expected to occur within the habitats available in the DCFA vicinity. These include species that would be expected to maintain residence within the area, or reasonably would be expected to pass through the site during migration or foraging activities. Where possible, literature data were augmented with field survey data collected in the area over the past several years.

2.8.2.1 Mammals

Mammals at Fort Riley present the transitional nature of the area from eastern forest to grass prairie (Table 2-2). The availability of riverine habitat and contiguous woodlands from eastern portions of the state have provided invasion corridors for eastern woodland species into the prairie biome. Many species are restricted to these corridors. While much of the area has been modified to agriculture and other land uses, the river corridors have tended to remain undeveloped. Expected in the vicinity of the DCFA are species that use these river corridors as primary habitat, foraging grounds, and dispersal corridors. Rodents are expected to dominate the resident mammal population.

Bats are expected to utilize areas in the vicinity of the DCFA for foraging and roosting. Species will typically consist of the non-cave-dwelling solitary species such as members of the genus *Lasiurius, Eptisicus,* and others. Species of the genus *Myotis* can be expected during the summer months but will usually retire to caves or similar areas for hibernation during the winter.

Predatory species expected in the area include coyotes, domestic cats, raccoons, foxes, mink, and similar species. These species will likely feed opportunistically on a variety of species, including fish, reptiles and amphibians, and small mammal species.

The terrestrial wildlife in the vicinity of the site is concentrated primarily on The Island, with transient use and habitat in the area between DCFA and the cemetery. The most common larger mammals in the area include the white-tailed deer (*Odocoileus virginianus*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), badger (*Taxidea taxus*), eastern mole (*Scalopus aquaticus*), and fox squirrel (*Sclurus niger*). The most common small mammals are the deer mouse (*Peromyscus maniculatus*), white-footed mouse (*Peromyscus leucopus*), and prairie vole (*Microtus ochrogaster*).

2.8.2.2 Birds

Numerous bird species exist at Fort Riley and in the site vicinity. Species frequently found primarily in upland areas, grasslands, and brush plots include the brown-headed cowbird (*Molothrus ater*), dickcissel (*Spiza americana*), and eastern meadowlark (*Sturnella magna*). Game species, also found primarily in upland areas, grasslands, and brush plots, include bobwhite quail (*Colinus virginianus*), ring-necked pheasant (*Phasianus colchicus*), greater prairie-chicken (*Tympanuchus cupido*), wild turkey (*Meleagris gallopavo*), and mourning dove (*Zenaida macroura*). Common wintering raptors observed in the vicinity of the site and on The Island include the bald eagle (*Haliaeetus leucocephalus*), red-tailed hawk (*Buteo jamaicensis*), northern harrier (*Circus cyaneus*), American kestrel (*Falco sparverius*), and rough-legged hawk (*Buteo lagopus*). Other observed raptors at Fort Riley include the sharp-shinned hawk (*Accipter striatus*), Swainson's hawk (*Buteo swainsoni*), Cooper's hawk (*Accipter cooperii*), peregrine falcon (*Falco peregrinus*), and prairie falcon (*Falco mexicanus*). The numerous ponds, lakes, and rivers on Fort Riley provide breeding areas for a variety of wetland-dependent birds. Waterfowl known to breed on Fort Riley include the mallard (*Anas platyrhynchos*), blue-winged teal (*Anas discors*), and wood duck (*Aix sponsa*) (CEMRK, 1993d).

2.8.2.3 Reptiles and Amphibians

As is the case with the mammals of the area, the reptiles and amphibians, listed in Table 2-3, are also in a transitional zone between the eastern forest species and the prairie species. Central and eastern United States reptiles and amphibians have utilized the river corridors as a means of westward dispersal. Western species reach the margins of their ranges in this vicinity owing to the limits of the former prairie grasslands. Of the reptiles and amphibians likely to occur in the vicinity of the DCFA, most species will likely occur in the riverine woodland areas.

2.8.2.4 Fish

Prior to settlement of the area, the Kansas River probably supported a greater diversity of fish life than it does at present times. At present, the water quality of the Kansas River system is affected by surface runoff throughout the rivers drainage system. The water in the DCFA vicinity is generally clear, and the bottom substrate consists of silt and sand. Fish species likely to occur will include species adapted for life in mature, graded streams.

Potential species that might be found in the portions of the river systems adjacent to the DCFA are presented in Table 2-4. A stream survey conducted in July 1991 and January 1992 produced 23 species in 9 families, as shown in Table 2-5. The survey results indicated the presence of 9 of the 13 fish families that can be expected for the area. It is likely that additional sampling will result in additions to the list.

2.8.3 Endangered Species and Species of Concern

Two federally listed species, the threatened bald eagle and the endangered peregrine falcon, have been confirmed to exist in the vicinity of The Island at Fort Riley. Surveys have documented bald eagles wintering in mature trees and large snags along the Republican and Kansas Rivers, in addition to the Farnum and Madison Creek coves at Milford Reservoir.

2.8.3.1 Bald Eagles

Risks to bald eagles on the site were examined specifically. This is because of the eagle's threatened status. The bald eagles have been observed roosting on The Island. According to interviews with Fort Riley personnel, the bald eagles arrive during the first week of November and use the area until the middle of March. The number of birds using the site annually ranges between 60 and 100 birds.

The eagles forage along Milford Lake, the Republican River, the Smoky Hill River, and downstream from The Island, along the Kansas River. The Kansas River, downstream from The Island, is the only portion of the foraging habitat that could be affected by contaminants issuing from the DCFA. Eagles have been observed foraging in the vicinity of The Island. Tributaries A and B, on The Island, do not support any fish and could not be used by the eagle population. Eagles have been observed since 1986 at this location, and the numbers observed have been stable with no reported indications of stress or unusual behaviors due to known causes observed in this population.

2.8.3.2 Peregrine Falcons

A single peregrine sighting was made by the Fort Riley natural resources staff in the southeastern portion of the installation (personal communication, U.S. Army, 1993). This species is a spring and fall migrant and an occasional winter resident in some areas. Six additional federally listed species identified by the U.S. Fish and Wildlife Service, Kansas Field Office, as potentially occurring at Fort Riley, and their preferred habitats, are as follows:

- **Whooping crane (*Grus american*).** This bird species prefers a wetland habitat, typically a riverine environment with wide channels, exposed sandbars that are low and bare, slow or shallow water, and isolation from human disturbance. Fort Riley is on the eastern edge of the typical migration corridor for the whooping crane (USFWS, 1992).

- **Eskimo curlew (*Numenius borealis*).** The migrating Eskimo curlew prefers to be in wet meadow and open grassland habitats but may also occur in plowed fields and burned prairies. This species may have formerly been an abundant spring migrant in Kansas, but the last confirmed sighting in the state was reported in 1902 (USFWS, 1992).

- **American burying beetle (*Nicrophorus americanus*).** The preferred habitats and habitat requirements of this species are unclear, as this species exists in a variety of diverse environments. The availability of a significant amount of humus and topsoil suitable for burying carrion appears to be one essential requirement for this beetle (Schwitzer and Master, 1987 as cited in USFWS, 1992). Occurrences of this beetle have been verified in Riley County but not on Fort Riley.

- **Piping plover (*Charadrius melodus*).** This small shorebird is considered to be a breeding associate with the least tern, exhibiting similar habitat preferences (Dryer and Dryer, 1985, and Faanes, 1983, as cited in USFWS, 1992). Unverified occurrences of this species have been reported in Geary County, and no confirmed sightings have occurred on Fort Riley. Although this bird species is federally listed as endangered, its status in Kansas and much of the Midwest Region, according to the USFWS, Kansas Field Office, is threatened. This regional status is reflective of a larger and healthier population of the piping plover in the area (personal communication, USFWS, 1994).

Additionally, four state-listed threatened species identified by the U.S. Fish and Wildlife Service, Kansas Field Office, as or potentially occurring at Fort Riley and their preferred habitats are as follows:

- **Eastern spotted skunk (*Spilogal putorius interrupta*).** In Kansas, this species prefers forest edges and upland prairie grasslands (personal communication, University of Kansas, 1981, as cited in U.S. Department of the Army, 1994). The skunk is also attracted to natural and manmade structures such as fences, embankments, hedgerows, brush piles, abandoned buildings, and wooded stream corridors. According to the USFWS evaluation, the Kansas Department of Wildlife Protection (KDWP) has no records of occurrence for this species on Fort Riley or in Riley County despite the availability of suitable habitat. According to mammal surveys conducted by Pitts, et al. (1987), at least one Eastern spotted skunk may have been trapped on Fort Riley between 1984 and 1986 at unspecified location(s). However, this record has not been verified (personal communication, U.S. Department of the Army, 1994).

- **White-faced ibis (*Plegadis chihi*).** This medium-sized wading bird utilizes small ponds and shorelines for resting and feeding on aquatic prey items. These habitats are found throughout Fort Riley, especially along the Kansas River. A white-faced ibis was reportedly sighted from an oxbow lake at Camp Funston on Fort Riley in 1988 by the KDWP. According to the USFWS, this species is expected to occur on Fort Riley as a transient migrant only.

- **Sturgeon chub (*Hybopis geldia*).** This species reportedly inhabits shallow areas with strong current and gravel bottoms and also turbulent areas where shallow water flows across sandbars, particularly at the upstream ends of small islands where a channel is divided (Cross and Colins, 1975, as cited in USFWS, 1992). During the riverine evaluation, numerous sandbars and channel divides were observed, some with turbulent shallow water. The 1992 USFWS survey of the Kansas, Republican, and Smoky Hill Rivers failed to locate any specimens of this fish on or near Fort Riley. However, on May 9, 1964, a sturgeon chub was collected from the Smoky Hill River just upstream of Fort Riley in Junction City, Geary County, at U.S. Highway 77 (Cross, University of Kansas, Museum of Natural History records, as cited in USFWS, 1992). This collection was made prior to the construction of Milford Dam.

- **Flathead chub (*Platygobia gracilis*).** This fish species' preferred habitat includes flowing streams or shallow pools with firm, sandy bottoms. It has not been sighted on Fort Riley, but records indicate its occurrence upstream in the Republican River (in Republican County) and downstream from Fort Riley in the Kansas River (personal communication, USFWS, 1994).

Additional information related to wildlife is presented in Chapter 6 concerning potential ecological receptors.

2.9 Pre-RI Conceptual Site Model

A pre-RI conceptual site model, as described below, was developed in the initial stages of the RI work based on a review of the available background information (as summarized in Chapter 1). The purpose of this model was to gain an understanding of the general nature and extent of contamination at the site, and potential source(s) of contaminants, migration pathways, and receptors. A more comprehensive conceptual site model, based on the RI work and related analyses, has been developed and is presented in Chapter 7, Summary and Conclusions. Elements of the pre-RI conceptual site model describing the sources and associated release mechanisms are provided below and in Figure 2-10. The sources for this model are presented in Figure 2-11.

2.9.1 Potential Source(s)

Two primary sources are believed to have been responsible for the contaminants present within the DCFA: (1) the release of contaminated effluent through leaky sewers, S-1-7 (Figure 2-11); and (2) potential accidental leaks or spills of Stoddard solvent behind Building 180/181, S-10 (Figure 2-11). The relative contribution of each source cannot be ascertained because quantitative records do not exist. Fort Riley authorities became aware of these events after their occurrence. A third possible source of contaminants was the presence of three underground storage tanks outside Building 180/181, S-8 (Figure 2-11). These tanks were removed in 1994, and no significant releases of contaminants have been associated with them (CEMRO, 1994a).

The first potential source is associated with accidental spills at the former (Building 180/181) and current (Building 183) dry cleaning and laundry facilities that resulted in sporadic releases of PCE to the storm and sanitary sewer system servicing the DCFA. Accidental spills of PCE on the floor of the laundry facilities may have drained directly into floor drains and were conveyed into the sewer system. Blankets, mattress pads, and/or other fabrics were used to clean up the PCE spills. Laundering of these fabrics would have resulted in PCE-contaminated rinsate to be conveyed to the sewer system. Once in the sewer system, a portion of the wastewater flow containing PCE may have entered the subsurface environment through leaks in the sanitary and storm sewer system. In addition, blockages in various parts of the system reduced flow capacity and resulted in sewer system back-ups and occasional overflows from manholes. Contaminated effluent thus entered either the unsaturated zone through surface infiltration or the nearby tributaries through overland flow.

The second source may be associated with potential spills of Stoddard solvent behind Building 180/181. If these potential spills occurred, leaching and infiltration of Stoddard solvent could have migrated to the unsaturated zone and groundwater.

2.9.2 Primary Contaminant(s)

The primary chemical used during operations at the former and current DCFs is the volatile organic solvent PCE and its breakdown products DCE, TCE, and vinyl chloride. Because of the potential past releases of PCE, a comprehensive environmental monitoring program was established at the site and extensive characterization studies were initiated and implemented (CEMRK, 1992a,b).

2.9.3 Migration Pathways

Two dominant migration pathways were seen as potentially associated with the DCFA:

- Downward migration of leaked or spilled contaminants through the vadose zone into the underlying groundwater, then via the groundwater pathway to the alluvium and ultimately the Kansas River; and
- Sewer system overflows and/or surface seeps along the embankment behind Building 180/181 resulting in overland flows that enter the nearby ephemeral streams (Tributaries A and B), which eventually flow to the Kansas River.

The following site-specific geologic and hydrogeologic factors appear to result in the potential migration pathways:

- The upper and lower Crouse limestone is exposed beneath the overburden soils beneath the DCFA;
- Groundwater flow in the saturated soils overlying bedrock is generally to the south-southwest direction beneath the DCFA, then southeasterly once it reaches the alluvium of the Kansas River floodplain;
- Groundwater flow vertically into the bedrock units underlying the DCFA is not considered to be a significant pathway due to numerous inter-bedded low permeability shales, which act as barriers to downward flow and the greater potential for groundwater to move laterally;
- Preferential pathways exist in the unsaturated zone due to the presence of buried utilities (such as pipelines, steam line tunnels, communications lines) as well as naturally occurring seams or layers of increased permeability soils within the overburden soils; and
- Periodic rises in the Kansas River water level may temporarily reverse prevailing groundwater flow directions and affect the distribution of contaminants beneath the DCFA.

2.9.4 Potential Receptors

The pre-RI Conceptual Site Model potential media-specific receptors were seen as the following:

- Human (site workers, children) and ecological receptors at or near the DCFA, through contact with soils and/or sediments and surface water in Tributaries A and B.
- Site/utility workers coming in contact with shallow subsurface soils and/or sediments in Tributaries A and B.
- The Kansas River (as it may be potentially impacted by two distinct pathways consisting of groundwater discharge near the eastern end of the alluvial island and surface water/sediment discharges at the mouth of Tributary B via Tributary A); and

As discussed in the Baseline Risk Assessment (Chapter 6), consumption of groundwater and/or residential type land use and associated exposure scenarios are not considered to be reasonable based on current and foreseeable site conditions and land use.

TABLE 2-1
DESCRIPTION OF ROCK UNITS FOUND WITHIN THE REGION AND DCFA
Dry Cleaning Facilities Area
Fort Riley, Kansas

Formation or Rock Unit	Thickness (feet)	Thickness in DCFA (feet)	Physical Characteristics
Chase Group			**Permian System**
Wymore shale	9-25	NL	Primarily gray-yellow shale but with red, green, and purple bands. Bright colored shale.
Schroyer limestone	8-20	NL	Light gray to nearly white flint-bearing. May have 3-foot non-flinty bed in upper part.
Havensville shale	6-18	16	Gray calcareous shale with thin limestone beds.
Threemile limestone	7-22	11	Light gray to nearly white flinty limestone; massive non-flinty beds in middle and lower part.
Council Grove Group			**Permian System**
Speiser shale	18-35	16	Shale and limestone. Consists of an upper fossiliferous shale underlain by persistent limestone bed 1-foot thick and about 3 feet below the Threemile Limestone. Remainder in varicolored shale with red being predominant color.
Funston limestone	5-26	7	Light gray to blue-gray limestone separated by gray to yellow-gray shale. May have bluish to nearly black shale in lower part. May contain flint.
Blue Rapids shale	15-30	19	Gray, red, and green shale containing local limestone and locally a coal bed.
Crouse limestone	10-18	15	Limestone and shale. An upper and lower limestone separated by a few feet of fossiliferous shale. Limestone beds are flinty.

TABLE 2-1 (CONTINUED)
DESCRIPTION OF ROCK UNITS FOUND WITHIN THE REGION AND DCFA

Formation or Rock Unit	Thickness (feet)	Thickness in DCFA (feet)	Physical Characteristics
Easly Creek shale	15-20	38	Somewhat calcareous red, green, and gray shale. Upper part light colored calcareous, lower part mostly red shale. Gypsum occurs in basal part in some locations.
Council Grove Group			**Permian System**
Bader limestone Middleburg Limestone Member Hooser Shale Member Eiss Limestone Member	15-30	4	Upper part is platy limestone and shale. Shale, olive to dark gray; lower part is slabby to massive limestone, 3 to 5 feet. Gray, green, red shale 3 to 8 feet or more limestone and shale. Upper limestone 2-3 feet locally flinty. Middle part is gray fossiliferous shale lower limestone is shale, thin bedded fossiliferous, 7 - 18 feet.

Notes:

NL = Not logged.

Sources: Thickness from geophysical log DCF93-18.
Moore et al., 1951; Zeller, 1968.

TABLE 2-2
POSSIBLE MAMMALS FOR HABITATS IN THE VICINITY
Dry Cleaning Facilities Area
Fort Riley, Kansas

Common Name	Order	Family	Scientific Name
Whitetail Deer	Artiodactyla	Cervidae	*Odocoileus virginianus macrourus*
Coyote	Carnivora	Canidae	*Canis latrans latrans*
Red Fox	Carnivora	Canidae	*Vulpes vulpes fulva*
Bobcat	Carnivora	Felidae	*Lynx rufus rufus*
Longtail Weasel	Carnivora	Mustelidae	*Mustela frenata primulinaa*
Mink	Carnivora	Mustelidae	*Mustela vison letifera*
Raccoon	Carnivora	Procyonidae	*Procyon lotor letifera*
Mexican Freetail Bat	Chiroptera	Molossidae	*Tadarida brasiliensis*
Big Brown Bat	Chiroptera	Vespertilionidae	*Eptesicus fuscus*
Silver-haired Bat	Chiroptera	Vespertilionidae	*Lasionycteris noctivagans*
Red Bat	Chiroptera	Vespertilionidae	*Lasiurus borealis*
Hoary bat	Chiroptera	Vespertilionidae	*Lasiurus cinereus*
Keen Myotis	Chiroptera	Vespertilionidae	*Myotis keeni*
Little brown Myotis	Chiroptera	Vespertilionidae	*Myotis lucifugus*
Evening Bat	Chiroptera	Vespertilionidae	*Nycticeius humeralis*
Eastern Pipistrelle	Chiroptera	Vespertilionidae	*Pipistrellus subflavus*
Short-tailed Shrew	Insectivora	Soricidae	*Blarina carolinensis*
Least Shrew	Insectivora	Soricidae	*Cryptotis parva*
Eastern Mole	Insectivora	Talpidae	*Scalopus aquaticus machrinoides*
Eastern Cottontail	Lagomorpha	Leporidae	*Sylvilagus floridanus*
Opossum	Marsupialia	Didelphiidae	*Didelphis marsupialis*
Beaver	Rodentia	Castoridae	*Castor canadensis*
Muskrat	Rodentia	Cricetidae	*Onadatra zibethica cinnamominus*
White-footed Mouse	Rodentia	Cricetidae	*Peromyscus leucopus noveboracensis*

TABLE 2-2 (CONTINUED)
POSSIBLE MAMMALS FOR HABITATS IN THE VICINITY

Common Name	Order	Family	Scientific Name
Deer Mouse	Rodentia	Cricetidae	*Peromyscus manicaultus bairdii*
Hispid Cotton Rat	Rodentia	Cricetidae	*Sigmodon hispidus texianus*
House Mouse	Rodentia	Muridae	*Mus musculus*
Norway Rat	Rodentia	Muridae	*Rattus norvegicus*
Woodchuck	Rodentia	Sciuridae	*Marmota monax bunkeri*
Eastern Fox Squirrel	Rodentia	Sciuridae	*Sciurus niger rufiventer*
Eastern Wood Rat			*Neotoma floridanus*
Woodland Vole			*Microtus pinneterum*
Striped Skunk			*Mephitis mephitis*
Gray Fox			*Urocyon cineroargentus*
Hispid Pocket Mouse			*Perognathus hispidus*
Meadow-Jumping Mouse			*Zapus husonius*

TABLE 2-3
POSSIBLE REPTILES AND AMPHIBIANS FOR HABITATS IN THE VICINITY
Dry Cleaning Facilities Area
Fort Riley, Kansas

Common Name	Family	Scientific Name
FROGS AND TOADS:		
American Toad	Bufonidae	*Bufo americanus americanus*
Great Plains Toad	Bufonidae	*Bufo cognatus*
Woodhouses's Toad	Bufonidae	*Bufo woodhousie woodhousie*
Blanchard's Cricket Frog	Hylidae	*Acris crepitans blanchardi*
Cope's Gray Treefrog	Hylidae	*Hyla chrysoscelis*
Western Chorus Frog	Hylidae	*Pseudacris triseriata triseriata*
Great Plains Narrow-mouthed Toad	Microhylidae	*Gastrophryne olivacea*
Plains Spadefoot Toad	Pleobatidae	*Scaphiopus bombifrons*
Plains Leopard Frog	Ranidae	*Rana blairi*
Bullfrog	Ranidae	*Rana catesbeiana*
SALAMANDERS:		
Barred Salamander	Ambystomatidae	*Ambystoma tigrinum mavortium*
LIZARDS:		
Western Slender Glass Lizard	Anguidae	*Ophisaurus attenuatus attenuatus*
Five-lined Skink	Scincidae	*Eumeces fasciatus*
Great Plains Skink	Scincidae	*Eumeces obsoletus*
Ground Skink	Scincidae	*Scincella lateralis*
Prairie Racerunner	Teiidae	*Cnemidophorus sexlineatus viridis*

TABLE 2-3 (CONTINUED)
POSSIBLE REPTILES AND AMPHIBIANS FOR HABITATS IN THE VICINITY

Common Name	Family	Scientific Name
SNAKES:		
Western Worm Snake	Colubridae	*Carphophis amoenus vermis*
Eastern Yellow-bellied Racer	Colubridae	*Coluber constrictor flaviventris*
Prairie Ringneck Snake	Colubridae	*Diadophis punctatus arnyi*
Black Rat Snake	Colubridae	*Elaphe obsoleta obsoleta*
Prairie Kingsnake	Colubridae	*Lampropeltis calligaster*
Speckled Kingsnake	Colubridae	*Lampropeltis getua holbrooki*
Desert Kingsnake	Colubridae	*Lampropeltis getula splendida*
Blotched Water Snake	Colubridae	*Nerodia erythrogaster transversa*
Diamondback Water Snake	Colubridae	*Nerodia rhombifer rhombifer*
Northern Water Snake	Colubridae	*Nerodia sipedon sipedon*
Gopher Snake	Colubridae	*Pituophis catenifer*
Marsh Brown Snake	Colubridae	*Storieria dekayi Limnetes*
Flat-headed Snake	Colubridae	*Tantilla gracilis*
Plains Blackhead Snake	Colubridae	*Tantilla nigriceps*
Western Ribbon Snake	Colubridae	*Thamnophis proximus proximus*
Western Plains Garter Snake	Colubridae	*Thamnophis radix haydeni*
Red-sided Garter Snake	Colubridae	*Thamnophis sirtalis parietalis*
Lined Snake	Colubridae	*Tropidoclonion lineatum*
Osage Copperhead	Viperidae	*Akistrodon contortrix phaeogaster*
Timber Rattlesnake	Viperidae	*Crotalus horridus horridus*
TURTLES:		
Common Snapping Turtle	Chelydridae	*Chelydra serpentina*
Western Painted Turtle	Emydidae	*Chrysemys picta belli*
Ouachita Map Turtle	Emydidae	*Graptemys ouachitensis*
Ornate Box Turtle	Emydidae	*Terrapene ornata ornata*
Red-eared Turtle	Emydidae	*Trachemys scripta elegans*
Midland Smooth Softshell	Tryonychidae	*Apalone muticus muticus*
Western Spiny Softshell	Tryonychidae	*Apalone spiniferus hartwegi*

TABLE 2-4
POSSIBLE FISH FOR HABITATS IN THE VICINITY
Dry Cleaning Facilities Area
Fort Riley, Kansas

Common Name	Family	Scientific Name
Shovelnose Sturgeon	Acipenseridae	*Scaphirhynchus platorynchus*
American Eel	Anguillidae	*Anguilla rostrata*
Green Sunfish	Centrarchidae	*Lepomis cyanellus*
Orangespotted Sunfish	Centrarchidae	*Lepomis humilis*
Bluegill	Centrarchidae	*Lepomis macrochirus*
Smallmouth Bass	Centrarchidae	*Micropterus dolomieu*
Largemouth Bass	Centrarchidae	*Micropterus salmoides*
White Crappie	Centrarchidae	*Pomoxis annularis*
Gizzard Shad	Clupeidae	*Dorosoma cepedianum*
Central Stoneroller	Cyprinidae	*Campostoma anomalum*
River Carpsucker	Cyprinidae	*Carpiodes carpio*
Quillback	Cyprinidae	*Carpiodes cyprinus*
White Sucker	Cyprinidae	*Catostomus commersoni*
Blue Sucker	Cyprinidae	*Cycleptus elongatus*
Red Shiner	Cyprinidae	*Cyprinella lutrensis*
Speckled Chub	Cyprinidae	*Extrarius aestivalis*
Western Silvery Minnow	Cyprinidae	*Hybognathus argritis*
Plains Minnow	Cyprinidae	*Hybognathus placitus*
Smallmouth Buffalo	Cyprinidae	*Ictiobus bubalus*
Bigmouth Buffalo	Cyprinidae	*Ictiobus cyprinellus*
Black Buffalo	Cyprinidae	*Ictiobus niger*
Common Shiner	Cyprinidae	*Luxilus cornutus*
Redfin Shiner	Cyprinidae	*Lythrurus umbratilis*
Sturgeon Chub	Cyprinidae	*Macrhybopsis gelida*
Sicklefin Chub	Cyprinidae	*Macrhybopsis meeki*
Silver Chub	Cyprinidae	*Macrhybopsis storeriana*

TABLE 2-4 (CONTINUED)
CANDIDATE FISH FOR HABITATS IN THE VICINITY

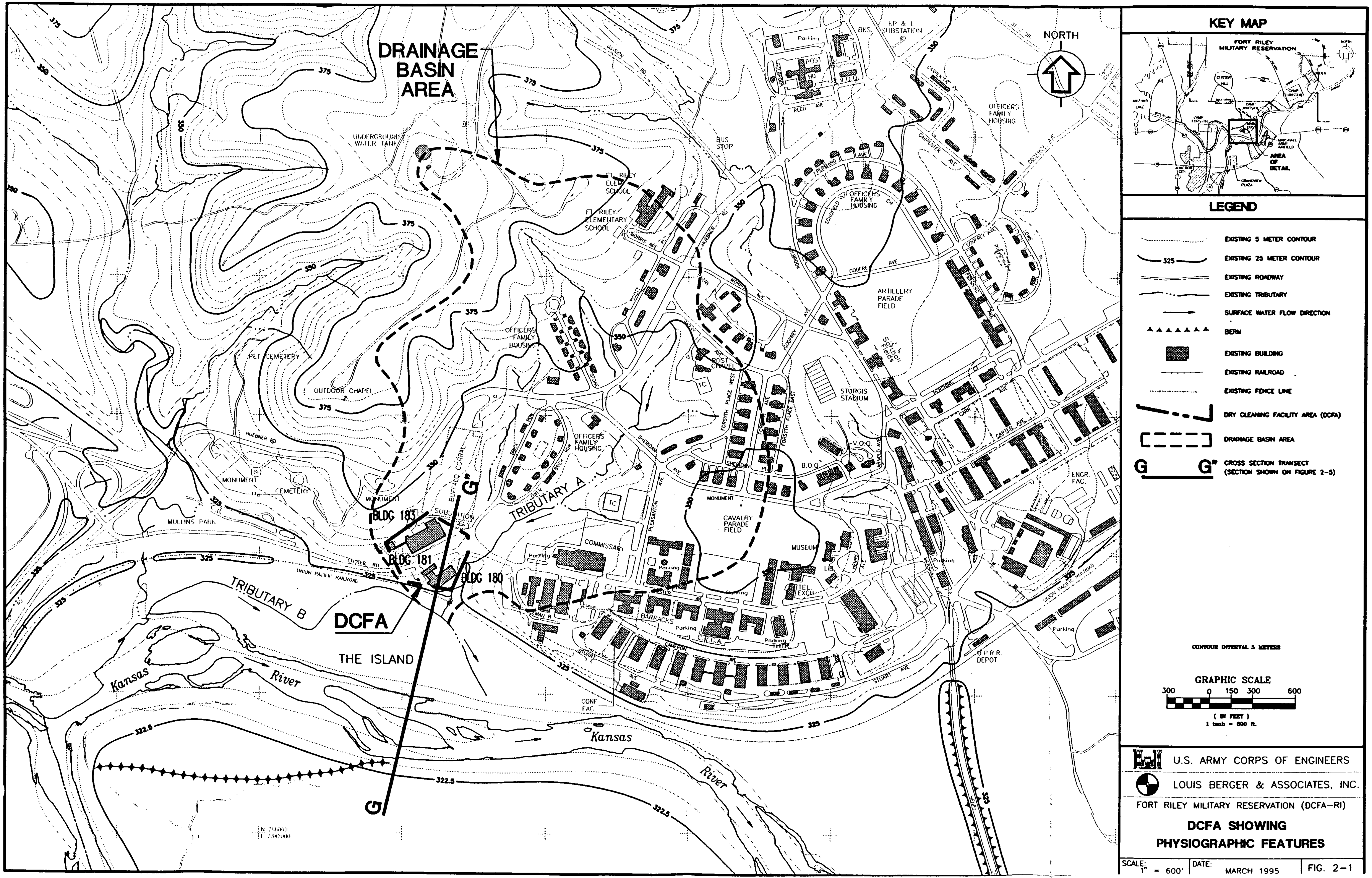
Common Name	Family	Scientific Name
River Redhorse	Cyprinidae	*Moxostoma carinatum*
Golden Redhorse	Cyprinidae	*Moxostoma erythrurum*
Shorthead Redhorse	Cyprinidae	*Moxostoma macrolepidotum*
Golden Shiner	Cyprinidae	*Notemigonus crysoleucas*
Emerald Shiner	Cyprinidae	*Notropis atherinoides*
River Shiner	Cyprinidae	*Notropis blennius*
Ghost Shiner	Cyprinidae	*Notropis buchanani*
Sand Shiner	Cyprinidae	*Notropis ludibundus*
Rosyface Shiner	Cyprinidae	*Notropis rubellus*
Silverband Shiner	Cyprinidae	*Notropis shumardi*
Suckermouth Minnow	Cyprinidae	*Phenacobius mirabilis*
Bluntnose Minnow	Cyprinidae	*Pimephales notatus*
Fathead Minnow	Cyprinidae	*Pimephales promelas*
Bullhead Minnow	Cyprinidae	*Pimephales vigilax*
Flathead Chub	Cyprinidae	*Platygobio gracilis*
Creek Chub	Cyprinidae	*Semotilus atromaculatus*
Goldeye	Hiodontidae	*Hiodon alasoides*
Black Bullhead	Ictaluridae	*Ameiurus melas*
Yellow Bullhead	Ictaluridae	*Ameiurus natalis*
Channel Catfish	Ictaluridae	*Ictalurus punctatus*
Stonecat	Ictaluridae	*Noturus flavus*
Flathead Catfish	Ictaluridae	*Pylodictis olivaris*
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*
Shortnose Gar	Lepisosteidae	*Lepisosteus platostomus*
White Bass	Moronidae	*Morone chrysops*
Jonny Darter	Percidae	*Etheostoma nigrum*
Orangethroat Darter	Percidae	*Etheostoma spectabile*
Logperch	Percidae	*Percina caprodes*

TABLE 2-4 (CONTINUED)
CANDIDATE FISH FOR HABITATS IN THE VICINITY

Common Name	Family	Scientific Name
Sauger	Percidae	*Stizostedion canadense*
Walleye	Percidae	*Stizostedion vitreum*
Mosquitofish	Poeciliidae	*Gambusia affinis*
Paddlefish	Polyodontidae	*Polyodon spathula*
Chestnut Lamprey	Pteromyzontidae	*Icthyomyzon castaneus*
Plains killifish	Rivulidae	*Fundulus zebrinus*
Freshwater Drum	Sciaenidae	*Aplodinotus grunniens*

TABLE 2-5
FISH FOUND IN THE KANSAS RIVER IN THE VICINITY
Dry Cleaning Facilities Area
Fort Riley, Kansas
1991 and 1992

Common Name	Family	Scientific Name
Shovelnose Sturgeon	Acipenseridae	*Scaphirhynchus platorynchus*
Smallmouth Bass	Centrarchidae	*Micropterus dolomieu*
Central Stoneroller	Cyprinidae	*Campostoma anomalum*
River Carpsucker	Cyprinidae	*Carpiodes carpio*
Red Shiner	Cyprinidae	*Cyprinella lutrensis*
Speckled Chub	Cyprinidae	*Extrarius aestivalis*
Golden Redhorse	Cyprinidae	*Moxostoma erythrurum*
Emerald Shiner	Cyprinidae	*Notropis atherinoides*
Sand Shiner	Cyprinidae	*Notropis ludibundus*
Suckermouth Minnow	Cyprinidae	*Phenacobius mirabilis*
Bluntnose Minnow	Cyprinidae	*Pimephales notatus*
Fathead Minnow	Cyprinidae	*Pimephales promelas*
Bullhead Minnow	Cyprinidae	*Pimephales vigilax*
Channel Catfish	Ictaluridae	*Ictalurus punctatus*
Stonecat	Ictaluridae	*Noturus flavus*
Flathead Catfish	Ictaluridae	*Pylodictis olivaris*
Longnose Gar	Lepisosteidae	*Lepisosteus osseus*
Shortnose Gar	Lepisosteidae	*Lepisosteus platostomus*
White Bass	Moronidae	*Morone chrysops*
Jonny Darter	Percidae	*Etheostoma nigrum*
Orangethroat Darter	Percidae	*Etheostoma spectabile*
Mosquitofish	Poeciliidae	*Gambusia affinis*
Freshwater Drum	Sciaenidae	*Aplodinotus grunniens*



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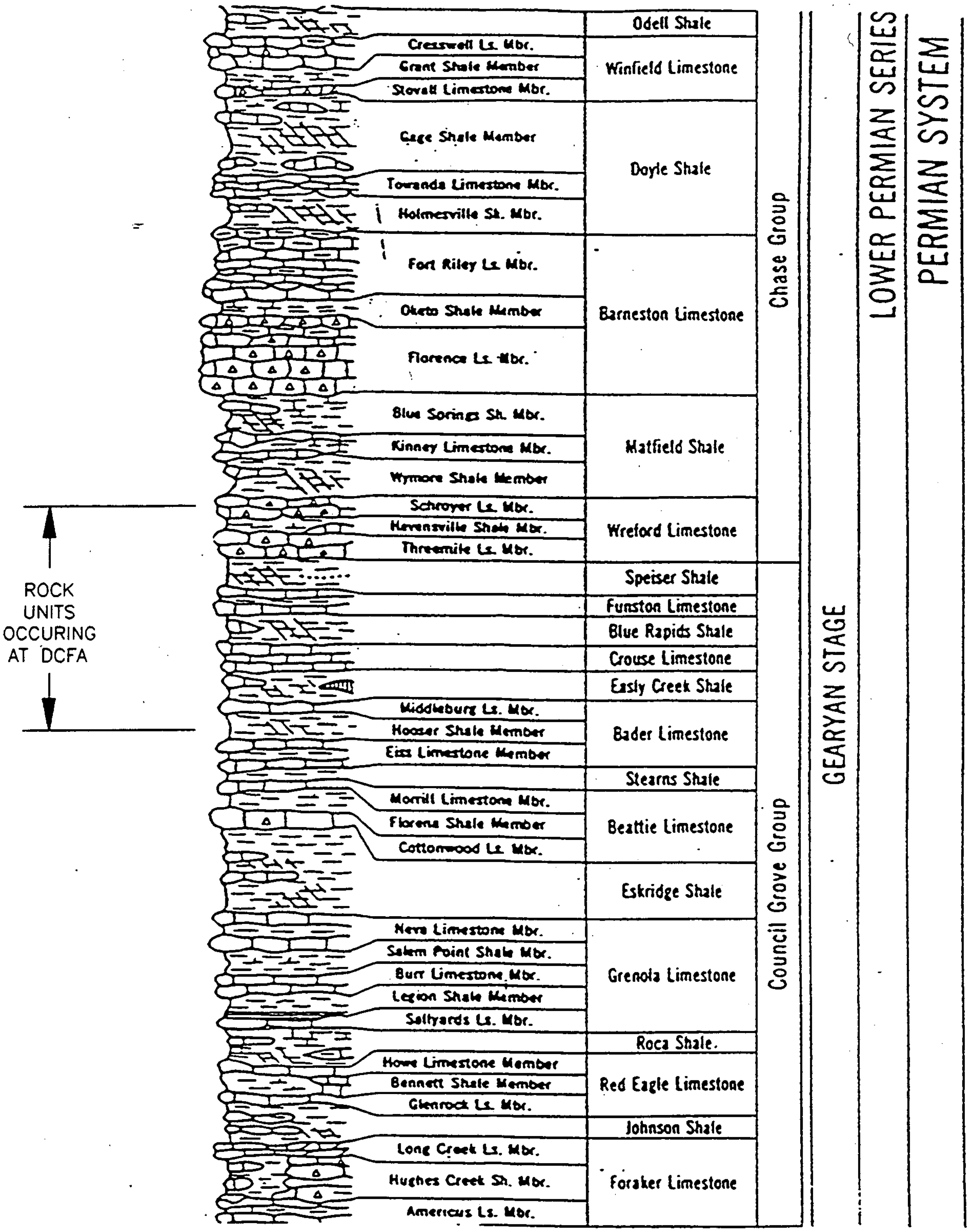
FORT RILEY MILITARY RESERVATION (DCFA–RI)

DCFA SHOWING PHYSIOGRAPHIC FEATURES

SCALE: 1" = 600' | DATE: MARCH 1995 | FIG. 2–1



SOURCE: ZELLER, 1968

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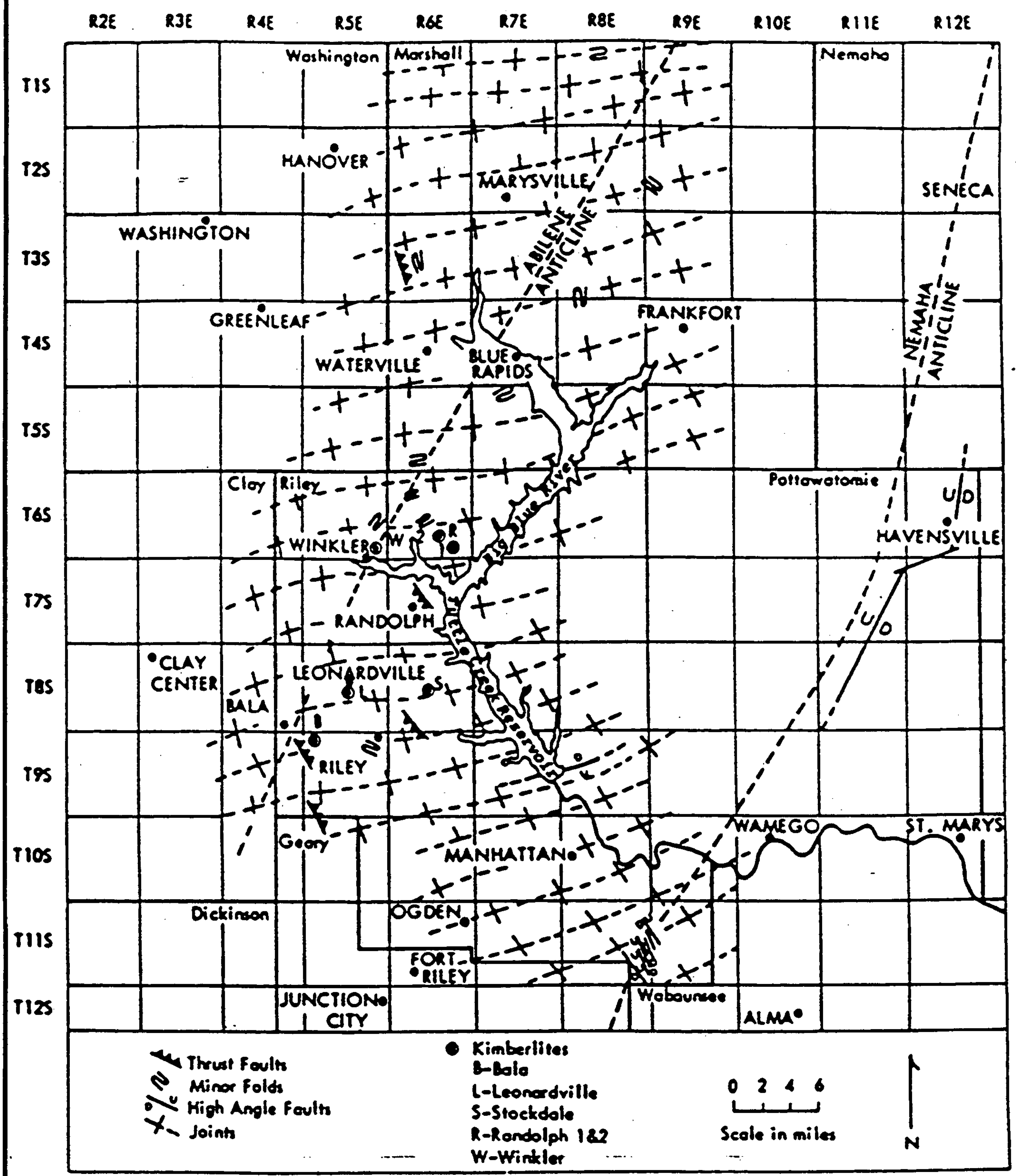
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GENERAL STRATIGRAPHIC SEQUENCE - ROCK COLUMN

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 2-2

2-GSSR/30MAR95



SOURCE: Kansas Geological Survey, Bulletin 204, Part 4

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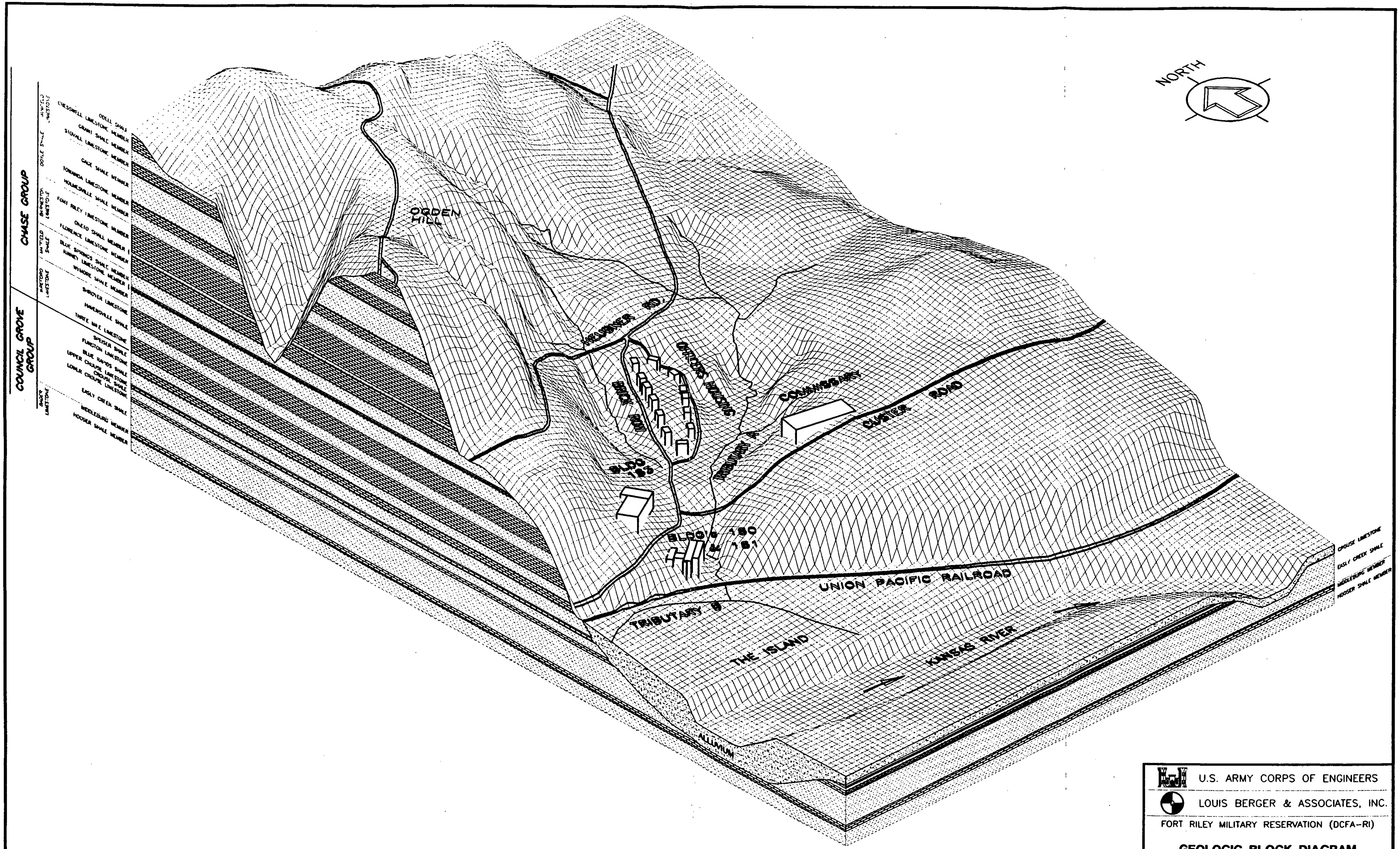
FORT RILEY MILITARY RESERVATION (DCFA-RI)

REGIONAL ROCK JOINT PATTERN

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 2-3

2 - RJP/30MAR95



Source: Geology (Zeller, 1989)
For Generalized Stratigraphy shown

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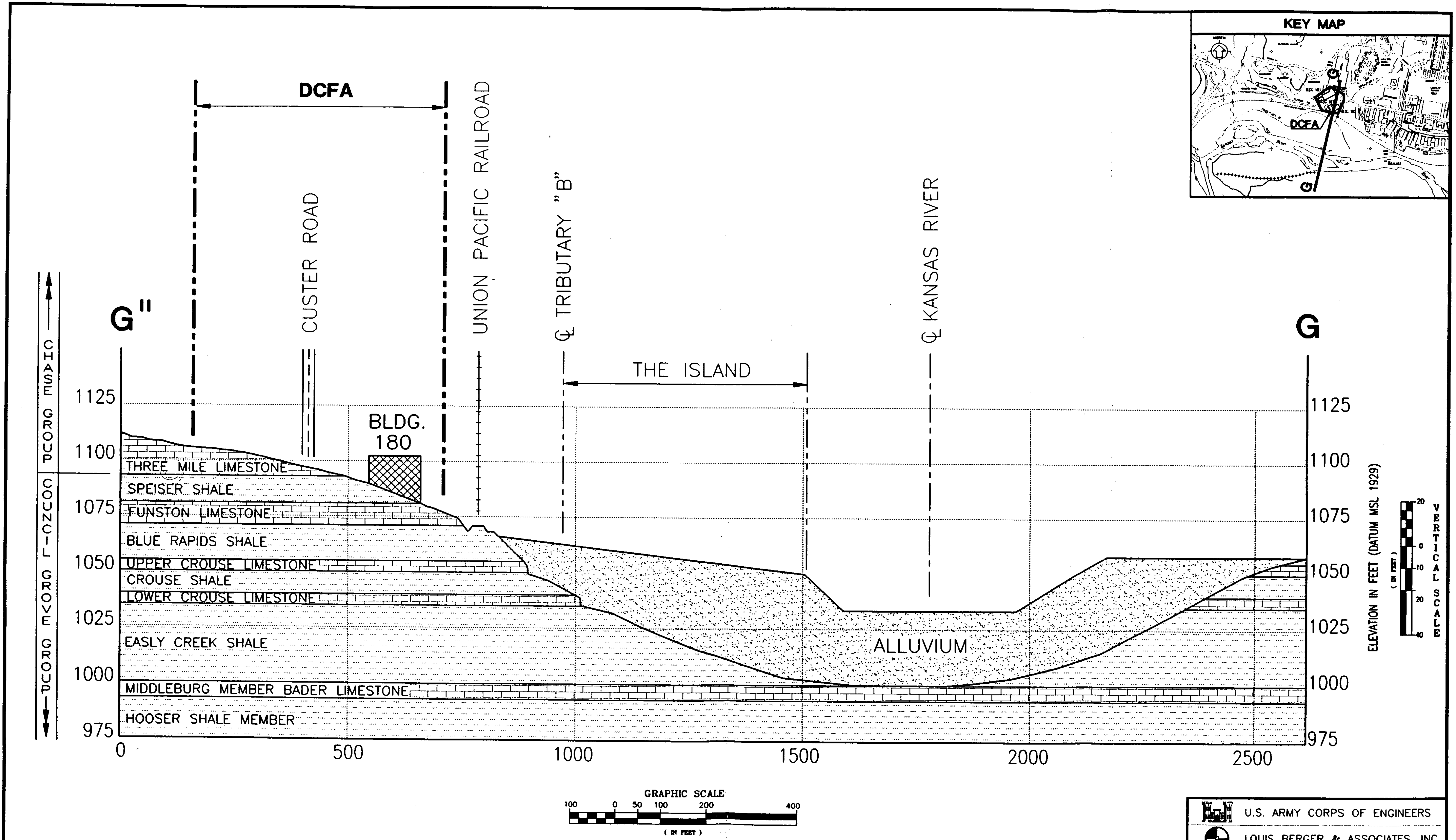
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GEOLOGIC BLOCK DIAGRAM
DCFA AND VICINITY

SCALE: NONE	DATE: MARCH 1995	FIG. 2-4



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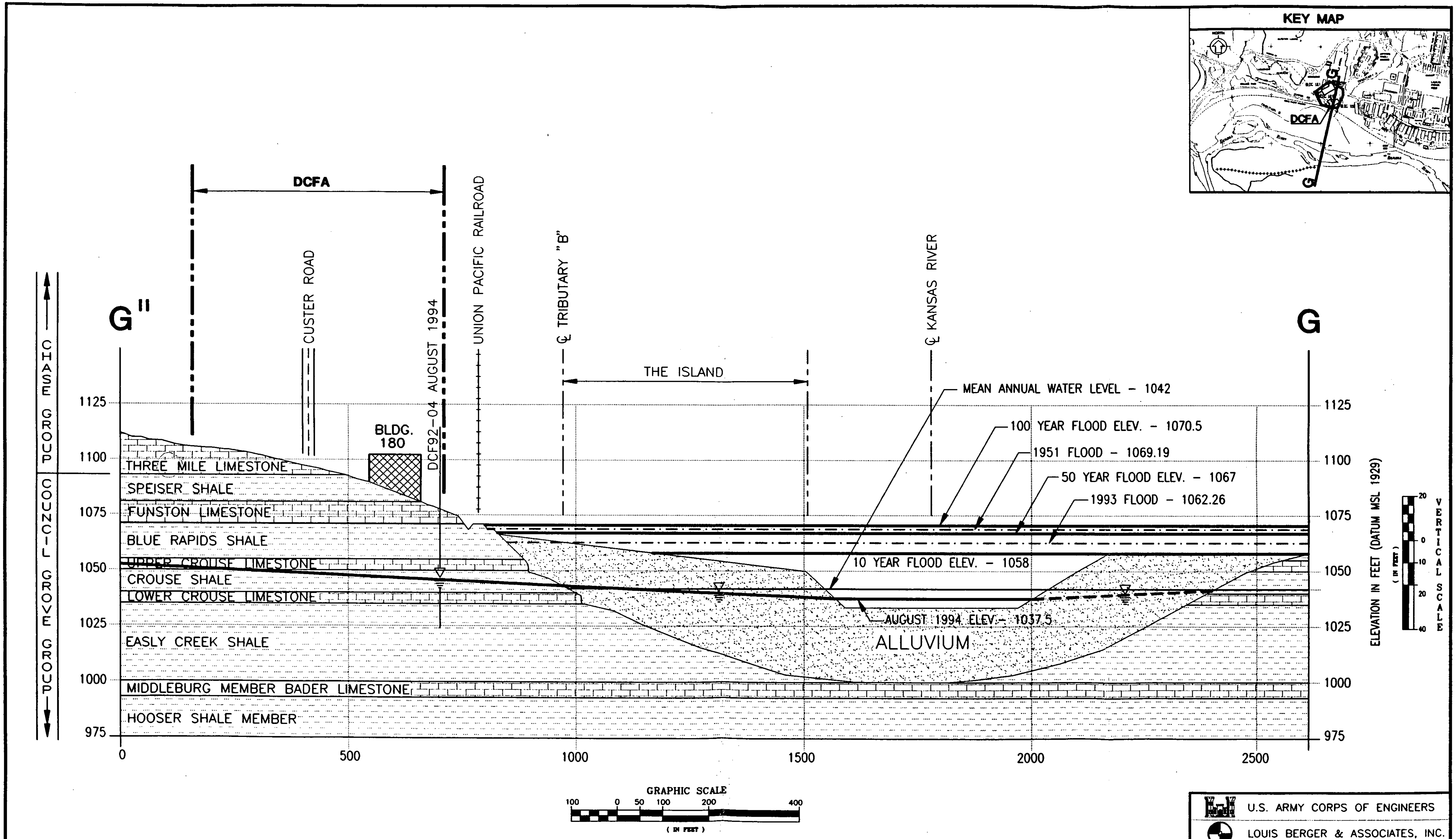
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DCFA AND VICINITY
GEOLOGIC CROSS SECTION

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 2-5

NOTES:
1. Geology After Zeller, 1989.
2. Location of Section Line Also Shown on Figure 2-1.



SOURCES:

1. Flood Insurance Study; Geary County, Kansas; Federal Emergency Management Agency.
2. Water Level Elevations from the U.S. Dept. of the Interior - Geological Survey - Kansas - Water Year 1993.
3. Discharge Rates to Kansas River Basin from the U.S. Geological Survey Water-Data Report KS-93-1.
4. Geology after Zeller, 1989.

NOTES:

1. Heavy dashed line indicates inferred August, 1994 groundwater elevation level south of the Kansas River.

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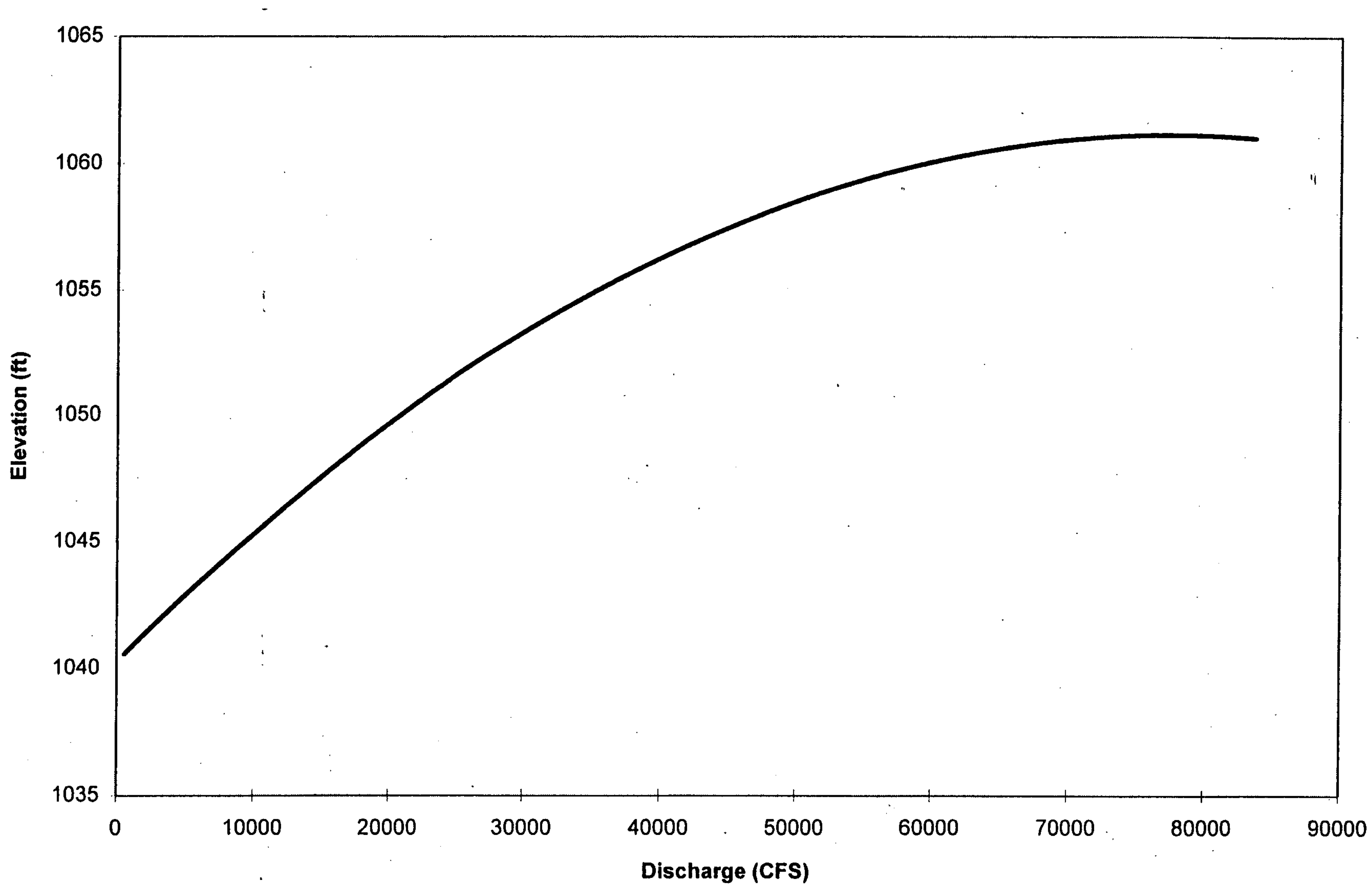
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GEOLOGIC CROSS-SECTION WITH RIVER STAGE ELEVATIONS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 2-6



Sources:
United States Department of the Interior - Geological Survey - Kansas - Water Year 1993.
United States Geological Survey Water-Data Report KS-93-1.
Federal Emergency Management Agency Flood Insurance Study - Geary County, Kansas.

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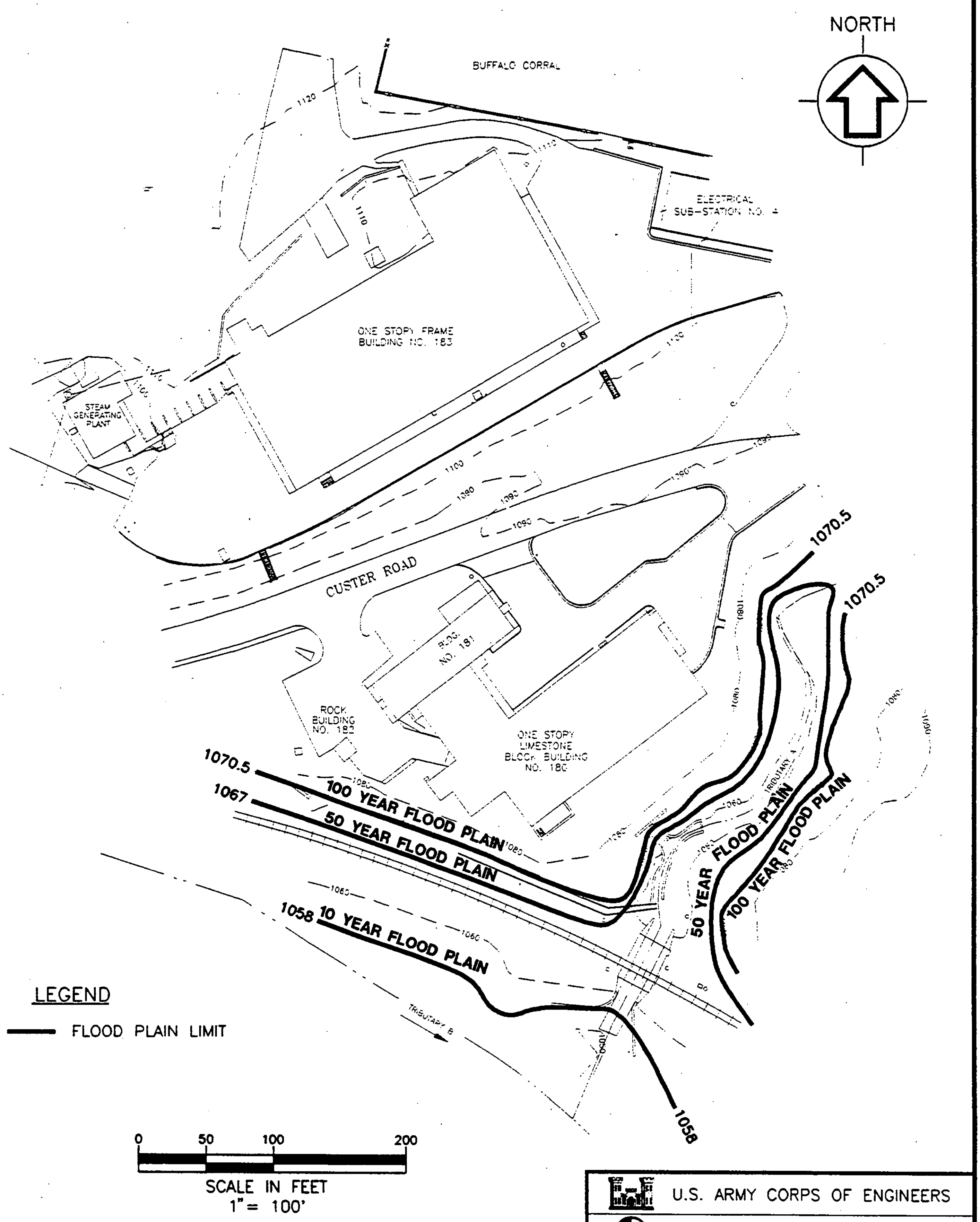
FORT RILEY MILITARY RESERVATION (DCFA-RI)

STAGE/DISCHARGE GRAPH
KANSAS RIVER

SCALE: AS SHOWN
DATE: MARCH 1995
FIG. 2-7



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: FEMA, 1988.

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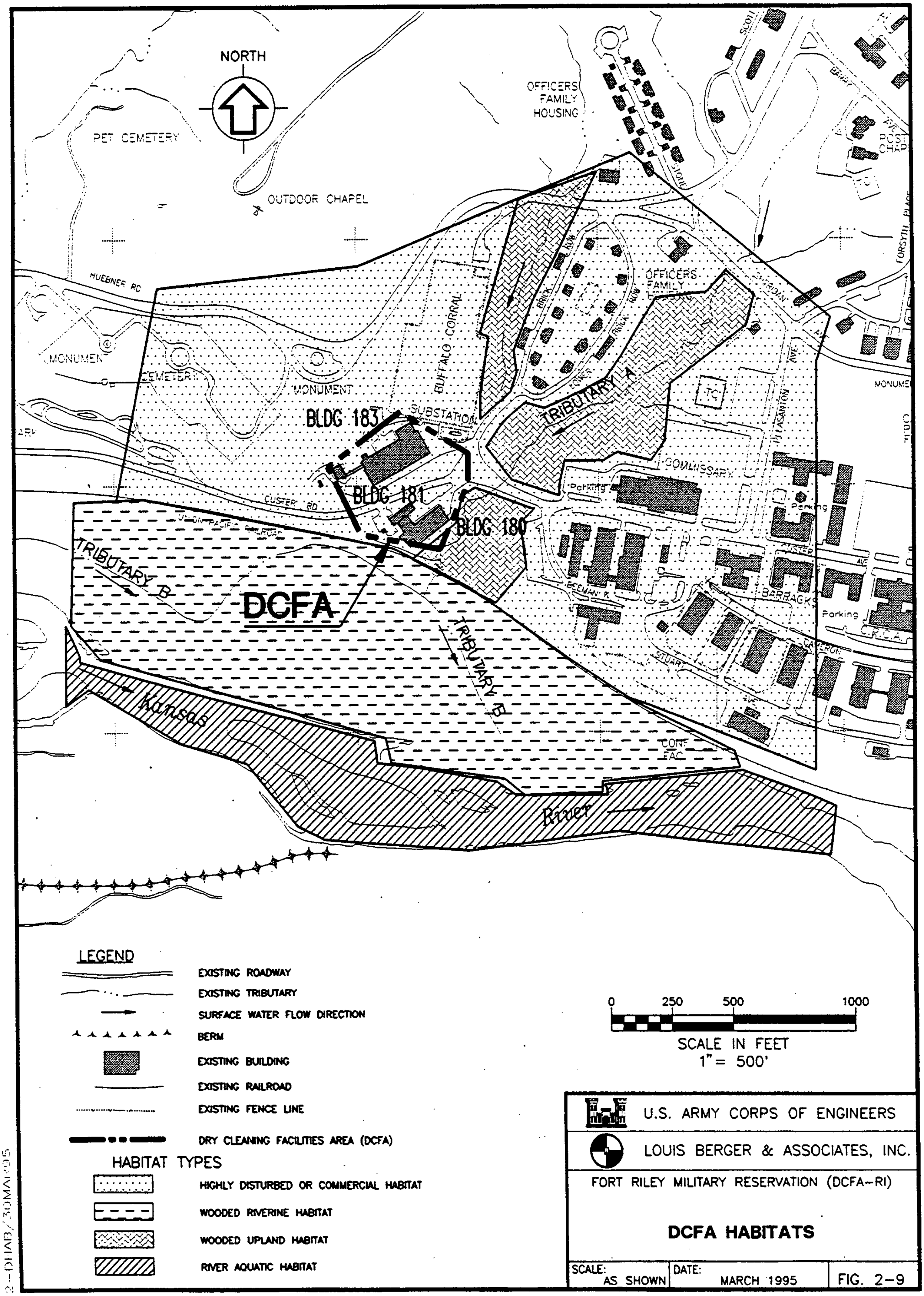
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DELINEATIONS OF
10, 50 AND 100 YEAR FLOOD PLAINS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 2-8



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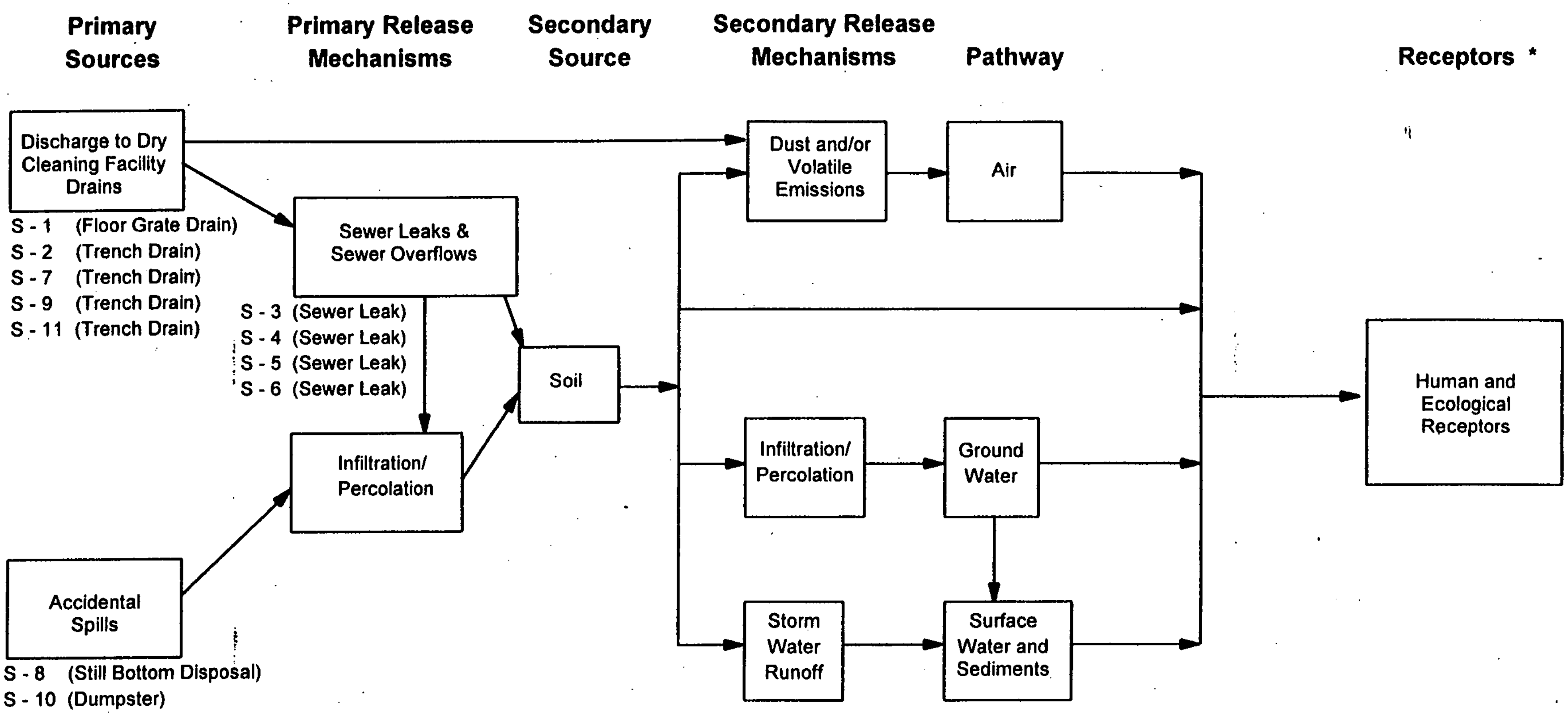
FORT RILEY MILITARY RESERVATION (DCFA–RI)

DCFA HABITATS

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 2–9

2-DHAB/30MAR95



Notes:

S-1 Potential Source.

* A more detailed discussion (Post-RI) of pathways and receptors is provided in Chapter 5 and Chapter 6 .

See Figure 2-8 for source locations.

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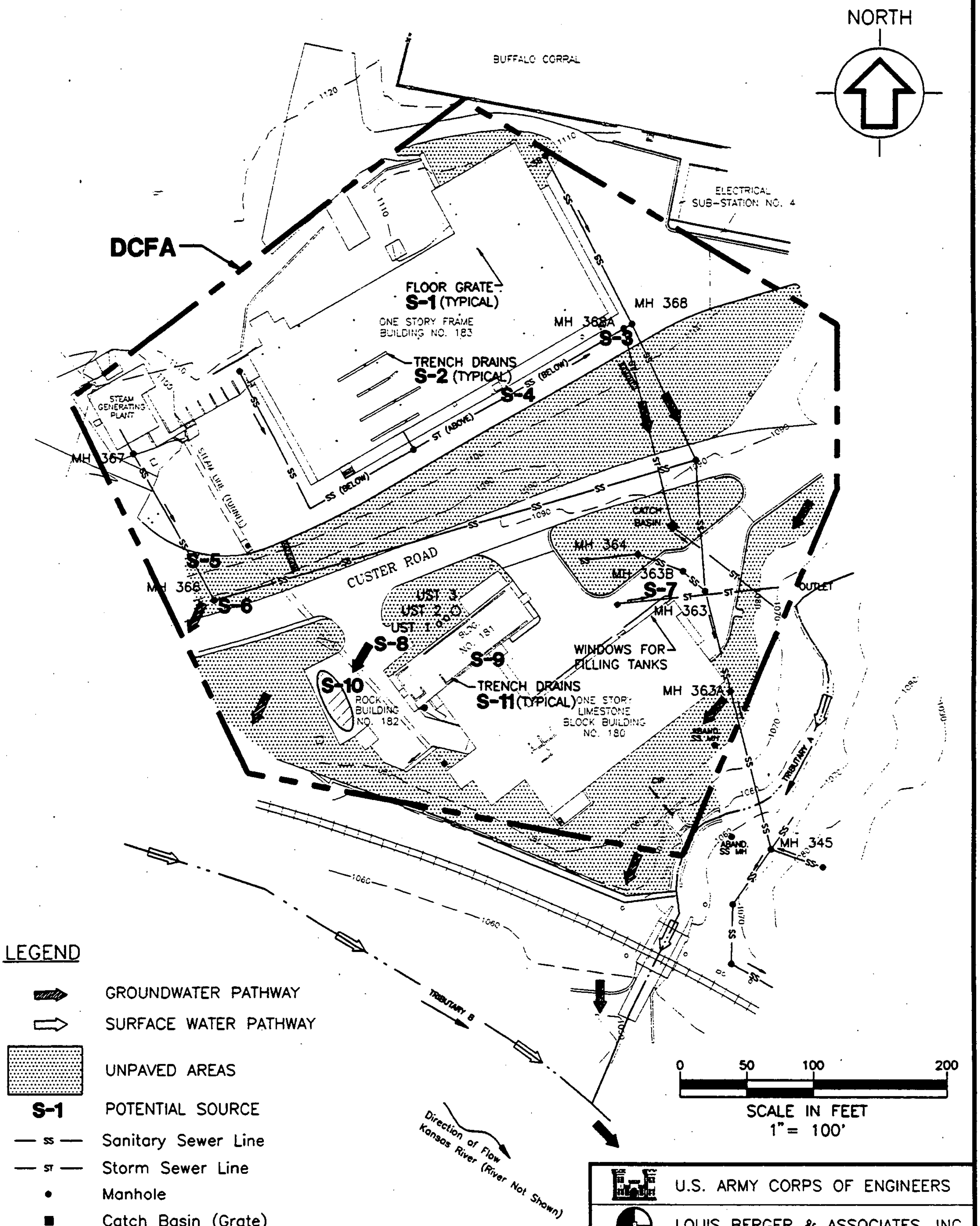
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PRE-RI CONCEPTUAL SITE MODEL POTENTIAL SOURCES, PATHWAYS AND RECEPTORS

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 2-10



LEGEND

- GROUNDWATER PATHWAY
- SURFACE WATER PATHWAY
- ▨ UNPAVED AREAS
- **S-1** POTENTIAL SOURCE
- — SS — Sanitary Sewer Line
- — ST — Storm Sewer Line
- ● Manhole
- ■ Catch Basin (Grate)
- SUSPECTED ACCIDENTAL SPILL AREA

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. A POTENTIAL ECOLOGICAL RECEPTOR IS THE KANSAS RIVER.

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FORT RILEY MILITARY RESERVATION (DCFA-RI)

PRE-RI CONCEPTUAL
SITE MODEL

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 2-11

TABLE OF CONTENTS

CHAPTER 3
STUDY AREA CHARACTERIZATION

Section 1.2.3 described the findings of previous investigations conducted within the DCFA. This chapter will concentrate on the investigation conducted during the RI, but will integrate the findings of previous investigations that led to the work conducted during the RI. The RI began with the Initial Field Investigation (IFI), whose purpose was to scope and focus the RI. Results of the IFI investigations are provided in Section 3.1. The description of work conducted during the main phase of the RI begins with surface soils and geology, and continues with discussions on surface water, sediment, groundwater, and air. The analytical procedures and methods are discussed in Chapter 4. A summary of RI activities and objectives is provided in Table 3-1.

Activities conducted during the PA/SI and IFI phase of the RI were conducted in accordance with the Draft Final Modified Chemical Data Acquisition Plan and Site-Specific Sampling Plan for Preliminary Assessment/Site Investigation (CEMRK, 1991; CEMRK, 1992c).

Subsequent to the preparation of the Draft Final Work Plan for RI/FS at the Dry Cleaning Facility, Fort Riley, Kansas, the Army changed contractors for execution of the RI/FS. The RI was conducted in accordance with the Draft Final Work Plan for the RI/FS at the Dry Cleaning Facility as modified (CEMRK, 1993d) and the Comprehensive Basic Documents (CEMRK, 1993f). The technical memoranda prepared during this investigation are presented in Appendix A. Three technical memoranda were prepared to address deviations from the Work Plan. These memoranda addressed relocation of monitoring wells due to utility interferences, elimination of two soil borings for similar reasons, and installation of driven wells in the alluvium of The Island.

3.1 RI/FS Initial Field Investigations

Results of the PA/SI showed that VOCs and SVOCs were present in the soils and groundwater at the site. The source was associated with suspected accidental leaks or spills and reported historical operating practices of the dry cleaning facilities. The lateral and vertical extent of contaminants found was not sufficiently characterized, and all the routes of migration in the environment were not established. As a result, initial field investigations (the IFI) were conducted before the full RI was initiated to provide data for use during the RI scoping process.

IFI activities initiated in February 1993 included a soil gas survey, collection of water samples from the sanitary and storm sewer lines, and collection of surface water and sediment samples from Tributary A adjacent to the former DCF. In addition to these tasks, supplemental field investigations were conducted as part of the IFI. Supplemental field investigations included video surveys of the sanitary and storm sewers, sampling of water from the dry cleaning machines, and a topographic survey of selected manholes. Results of these activities are described in the following sections.

3.1.1 Soil Gas Surveys

Two soil gas surveys were conducted — one during the PA/SI, and another during the IFI — for the scoping phase of the RI. The first was conducted in October 1991 with on-site analyses utilizing U.S. EPA analytical methods 601/602. Samples were analyzed by gas chromatography (GC) using electron capture detection (ECD) and by flame ionization detection (FID). Tetrachloroethylene (PCE) was the only analyte for which a standard on the ECD was run. FID analyses were performed for benzene, toluene, ethylbenzene, xylenes and total FID volatiles. The results of both analytical methods showed the highest PCE concentration at the northeast corner of Building 180/181. The survey results are presented in Figure 1-4 (PCE concentration contours) and Figure 1-5 (total FID concentration contours).

The second soil gas survey was conducted in February 1993 to further evaluate the presence and extent of chlorinated hydrocarbons in the DCFA. The chlorinated hydrocarbons analyzed included 1,1-dichloroethylene (1,1-DCE), *trans*-DCE (t-DCE), *cis*-DCE (c-DCE), dichloromethane, 1,1,2-trichloroethylene (TCE), PCE, and vinyl chloride. Soil gas samples were collected at 55 locations in October 1991 and at 52 locations during February 1993 (Figures 3-1 and 3-2). The only compounds detected in these samples were PCE, TCE, and c-DCE. The sampling depth ranged from 5 to 15 feet below ground surface (bgs); the majority of samples were collected at or near the depth of sewer lines at 10 to 15 feet bgs. As with the October 1991 soil gas survey, the highest PCE levels (1,000s of μg/l) were found at the northeast corner of Building 180/181 (107 to 5,975 μg/l). More moderate levels (100s of μg/l) surround this area and extend northward to Building 183. An isopleth map of PCE concentrations is presented in Figure 3-3.

TCE and c-DCE were detected only in samples collected near the northeast corner of Building 180/181. TCE was detected in three samples (107, 108, and 109) at concentrations ranging from 1.5 to 9.7 μg/l. Concentrations of c-DCE were detected in two samples (105 and 108) at concentrations of 1.5 and 14 μg/l, respectively.

3.1.2 Sewer Water Sampling

Water samples were collected in November 1992 and February 1993 from sanitary sewer lines and storm water sewer lines leading from the former and current DCF (Figure 3-4). The current DCF was operating while the samples were being collected. The flow rate within most sewer lines was approximately 5 to 10 gallons per minute (gpm), except at the location of sample DCFSSW-07, where the flow was less than 1 gpm. Although approximately 2 inches of rainfall occurred 2 days prior to this sampling event, a storm sewer water sample could not be collected at the outfall just north of the sampling location of DCFSTW-01 because there was no flow.

These samples were analyzed for VOCs and SVOCs to determine the contaminant coneentrations at various points throughout the sewers and to determine the likely source of contamination found in previous soil gas, water, and sediment samples at the site. Samples from sanitary sewer lines and storm water sewer lines were given the prefixes "DCFSSW" and "DCFSTW," respectively. Analytical results indicate the presence of VOCs and SVOCs in the water samples collected from the sanitary sewer lines. The VOCs detected included acetone, bromodichloromethane, trichloromethane, dibromochloromethane, PCE, toluene, and total xylenes. Dichloromethane was also detected, but like acetone, was suspected of being due to laboratory contamination (CEMRK, 1993a,b).

3.1.3 Surface Water and Sediment Sampling

Four sediment and two surface water samples were collected in February 1993 in Tributaries A and B at the locations shown in Figure 4-6. Surface water was not present at two locations (DCFSD-08 and DCFSD-09). Sediment sample DCFSD-08 was collected upgradient of site-impacted groundwater to determine whether an upgradient contamination source was present. Sediment sample DCFSD-09 was collected to determine whether Tributary B had been impacted. Samples DCFSD-10 and DCFSW-10 were collected to determine whether PCE detected upstream in Tributary A the March 1992 sampling event had migrated downstream. Samples DCFSD-11 and DCFSW-11 were collected to determine the extent of contamination downstream from the site.

All samples collected were analyzed for VOCs and SVOCs. Concentrations of SVOCs were not detected in any samples. The only VOC detected was acetone in sediment samples DCFSD-08 and DCFSD-09. During the initial analysis for VOCs in these samples, acetone concentrations were estimated at 1,800 μg/kg (DCFSD-08) and 2,100 μg/kg (DCFSD-09). The presence of acetone in these samples was confirmed through mass spectral identification. However, the concentration exceeded the linear range of the instrument, which required qualification of the data. Results of all associated quality control activities (including surrogate spikes, method blanks, matrix spike/matrix spike duplicates) were within control limits, indicating acceptable analytical system performance. After a method-required dilution (125:1), the samples were re-analyzed and concentrations of acetone were not detected; however, the detection limit was raised. A discussion of surface water and sediment sampling analytical results can be found in Chapter 4.

3.1.4 Other IFI Activities

Following the IFI, it was determined necessary to conduct supplemental investigations to further scope and focus the RI. Supplemental IFI activities initiated in April 1993 included a video survey of the sanitary and storm sewer lines in the area of the former and current DCFs, sampling of process water used by the dry cleaning machines within the current DCF (Building 183), and a survey of the manholes associated with the sanitary and storm sewers. The results of these activities, as provided in CEMRK (1993b), are presented in the following sections.

3.1.4.1 Video Survey of the Sanitary and Storm Sewer Lines

A video survey of the sanitary and storm sewer lines in the DCF was performed to evaluate pipe conditions and intersecting pipe locations that are not observable in the manholes. A continuous video record was made using either a large remote video camera (approximately 2.5 feet in length and 6 inches in diameter) or a smaller camera (minicam) that was approximately 8 inches in length and 3 inches in diameter. As part of this survey, smoke and dye tracing surveys were performed to determine the discharge point from sanitary or storm sewer lines to the floor drains located within the current DCF (Building 183).

Sanitary Sewers. The survey area included approximately 1,490 feet of sanitary sewer lines. The extent of the video survey included approximately 500 feet of this total (Figure 3-5). All video work was performed using a minicam, except for a portion of the sewer line running east from manhole (MH) 366. This section was surveyed using the large camera. Certain reaches of sanitary sewer lines were not accessible to the video cameras, as described below.

- Approximately 300 feet of the 6-inch clay pipe, which runs along the south and southwest side of Building 183, could not be surveyed because of buildup sludge within the line. This sludge coated the camera lens, distorted the video, and did not allow proper drainage of the water used by a water jet in an attempt to clear the line.

- Approximately 20 feet of the 6-inch clay pipe south of the suspected clean-out pipe at the northeast corner of Building 183 was fully obstructed with roots. The expected clean-out entry point was completely filled with sand. This entry point may not, in fact, be a clean-out point for this line, although no other possible clean-out points were observed.

- Approximately 30 feet of the 6-inch clay pipe, about midway between MH 368 and the manhole in Custer Road, was inaccessible because of the increased slope of this line. Maneuverability of the camera was prevented by the slope of the line in this reach.

- Approximately 20 feet of the 6-inch clay pipe immediately south of MH 367 (near Building 184) was inaccessible because of calcium carbonate deposits at the mouth of this pipe. These deposits may be attributed to the daily release of blowdown water from the steam plant (Building 184).

- Approximately 340 feet of the 6-inch clay pipe running east from MH 366 to the manhole in the middle of Custer Road was partially restricted. The cause of the restriction could not be determined.

- Approximately 280 feet of the 8-inch clay pipe running south from the manhole in the middle of Custer Road to MH 345, which was the terminus of the survey, was clogged with calcium carbonate deposits, greasy sludge, and clothing fibers (lint). This line runs roughly north-south through MH 363. The mouth of this 8-inch line has only 1 to 2 inches of clearance on both upstream and downstream sides of the MH 363.

The following breaks, offsets, cracks, or areas of root intrusion were noticed in the sanitary sewer lines:

- The 6-inch clay pipe running north from MH 368 to northeast corner of Building 183.
  - Approximately 10 feet north of MH 368: Offset at joint in pipe
  - Approximately 80 feet north of MH 368: Area of root intrusion
  - Approximately 130 feet north of MH 368: Area of root intrusion (large mass of roots completely obstructed further survey of this line)
- The 6-inch clay pipe running north from MH 366 to MH 367 (south side of steam plant).
  - Approximately 40 feet north of MH 366: Crack at joint in pipe

These breaks and other distress features in the sanitary sewer lines are shown on Figure 3-5 and on engineering profile drawings developed for all sections of the sanitary sewer lines within the surveyed area (Figures 3-6 through 3-10).

Storm Sewers. The survey area included approximately 590 feet of storm sewer lines. The extent of the video survey included approximately 490 feet of this total (Figure 3-11). All video work was done using the larger camera. The areas of storm sewer lines that were not accessible to the video camera are described below:

- Approximately 80 feet of the 18-inch concrete pipe running southeast from the grate in the grassy area north of the northeast corner of Building 180/181 to Outfall C. This line connects with a former curb or box drain approximately 12 feet southeast of the grate. The line offsets at this point and was impassable to the camera. Also, large debris (rocks, pieces of cement, and dirt) could be seen in this line approximately 10 feet downstream of this point. It could not be determined whether the line had collapsed on itself or had just become clogged with debris. The terminating point to this line (Outfall C) was covered by fill material placed on the slope along the east side of Building 180/181 and was inaccessible to the camera.

- Approximately 30 feet of the 8-inch clay pipe running east from the grate in the driveway along the north side of Building 180/181 to Outfall D. The length of line from 20 to 53 feet west of Outfall D could not be surveyed because of sharp turns in the line.

The following breaks, offsets, cracks, or areas of root intrusion were noticed in the storm sewer lines:

- The 10-inch steel pipe running east from MH 369 to MH 368A.
  - Approximately 26 feet east of MH 369: Break in joint of pipe
  - Approximately 132 feet east of MH 369: Large cavity on north side of pipe (possible location of a service connection)
  - Approximately 159 feet east of MH 369: Crack in pipe of uncertain extent
- The 15- to 18-inch clay pipe running south-southeast from MH 368A to grate in the grassy area north of the northeast corner of Building 180.
  - Approximately 32 feet south of MH 368A: Slight offset (less than 1 inch) at joint in pipe
  - Approximately 68 feet south of MH 368A: Slight offset (less than 1 inch) at joint in pipe
  - Approximately 114 feet south of MH 368A: Slight offset (less than 1 inch) at joint in pipe
- The 8-inch clay pipe running east from the grate in the driveway along the north side of Building 180/181 to Outfall D.
  - Approximately 3 feet west of Outfall D: Offset (2 inches) in pipe at joint
  - Approximately 13 feet west of Outfall D: Offset (2 inches) in pipe at joint
  - Approximately 5 feet east of grate: Crack at joint in pipe of uncertain extent
  - Approximately 24 feet east of grate: Crack at joint in pipe of uncertain extent
  - Approximately 43 feet east of grate: Crack at joint in pipe of uncertain extent

These breaks in the storm sewer lines are shown on Figure 3-11. Engineering profile drawings were developed for all sections of the storm sewer lines within the surveyed area (Figures 3-12 through 3-14).

Smoke Testing. Smoke testing was performed in the 10-inch storm sewer line running along the south side of Building 183. The section of line to the west of MH 369 was smoke tested to help evaluate its point of origin (the video survey of this section of line was inconclusive because of heavy buildup of a greasy sludge within the line). No smoke was noticed coming from manholes or box drains outside Building 183, but smoke was present inside the building. This smoke came out of roof drains within the building; the source of water to the lines was thus established, but the distribution was not determined.

Dye Tracing. Five floor drains, one toilet drain, and one trench drain within Building 183 (Figure 3-15) were tested to evaluate the direction of flow. Dye tablets and water were added to the drain openings. The dye introduced to the floor drains was later seen in the 10-inch storm sewer line at the bottom of MH 368A. The dye introduced to the trench drain was later seen in the 6-inch sanitary sewer line at the bottom of MH 368. The dye introduced to the toilet drain was observed in the 6-inch sanitary sewer line at MH 368. None of the monitoring wells installed at this time were sampled and tested for the presence of any dye. The primary objective of dye testing was to determine sewer line connections.

The locations of floor and trench drains within Building 180/181 are provided on Figure 3-16. These floor drains had been previously filled with concrete. Because they were filled with concrete, these drains could not be dye tested.

3.1.4.2 Water Sampling at the Dry Cleaning Machines

Water samples were collected in April 1993 from the cooling water discharge lines connected to the two dry cleaning machines and from the 5-gallon bucket used to capture condensates associated with each of machines (the west and east machines operating at the current DCF [Building 183]). These condensates were formerly disposed down floor drains or to the sanitary sewer system. Currently these buckets of condensate are discharged to 55-gallon drums that are then removed by a licensed waste hauler. These water samples were analyzed to determine whether VOCs were present in the effluent from the dry cleaning machines.

3.1.4.3 Water Sample From Washing Machine

In January 1994, effluent from a washing machine used to launder the rags from the Consolidated Maintenance Facility, that is, garages, in Building 8110, was analyzed, At a frequency of about once or twice a month, the rags used in the garages — which would contain materials including but not limited to oils, greases, and lubricants — are laundered there.

3.1.4.4 Elevation Survey of Manholes

An elevation survey of selected manholes in the DCFA was performed to determine elevations of various sewer lines that intersect the manholes. These survey data are presented on Figure 3-17.

In conjunction with this elevation survey, surveying activities were performed inside Buildings 180/181 and 183 to locate the position of floor drains. The locations of floor drains within Building 183 are provided on Figure 3-15. These floor drains were dye tested (as discussed in Section 3.1.4.1) to determine the sewer lines to which they are connected.

3.2 RI Field Investigation

The IFI and earlier investigative efforts established the base from which to build the RI field investigations. Although addressing some of the same media, the RI investigations included more testing and evaluation of the media. In the following sections, soils geology, surface water, sediment, groundwater, and air media will be described in relation to the DCFA. In addition, several supplemental activities that contributed to an understanding of the site characteristics occurred and will be described. These included sanitary sewer line repair, investigation, flow studies, and groundwater monitoring; UST removal; comparative water level data evaluation; and data collected concurrently with activities related to pilot test studies.

During the investigations of various media, sampling procedures were conducted in accordance with the Comprehensive Basic Documents issued and revised (CEMRK, 1993f). Deviations from these procedures pertain to proposed sampling locations, which are addressed in Technical Memoranda (Appendix A-I). Investigation-derived waste was likewise handled according to the Basic Documents.

3.2.1 Surface Soils

Surface soil samples (0-1.0 feet) were collected in November 1993 during the RI at six locations to assess potential dermal exposure (Figure 3-18). Surface soils were collected in areas where trucks formerly parked to deliver PCE to the current DCF, where relatively high pedestrian traffic occurs, and where the storm sewer line that terminates in the steep west bank of Tributary A discharges. In addition, the 0- to 5-foot samples subsequently collected from soil and monitoring well boreholes provided additional data with respect to near-surface soil conditions.

Surface soil samples collected with a stainless steel scoop were placed into a stainless steel bowl and then immediately placed into sample containers. It must be noted that very little of the exposed soil in the area is likely to be native to the area. Native soils, and thus any contamination that may have been present, have most likely been covered or removed during the history of the site. The little soil present between the concrete and asphalt is either fill or crushed rock used to improve the surface for vehicular traffic. Less than 20 percent of the DCFA has exposed soil surfaces. The remainder of the area is paved, built upon, covered with crushed rock, or in extreme slope.

3.2.2 Geology

An interpretation of the geologic conditions associated with the site was based on a literature review, on data gathered during previous investigations, on a reconnaissance of outcrops on and adjacent to the DCFA, and on the installation of boreholes and monitoring wells during this RI. The boreholes and monitoring wells installed during earlier investigations of the area have been incorporated into discussions of the investigation recently completed.

Literature Review. A review of geologic reports completed by the U.S. Geological Survey (USGS) and the Kansas Geological Survey (KGS) was conducted to obtain information on the stratigraphy of the sedimentary rocks in the area. Four documents were particularly useful: KGS Bulletin 39, *Geology of Riley and Geary Counties*; KGS Bulletin 89, *The Kansas Rock Column*; KGS Bulletin 189, *The Stratigraphic Succession in Kansas*; and KGS Bulletin 206, *Ground Water in the Kansas River Valley Junction City to Kansas City, Kansas*. Bulletin 206 provided valuable information on the depth to bedrock below the Kansas River and on the hydrogeology of the alluvial materials adjacent to the DCFA.

The rock units encountered within the DCFA consist of the Council Grove and Chase Groups. The formations within these groups include the Havensville shale and Threemile limestone of the Council Grove Group, and the Speiser shale, Funston formation, Blue Rapids shale, Crouse limestone, and Easly Creek shale of the Chase Group. All these units are of Permian age and have similar characteristics within the respective media (i.e., the physical characteristics of the shales and the limestones are similar in both Groups) (Table 2-1). The shales are described as variegated, meaning that green, gray, red, and other coloration exists, and the limestones are described as being cherty.

Field Reconnaissance. As an initial step in understanding the geologic units presented in the DCFA, a walkover of the rocks exposed in and around the site was conducted prior to the installation of monitoring wells. This task began north of the DCFA in the area utilized as an outdoor chapel. The outdoor chapel resides on the base of the Fort Riley limestone, which is a prominent geologic feature (known as the Rimrock) throughout the post (Figure ES-2). From this location downward in elevation, the rock units outcropping consist of the Kinney limestone, adjacent to the road above the post cemetery; the Wymore shale and Shroyer limestone, behind the steam plant; and the Funston formation, adjacent to the railroad tracks below Building 180/181. Identification of these units in outcrop facilitated the stratigraphic interpretation of rock cores and rock cuttings.

3.2.2.1 Soil Borings

Soil borings were drilled during the IFI and the RI using hollow stem augers. The primary purpose of installing boreholes was to determine the lateral and vertical extent of contaminants in soils, characterize the unconsolidated materials, and determine the depth of bedrock. The unconsolidated materials ranged from a thin, dark, sandy soil to various fill materials, underlain by silts, clayey silts, and sands. These materials — interchangeably referred to as soils, overburden and unconsolidated materials — ranged in thickness from 3 feet along the west side of Building 183, to 42 feet south of Building 180/181. Figure 3-19 shows the location of the soil borings and Figure 3-20 shows the thickness of overburden materials over the site area.

Twenty-one soil borings, in addition to those completed during the PA/SI, were planned based on investigative work completed during the PA/SI and the IFI. Two boreholes planned for completion during the RI, DCFSB-23 and DCFSB-24, could not be drilled because of underground and overhead utilities. For the same reasons, no alternative locations in these general areas could be substituted. Boreholes during the RI investigation were drilled to bedrock using 8-inch hollow stem augers and continuous sampling procedures. The samples were screened with an HNu meter immediately upon exposure and collected for chemical laboratory analysis. The rationale for the location of the boreholes installed during the RI was to identify the lateral and vertical extent of contaminants in the overburden material and, in particular, to check for contamination adjacent to known sanitary sewer pipeline break. Table 3-2 provides the rationale for soil boring locations emplaced during this investigation.

In addition to samples collected for analyses of contaminants, samples were collected for geotechnical testing. Table 3-3 presents the test results, including moisture content, organic content, liquid limits, plastic limits, plasticity index, and soil classification. Soil classifications are based on the unified soil classification system (UCS). Review of the test data indicates that the subsurface materials are generally variable in texture, ranging from the slightly organic, plastic, silty sands (SM) to the highly plastic clays (CH). The moisture content data indicate that these materials are moist but unsaturated. Based on the grain size distribution curves, the materials can be regarded as uniform and well-graded (Appendix B-I).

The borehole data were used in conjunction with data from monitoring well installations to determine the top of bedrock in the area (Figure 3-21). The bedrock contour map provides a topographic expression of the rock surface beneath the site.

3.2.2.2 Monitoring Well Installation

The procedure for installing monitoring wells in the DCFA is described in the Revised Final Sampling and Analysis Plan (SAP) (CEMRK, 1993h) and accompanying Comprehensive Basic Document on Monitoring Well Installation (CEMRK, 1993f). Three installation procedures were followed depending upon the formation in which a well was to be completed. In the unconsolidated material, the well was drilled with hollow stem auger equipment, and the well was completed through the hollow stem. For wells completed in the upper Crouse limestone, a hole was drilled through the unconsolidated material to bedrock, a temporary casing was installed, and then a dual tube reverse air rotary rig was used to drill through bedrock to the upper Crouse formation. A monitoring well was then completed within the open hole below the surface casing, and the temporary surface casing was withdrawn.

For wells completed in the lower limestone unit of the Crouse formation, the well was cored and reamed to the shale below the upper Crouse, and then a permanent surface casing was installed to seal the upper Crouse limestone from the lower. After allowing the required time for the grout seal to set, the portion of the Crouse formation below the upper limestone was cored, then reamed with dual tube reverse air methods, and a well was completed opposite this lower limestone unit. All wells completed through and in rock material were geophysically logged during the times in construction when open hole conditions existed.

Seven groundwater monitoring wells were installed during the PA/SI, and 15 were installed during the RI (Figure 3-22). Of the PA/SI wells installed, four were completed in the upper limestone unit of the Crouse formation, and two were completed in unconsolidated materials (DCF92-01, DCF92-02, DCF92-04, and DCF92-06, and DCF92-03 and DCF92-05, respectively). Well DCF92-07, which was drilled to determine the presence of any perched water, was observed to be a dry hole. Figure 3-23 shows the top of casing elevations and the geologic unit in which each well was completed.

Of the RI wells installed, six were completed in the upper limestone unit of the Crouse formation, wells DCF93-08, 12, 14, 15, 16 and 17; three were completed in the lower limestone unit of the Crouse formation, wells DCF93-18, 19, and 20; and two, DCF93-13 and DCF94-21, were completed in the unconsolidated materials beneath the site. Four wells were also driven into the alluvial materials south of the railroad and Building 180/181 (wells DCF93-09, 10, 11 and 22). DCF94-22 was driven into the alluvium south of DCF94-11 when 11 could not be sampled as a result of water level declines. The well locations were selected to further define the horizontal and vertical extent of subsurface contaminants. The specific rationale for location of the wells is provided in Table 3-4.

The three wells originally expected to be completed in the Middleburg member of the Bader formation, wells DCF93-18, DCF93-19 and DCF93-20, were ultimately installed in the lower limestone unit of the Crouse. The first of these to be drilled, DCF93-18, was cored to a depth of 140 feet below land surface into the top of the Bader limestone. From the bottom of the lower Crouse to this depth, the hole was dry. A decision was then made to screen the first water-bearing zone below the upper Crouse limestone. This turned out to be the lower Crouse limestone. Cores and geophysical logs were taken on these three holes, and all wells completed in the Crouse were geophysically logged. As-built drawings and geologic and geophysical logs for the wells completed during the RI can be found in Appendix B.

3.2.2.3 Geophysical Logging

Borehole geophysical logs were recorded using COLOG portable logging equipment (Table 3-5). The following borehole geophysical tools were planned to be used:

- A gamma/stratigraphic tool, consisting of natural gamma, single-point resistance, and spontaneous potential;
- A caliper tool; and
- A combined temperature/fluid resistivity tool.

It was not always possible to record the full suite of geophysical logs in all monitoring wells due to the lack of fluid in wells immediately after drilling, electromechanical failure of logging equipment, and calibration problems with the caliper tool. Attempts to correct or remedy these problems could not always be accomplished in the field, given the required time for well construction. Although the amount of data collection planned was reduced, interpretation of geologic conditions was not impacted.

The natural gamma log depicts the difference between shales and other materials very well, and provides repeatable data for the same geologic materials. This allows correlation of formations from well to well. The gamma logs were used to determine the thicknesses and depths of the Crouse limestone, which were correlatable among the wells being installed. Additionally, a natural gamma log taken in existing well DCF92-06 was found to correlate with the screened interval of the 1993 wells being installed. Copies of the logs are provided in Appendix B-II.

Correlating from west to east among the recently installed monitoring wells DCF93-08, DCF93-19, DCF93-15, DCF93-14, and DCF93-12, the upper Crouse limestone is well-defined on the gamma logs. Two thin distinctive limestone stringers, each approximately 1.5 feet thick, occur in the base of the Blue Rapids shale just above the Crouse. The elevations of the top of the Crouse formation were determined from these logs and correlated with other borehole data, and a structure contour map of the top of the Crouse formation was prepared (Figure 3-24). In monitoring wells DCF93-18, DCF93-19 and DCF93-20, the lower limestone unit of the Crouse formation was also correlatable among the natural gamma logs of these wells. The shale unit separating the upper and lower limestone in the Crouse formation is approximately 9 feet thick.

The spontaneous potential and single-point resistance logs recorded in wells DCF93-17, DCF93-18, and DCF93-19 support the correlations of the upper and lower screened intervals. Temperature logs, recorded in wells DCF93-08, DCF93-17, DCF93-18, and DCF93-19, were too few to provide a basis for areal interpretation of the data.

3.2.3 Surface Water and Sediment

Surface water and sediment are discussed in the same section because sampling of these two media occurs essentially at the same location and time. On the site, there are no standing bodies of water and only two surface drainages. The two surface drainages were designated as Tributary A and Tributary B during the PA/SI. Tributary A is located to the east of Building 180/181 and is tributary to Tributary B. The drainage area for Tributary A is approximately 140 acres (Figure 2-1). Both tributaries are designated as ephemeral streams, meaning that the stream bottom is above the water table and no flow exists except following a precipitation event.

Tributary B is not depicted on USGS topographic maps and is evidenced only by a slight depression until it meets Tributary A. Following the flood of 1993, Tributary B, in the stretch upstream of Tributary A, became more of a swale or drainage ditch than a stream channel due to deposition of sands during the flood. Flood levels for the 10-, 50-, and 100-year flood events, and for the 1951 and 1993 flood events, are shown on Figure 2-6.

Three surface water and sediment samples were collected during the PA/SI, and two more sample collections were planned to be taken during the RI. Figure 4-6 shows the locations of all sediment and surface water sample locations. Concentrations are discussed in Chapter 4. One of the two surface water samples to be collected during the RI, was to have been upstream on Tributary B; however, it was dry at the time of sampling and only a sediment sample could be collected. Results of all surface water sediment sampling events are shown in Tables 4-6 and 4-7.

3.2.4 Groundwater

The groundwater investigation is discussed in relation to three characteristics: recharge, movement, and discharge. Sections 2.4 and 3.2 provide information on the geologic environment in which groundwater is being evaluated for the DCFA. There are basically three hydrogeologic units of interest with respect to the DCFA: the sedimentary limestones of the Crouse formation, the unconsolidated materials adjacent to Building 180/181, and the alluvial materials beneath The Island and associated with the Kansas River.

All three geologic units are hydraulically interconnected, and the discussion relating to recharge, movement and discharge will be identified when a distinction is necessary. A discussion of river water levels and groundwater levels on The Island is provided to relate the interconnection between surface water and groundwater. The data gathered from previous investigations (PA/SI and IFI) have been evaluated and incorporated in the discussions that follow. Results of work conducted during supplemental RI activities discussed in Section 3.3 are also incorporated.

3.2.4.1 Recharge

Recharge to groundwater within the DCFA and The Island is occurring as a result of three mechanisms: infiltration of precipitation; when water levels in the river rise above the adjacent levels of groundwater; and as a result of leakage from storm and sanitary sewer lines that traverse the site. The storm and sanitary sewers are above the water table such that leakage migrates downward and recharges the groundwater. Where those leaks occur in the unconsolidated materials, a groundwater mound has developed. This discernible mound is reflected by the contours in Figure 3-25 and by the schematic in Figure 3-26.

A potentially third source of recharge may be from the northeast in the Tuttle Creek Reservoir area. The Crouse formation is known to outcrop in this area and would receive infiltration from precipitation. Given the thickness and characteristics of the limestone units within the Crouse, less than 6 feet for the upper limestone and less than 5 feet for the lower, the potential for significant recharge from this source is not great.

Recharge in the lower Crouse limestone could occur in the area east of Building 180/181 where the upper Crouse, and a large portion of the shale between limestone units, has been eroded. However, the lower Crouse limestone is beneath the level of the river during most years, and could be recharged by the river (Figure 2-6). No data exists to determine definitively if the Kansas River is gaining or losing through the stretch of river that passes the DCFA.

3.2.4.2 Groundwater Movement

An evaluation of the movement of groundwater was based on evaluation of water levels obtained for wells completed in the upper Crouse limestone and in the unconsolidated materials (Table 3-6). Figure 3-27 shows contours of water levels from wells completed in the upper Crouse limestone. This figure shows groundwater movement to be to the southwest. Figure 3-28 shows contours of water levels from wells completed in the unconsolidated materials beneath the site. These contours also reflect movement to the southwest. Contouring of water levels in both media results in the configuration shown on Figure 3-25.

Groundwater movement is primarily to the southwest; in addition, mounding in the area of unconsolidated materials is evidenced by the contours that extend from the northern edges of the unconsolidated materials and loop southwest toward the alluvial materials. This mounding is a result of the higher permeability of the unconsolidated materials compared to the surrounding bedrock. Contribution of recharge from the leaking sewer system accentuates the presence of the mound. No specific effects to contaminant transport result because of the groundwater mounding. PCE that entered the system via the leaking sewer lines would continue to move in the south-southwest direction until reaching the alluvium, where it would then move to the east with the groundwater in the alluvium.

Movement of groundwater to the east, essentially parallel to the Kansas River, is evidenced by the water level elevations in wells DCF93-09, DCF93-10, and DCF94-22. This phenomenon is more readily observed in the work conducted by Fader (1974). In his study of groundwater in the Kansas River Valley from Junction City to Kansas City, Kansas, the flow through the floodplain alluvial deposits is essentially parallel to the valley.

Groundwater movement vertically is limited by the shale units that occur between the various limestone formations (Figure 2-5). Of particular interest is the vertical movement of groundwater from the unconsolidated materials east of Building 180/181 to the upper Crouse limestone, the movement between the upper and lower limestone units of the Crouse formation, and any vertical movement downward to beds below the Easly Creek. Vertical movement from these unconsolidated materials to the underlying bedrock units is dependent upon the level of water in the river. Figure 3-29 shows the relationship of water levels in wells completed in the unconsolidated materials east of Building 180/181 with the water level in the river, and Figure 2-6 shows the position of the underlying geologic units with respect to the river.

Vertical groundwater movement, interconnectivity between the upper and lower Crouse units, was to have been evaluated by conducting a pumping test in the lower Crouse limestone and measuring water levels in adjacent wells completed in the upper Crouse limestone. The wells intended to be pumped for this test were the lower Crouse wells DCF93-19 or DCF93-20. Water levels were to be measured in adjacent upper Crouse wells DCF92-04 or DCF93-12 respectively. Lack of measurable water in the upper Crouse limestone wells (DCF92-04 or DCF93-12) and insufficient yields from the lower Crouse limestone wells (DCF93-19 or DCF93-20) made this test impractical to conduct. Figure 3-30 shows water levels within wells completed in both the upper and lower Crouse limestone units. This figure shows that the water level in the upper Crouse is above the water level in the lower Crouse, and the potential for downward movement exists. The water level in the lower Crouse however, is above the top of the lower Crouse unit indicating a confined condition. The vertical downward movement of groundwater from the upper to the lower Crouse is therefore strongly inhibited. (Figures of contours for water levels of all sampling events are provided in Appendix H-I).

Both the upper and lower Crouse limestone units are exposed to the alluvium, and both are subject to recharge when water level elevations are above elevations of these rock units. Based on the groundwater elevations recorded during quarterly sampling events, the potential for flow from the upper Crouse to the lower Crouse does exist. Shale between these two units impedes this flow, and the lower Crouse is a confined unit between the shale unit of the Crouse and the underlying Easly Creek Shale Formation (Figure 2-5).

Potential movement from the alluvium to bedrock units below the alluvium exists along the extent of the river. This downward movement or recharge potential is retarded by the shales of the Easly Creek formation.

Along the west side of Building 180/181, the thickness of unconsolidated materials is considerably thinner. Any vertical movement of surface spills or discharges would readily move downward through the unconsolidated materials, and then through fractures in the underlying shales and limestones. Preferred permeability pathways created by the numerous utilities that transect the site would also deter the downward migration of fluids. Ultimately, all fluids and groundwater move to the south to the alluvium before becoming part of the alluvial groundwater system that is moving to the east. Figure 3-30 shows the geologic conditions along the west side, and Figure 3-31 shows the potentiometric contours associated with the site and schematically included for The Island.

In an effort to obtain an indication of the hydraulic conductivity of the water-bearing units beneath the DCFA, slug tests were conducted in seven wells. The tests consisted of inserting and withdrawing a section of pipe sealed at both ends into a well to effect a rise or fall in water level that is measured with a pressure transducer (DCF92-02, DCF92-03, DCF92-05, DCF93-13, DCF94-21, DCF94-ES2B, and DCF94-ES3B). These tests were conducted to obtain information on aquifer properties for use in the design of a groundwater extraction system for the pilot study. All wells, except DCF92-02, are completed in the unconsolidated materials beneath the site. DCF92-02 is completed in the upper Crouse limestone. A description of the slug test procedures and analytical methods is provided in Appendix F-I.

The values of hydraulic conductivity (k) from slug tests ranged from 13.0×10^{-4} cm/sec (25.1×10^{-4} ft/min) to 1.9×10^{-4} cm/sec (3.7×10^{-4} ft/min) (Table 3-7). These values are consistent with hydraulic conductivity values characteristic of silty to fine sands present in the area. Hydraulic conductivity obtained for well DCF92-02 falls within the range of values for the unconsolidated materials. The value obtained, 5.5×10^{-4} cm/sec, is close to the average for the unconsolidated materials. Appendix F-I provides more detailed discussion of the slug test methods and results. The calculated values of hydraulic conductivity determined by the slug test do reflect the relative yields of the wells; i.e., those with higher hydraulic conductivity also had higher yields. Well DCF94ES-2B had the lowest yield (0.2 gpm) and the lowest hydraulic conductivity. The reverse is true for well DCF93-13. Hydraulic conductivity was also estimated using grain size distribution data obtained from soil samples collected during the various investigations (Tables 3-8 and 3-9). Hydraulic conductivity values obtained from these methods ranged from 6.7×10^{-7} cm/sec to 2.5×10^{-4} cm/sec. Geotechnical test data can be found in Appendix I.

3.2.4.3 Groundwater Discharge

Groundwater discharge from the DCFA is to the alluvial materials and ultimately to the Kansas River. Elevation of the bedrock beneath the river opposite the DCFA is estimated to be 990 to 1,000 feet, which is below the elevation of the Crouse limestone beneath the site (Fader, 1974). The depth of sediment in the river in this area varies; however, the datum of the USGS surface water gaging station at the Marshall Field bridge is set at 1,034.69 feet. This suggests that there may be approximately 35 feet of alluvium over the bedrock including the Crouse formation in this area. Surface water elevations fluctuate around the 1,049-foot level, and the elevation of the upper Crouse limestone is around 1,052 feet. Thus, groundwater discharge from the Crouse and from the unconsolidated materials would ultimately be to the river. The river will serve as a receptacle for groundwater whenever groundwater levels are higher than the river, and as a recharge source during times river levels are higher than groundwater (Figure 2-6).

3.2.4.4 Comparative Water Level Data

During the later stages of the RI, water levels in the alluvium of The Island were recorded to compare these data with the stage (elevation of river water) of the Kansas River. The objective of conducting this comparative analysis was to evaluate the extent to which the river had an effect on water levels in the alluvium and beneath the site. August 1994 was the first month for which such data were compiled. Figure 3-32 shows the correlation of water levels between the Kansas River and well DCF94-22 installed in the alluvium. This figure clearly shows the close correlation between the alluvial groundwater levels and the level of the Kansas River. Water levels for the Kansas River were obtained from the USGS for the gaging station (06879100) located at the bridge on Henry Road west of Marshall Army Air Field. This gaging station is approximately 1,400 meters (4,620 feet) downstream from the DCFA. Therefore, water level elevations opposite the site would be a few feet higher than those recorded downstream. The isolated peaks occurring on the plot of river water levels are attributable to release from the Milford Reservoir during periods of high water. These releases were too short-term to have been reflected in well DCF94-22.

A comparison of water level data was also made for the wells completed within the DCFA. Figure 3-33 shows the level of the river with respect to the water level in these wells. From February 1993 to

September 1993, the level of the river was above the level in the wells. This meant that the river was recharging the groundwater. From September 1993 to September 1994, a decline in both river and groundwater levels occurred. Wells DCF93-09, DCF93-10 and DCF94-22 completed in the alluvium of The Island, as expected, respond more closely to changes in river level. Similar hydrographs for wells completed within the different geologic materials and for individual wells are provided in Appendix H-II. The conclusion to be drawn from these comparisons is that the groundwater beneath the DCFA is hydraulically connected to the Kansas River.

3.2.5 Air

A small percentage of the land area in the immediate vicinity of the DCFA is unpaved or without a structure (Figure 1-2). The unpaved area is grass-covered such that the potential for contamination, if it were present from shallow soil fugitive dust, would be minimal to non-existent. A review of surface soil sample analyses and of the 0- to 5-foot soil samples collected over the DCFA showed non-detects. The only potential for contaminant migration via air would be from exposure of contaminated soils during excavation activities. During the sanitary sewer line repair (Section 3.3.1), air monitoring was conducted for health and safety purposes and for the purposes of determining if this activity released contaminants of measurable quantity. No readings at or above levels, taken to be 75 ppm, were recorded during this activity (CEMRO, 1994b). Figure 3-34 shows the location of air monitoring stations utilized during the excavation.

In addition to the air monitoring conducted by the rapid response contractor, the U.S. EPA was requested to conduct a one-day survey of air quality during the excavation of the sanitary sewer line. An Open Path Fourier Transform Infrared Spectroscopy (OP-FTIR) was used to conduct ambient air measurements of targeted VOCs that may be emitted during the excavation. The target compounds for this air monitoring consisted of tetrachloroethylene, dichloromethane and 1,1,1-trichloroethane. Field-generated detection limits established for the compounds were 22.8, 34.5, and 5.3 ppb, respectively. "None of the target compounds were identified above their actual field levels of detection over the entire duration of this survey" (U.S. EPA, 1994b).

3.2.6 Analytical Procedures and Sample Locations

All analytical methodologies employed during the course of the field investigations, the PA/SI (March 1992 through February 1993), the IFI (February 1993 through November 1993), and the RI (November 1993 to January 1995) followed protocols established in U.S. EPA SW-846, Third Edition, July 1992. Use of these methods, identified in the associated work plans for the investigations, ensures that the data generated will be comparable.

Method Detection Limits (MDLs) for all methodologies are derived from the Department of the Army Regulation ER 1110-1-263 and the Kansas Department of Health and Environment. MDLs for the RI are listed for VOCs and SVOCs, respectively, in Exhibits 1-3 and 1-4 of the Quality Assurance Project Plan (QAPP) for Site Investigations at Fort Riley (CEMRK, 1993g). MDLs associated with the PA/SI are provided in Tables 6-4 (VOCs) and 6-5 (SVOCs) of the Draft Final Modified Chemical Data and Acquisition Plan and Site-Specific Sampling and Analysis Plan (CEMRK, 1992c).

The Data Quality Objectives of the RI are to gather sufficient and reliable sampling data to characterize the nature and extent of potential risks posed by previously uncontrolled releases of PCE within the DCFA. A quantity of data sufficient to represent the site has been detailed by locations and media in Chapter 3 of the Draft Final Sampling and Analysis Plan (CEMRK, 1993h). Data quality is assessed through Quality Assurance/Quality Control (QA/QC) samples, such as field blanks, trip blanks, split samples sent to the Missouri River Division Laboratory (MRD) for third-party QA, and analysis of blind field duplicate samples. The accuracy, precision, and usability of the analytical results are assessed through standard validation methods for review of laboratory protocols and the laboratory QC Report. Assessment of data generated from samples collected during the RI was reported under separate cover in the Quality Control Summary Reports (QCSRs) (CEMRK 1994a,b,d,e,f,i,j,k,l,m and 1995a,b) and is summarized in Section 3.4.

The Target Compound List (TCL) for VOCs includes 37 analytes; some of these are low molecular weight halogenated hydrocarbons associated with dry cleaning processes, particularly PCE and its breakdown products. The TCL for SVOCs includes 65 analytes that encompass a broad range of chemical compounds, found in sediment and surface water samples from sewer lines around the site. For both VOCs and SVOCs, gas chromatography/mass spectroscopy (GC/MS) was the methodology used for analyte detection.

In addition to the VOCs and SVOCs analyzed, additional parameters were analyzed on specific occasions. During the PA/SI in November 1992, three metals — iron (Fe), manganese (Mn) and magnesium (Mg) — as total recoverable metals and inorganic parameters were analyzed for all six of the groundwater monitoring wells in place. This was the only time that this suite of analyses was performed in its entirety. One additional sampling event in February 1993 included the metals identified above, but only for well DCF92-04. In addition, as indicated in Section 1.2.3.4, one sample, DCF92-04, was also analyzed for U.S. EPA 8015 for fuel identification.

Samples were collected and analyzed during the various investigations from March 1992 to January 1995. These events are shown below by date, medium, number of samples, and type of analysis.

- **PA/SI**

March 1992	soil	32 @ 15 locations	VOC/SVOC
March-April 1992	soil	29 @ 6 locations	VOC/SVOC
March 1992	surface water	3	VOC/SVOC
March 1992	sediment	3	VOC/SVOC
July 1992	groundwater	6	VOC/SVOC (DCF92-04 for 8015)
November 1992	groundwater	6	VOC/SVOC; iron, manganese, magnesium; inorganics (see Table 4-13)
November 1992	aqueous storm sewer	1	VOC/SVOC
	sewer sediment (1 sanitary, 1 storm)	2	VOC/SVOC
February 1993	groundwater	6	VOC/SVOC

- **IFI**

February 1993	surface water	2	VOC/SVOC
February 1993	sediment	2	VOC/SVOC
February 1993	aqueous sanitary sewer	7	VOC/SVOC
February 1993	aqueous storm sewer	3	VOC/SVOC

- **RI**

November 1993	soil borings	73 @ 28 locations	VOC: all SVOC: 6
(Note: 31 locations proposed in Work Plan, 28 actual as enumerated in Tech Memo)			
November 1993	groundwater	6	VOC SVOC (DCF92-04)
November 1993	surface water	2	VOC
November 1993	sediment	4	VOC
November 1993	surface soils	6	VOC/SVOC
December 1993	groundwater	16	VOC/SVOC
December 1993	surface water	1	SVOC
February 1994	groundwater	18	VOC/SVOC
May 1994	soil	9 @ 4 locations	VOC 8010
June 1994	groundwater	15	VOC/SVOC
July-August 1994	groundwater	20	VOC
October 1994	soil	9 @ 3 locations	VOC 8010
October 1994	soil (from UST location)	16 @ 3 locations	VOC: for most SVOC: TPHC GRO/DRO
January 1995	groundwater	19	VOC
January 1995	seep	2	VOC
January 1995	surface water	7	VOC
January 1995	sediment	18	VOC

3.3 Other Activities Concurrent with the RI

In May 1994, during the installation of groundwater extraction wells for a pilot study within the DCF, the elevated groundwater temperatures were found to persist in the area to the northeast of Building 180/181. This finding led to the supposition that leakage was occurring along the sewer line adjacent to the wells, which is between MH 363 and MH 363A. In an effort to verify this supposition and to evaluate the effects on the local groundwater conditions, investigations of the sanitary sewer line between MH 363 and 363A were initiated in conjunction with the previously scheduled sewer line repair. These investigations consisted of flow studies and hydrostatic testing.

The presence of USTs was suspected on the northwest side of Building 180/181 and investigated and removed by a rapid response contractor under contract with the Omaha District of the U.S. Army Corps of Engineers. Electromagnetic surveys were conducted that confirmed the locations (CERMO, 1994a).

In conjunction with the pilot test study, a sustained yield test, a groundwater test, and slug tests were planned. The first of these activities conducted was the sanitary sewer line repair. This work was conducted by a rapid response contractor under contract to the Omaha District of the U.S. Army Corps of Engineers, and is described here based on a review of the resulting report (CEMRO, 1994b). These activities, in addition to the UST removal, are described in the sections that follow, as well as a description of comparative water levels between the Kansas River and the alluvial groundwater.

3.3.1 Sanitary Sewer Line Repair

The sewer line repair work took place between sanitary MH 365, located in the middle of Custer Road, and MH 363, located adjacent to Building 180/181. Figures 3-35 and 3-36 show the location of this repair work and the as-built details, respectively. Screening of soils excavated was conducted with a photoionization detector at intervals of 7 cubic yards. Action limits for upgrading to a higher level of personal protection were set at readings of 75 ppm; however, levels measured were considerably lower (CEMRO, 1994b). In addition to the screening of excavated materials, air-monitoring stations were established at various locations during conduct of the work from which air samples were collected for analysis (Figure 3-34). All analyses showed non-detects for PCE, acetone, and dichloromethane (Appendix F-HI) (U.S. EPA, 1994b).

During the excavation work, an 8-inch clay tile storm sewer pipe was ruptured but not immediately repaired. The contractor was advised by Directorate of Engineering and Housing (DEH) personnel at the time of the rupture that the line was abandoned. Subsequent to demobilization, it was learned that the line was active. DEH personnel made the appropriate repairs. Also during excavation, the sanitary sewer line being replaced was found to be disconnected from the manhole. (It should be noted that the odor and discoloration typically associated with prolonged sewage discharge were absent from the immediate area where the sanitary sewer line was disconnected from the manhole.) A sample of excavated material was collected and analyzed for PCE before it was conveyed to the construction/debris landfill on Fort Riley to be used as daily cover. This sample contained 25.1 μg/kg of PCE (CEMRO, 1994a). These analytical data were submitted to KDHE, and approval was obtained before the excavated material was used as daily cover at the landfill (Interoffice Memo KDHE to DEH 6/22/94, Appendix G).

From a site characterization viewpoint, the lack of connection between the sewer line and the manhole represented a potentially significant contributing source to the groundwater beneath the site. If the disconnect had been in existence for an extended period (prior to October 1993), it would have allowed for entry of PCE into the unconsolidated materials and ultimately to the groundwater. In October 1993, Fort Riley cemented all floor drains and implemented maintenance management measures that have prevented any subsequent releases to the sewers and, thus, to the environment.

In addition, this disconnect, in conjunction with other sewer line leakage identified by video survey, would cause local recharge to groundwater. A review of water level elevations in Table 3-6 and Figure 3-26 illustrates the mechanism for the presence of mounding. Subsequent to the repair, this recharge would have been considerably reduced. It appears that the removal of the artificial recharge from the unconnected sanitary sewer line, in conjunction with recession of 1993 flood waters, has caused some of the monitoring wells completed in the upper Crouse limestone to become dry (Figure 3-33). The bottom of the upper Crouse limestone is at an elevation of 1,048± feet across the site.

3.3.1.1 Sanitary Sewer Line Investigation

The sanitary sewer system serving the DCFA was initially investigated by video surveying (Section 3.1.4.1). At that time, video cameras were introduced into the various lines to determine the physical conditions of the piping. Figure 3-5 shows the locations of breaks and blockages along the sanitary sewer lines. In May 1994, the sewer line between MH 365 and MH 363 was replaced, as described in Section 3.3.1, by a rapid response contractor under contract with the Omaha District of the U.S. Army Corps of Engineers.

In June 1994, construction of a pilot test system was initiated that included the installation of background, monitoring, and extraction wells. During this stage of the preparation for pilot testing, elevated groundwater temperatures were encountered and found to range from 75 to 88 degrees Fahrenheit (29 to 32.5 degrees Celsius) in the newly installed extraction wells, DCF94ES-1B, DCF94ES-2B, and DCF94ES-3B. In an effort to verify the source of the elevated groundwater temperatures (strongly suspected to be the sanitary sewers), supplemental sewer line investigations were proposed. These consisted of flow study and piping integrity evaluations, and groundwater temperature and level monitoring.

3.3.1.2 Flow Study and Piping Integrity Evaluations

In July 1994, preparations for the diversion of the sanitary flow between MH 363 and MH 363A were made by first conducting a flow study on the lines between MH 363 and MH 345. A survey logger was installed in the sanitary pipe entering MH 345 from MH 363A to record daily flow. A graph of this data is shown in Figure 3-37. The results of this survey show that the flow through the system, less any leakage, followed a cyclical pattern. In the early morning hours from 0600 to 1100, flows increased from less than quantifiable (below 15 gpm) to an average of 107 gpm. A peak flow of 206 gpm occurred shortly before 1100 hours. With the exception of another smaller peak around 1400 hours, the flow from 1100 to 1800 hours decreased to less than 15 gpm. The daily average flow rate was approximately 60 gpm.

After obtaining these baseline data, a diversion from MH 363 to MH 345 was installed. With the survey logger still in place, various controlled flows of clean water were introduced into MH 363 and recorded in MH 345. A comparison of flow-in versus flow-out indicated a loss of 13.65 gpm while introducing a flow of 160 gpm (Figure 3-37). At lower introduced rates, the losses were also lower: 6.5 gpm with a flow of 130 gpm, and 1.3 gpm with a flow of 80 gpm.

The integrity of the piping system was further evaluated by conducting a hydrostatic test on the sanitary sewer line from MH 363 to MH 363A. This test consisted of installing a plug in MH 345 and installing a pressure transducer in MH 363 to measure water levels. Water was fed into MH 363 until a constant water level was observed in both MH 363 and MH 363A (Figures 3-37 C and D). When this occurred, flow into MH 363 was stopped and water levels were recorded in both MH 363 and MH 363A. Figure 3-37D shows the decline in water level after inflow to MH 363 was stopped. It can be concluded, based on the flow test and the hydrostatic test, that leaks exist in the sanitary sewer line segment between MH 363 and MH 363A, but the specific location cannot be determined on the basis of this testing.

3.3.1.3 Groundwater Monitoring

From 16 June to 22 July 1994, prior to the diversion and testing activities discussed above, temperature, conductivity and water level elevations were being recorded in wells DCF94ES-1B, DCF94ES-2B, and DCF94ES-3B, DCF92-02, DCF92-03, and DCF92-05, and in wells DCF93-13 and DCF-94-21 to establish baseline conditions. (These data were recorded manually or with continuous monitoring probes. The temperature-monitoring probes were found to be insensitive to the changes occurring, and the data were not used.) Groundwater samples were also collected from the extraction wells and analyzed to establish baseline chemistry (Table 4-25). Monitoring of these wells continued throughout the various testing activities and for a period of 12 days beyond cessation of the diversion program. Graphs of these data are provided in Figure 3-38.

Quarterly water level data indicate a trend of declining water level within the DCFA (Figure 3-33). This trend is especially apparent in wells DCF93-09, DCF93-10, and DCF93-11, which are located in the alluvium of The Island and are more responsive to water levels in the river. Because the silts and sands of The Island are contiguous with the silts and sands beneath the site, water levels beneath the site are influenced by changes in river water levels.

Based on the graphs developed, a response in temperature was observed for 5 days after the diversion was begun (Figure 3-39). These minor temperature fluctuations were similar to the temperature fluctuations observed in the sanitary sewer system (Figure 3-40). Attempts to calculate the time for dissipation of the elevated groundwater temperatures were unsuccessful because of the many variables involved, including the time when leakage first began, the effects of natural recharge, the effects of convective heat transfer, the presence of any preferred pathways to the wells, and the effects of concrete-covered areas. Groundwater temperatures recorded for the quarterly sampling events are shown on Figures 3-41 and 3-42. Fluctuations in groundwater elevations were minimal throughout the short period during which various testing activities were conducted. Conductivity readings were found to be too variable to serve as useful data.

In addition to the groundwater monitoring discussed above, contaminants detected during quarterly monitoring were graphed to establish a point of reference within the DCFA (Figures 3-43a through 3-43u). Well DCF92-01 served as a background well and exhibited no change in concentration. Well DCF92-02 is located where the center of highest concentration in the area was found earlier in the investigation. Wells DCF92-03 and DCF92-05 are downgradient from this former center of highest concentration. It can be seen from the graphs that the area of highest concentration has migrated downgradient (south) to where wells DCF92-03 and DCF92-05 are located (Figure 3-43). This migration is commensurate with the local groundwater flow direction.

3.3.2 Pilot Test Studies

The sustained yield and groundwater tests were conducted over the period of 15 August through 22 August 1994. The sustained yield test was conducted to measure the maximum continuous flow rate that could be expected from the extraction well pumps installed in extraction wells DCF94ES-1B, DCF94ES-2B, and DCF94ES-3B. Figure 4-5 shows the location of the extraction wells.

During installation of the extraction wells, soil samples were collected to obtain additional baseline PCE concentration data in the soils. The results are shown in Table 4-5. The highest concentration detected was 130 μg/kg. The groundwater test was conducted to evaluate the effects on the system of pumping the extraction wells at a maximum sustained yield.

The procedure for the sustained yield test consisted of operating one pump at a time for a period of 6 to 8 hours to establish a maximum sustained flow rate for that pump. The sustained yield for each of the extraction wells when tested individually was 0.23, 0.16, and 0.34 gpm for wells DCF94ES-1B, DCF94ES-2B, and DCF94ES-3B, respectively. The combined yield of the wells was 0.73 gpm. After the individual sustained yield tests were completed, the wells were allowed to receiver before the groundwater test, during which all three pumps were pumping, was initiated.

In a separate test initiated on August 19, 1994, all three pumps in extraction wells DCF94ES-1B, DCF94ES-2B, and DCF94ES-3B were started within approximately 2 minutes of each other and were allowed to pump continuously for 74 hours at a constant rate of 0.73 gpm. During this test, the water levels and temperature were recorded in the adjacent monitoring wells as noted above. The data are shown in Appendix F-II. The water level measurements recorded in well DCF92-03 during the sustained pumping were evaluated to determine if hydraulic conductivity values could be calculated. These data were not able to be so utilized.

The extremely low discharge from the combined pumping of the wells did not provide sufficient stress on the system to yield interpretable data.

The DCF Pilot Study was initiated in the fall of 1994 and investigated the potential impact of dry cleaning operations on soils. The 30-day study involved continuous operation of 4 vapor extraction wells, from which VOCs were removed. The study began on 21 November 1994, and ended on 20 December 1994. The starting total VOC removal rate was 0.78 pound per day. At the end of the 30-day study, the total VOC removal rate was 0.41 pound per day. The total mass of VOCs removed totaled 21 pounds over the duration of the study.

3.3.3 UST Removal

Subsequent to replacement of the sewer line, excavation along the northwest side of Building 180/181 was conducted to determine the presence of suspected underground storage tanks (USTs). Verification of the presence and content of these tanks was determined to be important for further site characterization. Analytes other than PCE found in monitoring wells, such as toluene, might be attributable to materials previously stored in the tanks. The presence of the tanks was initially identified by U.S. Army Construction Engineering Research Laboratories (USCERL) utilizing an electromagnetic profiling system. Surveys were conducted in two areas adjacent to Building 180/181 (Figure 3-44). No indication of a tank was identified in Area 1, but a tank was identified in Area 2 (USCERL, 1994).

The excavation revealed three cylindrical steel tanks installed vertically. Tank capacities were 300, 500 and 5,000 gallons for USTs 1, 2 and 3, respectively (Figure 3-45) (CEMRO, 1994b). The tanks were accessed and contents were transferred to a vacuum truck for disposal at a licensed facility. Removal of the 5,000-gallon tank, which extended approximately 20 feet below grade, was impractical, as it would have jeopardized the integrity of Building 180/181 and an adjacent water main. Therefore, the 5,000-gallon tank was abandoned in place and filled with washed sand. (A KDHE representative was present during the UST in-place abandonment.) The two smaller tanks and associated piping were cleaned and removed. (Photos of the tanks are provided in Appendix F-IV.) Cleaning consisted of purging with nitrogen to render the gases inert and then flushing the tanks. Rinseates were transferred to a vacuum truck for disposal. Samples were taken of tank content and analyzed by U.S. EPA Methods 8240 and 8270. Results of these analyses can be found in Tables 4-27 and 4-28.

Six soil samples were taken from soils beneath the tanks and analyzed for volatiles, semivolatiles, and total petroleum hydrocarbons (TPH). U.S. EPA Methods 8240 and 8270 were used for VOCs and SVOCs, respectively. Both a gasoline and a diesel range were analyzed using modified U.S. EPA Method 8015 for TPH. The six samples were identified as follows:

- 001 from the bottom of Tank 1;
- 002 from the bottom of Tank 2;
- 003 from the west end of the excavation;
- 004 from the bottom side of the south wall;
- 005 from the bottom side of the north wall; and
- 006 from the top side of the south wall.

Analytical results of all samples collected in conjunction with UST removal can be found in Section 4.8.3.

3.4 General Evaluation of Data Adequacy

A considerable amount of data has been collected during the course of the PA/SI, IFI and RI investigations. These data have been discussed in this and preceding chapters; however, prior to providing a discussion on the nature and extent, it is helpful to evaluate this data. The following sections provide this evaluation.

3.4.1 Evaluation of Previous Investigations

Evaluation of previous investigation data during the RI process facilitates both an understanding of site conditions and development of appropriate field programs. The following paragraphs present an evaluation of the data generated during the PA/SI investigation and the IFI.

The data collected during these investigations indicate that the soils and groundwater in the DCFA have been contaminated with VOCs and infrequent detections of SVOCs. The area with the greatest concentrations of subsurface contaminants (mostly chlorinated VOCs) is near the northeast corner of Building 180/181. The concentration of chlorinated VOCs detected in the sewer sediment sample (DCFSD-06) retrieved from the abandoned sanitary sewer line connecting to MH 363B, approximately 20 feet northeast of the northeast corner of Building 180/181 (Figure 4-7) showed concentrations of 470,000 μg/kg of PCE, 160,000 μg/kg of DCE, and 15,000 μg/kg of TCE. TCE and DCE are breakdown products of PCE. Recorded field observations stated that this sample consisted mainly of clothing fibers (lint). The most likely source of these fibers was the current DCF (the starting point of this sanitary sewer line). Most samples collected in this area (soil gas, soil, and groundwater) contained high levels of PCE and concentrations of PCE-degradation products (TCE and DCE). These contaminated fibers were removed during the sewer line repair discussed in Section 3.3.1.

These data support the assumption that the storm and sanitary sewer lines from the current DCF and adjacent to the former DCF may have been the main pathway of PCE contamination in this area (Figures 3-5 and 3-11). However, water samples collected from the storm sewers also contained PCE concentrations at levels significantly less than those found in sample DCFSD-06. The PCE contamination in this area extends to the south, toward monitoring wells DCF92-03 and DCF92-05.

PCE concentrations were detected in soil samples from boring DCF92-03 at depths ranging from 9 to 32 feet bgs. PCE was detected only in the deepest soil sample (35 feet bgs) collected at boring DCF92-05. The groundwater samples collected from monitoring wells DCF92-03 and DCF92-05 also contained concentrations of PCE and its breakdown products (TCE and DCE).

Another area of VOC contamination at the DCFA site is located west of Building 180/181 at monitoring well DCF92-04. While no volatile contaminants were detected in the soil sample collected from this boring, low concentrations of PCE and its breakdown products (DCE and vinyl chloride) have been detected in the groundwater samples.

The contamination in this area might be due to reported accidental spills or leaks (resulting from recycling of spent dry cleaning solvent) on the ground while the DCF operated in Building 181. Another possible source is the USTs along the north side of Building 181, which were found to contain solvent and petroleum products. UST removal is discussed in Section 3.3.3.

SVOC concentrations in groundwater samples have been detected only at monitoring well DCF92-04. SVOCs were detected in soil samples collected from three monitoring well borings (DCF92-01, DCF92-03, and DCF92-06) and two shallow soil borings (DCFSB-07 and DCFSB-13). The depth of these samples ranged from 1 to 15 feet bgs. At monitoring well borings DCF92-01, 03, and 06 and at soil boring DCFSB-13, the samples with SVOC were collected within or immediately below fill material. The SVOC monitoring well at boring DCF92-06 was detected just beneath an inactive utility line. Three potential sources are identified that may have contributed to the presence of SVOCs: (1) construction-related fill material in the area of DCF92-03; (2) the laundering of SVOC-saturated rags and clothing and subsequent leakage of laundry water from the sanitary sewer; and (3) accidental spills and discharges associated with USTs behind Building 180/181.

3.4.2 Evaluation of Geological Investigation

An evaluation of the geologic investigation results is best addressed through presentation of the data in figures generated to evaluate the geological and goechemical relationships of various layers of data that are or may be interrelated. The resulting figures provide a basis for interpretation of conditions.

Figure 3-20 shows the thickness of the unconsolidated materials over the site. A corollary to this overburden thickness map is the bedrock contour map (Figure 3-21). The bedrock contour map can be viewed as a topographic map on the rock surface beneath the unconsolidated materials. This figure depicts the axis of a stream channel somewhat west of the current Tributary A, indicating a west-to-east shift of approximately 120 feet during geologic time. Figure 3-24, a structure contour map, is essentially a topographic map on top of the Crouse formation. The surface of this rock formation slopes gently to the west-southwest. It should be noted that a portion of the Crouse to the southeast has been eroded. The middle shale member of the Crouse formation is the bedrock unit in this eroded area.

Three geologic cross-sections were generated to show the relationship between geologic materials through portions of the DCFA. Figure 3-46 shows the orientation of these sections. Section AA′ (Figure 3-47) runs essentially north to south and shows the slope of the bedrock surface to the south and the relationship between wells completed in the unconsolidated material and in the upper Crouse limestone. Section BB′ (Figure 3-48) is a west-to-east section through the contaminated zone, and shows the relation between bedrock, unconsolidated material, and the Crouse formation. Also to be noted on this section is the relationship between the current channel of Tributary A and the former channel. This buried channelway can be expected to serve as the subsurface drainageway for the area. Section CC′ is taken from the southwest to northeast and is somewhat similar to Section BB′. The purpose of preparing Section CC′ is to show the relationship between the various geologic materials and the PCE concentrations in the unconsolidated materials (Figure 3-49).

3.4.3 Evaluation of Hydrologic Investigation

The most significant findings related to the hydrologic investigation are that no aquifers (geologic materials able to transmit significant quantities of water on a sustained basis) were found beneath the site, and no perennial surface water bodies exist on the site. Groundwater containing concentrations of PCE occurs in unconsolidated materials east of Building 180/181 and in the limestone units of the Crouse formation. This groundwater is moving laterally to the south and southwest prior to joining the groundwater in the alluvium adjacent to the site that is moving parallel to and in the same direction as the Kansas River.

Vertical groundwater movement is limited by shale layers that occur between and below the Crouse formation limestone units. The potential for downward groundwater movement exists from the upper to lower Crouse and from the unconsolidated materials to the lower Crouse. Water levels measured in the lower Crouse limestone are typically above the top of the unit, indicating a confined condition for the lower Crouse limestone. Because the Crouse formation is exposed beneath the alluvium adjacent to the site, the limestone units are hydraulically connected to the groundwater in the alluvium. The alluvium is in turn hydraulically connected to the river, such that river level fluctuations are reflected in groundwater levels.

3.4.4 Assessment of Data

Assessment of data for analyses of samples collected prior to November 1993 is presented in Quality Control Summary Reports (QCSRs) provided for the appropriate sampling events (CEMRK, 1992b, 1993a,b,e).

Data validation for analyses of samples collected during the RI since November 1993 was performed as prescribed in the U.S. EPA's National Functional Guidelines for Organic Data Review. The guidelines address the quality requirements for precision and accuracy through assessment of the laboratory quality control program. This program demonstrates the laboratory's ability to detect and quantify the analytes of interest at the concentrations necessary. Accuracy of the analytical results is expressed through recovery data for laboratory spiked samples, i.e., matrix spike (MS), laboratory control (LCS) and surrogate samples. Precision is assessed through analysis of the matrix spike and laboratory control sample duplicates (MSD, LCSD) and calculation of their Relative Percent Difference (RPD).

Method blanks were run to ensure that contamination was not introduced during laboratory procedures. Laboratory Quality Control (QC) procedures were performed at a minimum of once per sample batch (maximum of 20 samples) and for each sample matrix. Complete data packages from the analytical laboratory, including laboratory QC reports, for all sampling events within the DCFA have been released under separate cover, while this report presents only an overview of the information contained there.

Sampling techniques and analytical methodologies were consistent with those previously performed to ensure that the data presented were qualitatively and quantitatively comparable to data previously reported as discussed in Section 3.4.5 on data evaluation.

Data usability is further assessed by evaluating the proper sample preservation procedures and adherence to sample holding times as stated in ER 1110-1-263. Comparability of the analytical data was further addressed through spilt samples sent to the U.S. Army Corps of Engineers, MRD (CEMRD) laboratory for analysis and evaluation. Completeness based on the sampling and data objectives is assessed for the overall sampling effort through evaluation of the previously described parameters, as well as review of field notes, chain-of-custody records and cooler receipt forms.

QC of the data is assessed through the analysis of blind field duplicates of record samples, field blanks and trip blanks. Blind field duplicates address the representativeness of the field samples through calculation of the RPD. The field quality objective to collect duplicates for 10 percent of the field samples was exceeded for each sample type.

3.4.4.1 Data Assessment: Soils

The analytical results for soil samples were reviewed for all parameters as described in Section 3.4.4. Preservation temperatures were within acceptable limits (4° ± 2°C) for all samples. Problems with sample labelling on 5 chain-of-custody records were corrected through identification in the field notes. However, one blind field duplicate (DCF93-31, 5-10 feet) could not be identified with any record sample. All other sampling protocols were adhered to as stated in the Field Sampling Plan.

Holding times were met for all samples and all methods. QCSRs have been provided for all samples collected and data generated during the RI. The complete listing of QCSRs is provided in the References section. Matrix interference encountered for all surface soil samples resulted in higher than normal reporting limits for semivolatiles. Higher than normal reporting limits for Target Compound List (TCL) volatiles were encountered for samples DCFSB-17, DCFSB-20 and DCF93-13 at 0-5′ and DCFSB-19 at

0-5′ and 10-15′ due to matrix interference. Volatile data for DCFSB-19 and DCFSB-20 are positive for PCE, while DCFSB-17 and DCF93-13 are nondetect for all analytes of concern at quantitation limits of 14 µg/kg and 15 µg/kg, respectively. While it can be concluded that data for DCFSB-19 and DCFSB-20 meet the DQOs for characterizing the nature and extent of contamination, data for DCFSB-17 (0-5′) and DCF93-13 (0-5′) are inconclusive for TCL volatiles below the quantitation limits.

The laboratory demonstrated accuracy and precision within control limits specified in SW-846 for all analytical techniques to support the data quality requirements, through evaluation of their quality control data. All surrogate recovery data were within limits specified in the National Functional Guidelines, except for low phenol recovery for sample DCFSS-06 (CEMRK, 1994e). However, phenols are not among the chemicals of concern for this investigation; thus the DQOs are not affected. All LCSD samples were within the specified range for accuracy and precision for all sample batches.

MS/MSD analyses exhibited high recovery for pyrene in 2 QC batches; one batch had high recovery of 2-chlorophenol, 1,2,4-trichlorobenzene and 2,4-dinitrotoluene. High recovery indicates that the analytical result may be biased high; i.e., the actual sample concentration may be lower than reported. However, all samples were nondetect for these analytes; thus a lower result would not affect the DQOs. One QC batch exhibited low recovery for 2-chlorophenol; however, as this is not an analyte of concern, the low recovery does not affect the DQOs. All other MS/MSD data were within specified limits.

Representativeness and comparability of the data are assessed through the QC field samples. Eleven blind duplicate samples were analyzed, with only one sample, DCFSB-20, showing a major discrepancy in concentration of over two orders of magnitude. Although soil samples can exhibit a great deal of variability due to their nonhomogeneous nature, this specific discrepancy may be the result of the laboratory sampling a "hot spot," i.e., a portion of the sample which has a higher concentration than the rest of the sample. This is the only such discrepancy encountered during sampling events at the DCFA. Two other duplicate analyses were positive for analytes slightly above or at the quantification limit in one sample while nondetect in the other. As samples for volatile analyses are not field homogenized, occasional disparities are not unexpected. All other duplicate samples exhibited consistency for analytes detected and for reported concentrations. Two field blanks had low concentrations of trichloromethane; however, this contaminant was not detected in any of the samples. From this information it can be concluded that a sufficient percentage of duplicates (15 percent) were analyzed to confirm the representativeness of the field sampling effort. Analysis of the field blanks confirms that the contaminants detected were due to contamination present at the site, and not due to the sampling equipment.

Completeness of the sampling effort is assessed by collecting a sufficient quantity of samples to determine the vertical and horizontal extent of contamination at the DCF. Based on collection of 73 soil boring samples during the RI and 36 pilot study soil boring samples, 6 surface soils, 16 duplicate and 12 QA split samples, the overall sampling objective was satisfied. None of the data were rejected as unusable; therefore, completeness of the data quality has been satisfied.

The data for the soil samples meet the stated DQOs for sufficient and reliable data to characterize the nature and extent of potential risks posed by previously uncontrolled releases of PCE within the DCFA. This conclusion is supported by the method of data assessment for meeting the requirements as stated in Section 3.4.4.

3.4.4.2 Data Assessment: Sediment and Surface Water

The analytical results presented for sediment and surface water were reviewed for all QA/QC criteria as stated in Section 3.4.4. All laboratory QC data (MS/MSD, LCS/LCSD, surrogates) were within specified limits for precision and accuracy. The number of field duplicates collected exceeded the 10 percent requirement. No reporting limits were raised, all preservation procedures were as specified, and all samples were analyzed with specified holding times. Therefore, it is concluded that the data presented for sediment and surface water samples meet the stated objectives to gather sufficient and reliable data to characterize the nature and extent of potential risks within this media posed by previously uncontrolled PCE releases with the DCFA.

3.4.4.3 Data Assessment: Groundwater

Groundwater was analyzed for samples collected from wells existing prior to November 1993 and for samples collected through January 1995 for the existing and the DCF93 wells. Occasional low recoveries of semivolatile surrogate phenol and chlorobenzene compounds have occurred for samples collected during the quarterly monitoring. Repreparation and re-analysis were performed during the December 1993 sampling event for three samples. Subsequent low surrogate recovery confirmed matrix interference for these compounds. The results are appropriately flagged in the QCSR (CEMRK, 1994d,e). This has limited effect on the data usability, as acid extractable analytes (e.g., phenols) are not among the analytes of concern, nor have any been previously detected at the site.

The QC data for groundwater samples were assessed as stated in Section 3.4.4. Recovery data for MS/MSD, LCS/LCSD and surrogate analyses are all within specified limits, with the exceptions cited previously for the surrogate recoveries. RPDs are within specified limits for all MS/MSD and LCS/LCSD data. All method blanks analyzed are nondetect for all analytes. Therefore, the analytical data presented meet the requirements for precision and accuracy through evaluation of CAS quality control protocol.

Analyses of blind field duplicate groundwater samples exhibit no discrepancies either in analytes detected or in concentration of contaminants. Field blanks and trip blanks for the December sampling are positive for trichloromethane. This contaminant is also detected in two of the DCF92 wells and in DCF93-15 at concentrations greater than 10 times the blank concentration. The presence of this contaminant is likely due to site contamination; however, the origin is inconclusive. The objectives for obtaining a minimum of 10 percent duplicate samples and 10 percent split samples were both exceeded. The groundwater samples analyzed are concluded to be representative of the nature and extent of contamination. Comparability was assessed through analyses performed on the split samples sent to CEMRD and the quarterly groundwater monitoring.

Analyses of the six existing wells in November 1993, and the subsequent analyses in December 1993 of the same six wells plus the seven new monitoring wells and the three alluvial wells, are adequate to represent groundwater quality within the DCFA. The same is true in the February 1994 first Quarterly Sampling event. Subsequent sampling events in June and August 1994 and January 1995 did not include sampling of all wells, as explained in previous sections.

The objectives of the groundwater data for completeness are met through collection of greater than 10 percent duplicate and 10 percent QA samples, and are of sufficient quantity to characterize groundwater quality within the DCFA. None of the groundwater data has been rejected; therefore, completeness of the data quality is satisfied. It can be concluded that the data presented for groundwater samples are of sufficient quality to meet the stated objectives of providing adequate and reliable data to characterize the nature and extent of any contaminant releases.

3.4.5 Data Evaluation and Comparability

From the PA/SI to the RI, all analytical procedures used for both sampling and analysis were done in accordance with the approved work plans with deviation as documented either in the Technical Memoranda or, in the case of analytical methodologies, in the appropriate QCSRs as indicated in the preceding data assessment section. From the PA/SI through the IFI through the June 1994 quarterly groundwater sampling, both semivolatiles and volatiles were collected and analyzed. For the August 1994 sampling, SVOCs were eliminated from the analytical suite. For the soil borings collected during the pilot study, U.S. EPA 8010 was substituted for U.S. EPA 8240 for the VOC analyses. The only effect of this change was to decrease the number of analytes from 37 to 35. All VOC analytes of concern, the PCE and its breakdown products were still determined with lower level of detection achieved. The difference in the method is primarily the use of a halogen-specific detector.

For the volatile analysis, all field work starting in November 1993, except for the differences enumerated above, were conducted using U.S. EPA 8240 instead of U.S. EPA 8260, the method stated in the original work plan (CEMRK, 1991; CEMRK, 1992c). For the aqueous sample, this meant, in general, achieving a lower detection limit.

For soil and sediment, the detection limits for U.S. EPA 8240 are 2 to 5 times higher than those of U.S. EPA 8260. For PCE and its degradation products, the primary analyte of concern, the detection limits were not higher than a factor of 2. For example, instead of a 2.5 μg/l detection limit for PCE by U.S. EPA 8260, U.S. EPA 8240 has a detection limit of 5 μg/kg. These differences do not affect either the usability of the data to meet the Data Quality Objective, or the comparability of the data throughout the course of the field investigation. As such, the data as presented in Chapter 4 can be used to determine the nature and extent of contamination, as well as be used in the calculation of risk assessment in Chapter 6.

TABLE 3-1
REMEDIAL INVESTIGATION ACTIVITIES AND OBJECTIVES
Dry Cleaning Facilities Area
Fort Riley, Kansas

Activity	Objective
Review and Evaluation of Previous Investigations	■ Retrieve and incorporate pre-existing data.
Sample and Analyze Surface Soils	■ Evaluate potential for human exposure to any contaminants in more highly frequented areas of the DCFA.
Conduct Soil Boring Program that Includes Sampling and Analysis	■ Delineate lateral and vertical extent of contaminants in soil, and in particular, in areas adjacent to known sewer line breaks. ■ Determine the depths to bedrock throughout the DCFA. ■ Obtain geotechnical data.
Install Additional Monitoring Wells	■ Delineate lateral and vertical extent of contaminants in groundwater. ■ Provide additional water level elevation data for use in interpretation of groundwater flow directions.
Sample Surface Water and Sediments in Tributaries A and B	■ Evaluate presence, fate, and transport of contaminants.
Conduct Periodic Samples of Groundwater	■ Determine any temporal and spatial changes in contaminant concentration.
Conduct Supplemental Sewer Inventory and Air Monitoring	■ Determine effects of sewerline conditions on groundwater and effects of excavation on air quality emissions.

TABLE 3-2
RATIONALE FOR RI SOIL BORING LOCATIONS
Dry Cleaning Facilities Area
Fort Riley, Kansas

Soil Boring Identification	Rationale
DCFSB-17, DCFSB-18	Provide horizontal and vertical extent of PCE contamination detected in soil gas samples and previous shallow soil borings.
DCFSB-23	Evaluate impact of USTs possibly located in this area. Determine vertical extent of PCE contamination detected during soil gas survey.
DCFSB-29, DCFSB-30 DCFSB-31, DCFSB-32 DCFSB-33, DCFSB-34	Determine horizontal extent and vertical extent (if contamination is present) PCE detected during the soil gas survey. These borings are adjacent to the sewer lines around Bldg. 183 and borings 29, 31, and 32 are located adjacent to breaks detected within these lines.
DCFSB-24, DCFSB-25	Determine horizontal extent of PCE contamination detected during the soil gas survey. These locations are adjacent to the sanitary sewer that originates at the steam plant (Bldg. 184) and provide general area coverage.
DCFSB-19, DCFSB-26	Determine horizontal and vertical extent of PCE contamination detected during the soil gas survey. These locations are adjacent to breaks detected within the storm sewer lines.
DCFSB-16, DCFSB-20 DCFSB-21	Determine vertical extent of contamination detected in previous soil gas surveys, soil borings, and monitoring well borings. These locations are adjacent to the sanitary sewer line.
DCFSB-22	Determine horizontal and vertical extent of PCE detected in previous soil gas surveys, soil borings, and monitoring well borings.
DCFSB-35	Provide background data. Located upgradient of current DCF.
DCFSB-27, DCFSB-28 DCFSB-36	Determine presence of residual PCE contamination and vertical extent of contamination (if present).

Note:

This table was adapted from CEMRK, 1993h.

TABLE 3-3
GEOTECHNICAL CHARACTERISTICS OF SELECTED SOIL SAMPLES
Dry Cleaning Facilities Area, Fort Riley, Kansas
November 1993

Sample Identification	% Moisture	% Organic Matter	Liquid Limit	Plastic Limit	Plasticity Index	Classification
DCF 93-12 5-10′	14.7	1.8	26	14	12	SC
DCF 93-08 0-5′	12.3	1.5	22	12	10	SC
DCF 93-13 20-25′	16.2	1.5	26	13	13	CL
DCF 93-13 35-40′	16.4	ND	NP	NP	NP	SM
DCF 93-14 0-5′	15.0	4.3	34	16	18	CL
DCF 93-15 15-20′	14.7	1.0	51	16	35	CH
DCF 93-16 5-10′	20.8	1.9	22	14	8	CL
DCF 93-19 5-10′	10.7	0.9	27	17	10	SC
DCF 93-20 5-9′	9.6	1.1	22	15	7	SC-SM

<u>Notes</u>:

ND	Not Detected.
NP	Not Present.
SC	Clayey Sand
SC-SM	Clayey Sand to Silty Sand
CL	Lean Clay
SM	Silty Sand
CH	Fat Clay

Source: Unified Soil Classification System.

TABLE 3-4
RATIONALE FOR MONITORING WELL LOCATIONS
Dry Cleaning Facilities Area
Fort Riley, Kansas

Groundwater Monitoring Well Identification	Rationale
DCF93-01 - DCF93-07	Installed during the PA/SI for the purpose of verifying results from soil gas surveys and to provide data on soil and groundwater contamination. ■ DCF92-01 was located where it was believed to be upgradient of the site. ■ DCF92-03 and 05 were located where they were believed to be downgradient of the site. ■ DCF92-02,04 and 06 were located based on soil gas survey and soil borings. ■ DCF92-07 was installed to determine potential presence of perched water.
DCF93-08	Determine horizontal extent of groundwater contamination detected west of Building 181.
DCF93-09, DCF93-10 DCF93-11	Determine if contamination has reached alluvial materials.
DCF93-12, DCF93-13 DCF93-14	Determine horizontal extent of PCE contamination detected along east side of Building 180.
DCF93-15	Determine horizontal extent of PCE contamination detected in monitoring well DCF92-02. Evaluate impact of former USTs possibly located in this area.
DCF93-16	Determine horizontal extent of PCE contamination detected in monitoring well DCF92-02. This boring is adjacent to sanitary sewer running east-west under north side of Custer Road.
DCF93-17, DCF93-18	To be utilized as upgradient background wells for shallow and deep water-bearing rock units, respectively.
DCF93-19, DCF93-20	Determine groundwater conditions in the water-bearing unit below the upper Crouse limestone.
DCF94-21	Installed to serve as a dual groundwater and vapor extraction well for a pilot study.
DCF94-22	Installed as replacement well for DCF93-11 when water levels declined below the screen zone of DCF93-11.

Note:

This table was adapted from CEMRK, 1993h.

TABLE 3-5
SUMMARY OF GEOPHYSICAL LOGGING PERFORMED
Dry Cleaning Facilities Area
Fort Riley, Kansas
1993
RI Field Investigations

Monitoring Well	Date	Geophysical Log	Depth (ft)
DCF92-06	12/9/93	Natural Gamma	2.5-48.0
DCF93-08	12/1/93	Natural Gamma Fluid Resistivity Temperature	2.5-42.5 36.1-42.5 36.4-43.0
DCF93-12	11/29/93	Natural Gamma	2.5-42.0
DCF93-14	11/30/93	Natural Gamma Caliper	2.5-34.0 4.5-34.7
DCF93-15	12/4/93	Natural Gamma	2.5-41.0
DCF93-16	11/30/93	Natural Gamma Caliper	2.5-45.0 4.0-45.9
DCF93-17	12/2/93	Natural Gamma Caliper Spontaneous Potential Single-Point Resistance Fluid Resistivity Temperature	2.5-81.0 4.5-81.0 58.3-81.6 58.3-81.6 60.4-79.1 61.0-79.8
DCF93-18	12/7/93	Natural Gamma	2.5-138.4
DCF93-18	11/20/93	Natural Gamma Spontaneous Potential Single-Point Resistance Fluid Resistivity Temperature	2.5-84.0 53.7-84.2 53.7-84.2 55.5-83.9 55.9-84.2
DCF93-19	12/8/93	Natural Gamma Natural Gamma Spontaneous Potential Single-Point Resistance Fluid Resistivity Temperature	2.5-61.5 2.5-42.6 35.2-43.1 35.2-43.1 35.5-43.0 36.0-43.5
DCF93-20	11/22/93	Natural Gamma	2.5-37.4
DCF93-20	12/8/93	Natural Gamma	2.5-61.0

TABLE 3-6
WATER LEVEL ELEVATIONS
DCFA MONITORING WELLS
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in feet above mean sea level unless otherwise noted.

Monitoring Well No.	T/C Elev.	Aug. 1992	Nov. 1992	Feb. 1993	Feb. 1993	Nov. 1993	Dec. 1993	Feb. 1994	May 1994	June 1994	July 1994	Aug. 1994	Jan. 1995
DCF92-01	1092.04	1052.86	1050.34	1050.42	1050.56	1052.26	1051.38	1050.55	1053.30	1050.35	TI	1050.02	1050.00
DCF92-02	1088.98	1051.82	1047.87	1047.89	1048.22	1050.04	1049.40	1047.98	1047.93	1047.96	1047.92	1047.88	1048.04
DCF92-03	1086.53	1050.42	1048.34	1048.53	1048.72	1048.86	1049.01	1048.78	1048.59	1048.61	TI	1047.91	1048.54
DCF92-04	1087.33	1051.52	1046.59	1047.14	1048.24	1049.08	1048.58	1047.31	DRY	1046.80	DRY	1046.07	1047.09
DCF92-05	1082.73	1050.34	1047.96	1048.28	1048.59	1048.78	1048.81	1048.55	1048.42	1048.40	TI	1047.70	1048.37
DCF92-06	1092.35	1052.00	1048.95	1049.00	1049.03	1050.95	1050.15	1049.43	1049.29	1049.34	1049.21	1049.05	1049.01
DCF93-08	1086.49	WELLS NOT IN EXISTENCE DURING THIS TIME					1048.27	1046.92	DRY	1046.46	DRY	1046.30	1046.55
DCF93-09	1059.93						1045.68	1044.28	1043.17	1041.86	1042.19	1040.56	1039.95
DCF93-10	1060.37						1045.52	1043.82	1043.07	1041.67	1041.93	1040.42	1040.90
DCF93-11	1060.18						1047.58	1045.47	1044.42	1042.75	1042.96	1041.54	DRY
DCF93-12	1088.97						1048.25	1047.26	DRY	1045.17	NM	1044.64	NM
DCF93-13	1082.86						1048.70	1048.05	1047.88	1047.51	TI	1046.75	1047.30
DCF93-14	1083.33						1049.33	1049.24	DRY	1049.21	NM	1049.13	NM
DCF93-15	1085.62						1049.30	1047.95	1049.62	1047.57	DRY	1047.39	1047.92
DCF93-16	1091.67						1049.37	1048.07	DRY	DRY	DRY	1047.48	1047.60
DCF93-17	1129.22						1049.66	1048.70	1048.54	1048.97	NM	1048.49	NM
DCF93-18	1128.74						1029.80	1029.12	1028.50	1028.85	NM	1028.04	NM
DCF93-19	1087.54						1047.02	1047.14	1047.16	1046.51	1046.44	1045.84	1046.65
DCF93-20	1088.98						1048.16	1046.60	1046.06	1045.18	NM	1044.51	1044.29
DCF94-21	1082.37						WELLS NOT IN EXISTENCE DURING THIS PERIOD		1046.93	1046.69	NM	1046.89	NM
DCF94-22	1060.77											1040.69	1039.73

Notes: TI Transducer Installed. T/C Top Casing Elevation. NM Not Measured due to other activites occurring in association with the well..

TABLE 3-7
HYDRAULIC CONDUCTIVITY (k) VALUES FROM SLUG TEST
DCFA GROUNDWATER MONITORING WELLS

Dry Cleaning Facilities Area
Fort Riley, Kansas
June 1994

Well	Initial Drawdown (ft)	Well Casing Radius (ft)	Borehole Radius (ft)	Saturated Thickness (ft)	Screen Length (ft)	k (ft/min)	k (cm/sec)
DCF92-02	2.24	0.083	0.25	6.53	10	10.9×10^{-4}	5.5×10^{-4}
DCF92-03	1.66	0.083	0.50	9.24	10	14.9×10^{-4}	7.5×10^{-4}
DCF92-05	1.14	0.083	0.50	7.84	10	26.1×10^{-4}	13.0×10^{-4}
DCF93-13	2.30	0.083	0.33	6.41	5	6.8×10^{-4}	3.5×10^{-4}
DCF94-21	1.56	0.167	0.50	6.05	10	4.3×10^{-4}	2.2×10^{-4}
DCF94 ES-2B	1.29	0.167	0.50	6.26	10	3.7×10^{-4}	1.9×10^{-4}
DCF94 ES-3B (1)	1.39	0.167	0.50	7.48	10	4.5×10^{-4}	2.3×10^{-4}
DCF94 ES-3B (2)	1.43	0.167	0.50	7.48	10	4.7×10^{-4}	2.4×10^{-4}
Average						9.5×10^{-4}	4.8×10^{-4}

TABLE 3-8
HYDRAULIC CONDUCTIVITY (k) ESTIMATES BASED ON GEOTECHNICAL DATA
Dry Cleaning Facilities Area
Fort Riley, Kansas
1992 PA/SI WELLS

Sample Location, Depth	% Passing #10 Sieve (2.00 mm)	% Passing #200 Sieve (0.075 mm)	% Clay (0.005 mm)	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plasticity Index[a] (PI) (%)	D_{10}[b] (mm)	D_{20}[b] (mm)	D_{30}[b] (mm)	D_{60}[b] (mm)	C_u[c]	C_c[d]	k[e] (cm/sec) x10^{-4}	k[f] (cm/sec) x10^{-4}	Soil Description (USCS)[g]
DCF92-02GT, 5′	100	88	18	23	15	8	—	0.008	0.023	0.05	—	—	—	0.07	Lean Clay (CL)
DCF92-03GT, 15′	100	68	28	41	19	22	—	0.002	0.006	0.05	—	—	—	0.006	Lean Clay (CL)
DCF92-03GT, 35′	100	66	20	22	13	9	—	0.005	0.02	0.06	—	—	—	0.03	Lean Clay (CL)
DCF92-04GT, 5′	98	78	32	34	17	17	—	0.002	0.005	0.02	—	—	—	0.006	Lean Clay (CL)
DCF92-04GT, 10′	88	48	27	35	16	19	—	0.002	0.088	0.05	—	—	—	0.006	Clayey Sand (SC)
DCF92-05GT, 5′	100	80	17	25	22	3	0.002	0.015	0.025	0.05	25	6.3	0.04	0.25	Silt (ML)
DCF92-05GT, 20′	100	54	14	20	16	4	0.001	0.02	0.035	0.15	150	8.2	0.01	0.45	Lean Clay (CL)
DCF92-06GT, 20′	100	44	14	20	20	10	—	0.02	0.04	0.1	—	—	—	0.45	Silty Sand (SM)

Notes:

a Plasticity Index (PI) = [Liquid Limit (LL) - Plastic Limit (PL)], %
b D_{10}, D_{20}, D_{30}, and D_{60}: Represent equivalent particle sizes (diameters) associated with the 10%, 20%, 30%, and 60% finer than the corresponding equivalent particle sizes (diameters), as determined from the grain size distribution curves.
c C_u: Coefficient of Uniformity, $C_u = D_{60}/D_{10}$
d C_c: Coefficient of Gradation, $C_c = (D_{30})^2/(D_{10} x D_{60})$
e k: Based on Hazen equation, $k = C. D_{10}^2$, cm/sec, where C = 100
f k: Creager, Justin, and Hinds, "Engineering for Dams," Table 2, page 649, based upon k-D_{20} correlation graphs.
g USCS: Unified Soil Classification System
h —: Equivalent sizes cannot be determined from the associated grain size distribution curves.

See Appendix B-III for grain size distribution curves.

Source: (CEMRK, 1992d)

TABLE 3-9
HYDRAULIC CONDUCTIVITY (k) ESTIMATES BASED ON GEOTECHNICAL DATA
Dry Cleaning Facilities Area
Fort Riley, Kansas
1994 Pilot Test

Sample Location	% Passing #10 Sieve (2.00 mm)	% Passing #200 Sieve (0.075 mm)	% Clay (0.005 mm)	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plasticity Index[a] (PI) (%)	D_{10}[b] (mm)	D_{20}[b] (mm)	D_{30}[b] (mm)	D_{60}[b] (mm)	C_u[c]	C_c[d]	k[e] (cm/sec) x10^{-4}	k[f] (cm/sec) x10^{-4}	Soil Description (USCS)[g]
DCF94-1-1	56	25	9	25	18	7	0.006	0.045	0.25	2.5	454.5	4.5	0.3025	2.5	Clayey Sand w/ Gravel (SC)
DCF94-1A-0	100	66	24	24	14	10	—	0.003	0.015	0.06	—	—	—	0.009	Sandy Lean Clay (CL)
DCF94-1B-1	93	53	18	25	15	10	0.002	0.007	0.025	0.17	113.3	2.5	0.0225	0.065	Sandy Lean Clay (CL)
DCF94-1B-2	100	70	26	28	14	14	—	—	0.009	0.05	—	—	—	—	Sandy Lean Clay (CL)
DCF94-1B-3	100	60	15	18	16	2	0.006	0.013	0.03	0.075	13.6	2.2	0.3025	0.18	Sandy Silt (ML)
DCF94-2A-0	100	74	35	31	14	17	—	—	0.0024	0.04	—	—	—	—	Lean Clay w/ Sand (CL)
DCF94-3B-0	100	98	22	29	24	5	—	0.004	0.012	0.025	—	—	—	0.02	Silt (ML)
DCF94-3B-2	100	81	24	28	18	10	—	0.002	0.015	0.05	—	—	—	0.006	Lean Clay w/ Sand (CL)

TABLE 3-9 (CONTINUED)
HYDRAULIC CONDUCTIVITY (k) ESTIMATES BASED ON GEOTECHNICAL DATA

Sample Location	% Passing #10 Sieve (2.00 mm)	% Passing #200 Sieve (0.075 mm)	% Clay (0.005 mm)	Liquid Limit (LL) (%)	Plastic Limit (PL) (%)	Plasticity Index[a] (PI) (%)	D_{10}[b] (mm)	D_{20}[b] (mm)	D_{30}[b] (mm)	D_{60}[b] (mm)	C_u[c]	C_c[d]	k[e] (cm/sec) $\times 10^{-4}$	k[f] (cm/sec) $\times 10^{-4}$	Soil Description (USCS)[g]
DCF94-21-0	100	84	31	33	15	18	—	—	0.005	0.027	—	—	—	—	Lean Clay w/ Sand (CL)
DCF94-21-1	99	95	34	40	19	21	—	—	0.0023	0.028	—	—	—	—	Lean Clay (CL)
DCF94-21-2	99	94	32	37	17	20	—	—	0.004	0.026	—	—	—	—	Lean Clay (CL)
DCF94-21-3	98	19	8	NP[h]	NP[h]	NP[h]	0.002	0.08	0.17	0.34	17.0	4.3	4	9	Silty Sand (SM)
DCF94-ES-38	83	58	28	33	18	15	—	0.002	0.006	0.1	—	—	—	0.006	Sandy Lean Clay (CL)

Notes:

a Plasticity Index (PI) = [Liquid Limit (LL) - Plastic Limit (PL)], %

b D_{10}, D_{20}, D_{30}, and D_{60}: Represent equivalent particle sizes (diameters) associated with the 10%, 20%, 30%, and 60% finer than the corresponding equivalent particle sizes (diameters), as determined from the grain size distribution curves.

c C_u: Coefficient of Uniformity, $C_u = D_{60}/D_{10}$

d C_c: Coefficient of Gradation, $C_c = (D_{30})^2/(D_{10} x D_{60})$

e k: Based on Hazen equation, $k = C.\ D_{10}^2$, cm/sec, where $C = 100$

f k: Creager, Justin, and Hinds, "Engineering for Dams," Table 2, page 649, based upon k-D_{20} correlation graphs.

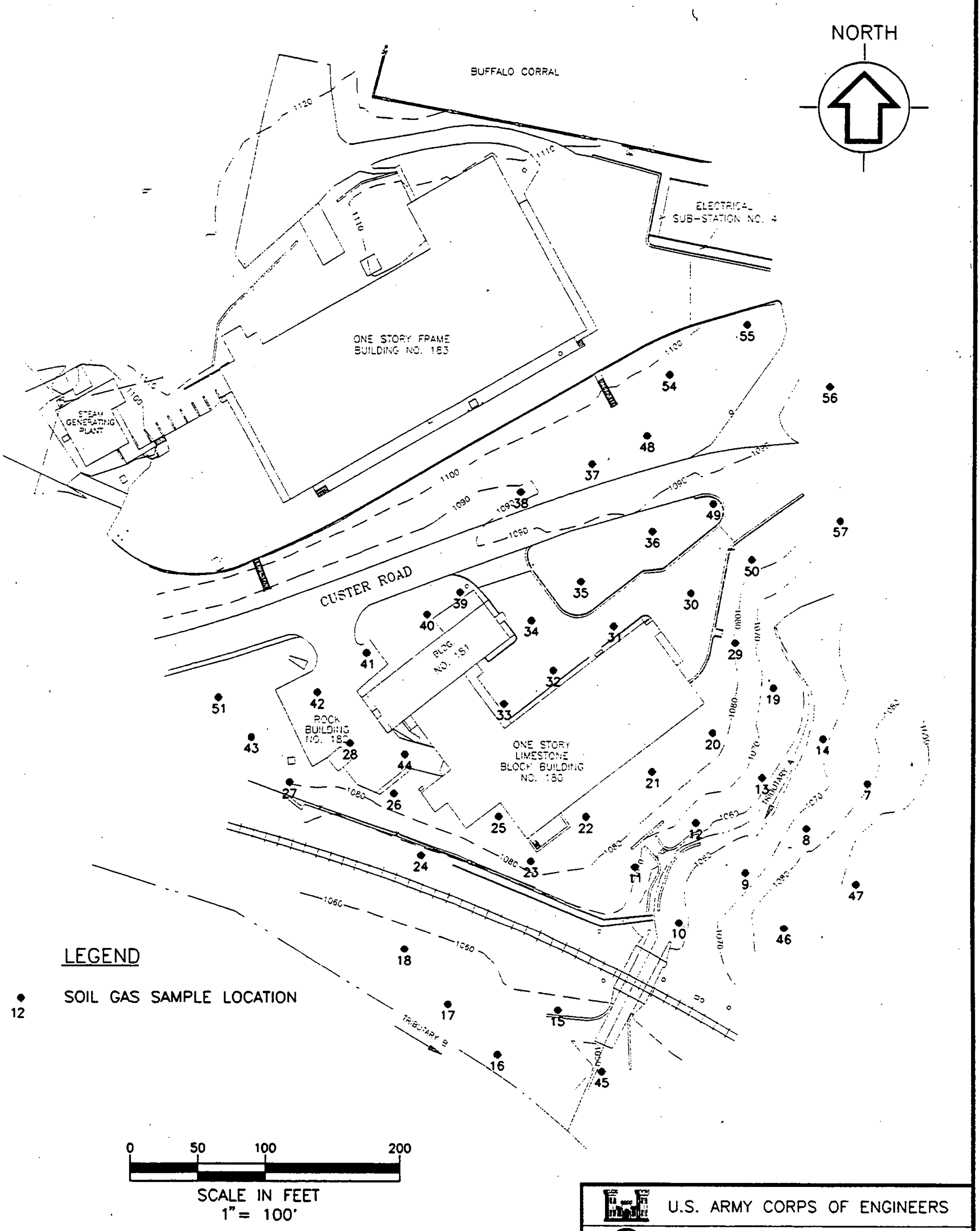
g USCS: Unified Soil Classification System

h NP: Not Present

i —: Equivalent sizes cannot be determined from the associated grain size distribution curves.

See Appendix B-III for grain size distribution curves.

Source: Terracon, Inc.



LEGEND

● 12 SOIL GAS SAMPLE LOCATION

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.

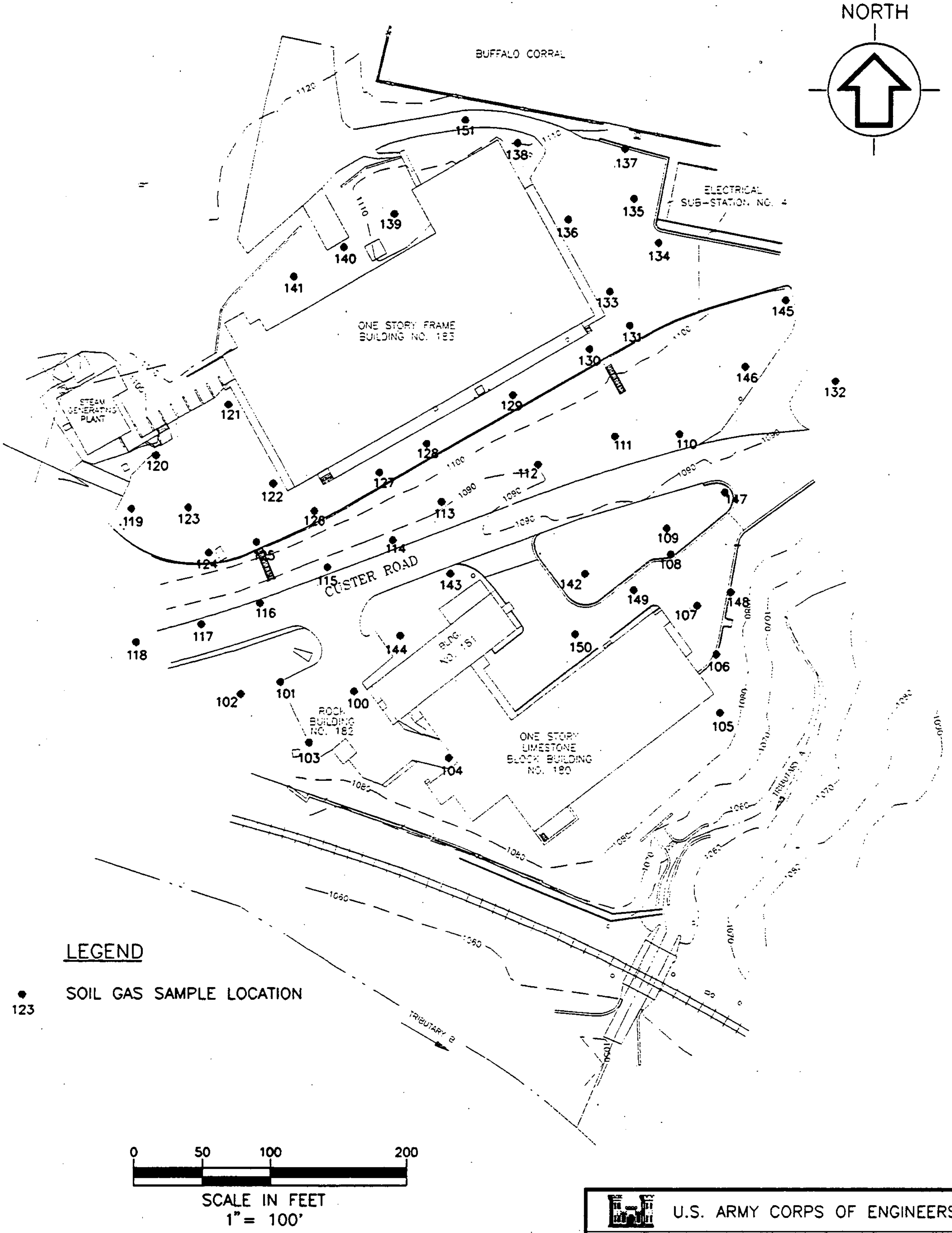
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

SOIL GAS SURVEY
LOCATION MAP, 10/91

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3–1



LEGEND

● 123 SOIL GAS SAMPLE LOCATION

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.

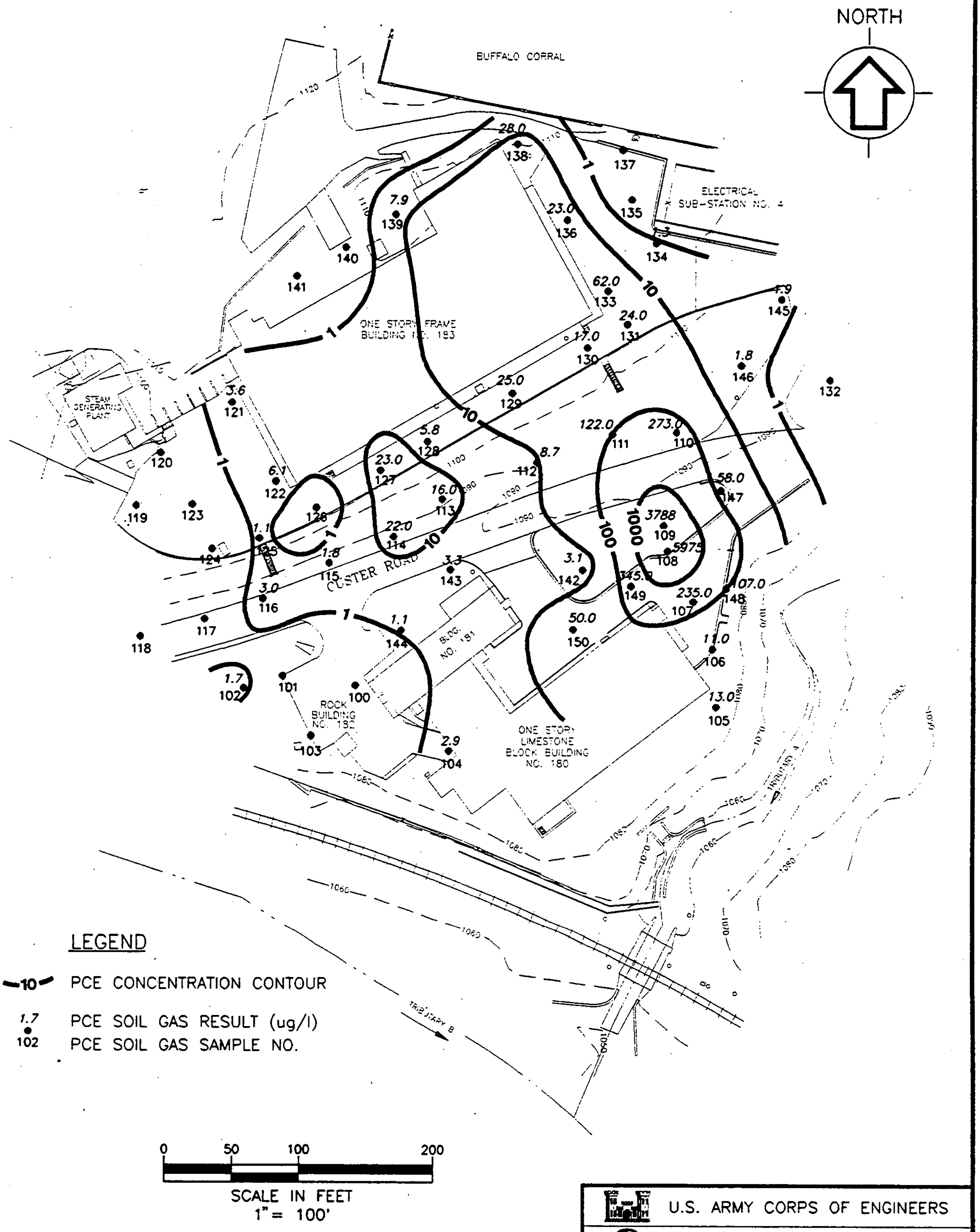
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

SOIL GAS SURVEY
LOCATION MAP, 2/93

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3–2



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992a.

U.S. ARMY CORPS OF ENGINEERS

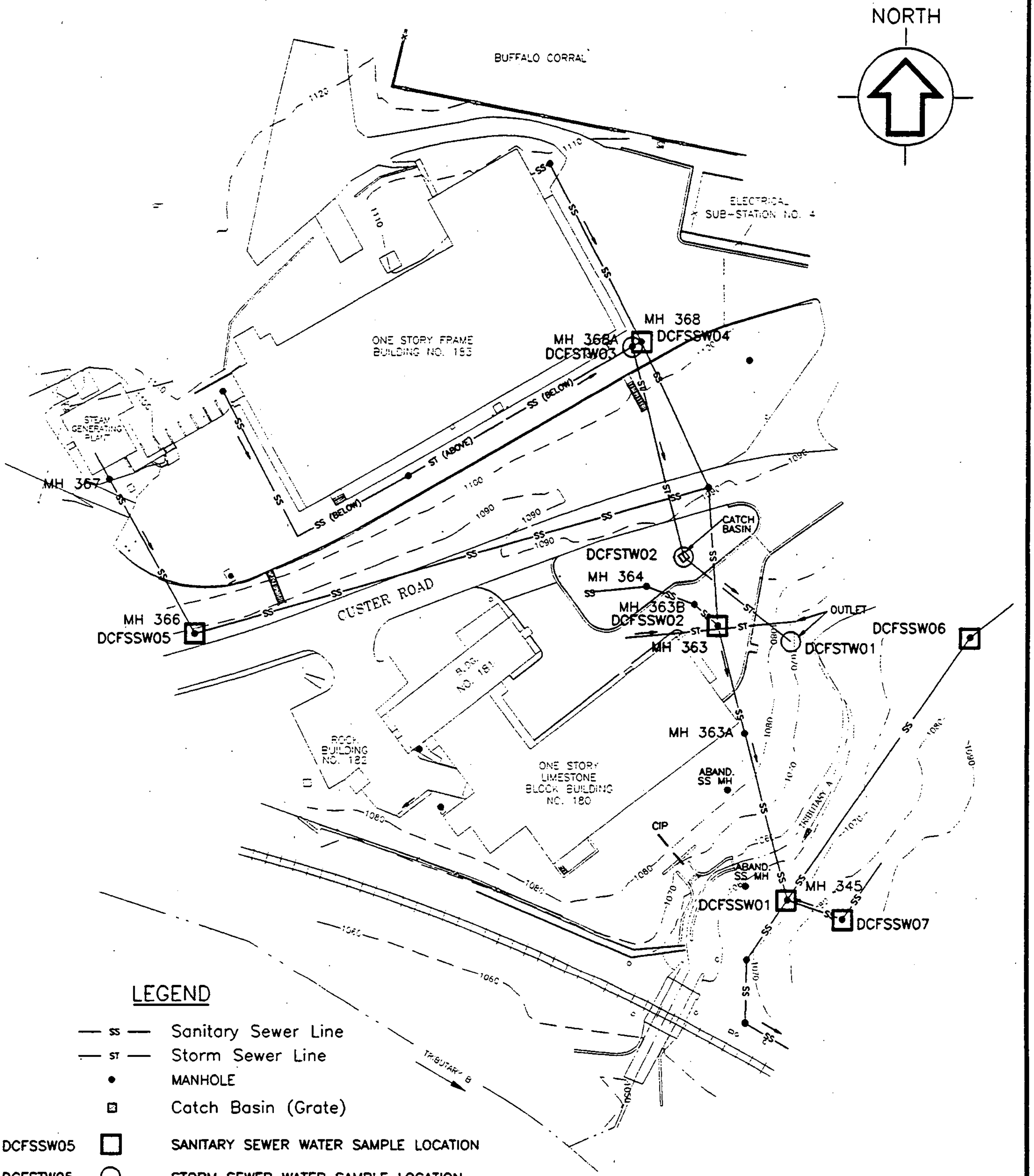
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE CONCENTRATION CONTOURS (ug/l) FROM SOIL GAS SURVEY, 2/93

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-3

5-PCECC/30MAR95



LEGEND

— ss —	Sanitary Sewer Line
— st —	Storm Sewer Line
●	MANHOLE
▨	Catch Basin (Grate)
DCFSSW05 ☐	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW05 ○	STORM SEWER WATER SAMPLE LOCATION

0 50 100 200

SCALE IN FEET
1" = 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993b.

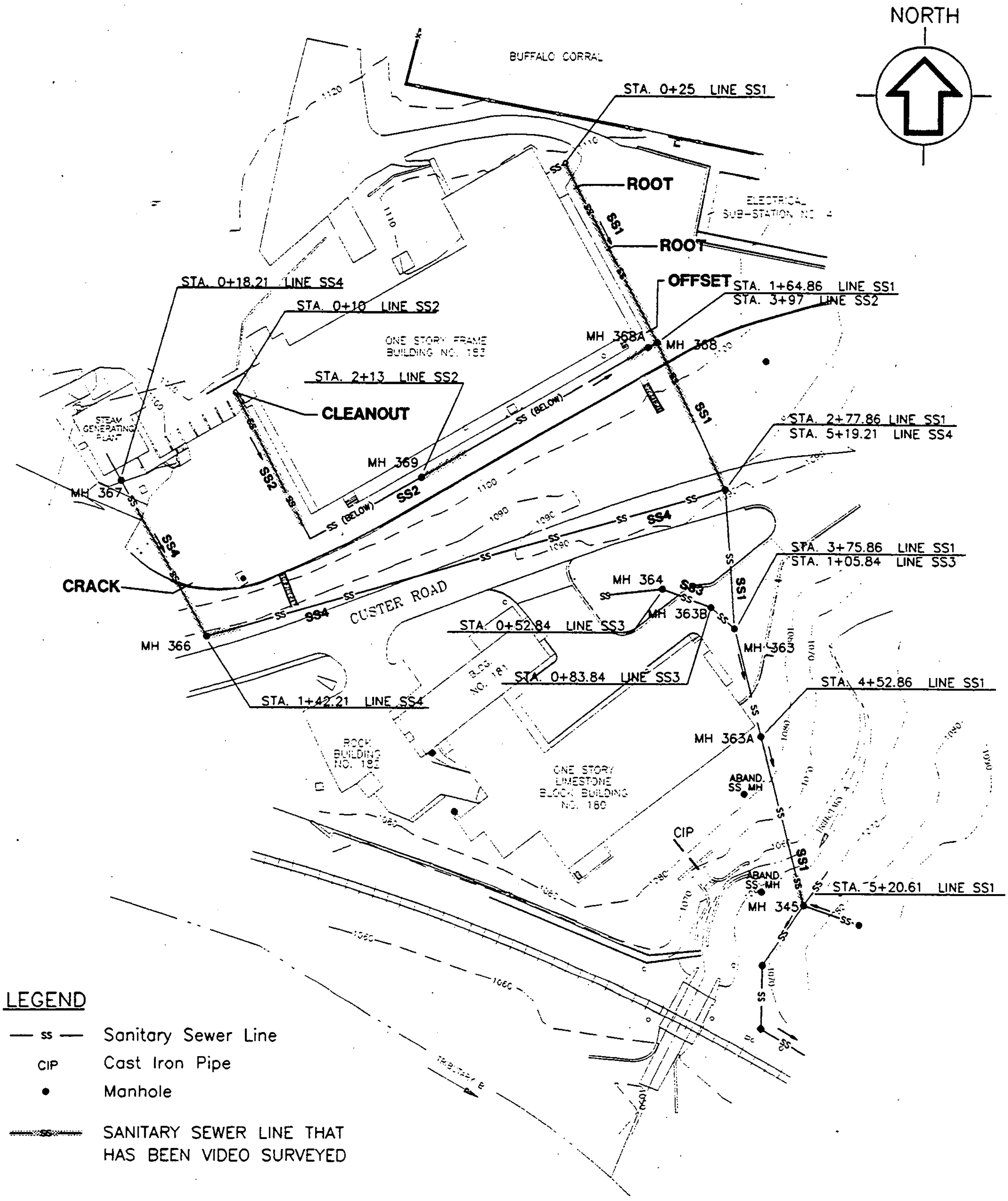
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

SANITARY & STORM SEWER LINES WATER SAMPLE LOCATIONS, 2/93

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3–4



0 50 100 200

SCALE IN FEET
1" = 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993d.
3. SEE FIGURES 3–6 THROUGH 3–10 FOR PROFILES OF SANITARY SEWER LINES.

U.S. ARMY CORPS OF ENGINEERS

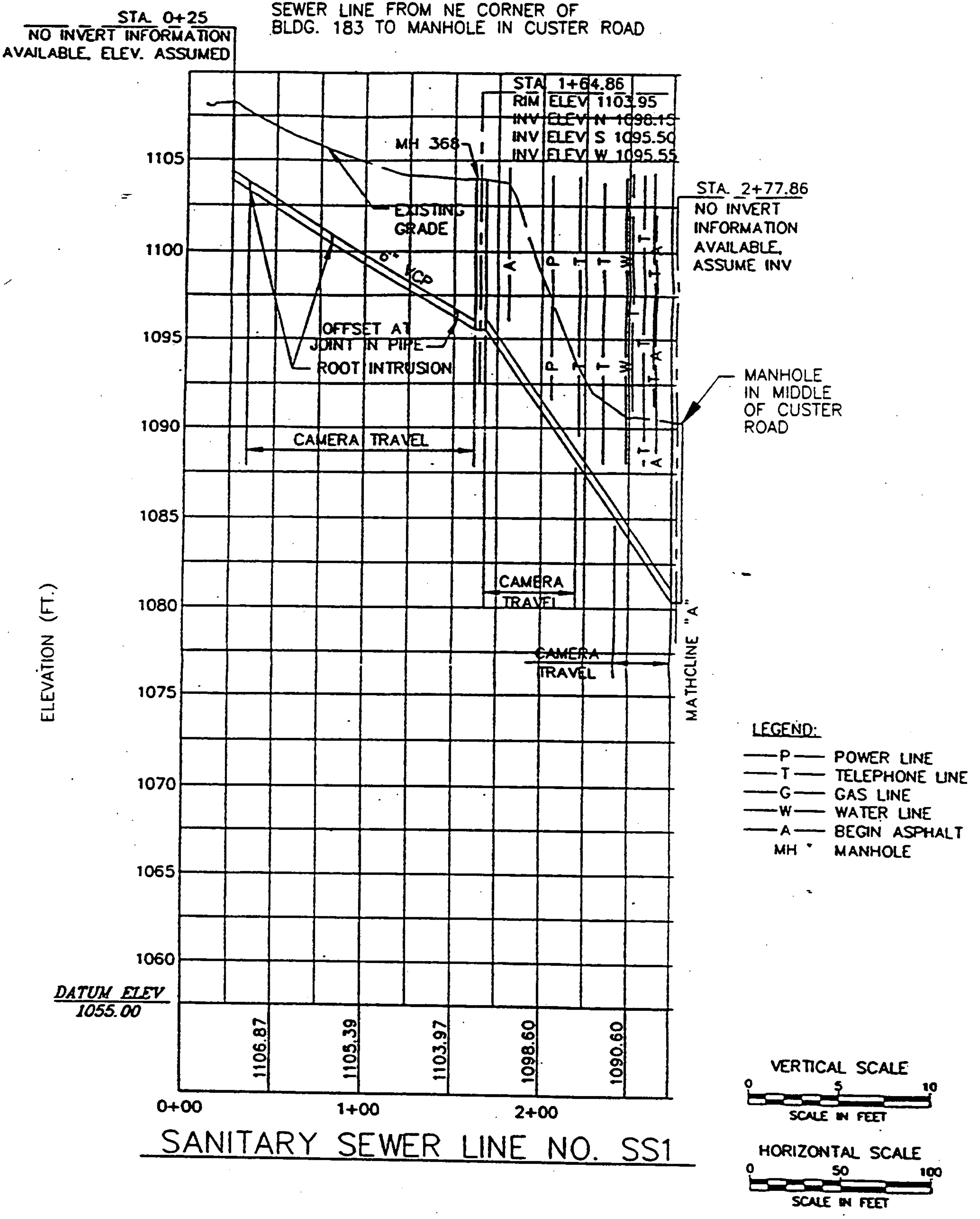
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

EXTENT OF VIDEO SURVEY IN SANITARY SEWER SHOWING DETECTED BREAKS, CRACKS, ROOT INTRUSIONS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3–5

ENGINEERING PROFILE OF SANITARY SEWER LINE FROM NE CORNER OF BLDG. 183 TO MANHOLE IN CUSTER ROAD



SANITARY SEWER LINE NO. SS1

NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO – NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI–ROOTER, KANSAS CITY, MO APRIL 12 – 30, 1993d.
3. SEE FIGURE 3–5 FOR PLAN VIEW OF SANITARY SEWER LINES.

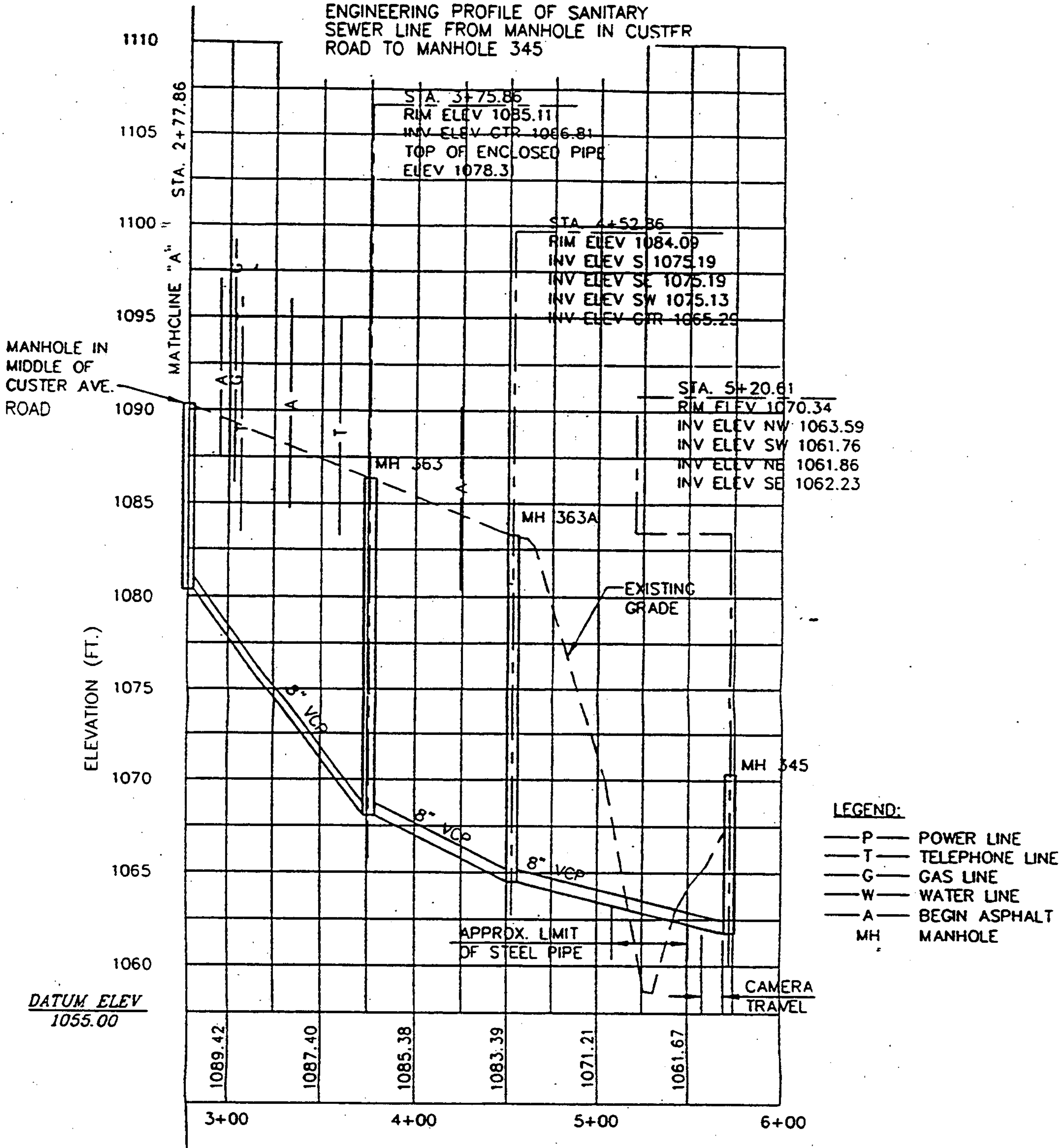
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

ENGINEERING PROFILE OF SANITARY SEWER LINE NO. SS1 STA. 0+25 TO STA. 2+78

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3–6



SANITARY SEWER LINE NO. SS1

NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO – NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI–ROOTER, KANSAS CITY, MO APRIL 12 – 30, 1993d.
3. SEE FIGURE 3–5 FOR PLAN VIEW OF SANITARY SEWER LINES.

U.S. ARMY CORPS OF ENGINEERS

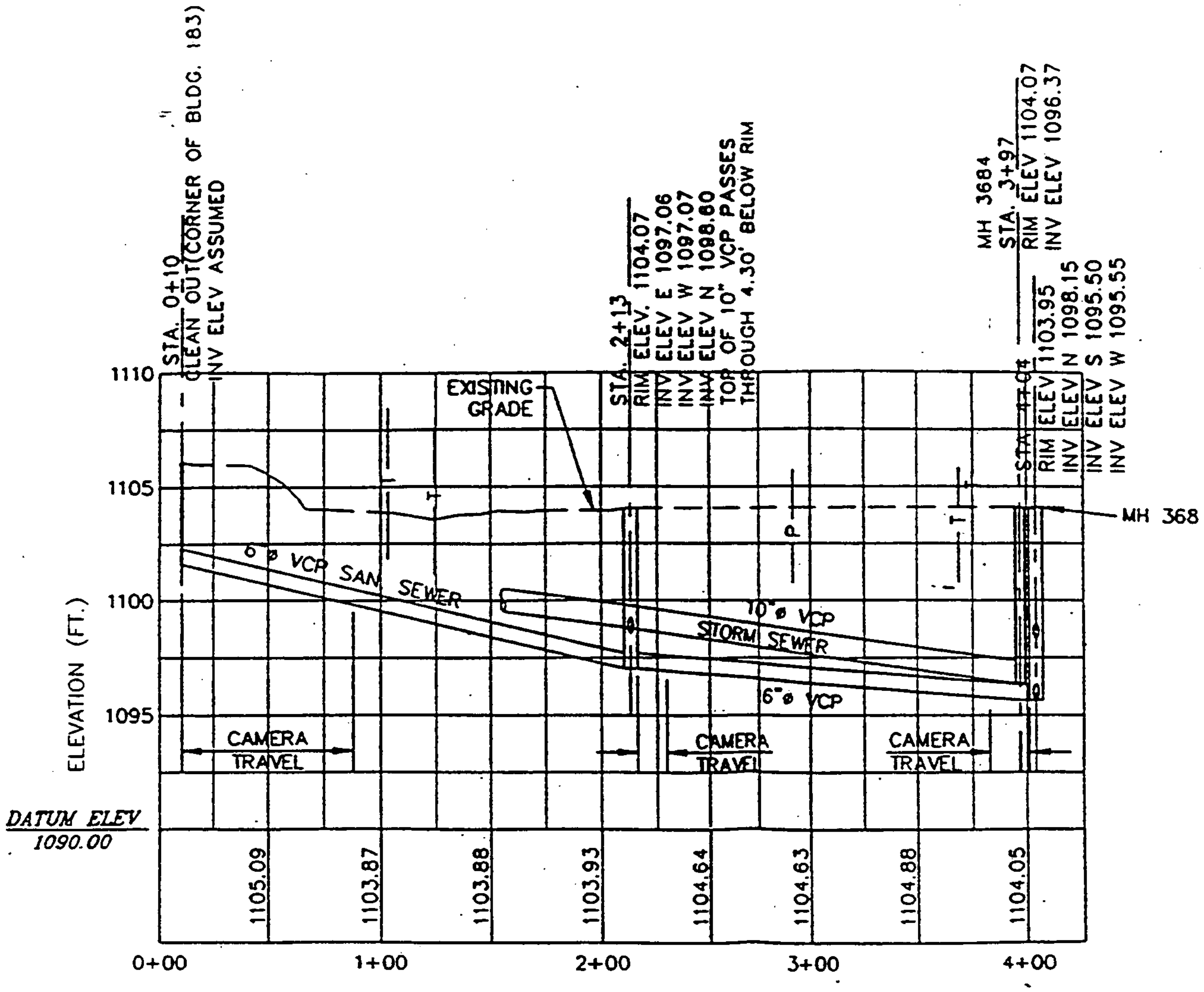
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

ENGINEERING PROFILE OF SANITARY SEWER LINE NO. SS1 STA. 2+78 TO STA. 5+21

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3–7

ENGINEERING PROFILE OF SANITARY
SEWER LINE FROM CLEANOUT (NW
CORNER OF BLDG. 183) TO MH 368



SANITARY SEWER LINE NO. SS2

LEGEND:

——P—— POWER LINE
——T—— TELEPHONE LINE
——G—— GAS LINE
——W—— WATER LINE
——A—— BEGIN ASPHALT
MH MANHOLE

VERTICAL SCALE
0 5 10
SCALE IN FEET

HORIZONTAL SCALE
0 50 100
SCALE IN FEET

NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO – NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI-ROOTER, KANSAS CITY, MO APRIL 12 – 30, 1993d.
3. SEE FIGURE 3-5 FOR PLAN VIEW OF SANITARY SEWER LINES.

U.S. ARMY CORPS OF ENGINEERS

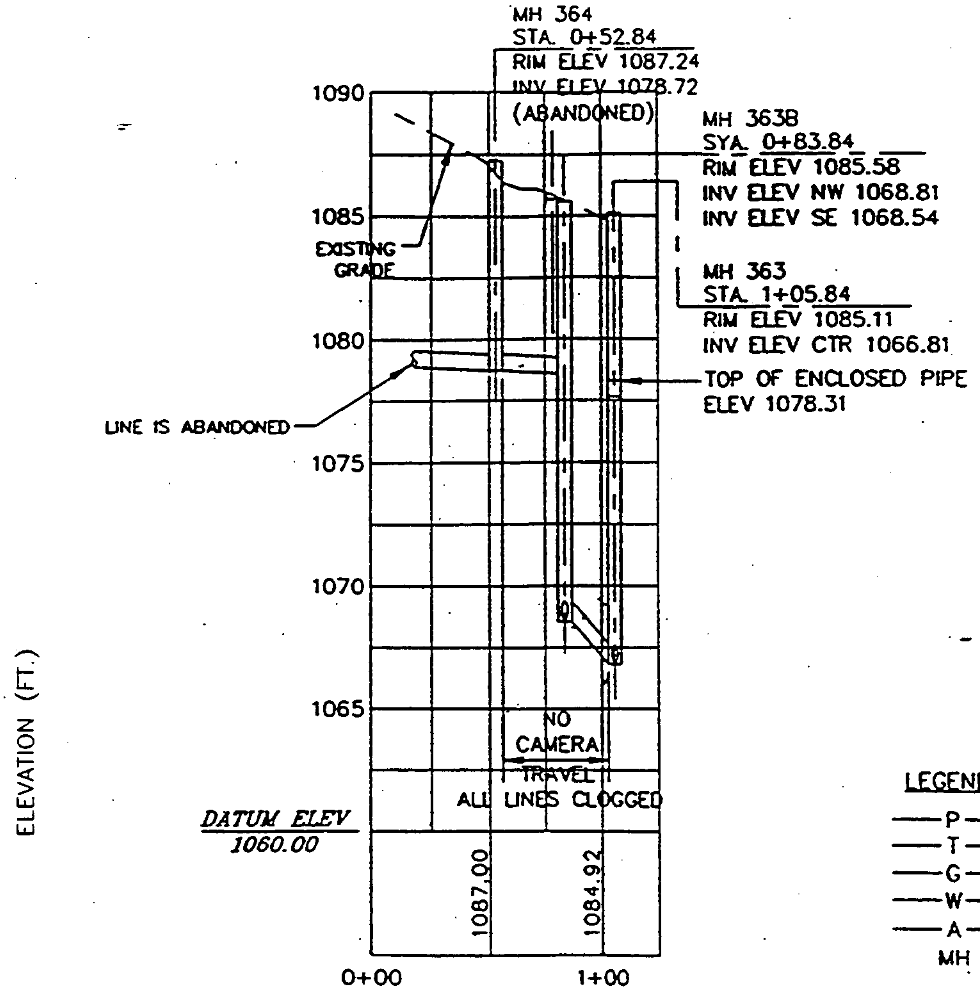
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

ENGINEERING PROFILE OF
SANITARY SEWER LINE NO. SS2
STA. 0+10 TO STA. 3+97

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3–8

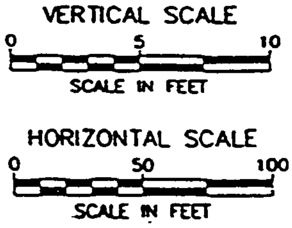
ENGINEERING PROFILE OF SANITARY
SEWER LINE FROM MH 364 TO MH 363
CORNER OF BLDG. 183) TO MH 368



SANITARY SEWER LINE NO. SS3

LEGEND:

——P—— POWER LINE
——T—— TELEPHONE LINE
——G—— GAS LINE
——W—— WATER LINE
——A—— BEGIN ASPHALT
MH • MANHOLE



NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO – NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI-ROOTER, KANSAS CITY, MO APRIL 12 – 30, 1993d.
3. SEE FIGURE 3-5 FOR PLAN VIEW OF SANITARY SEWER LINES.

U.S. ARMY CORPS OF ENGINEERS

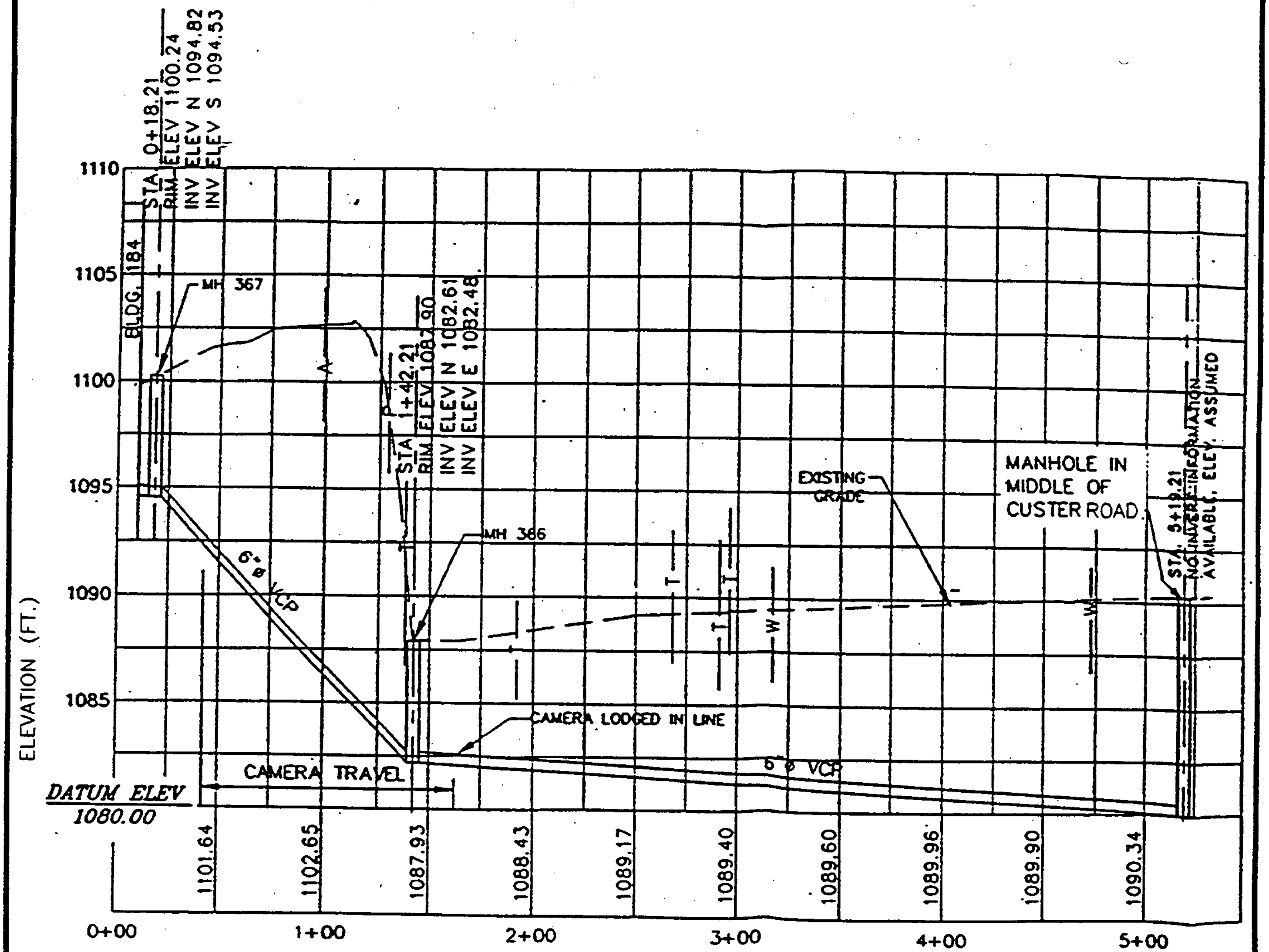
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

ENGINEERING PROFILE OF
SANITARY SEWER LINE NO. SS3
STA. 0+53 TO STA. 1+06

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-9

ENGINEERING PROFILE OF SANITARY
SEWER LINE FROM MH 367 TO
MH IN MIDDLE OF CUSTER ROAD



SANITARY SEWER LINE NO. SS4

LEGEND:

——P——	POWER LINE
——T——	TELEPHONE LINE
——G——	GAS LINE
——W——	WATER LINE
——A——	BEGIN ASPHALT
MH	MANHOLE

VERTICAL SCALE
0 5 10
SCALE IN FEET

HORIZONTAL SCALE
0 50 100
SCALE IN FEET

NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO – NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI-ROOTER, KANSAS CITY, MO APRIL 12 – 30, 1993d.
3. SEE FIGURE 3-5 FOR PLAN VIEW OF SANITARY SEWER LINES.

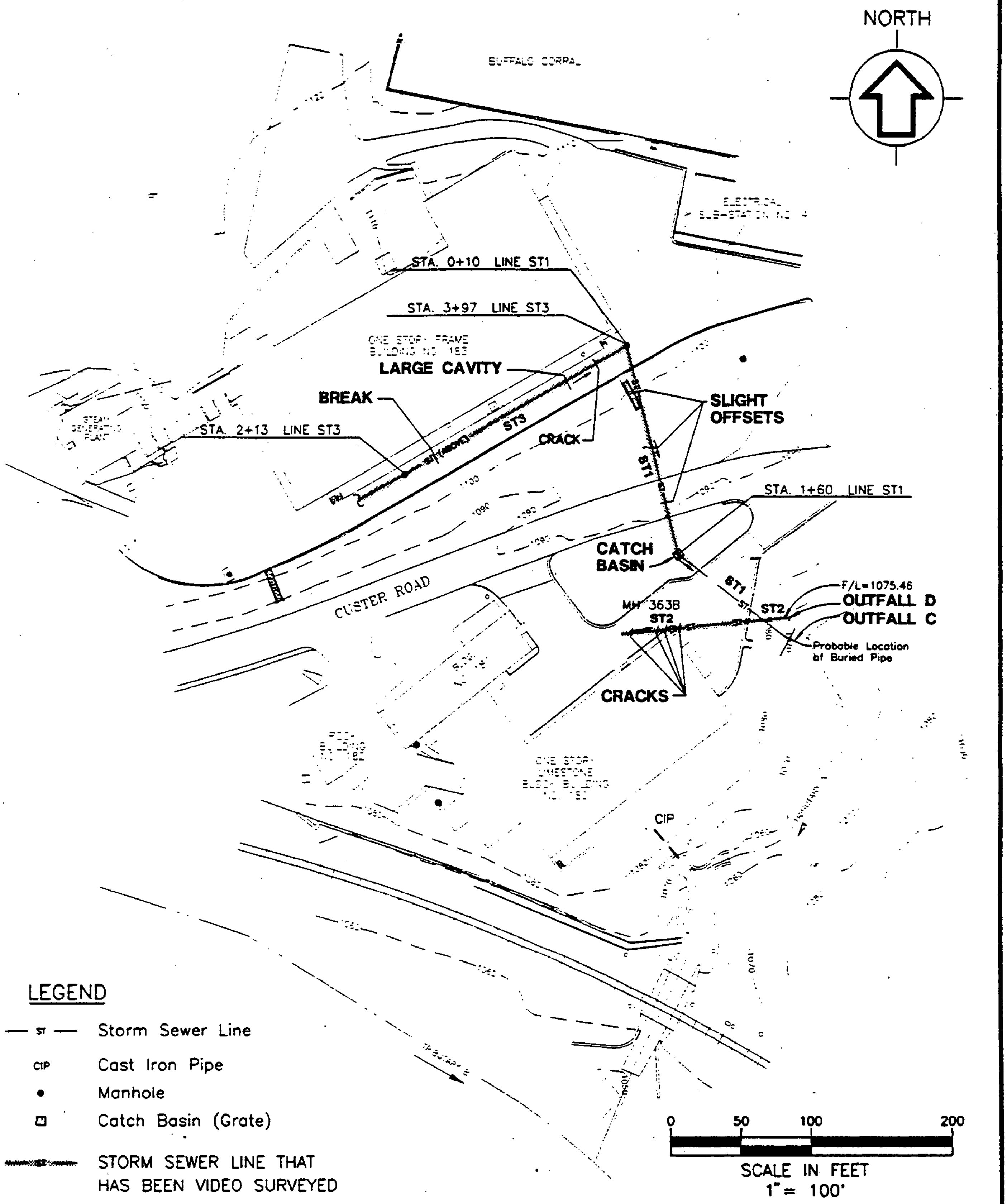
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

**ENGINEERING PROFILE OF
SANITARY SEWER LINE NO. SS4
STA. 0+18 TO STA. 54+19**

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-10



LEGEND

— ST — Storm Sewer Line

CIP Cast Iron Pipe

● Manhole

▣ Catch Basin (Grate)

—ST— STORM SEWER LINE THAT HAS BEEN VIDEO SURVEYED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993d.
3. SEE FIGURES 3-12 THROUGH 3-14 FOR PROFILES OF OF STORM SEWER LINES.

U.S. ARMY CORPS OF ENGINEERS

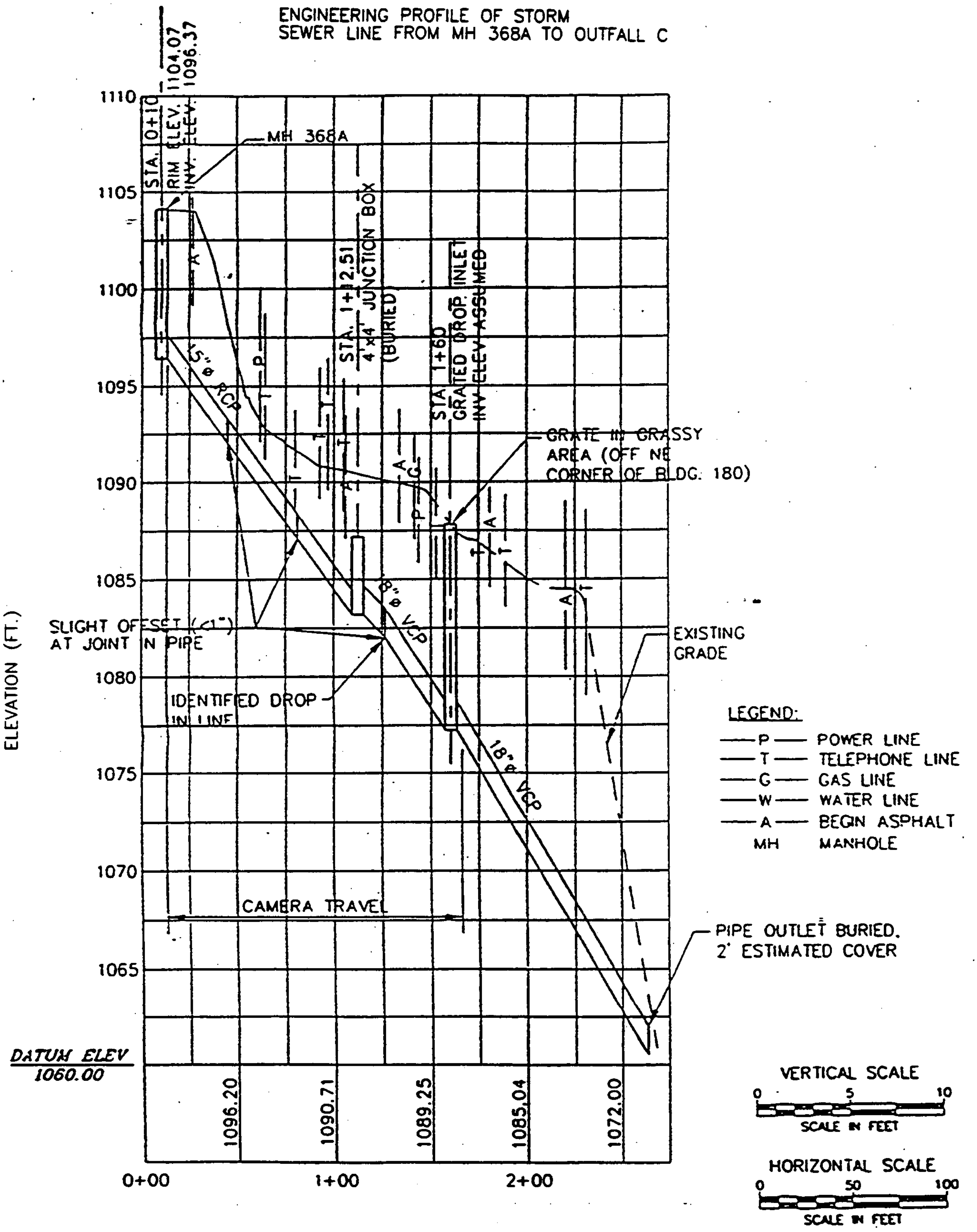
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

EXTENT OF VIDEO SURVEY IN STORM SEWER SHOWING DETECTED BREAKS, CRACKS AND CAVITY

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-11

ENGINEERING PROFILE OF STORM
SEWER LINE FROM MH 368A TO OUTFALL C



STORM SEWER LINE NO. ST1

NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO - NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI-ROOTER, KANSAS CITY, MO APRIL 12 - 30, 1993d.
3. SEE FIGURE 3-11 FOR PLAN VIEW OF STORM SEWER LINES.

U.S. ARMY CORPS OF ENGINEERS

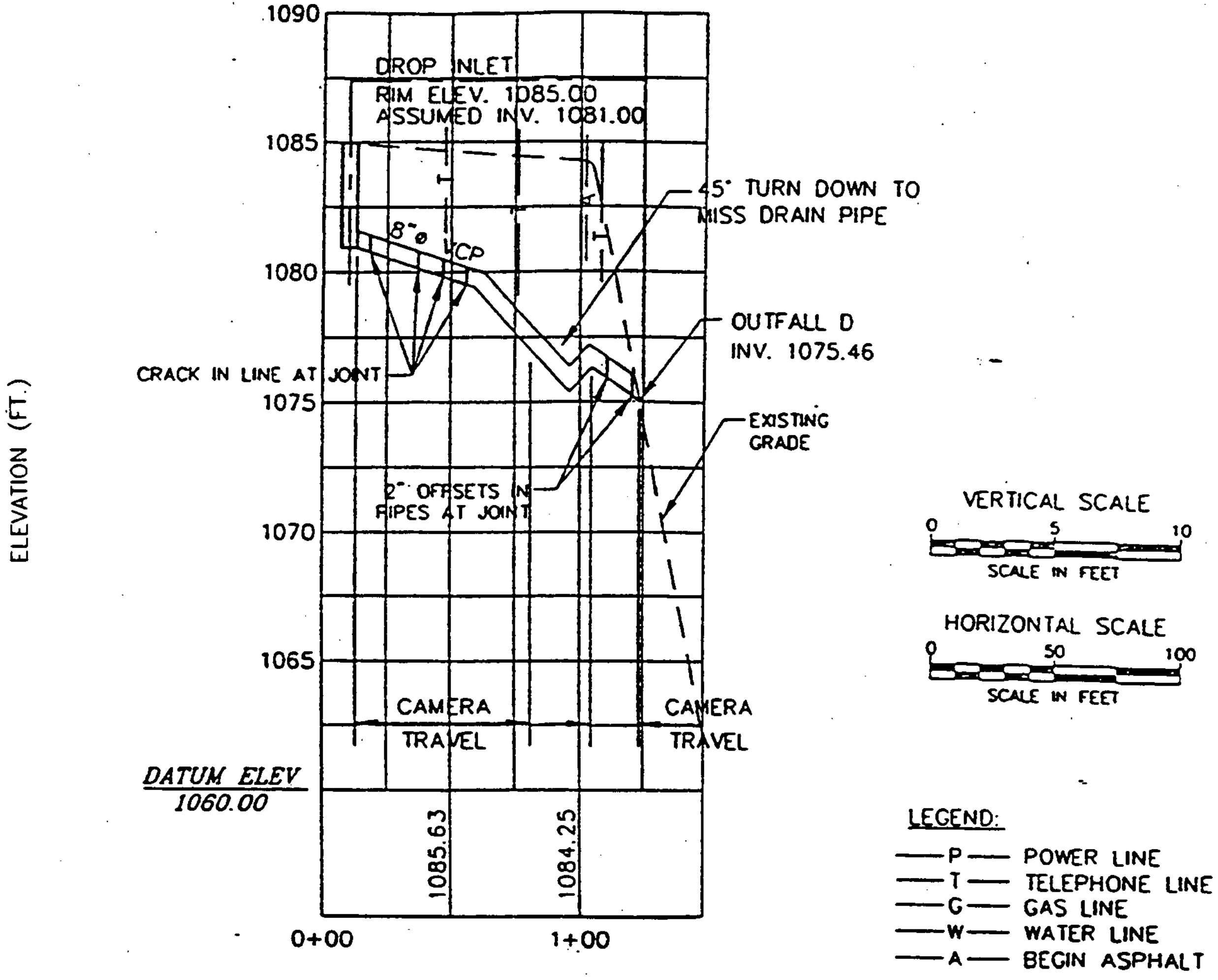
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

ENGINEERING PROFILE OF
STORM SEWER LINE NO. ST1
STA. 0+10 TO STA. 2+65

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-12

ENGINEERING PROFILE OF STORM SEWER LINE FROM DRIVEWAY (NORTH SIDE OF BLDG. 180) TO OUTFALL D



STORM SEWER LINE NO. ST2

NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO – NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI-ROOTER, KANSAS CITY, MO APRIL 12 – 30, 1993d.
3. SEE FIGURE 3-11 FOR PLAN VIEW OF STORM SEWER LINES.

U.S. ARMY CORPS OF ENGINEERS

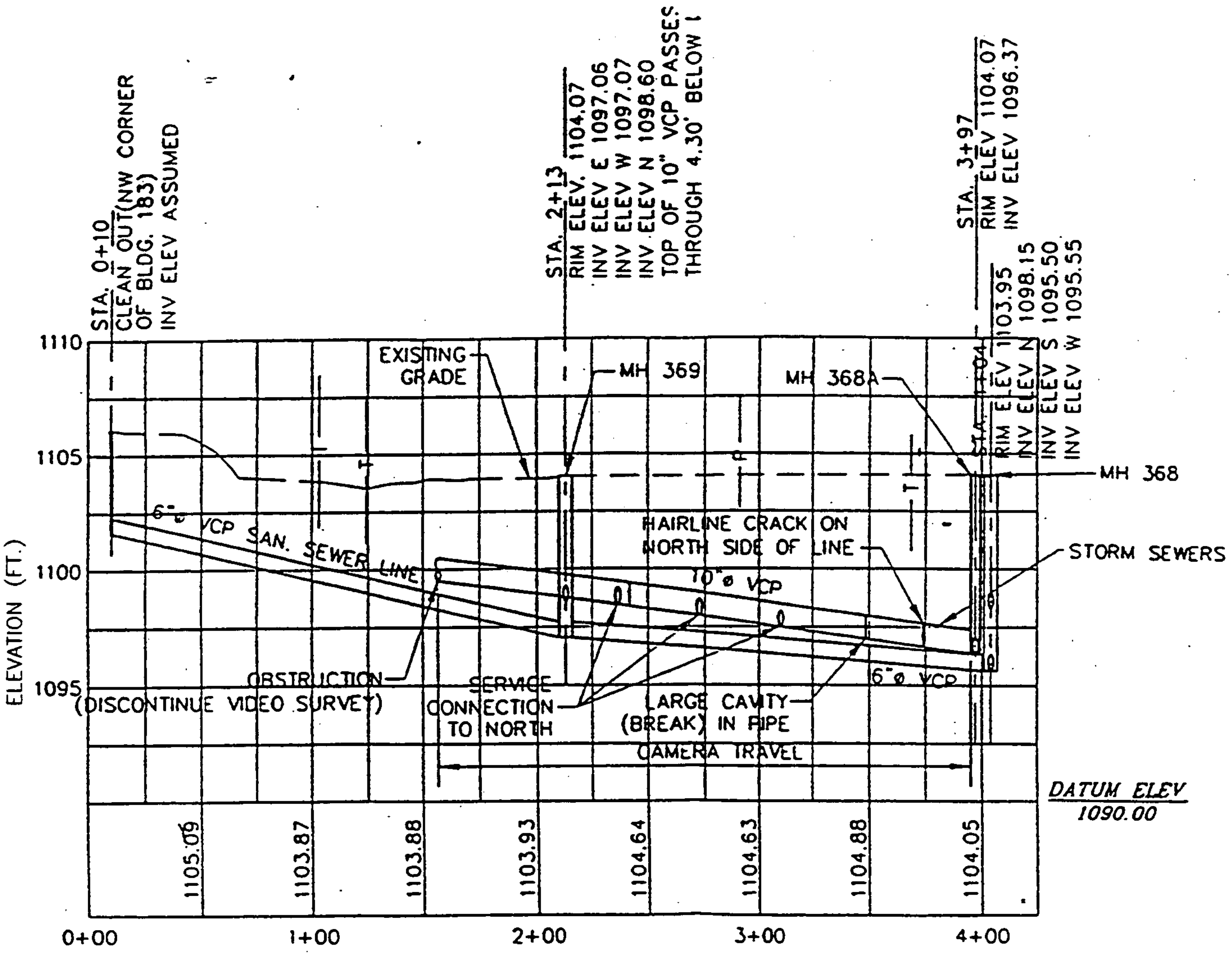
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

ENGINEERING PROFILE OF STORM SEWER LINE NO. ST2 STA. 0+12 TO STA. 1+25

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-13

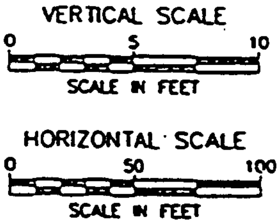
ENGINEERING PROFILE OF STORM SEWER LINE FROM MH 369 TO MH 368A



STORM SEWER LINE NO. ST3

LEGEND:

——P—— POWER LINE
——T—— TELEPHONE LINE
——G—— GAS LINE
——W—— WATER LINE
——A—— BEGIN ASPHALT
MH MANHOLE



NOTE:

1. TOPOGRAPHIC SURVEY PERFORMED BY ANDERSON SURVEY CO. KANSAS CITY, MO – NOVEMBER 19, 1991.
2. SEWER VIDEO PERFORMED BY REDDI-ROOTER, KANSAS CITY, MO APRIL 12 – 30, 1993d.
3. SEE FIGURE 3-11 FOR PLAN VIEW OF STORM SEWER LINES.

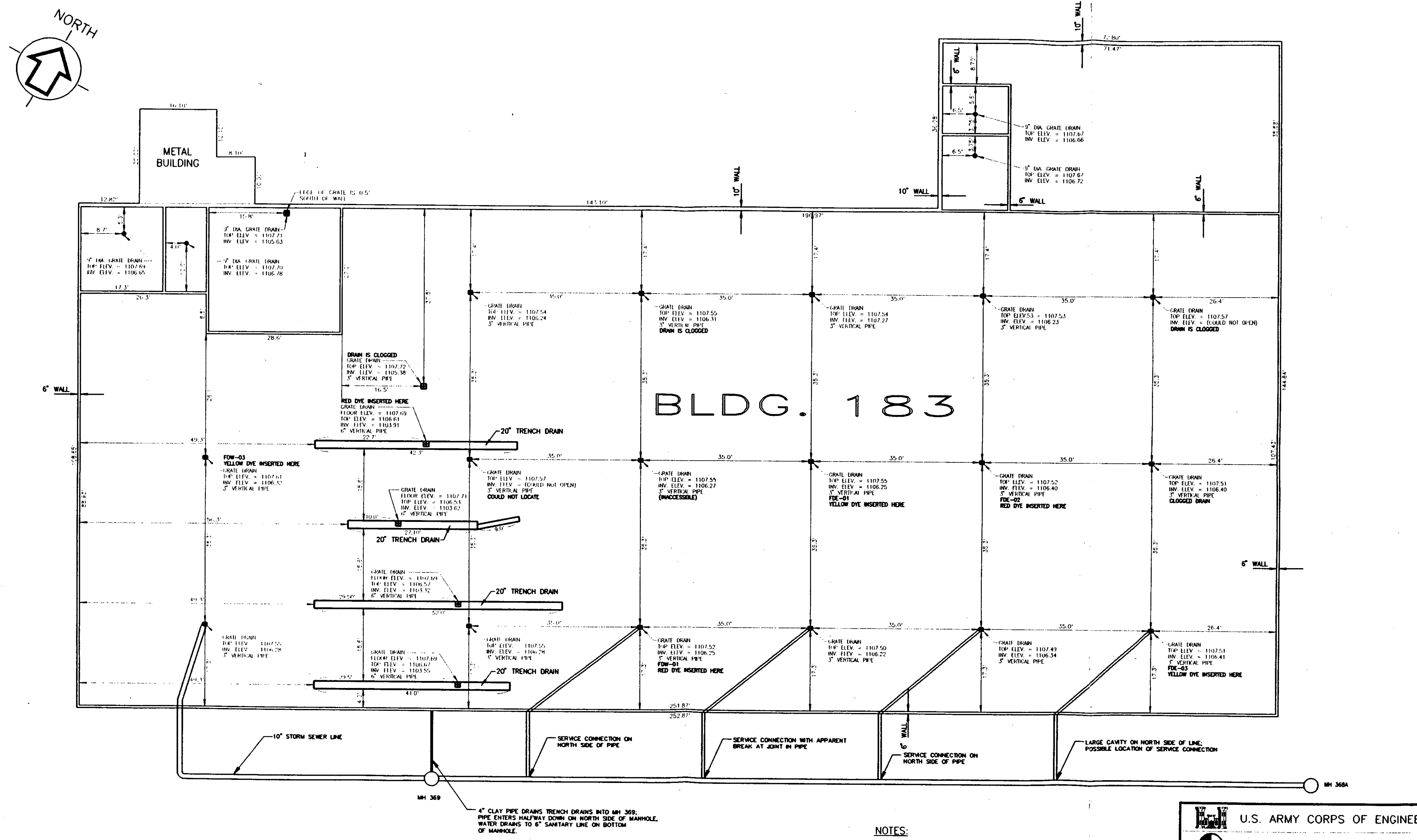
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

ENGINEERING PROFILE OF
STORM SEWER LINE NO. ST3
STA. 2+13 TO STA. 3+97

SCALE: AS SHOWN
DATE: MARCH 1995
FIG. 3–14



0 10 20 40

SCALE IN FEET

NOTES:

1. PIPE SIZES SHOWN WHERE ACCESSIBLE.
2. ALL DIMENSIONS SHOWN HERE ARE TO THE NEAR EDGE OF EACH DRAIN.
3. REFERENCE: AFTER – CEMRK 1993.

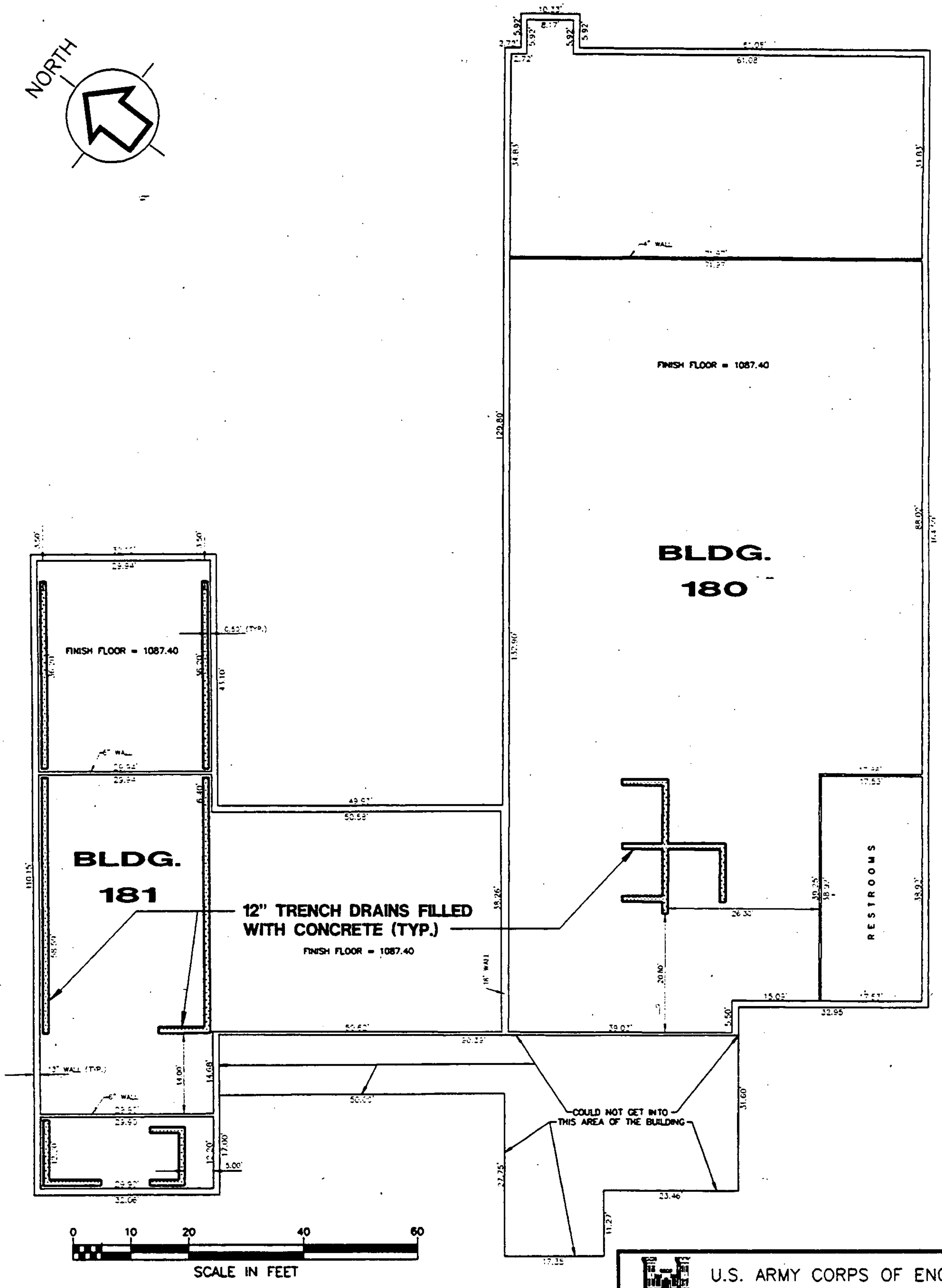
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

LOCATION OF DRAINS WITHIN BUILDING 183

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3–15



NOTES:

1. PIPE SIZES SHOWN WHERE ACCESSIBLE AND MEASURED.
2. ALL DIMENSIONS SHOWN HERE ARE TO THE NEAR EDGE OF EACH DRAIN.
3. REFERENCE: AFTER - CEMRK 1993d.

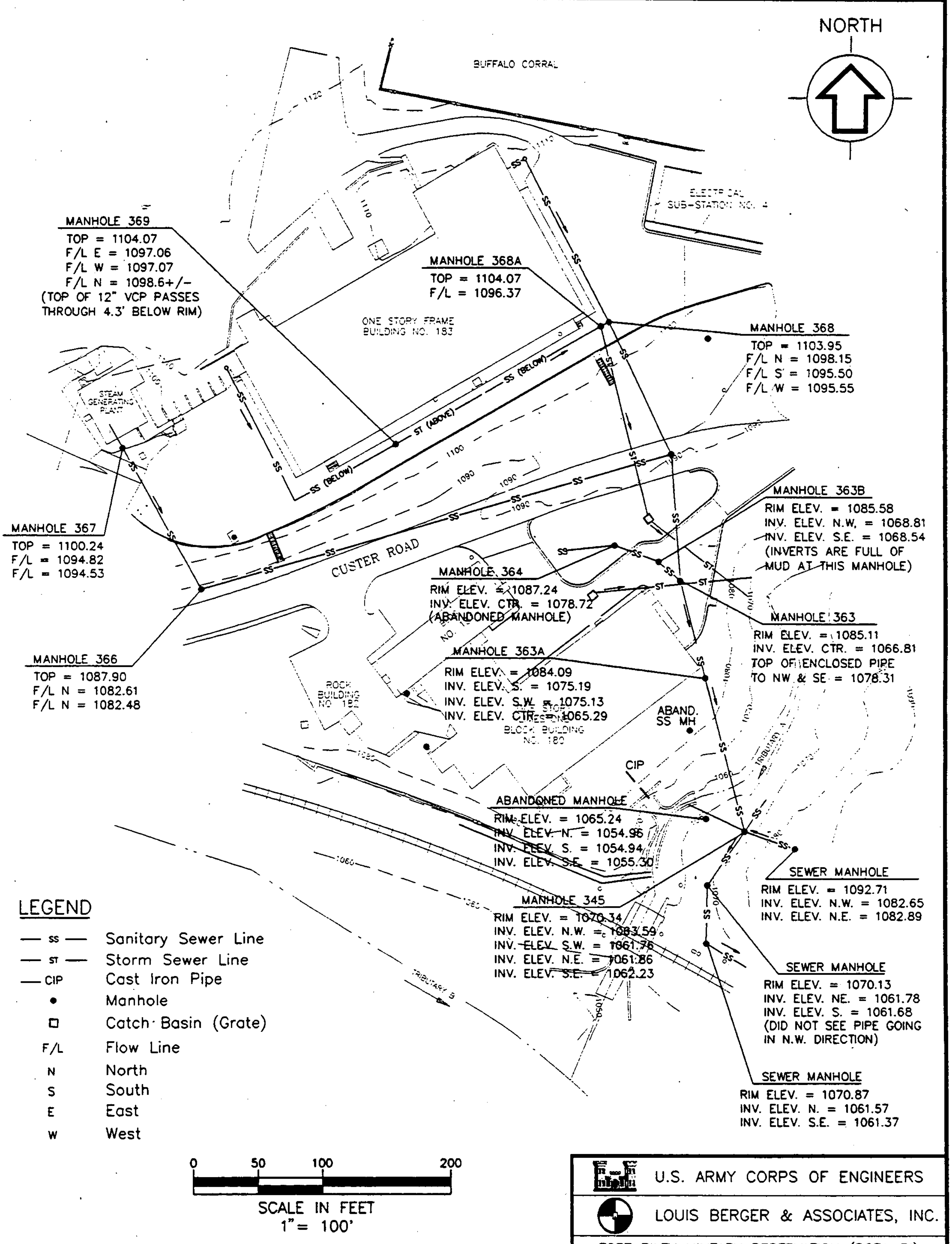
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

LOCATION OF TRENCH DRAINS WITHIN BUILDING 180/181

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 3-16



LEGEND

— SS —	Sanitary Sewer Line
— ST —	Storm Sewer Line
— CIP	Cast Iron Pipe
●	Manhole
☐	Catch Basin (Grate)
F/L	Flow Line
N	North
S	South
E	East
W	West

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993d.

U.S. ARMY CORPS OF ENGINEERS

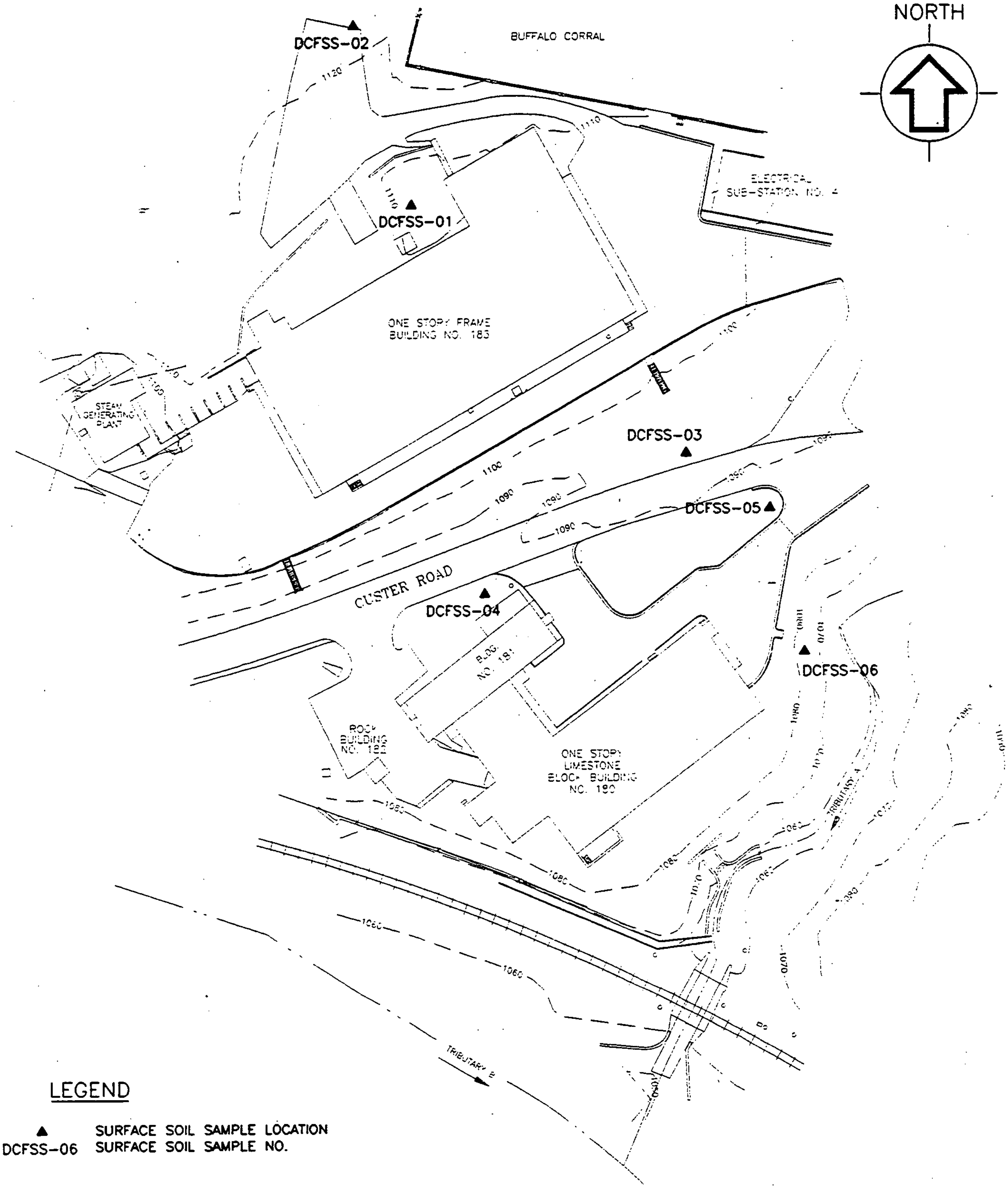
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

RESULTS OF ELEVATION SURVEY ON MANHOLES

SCALE: AS SHOWN
DATE: MARCH 1995
FIG: 3-17

5-RTSMH/30MAR95



LEGEND

▲	SURFACE SOIL SAMPLE LOCATION
DCFSS-06	SURFACE SOIL SAMPLE NO.

0 50 100 200

SCALE IN FEET
1" = 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. ALL SAMPLES TAKEN FROM 0-5' BELOW GROUND SURFACE.
3. REFERENCE: AFTER - CEMRK 1993d.

U.S. ARMY CORPS OF ENGINEERS

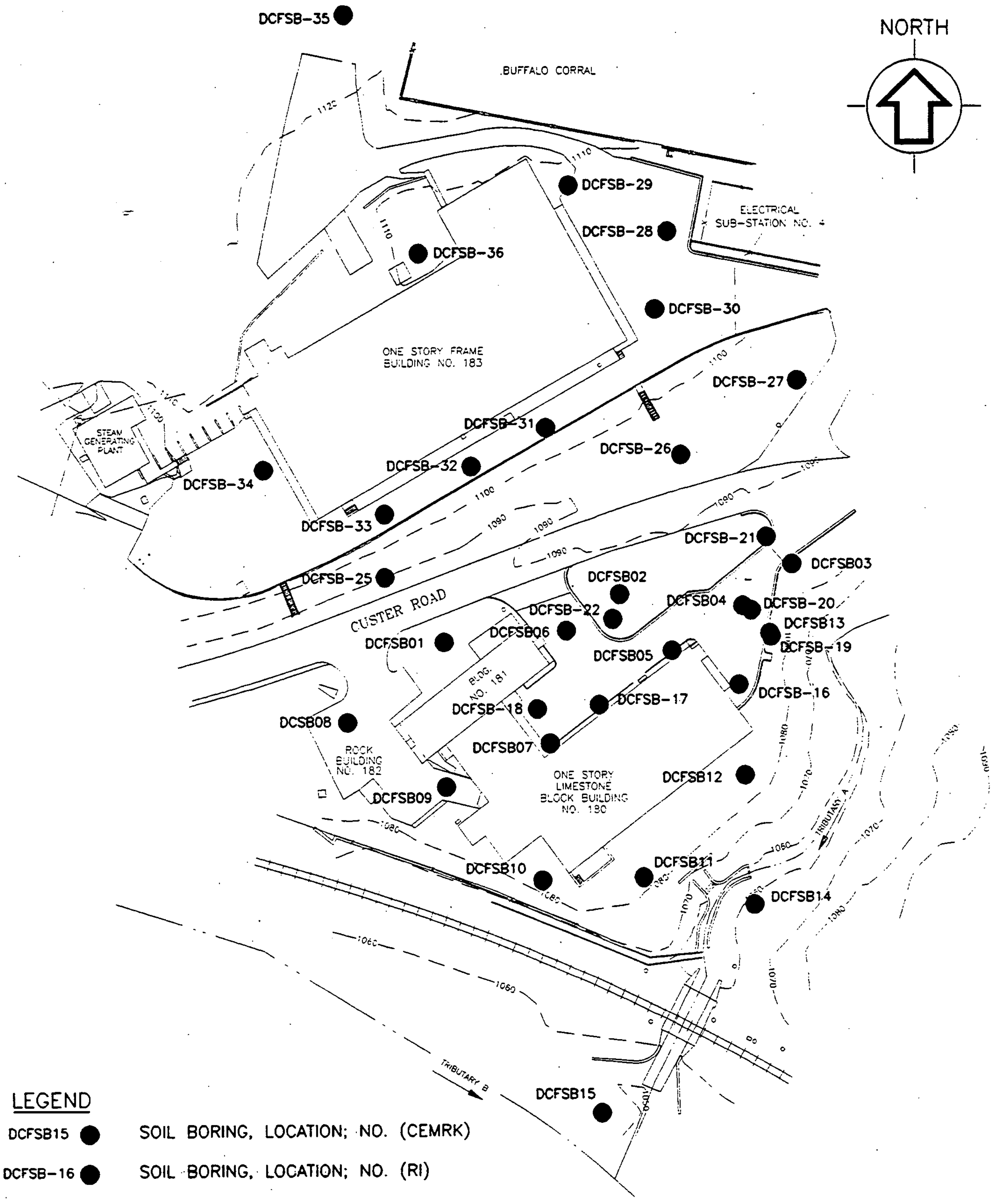
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

**LOCATION OF SURFACE SOIL SAMPLES
RI INVESTIGATION - 11/93**

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 3-18

3-SSS/30MAR95



LEGEND

DCFSB15 ●	SOIL BORING, LOCATION; NO. (CEMRK)
DCFSB-16 ●	SOIL BORING, LOCATION; NO. (RI)

0 50 100 200

SCALE IN FEET
1" = 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992b, 1994b AND 1994e.
3. DCFSB01 THROUGH DCFSB15, CEMRK 1992b.
   DCFSB-16 THROUGH DCFSB-36, RI INVESTIGATION.

U.S. ARMY CORPS OF ENGINEERS

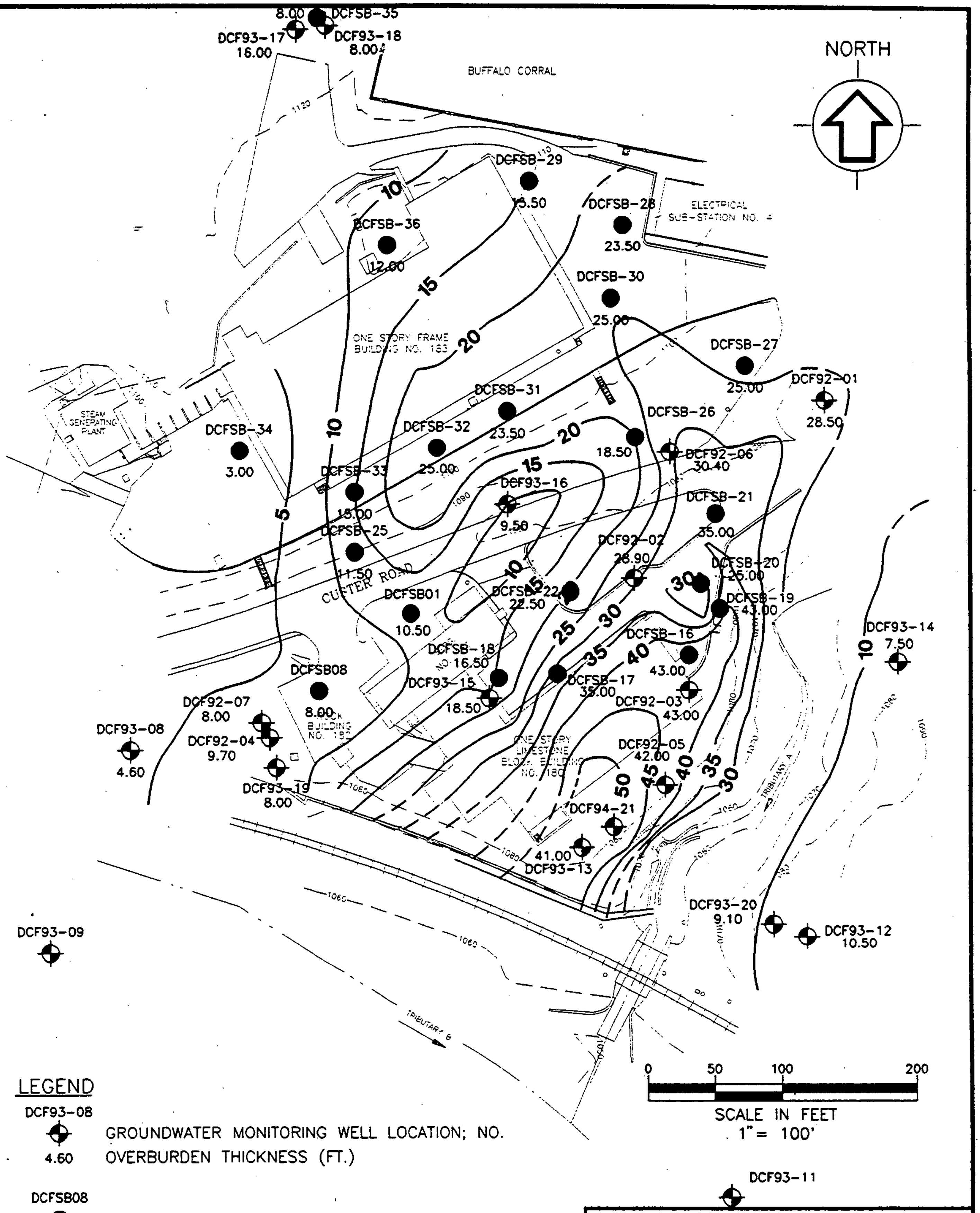
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

SOIL BORING LOCATION MAP - 11/93

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-19

3—ALBUR2/30MAR95



LEGEND

DCF93-08

⊕ GROUNDWATER MONITORING WELL LOCATION; NO.

4.60 OVERBURDEN THICKNESS (FT.)

DCFSB08

● SOIL BORING LOCATION

8.00 OVERBURDEN THICKNESS VALUE (FT)

—40— OVERBURDEN THICKNESS (FT) CONTOUR

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.

U.S. ARMY CORPS OF ENGINEERS

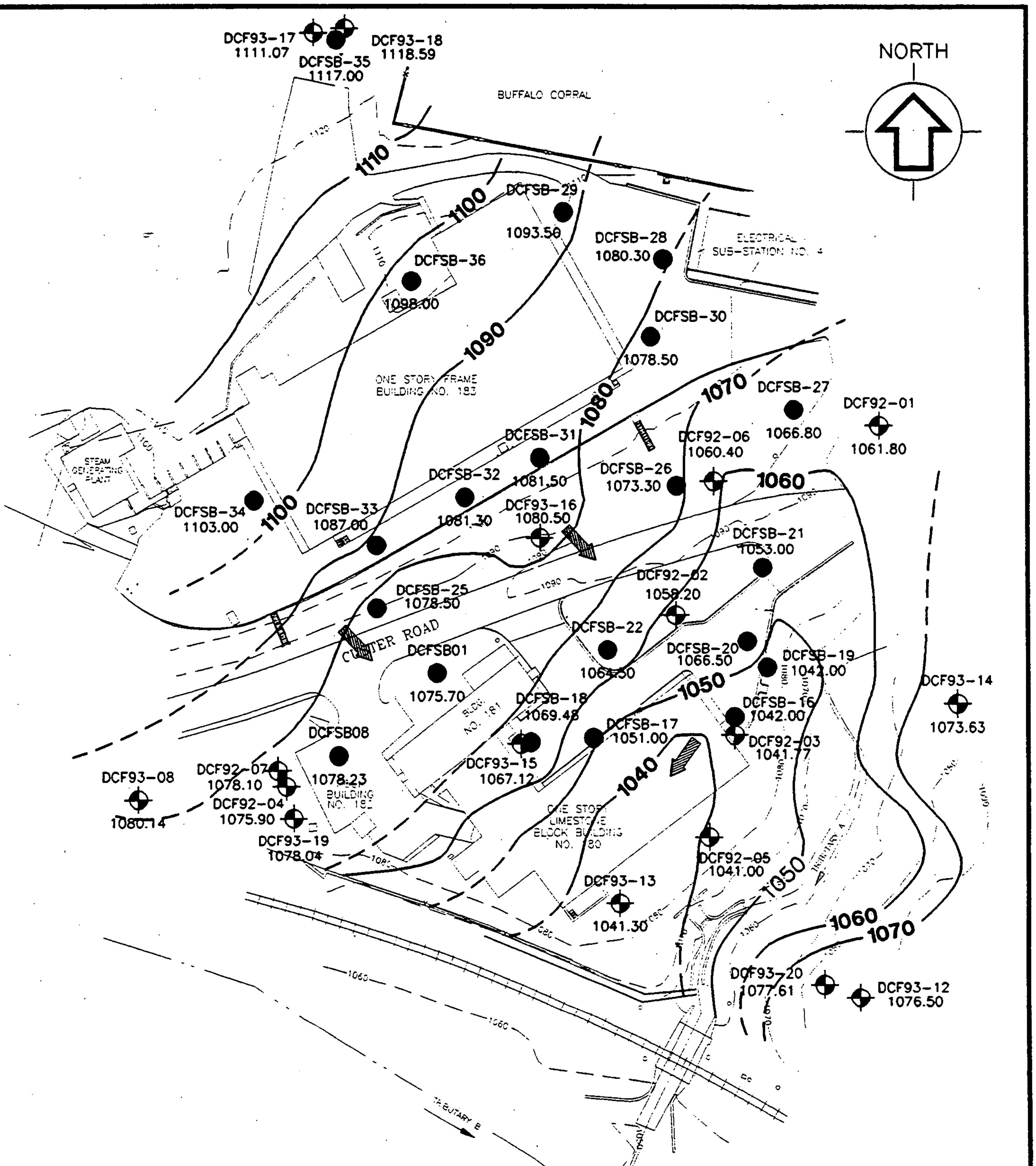
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

OVERBURDEN ISOPACH MAP, 11/93

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-20

3-ORTHK/30MAR95



LEGEND

DCF93-08
⊕ GROUNDWATER MONITORING WELL LOCATION; NO.
1080.14 BEDROCK ELEVATION (FT.)

DCFSB08
● SOIL BORING LOCATION
1078.23 BEDROCK ELEVATION (FT.)

-1040- BEDROCK ELEVATION CONTOUR (FT)

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.

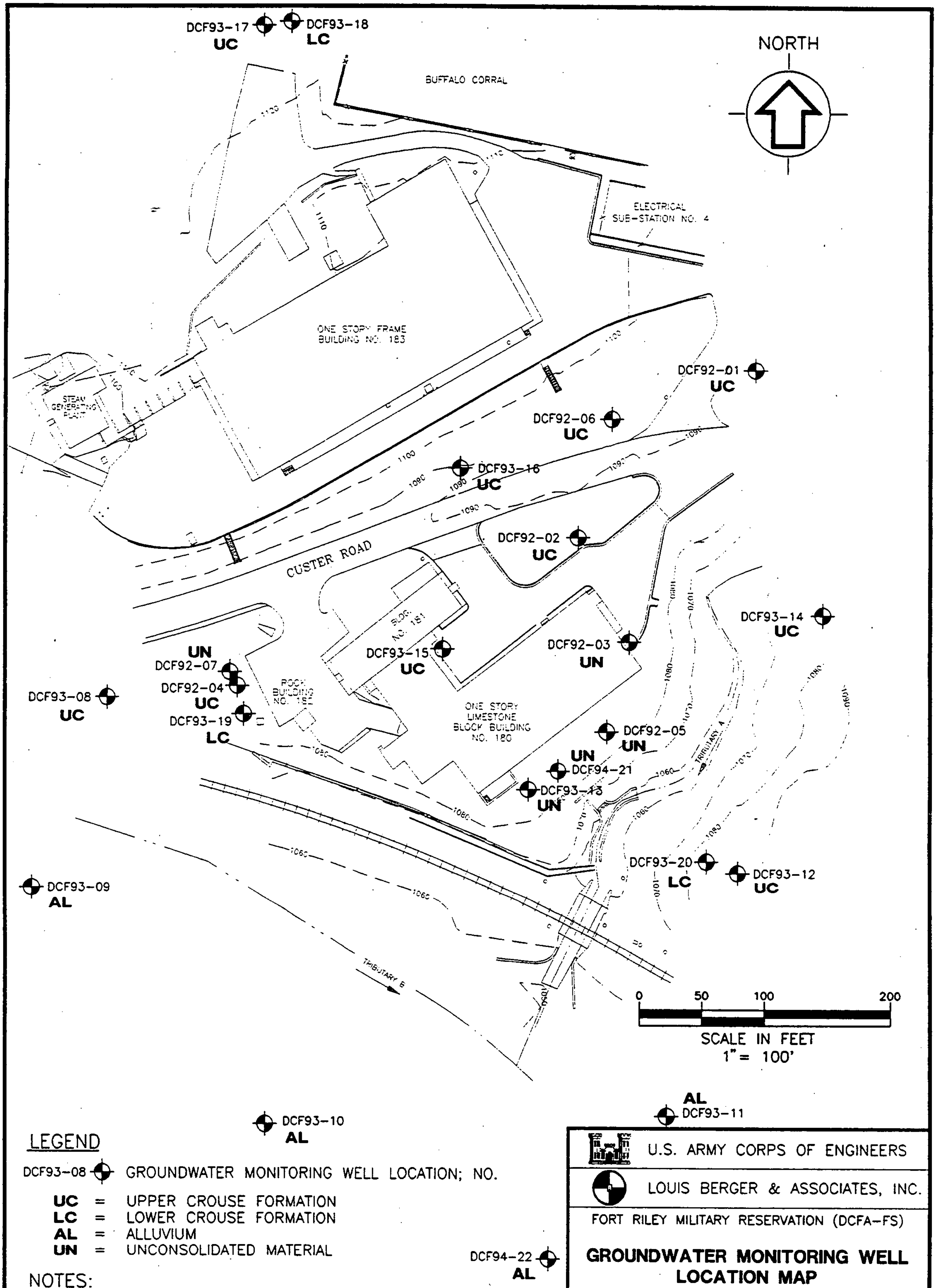
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

DCFA BEDROCK CONTOUR MAP
11/93

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-21



LEGEND

DCF93-08 ⊕ GROUNDWATER MONITORING WELL LOCATION; NO.

UC = UPPER CROUSE FORMATION
LC = LOWER CROUSE FORMATION
AL = ALLUVIUM
UN = UNCONSOLIDATED MATERIAL

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.

U.S. ARMY CORPS OF ENGINEERS

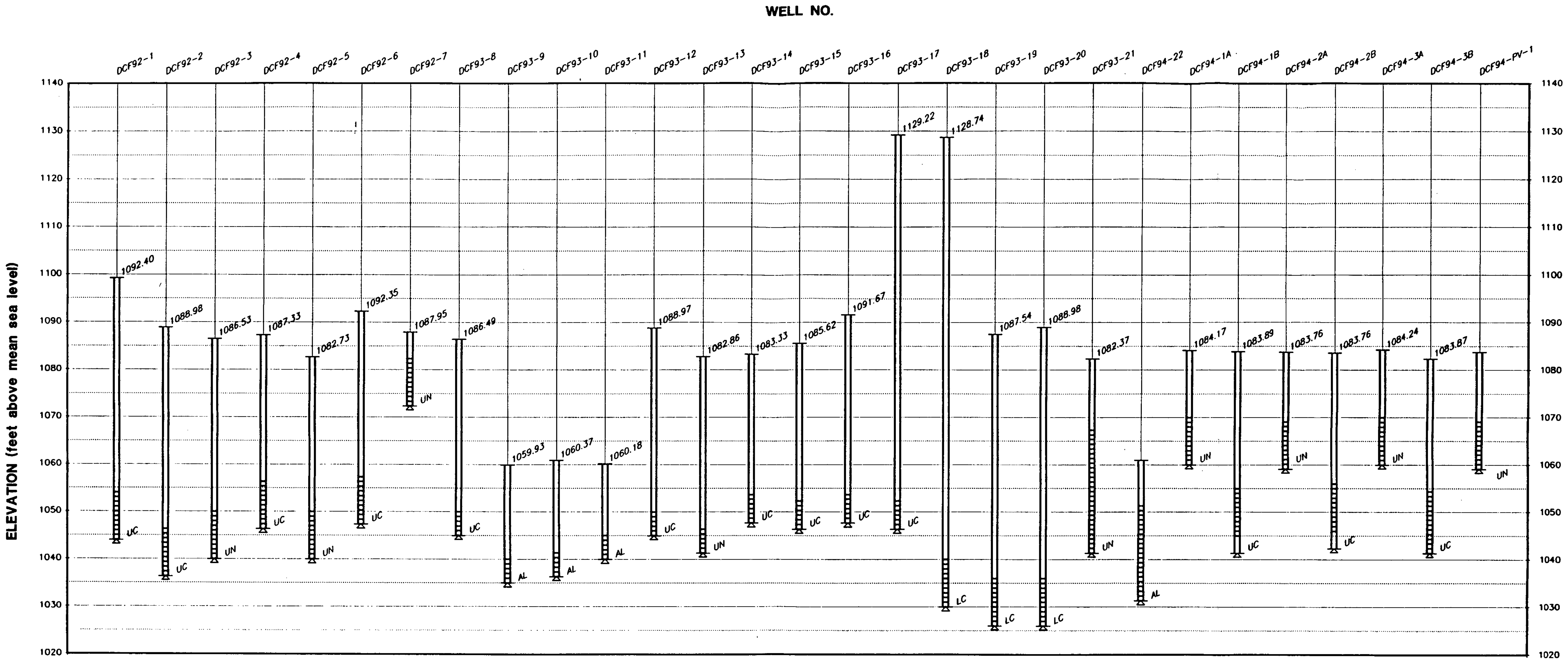
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-FS)

GROUNDWATER MONITORING WELL LOCATION MAP

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-22

3-AI WELL/ 30MAR95



LEGEND:

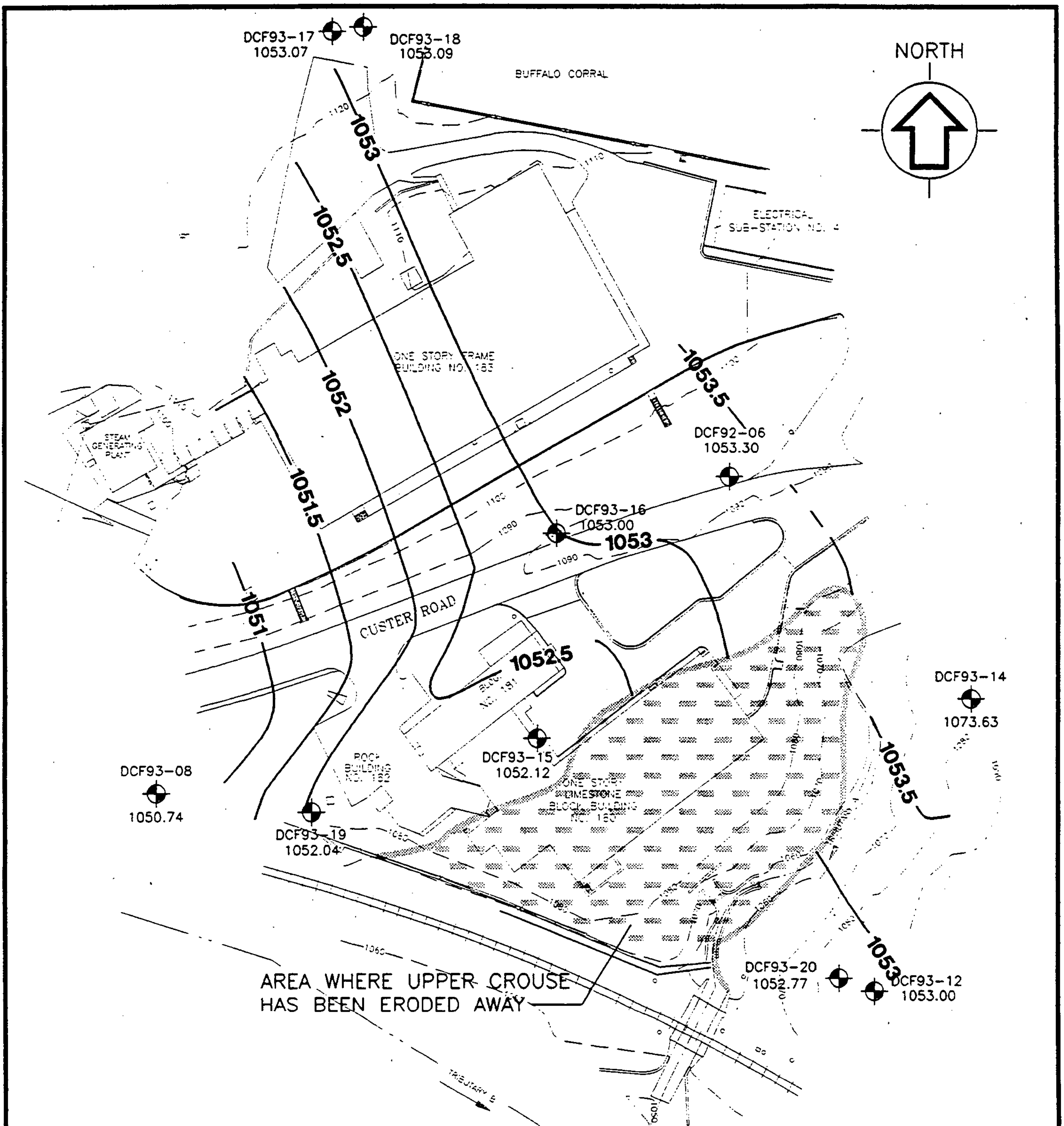
UC - UPPER CROUSE
LC - LOWER CROUSE
UN - UNCONSOLIDATED
AL - ALLUVIUM

1087.95
TOP OF CASING ELEVATION
SCREEN ZONE
TOTAL DEPTH

U.S. ARMY CORPS OF ENGINEERS
LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER MONITORING WELL COMPLETIONS WITHIN DCFA

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-23



LEGEND

DCF93-08
GROUNDWATER MONITORING WELL LOCATION; NO.
4.60 UPPER CROUSE ELEVATION VALUE (FT)

— **40** — TOP OF UPPER CROUSE ELEVATION (FT) CONTOUR

0 50 100 200
SCALE IN FEET
1" = 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. THE ONLY WELLS SHOWN ARE THOSE IN WHICH THE LOCATION OF THE UPPER CROUSE COULD BE CONFIRMED.

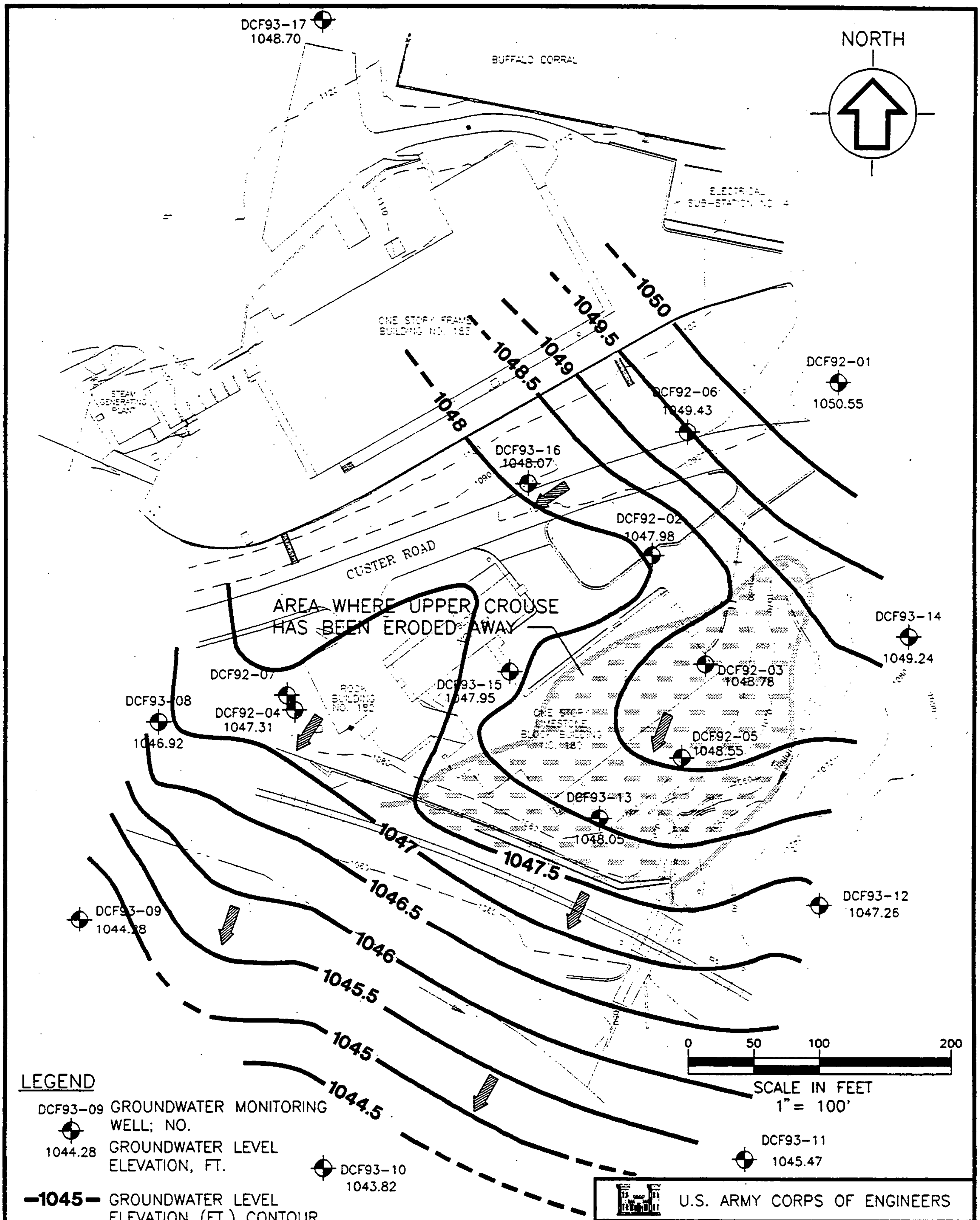
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

STRUCTURE CONTOUR MAP
TOP OF UPPER CROUSE

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-24



LEGEND

DCF93-09 ⊕ 1044.28 — GROUNDWATER MONITORING WELL; NO. GROUNDWATER LEVEL ELEVATION, FT.

—1045— GROUNDWATER LEVEL ELEVATION (FT.) CONTOUR

⇦ GROUNDWATER FLOW DIRECTION

Notes:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. DEEP WELLS DCF93-18, DCF93-19 & DCF93-20 ARE NOT SHOWN
3. GROUNDWATER LEVEL DATA COLLECTED DURING 2/94 SAMPLING EVENT.

U.S. ARMY CORPS OF ENGINEERS

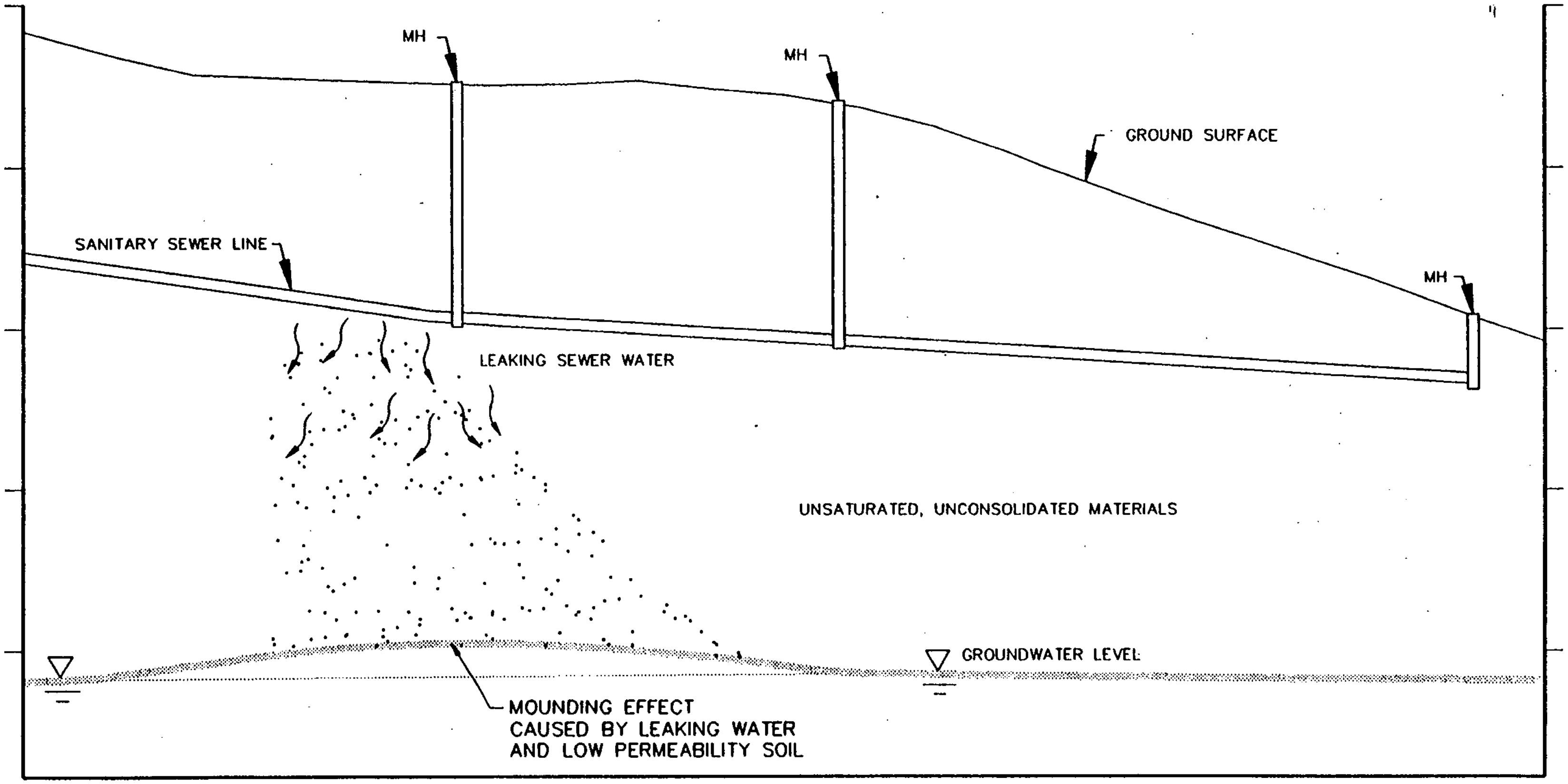
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

POTENTIOMETRIC CONTOURS UPPER CROUSE & UNCONSOLIDATED MATERIALS COMBINED - 2/94

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-25

5-95SLLCM/30MAR95



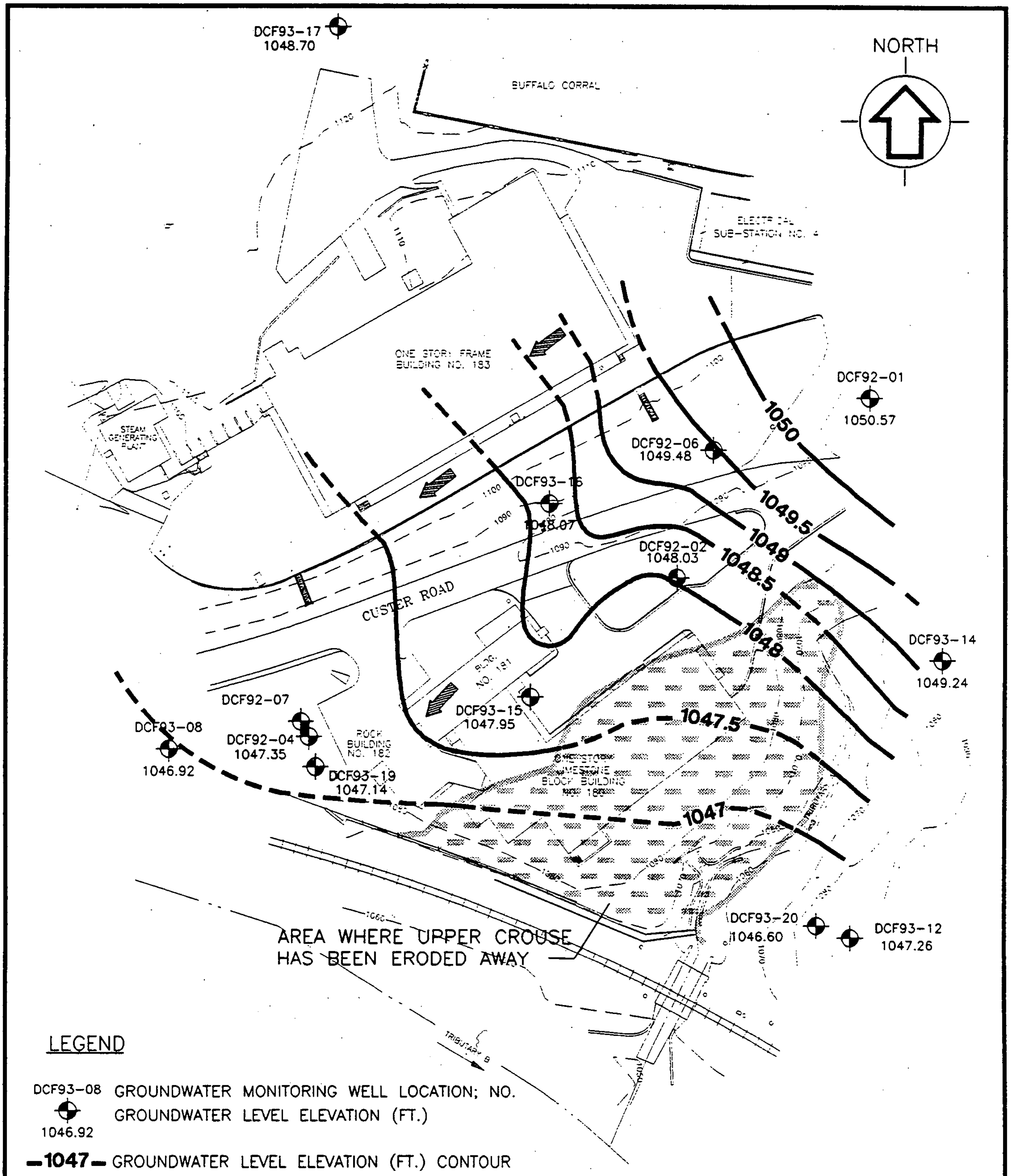
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

SCHEMATIC OF APPARENT SEWER LINE LEAKS CAUSING MOUNDING OF GROUNDWATER

SCALE:	DATE:	
NONE	MARCH 1995	FIG. 3-26



LEGEND

DCF93-08 1046.92 GROUNDWATER MONITORING WELL LOCATION; NO. GROUNDWATER LEVEL ELEVATION (FT.)

—1047— GROUNDWATER LEVEL ELEVATION (FT.) CONTOUR

GROUNDWATER FLOW DIRECTION

0 50 100 200

SCALE IN FEET
1"= 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. GROUNDWATER LEVEL DATA COLLECTED DURING 2/94 SAMPLING EVENT

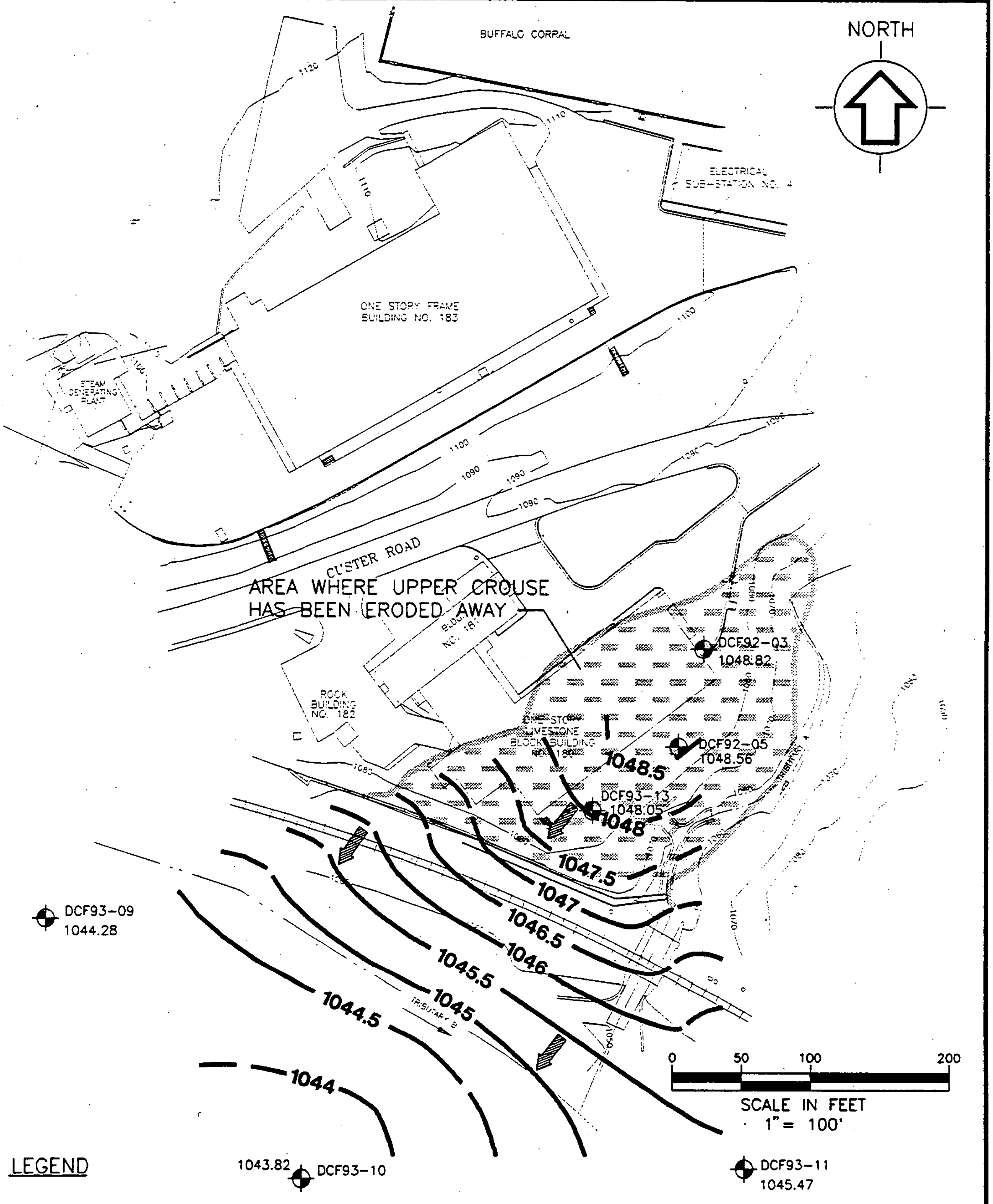
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

POTENTIOMETRIC CONTOURS UPPER CROUSE LIMESTONE

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-27



LEGEND

DCF93-08 ⊕ 1046.92 GROUNDWATER MONITORING WELL LOCATION; NO. GROUNDWATER LEVEL ELEVATION (FT)

—1047 — GROUNDWATER LEVEL ELEVATION (FT) CONTOUR

⇦ GROUNDWATER FLOW DIRECTION

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. GROUNDWATER LEVEL DATA COLLECTED DURING 2/94

U.S. ARMY CORPS OF ENGINEERS

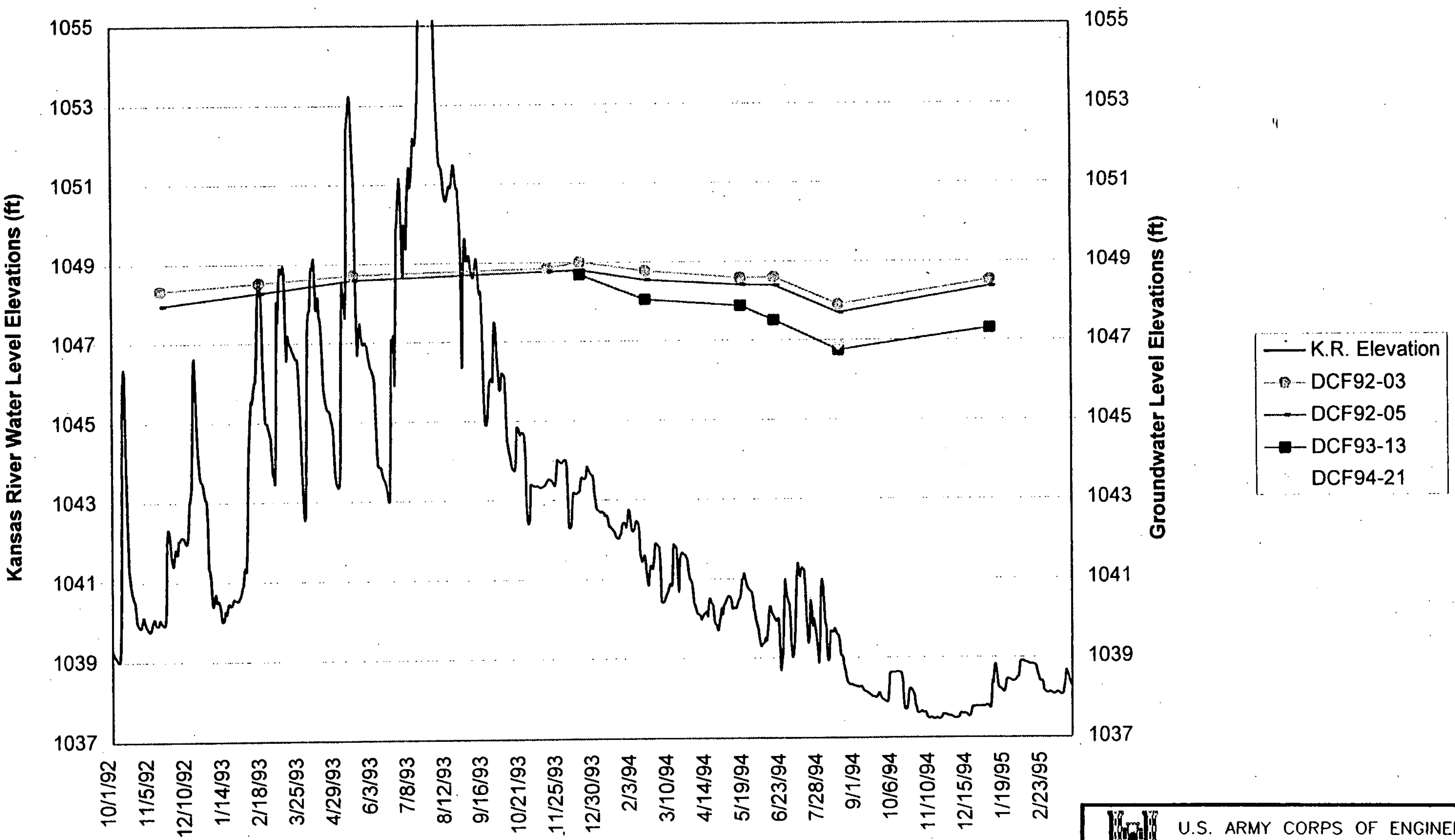
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

WATER TABLE MAP IN UNCONSOLIDATED MATERIALS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-28

3-4.3a/30MAR95



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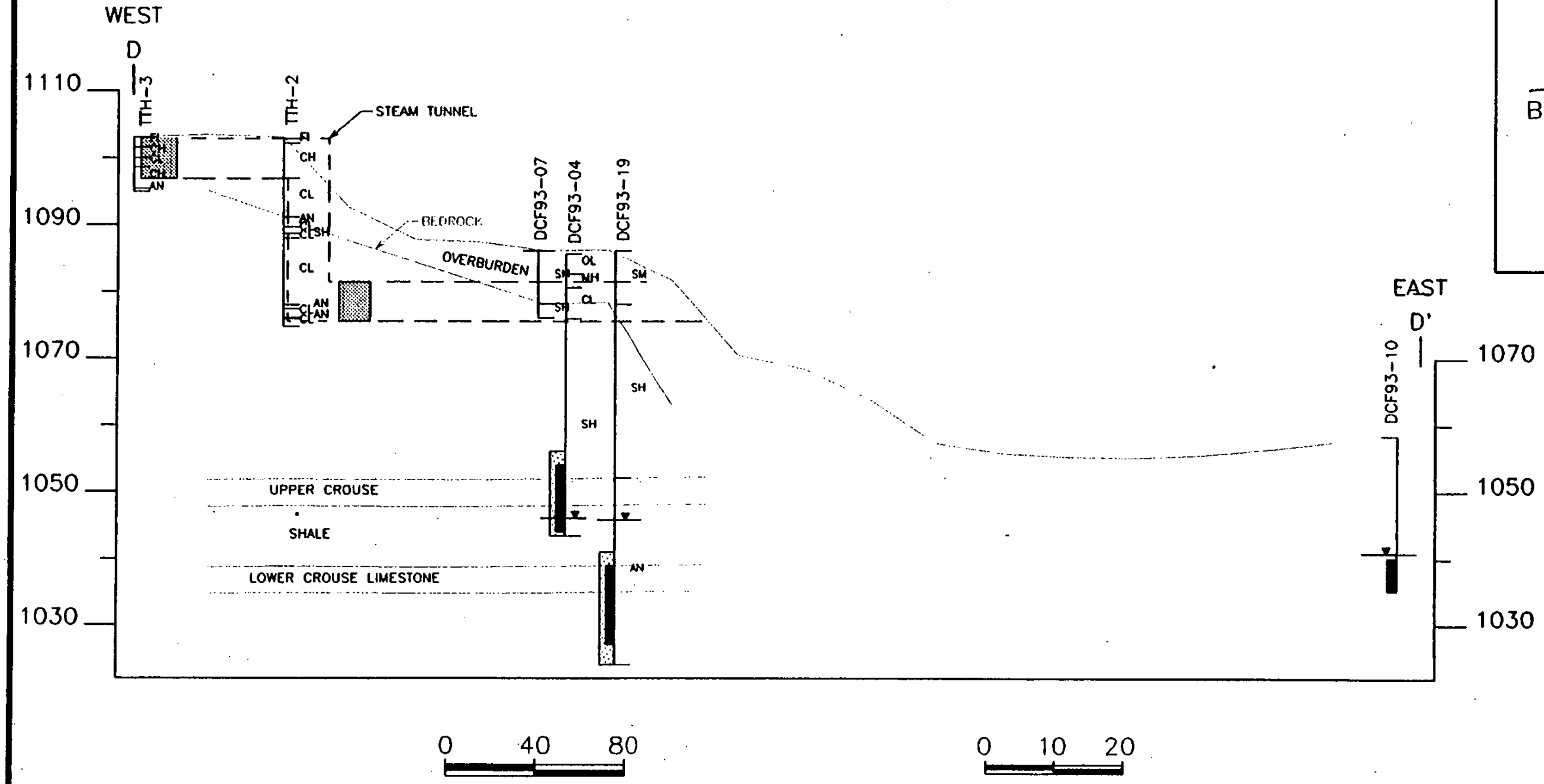
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUDWATER/KANSAS RIVER WATER LEVEL ELEVATIONS VS. TIME UNCONSOLIDATED MATERIALS

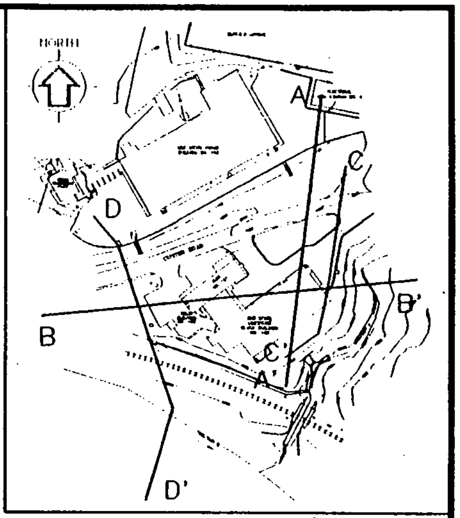
SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-29

3 - GEODD / 30MAR95



HORIZONTAL SCALE: 1" = 80'

VERTICAL SCALE: AS SHOWN



KEY TO CROSS SECTIONS
N.T.S.

NOTES:

1. Ground surface profile created based on survey data of ground surface at wells and borings combined with topographic survey data points.
2. Bedrock profile created based on data collected from split spoons taken during well/boring installation.
3. Upper Crouse profile created based on data collected from split spoon samples taken during well/boring installation.
4. Water level information taken from January 1995 sampling event.

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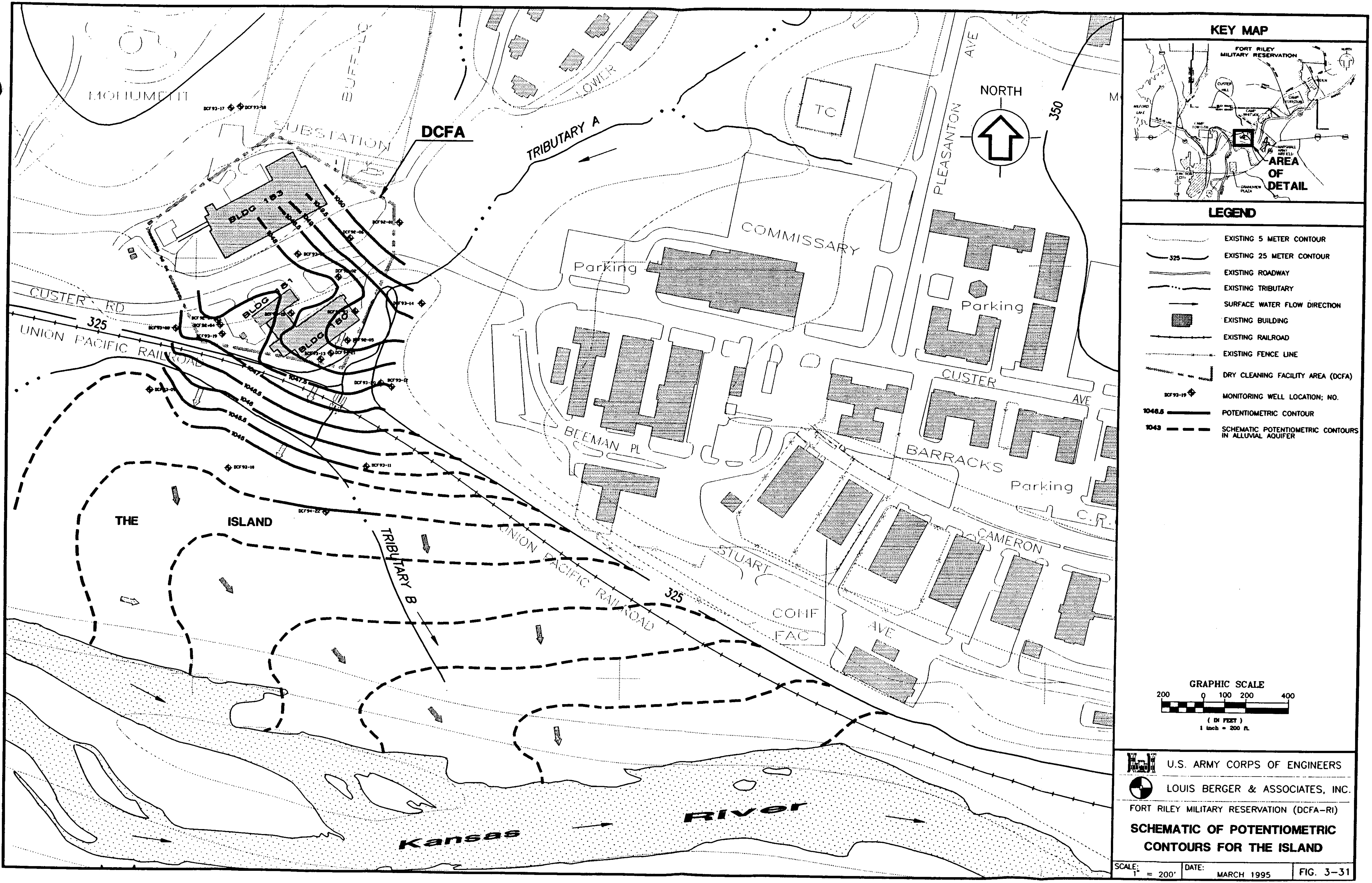
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

GEOLOGIC CROSS SECTION D-D

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-30



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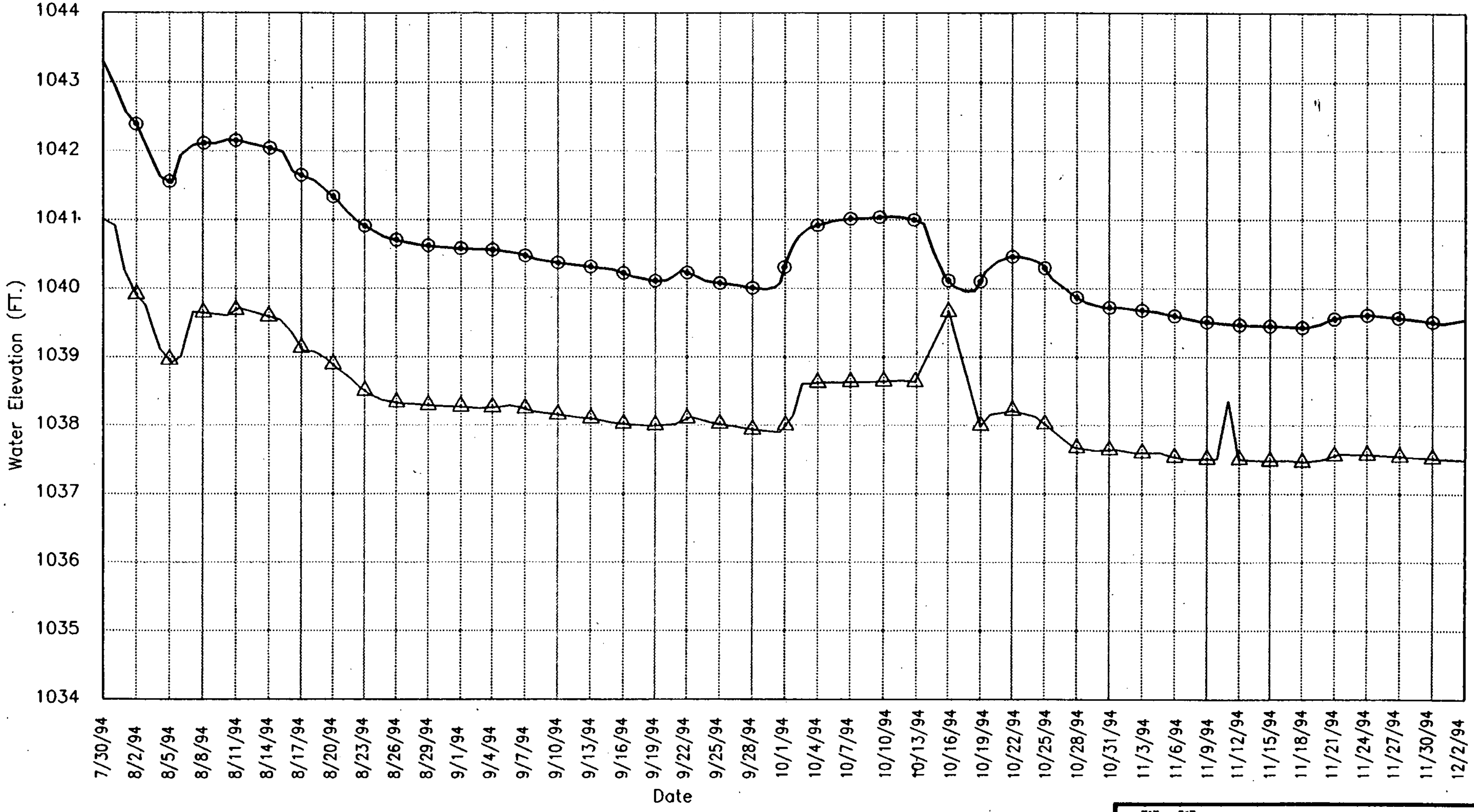
FORT RILEY MILITARY RESERVATION (DCFA-RI)

SCHEMATIC OF POTENTIOMETRIC CONTOURS FOR THE ISLAND

SCALE: 1" = 200'	DATE: MARCH 1995	FIG. 3-31

DCF94-22 and KANSAS RIVER HYDROGRAPH
JULY 30 to DECEMBER 2 1994



⊙ = DCF94-22 WATER LEVEL
△ = KANSAS RIVER LEVEL

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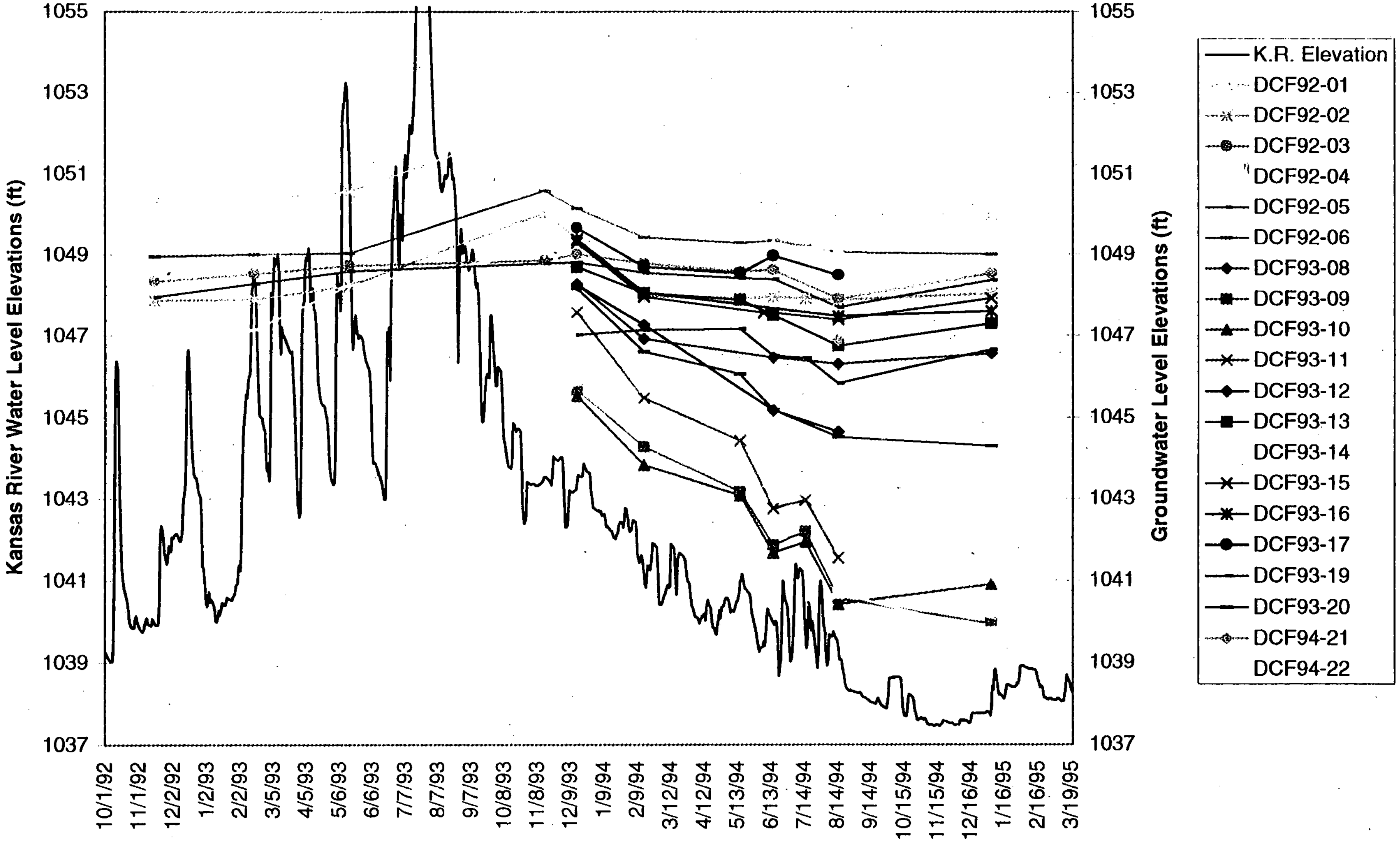
LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-RI)

COMPARATIVE WATER LEVEL DATA

SCALE: NONE	DATE: MARCH 1995	FIG. 3-32

3-43a/30MAR95



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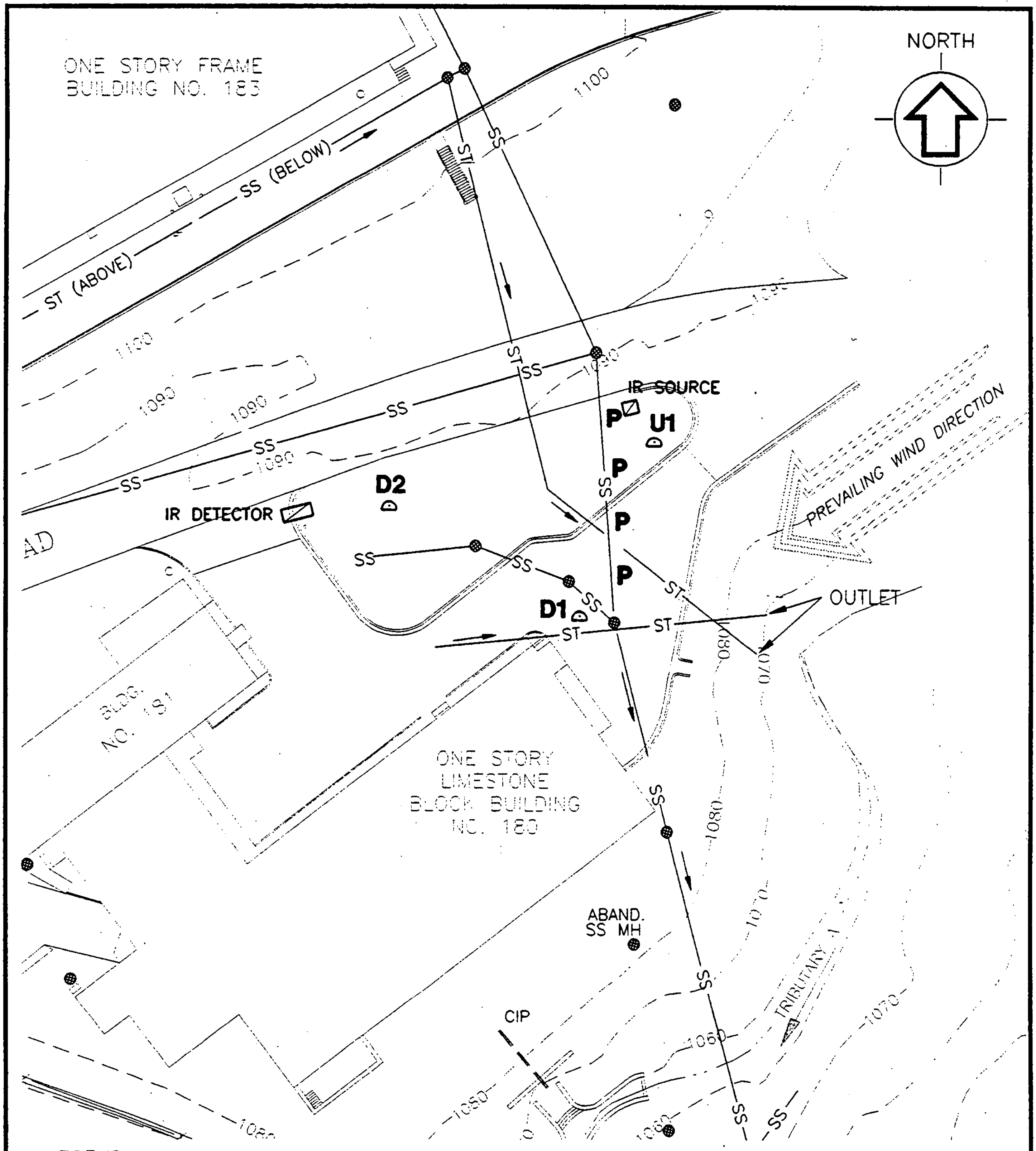
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER/KANSAS RIVER WATER LEVEL ELEVATIONS VS. TIME

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-33



0 25 50 100

SCALE IN FEET

LEGEND:

⌓ **U1** = UPWIND
⌓ **D1** = DOWNWIND, LOC.1
⌓ **D2** = DOWNWIND, LOC.2
P = PID SAMPLING PT.
IR = INFARED EPA MONITOR

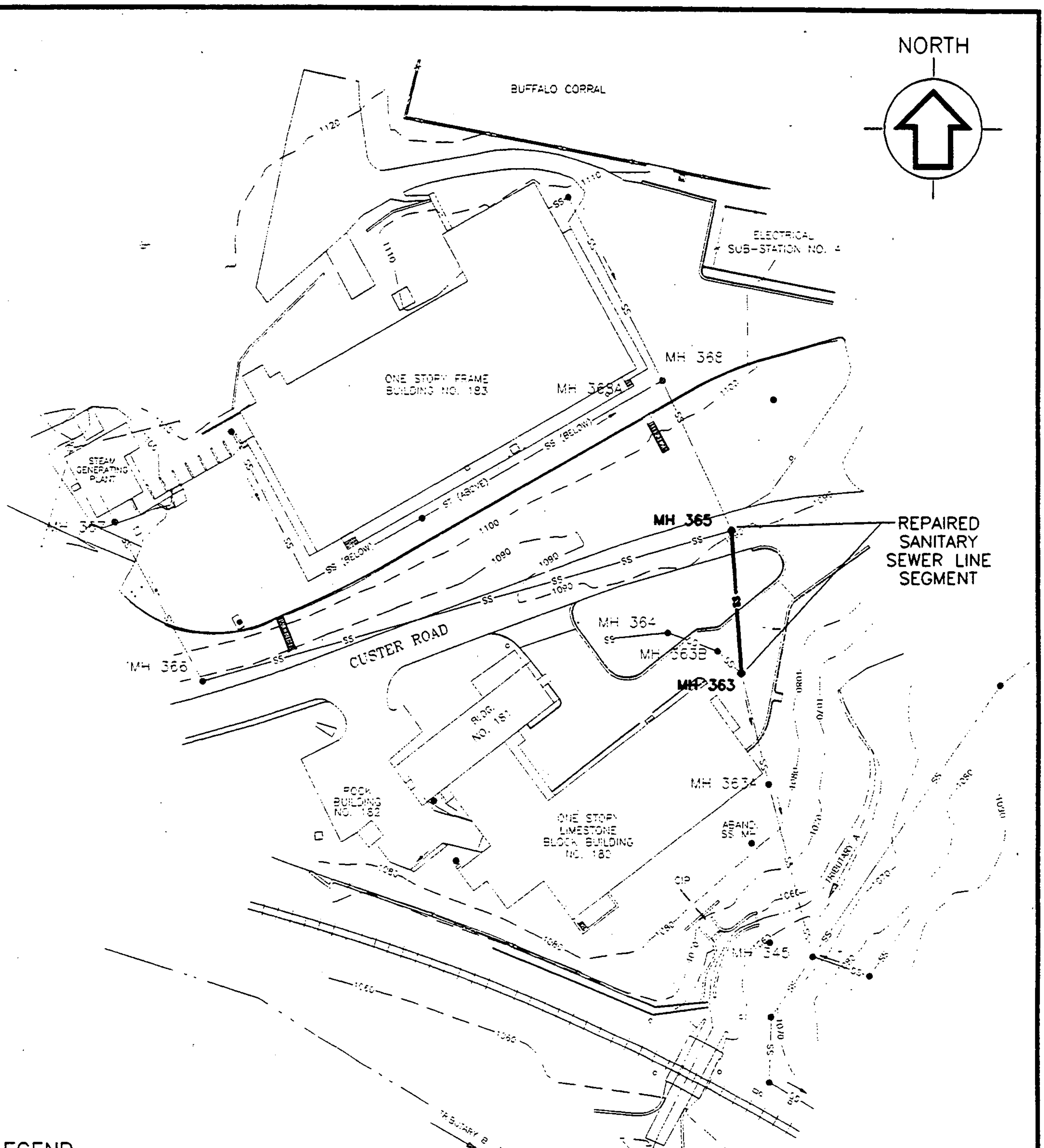
NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE USEPA, 1994b.

U.S. ARMY CORPS OF ENGINEERS
LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-FS)

APPROXIMATE PERIMETER AIR MONITORING LOCATIONS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-34



LEGEND

— ss — Sanitary Sewer Line

● MANHOLE

●— ss —● Repaired Sanitary Sewer Line

0 50 100 200

SCALE IN FEET
1"= 100'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993d.

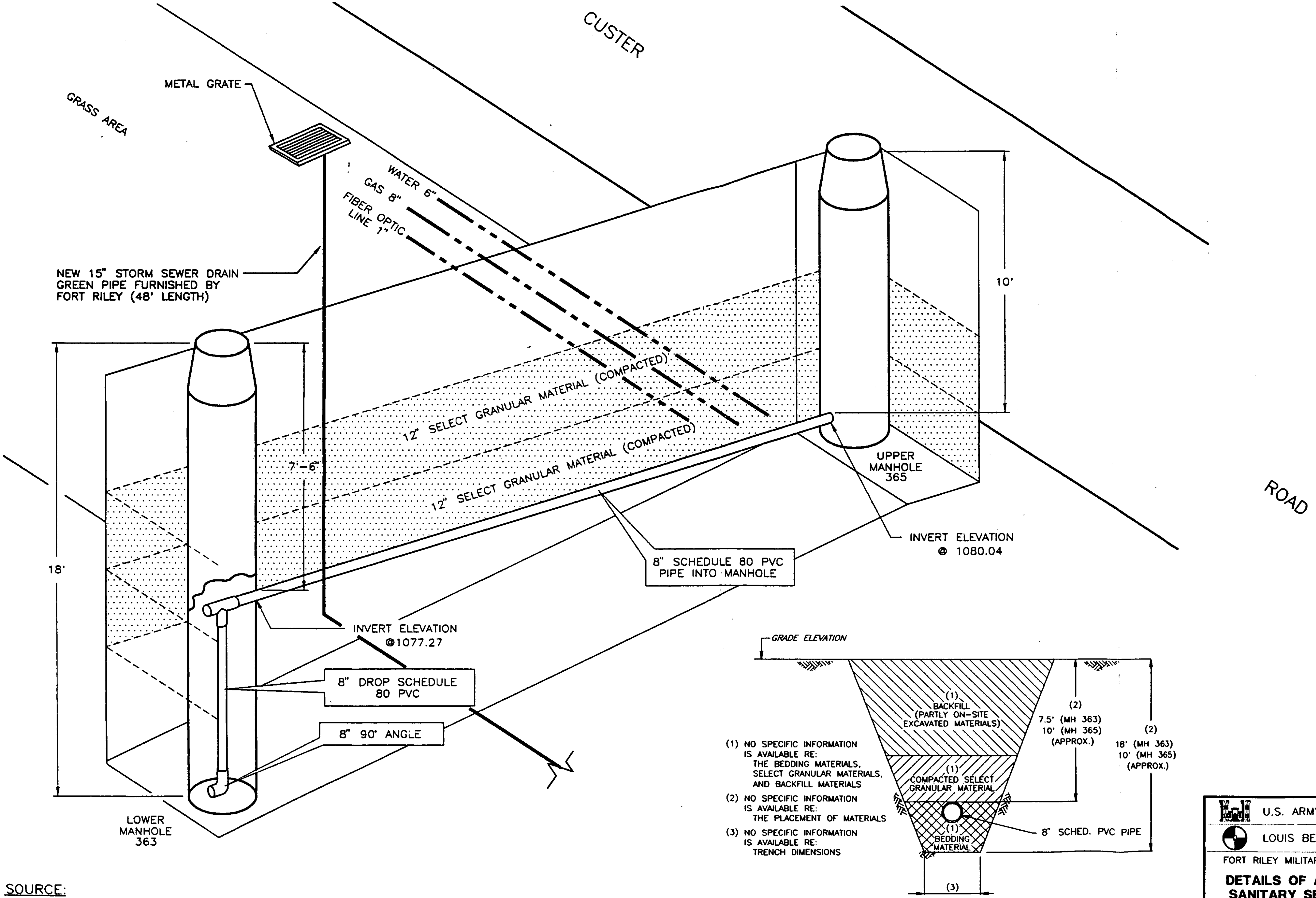
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA–RI)

LOCATION OF REPAIRED SANITARY SEWER LINE

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3–35



(1) NO SPECIFIC INFORMATION IS AVAILABLE RE: THE BEDDING MATERIALS, SELECT GRANULAR MATERIALS, AND BACKFILL MATERIALS

(2) NO SPECIFIC INFORMATION IS AVAILABLE RE: THE PLACEMENT OF MATERIALS

(3) NO SPECIFIC INFORMATION IS AVAILABLE RE: TRENCH DIMENSIONS

TYPICAL SECTION: SANITARY SEWER LINE

SOURCE:

FINAL REPORT FOR THE RAPID RESPONSE
OHM REMEDIATION SERVICE CORP. (SEPT. 8 1994)

U.S. ARMY CORPS OF ENGINEERS
LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DETAILS OF AS-BUILT REPAIRED SANITARY SEWER LINE NO. SS1 FROM MH 363 TO MH 365

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-36

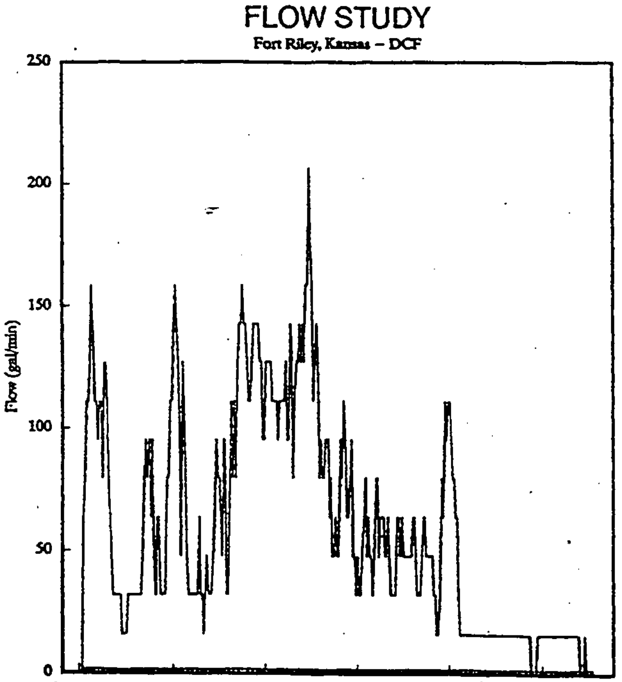


Figure 1. Discharge @ MH 345

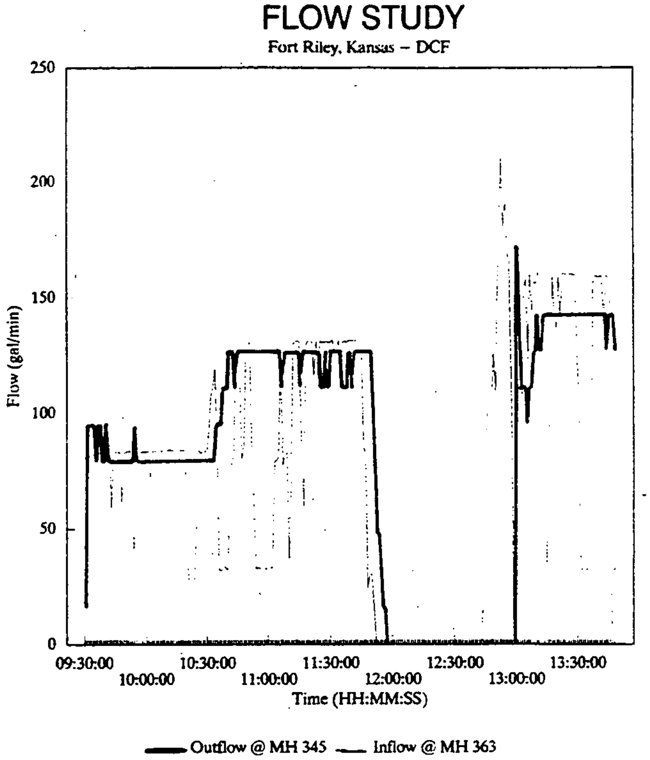


Fig. 3: Outflow & Inflow vs. Time
July 23, 1994.

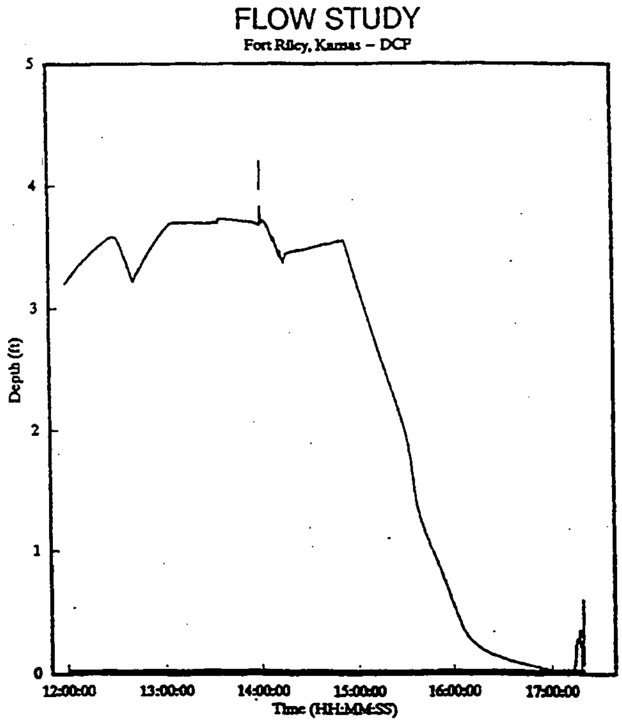


Figure 2. Level @ MH 363 A

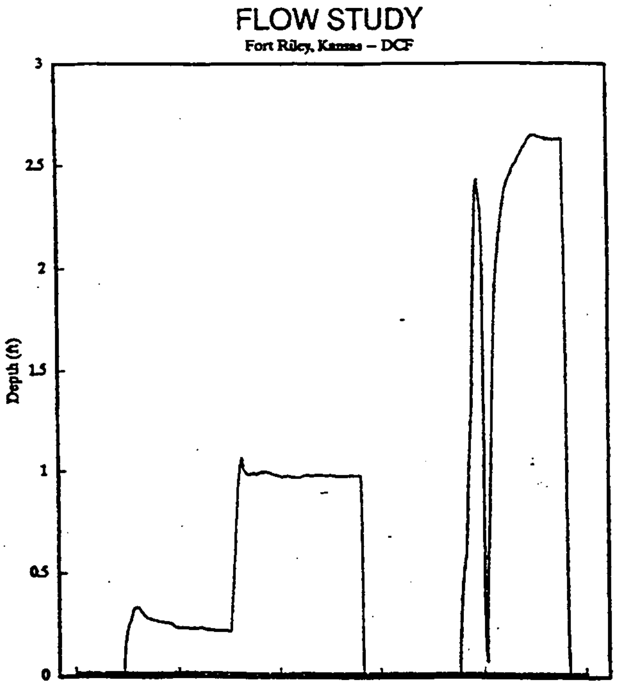


Figure 4. Level @ MH 363

SOURCE: Heath, Sewer Flow Study; 7/94

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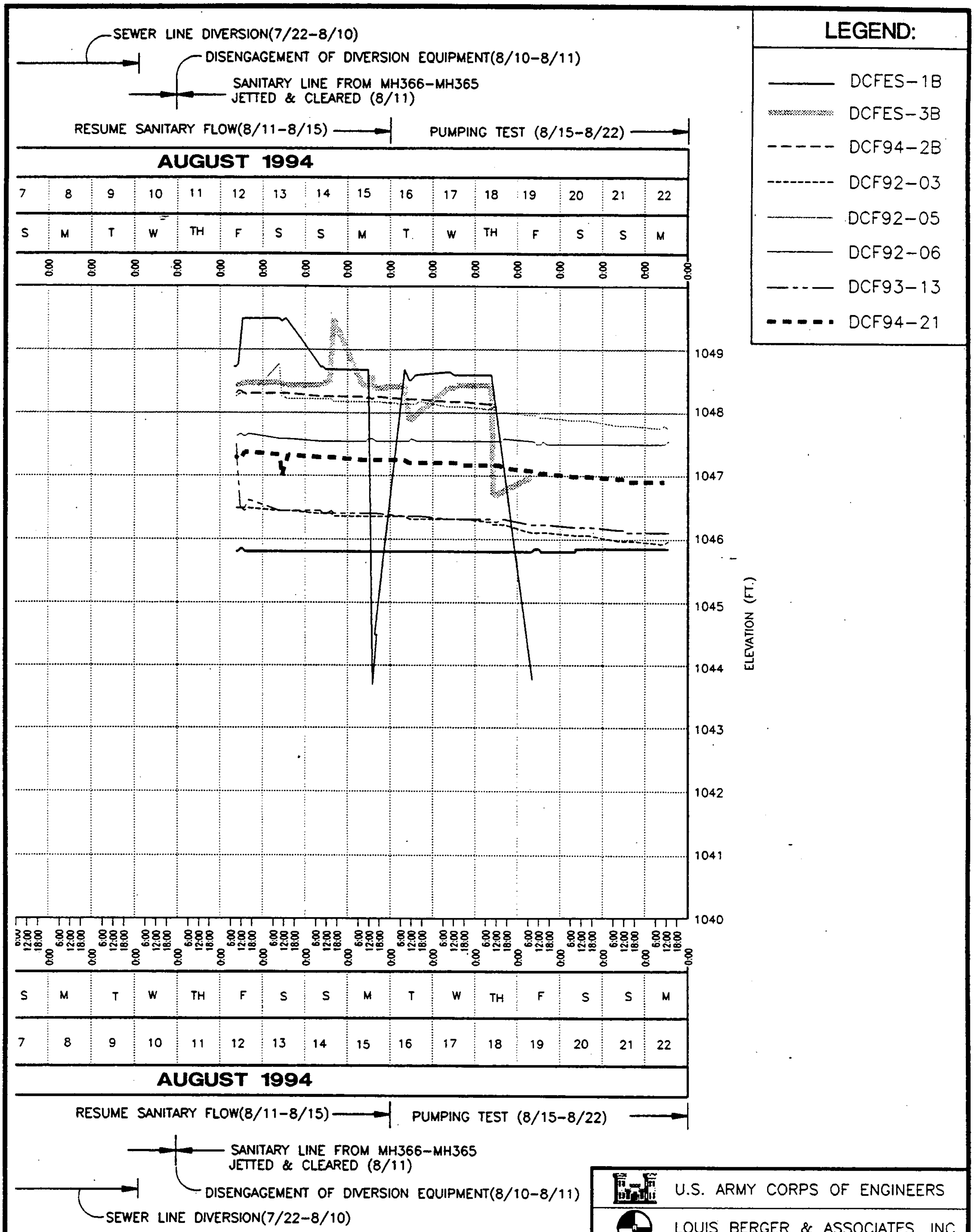
FORT RILEY MILITARY RESERVATION (DCFA-RI)

SEWER LINE FLOW DATA

SCALE: NONE	DATE: MARCH 1995	FIG. 3-37



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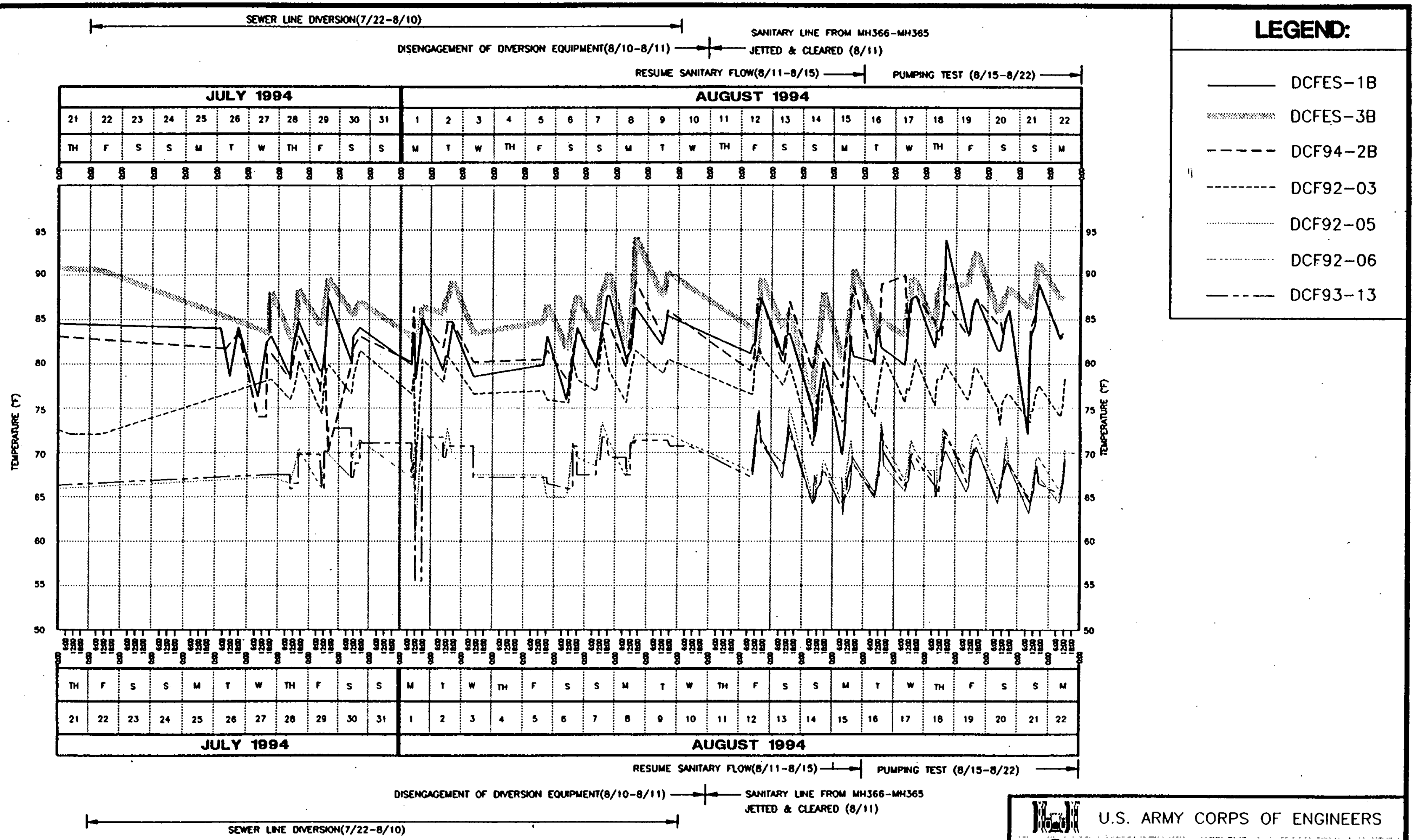
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER ELEVATION DATA PLOTS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-38



MANUALLY OBTAINED GROUNDWATER TEMPERATURE DATA PLOTTED VS. TIME FOR WELLS 1B, 2B, 3B, 03, 05, 06, & 13

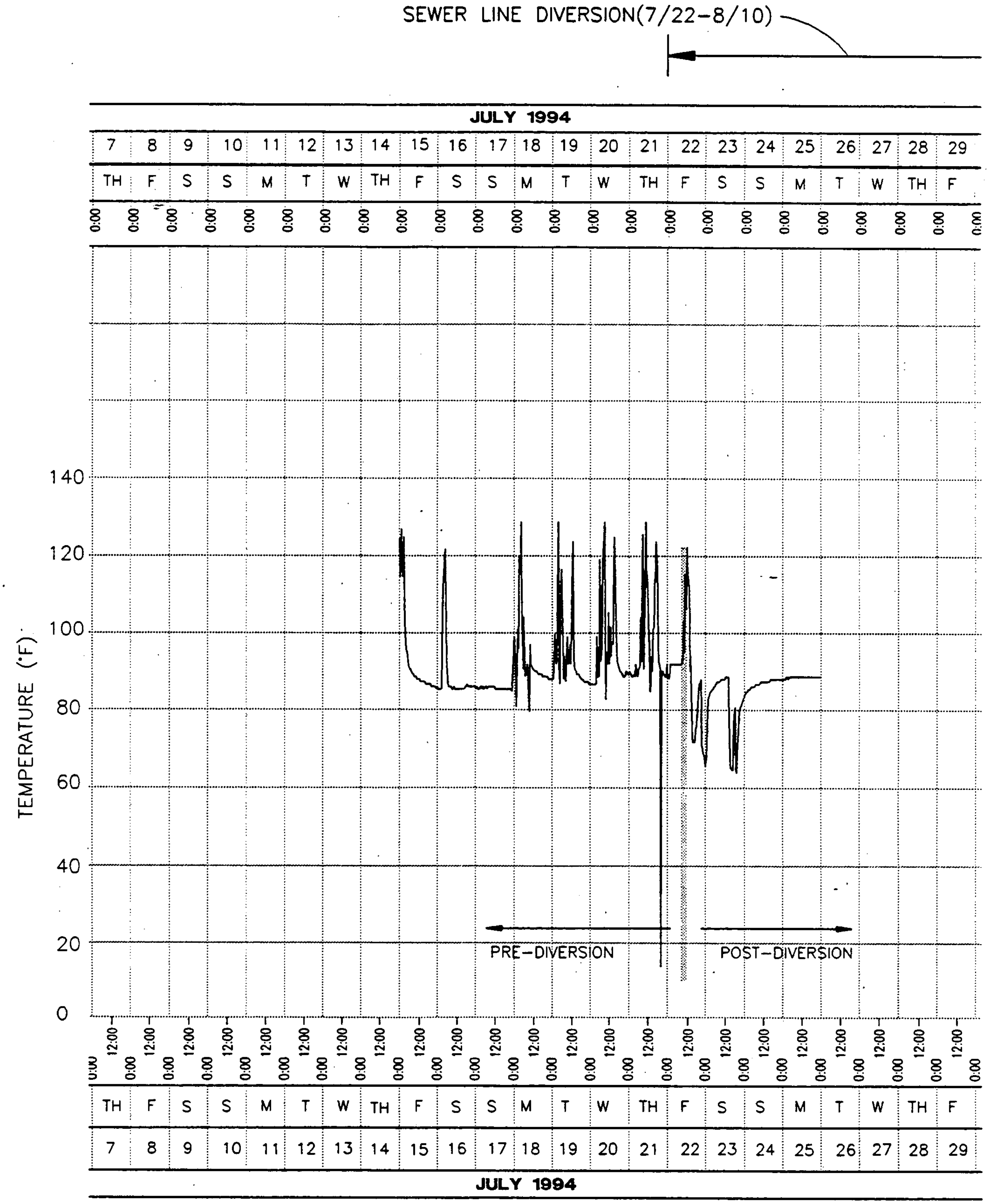
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER TEMPERATURE DATA PLOTS

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-39



NOTES:

1. SEWER LINE DIVERSION OCCURRED 7/22 TO 8/10.
2. DISENGAGEMENT OF DIVERSION EQUIPMENT 8/10 TO 8/11.
3. SANITARY LINE FROM MH366-MH365 JETTED AND CLEARED 8/11.
4. RESUME SANITARY FLOW 8/11 TO 8/15.
5. PERFORM PUMPING TEST 8/15 TO 8/22.

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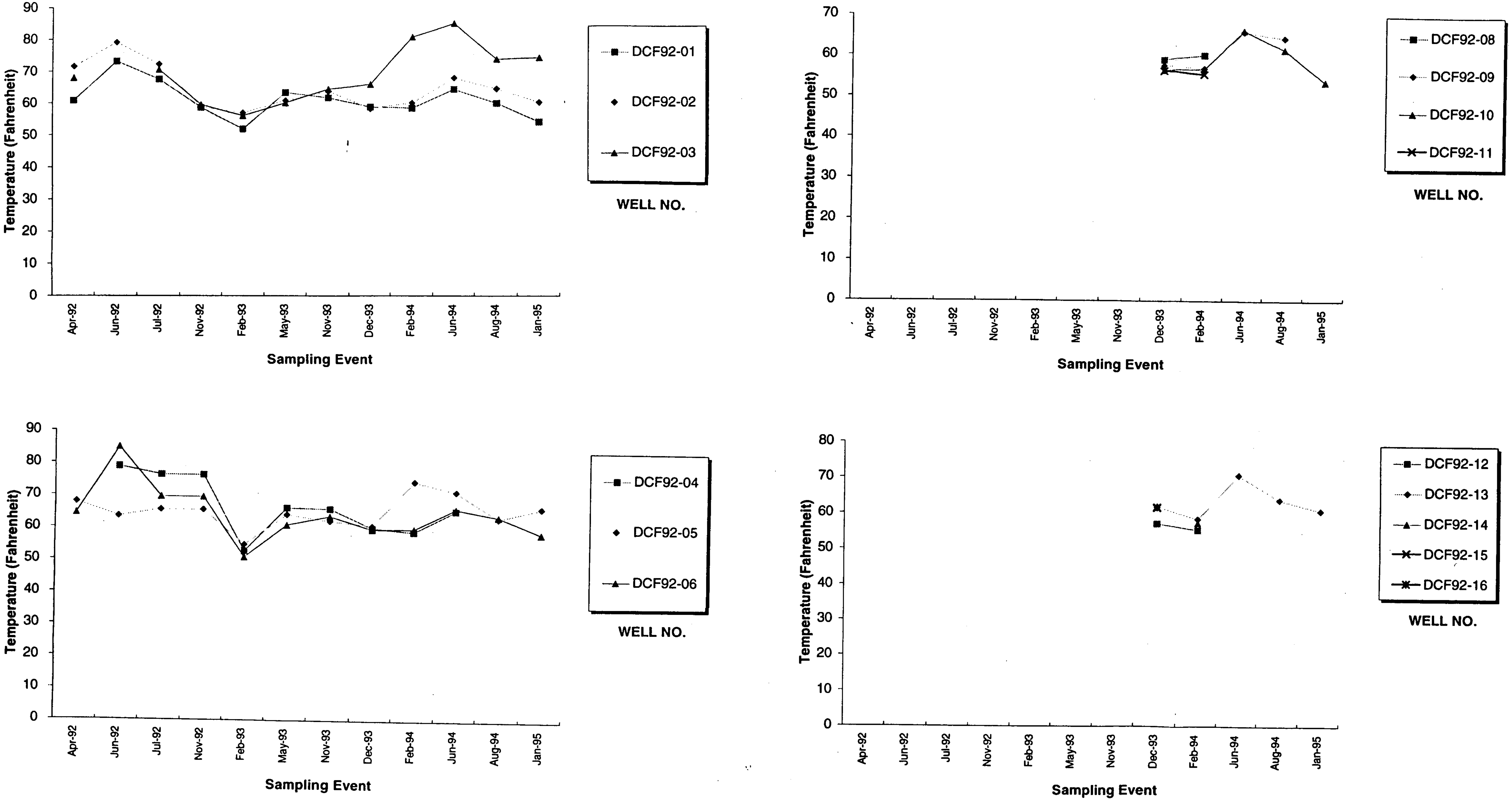
FORT RILEY MILITARY RESERVATION (DCFA-RI)

MANHOLE 363
TEMPERATURE PROFILE

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-40



NOTE:

1. SEE TABLE 4-25 FOR COMPLETE LIST OF GROUNDWATER TEMPERATURES.

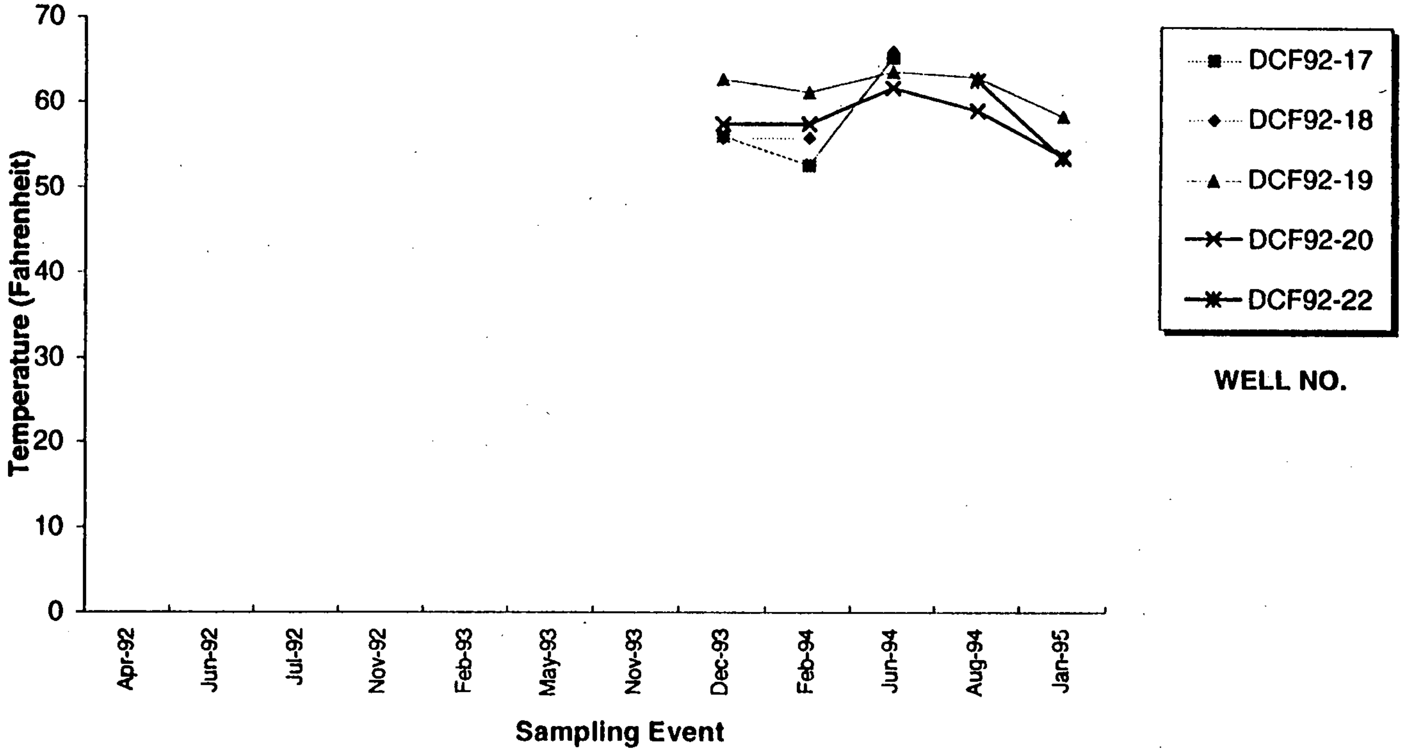
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER TEMPERATURES FOR SAMPLING EVENTS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-41



NOTE:

1. SEE TABLE 4-25 FOR COMPLETE LIST OF GROUNDWATER TEMPERATURES.

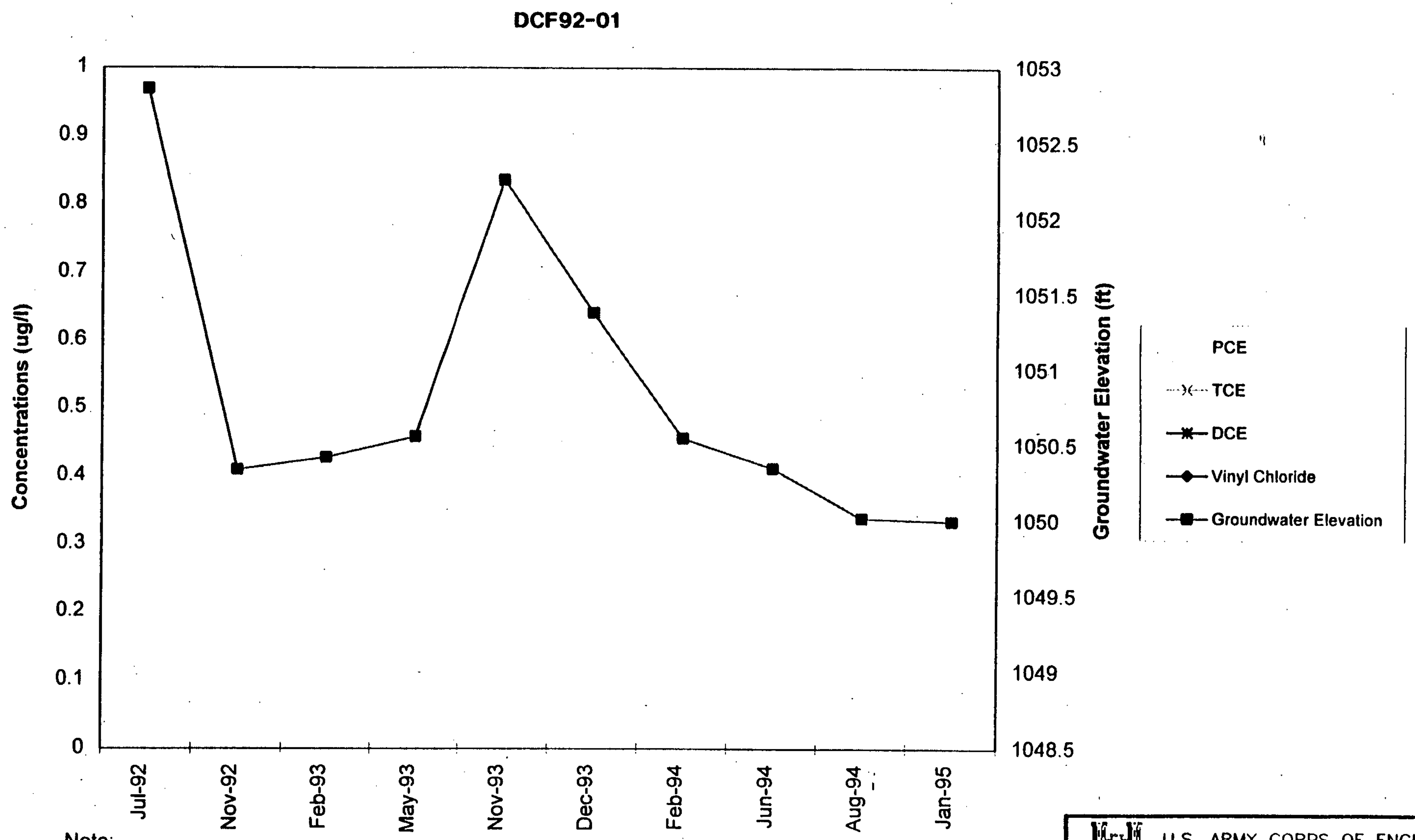
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER TEMPERATURES FOR SAMPLING EVENTS

SCALE: NONE	DATE: MARCH 1995	FIG. 3-42



Note:
There have been no detections of PCE or its breakdown products in DCF92-01.

U.S. ARMY CORPS OF ENGINEERS

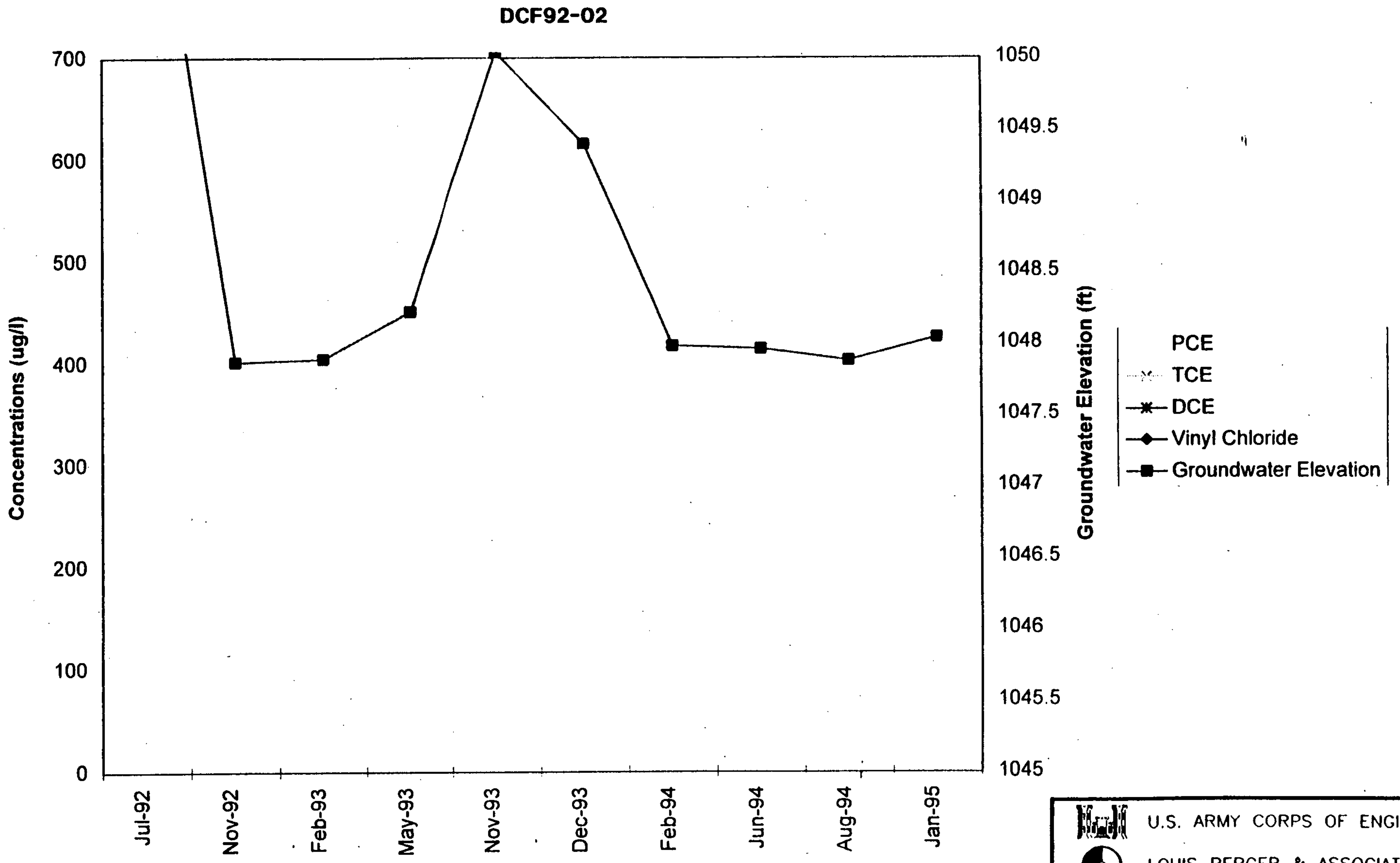
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF92-01

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43o

[illegible]



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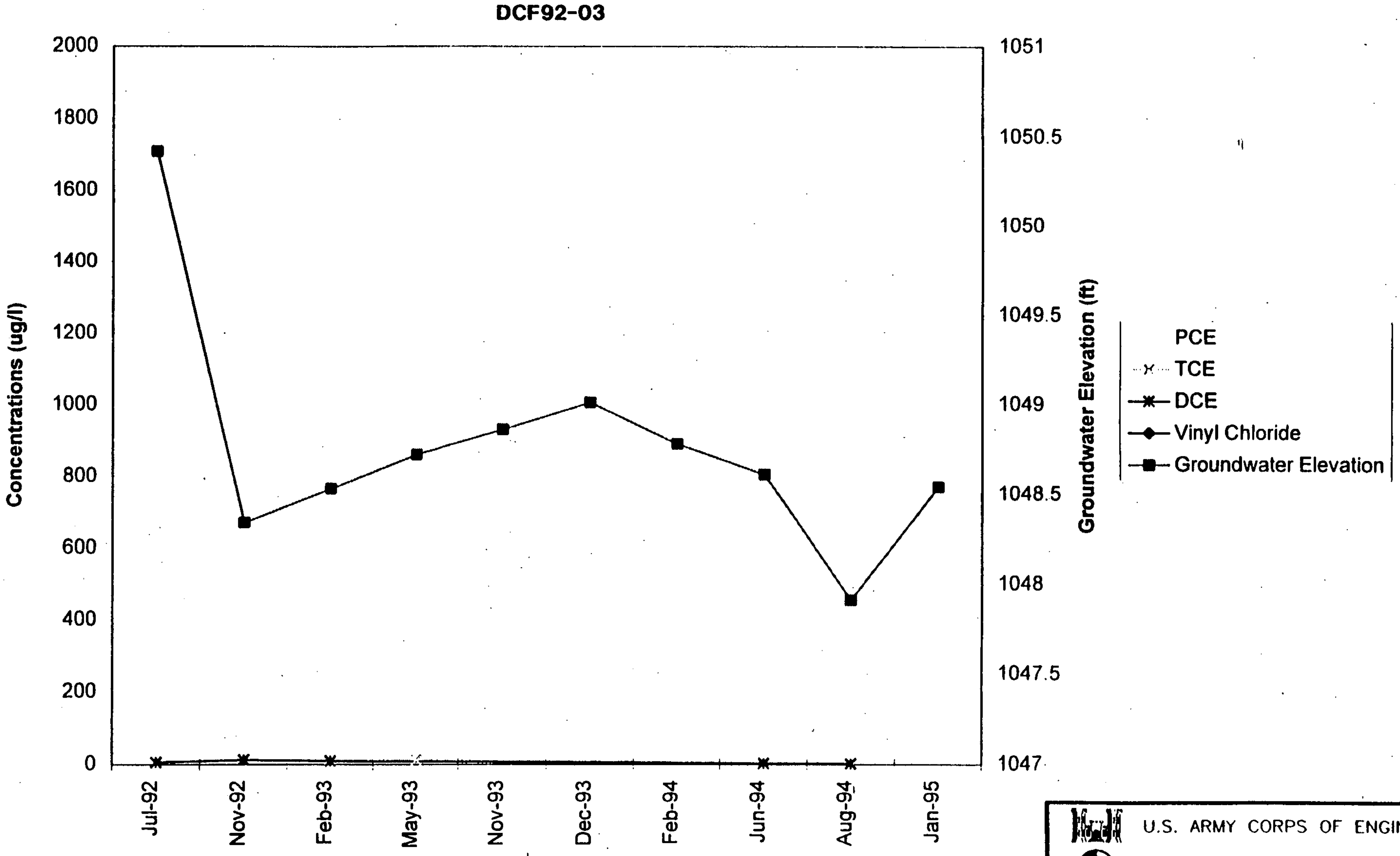
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF92-02

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43b



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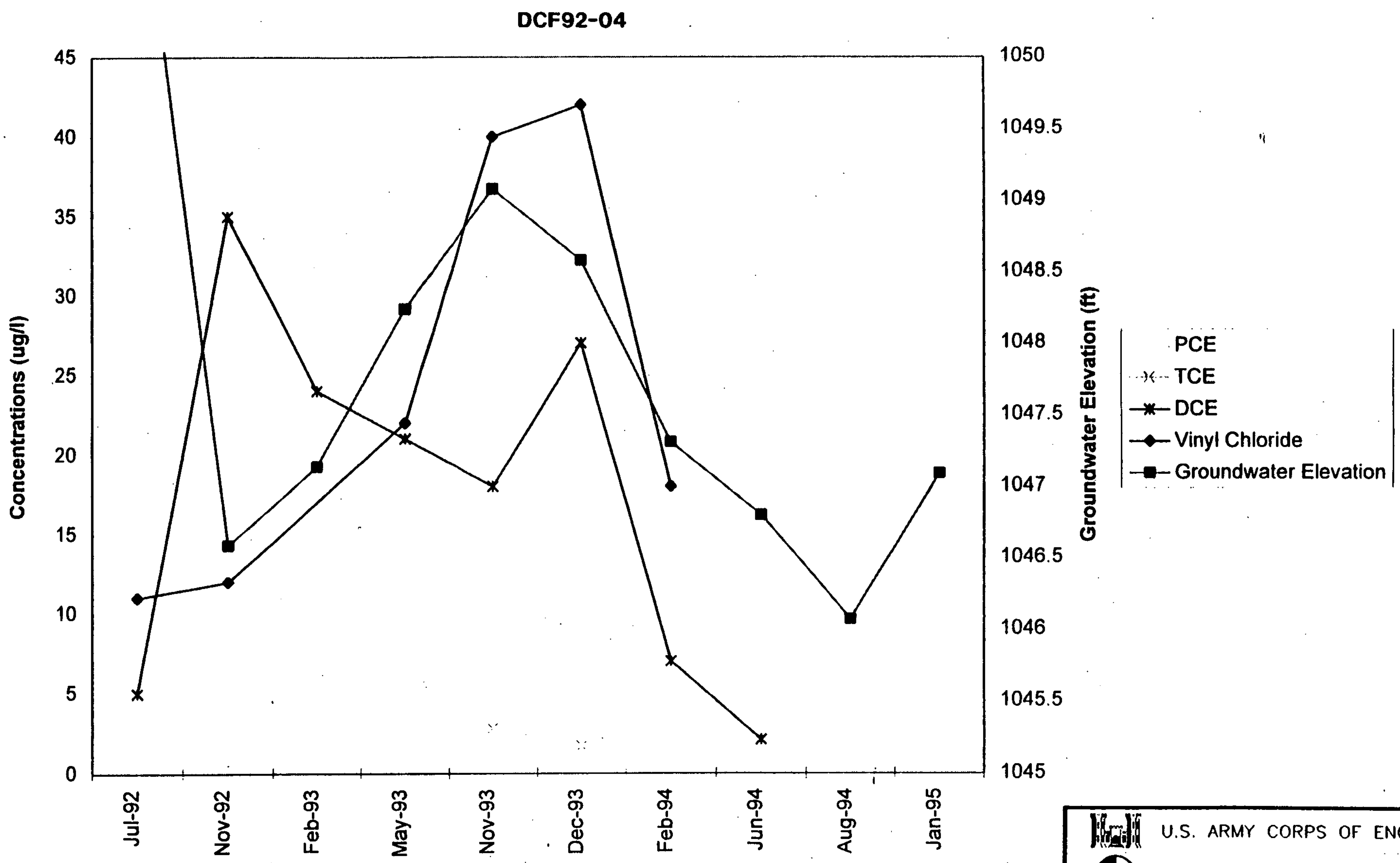
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF92-03

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43c



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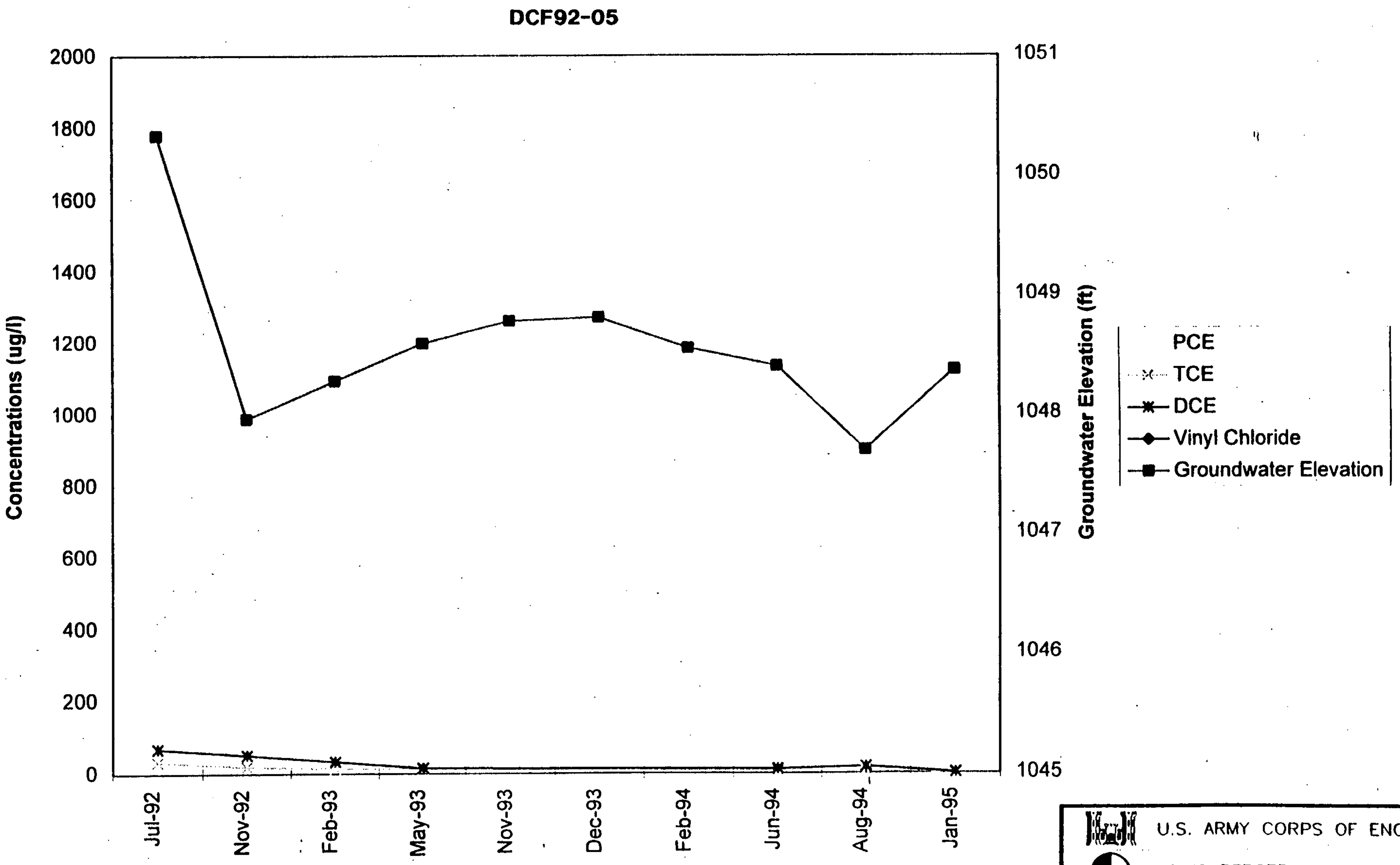
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF92-04

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43d

3-43e [illegible]



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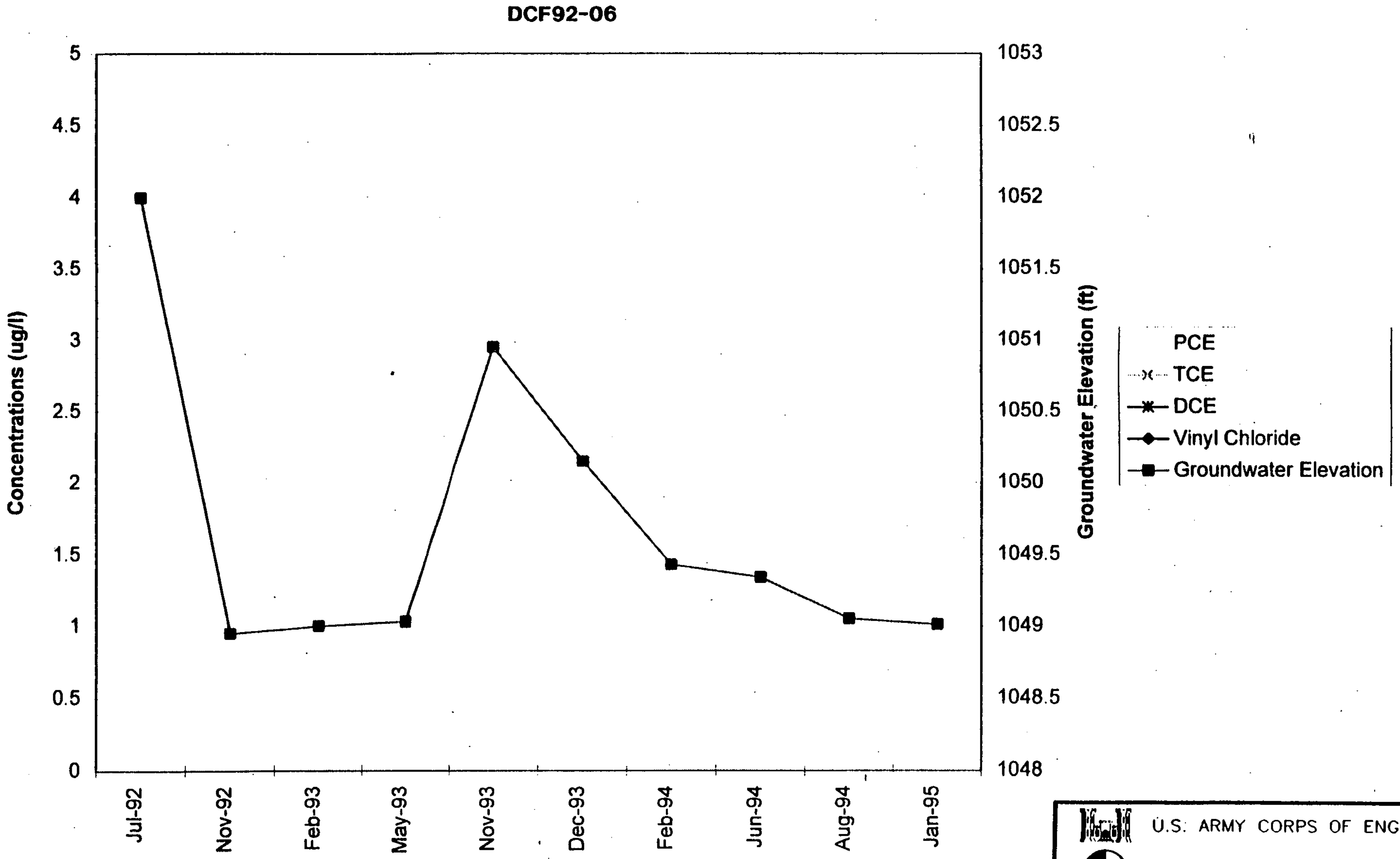
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF92-05

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-43e



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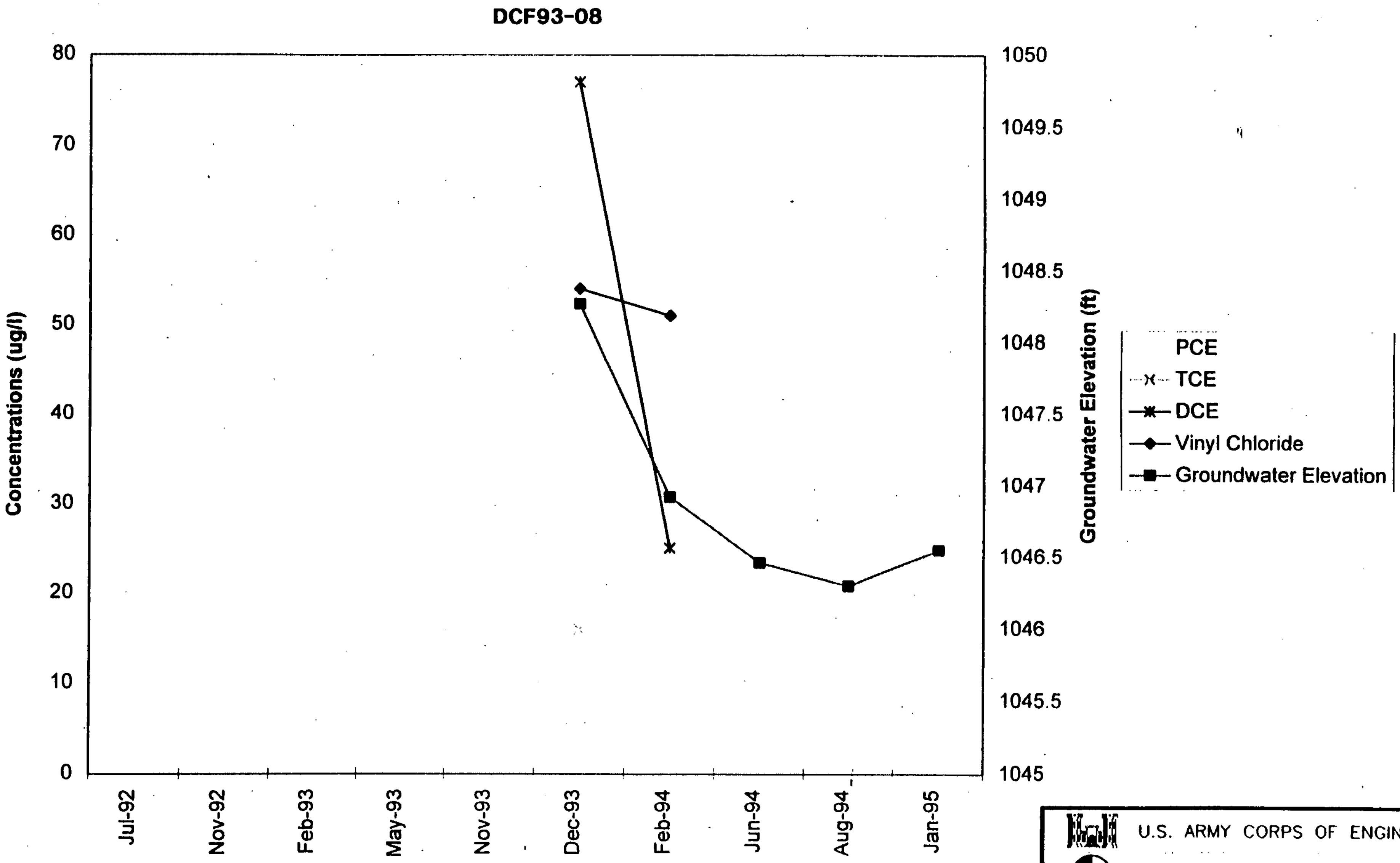
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF92-06

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43f



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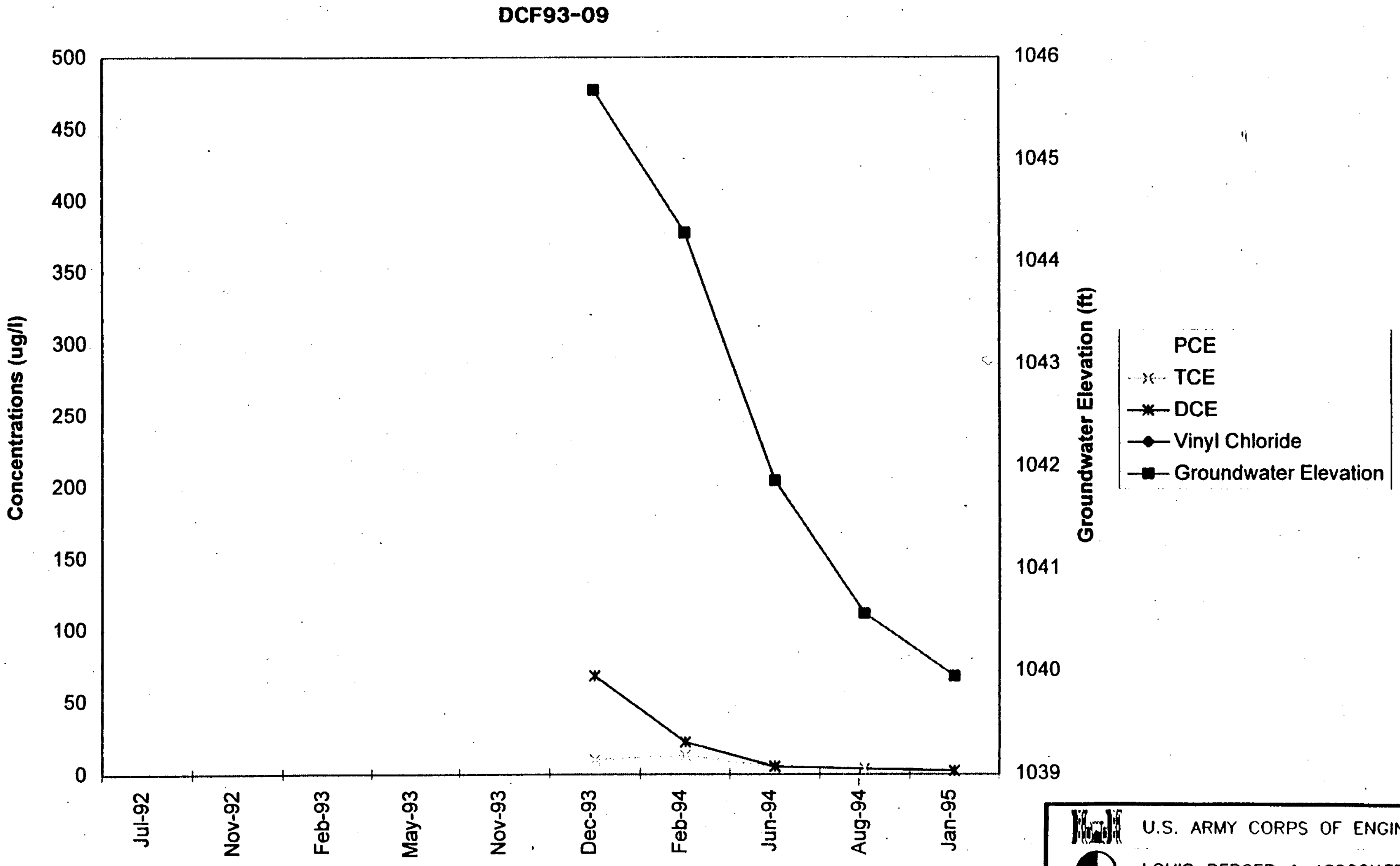
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-08

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43g



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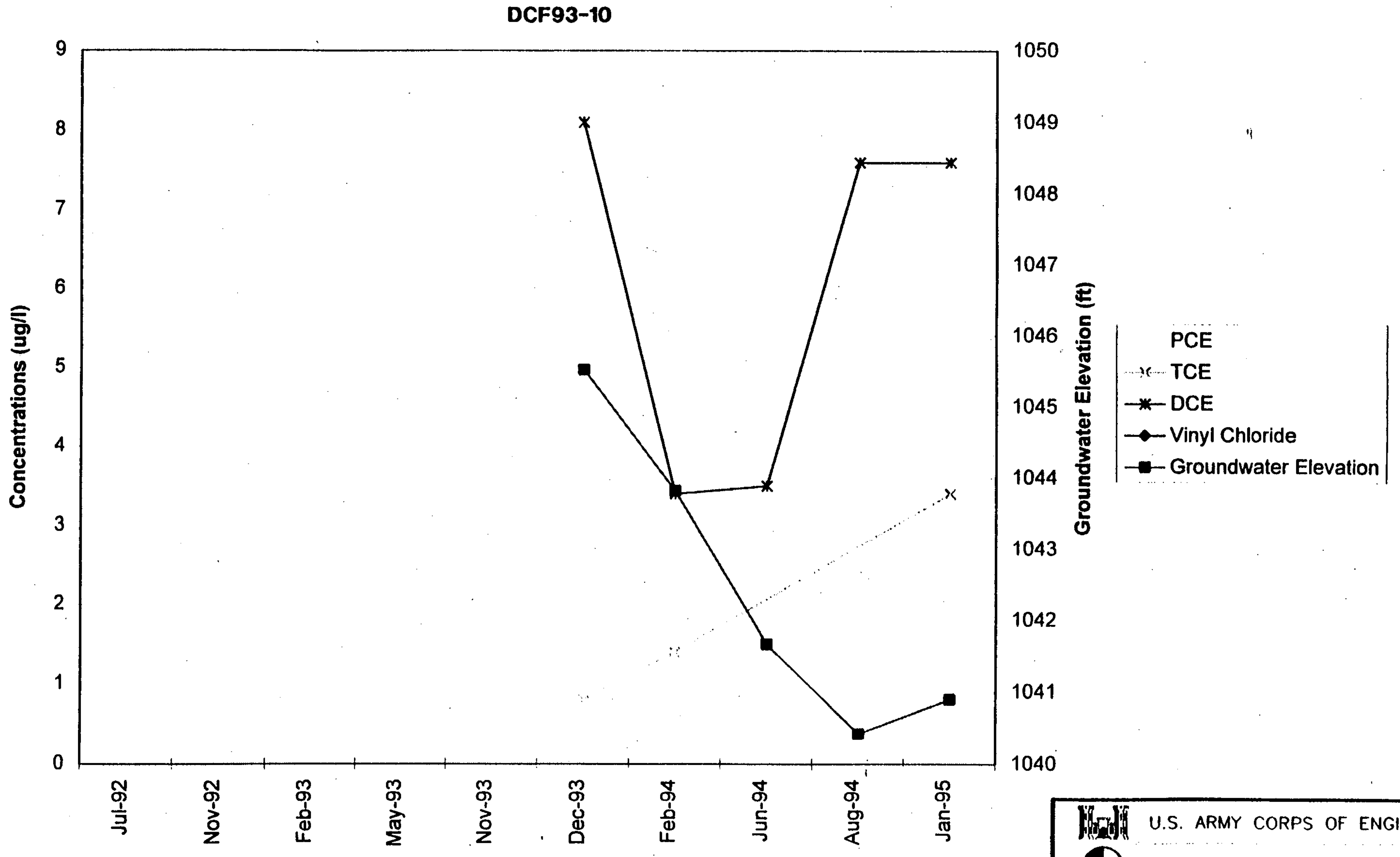
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-09

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43h

[illegible]



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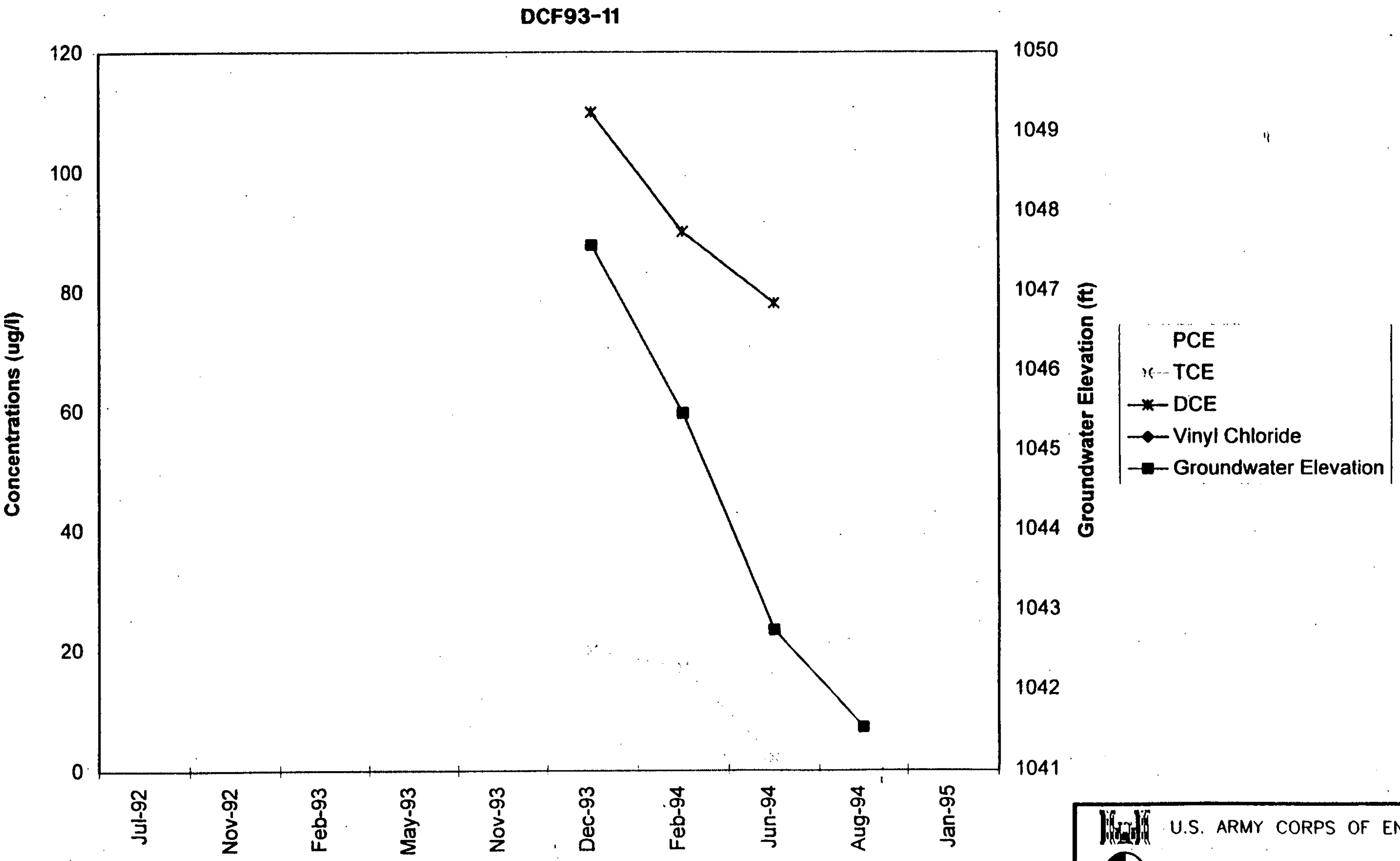
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-10

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-43i



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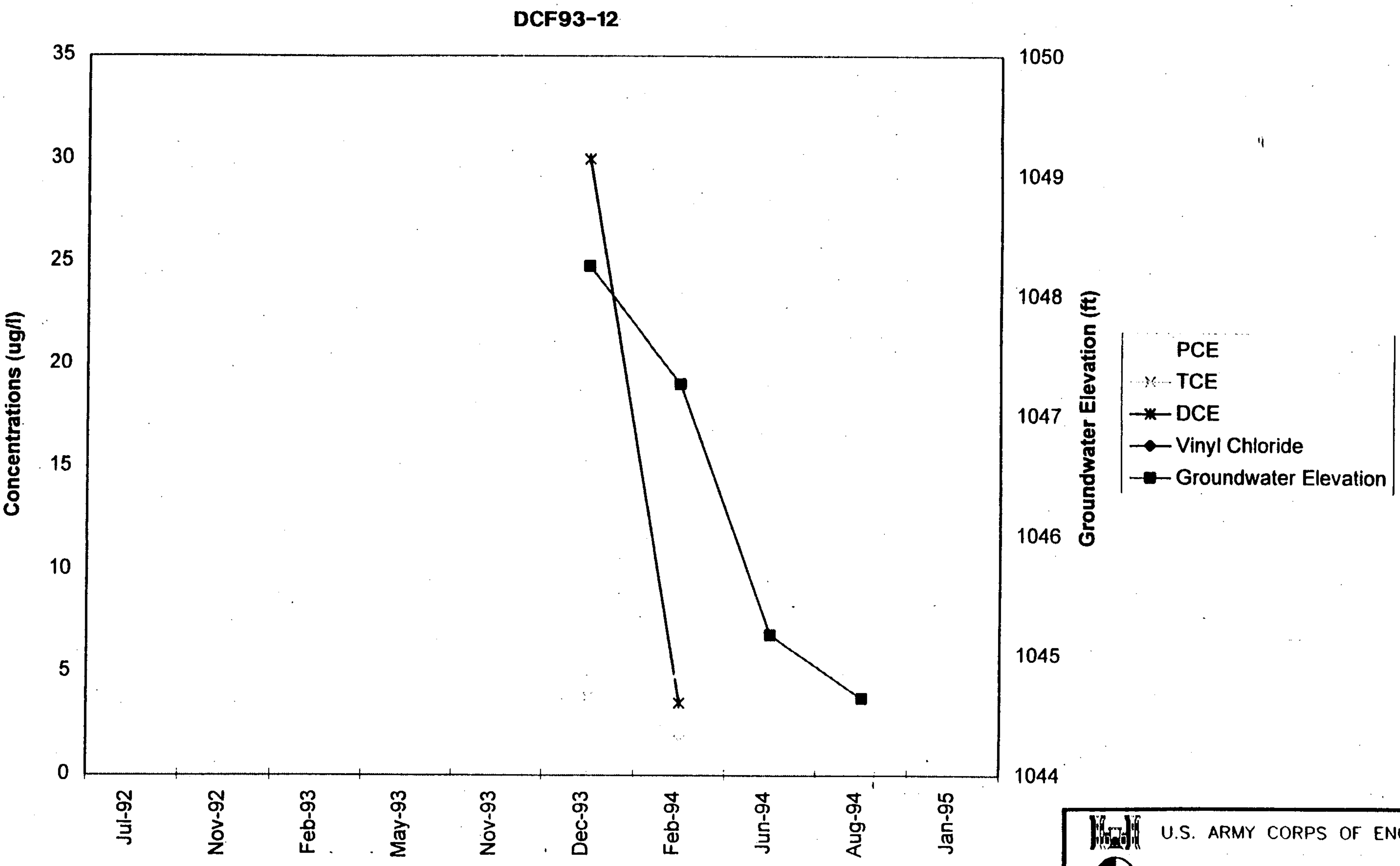
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-11

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43j



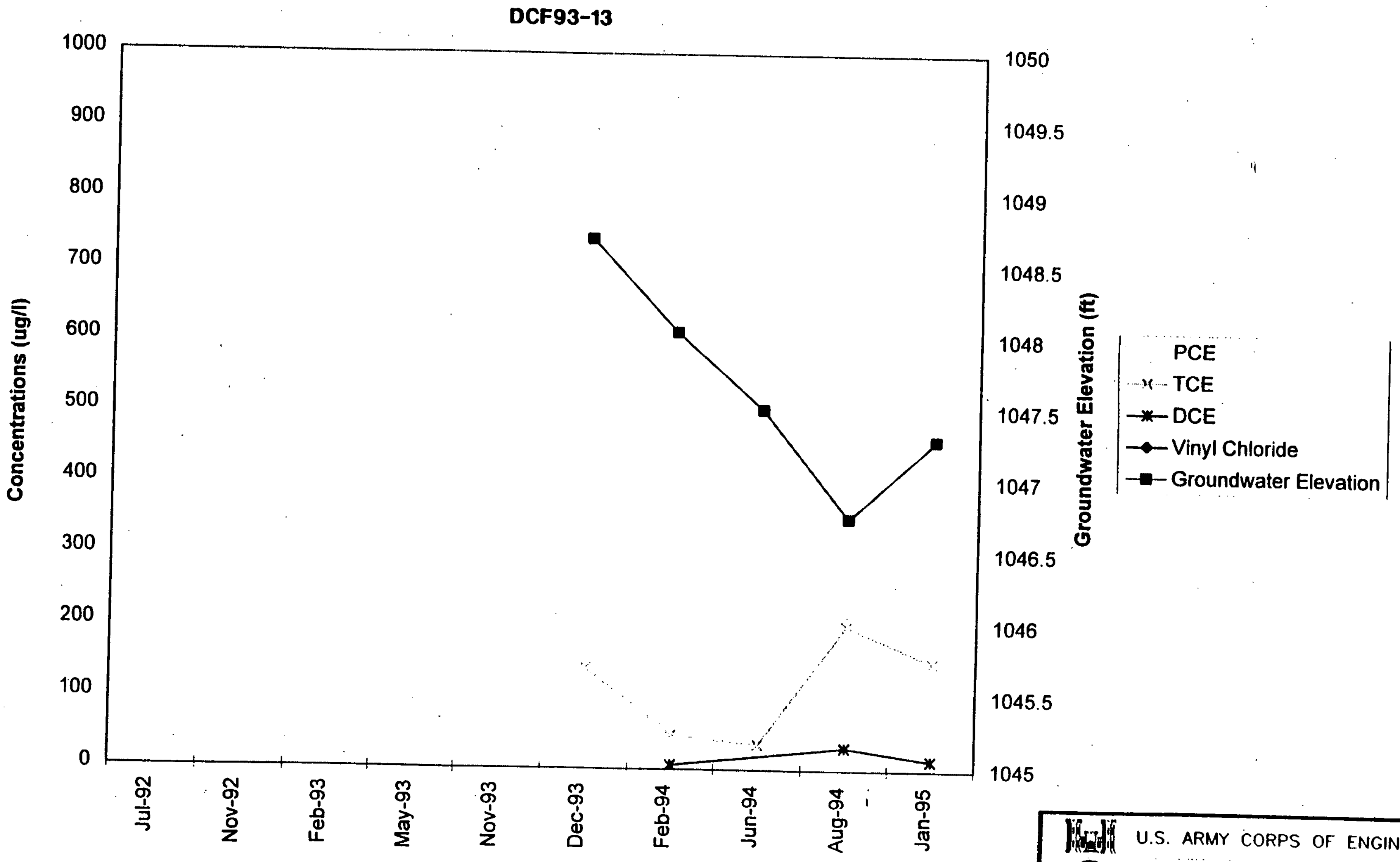
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-12

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43k



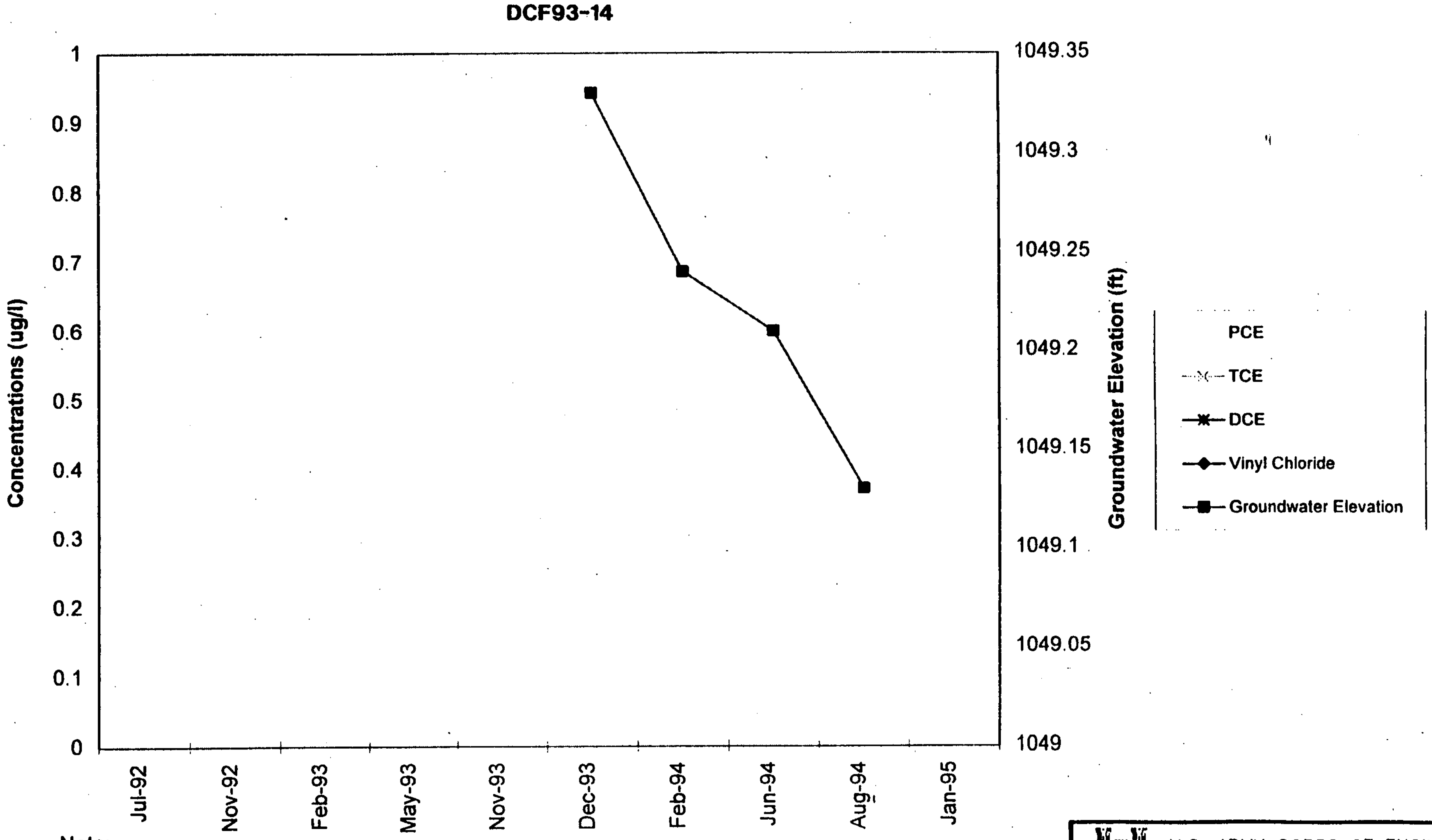
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-13

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-431



Note:
There have been no detections of PCE or its breakdown products in DCF93-14.

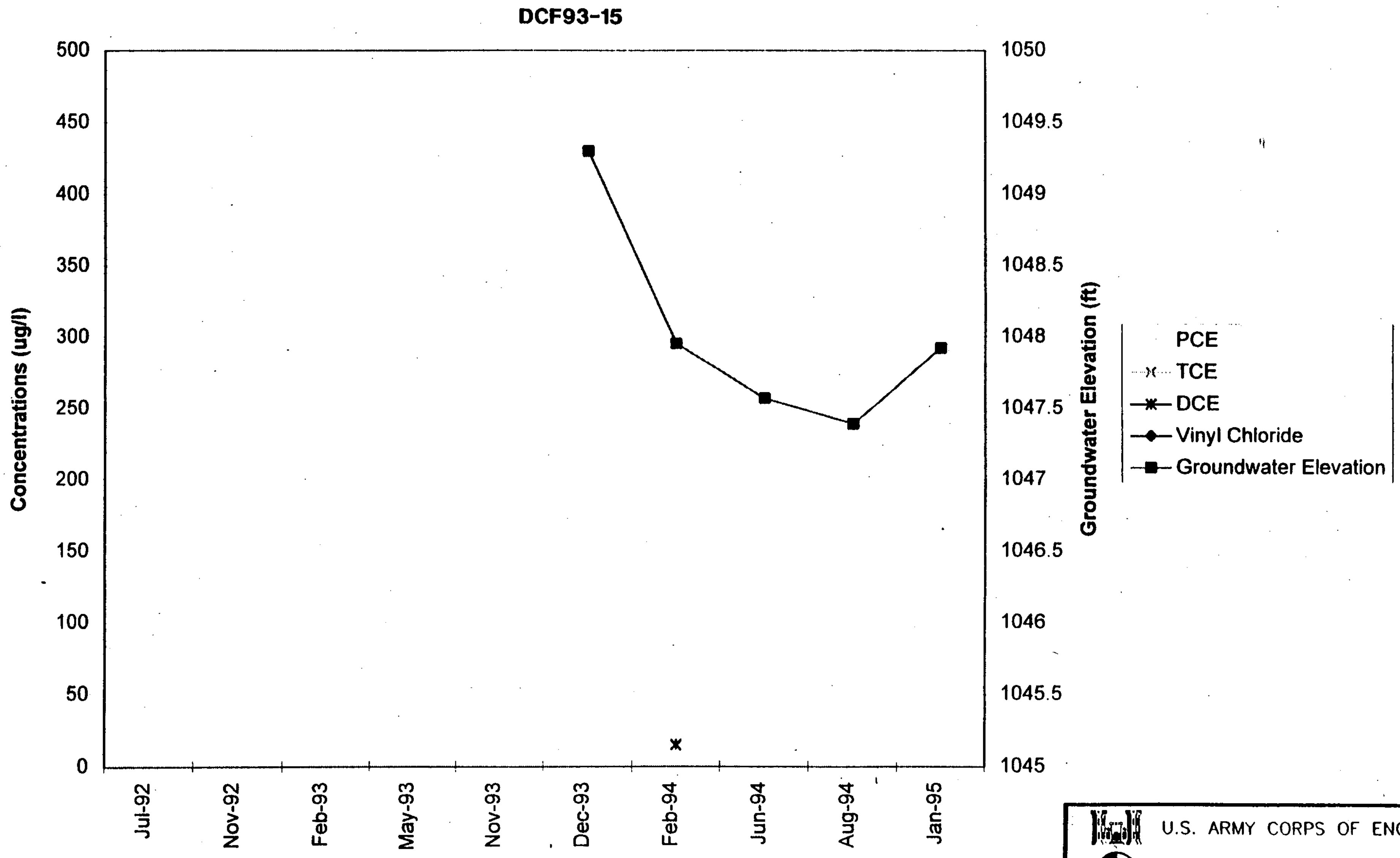
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-14

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43m



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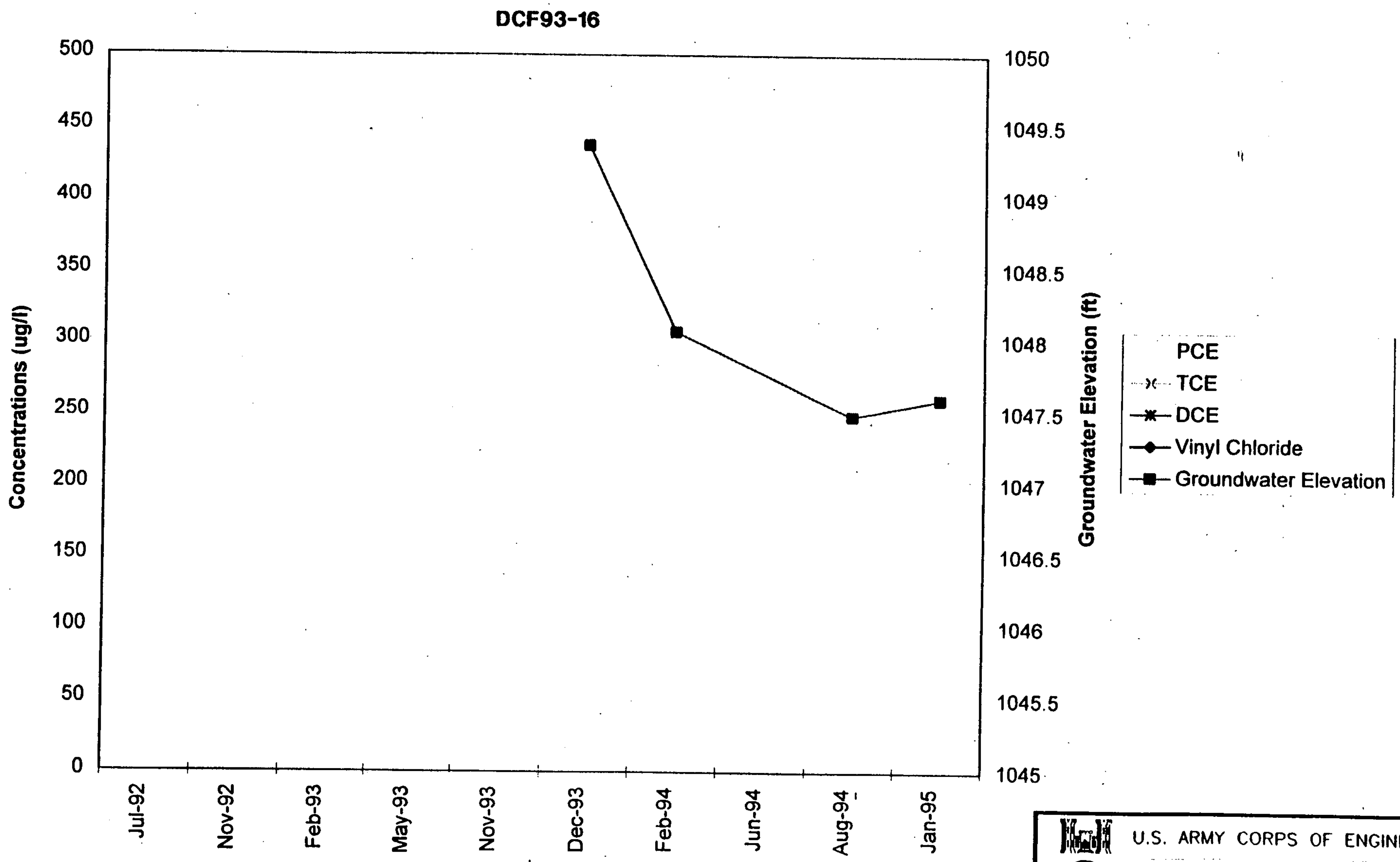
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-15

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43n



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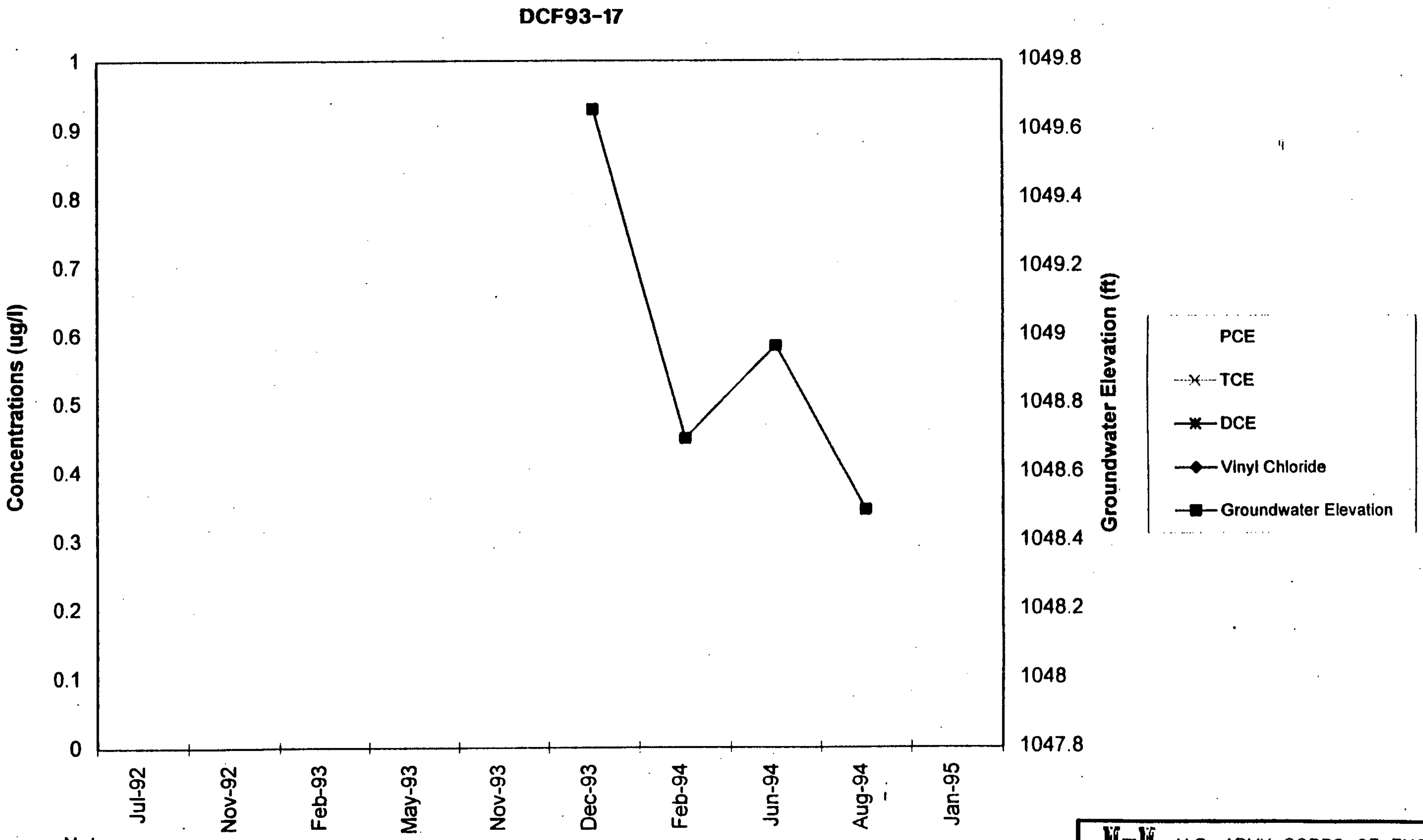
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-16

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43o



Note:
There have been no detections of PCE or its breakdown products in DCF93-17.

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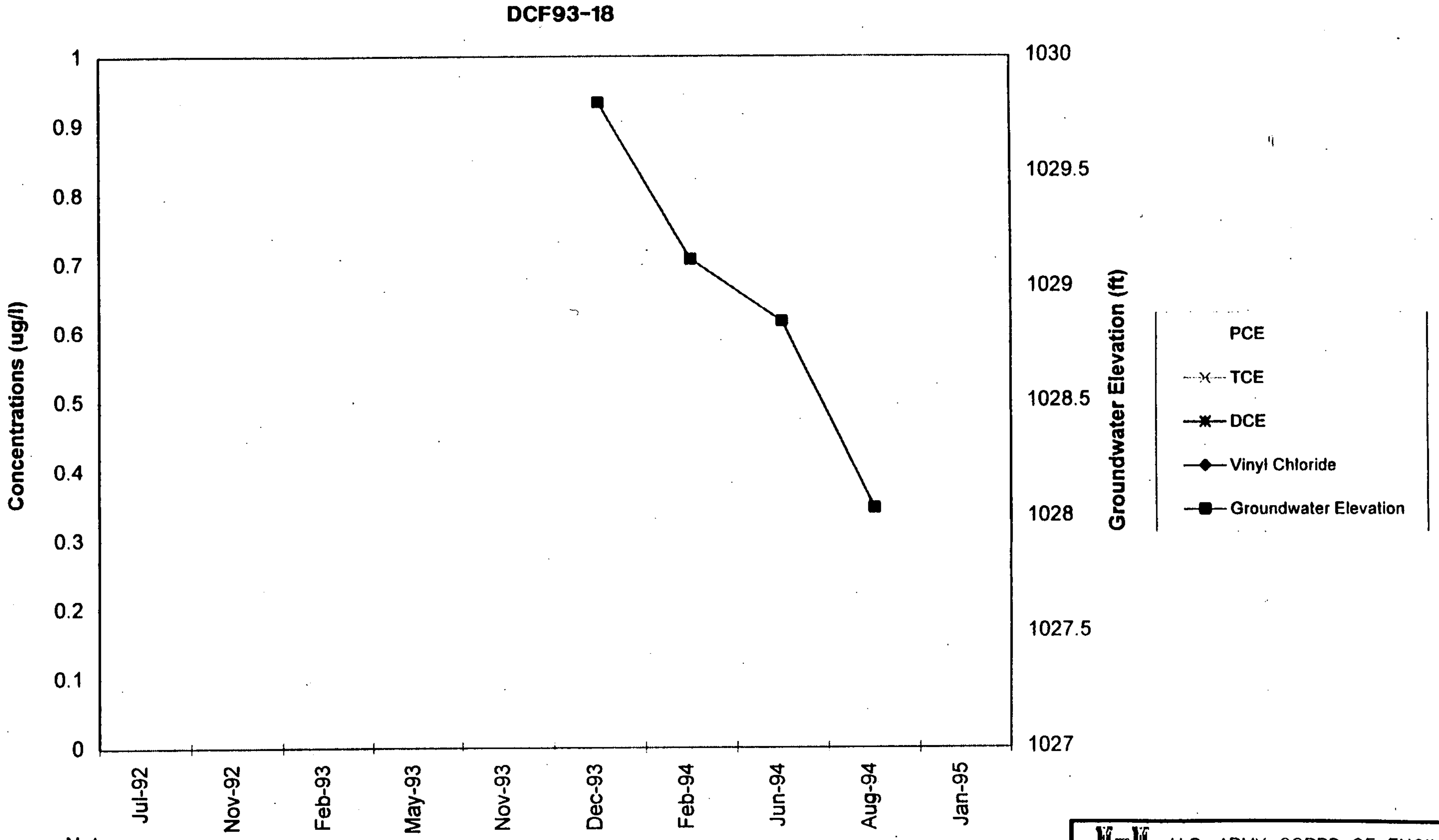
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-17

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43p



Note:
There have been no detections of PCE or its breakdown products in DCF93-17.

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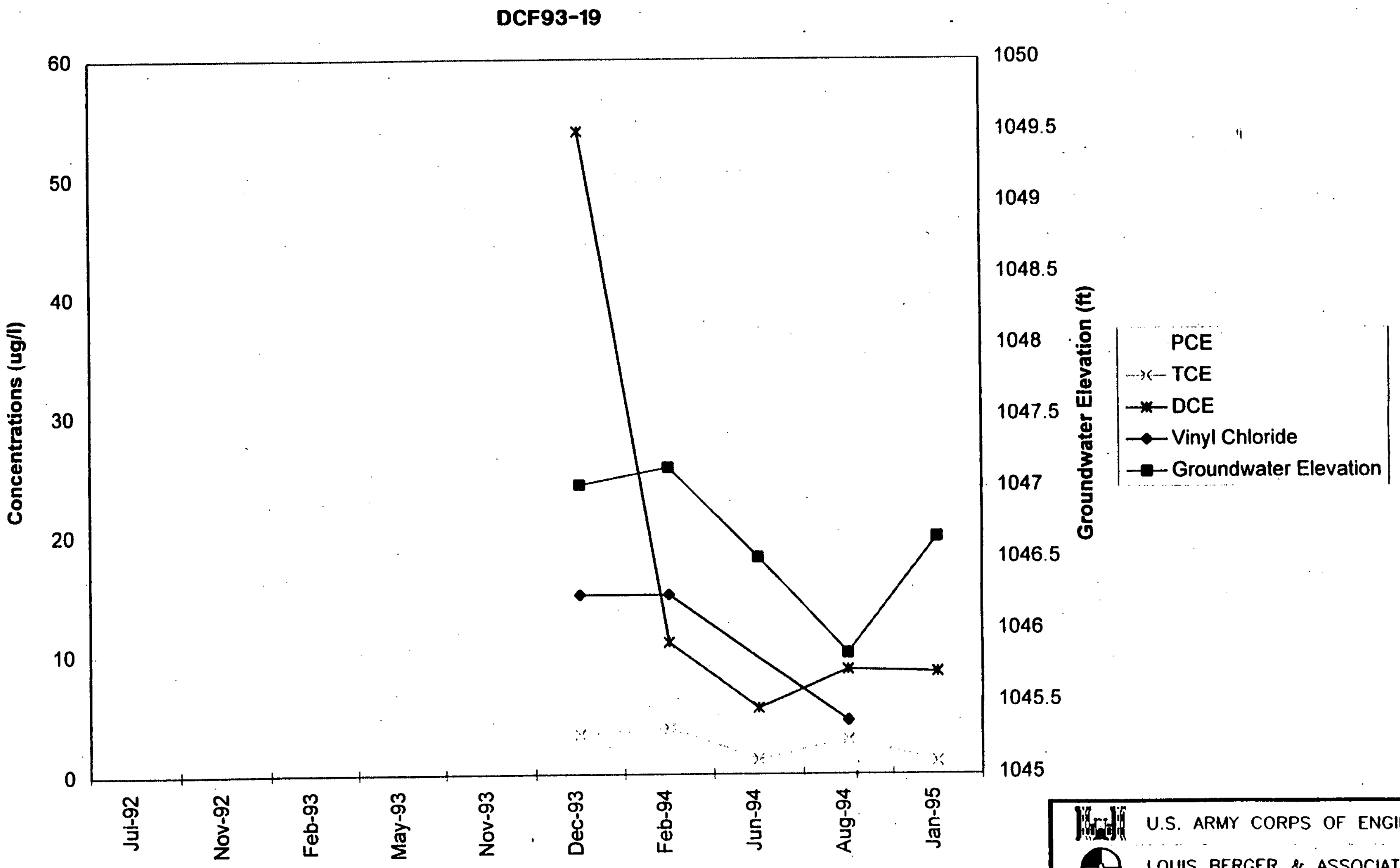
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-18

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-43q

[illegible]



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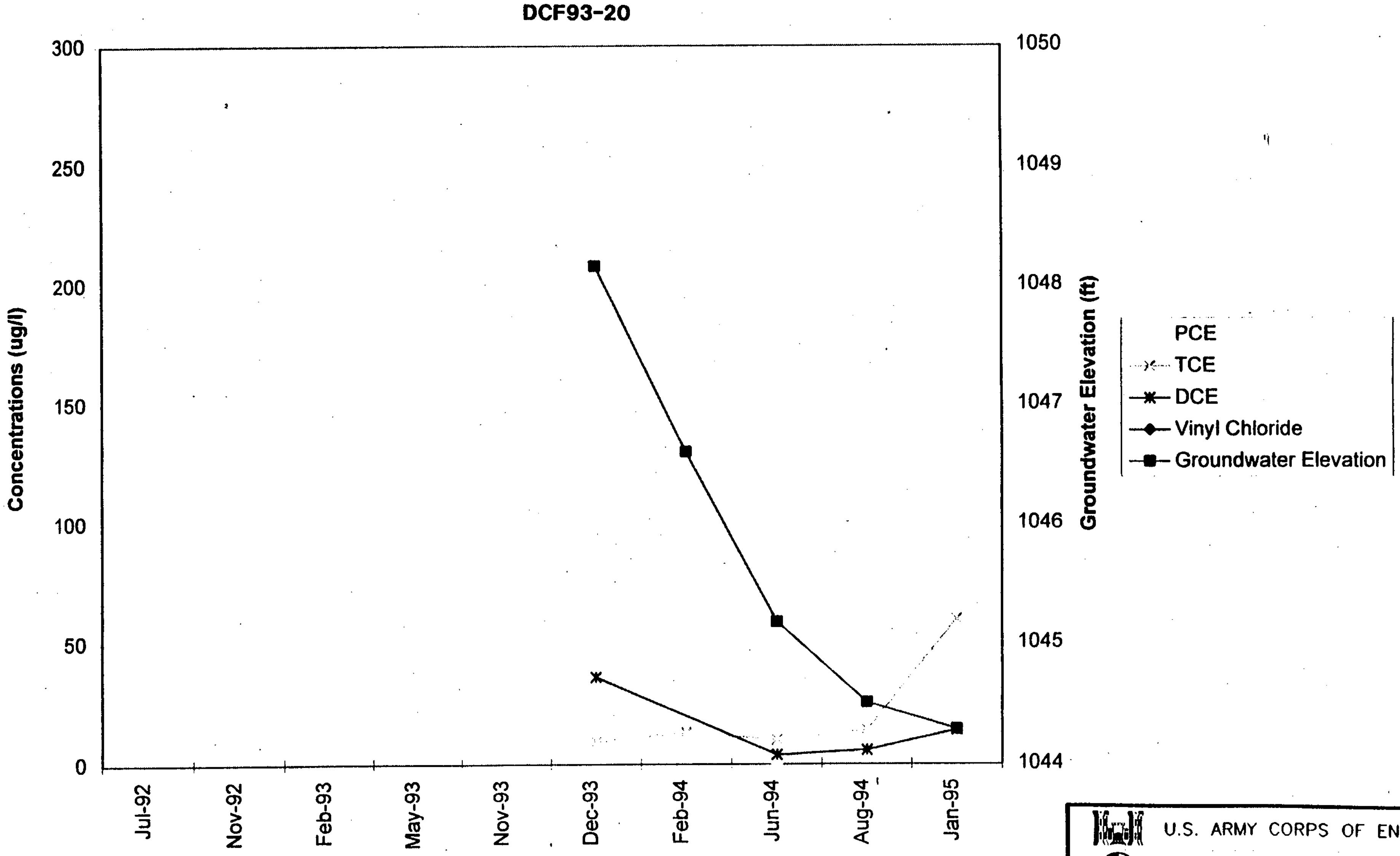
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-19

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43r

[illegible]



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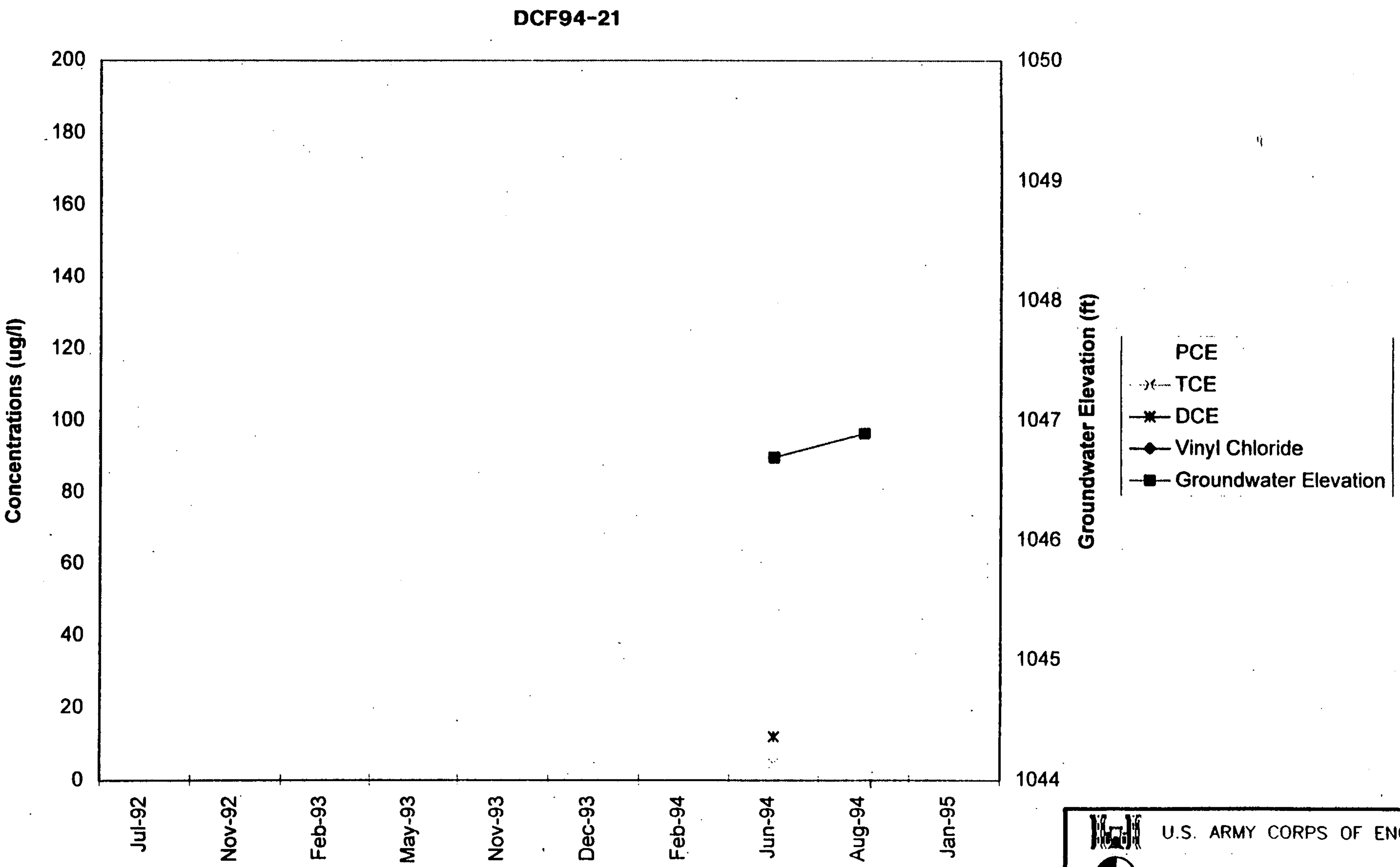
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF93-20

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 3-43s



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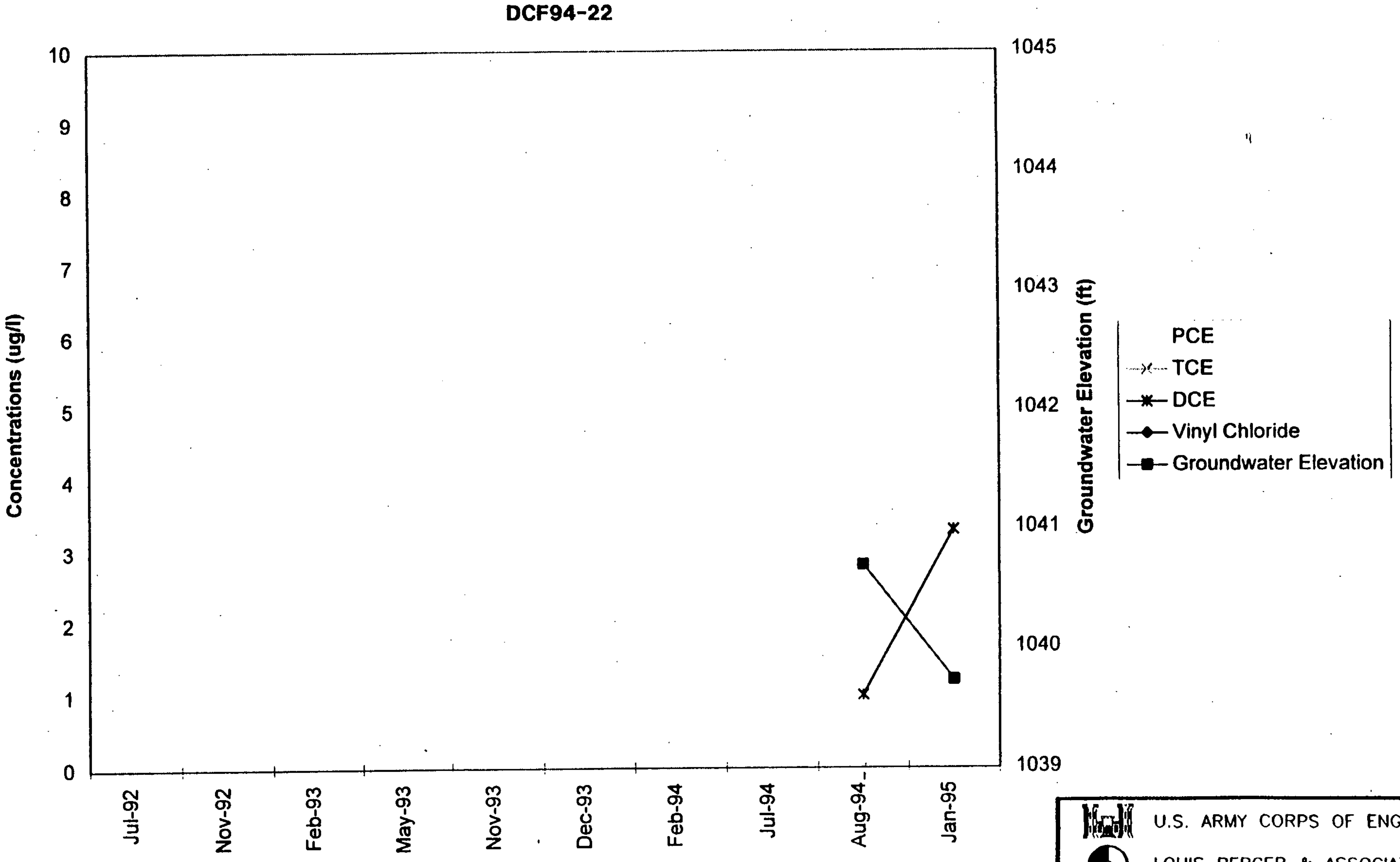
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF94-21

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43t



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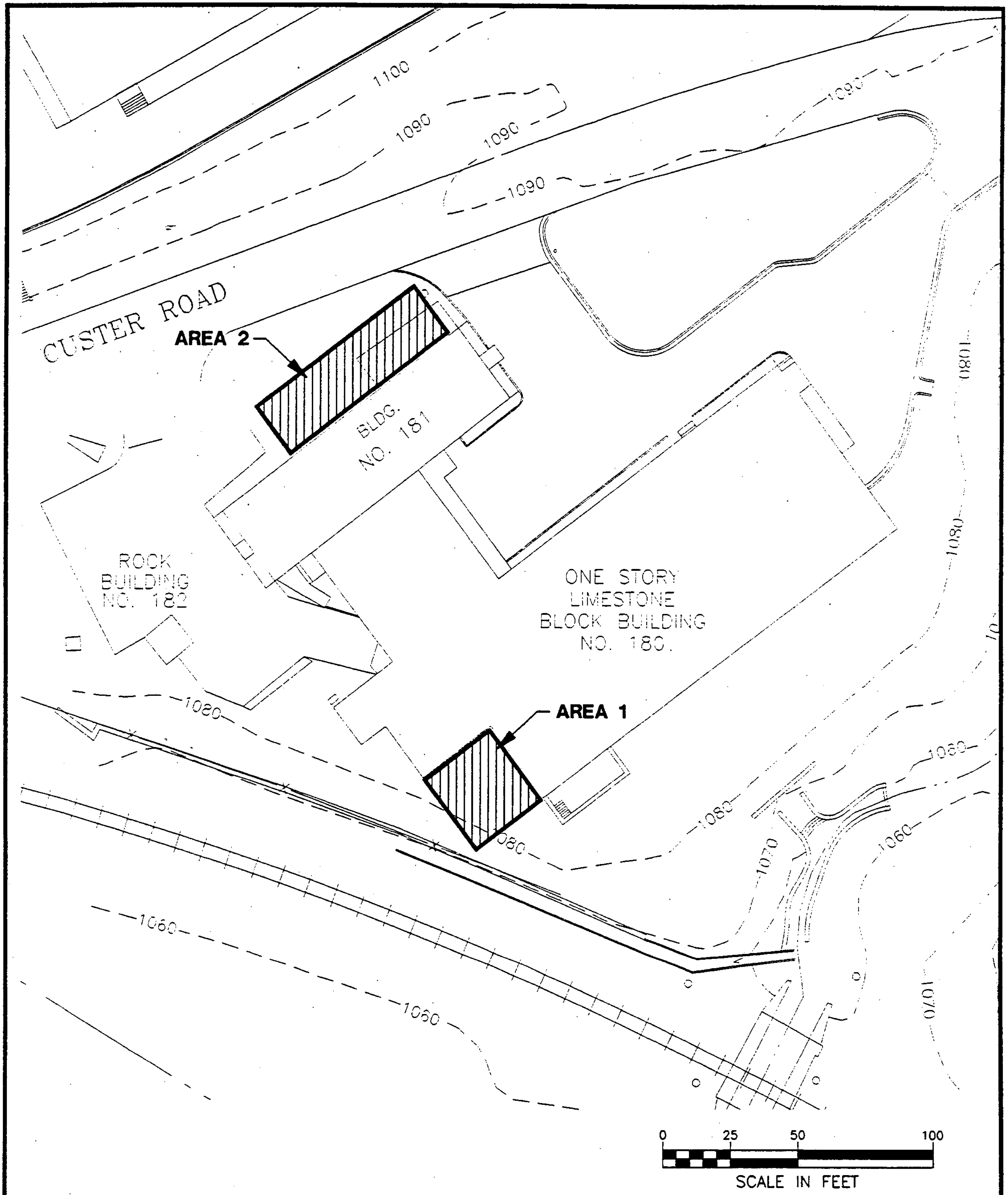
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER VS. GROUNDWATER ELEVATIONS, DCF94-22

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-43u



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FORT RILEY MILITARY RESERVATION (DCFA-FS)

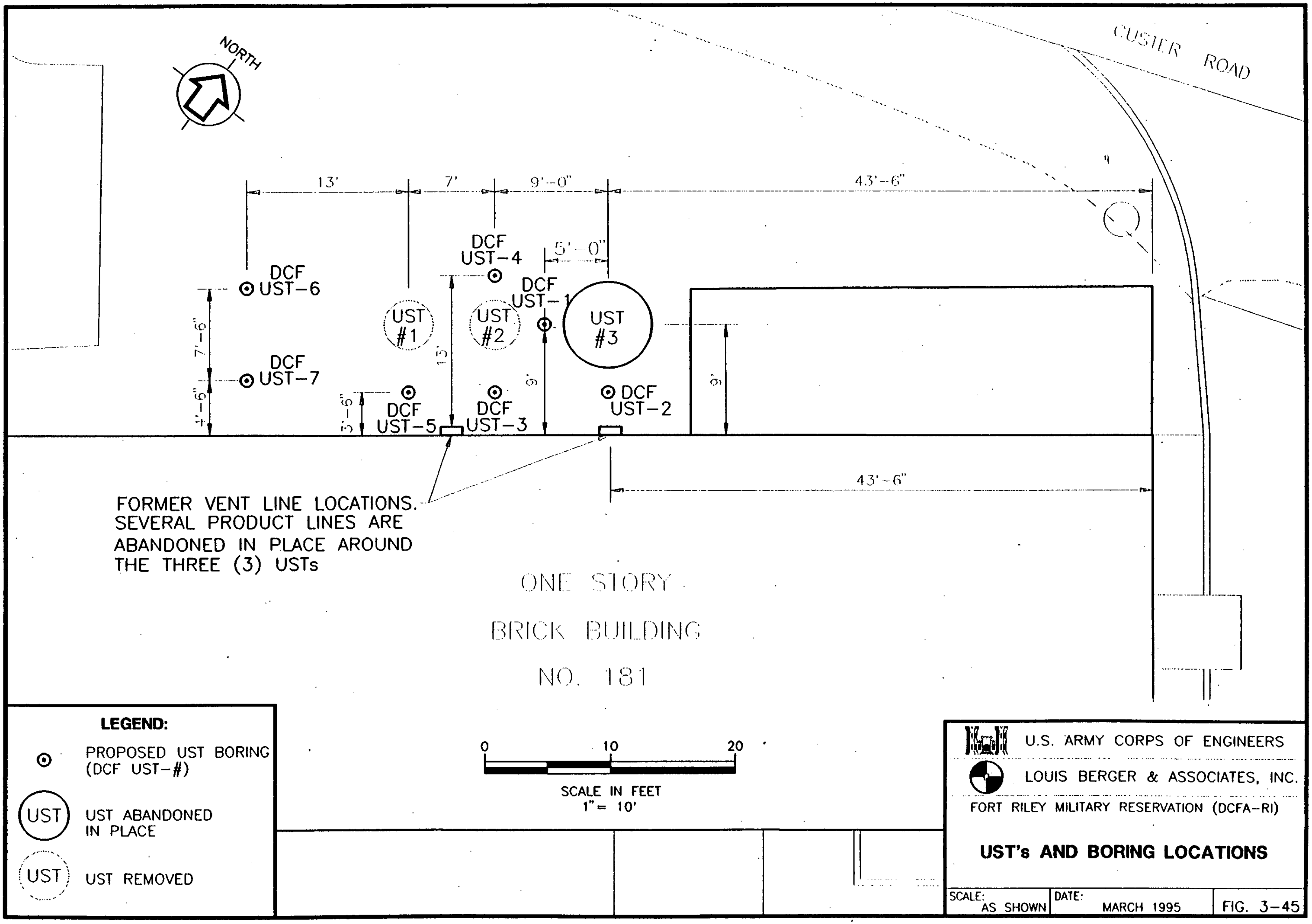
ELECTROMAGNETIC SURVEY AREAS FOR USTs IN VICINITY OF BUILDING 180/181

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-44

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.

3-USTSL/30MAR95



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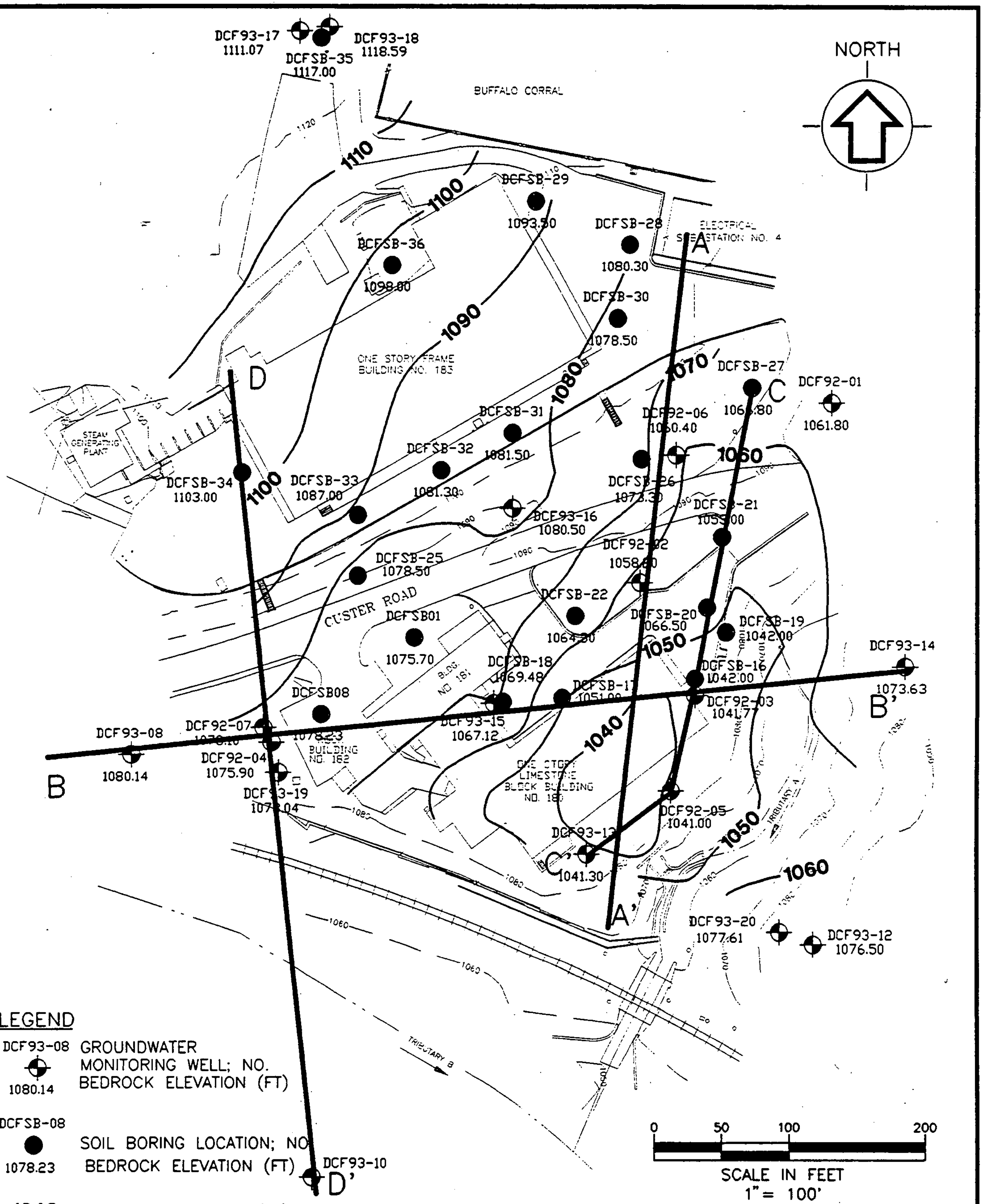
FORT RILEY MILITARY RESERVATION (DCFA-RI)

UST's AND BORING LOCATIONS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-45



LEGEND

DCF93-08 1080.14	GROUNDWATER MONITORING WELL; NO. BEDROCK ELEVATION (FT)
DCFSB-08 ● 1078.23	SOIL BORING LOCATION; NO. BEDROCK ELEVATION (FT)
—1040—	BEDROCK ELEVATION (FT) CONTOUR

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. BEDROCK SUBSURFACE SHOWN IS THE FIRST ROCK FORMATION ENCOUNTERED DURING DRILLING, OR "REFUSAL".

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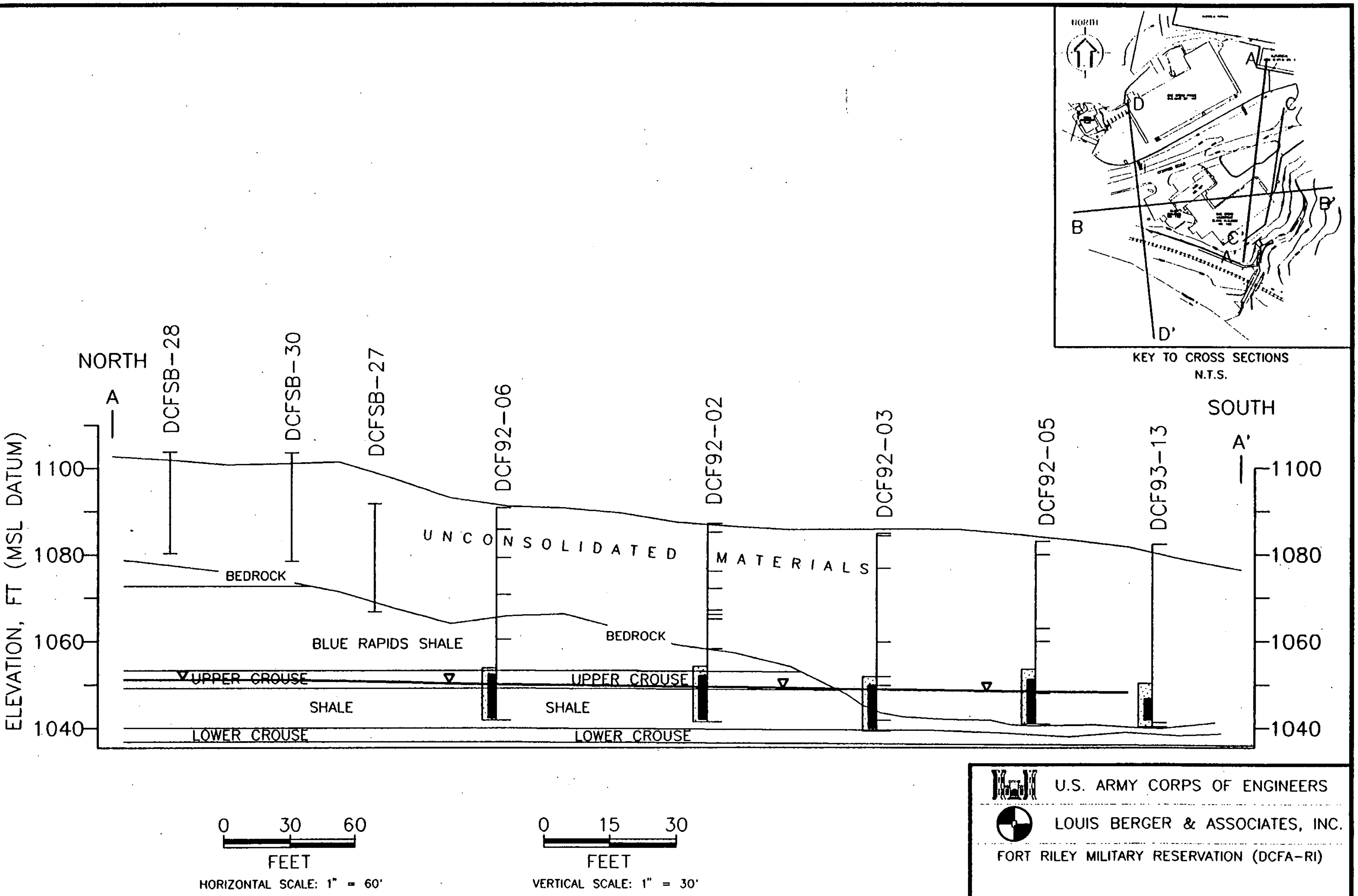
FORT RILEY MILITARY RESERVATION (DCFA-RI)

LOCATION OF CROSS SECTIONS

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 3-46

3-XSLINES/30MAR95

5-GEOAA/30MAR95



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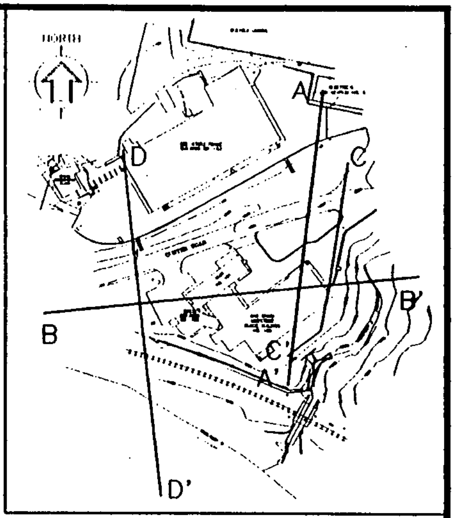
FORT RILEY MILITARY RESERVATION (DCFA-RI)

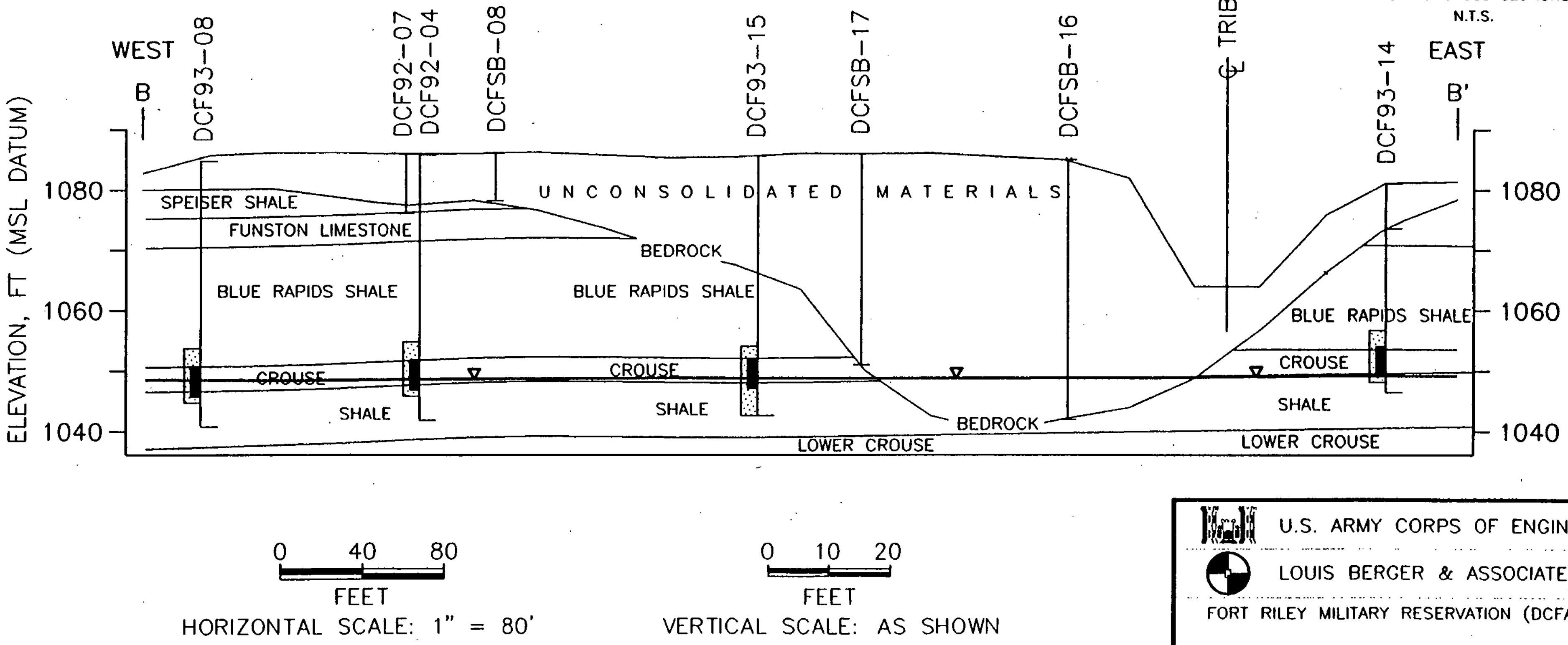
GEOLOGIC CROSS SECTION A-A'

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-47

3-GEOBB/30MAR95



KEY TO CROSS SECTIONS
N.T.S.



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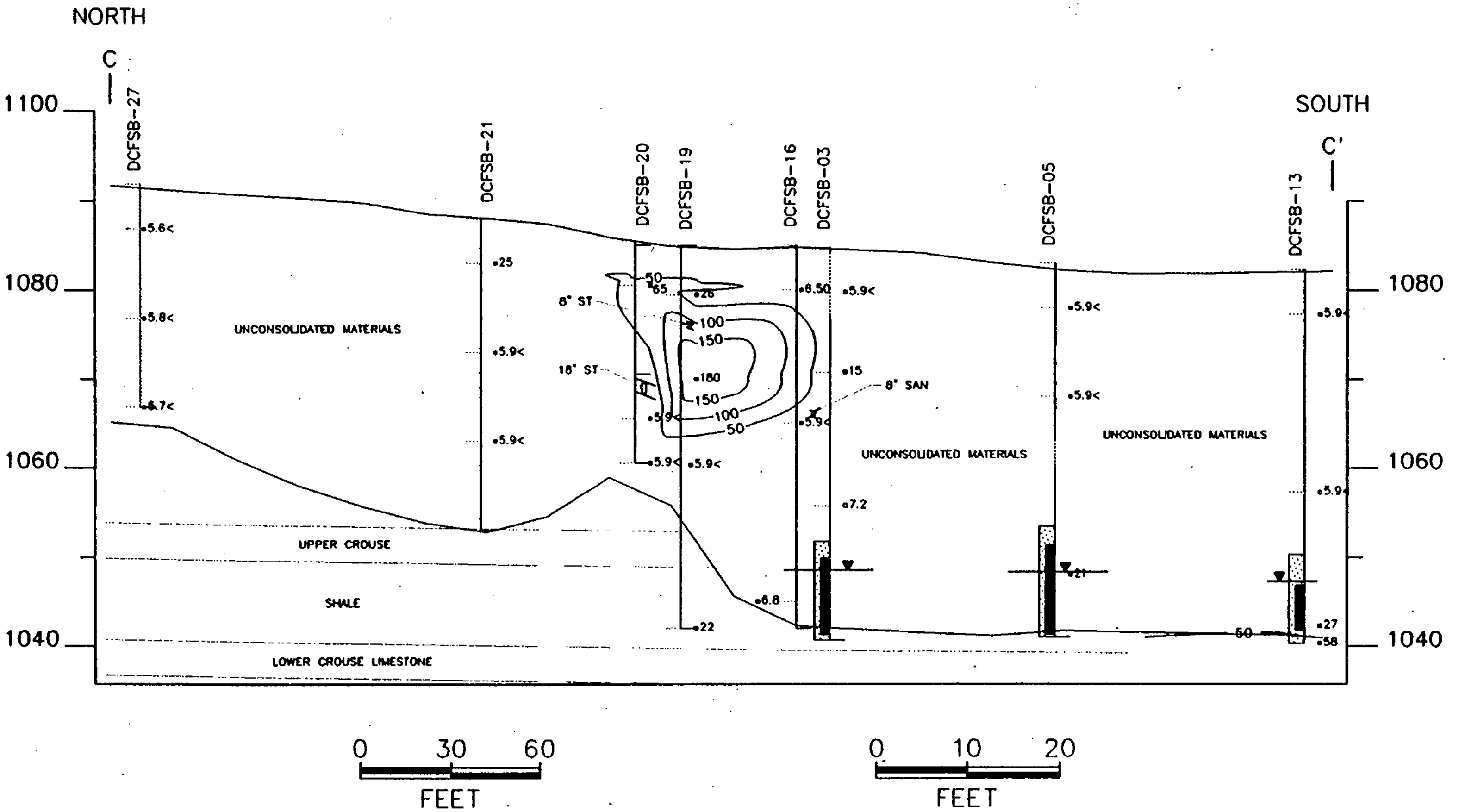
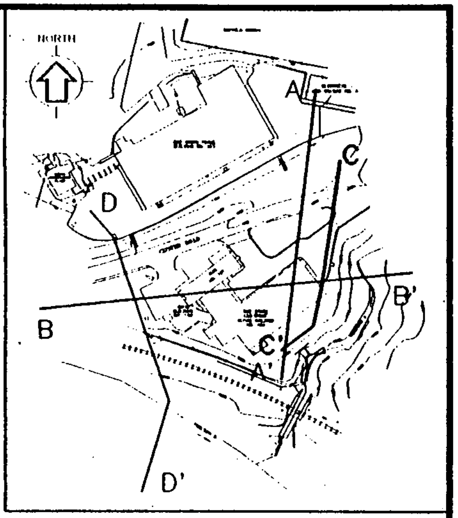
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GEOLOGIC CROSS SECTION B-B'

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-48



HORIZONTAL SCALE: 1" = 60'   VERTICAL SCALE: AS SHOWN



KEY TO CROSS SECTIONS
N.T.S.

NOTES:

1. Ground surface profile based on survey data of ground surface at wells and borings combined with topographic survey data points.
2. PCE contours based on analytical data from soil samples collected during well or soil boring activities.
3. Bedrock profile based on data collected during well/boring installation.
4. Upper Crouse profile based on data collected from geophysical logs.
5. Sewer Line projections based on elevation information from sewer profiles presented in PA/SI report (CEMRK 1992a).

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GEOLOGIC CROSS SECTION C-C'

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 3-49

TABLE OF CONTENTS

CHAPTER 4
NATURE AND EXTENT OF CONTAMINATION

This chapter presents analytical results of the samples collected during the field investigations at locations identified in Chapter 3. As described therein, these samples included different media: soils, groundwater, surface soils, sediments, surface water and air. Other supplement field samples included sewer sediment samples from both sanitary and storm sewers, as well as soil borings from UST locations. These results were evaluated to define the chemical characteristics of the study area. As described in Chapter 3, the chemical characteristics, in conjunction with the physical characteristics, facilitated the overall study area characterization. The RI data and the previous data for PA/SI were integrated for determining the chemical characteristics.

The nature and extent of contamination within the DCFA are discussed in terms of the sources and in the context of each of the media where encountered. The most frequently detected contaminants are chlorinated volatile organic compounds (VOCs), notably PCE and its breakdown products TCE, DCE, and vinyl chloride. Characteristic properties of chlorinated VOCs include low water solubility and high vapor pressure (Table 5-1). The low solubility suggests that these materials do not mix well with water, and the high vapor pressure suggests rapid volatilization (Howard, 1990). Although having a low solubility, VOCs do dissolve in water, and from an environmental standpoint can be pervasive. Fate and transport phenomena for chlorinated VOCs are discussed in Chapter 5.

SVOCs detected during the PA/SI consisted of polynuclear aromatic hydrocarbons (PAHs) found in shallow soils in the area of DCF92-03 and bis(2-ethylhexyl)phthalate found in soil boring DCF9206B. SVOCs detected in groundwater in monitoring well DCF92-04 consisted of 2,6-dinitrotoluene, hexachloroethane, naphthalene and N-nitrosodi-n-propylamine. Soil samples collected during the RI were biased to analyze for SVOCs in areas of prior detections based on previous investigations. No SVOCs were detected in soils collected during the RI. SVOC detections in groundwater during the RI were infrequent and restricted to bis(2-ethylhexyl)phthalate (a common plasticizing agent) detected in background well DCF93-18 (14 μg/l) and alluvial wells DCF93-09 (44 and 30 μg/l) and DCF93-11 (15 μg/l), and 1,4-dichlorobenzene detected in background well DCF93-17 (11 μg/l). This defines the extent of SVOC contamination in soil and groundwater at the DCFA detected during the PA/SI and RI.

A number of contaminants have been detected infrequently at various locations and in various media at the DCFA. Detections of toluene, benzene, ethylbenzene and trichloromethane appear at low concentrations at relatively few locations and do not indicate widespread contamination representative of general site conditions. Trihalomethanes (THMs) and phthalates have been detected in aqueous samples collected from sewer lines as well as surface water samples from the tributaries. Initial detections of acetone and pyrene in sediment samples collected from the tributaries in March 1992 and February 1993 were not detected in subsequent samples collected in January 1995. These infrequently detected compounds are not associated with PCE and its breakdown products, and their sporadic detection indicates that there is not an ongoing or more pervasive source at the DCFA.

PCE, the most widespread contaminant detected, which would have been discharged as a water mixture to soils at the DCFA, will migrate downward through the unsaturated zone to groundwater in a dissolved state. Concentrations of PCE and its breakdown products in groundwater have been decreasing since the November 1993 (i.e., spills into the sewers) sampling event, following the flood. This may indicate that the combination of the removal of possible sources of contamination and the migration of contaminants along the direction of groundwater flow towards the Kansas River are removing contaminants from the DCFA.

Repair and cleaning of the sewer line, enhanced management practices at the laundry and dry cleaning facilities and the closing of the floor drains in Building 183 have apparently removed the possible source of contamination. Quarterly groundwater sampling has shown that the areas of highest PCE concentration are moving in a southerly direction toward the Kansas River. Detections at the alluvial wells located on The Island show lower concentrations of contaminants probably due to dilution effects of mixing with groundwater. The detections at the alluvial wells toward the southeast end of The Island exhibit higher concentrations of breakdown products than PCE, indicative of degradation occurring along the migratory pathway. The effects of dilution and degradation further reduce the concentration of PCE in groundwater prior to migration off-site into the River. Thus, by the time the groundwater mixes with water in the Kansas River, the concentration of PCE and its breakdown products would most likely be below the analytical detection limits.

4.1 Overview of Contamination in the Environment

Based on the history of operations at the former and current DCF, the potential sources of PCE in the DCFA have apparently been discharges and accidental spills that have resulted in discharges to the sanitary or storm drainage system. Accidental spills may have occurred both within the facilities and on the exterior during transfer of product by vendors. Discharge of condensate water containing PCE has occurred to the sanitary sewers via floor drains. Spills and other discharges were reported during interviews with Fort Riley personnel for Building 183, for the loading dock area of Building 180/181, and to the west of Building 180/181 to the bank area above the railroad (Figure 2-10). USTs removed from the northwest side of Building 180/181 are a potential source of SVOCs detected in the July and November 1992 and May 1993 sampling of groundwater monitoring well DCF92-04.

The primary suspected sources of contaminant contact with the environment are breaks in the sanitary/storm sewer lines serving the facilities and accidental spills and discharges adjacent to Building 180/181. The dates of the breaks are not determinable; therefore, the duration of leakage to the environment is not known. Based on detections of PCE and its breakdown products to date, it is estimated that a total mass of 50-65 pounds of PCE is present in the environment. The calculation of this mass and the assumptions made to characterize PCE concentrations in soil and groundwater are provided in Appendix D-I; a brief description of these assumptions follows.

To perform this calculation for soils, the horizontal extent of PCE is estimated to be in a 400×300-foot area with a soil-to-bedrock depth of 45 feet. A soil density of 115 lbs/ft^3 and a conservative estimate of porosity of 31 percent are assumed to be representative values for this volume (DAS, 1990). For computational purposes, PCE detections from soil samples collected during the PA/SI (March and April 1992) and the RI (November 1993) were categorized into discrete 5-foot-thick layers (Tables 4-1 through 4-3). Concentration for each layer were conservatively averaged based on the number of detections (not on the number of samples) and this value was used as the concentration for that layer. Using the assumed soil density, the soil layers volume were then converted into mass. Average PCE concentrations were then multiplied with the total soil mass for each layer to arrive at total PCE mass.

To derive a total PCE mass for groundwater, the horizontal extent of PCE was estimated to be within a 300×300-foot area, with an average saturated thickness of 5 feet. A porosity of 31 percent for dense sand/silty sand is conservatively assumed to be representative of site characteristics (DAS, 1990). A PCE concentration of 400 μg/l is considered representative based on the median value of all wells sampled in December 1993 (Table 4-4) and some interpolation based on PCE contours presented in Appendix D-I.

Using 31 percent porosity and the volume of the estimated impacted area, a volume of impacted groundwater was calculated. This value was then multiplied with the average concentration to generate a total mass of PCE.

The total mass for each medium using these assumptions is estimated to be between 40 and 50 pounds in soils and between 10 and 15 pounds in groundwater. The estimate is limited by the lack of analytical data prior to investigations begun in 1992. However, the assumptions employed were conservative in an effort to derive an upper limit value for the total mass of PCE. All assumptions and calculations are presented in Appendix D-1.

As stated in the introduction to this chapter, several contaminants are detected infrequently at various locations at the DCFA. Naphthalene detected in groundwater on the west side of Building 180/181 in monitoring well DCF92-04 between July and November 1992 and May 1993 may be attributable to the use of Stoddard solvent in Building 180/181 prior to 1966. During installation of monitoring well DCF92-04, a sheen was noticed on the coring return water. An analysis of this water for Total Petroleum Hydrocarbons (TPH) by modified U.S. EPA Method 8015 indicated weathered gasoline or mineral spirits (Stoddard solvent). Prior to removal of the USTs in July 1994, the tank contents were analyzed to determine waste characterization. Naphthalene was detected in each tank sample as well as other volatile and semivolatile compounds (Section 4.8.3). Naphthalene was not detected in any of the soil samples at the DCFA.

THMs were detected in surface water samples collected in January 1995 as well as in the storm water and sanitary sewer water samples collected in November 1992 and February 1993. THMs are formed during chlorination treatment processes of water, and this appears to be the most likely source of these compounds. THMs were detected in a water sample collected from a tap at the Fort Riley Fire Headquarters in June 1994 and analyzed by GC/MS by KDHE. Potable water at Fort Riley undergoes chlorination treatment at the Main Post Treatment Plant. Other infrequently detected compounds include acetone and phthalate compounds. Phthalate compounds appear in all media sampled at various times at the DCFA. This is not unusual, as these compounds are common plasticizing materials and ubiquitous contaminants in the environment. Another potential source may be inadvertent leaching from PVC pipe, plastic gloves worn during sampling or laboratory preparation, or plastic tubing.

The detections of acetone appear to be related to samples associated with the sewer lines. All storm sewer water samples and four of the sanitary sewer water samples had detections of acetone, as did the seep sample collected in January 1995 from Tributary A. During collection of the seep sample, it was noted that the water emanating was warm, indicating that the source of this seep may have been the sewer line which is known to receive discharge from both the steam plant and Building 183. A potential source of acetone, outside of laboratory contamination, is natural formation from humic materials.

Detection of benzene, ethylbenzene and xylenes has occurred infrequently during the PA/SI and RI investigations. Toluene has been detected at low levels more frequently in groundwater and soil and sanitary sewer samples. Potential sources of toluene and BTEX compounds are Stoddard solvent formerly used in Building 180/181, the effluent water from laundered rags discharged from Building 183, or lab contamination in the case of toluene (Section 4.4).

4.2 Soils

The nature and extent of contamination in "soils" (defined as all unconsolidated materials) are shown in tables, figures, and cross-sections. In addition, results from soil gas analyses are evaluated and shown as figures. The tables show analytical results in soils collected from soil borings and from soils encountered during monitoring well installations. For this RI report, an effort has been made to present in a similar format all data collected during both the PA/SI and RI field investigations over a 2-year period. All the tables in this section list only the positive detections from the complete analysis suite. As such, while the tables depict the same information, they list only the detections for that timeframe and may therefore look different.

Two investigative methods were used to identify the presence of contaminants in soils: soil gas analysis and soil sample analysis. The soil gas analyses were performed during preparation of the PA/SI, and soil sample analyses were performed during both the PA/SI and the RI. Results of the soil gas analyses are shown in Figures 1-4 and 1-5. Figure 1-4 isopleths show higher PCE concentrations centered near the northeast corner of Building 180/181, and Figure 1-5 shows similar areas of higher concentrations.

Surface soils sampled at six locations (Figure 3-18) in November 1993 during the RI were selected to assess dermal exposure in areas of high potential exposure to workers and pedestrians. All samples analyzed for VOCs were non-detects for all analytes, except for ethylbenzene detected at 6.4 μg/kg in the duplicate sample of DCFSS-06. Because this result is approximately the same as the Sample Quantitation Limit (SQL) for this analyte (6.1 μg/kg) and because it is normal for soils to exhibit variation, the lack of detection of this analyte in the record sample is not unexpected. Appendix D lists the analytical results for surface soil samples. A complete table of analytical results, including field duplicate samples, is presented in Appendix D-II for all samples collected and analyzed at the DCFA since November 1993. Data assessment is discussed in Section 7.3 and was previously reported under separate cover in the QCSRs (CEMRK, 1994b,e).

All surface soil samples were non-detects for SVOCs; however, the reporting limits were raised because of matrix interferences. Organic material present in the sample matrix interfered with the extraction procedure for SVOCs, which made dilution of the extract necessary prior to analysis. The nature of organic material compounds, other than the VOC and SVOC constituents analyzed for, were possibly vegetative matter. The reporting limits for the analytes ranged from 3,400 to 16,000 μg/kg (3.4 to 16 mg/kg); data assessment is discussed in Section 3.2 and in the QCSRs (CEMRK, 1994b,e). Exposure pathways of these constituents are discussed in Chapter 6, Risk Assessment.

Soil boring sites were selected to determine the horizontal and vertical extent of PCE contamination and the extent of contamination from breaks in storm and sanitary sewer lines, and to provide baseline information for comparison with any subsequent remedial efforts. Figures 4-1 and 4-2 show the location of all soil borings at the DCFA; Table 4-1 provides the positive detections for all soil boring record samples collected in March 1992 and November 1993 within the DCFA. SVOC analyses showed positive detections at two locations: DCFSB07—(bis(2-ethylhexyl)phthalate at 10 and 15 feet (380 and 360 μg/kg, respectively); and DCFSB13B—2-methylnaphthalene (220 μg/kg) and phenanthrene (290 μg/kg). SVOC analyses performed during the RI on samples collected from four locations adjacent to the sanitary sewer line (DCFSB-20, DCFSB-21, DCFSB-30, DCFSB-31) were non-detects for all analytes.

PCE was detected at 11 locations with concentrations ranging from 3.7 to 960 μg/kg. The highest concentration was detected near the northeast corner of Building 180/181 at locations DCFSB13 and DCFSB-19. Both soil boring locations represent the same area of the site adjacent to breaks detected in the storm sewer line; DCFSB13 was sampled in March 1992, and DCFSB-19 was sampled in November 1993. PCE was detected from both sampling events at all sample depths, and toluene was detected in the 0- to 5-foot sample of DCFSB-19 (14 μg/kg) and both DCFSB13 samples (5.9 μg/kg at 10 feet, 31 μg/kg at 15 feet).

PCE was detected at sites DCFSB03A, DCFSB04A, DCFSB07(A and B), and DCFSB14A during the PA/SI. "A" refers to samples collected at depths between 9 and 10 feet, and "B" refers to samples collected at depths between 14 and 15 feet. During the RI, PCE was detected at sites DCFSB-16, DCFSB-20, and DCFSB-21, with concentrations ranging from 6.5 to 65 μg/kg in the 0- to 5-foot sample. In the 35- to 40-foot sample for DCFSB-16, the concentration was 6.3 μg/kg. Five of these sites are adjacent to the sanitary sewer line; site DCFSB07 is located in an area near Building 180/181 where PCE spills are suspected, and DCFSB14 is southeast of Building 180/181 near Tributary A. PCE was detected at sites DCFSB-29 and DCFSB-30 (18 and 8.1 μg/kg, respectively) at 0 to 5 feet. Both sites are located on the northeast side of Building 183 and are adjacent to detected breaks in the sanitary sewer lines. TCE was detected at 4.2 μg/kg in sample DCFSB04B. This is the only soil sample showing a detection of a PCE degradation product during the PA/SI.

Figure 4-1 represents results of soil analyses for samples from soil borings collected during the PA/SI, and Figure 4-2 shows results from the RI. While still showing high concentrations to the northeast of Building 180/181, two other areas show detections of PCE. These are just east of Building 183 and at the open area between Building 180/181. Results from these data will be compared to the groundwater results discussed in Section 4.6.

Detections of PCE show consistency among samples at the 0- to 10-foot and 11- to 20-foot intervals, which are centered northeast of Building 180/181 where effluent might enter the environment via leaks in the sewer systems. Noticeably absent is any indication of contaminants in areas that received accidental spills or discharges, such as west of Building 180/181. This absence at the lower depth may indicate discharges that were not continuous and that took place at the surface, allowing some volatilization to occur before any movement downward.

PCE was detected in soils during installation of groundwater monitoring wells in March 1992 and November 1993. Monitoring well locations are presented in Figure 4-3 (PA/SI) and Figure 4-4 (RI). Tables 4-2 and 4-3 indicate the positive detections for samples collected during monitoring well installations at the DCFA. Concentrations ranged from 4.5 to 110 μg/kg. PCE was detected at various depths at locations DCF92-02 (from 4.5 to 53 μg/kg) and DCF92-03 (7.2 to 110 μg/kg), to the north and east of Building 180/181. Toluene was detected at DCF92-01 at 27 feet (5.8 μg/kg) and at DCF92-03 at 4 feet (7.4 μg/kg). PCE was detected at location DCF92-05 at 35 feet (21 μg/kg). At DCF93-13, PCE was detected at 35 to 40 feet (27 μg/kg) and at 40 to 42 feet (58 μg/kg); TCE was detected at 40 to 42 feet at 7.8 μg/kg. This is the only detection of a PCE breakdown product in a soil sample during the RI. PCE (12 μg/kg) and toluene (5.8 μg/kg) were detected at DCF93-15 at 0 to 5 feet. Toluene was also detected at DCF93-20 at 0 to 5 feet.

Soils from monitoring well borings at DCF92-03 at a depth of 4 feet were positive for six PAHs associated with coal tar derivatives (Table 4-2). Potential sources of PAHs are road-tarring activities including asphalt, roofing pitch, and wood preservatives. Other SVOC analytes detected were pyrene in DCF92-01 at a depth of 1 foot (110 μg/kg), and bis(2-ethylhexyl)phthalate in DCF92-06 at 9 feet (2,400 μg/kg). Well borings at DCF93-08 and DCF93-15 analyzed for SVOCs were non-detects for all analytes.

All soil samples obtained from monitoring well borings during the RI were also analyzed for total organic carbon (TOC). Results ranged from 1,040 to 53,100 mg/kg (Table 4-3). TOC analysis is one of the methods used to evaluate the tendency for soil to leach contaminants. Moderate TOC levels were characteristic of most soils in the 0- to 5-foot range, and TOC concentrations generally decreased with increasing depth. Two exceptions were noted: DCF93-14 showed nearly a fivefold TOC increase from 0 to 5 and from 5 to 10 feet, from 2,910 to 13,800 mg/kg); and DCF93-13 showed decreased TOC from 0 to 5 through 35 to 40 feet, then increased TOC at 40 to 42 feet, from 1,040 to 53,100 mg/kg. The

53,000 mg/kg concentration at 40 to 42 feet is associated with a PCE concentration of 58 μg/kg, indicating a strong correlation between the concentration of organic matter in soils and the adsorption of chlorinated VOCs.

In summary, the highest overall concentrations are in the area northeast of Building 180/181 where the storm and sanitary sewers cross the subsurface. Because of breaks in both systems just north of this location, greater opportunity existed for discharge of effluent. The percentage of the flow-through volume that may have leaked to the subsurface and the associated PCE concentrations in the leaked volume are unknown and indeterminable.

4.3 Surface Water/Sediment

The only surface water systems within the immediate vicinity of the DCFA are those designated Tributary A and Tributary B. Both are considered ephemeral in nature; i.e., the stream bottom is above the water table and flow is present only after a precipitation event. Flow from the storm sewer serving Building 183 discharges at a point off the southeast corner of Building 180/181 into Tributary A.

Results of sampling during the PA/SI in March 1992 indicated PCE at the lower end of Tributary A in both the surface water and the sediment samples. The surface water contained 4.5 μg/l of PCE, and the sediment contained 6.6 μg/kg (CEMRK, 1992a; 1993d). Samples taken from Tributary B downstream from Tributary A contained no PCE, but 120 μg/kg of pyrene (a PAH) was detected in the sediment sample collected in March 1992. Pyrene is not generally associated with DCFA activities and may be due to the presence of asphalt-containing fill material used in the vicinity of Building 180/181.

Surface water and sediment samples collected during February 1993 were non-detects for PCE and its degradation products. Acetone and dichloromethane were detected at 1,800 and 2,100 μg/kg (acetone) and 1,100 μg/kg (dichloromethane) in samples DCFSD08 and DCFSD09 located in Tributary B. The dichloromethane detections appear frequently in laboratory method blanks and may be attributable to laboratory contamination. Acetone is another common laboratory contaminant; however, detection of acetone in associated method blanks is not reported. Locations for surface water and sediment samples appear in Figure 4-6; analytical results are presented in Tables 4-6 and 4-7.

Initial sampling of four sediment and three surface water samples (November/December 1993) conducted during the RI provided no detections of volatile or semivolatile analytes. An additional sampling event in January 1995 of 7 surface water samples, 2 seep samples and 18 sediment samples was performed to determine current conditions in the tributaries and to investigate possible contaminant redistribution due to deposition and erosion caused by the 1993 flooding. All sediment samples were non-detects for all analytes. PCE was detected in the two seep samples, DCFSW-24 and DCFSW-26, at 1.4 and 17 μg/l, respectively. DCFSW-24 was collected at a seep below the southeast corner of Building 180/181 above Tributary A. DCFSW-26 was collected southwest of Building 182 in an area of cattail growth in Tributary B.

Sample DCFSW-24 additionally had detections of acetone (180 μg/l), benzyl alcohol (37 μg/l), and phthalate compounds. Phthalates were also detected in samples DCFSW-20, DCFSW-23, and DCFSW-27. Seven surface water samples had detections of trihalomethanes (THMs); exceptions were DCFSW-16 and DCFSW-17 located upstream, northeast of Building 180/181. THMs commonly found in waters that have undergone chlorination treatment are not associated with PCE or its breakdown products and are attributed to the chlorination process. The locations of all surface water and sediment samples are provided in Figure 4-6. Positive detections for surface waters and sediment samples appear in Tables 4-6 and 4-7; results for both sediments and surface waters collected since November 1993 appear in Appendix D-II.

The absence of contaminants in the sediment is likely due to volatilization. Deposits of silts and sands from 6 to 18 inches occurred along the extent of Tributary B as a result of the Kansas River flooding. There was no flow in Tributary B above the confluence with Tributary A at the time of the RI sampling event. The effects of precipitation and runoff on Tributary A during the period of flooding were more erosional than depositional, which may have resulted in removal of contaminated sediment, if any was present (CEMRK, 1994a,b,e).

4.4 Laundry/Dry Cleaning and Sewers

In addition to sediment samples collected from the tributaries, 2 sewer sediment samples and 10 surface water samples were collected from the sanitary and storm sewer systems in November 1992 and February 1993. All water samples from the sanitary sewer lines had positive detections of acetone and various THMs (Table 4-8 and Table 4-9). PCE was detected in DCFSSW02 and DCFSSW04 at 21 and 4.5 μg/l, respectively; toluene was detected in DCFSSW02 and DCFSSW06 at 1.6 and 6.5 μg/l, respectively; and xylenes were detected in DCFSSW02 at 6.0 μg/l. SVOCs, particularly PAHs and phthalates, detected in DCFSSW01, DCFSSW02, and DCFSSW04, ranged from 5.0 to 120 μg/l. Sewer sediment sample DCFSD06, collected in November 1993 from MH 363B (Figure 1-16), was described as bluish-gray material consisting mainly of clothing fibers (CEMRK, 1993a). Analysis of this sample showed high levels of PCE, TCE, DCE, phthalates, and 4-methylphenol.

All waters collected from storm sewer lines had detections of PCE ranging from 3.7 to 26 μg/l, as well as detections of THMs. PCE, DCE, and TCE were detected in sewer sediment sample DCFSD05 (at 100, 42, and 55 μg/kg, respectively) collected from a storm sewer line catch basin in November 1992, as well as PAHs and phthalates. Sample DCFSD05 was described as consisting of silty sand and gravel (CEMRK, 1993d). The associated water sample, DCFSW05, had detections of PCE (19 μg/l), THMs, and phthalates. Locations of sewer, water and sediment samples appear in Figure 4-7; analytical results are presented in Tables 4-7 and 4-8.

Two water samples were collected in April 1993 from the cooling water discharge lines of the two dry cleaning machines operating in Building 183. Two water samples were additionally collected from the 5-gallon buckets that received the water extracted and separated during the dry cleaning process, which had been discharged into nearby floor drains in the past. PCE was detected in all four samples at 3.2 μg/l and 29 μg/l from the cooling water lines and at 5,100 μg/l and 4,400 μg/l from the bucket samples. The concentrations from the bucket samples were estimated because the dilution factor was 100:1. THMs were detected from the cooling water lines but were not detected above the raised quantitation limits of the bucket samples (Table 4-10).

In January 1994, effluent water from a laundry machine in Building 183 used to launder rags was analyzed for VOCs by U.S. EPA Method 8240, pH, flashpoint and TCLP metals (Table 4-11). The rags are received once or twice per month from the Consolidated Maintenance Facility in Building 8100. Detections of toluene (900 μg/l) and ethylbenzene (13,200 μg/l) were reported in this effluent, as well as a flashpoint of 126°F (KDPS, 1994). [The quality of the data as well as the sampling protocols have not been verified.]

4.5 Groundwater

The nature and extent of contamination in groundwater should be interpreted in the context of the site geology and hydrogeology. Groundwater is recharged by direct infiltration of precipitation and perhaps, to a limited extent, influenced by outcropping or subcropping of the Crouse limestone somewhere to the northeast. Groundwater movement is to the southwest and south off the site and, ultimately, in the direction of and parallel to the Kansas River. Discharge of groundwater will be to the river alluvium and, ultimately, to the river.

During the PA/SI effort, the first water-bearing horizon below the DCFA was targeted for monitoring well installation. This effort resulted in six wells from which water levels could be measured and samples taken. Four of these were completed in what is identified as the upper limestone of the Crouse limestone, and two were completed in unconsolidated silts and sands. These wells are identified by the prefix DCF92. A seventh shallow well, DCF92-07, was drilled but was found to be dry. Tables 4-12 through 4-15 present chemical detections of groundwater samples for quarterly sampling events prior to November 1993.

Analyses of the six 1992 groundwater monitoring wells were performed before reverse air rotary drilling was initiated in November 1993 and after drilling was completed in December 1993. The objective of these two sampling events was to assess the impact of new monitoring well construction on the existing wells resulting from use of air rotary methods. Table 4-16 shows comparative results for DCF92 wells. PCE was detected in three wells for both sampling events; however, DCF92-03 shows a decrease from 1,600 to 820 μg/l, while DCF92-05 shows an increase from 430 to 710 μg/l from November to December. Comparison of the results yields no definitive conclusion, but the likelihood of any effects is remote. The differences obtained in DCF92-03 and DCF92-05 are most likely from natural migration.

4.5.1 Nature of Groundwater Contamination

Analytical results for groundwater samples collected following development of the DCF92 wells in July 1992 indicated that the highest PCE concentrations occurred in the vicinity of well DCF92-02. Wells DCF92-05 and DCF92-03 exhibited concentrations of PCE as well as breakdown products TCE and DCE. Well DCF92-04 exhibited higher concentrations of PCE breakdown products than of PCE. These data indicate that the source of the PCE is near DCF92-02, in the area of detected sewer line leaks, while the downgradient wells DCF92-03 and DCF92-05 are consistent with degradation of PCE over time as the contaminants moved through the unsaturated zone. The source of contamination at well DCF92-04 appears to be an older discharge (possibly attributable to the former practice of disposing still bottoms in this area) because the final degradation products of PCE (DCE and vinyl chloride) are prevalent.

It is noteworthy that this area is the only DCFA location where vinyl chloride was detected with any frequency, and wells completed in this area in 1993 exhibit similar contaminants; that is, DCE and vinyl chloride were detected, and PCE was not detected. In addition, DCF92-04 had positive detections of SVOCs during the July and November 1992 sampling events (Tables 4-12 and 4-13). Comments at the time of sampling indicated that a petroleum odor was present. The source of SVOCs may be one of the three underground storage tanks discovered on the north side of Building 181 (Section 3.3.4). Soil samples collected from beneath the USTs following removal indicate the presence of gasoline and diesel range petroleum hydrocarbons (Table 4-17).

Groundwater samples from the DCF93 groundwater monitoring wells were collected for the first time in December 1993. Contaminants were detected in all seven DCF93 groundwater monitoring wells sampled and in the three alluvial wells (DCF93-09, DCF93-10, and DCF93-11). Both DCF93-08 and DCF93-19, in the same area as DCF92-04, showed non-detects for PCE. As is the case for DCF92-04, both are positive for the PCE breakdown products DCE (77 and 54 μg/l), TCE (16 and 3.3 μg/l), and vinyl chloride (54 and 15 μg/l).

At DCF93-13, located south of Building 180/181, PCE was detected at 420 μg/l and TCE at 140 μg/l. Subsequent sampling at this well showed decreasing concentrations until the August 1994 sampling event, when levels of PCE, TCE, and DCE more than doubled (Table 4-18). The January 1995 data show a decrease in concentration for all analytes. DCF93-15, located in front of Building 180/181 (the former DCF), was positive for PCE and trichloromethane (490 and 30 μg/l, respectively). In February 1994, sample results from DCF93-15 showed a decrease in PCE and detections of DCE and TCE as well. This well has been dry since June 1994. DCF93-16, located downhill from the current DCF, was positive for PCE at 200 μg/l. Well DCF93-16 has been dry since the quarterly sampling in February 1994.

PCE, TCE, and DCE were detected in samples from DCF93-12 and DCF93-20 located south and east of Building 180, across Tributary A. Trichloromethane, detected at 6 μg/l in a sample from DCF93-12, was also detected in the associated trip and field blanks (1.4 and 1.8 μg/l). Any analyte detected in the sample that was also detected in an associated blank is qualified if the sample concentration is less than five times (5×) the blank concentration. For common laboratory contaminants (e.g., acetone, dichloromethane), the result is qualified if the sample concentration is within 10× the blank concentration (tenfold rule). DCF93-12 went dry in June 1994; concentrations in DCF93-20 decreased until August 1994, when concentrations of PCE, DCE, and TCE increased over the June 1994 levels. Levels of DCE and TCE were higher in the January 1995 sampling event than in August, while PCE levels increased slightly (Table 4-18). Well DCF94-21 was installed in May 1994 as an extraction well for the pilot test study.

Two of the three alluvial wells, DCF93-09 and DCF93-11, showed detections of PCE, TCE, and DCE for the January 1995 sampling events. DCF93-11 showed non-detect for the June 1994 sampling event, which may be a result of the lowering of the water level in the well as the water table declined. This well was dry in August 1994 and was replaced by well DCF94-22 (Figure 3-22). Well DCF94-22 showed low concentrations of DCE. Well DCF93-09 had PCE detections of 160 μg/l in February and 48 μg/l in June. This peak concentration may have been the result of back-flushing, as the water table declined following the flood of 1993. The August 1994 and January 1995 levels were both 28 μg/l for PCE, and 5.2 and 3.9 μg/l for TCE, respectively. Table 4-18 provides the chemical detections for all groundwater samples collected within the DCFA as of January 1995 except for pilot study wells. Quarterly groundwater results are presented in Table 4-11 and Tables 4-19 through 4-23. Figures 4-8 through 4-17 provide chemical detections of PCE and its breakdown products in groundwater.

Groundwater samples from the extraction wells were collected in June 1994 and analyzed for halogenated volatile organics by U.S. EPA Method 8010. U.S. EPA Method 8010 provides lower detection limits for chlorinated VOCs than U.S. EPA Method 8240 (Exhibit 1-3, QAPP, CEMRK [1993g]); however, the results are comparable as the data are assessed using the same Quality Control parameters. PCE was detected in all wells at concentrations ranging from 46 to 280 μg/l. TCE and *cis*-DCE were detected in all wells at levels ranging from 1.9 to 12 μg/l (*cis*-DCE) and 1.5 to 8.1 μg/l (TCE). Trichloromethane was also detected in all wells at levels from 6.3 to 10 μg/l. The four extraction wells and well DCF92-02 were additionally analyzed for iron, manganese and TSS (Table 4-24).

4.5.2 Extent of Groundwater Contamination

An understanding of the extent of groundwater contamination is placed into perspective by recalling that the introduction of contaminants into the unsaturated zone and subsequent migration to the groundwater primarily resulted from sporadic, accidental spills or leaks. For this reason, there is no well-contained plume, as would be expected with a major one-time release or a continuous point source release. Adding to the complexity of the extent of contamination is the fact that releases occurred in the unsaturated zone from various locations associated with sewer line leaks and migrated vertically and horizontally through materials of varying permeability before reaching the groundwater. In addition, groundwater conditions at the DCFA are influenced by flows in the Kansas River. During periods of high river flows such as the 1993 flood event, groundwater at the DCFA is recharged from the river. Because of these conditions, calculations of groundwater velocity and contaminant velocity are uncertain values at best.

Review of the analytical data indicates the horizontal and vertical distribution of the groundwater contamination in the study area. Figures 4-8 through 4-17 show detection of PCE and its breakdown products for sampling events. The first three figures indicate concentrations for wells DCF92-01 through DCF92-06, and the remainder indicate concentrations for all wells. Comparing concentrations between DCF92-02 and DCF92-03 between the November 1992 (Figure 4-9) and November 1993 (Figure 4-12) sampling events shows that the highest concentration has shifted from DCF92-02 to DCF92-03.

At the time of this report, the quarterly sampling being conducted has been completed through January 1995. In general, the data exhibit an overall trend of declining concentrations, although February and June of 1994 were the first months during which some wells could not be sampled because there was insufficient water for sampling. In February 1994, well DCF93-16 was dry, and in June of 1994, wells DCF93-08, DCF93-12, and DCF93-15 were dry. In August 1994, wells DCF92-04, DCF93-11, DCF93-14, DCF93-17, and DCF93-18 went dry as well. This lack of available water has been attributed to the combination of natural water level decline in the area following the flood of 1993 and the repair of leaks and blockages on a section of sanitary sewer line as discussed in Section 3.3.1.

The potentiometric map of the DCFA is included to serve as a reference when considering the nature and extent of contamination in the groundwater (Figure 3-25). These contours reflect water level readings taken during the second quarterly sampling event in February 1994. Wells DCF93-18, DCF93-19, and DCF93-20 were not included because they were completed in the lower Crouse limestone.

In an effort to further understand the migration of contaminants in groundwater, groundwater temperatures recorded at the time of sampling were contoured (Figure 4-18 and Table 4-25). It was reasoned that if the waters leaking from the sewers (the suspected primary source of contaminants) were of a higher temperature than the ambient groundwater temperature, the contaminants could be traced. Ambient groundwater temperatures are plus or minus the average annual air temperature of the region being investigated at least to depths up to 100 feet. The average annual air temperature in the Fort Riley area is 13.3°C (56°F); therefore, the groundwater should be between 13° and 14°C. Figure 4-18, which represents field measurements of temperature at the time of sampling, provides strong evidence as to where the contaminant concentration exists (i.e., in the area of DCF92-03 and DCF92-05, where the groundwater temperature was about 26°C). A warm spot also occurs to the area west of Building 180/181, which has received flow from the overflow of MH 366 and from the break in the sewer line from the steam plant.

4.6 Air

Given the nature and extent of contamination in the soils and in the groundwater, which are both at some depth below the land surface, there is little opportunity for air contamination. Surface soil sampling resulted in negative findings and further substantiates this conclusion. Monitoring of air quality during utility work conducted during the RI where excavations are greater than 5 feet have also shown that this potential source is not significant (Section 3.2.5).

4.7 Chemical Characterization from Other Activities

Several investigations have been performed at the DCFA since the initial sampling of the DCF93 groundwater monitoring wells. Although these events were not part of the RI, they have further helped to characterize the nature and extent of contamination. These events are discussed in the following subsections.

4.7.1 Pilot Test Sampling

A pilot test study was conducted to evaluate the effectiveness of soil vapor extraction technology on reducing VOC contaminant levels in the soil and groundwater at the DCFA. Soil samples were collected at various depths during installation of the four extraction wells in May 1994 to establish baseline soil conditions prior to the pilot test study (Figure 4-5). Baseline soil samples were collected again in October 1994 because the pilot test study had been delayed as a result of the sewer line repair and UST removal process. Boring locations for the October sampling event were farther south than those collected in May, as it appeared that the highest PCE concentrations were shifting south toward the river.

During the May 1994 sampling event, PCE was detected in four of nine soil samples collected at levels ranging from 7.2 μg/kg to 130 μg/kg. Dichloromethane was additionally detected in two samples at 13 μg/kg and 10 μg/kg. Although dichloromethane was not detected in the associated lab method blanks, its presence as a result of laboratory contamination cannot be discounted because the quantitation limit for dichloromethane falls within the parameters of the tenfold rule (i.e., within 10× the sample concentrations). PCE was detected in 8 of 9 samples collected in October; levels ranged from 4.5 to 100 μg/kg. TCE and 1,2-dichloroethane were also detected in sample DCF94-B5-3 at 4.7 μg/kg and 3.4 μg/kg, respectively (Table 4-5).

4.7.2 Manhole Cleanout

During repair of the sewer line by a rapid response contractor (May 1994) between sanitary MH 365 and MH 363B (Figure 3-35), samples of excavated soil, manhole sediment/lint, and the contents of USTs found along the northwest side of Building 181 were collected for characterization prior to disposal. Excavated soils were screened with a PID for PCE contamination approximately every 7 cubic yards. No readings above action levels (75 ppm) were noted. The excess soil was placed in lined roll-off boxes for disposal. A composite sample of excavated soils showed a PCE concentration of 25.1 μg/kg (Table 4-26).

4.7.3 Manhole 363B

The rapid response contractor was also tasked to remove sludge and sediment/lint from sanitary MH 363B. Approximately 10 gallons of a black/brown opaque solid material was removed and stored in a drum. The manhole sediment/lint showed detections of acetone (25.6 μg/kg), 1,1-dichloroethylene

(12.3 µg/kg), DCE (36,400 µg/kg), TCE (3,760 µg/kg), and PCE (34,600 µg/kg). Quantitation of DCE, TCE, and PCE required a dilution of 1:500 and are estimated (Table 4-26).

4.7.4 UST Contents and Surrounding Soils

In May 1994, 3 USTs were accessed and the tank contents analyzed for waste characterization prior to removal of the USTs. The contents of UST 2 showed detections of DCE (218 µg/l), PCE (31.3 µg/l), xylenes (94.2 µg/l), naphthalene (42 µg/l), 4-methylphenol (62 µg/l), and total recoverable petroleum hydrocarbons (TRPH) (13.4 mg/l). The samples of UST 1 contents were combined and separated by layers. The top layer showed detection of TRPH (974,000 mg/l), xylenes (171,000 µg/l), and naphthalene (226 µg/l). The bottom layer showed detections of TRPH (2,350 mg/l), xylenes (34,500 µg/l), naphthalene (797 µg/l), and 2-methylnaphthalene (106 µg/l) (Table 4-27). The concentration of PCE found in these samples would seem to indicate that the PCE detection could be attributable to possible commingling of PCE with petroleum products rather than a bulk storage of PCE in these tanks. UST 3 was not sampled.

In addition to the identification and quantification of defined analytes in both the volatile and semivolatile fraction, a plus search was conducted. This search attempts to identify the largest 10 or 15 peaks eluted from the gas chromatograph by matching both the retention time (the time in which the compound elutes from the column) and the mass spectrum to that unidentified peak. The mass spectrum is stored in a spectral library on the instrument, and when a peak is found the two files are searched for a potential match. As a result, both the identity and the quantification are considered tentative. The analyst then makes an assumption both to the response factor needed for calibration of an analyte, and the resultant mass spectrum considered a "fingerprint" of a compound. The Tentatively Identified Compounds (TICs) resulting from this search were C3 to C16 saturated and unsaturated hydrocarbons. The compounds tentatively identified in the USTs provide a potential source for the SVOCs detected in groundwater west of Building 180/181.

During removal of the USTs in July 1994 from the northwest side of Building 181, six soil samples were collected and analyzed for VOCs, SVOCs, and TPH (gasoline range and diesel range). VOCs were found in one sample at 15.3 µg/kg (toluene) and 6.7 µg/kg (xylenes). Bis(2-ethylhexyl)phthalate was detected in all six samples and was attributed to laboratory contamination. TPH (gasoline range) was detected in samples 001, 002, and 005 at 1,170, 1,260, and 0.24 mg/kg, respectively. TPH (diesel range) was detected in samples 001, 002, 003, and 005 at 37, 471, 10.2, and 30.8 mg/kg, respectively (Table 4-17). A "plus search" for TICs was performed on sample 002 for VOCs and SVOCs. Compounds detected were tentatively identified as C5 to C11, saturated and unsaturated hydrocarbons.

Sixteen soil samples were collected from seven locations at various depths in the area of UST removal and closure in October 1994 (CEMRK, 1994j). The soils were analyzed for VOCs, SVOCs, and TPH (diesel and gasoline range). PCE was detected in one sample (DCFUST-3-3) at 13 µg/kg, and xylene was detected in one sample (DCFUST-3-4) at 71 µg/kg. TPH (gasoline range) was detected in four samples at levels ranging from 50 to 5,400 mg/kg. The detection of 50 mg/kg did not exhibit a chromatogram characteristic of gasoline contamination and may be attributable to other low-boiling hydrocarbons. TPH (diesel range) was detected in six samples from 13 to 5,100 mg/kg (Table 4-28). The locations of the soil borings are provided in Figure 4-19.

4.7.5 Former Substations

During the site investigations of the "Other Sites" at Fort Riley, soil samples were collected near the former substation owned by Kansas Power and Light located west of Building 180/181 in March 1994 (CEMRK, 1994i). The samples were analyzed for PCBs by U.S. EPA Method 8080. Five soil borings were installed in and around the former KPL laundry substation. Two samples were collected from each boring, one from the surface to a depth of 1 foot, and the second between 1 and 3 feet, using hand augers. One of 10 samples analyzed showed a detection of Aroclor-1254 at 60.6 μg/kg (Table 4-29). Samples collected at the KPL substation correspond to the following locations indicated on Figure 4-20: KPLSUB-2 (SB-1); KPLSUB-4 (SB-2); KPLSUB-5 and -6 (SB-3); KPLSUB-7 and -8 (SB-4); KPLSUB-9 and -10 (SB-5). Samples KPLSUB-6MS and -6MSD were collected for site-specific MS/MSD analyses but were inadvertently analyzed as record samples. Sample KPLSUB-9 was subsequently used for the MS/MSD analyses.

4.8 Summary and Conclusions

In the course of these investigations in the media sampled — soil, groundwater, surface water and sediment (from the tributaries) and other media which includes sewer sediment samples, one described as primarily lint, manhole debris and UST contents — the analytes determined can be categorized into five general classes after separating out the PCE and its breakdown products. These five categories are phthalates and common laboratory contaminants including toluene and acetone; polyaromatic hydrocarbons (PAHs); BTEX, benzene, toluene, ethylbenzene and xylenes; other non-specific analytes that include carbon disulfide, hexachloroethane, 2,6-dinitrotoluene, N-nitrosodi-n-dipropylamine, and 1,4-dichlorobenzene; and trihalomethanes (THMs). Figures 4-21 through 4-25 pictorially represent the detections of these compounds.

Based on the data presented, the following conclusions can be drawn regarding the extent of contamination. For the primary analyte associated with dry cleaning, PCE and its breakdown products, TCE, DCE and vinyl chloride, the details of its fate and transport, to be discussed in Chapter 5, are found in all media at specific sampling events.

The detection of THMs is limited generally to the sanitary and storm sewer waters, groundwater (in approximately 17 percent of the samples), and surface water (Figure 4-21). It is not uncommon to find THMs in potable water systems that undergo chlorination; therefore, the presence of THMs in the sewers that receive this water is not unexpected. Neither is it unexpected that THMs are present in surface waters and groundwater given the knowledge that sanitary and storm sewers leak. Either way, the frequency of detections for the limited number of surface water samples is still low. In groundwater, the frequency is lower still. A pictorial representation of cross media detection is shown in Figure 4-21.

Phthalates and common laboratory contaminants, acetone and toluene, have shown contaminant detection across all media (Figure 4-22). Phthalates are ubiquitous in environmental samples, due to their use as common plasticizers. The sporadic detections demonstrate the pervasiveness of these compounds, while demonstrating no link to site-related activities. A pictorial representation of cross media detection is shown in Figure 4-22.

BTEX compounds and PAHs were found inconsistently and relatively infrequently. As seen in Figures 4-23 and 4-24, the cross media representation of detections, no conclusion regarding a single source can be drawn. However, it is possible that the isolated detection of the PAHs can be attributable to the previous usage of Stoddard solvent or asphalt products such as roofing tars at the facility. As demonstrated by the analytical results from the USTs sampled, the analytical results reported as TPH (gasoline or diesel range) may, in fact, be mineral spirits or Stoddard solvents, since there was no reason for motor gasoline to have ever been at the facility. Therefore, detection of TPH (gasoline or diesel range) does not necessarily mean that gasoline or diesel was stored in the tanks. The most important consideration of this point for these chemical classes is, however, that both the infrequency, as well as the concentration found of these analytes, would support the conclusion that these compounds resulted from incidental spills, rather than an ongoing or more pervasive source. Additionally, the leaking sewers carrying discharge water from the washing machine, particularly those laundering rags from the Consolidated Maintenance Facility may have contributed compounds consistent with oils and similar products.

For the category identified as "other," the detections of carbon disulfide were limited to a one-time occurrence in a soil boring during the PA/SI, and a one-time occurrence in groundwater along with 1,4-dichlorobenzene. Three analytes were detected once in groundwater at one well during one sampling round. They were 2,6-dinitrotoluene, hexachloroethane, and N-nitrosodi-n-propylamine.

Acetone, which also was included in the common laboratory contaminants category, is included in the other category, as it has been documented (Micromedex, 1995) as forming as a result of the natural decay of humic materials. Two other analytes, 4-methylphenol and benzyl alcohol, were detected in either a sewer water sample or a seep at one single event. In all cases for non-PCE related analytes, the detections were infrequent, indicating that no widespread contamination from these compounds has occurred. The cross media detections of these other contaminants are presented in Figure 4-25.

TABLE 4-1
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS
Dry Cleaning Facilities Area
Fort Riley, Kansas
1992 PA/SI and 1993 RI

All results shown in μg/kg unless otherwise noted, expressed as dry weight.

Analyte/Depth or Interval (ft)	Tetra-chloro-ethylene	Tri-chloro-ethylene	Toluene	Carbon Disulfide	Dichloro-methane	2-Methyl-naphthalene	Phenanthrene	Bis(2-ethylhexyl) phthalate
DCFSB01A 10^{Δ}	ND(4.7)	ND(4.7)	ND(7.8)	ND(4.7)	28	ND(160)	ND(160)	ND(400)
DCFSB01B 5^{Δ}	ND(3.2)	ND(3.2)	ND(5.3)	ND(3.2)	33	ND(140)	ND(140)	ND(330)
DCFSB02A 10^{Δ}	ND(3.4)	ND(3.4)	ND(5.6)	ND(3.4)	24	ND(150)	ND(150)	ND(370)
DCFSB02B 15^{Δ}	ND(3.5)	ND(3.5)	ND(5.8)	ND(3.5)	23	ND(160)	ND(160)	ND(390)
DCFSB02C 19	ND(3.4)	ND(3.4)	ND(5.7)	ND(3.4)	24	ND(150)	ND(150)	ND(380)
DCSB03A* 10^{Δ}	32	ND(3.5)	ND(5.8)	ND(3.5)	64B	ND(160)	ND(160)	ND(390)
DCSB03B* 15^{Δ}	ND(3.3)	ND(3.3)	ND(5.6)	ND(3.3)	79B	ND(150)	ND(150)	ND(380)
DCSB04A* 10^{Δ}	7.0	ND(3.3)	ND(5.5)	9.2	130	ND(140)	ND(140)	ND(350)
DCSB04B* 15^{Δ}	ND(3.4)	4.2	ND(5.6)	ND(3.4)	100	ND(150)	ND(150)	ND(370)
DCSB04C* 15	ND(3.4)	ND(3.4)	ND(5.8)	ND(3.4)	56	ND(150)	ND(150)	ND(380)
DCSB05A* 10^{Δ}	ND(3.5)	ND(3.5)	ND(5.8)	ND(3.5)	41	ND(160)	ND(160)	ND(390)
DCSB05B* 15^{Δ}	ND(3.5)	ND(3.5)	ND(5.8)	ND(3.5)	46	ND(160)	ND(160)	ND(390)
DCSB06A* 10^{Δ}	ND(3.6)	ND(3.6)	ND(6.0)	ND(3.6)	39	ND(160)	ND(160)	ND(390)
DCSB06B* 15^{Δ}	ND(3.2)	ND(3.2)	ND(5.4)	ND(3.2)	37	ND(140)	ND(140)	ND(360)
DCSB07A* 10^{Δ}	29	ND(3.4)	ND(5.8)	ND(3.4)	36	ND(150)	ND(150)	380
DCSB07B* 15^{Δ}	3.7	ND(3.2)	ND(5.4)	ND(3.2)	27	ND(150)	ND(150)	460
DCSB08A* 5^{Δ}	ND(3.3)	ND(3.3)	ND(5.6)	ND(3.3)	33	ND(140)	ND(140)	ND(360)
DCSB08B* 8^{Δ}	ND(3.1)	ND(3.1)	ND(5.2)	ND(3.1)	27	ND(140)	ND(140)	ND(350)

TABLE 4-1 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS

Analyte/Depth or Interval (ft)	Tetra-chloro-ethylene	Tri-chloro-ethylene	Toluene	Carbon Disulfide	Dichloro-methane	2-Methyl-naphthalene	Phenanthrene	Bis(2-ethylhexyl) phthalate
DCFSB09A 10$^{\Delta}$	ND(4.5)	ND(4.5)	ND(7.4)	ND(4.5)	27	ND(150)	ND(150)	ND(370)
DCFSB09B 15$^{\Delta}$	ND(3.1)	ND(3.1)	ND(5.2)	ND(3.1)	22	ND(140)	ND(140)	ND(360)
DCFSB10A 10$^{\Delta}$	ND(3.8)	ND(3.8)	ND(6.4)	ND(3.8)	23	ND(170)	ND(170)	ND(430)
DCFSB10B 15$^{\Delta}$	ND(3.6)	ND(3.6)	ND(6.0)	ND(3.6)	25	ND(160)	ND(160)	ND(400)
DCFSB11A 10$^{\Delta}$	ND(3.4)	ND(3.4)	ND(5.6)	ND(3.4)	25B	ND(160)	ND(160)	ND(410)
DCFSB11B 15$^{\Delta}$	ND(4.4)	ND(4.4)	ND(7.4)	ND(4.4)	124	ND(140)	ND(140)	ND(360)
DCFSB12A 10$^{\Delta}$	ND(3.3)	ND(3.3)	ND(5.4)	ND(3.3)	48B	ND(150)	ND(150)	ND(370)
DCFSB12B 15$^{\Delta}$	ND(3.3)	ND(3.3)	ND(5.5)	ND(3.3)	51B	ND(150)	ND(150)	ND(370)
DCFSB13A 10$^{\Delta}$	180	ND(3.1)	5.9	ND(3.1)	98	ND(140)	ND(140)	ND(350)
DCFSB13B 15$^{\Delta}$	960	ND(14)	31	ND(14)	180	220	290	ND(360)
DCFSB14A 10$^{\Delta}$	5.5	ND(3.6)	ND(6.0)	ND(3.6)	37	ND(140)	ND(140)	ND(350)
DCFSB14B 15$^{\Delta}$	ND(3.2)	ND(3.2)	ND(5.2)	ND(3.2)	93	ND(170)	ND(170)	ND(430)
DCFSB15A 10$^{\Delta}$	ND(3.7)	ND(3.7)	ND(6.2)	ND(3.7)	40	ND(160)	ND(160)	ND(410)
DCFSB15B 15$^{\Delta}$	ND(3.6)	ND(3.6)	ND(6.0)	ND(3.6)	49	ND(160)	ND(160)	ND(400)
DCFSB-16 0-5	6.5	ND(5.7)	ND(5.7)	ND(5.7)	ND (5.7)	NA	NA	NA
DCFSB-16 20-25	ND(6.2)	ND(6.2)	ND(6.2)	ND(6.2)	ND(6.2)	NA	NA	NA
DCFSB-16 35-40	6.3	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	NA	NA	NA
DCFSB-17 0-5	ND(14)	ND(14)	ND(14)	ND(14)	ND(14)	NA	NA	NA
DCFSB-17 15-20	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-17 30-35	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	NA	NA	NA
DCFSB-18 0-5	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA

TABLE 4-1 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS

Analyte/Depth or Interval (ft)	Tetra-chloro-ethylene	Tri-chloro-ethylene	Toluene	Carbon Disulfide	Dichloro-methane	2-Methyl-naphthalene	Phenanthrene	Bis(2-ethylhexyl) phthalate
DCFSB-18 5-10	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-18 15-16.5	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-19 0-5.5	26	ND(14)	14	ND(14)	ND(14)	NA	NA	NA
DCFSB-19 10-15	180	ND(27)	ND(27)	ND(27)	ND(27)	NA	NA	NA
DCFSB-19 40-43	22	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA
DCFSB-20 0-5	65	ND(29)	ND(29)	ND(29)	ND(29)	ND(700)	ND(700)	ND(700)
DCFSB-20 15-20	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(700)	ND(700)	ND(700)
DCFSB-20 20-25	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(800)	ND(800)	ND(800)
DCFSB-21 0-5	25	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(800)	ND(800)	ND(800)
DCFSB-21 10-15	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	ND(800)	ND(800)	ND(800)
DCFSB-21 20-25	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(700)	ND(700)	ND(700)
DCFSB-22 0-5	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-22 10-15	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-22 20-25	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	ND(6.0)	NA	NA	NA
DCFSB-25 0-5	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-25 5-10	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	NA	NA	NA
DCFSB-25 10-11.5	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA
DCFSB-26 0-5	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-26 10-15	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA
DCFSB-26 15-18.5	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	NA	NA	NA
DCFSB-27 0-5	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA

TABLE 4-1 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS

Analyte/Depth or Interval (ft)	Tetra-chloro-ethylene	Tri-chloro-ethylene	Toluene	Carbon Disulfide	Dichloro-methane	2-Methyl-naphthalene	Phenanthrene	Bis(2-ethylhexyl) phthalate
DCFSB-27 10-15	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	NA	NA	NA
DCFSB-27 20-25	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA
DCFSB-28 0-5	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	NA	NA	NA
DCFSB-28 10-15	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	NA	NA	NA
DCFSB-28 20-23.5	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA
DCFSB-29 0-5	18	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA
DCFSB-29 5-10	ND(5.4)	ND(5.4)	ND(5.4)	ND(5.4)	ND(5.4)	NA	NA	NA
DCFSB-29 10-15	ND(5.3)	ND(5.3)	ND(5.3)	ND(5.3)	ND(5.3)	NA	NA	NA
DCFSB-30 0-5	8.1	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	NA	NA	NA
DCFSB-30 5-10	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	NA	NA	NA
DCFSB-30 15-20	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-31 0-5	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(800)	ND(800)	ND(800)
DCFSB-31 10-15	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(700)	ND(700)	ND(700)
DCFSB-31 20-24.5	ND(6.6)	ND(6.6)	ND(6.6)	ND(6.6)	ND(6.6)	ND(900)	ND(900)	ND(900)
DCFSB-32 0-5	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(700)	ND(700)	ND(700)
DCFSB-32 5-10	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(5.7)	ND(800)	ND(800)	ND(800)
DCFSB-32 15-20	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	ND(800)	ND(800)	ND(800)
DCFSB-33 0-5	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA
DCFSB-33 5-10	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	NA	NA	NA
DCFSB-33 10-15	ND(5.5)	ND(5.5)	ND(5.5)	ND(5.5)	ND(5.5)	NA	NA	NA
DCFSB-34 0-3	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	ND(5.6)	NA	NA	NA

TABLE 4-1 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM SOIL BORINGS

Analyte/Depth or Interval (ft)	Tetra-chloro-ethylene	Tri-chloro-ethylene	Toluene	Carbon Disulfide	Dichloro-methane	2-Methyl-naphthalene	Phenanthrene	Bis(2-ethylhexyl) phthalate
DCFSB-35 0-4	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	NA	NA	NA
DCFSB-35 4-8	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	ND(5.9)	NA	NA	NA
DCFSB-36 1.5-5	ND(5.2)	ND(5.2)	ND(5.2)	ND(5.2)	ND(5.2)	NA	NA	NA
DCFSB-36 5-10	ND(5.3)	ND(5.3)	ND(5.3)	ND(5.3)	ND(5.3)	NA	NA	NA
DCFSB-36 10-12	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	ND(5.8)	NA	NA	NA

<u>Notes</u>:

NA	Not Analyzed.
ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
Δ	1992 PA/SI data depicted as received. Samples are DCFSB-16 through 36 collected November 1993, during the RI.
*	Indicates identification code from CEMRK (1992b); soils taken from shallow borings where the F was not used as an identifier.

This table, above double line, contains data from the 1992 PA/SI (CEMRK, 1992b) and has been modified to be consistent with other tables produced for this document. RI Reference CEMRK (1994b,e) for samples collected in 1993.

TABLE 4-2
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM MONITORING WELL BORINGS
Dry Cleaning Facilities Area
Fort Riley, Kansas
1992 PA/SI
Sampling March and April 1992

All results shown in μg/kg unless otherwise noted, expressed as dry weight.

Analyte/Depth or Interval (ft)		Tetra-chloro-ethylene	Toluene	Dichloro methane	Phenanthrene	Benzo(a) anthracene	Pyrene	Benzo(a) pyrene	Chrysene	Fluoranthene	Bis(2-ethyl hexyl)phthalate
DCF92SB01A	1	ND(3.4)	ND(5.7)	68	ND(150)	ND(110)	110	ND(270)	ND(110)	ND(150)	ND(380)
DCF92SB01B	6	ND(3.4)	ND(5.8)	60	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF92SB01C	14	ND(3.2)	ND(5.4)	61	ND(160)	ND(120)	ND(120)	ND(270)	ND(120)	ND(160)	ND(390)
DCF92SB01D	UKN	ND(3.5)	ND(5.8)	56	ND(160)	ND(120)	ND(120)	ND(290)	ND(120)	ND(160)	ND(410)
DCF92SB01E	27	ND(3.3)	5.8	50	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF9202A	4	9.1	ND(5.0)	43	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF9202B	9	10	ND(5.6)	40	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF9202C	19	53	ND(5.8)	44	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF9202D	24	ND(3.1)	ND(5.1)	31	NA	NA	NA	NA	NA	NA	NA
DCF9202E	9	4.5	ND(5.6)	44	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
D9202E	29	ND(4.2)	ND(7.1)	35	ND(140)	ND(120)	ND(120)	ND(260)	ND(120)	ND(140)	ND(370)
DC9203A	4	110*	7.4*	34*	610	380	530	270	300	610	ND(380)
DC9203B	9	38*	ND(5.5)*	26*	ND(140)	ND(110)	ND(110)	ND(250)	ND(110)	ND(140)	ND(360)
DC9203C	14	15	ND(6.2)	30	ND(160)	ND(120)	ND(120)	ND(290)	ND(120)	ND(160)	ND(410)
DC9203D	UKN	ND(3.4)	ND(5.8)	25	NA	NA	NA	NA	NA	NA	NA
DC9203E	24	ND(3.8)	ND(6.4)	37	ND(160)	ND(120)	ND(120)	ND(280)	ND(120)	ND(160)	ND(400)
DC9203F	29	7.2	ND(6.1)	32	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF92SB03E	35	44	ND(5.8)	25	ND(160)	ND(120)	ND(120)	ND(260)	ND(120)	ND(160)	ND(380)
DC92SB04A	3	ND(3.4)	ND(5.6)	89	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)

TABLE 4- ONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM MONITORING WELL BORINGS

Analyte/Depth or Interval (ft)		Tetra-chloro-ethylene	Toluene	Dichloro methane	Phenanthrene	Benzo(a) anthracene	Pyrene	Benzo(a) pyrene	Chrysene	Fluoranthene	Bis(2-ethyl hexyl)phthalate
DCF92SB05A	9	ND(3.3)	ND(5.5)	26	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF92SB05B	10	ND(3.1)	ND(5.2)	22	ND(140)	ND(100)	ND(100)	ND(240)	ND(100)	ND(140)	ND(340)
DCF92SB05C	24	ND(3.2)	ND(5.4)	24	ND(150)	ND(110)	ND(110)	ND(260)	ND(110)	ND(150)	ND(370)
DCF92SB05D	UKN	ND(3.4)	ND(5.6)	65	NA	NA	NA	NA	NA	NA	NA
DCFSB05E	35	21	ND(7.1)	31	ND(180)	ND(120)	ND(120)	ND(300)	ND(120)	ND(180)	ND(430)
DCF9206A	4	ND(3.3)	ND(5.6)	37	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)
DCF9206B	9	ND(3.4)	ND(5.8)	46	ND(150)	ND(110)	ND(110)	ND(270)	ND(110)	ND(150)	2,400
DCF9206C	19	ND(3.1)	ND(5.2)	32	ND(140)	ND(100)	ND(100)	ND(240)	ND(100)	ND(140)	ND(340)
DCF9206D	UKN	ND(4.1)	ND(6.9)	55	NA	NA	NA	NA	NA	NA	NA
DC92SB06E	28	ND(3.4)	ND95.60	50	ND(150)	ND9110)	ND(110)	ND(270)	ND(110)	ND(150)	ND(380)

Notes:

UKN	Unknown.
NA	Not Analyzed.
ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
*	Re-analysis result reported. In original analysis of sample DCF9203A, 1,1,2-trichloroethane was detected at 8.6 μg/kg, and dibromochloromethane was detected at 190 μg/kg.

This table was adapted from CEMRK (1992c). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-3
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM MONITORING WELL BORINGS
Dry Cleaning Facilities Area
Fort Riley, Kansas
November 1993

All results shown in μg/kg unless otherwise noted, expressed as dry weight.

Analyte/Depth or Interval (ft)	TOC (mg/kg)	Tetrachloroethylene	Trichloroethylene	Toluene
DCF93-08 0-5	13,600	ND(5.6)	ND(5.6)	ND(5.6)
DCF93-12 0-5	NA	ND(5.4)	ND(5.4)	ND(5.4)
DCF93-12 5-10	1,850	ND(5.6)	ND(5.6)	ND(5.6)
DCF93-13 0-5	15,400	ND(15)	ND(15)	ND(15)
DCF93-13 20-25	3,050	ND(6.0)	ND(6.0)	ND(6.0)
DCF93-13 35-40	1,040	27	ND(6.1)	ND(6.1)
DCF93-13 40-42	53,100	58	7.8	ND(5.8)
DCF93-14 0-5	2,910	ND(5.7)	ND(5.7)	ND(5.7)
DCF93-14 5-10	13,800	ND(6.8)	ND(6.8)	ND(6.8)
DCF93-15 0-5	2,790	12	ND(5.8)	5.8
DCF93-15 5-10	NA	ND(5.6)	ND(5.6)	ND(5.6)
DCF93-15 10-15	NA	ND(5.4)	ND(5.4)	ND(5.4)
DCF93-15 15-20	1,120	ND(5.7)	ND(5.7)	ND(5.7)
DCF93-16 0-5	5,770	ND(5.6)	ND(5.6)	ND(5.6)
DCF93-16 5-10	1,540	ND(5.8)	ND(5.8)	ND(5.8)
DCF93-19 0-5	4,480	ND(5.6)	ND(5.6)	ND(5.6)
DCF93-19 5-10	1,010	ND(5.5)	ND(5.5)	ND(5.5)
DCF93-20 0-5	11,500	ND(5.6)	ND(5.6)	17
DCF93-20 5-10	3,020	ND(5.5)	ND(5.5)	ND(5.5)

Notes:

TOC	Total Organic Carbon.
ND	Not Detected.
NA	Not Analyzed.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

For a complete list of analytes, see Appendix D.
This table contains data from CEMRK (1994b,e).

TABLE 4-4
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
December 1993

Well No.	Trichloro ethylene	Trichloro methane	Benzene	Tetrachloro ethylene	1,2-Dichloro ethylene	Vinyl Chloride	Ethyl benzene	Bis(2-ethylhexyl)phthalate
DCF92-01	ND(0.6)	1.1B	ND(0.4)	ND(1.1)	ND(0.5)	ND(0.8)	ND(0.7)	ND(10)
DCF92-02	ND(3.0)	ND(2.5)	ND(2.0)	38	ND(2.5)	ND(4.0)	ND(3.5)	ND(10)
DCF92-03	ND(30)	36	ND(20)	820	ND(25)	ND(40)	ND(35)	ND(10)
DCF92-04	1.7	ND(0.5)	0.5	ND(1.1)	27	42	1.1	ND(10)
DCF92-05	ND(30)	29	ND(20)	710	ND(25)	ND(40)	ND(35)	ND(10)
DCF92-06	ND(0.6)	0.9B	ND(0.4)	ND(1.1)	ND(0.5)	ND(0.8)	ND(0.7)	ND(10)
DCF93-08	16	ND(2.5)	ND(2.0)	ND(5.5)	77	54	ND(3.5)	ND(10)
DCF93-09	10	ND(2.5)	ND(2.0)	64	68	ND(4.0)	ND(3.5)	44^{a}
DCF93-10	0.8	ND(0.5)	ND(0.4)	ND(1.1)	8.1	ND(0.8)	ND(0.7)	ND(10)
DCF93-11	20	ND(2.5)	ND(2.0)	42	110	ND(4.0)	ND(3.5)	15^{a}
DCF93-12	3.8	6.0B	ND(0.4)	32	30	ND(0.8)	ND(0.7)	ND(10)
DCF93-13	140	ND(25)	ND(20)	420	ND(25)	ND(40)	ND(35)	ND(10)
DCF93-15	ND(30)	30	ND(20)	490	ND(25)	ND(40)	ND(35)	ND(10)
DCF93-16	ND(15)	ND(13)	ND(10)	200	ND(13)	ND(20)	ND(18)	ND(10)
DCF93-19	3.3	ND(2.5)	ND(2.0)	ND(5.5)	54	15	ND(3.5)	ND(10)
DCF93-20	9.2	ND(2.5)	ND(2.0)	29	36	ND(4.0)	ND(3.5)	ND(10)

<u>Notes</u>:

ND	Not Detected.
B	Reported concentration is within 10× that detected in the associated field and trip blanks. Results have not been blank corrected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

Wells 93-14, 17, and 18 were not sampled; wells were dry.
For a complete list of analytes, see Appendix D.

This table contains data from CEMRK (1994d,e).

TABLE 4-5
SUMMARY OF CHEMICAL DETECTIONS OF SOIL BORINGS FOR THE PILOT TEST STUDY
Dry Cleaning Facilities Area
Fort Riley, Kansas
May and October 1994

All results are shown in μg/kg unless otherwise noted, expressed as dry weight.

Well No.	Dichloromethane	Tetrachloroethylene	1,2-Dichloroethane	Trichloroethylene
DCF94-B1-1 May 1994	ND (6.0)	17	ND (6.0)	ND (6.0)
DCF94-B1-2 May 1994	ND (6.3)	16	ND (6.3)	ND (6.3)
DCF94-B2-3 May 1994	13	ND (5.4)	ND (5.4)	ND (5.4)
DCF94-B3-1 May 1994	ND (6.0)	130	ND (6.0)	ND (6.0)
DCF94-B3-2 May 1994	ND (6.1)	7.2	ND (6.1)	ND (6.1)
DCF94-B3-3 May 1994	10	ND (6.0)	ND (6.0)	ND (6.0)
DCF94-B6-2 October 1994	ND (1.2)	62	ND (1.2)	ND (1.2)
DCF94-B6-3 October 1994	ND (1.2)	6.8	ND (1.2)	ND (1.2)
DCF94-B5-2 October 1994	ND (1.2)	4.5	ND (1.2)	ND (1.2)
DCF94-B5-3 October 1994	ND (1.3)	16	3.4	4.7
DCF94-B5-4 October 1994	ND (1.1)	1.8	ND (1.1)	ND (1.1)
DCF94-B4-2 October 1994	ND (1.3)	22	ND (1.3)	ND (1.3)
DCF94-B4-3 October 1994	ND (1.2)	100	ND (1.2)	ND (1.2)
DCF94-B4-4 October 1994	ND (1.1)	9.8	ND (1.1)	ND (1.1)

<u>Notes</u>:

ND Not Detected.

( ) Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

For a complete list of analytes, see Appendix D-II.

TABLE 4-6
SUMMARY OF CHEMICAL DETECTIONS FOR SEDIMENT SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
March 1992 and February 1993

All results shown in μg/kg unless otherwise noted, expressed as dry weight.

Parameter Date Collected	DCSD01 March 1992	DCSD02 March 1992	DCSD03 March 1992	DCFSD08 Feb. 1993	DCFSD09 Feb. 1993
VOLATILE ORGANICS:					
Acetone	ND(130)	ND(120)	ND(120)	1800J	2100J
Dichloromethane	84B	80B	80B	1100	140B
Tetrachloroethylene	ND(6.3)	6.6	ND(3.6)	ND(4.2)	ND(4.2)
SEMIVOLATILE ORGANICS:					
Pyrene	ND(780)	ND(120)	120	ND(190)	ND(190)

Notes:

ND	Not Detected.
B	Compound detected in sample result is less than 10× the amount detected in the method blank. Result is estimated.
J	Estimated result; quantitation uncertain due to a 1000× dilution factor.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

This table was adapted from CEMRK (1992b; 1993e). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-7
SUMMARY OF CHEMICAL DETECTIONS FOR SURFACE WATER AND SEEP SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
July 1992 and January 1995

All results shown in μg/l unless otherwise noted.

Parameter Date Collected	DCSW01 March 1992	DCSW02 March 1992	DCSW03 March 1992	DCFSW-18 Jan. 1995	DCFSW-19 Jan. 1995	DCFSW-20 Jan. 1995	DSFWS-23 Jan. 1995	DCFSW-27 Jan. 1995	DCFSW-24* Jan. 1995	DCFSW-26* Jan. 1995
VOLATILE ORGANICS:										
Acetone	ND (100)	ND (100)	ND (100)	ND (100)	ND (100)	ND (100)	ND (100)	ND (100)	180	ND (100)
Bromodichloromethane	ND (1.0)	ND (1.0)	ND (1.0)	5.8	0.9	0.5	ND (0.5)	ND (0.5)	4.3	ND (0.5)
Dibromochloromethane	ND (1.0)	ND (2.0)	ND (2.0)	6.7	1.4	ND (0.7)	1.2	2.0	6.1	ND (0.7)
Dichloromethane	22J	21J	20J	ND (0.9)	ND (0.9)	ND (0.9)	ND (0.9)	ND (0.9)	ND (0.9)	ND (0.9)
Tetrachloroethylene	ND (3.0)	4.5	ND (3.0)	ND (1.1)	ND (1.1)	ND (1.1)	ND (1.1)	ND (1.1)	1.4	17
Tribromomethane	ND (5.0)	ND (5.0)	ND (5.0)	4.6	ND (1.5)	ND (1.5)	ND (1.5)	1.6	3.8	ND (1.5)
Trichloromethane	ND (1.0)	ND (1.0)	ND (1.0)	5.1	13	7.4	3.1	27	13	0.6
SEMIVOLATILE ORGANICS:										
Benzyl alcohol	ND (6.0)	ND (6.0)	ND (6.0)	ND (20)	ND (20)	ND (20)	ND (20)	ND (20)	37	ND (20)
Bis(2-ethylhexyl)phthalate	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	34	11	69	71	ND (10)
Butylbenzylphthalate	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	18	ND (10)
Di-N-octylphthalate	ND (10)	ND (10)	ND (10)	ND (10)	ND (10)	19	ND (10)	ND (10)	ND (10)	ND (10)

Notes:

ND Not Detected.

J Sample quantitation is estimated.

( ) Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

* Seep sample.

This table was adapted from CEMRK (1992b; 1993a) and contains data from CEMRK (1995b). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-8
SUMMARY OF CHEMICAL DETECTIONS FOR SANITARY SEWER WATER AND SEWER SEDIMENT[a] SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
November 1992 and February 1993

All results are shown in μg/l unless otherwise noted.

Parameter	DCFSSW01 February 1993	DCFSSW02 February 1993	DCFSSW04 February 1993	DCFSSW05 February 1993	DCFSSW06 February 1993	DCFSSW07 February 1993	DCFSD06[a] November 1992
VOLATILE ORGANICS:							
Acetone	60	50	50	140	110	140	ND(200,000)
Bromodichloromethane	1.2	3.1	3.9	ND(1.0)	2.3	ND(1.0)	ND(10,000)
1,2-Dichloroethylene	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	160,000J
Trichloromethane	1.7	8.3	6	ND(1.0)	3.2	ND(1.0)	ND(6,100)
Dibromochloromethane	2.0	3.0	3.7	ND(2.0)	3	ND(2.0)	ND(10,000)
Dichloromethane	ND(1.0)	ND(1.0)	ND(1.0)	18B1	11B1	18B1	26,000J
Tetrachloroethylene	ND(2.5)	21	4.5	ND(2.5)	ND(2.5)	ND(2.5)	470,000J
Toluene	ND(1.5)	1.6	ND(1.5)	ND(1.5)	6.5	ND(1.5)	ND(10,000)
Xylenes (total)	ND(4.0)	6.0	ND(4.0)	ND(4.0)	ND(4.0)	ND(4.0)	ND(10,000)
Trichloroethylene	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	ND(1.0)	15,000J
SEMIVOLATILE ORGANICS:							
2-Methylnaphthalene	46	25	8.2	ND(4.0)	ND(20)	NS	ND(2,700)
4-Methylphenol	ND(10)	ND(12)	ND(10)	ND(5.0)	ND(25)	NS	5,800
Acenaphthene	5.0	ND(5.0)	ND(4.0)	ND(2.0)	ND(10)	NS	ND(3,400)
Di-n-butylphthalate	10	ND(12)	ND(10)	ND(5.0)	ND(25)	NS	ND(6,700)

TABLE 4-8 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS FOR SANITARY SEWER WATER AND SEWER SEDIMENT[▲] SAMPLES

Parameter	DCFSSW01 February 1993	DCFSSW02 February 1993	DCFSSW04 February 1993	DCFSSW05 February 1993	DCFSSW06 February 1993	DCFSSW07 February 1993	DCFSD06[a] November 1992
Di-n-octylphthalate	8.6	ND(10)	ND(8.0)	ND(4.0)	ND(20)	NS	ND(6,700)
Naphthalene	20	11	ND(6.0)	ND(3.0)	ND(15)	NS	ND(2,000)
Phenanthrene	20	7.5	ND(4.0)	ND(2.0)	ND(10)	NS	ND(2,700)
Butylbenzylphthalate	ND(7.5)	ND(6.0)	ND(6.0)	ND(3.0)	ND(15)	NS	11,000
Bis(2-ethylhexyl)phthalate	120	60	30	ND(6.0)	ND(30)	NS	55,000

<u>Notes</u>:

NS	Not Sampled.
ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
B1	Sample results are less than 5× the amount detected in the method bank. Result is estimated.
J	Estimated result; quantitation uncertain due to a 1000× dilution factor.
a	Units are μg/kg.
▲	This sewer sediment sample has been described as containing primarily lint.

This table was adapted from CEMRK (1993a,b). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-9
SUMMARY OF CHEMICAL DETECTIONS FOR STORM SEWER WATER AND SEWER SEDIMENT[▴] SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
November 1992 and February 1993

All results are shown in µg/l unless otherwise noted.

Parameter Date Collected	DCFSTW01 February 1993	DCFSTW02 February 1993	DCFSTW03 February 1993	DCFSW05 November 1992	DCFSD05[a] November 1992
VOLATILE ORGANICS:					
Dichloroethylene	ND(5.0)	ND(5.0)	ND(5.0)	ND(5.0)	42
Dichloromethane	19	20	20	5.6B	22B
Tetrachloroethylene	6.7	26	3.7	19	100J
Trichloroethylene	ND (1.0)	ND (1.0)	ND (1.0)	ND (3.0)	55
Bromodichloromethane	3.3	4.4	6.3	5.3	ND (6.3)
Trichloromethane	3.7	5.7	7.5	4.4	ND (3.8)
Dibromochloromethane	4.6	4.7	6.7	5.1	ND (6.3)
Tribromomethane	2.4	ND (2.0)	3.0	ND (5.0)	ND (6.3)
SEMIVOLATILE ORGANICS:					
4-Methylphenol	ND (5.0)	ND (5.0)	ND (5.0)	ND (7.0)	ND (320)
Benzo(a)anthracene	ND (2.0)	ND (2.0)	ND (2.0)	ND (3.0)	140
Chrysene	ND (3.0)	ND (3.0)	ND (3.0)	ND (3.0)	160
Fluoranthene	ND (3.0)	ND (3.0)	ND (3.0)	ND (4.0)	210
Pyrene	ND (6.0)	ND (6.0)	ND (6.0)	ND (3.0)	260
Bis(2-ethylhexyl)phthalate	ND (4.0)	ND (4.0)	ND (4.0)	13	1900

Notes:

ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
a	Results are µg/kg.
▴	No further description of this sewer sediment sample was made.

This table was adapted from CEMRK (1993a,b). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-10
SUMMARY OF CHEMICAL DETECTIONS
WATER SAMPLES FROM DRY CLEANING MACHINES
Dry Cleaning Facilities Area
Fort Riley, Kansas
April 1993

All results shown in μg/l unless otherwise noted.

Parameter	DCFDCME02	DCFDCMW01	DCFWBUC01	DCFEBUC02
VOLATILE ORGANICS:				
Bromodichloromethane	16	15	ND(100)	ND(100)
Tribromomethane	5.5	5.2	ND(200)	ND(200)
Trichloromethane	9.3	9.1	ND(100)	ND(100)
Dibromochloromethane	17	16	ND(200)	ND(200)
Tetrachloroethylene	3.2	29	5100J	4400J

Notes:

ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
J	Sample quantitation is estimated.

This table was adapted from CEMRK (1993d). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-11
ANALYTICAL LABORATORY REPORT FOR EFFLUENT FROM WASHING MACHINE USED FOR LAUNDERING RAGS FROM BUILDING 8100

Dry Cleaning Facilities Area
Fort Riley, Kansas
January 1994

Units as indicated.

SAMPLE IDENTIFICATION	**9401-78**
VOLATILE ORGANICS (μg/l)	
Toluene	900
Ethylbenzene	13,200
pH	6.1
FLASH POINT	126°F
TCLP METALS (mg/l)	
Arsenic	0.1
Barium	2.5

Source: KDPS, 1994.

TABLE 4-12
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
July 1992

All results shown in μg/l unless otherwise noted.

Parameter	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
VOLATILE ORGANICS:						
1,2-Dichloroethylene	ND(5.0)J	ND(5.0)	5.5	5	69	ND(5.0)
Tetrachloroethylene	ND(3.0)J	660	80	9.3	160	ND(3.0)
Trichloroethylene	ND(3.0)J	ND(3.0)	6.8	ND(3.0)	33	ND(3.0)
Vinyl chloride	ND(2.0)J	ND(2.0)	ND(2.0)	11	ND(2.0)	ND(2.0)
Dichloromethane	5.0J	130B	13	ND(5.0)	14B	ND(5.0)
SEMIVOLATILE ORGANICS:						
Naphthalene	ND(3.0)J	ND(3.0)	ND(3.0)	7	ND(3.0)	ND(3.0)
TPHC[1]	NA	NA	NA	243	NA	NA

Notes:

ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
B	Compound detected in sample result is less than 10× the amount detected in the method blank. Result is estimated.
J	Sample quantitation is estimated.
1	Modified EPA 8015 for fuel identification; reported as highly weathered gasoline or mineral spirits (Stoddard solvent).

This table was adapted from CEMRK (1992a,b). The format has been modified to be consistent with other tables produced in this document.

TABLE 4-13
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
November 1992

All results shown in μg/l unless otherwise noted.

Parameter	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
VOLATILE ORGANICS:						
1,2-Dichloroethylene (total)	ND(5.0)	ND(5.0)	12	35	51	ND(5.0)
Dichloromethane	ND(5.0)	5.4B	ND(5.0)	5.0B	ND(5.0)	ND(5.0)
Tetrachloroethylene	ND(3.0)	360	190	3.7	95	ND(3.0)
Trichloroethylene	ND(3.0)	ND(3.0)	13	ND(3.0)	19	ND(3.0)
Vinyl Chloride	ND(10)	ND(10)	ND(10)	6.8J	ND(10)	ND(10)
SEMIVOLATILE ORGANICS:						
2,6-Dinitrotoluene	ND(7.0)	ND(7.0)	ND(7.0)	12J	ND(7.0)	ND(7.0)
Hexachloroethane	ND(7.0)	ND(7.0)	ND(7.0)	43J	ND(7.0)	ND(7.0)
N-Nitrosodi-n-propylamine	ND(6.0)	ND(6.0)	ND(6.0)	38J	ND(6.0)	ND(6.0)
Naphthalene	ND(3.0)	ND(3.0)	ND(3.0)	5.4	ND(3.0)	ND(3.0)
Bis(2-ethylhexyl)phthalate	ND(10.0)	ND(10.0)	ND(10.0)	10	ND(10.0)	ND(10.0)
TOTAL RECOVERABLE METALS:						
Iron	170	120	ND(50)	2,300	140	120
Magnesium	37,000	44,000	36,000	39,000	26,000	40,000
Manganese	36	34	34	990	33	34

TABLE 4-15 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Parameter	DCF9201	DCF9202	DCF9203	DCF9204	DCF9205	DCF9206
WET CHEMICAL INORGANICS (mg/l):						
Total Suspended Solids	5.00	2.00	1.00	5.00	8.00	8.00
Ammonia (N)	ND(0.10)	ND(0.10)	ND(0.10)	0.11	ND(0.10)	ND(0.10)
Total Organic Carbon	ND(2.0)	ND(2.0)	2.00	2.90	2.00	ND(2.0)
Hardness as $CaCO_3$	624.00	652.00	640.00	520.00	524.00	628.00
Alkalinity as $CaCO_3$	410.00	367.00	418.00	394.00	390.00	412.00
Total Kjeldahl Nitrogen	ND(1.00J)	ND(1.00J)	ND(1.00J)	ND(1.00J)	ND(1.00J)	ND(1.00J)
Chemical Oxygen Demand	ND(10.00)	ND(10.00)	ND(10.00)	11.30	ND(10.00)	ND(10.00)
Biochemical Oxygen Demand	ND(10.00)	ND(10.00)	ND(10.00)	ND(10.00)	ND(10.00)	ND(10.00)

Notes:

ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
B	Compound detected in sample result is less than 10× the amount detected in the method blank. Result is estimated.
J	Sample quantitation is estimated.

This table was adapted from CEMRK (1993a). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-14
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
February 1993

All results shown in μg/l unless otherwise noted.

Parameter	DCF92-01	DCF92-02	DCF92-03	DCF92-04	DCF92-05	DCF92-06
VOLATILE ORGANICS (METHOD 8260):						
1,2-Dichloroethylene (total)	ND(5.0)	ND(5.0)	9.1	24	33	ND(5.0)
Tetrachloroethylene	ND(2.5)	470	160	ND(2.5)	72	ND(2.5)
Toluene	ND(1.5)	ND(1.5)	ND(1.5)	ND(1.5)	26	ND(1.5)
Trichloroethylene	ND(1.0)	ND(1.0)	11	ND(1.0)	14	ND(1.0)
TOTAL RECOVERABLE METALS:						
Iron	NA	NA	NA	2800	NA	NA
Magnesium	NA	NA	NA	33000	NA	NA
Manganese	NA	NA	NA	830	NA	NA

Notes:

NA	Not Analyzed.
ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

This table was adapted from CEMRK (1993b). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-15
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
May 1993

All results shown in μg/l unless otherwise noted.

Parameter	DCF92-01	DCF92-02	DCF92-03	DCF92-04	DCF92-05	DCF92-06
VOLATILE ORGANICS (METHOD 8260):						
1,2-Dichloroethylene (total)	ND(5.0)	ND(5.0)	ND(5.0)	21	15	ND(5.0)
Tetrachloroethylene	ND(2.5)	240	410	ND(2.5)	140	ND(2.5)
Vinyl chloride	ND(2.0)	ND(2.0)	ND(2.0)	22	ND(2.0)	ND(2.0)
Trichloroethylene	ND(1.0)	ND(1.0)	12	ND(1.0)	14	ND(1.0)
SEMIVOLATILE ORGANICS:						
Napthalene	ND(3.0)	ND(3.0)	ND(3.0)	6.7	ND(3.0)	ND(3.0)

Notes:

NA	Not Analyzed.
ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

This table was adapted from CEMRK (1993e). The format has been modified to be consistent with other tables produced for this document.

TABLE 4-16
COMPARISON OF ANALYTES BEFORE AND AFTER UTILIZATION OF AIR DRILLING METHODS
Dry Cleaning Facilities Area
Fort Riley, Kansas
November and December 1993

All results are shown in μg/l unless otherwise noted.

Parameter	DCF92-01		DCF92-02		DCF92-03		DCF92-04		DCF92-05		DCF92-06	
Date	Nov. 1993	Dec. 1993	Nov. 1993	Dec. 1993	Nov. 1993	Dec. 1993	Nov. 1993	Dec. 1993	Nov. 1993	Dec. 1993	Nov. 1993	Dec. 1993
1,2-Dichloro-ethylene (total)	ND(0.5)	ND(0.5)	ND(0.5)	ND(2.5)	ND(25)	ND(25)	18	27	ND(25)	ND(25)	ND(0.5)	ND(0.5)
Trichloro-ethylene	ND(0.6)	ND(0.6)	ND(0.6)	ND(3.0)	ND(30)	ND(30)	2.8	1.7	ND(30)	ND(30)	ND(0.6)	ND(0.6)
Tetrachloro-ethylene	ND(1.1)	ND(1.1)	32	38	820	820	ND(1.1)	ND(1.1)	430	710	ND(1.1)	ND(1.1)
Vinyl chloride	ND(0.8)	ND(0.8)	ND(0.8)	ND(4.0)	ND(40)	ND(40)	40	42	ND(40)	ND(40)	ND(0.8)	ND(0.8)
Benzene	ND(0.4)	ND(0.4)	ND(0.4)	ND(2.0)	ND(20	ND(20)	(0.5)	0.5	ND(20)	ND(20)	ND(0.4)	ND(0.4)
Ethylbenzene	ND(0.7)	ND(0.7)	ND(0.7)	ND(3.5)	ND(35)	ND(35)	ND(0.7)	1.1	ND(35)	ND(35)	ND(0.7)	ND(0.7)
Trichloro-methane	ND(0.5)	ND(0.5)	ND(0.5)	ND(2.5)	36	36	ND(0.5)	ND(0.5)	ND(25)	ND(25)	ND(0.5)	0.9B

Notes:

( ) Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
For a complete list of analytes, see Appendix D.

This table contains data from CEMRK (1994a,d,e).

TABLE 4-17
SUMMARY OF CHEMICAL DETECTIONS OF SOILS FROM UST REMOVAL
Dry Cleaning Facilities Area
Fort Riley, Kansas
July 1994

All results shown in μg/kg unless otherwise noted, expressed as dry weight.

Sample Number	VOCs			SVOCs		Gasoline Fraction (mg/kg)	Diesel Fraction (mg/kg)
	Toluene	Xylenes	TICs	Bis(2-ethylhexyl)phthalate	TICs		
001	ND(1.2)	BD(0.35)	28J	428	ND	1,170	37*
002	ND(1.2)	ND(0.35)	8,000J	1,160	61,700J	1,260	471
003	15.3	6.7	ND	1,080	ND	ND(0.05)	10.2
004	ND(1.2)	ND(0.35)	ND	440	ND	ND(0.05)	ND(10.0)
005	ND(1.2)	ND(0.35)	ND	4,610	ND	0.24	30.8*
006	ND(1.2)	ND(0.35)	ND	2,270	ND	ND(0.05)	ND(10.0)

<u>Notes</u>:

ND	Not Detected.
*	This sample contains a later eluting oil calculated as diesel.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

All samples were analyzed for Tentatively Identified Compounds (TICs) by EPA Methods 8240 and 8270.

This table was adapted from CEMRO (1994b) and has been modified to be consistent with other tables produced for this document.

TABLE 4-18
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
January 1995

All results shown in μg/l unless otherwise noted.

Well No.	Volatiles										Semivolatiles						Inorganic
	1,2-Dichloro ethylene	Dichloro methane	Tetra chloro ethylene	Toluene	Trichloro ethylene	Vinyl Chloride	Trichloro methane	Benzene	Carbon Disulfide	Ethyl benzene	Bis (2-ethyl hexyl) phthalate	2,6-Dinitro toluene	Hexachloro ethane	Naph thalene	N-nitro sodi-n-propylamine	1,4-di chloro benzene	Sulfate (mg/l)
DCF92-01																	
7/92	ND(5.0)	5.0	ND(3.0)	ND(5.0)	ND(3.0)	ND(10)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
11/92	ND(5.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(3.0)	ND(10)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
2/93	ND(5.0)	ND(10)	ND(2.5)	ND(1.5)	ND(1.0)	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
5/93	ND(5.0)	11	ND(2.5)	ND(1.5)	ND(1.0)	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
11/93	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
12/93	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	1.1B	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
2/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
DCF92-02																	
7/92	ND(5.0)	130B	660	ND(5.0)	ND(3.0)	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
11/92	ND(5.0)	5.4B	360	ND(5.0)	ND(3.0)	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
2/93	ND(5.0)	ND(10)	470	ND(1.5)	ND(1.0)	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
5/93	ND(5.0)	ND(10)	240	ND(1.5)	ND(1.0)	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
11/93	ND(0.5)	ND(0.9)	32	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
12/93	ND(2.5)	ND(4.5)	38	ND(2.0)	ND(3.0)	ND(4.0)	ND(2.5)	ND(2.0)	ND(25)	ND(3.5)	NA	NA	NA	NA	NA	NA	NA
2/94	ND(5.0)	ND(9.0)	86	ND(4.0)	ND(6.0)	ND(8.0)	ND(5.0)	ND(4.0)	ND(50)	ND(7.0)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	ND(0.5)	ND(0.9)	64	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	ND(0.5)	ND(0.9)	84	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	ND(0.5)	1.3B	77	ND(0.4)	ND(0.6)	ND(0.8)	8.9	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
DCF92-03																	
7/92	5.5	13.0	80	ND(5.0)	6.8	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
11/92	12	ND(5.0)	190	ND(5.0)	13	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
2/93	9.1	ND(10)	160	ND(1.5)	11	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
5/93	ND(5.0)	ND(10)	410	ND(1.5)	12	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
11/93	ND(25)	ND(45)	1600	ND(20)	ND(30)	ND(40)	ND(25)	ND(20)	ND(250)	ND(35)	NA	NA	NA	NA	NA	NA	NA
12/93	ND(25)	ND(45)	820	ND(20)	ND(30)	ND(40)	36	ND(20)	ND(250)	ND(35)	NA	NA	NA	NA	NA	NA	NA
2/94	ND(5.0)	ND(9.0)	260	ND(4.0)	ND(6.0)	ND(8.0)	13	ND(4.0)	ND(50)	ND(7.0)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	2.3	ND(0.9)	230	ND(0.4)	5.0	ND(0.8)	7.6	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94*	1.3	ND(0.9)	140	ND(0.4)	4.4	ND(0.8)	4.7	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	ND(5.0)	ND(9.0)	94	ND(4.0)	ND(6.0)	ND(0.8)	ND(5.0)	ND(4.0)	ND(50)	ND(7.0)	NA	NA	NA	NA	NA	NA	NA

TABLE 4-18 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Well No.	Volatiles										Semivolatiles						Inorganic
	1,2-Dichloro ethylene	Dichloro methane	Tetra chloro ethylene	Toluene	Trichloro ethylene	Vinyl Chloride	Trichloro methane	Benzene	Carbon Disulfide	Ethyl benzene	Bis (2-ethyl hexyl) phthalate	2,6-Dinitro toluene	Hexachloro ethane	Naph thalene	N-nitro sodi-n-propylamine	1,4-di chloro benzene	Sulfate (mg/l)
DCF92-04																	
7/92	5.0	ND(5.0)	9.3	ND(5.0)	ND(3.0)	11	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	7.0	ND(6.0)	ND(6.0)	NA
11/92	35	5.0B	3.7	ND(5.0)	ND(3.0)	12	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	10	12J	43J	5.4	38J	ND(6.0)	NA
2/93	24	ND(10)	ND(2.5)	ND(1.5)	ND(1.0)	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
5/93	21	ND(10)	ND(2.5)	ND(1.5)	ND(1.0)	22	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	6.7	ND(5.0)	ND(4.0)	NA
11/93	18	ND(0.9)	ND(1.1)	ND(0.4)	2.8	40	ND(0.5)	0.5	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
12/93	27	ND(0.9)	ND(1.1)	ND(0.4)	1.7	42	ND(0.5)	0.5	ND(5.0)	1.1	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	7	ND(1.8)	ND(2.2)	ND(0.8)	ND(1.2)	18	ND(1.0)	ND(0.8)	ND(10)	ND(1.4)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	2.1	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCF92-05																	
7/92	69	14.0B	160	ND(5.0)	33	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
11/92	51	ND(5.0)	95	ND(5.0)	19	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
2/93	33	ND(10)	72	26	14	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
5/93	15	ND(10)	140	ND(1.5)	14	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
11/93	ND(25)	ND(45)	430	ND(20)	ND(30)	ND(40)	ND(25)	ND(20)	ND(250)	ND(35)	NA	NA	NA	NA	NA	NA	NA
12/93	ND(25)	ND(45)	710	ND(20)	ND(30)	ND(40)	29	ND(20)	ND(250)	ND(35)	NA	NA	NA	NA	NA	NA	NA
2/94	ND(5.0)	ND(9.0)	210	ND(4.0)	ND(6.0)	ND(0.8)	5	ND(4.0)	ND(50)	ND(7.0)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	12	ND(0.9)	62	ND(0.4)	7.6	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94*	18	ND(0.9)	55	ND(0.4)	7.1	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	2.2	ND(0.9)	30	ND(0.4)	1.5	ND(0.8)	3.1	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
DCF92-06																	
7/92	ND(5.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(3.0)	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
11/92	ND(5.0)	ND(10)	ND(3.0)	ND(5.0)	ND(3.0)	ND(2.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(3.0)	ND(10)	ND(7.0)	ND(7.0)	ND(3.0)	ND(6.0)	ND(6.0)	NA
2/93	ND(5.0)	ND(10)	ND(2.5)	ND(1.5)	ND(1.0)	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
5/93	ND(5.0)	ND(10)	ND(2.5)	ND(1.5)	ND(1.0)	ND(2.0)	ND(1.0)	ND(1.0)	ND(3.0)	ND(1.0)	ND(6.0)	ND(4.0)	ND(5.0)	ND(3.0)	ND(5.0)	ND(4.0)	NA
11/93	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
12/93	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	0.9B	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
2/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	ND(0.5)	ND(0.9)	1.2	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	ND(0.5)	ND(0.9)	1.5	ND(0.4)	ND(0.6)	ND(0.8)	0.5	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
DCF93-08																	
12/93	77	ND(4.5)	ND(5.5)	ND(2.0)	16	54	ND(2.5)	ND(2.0)	ND(25)	ND(3.5)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	25	ND(1.8)	ND(2.2)	ND(0.8)	ND(1.2)	51	ND(1.0)	ND(0.8)	ND(10)	ND(1.4)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

TABLE 4-18 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Well No.	Volatiles										Semivolatiles						Inorganic
	1,2-Dichloro ethylene	Dichloro methane	Tetra chloro ethylene	Toluene	Trichloro ethylene	Vinyl Chloride	Trichloro methane	Benzene	Carbon Disulfide	Ethyl benzene	Bis (2-ethyl hexyl) phthalate	2,6-Dinitro toluene	Hexachloro ethane	Naph thalene	N-nitro sodi-n-propylamine	1,4-di chloro benzene	Sulfate (mg/l)
DCF93-09																	
12/93	68	ND(4.5)	64	ND(2.0)	10	ND(4.0)	ND(2.5)	ND(2.0)	ND(25)	ND(3.5)	44	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	22	ND(9.0)	160	ND(4.0)	13	ND(8.0)	ND(5.0)	ND(4.0)	ND(50)	ND(7.0)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	5.3	ND(0.9)	48	ND(0.4)	5.2	ND(0.8)	1.1	ND(0.4)	ND(5.0)	ND(0.7)	30	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94*	ND(0.5)	ND(0.9)	28	ND(0.4)	3.9	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	2.2	ND(0.9)	28	ND(0.4)	2.5	ND(0.8)	0.8	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
DCF93-10																	
12/93	8.1	ND(0.9)	ND(1.1)	ND(0.4)	0.8	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	3.4	ND(0.9)	ND(1.1)	ND(0.4)	1.4	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	3.5	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	7.6	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	7.6	ND(0.9)	2.6	ND(0.4)	3.4	ND(0.8	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
DCF93-11																	
12/93	110	ND(4.5)	42	ND(2.0)	20	ND(4.0)	ND(2.5)	ND(2.0)	ND(25)	ND(3.5)	15	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	90	ND(1.8)	21	ND(0.8)	17	ND(1.6)	ND(1.0)	ND(0.8)	ND(10)	ND(1.4)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	78	ND(0.9)	ND(1.1)	ND(0.4)	2.1	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCF93-12																	
12/93	30	ND(0.9)	32	ND(0.4)	3.8	ND(0.8)	6.0B	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	3.5	ND(0.9)	5	ND(0.4)	1.7	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCF93-13																	
12/93	ND(25)	ND(45)	420	ND(20)	140	ND(40)	ND(25)	ND(20)	ND(250)	ND(35)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	5.9	ND(9.0)	230	ND(4.0)	47	ND(8.0)	ND(5.0)	ND(4.0)	ND(50)	ND(7.0)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	ND(2.5)	ND(4.5)	160	ND(2.0)	35	ND(4.0)	ND(2.5)	ND(2.0)	ND(25)	ND(3.5)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94*	31	ND(0.9)	420	ND(4.0)	200	ND(8.0)	ND(5.0)	ND(0.4)	ND(5.0)	ND(7.0)	NA	NA	NA	NA	NA	NA	NA
1/95	14	ND(4.5)	220	ND(2.0)	150	ND(4.0)	5.0	ND(2.0)	ND(25)	ND(3.5)	NA	NA	NA	NA	NA	NA	NA
DCF93-14																	
12/93	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2/94**	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(20)	ND(20)	ND(20)	ND(20)	ND(20)	ND(20)	133
6/94**	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(26)	ND(26)	ND(26)	ND(26)	ND(26)	ND(26)	NA
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

TABLE 4-18 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Well No.	Volatiles										Semivolatiles						Inorganic
	1,2-Dichloro ethylene	Dichloro methane	Tetra chloro ethylene	Toluene	Trichloro ethylene	Vinyl Chloride	Trichloro methane	Benzene	Carbon Disulfide	Ethyl benzene	Bis (2-ethyl hexyl) phthalate	2,6-Dinitro toluene	Hexachloro ethane	Naph thalene	N-nitro sodi-n-propylamine	1,4-di chloro benzene	Sulfate (mg/l)
DCF93-15																	
12/93	ND(25)	ND(45)	490	ND(20)	ND(30)	ND(40)	30	ND(20)	ND(250)	ND(35)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	15	ND(1.8)	52	ND(0.8)	14	ND(1.0)	ND(1.0)	ND(0.8)	ND(10)	ND(1.4)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCF93-16																	
12/93	ND(13)	ND(23)	200	ND(10)	ND(15)	ND(20)	ND(13)	ND(10)	ND(130)	ND(18)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
6/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCF93-17																	
12/93	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2/94	ND(0.5)	ND(0.9)	ND(1.1)	0.9	ND(0.6)	ND(0.8)	ND(0.5)	0.6	21	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	11	NA
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCF93-18																	
12/93	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
2/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	ND(0.5)	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	14	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
1/95	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
DCF93-19																	
12/93	54	ND(4.5)	ND(5.5)	ND(2.0)	3.3	15	ND(2.5)	ND(2.0)	ND(25)	ND(3.5)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	11	ND(1.8)	ND(2.2)	ND(0.8)	3.8	15	ND(1.0)	ND(0.8)	ND(10)	ND(1.4)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	5.5	ND(0.9)	2.3	ND(0.4)	1.2	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	8.7	ND(0.9)	5.4	ND(0.4)	2.8	4.4	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	8.5	ND(0.9)	ND(1.1)	ND(0.4)	1.0	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
DCF93-20																	
12/93	36	ND(4.5)	29	ND(2.0)	9.2	ND(4.0)	ND(2.5)	ND(2.0)	ND(2.5)	ND(3.5)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
2/94	ND(0.5)	ND(0.9)	5	ND(0.4)	13	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
6/94	3.8	ND(0.9)	2.2	ND(0.4)	9.9	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	5.7	ND(0.9)	10	ND(0.4)	14	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	14	ND(0.9)	14	ND(0.4)	60	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA

TABLE 4-18 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Well No.	Volatiles										Semivolatiles						Inorganic
	1,2-Dichloro ethylene	Dichloro methane	Tetra chloro ethylene	Toluene	Trichloro ethylene	Vinyl Chloride	Trichloro methane	Benzene	Carbon Disulfide	Ethyl benzene	Bis (2-ethyl hexyl) phthalate	2,6-Dinitro toluene	Hexachloro ethane	Naph thalene	N-nitro sodi-n-propylamine	1,4-di chloro benzene	Sulfate (mg/l)
DCF94-21[a]																	
6/94	12[b]	ND(1.0)	62	NA	4.5	ND(1.0)	1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
8/94	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
1/95	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC
DCF94-22																	
7/94	4.1	ND(0.9)	ND(1.1)	0.5	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	ND(10)	NA
8/94	1.0	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA
1/95	3.3	ND(0.9)	ND(1.1)	ND(0.4)	ND(0.6)	ND(0.8)	ND(0.5)	ND(0.4)	ND(5.0)	ND(0.7)	NA	NA	NA	NA	NA	NA	NA

<u>Notes</u>:

ND	Not Detected.
NA	Not Analyzed.
NS	No sample collected, wells dry.
NC	Not collected; with pilot system in place, unable to sample.
B	Compound detected in sample is less than 10× the amount detected in the method blank. Result is estimated.
J	Sample quantitation is estimated.
[a]	This sample was analyzed by EPA Method 8010; the sample was additionally analyzed for iron, manganese, and TSS (see Table 4-20).
[b]	Detection is of the *cis*- isomer.
*	PCE reported from diluted sample analysis; all others from initial undiluted sample analysis.
**	SVOC reporting limit raised due to limited sample volume.

For a complete list of analytes since November 1993, see Appendix D.

Results prior to November 1993 are adapted from CEMRK (1992b; 1993a,b,e). Results since November 1993 contain data from CEMRK (1994a,b,d,e,f,g,i; 1995a).

TABLE 4-19
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
November 1993

All results are shown in μg/l unless otherwise noted.

Well No.	Trichloroethylene	Trichloromethane	Tetrachloroethylene	1,2-Dichloroethylene	Vinyl Chloride	TCL SVOCs
DCF92-01	ND(0.6)	ND(0.5)	ND(1.1)	ND(0.5)	ND(0.8)	NA
DCF92-02	ND(0.6)	ND(0.5)	32	ND(0.5)	ND(0.8)	NA
DCF92-03	ND(30)	ND(25)	1600	ND(25)	ND(40)	NA
DCF92-04	2.8	ND(0.5)	ND(1.1)	18	40	ND(10)
DCF92-05	ND(30)	ND(25)	430	ND(25)	ND(40)	NA
DCF92-06	ND(0.6)	ND(0.5)	ND(1.1)	ND(0.5)	ND(0.8)	NA

<u>Notes</u>:

ND Not Detected.
( ) Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
For a complete list of analytes, see Appendix D.

This table contains data from CEMRK (1994a,e).

TABLE 4-20
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
February 1994

All results shown in μg/l unless otherwise noted.

Well No.	1,2-Dichloro ethylene	Toluene	Vinyl Chloride	Trichloro ethylene	Tetrachloro ethylene	Trichloro methane	Benzene	Carbon Disulfide	Sulfate*
DCF92-01	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.4)	ND(5)	NA
DCF92-02	ND(5.0)	ND(4.0)	ND(8.0)	ND(6.0)	86	ND(5.0)	ND(4.0)	ND(50)	NA
DCF92-03	ND(5.0)	ND(4.0)	ND(8.0)	ND(6.0)	260	13	ND(4.0)	ND(50)	NA
DCF92-04	7	ND(0.8)	18	ND(1.2)	ND(2.2)	ND(1.0)	ND(0.8)	ND(10)	NA
DCF92-05	ND(5.0)	ND(4.0)	ND(8.0)	ND(6.0)	210	5	ND(4.0)	ND(50)	NA
DCF92-06	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.4)	ND(5)	NA
DCF93-08	25	ND(0.8)	51	ND(1.2)	ND(2.2)	ND(1.0)	ND(0.8)	ND(10)	NA
DCF93-09	22	ND(4.0)	ND(8.0)	13	160	ND(5.0)	ND(4.0)	ND(50)	NA
DCF93-10	3.4	ND(0.4)	ND(0.8)	1.4	ND(1.1)	ND(0.5)	ND(0.4)	ND(5)	NA
DCF93-11	90	ND(0.8)	ND(1.6)	17	21	ND(1.0)	ND(0.8)	ND(10)	NA
DCF93-12	3.5	ND(0.4)	ND(0.8)	1.7	5	ND(0.5)	ND(0.4)	ND(5.0)	NA
DCF93-13	5.9	ND(4.0)	ND(8.0)	47	230	ND(5.0)	ND(4.0)	ND(50)	NA
DCF93-14	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.4)	ND(5.0)	133

TABLE 4-20 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Well No.	1,2-Dichloro ethylene	Toluene	Vinyl Chloride	Trichloro ethylene	Tetrachloro ethylene	Trichloro methane	Benzene	Carbon Disulfide	Sulfate*
DCF93-15	15	ND(0.8)	ND(1.6)	14	52	ND(1.0)	ND(0.8)	ND(10)	NA
DCF93-17	ND(0.5)	0.9	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	0.6	21	NA
DCF93-18	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.4)	ND(5.0)	NA
DCF93-19	11	ND(0.8)	15	3.8	ND(2.2)	ND(1.0)	ND(0.8)	ND(10)	NA
DCF93-20	ND(0.5)	ND(0.4)	ND(0.8)	13	5	ND(0.5)	ND(0.4)	ND(5.0)	NA

Notes:

ND	Not Detected.
NA	Not Analyzed.
*	Results are in mg/l
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

Well DCF93-16 not sampled; well was dry.
For a complete list of analytes, see Appendix D.

This table contains data from CEMRK (1994f).

TABLE 4-21
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
June 1994

All results shown in μg/l unless otherwise noted.

Well No.	1,2-Dichloroethylene	Trichloro ethylene	Tetrachloro ethylene	Trichloromethane	Bis(2-ethyl hexyl)phthalate	1,4-Dichlorobenzene
DCF92-01	ND(0.5)	ND(0.6)	ND(1.1)	ND(0.5)	ND(10)	ND(10)
DCF92-02	ND(0.5)	ND(0.6)	64	ND(0.5)	ND(10)	ND(10)
DCF92-03	2.3	5.0	230	7.6	ND(10)	ND(10)
DCF92-04	2.1	ND(0.6)	ND(1.1)	ND(0.5)	ND(10)	ND(10)
DCF92-05	12	7.6	62	ND(0.5)	ND(10)	ND(10)
DCF92-06	ND(0.5)	ND	ND(1.1)	ND(0.5)	ND(10)	ND(10)
DCF93-09	5.3	5.2	48	ND(0.5)	30	ND(10)
DCF93-10	3.5	ND	ND(1.1)	ND(0.5)	ND(10)	ND(10)
DCF93-11	78	2.1	ND(1.1)	ND(0.5)	NA	NA
DCF93-13	ND(2.5)	35	160	ND(2.5)	ND(10)	ND(10)
DCF93-14	ND(0.5)	ND(0.6)	ND(1.1)	ND(0.5)	ND(26)	ND(26)
DCF93-17	ND(0.5)	ND(0.6)	ND(1.1)	ND(0.5)	ND(10)	11
DCF93-18	ND(0.5)	ND(0.6)	ND(1.1)	ND(0.5)	14	ND(10)
DCF93-19	5.5	1.2	2.3	ND(0.5)	ND(10)	ND(10)
DCF93-20	3.8	9.9	2.2	ND(0.5)	ND(10)	ND(10)

Notes:

ND	Not Detected.
NA	Not Analyzed
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

Wells DCF93-08, 12, 15, and 16 were not sampled; wells were dry.
For a complete list of analytes, see Appendix D.

This table contains data from CEMRK (1994g).

TABLE 4-22
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
July and August 1994

All results shown in μg/l unless otherwise noted.

Well No.	1,2-Dichloroethylene	Toluene	Vinyl Chloride	Trichloro ethylene	Tetrachloro ethylene	Trichloro methane	Ethylbenzene
DCF92-01	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.7)
DCF92-02	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	84*	ND(0.5)	ND(0.7)
DCF92-03	1.3	ND(0.4)	ND(0.8)	4.4	140*	4.7	ND(0.7)
DCF92-04	NS	NS	NS	NS	NS	NS	NS
DCF92-05	18	ND(0.4)	ND(0.8)	7.1	55*	ND(0.5)	ND(0.7)
DCF92-06	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	1.2	ND(0.5)	ND(0.7)
DCF93-08	NS	NS	NS	NS	NS	NS	NS
DCF93-09	ND(0.5)	ND(0.4)	ND(0.8)	3.9	28*	ND(0.5)	ND(0.7)
DCF93-10	7.6	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.7)
DCF93-11	NS	NS	NS	NS	NS	NS	NS
DCF93-12	NS	NS	NS	NS	NS	NS	NS
DCF93-13	31	ND(4.0)	ND(8.0)	200	420	ND(5.0)	ND(7.0)
DCF93-14	NS	NS	NS	NS	NS	NS	NS
DCF93-15	NS	NS	NS	NS	NS	NS	NS

TABLE 4-22 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Well No.	1,2-Dichloroethylene	Toluene	Vinyl Chloride	Trichloro ethylene	Tetrachloro ethylene	Trichloro methane	Ethylbenzene
DCF93-17	NS	NS	NS	NS	NS	NS	NS
DCF93-18	NS	NS	NS	NS	NS	NS	NS
DCF93-19	8.7	ND(0.4)	4.4	2.8	5.4	ND(0.5)	ND(0.7)
DCF93-20	5.7	ND(0.4)	ND(0.8)	14	10	ND(0.5)	ND(0.7)
DCF94-22	1.0	0.8	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.7)
DCF94-22[a]	4.1	0.5	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.7)

<u>Notes</u>:

ND	Not Detected.
NS	Not Sampled.
*	Reported from analysis of diluted sample.
a	Sample collected in July 1994.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

Wells DCF93-08, 11, 12, 14, 15, 16, 17, 18, and DCF92-04 were not sampled; wells were dry.
Well DCF94-21 was not able to be sampled with the pilot study system in place.
For a complete list of analytes, see Appendix D-II.

This table contains data from CEMRK (1994i).

TABLE 4-23
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas
January 1995

All results shown in μg/l unless otherwise noted.

Well No.	1,2-Dichloro ethylene	Toluene	Vinyl Chloride	Trichloroethylene	Tetrachloroethylene	Trichloro methane	Dichloro methane
DCF92-01	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.9)
DCF92-02	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	77	8.9	1.3B
DCF92-03	ND(5.0)	ND(4.0)	ND(8.0)	ND(6.0)	94	ND(5.0)	ND(9.0)
DCF92-04	NS	NS	NS	NS	NS	NS	NS
DCF92-05	2.2	ND(0.4)	ND(0.8)	1.5	30	3.1	ND(0.9)
DCF92-06	ND(0.5)	ND(0.4)	ND(0.8)	ND(0.6)	1.5	0.5	ND(0.9)
DCF93-08	NS	NS	NS	NS	NS	NS	NS
DCF93-09	2.2	ND(0.4)	ND(0.8)	2.5	28	0.8	ND(0.9)
DCF93-10	7.6	ND(0.4)	ND(0.8)	3.4	2.6	ND(0.5)	ND(0.9)
DCF93-11	NS	NS	NS	NS	NS	NS	NS
DCF93-12	NS	NS	NS	NS	NS	NS	NS
DCF93-13	14	ND(0.4)	ND(0.8)	160	220*	0.8	ND(0.9)

TABLE 4-23 (CONTINUED)
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES

Well No.	1,2-Dichloro ethylene	Toluene	Vinyl Chloride	Trichloroethylene	Tetrachloroethylene	Trichloro methane	Dichloro methane
DCF93-14	NS	NS	NS	NS	NS	NS	NS
DCF93-15	NS	NS	NS	NS	NS	NS	NS
DCF93-17	NS	NS	NS	NS	NS	NS	NS
DCF93-18	NS	NS	NS	NS	NS	NS	NS
DCF93-19	8.5	ND(0.4)	ND(0.8)	1.0	ND(1.1)	ND(0.5)	ND(0.9)
DCF93-20	14	ND(0.4)	ND(0.8)	60	14	ND(0.5)	ND(0.9)
DCF94-22	3.3	ND(0.4)	ND(0.8)	ND(0.6)	ND(1.1)	ND(0.5)	ND(0.9)

<u>Notes</u>:

ND	Not Detected.
NS	Not Sampled.
*	Reported from analysis of diluted sample.
B	Analyte detected in the associated method blank.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

Wells DCF93-08, 11, 12, 14, 15, 16, 17, 18, and DCF92-04 were not sampled; wells were dry.
Well DCF94-21 was not able to be sampled with the pilot study system in place.
For a complete list of analytes, see Appendix D-II.

This table contains data from CEMRK (1995a).

TABLE 4-24
SUMMARY OF CHEMICAL DETECTIONS OF GROUNDWATER SAMPLES FROM PILOT STUDY WELLS
Dry Cleaning Facilities Area
Fort Riley, Kansas
June 1994

All results shown in μg/l unless otherwise noted.

Analyte	DCF94-ES-1B-GW	DCF94-ES-3B-GW	DCF94-ES-2B-GW	DCF94-21-GW	DCF92-02
Trichloromethane	6.5	10	6.3	1.0	NA
cis-1,2-Dichloroethylene	5.4	1.9	9.6	12	NA
Trichloroethylene	3.3	1.5	8.1	4.5	NA
Tetrachloroethylene	46	62	280	62	NA
Iron, Total (mg/l)	0.4	0.1	0.7	11.0	ND(0.1)
Manganese, Total (mg/l)	0.08	0.05	0.07	0.5	ND(0.01)
Total Suspended Solids (mg/l)	14	8	12	392	6

<u>Notes</u>:

ND Not Detected.
NA Not Analyzed.
( ) Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
For a complete list of analytes, see Appendix D-II.

This table contains data from CEMRK (1994h).

TABLE 4-25
SUMMARY OF GROUNDWATER TEMPERATURES COLLECTED FROM GROUNDWATER MONITORING WELLS
Dry Cleaning Facilities Area
Fort Riley, Kansas
July 1992 and January 1995

All results shown in degrees Celsius unless otherwise noted.

	Apr-92	Jun-92	Jul-92	Nov-92	Feb-93	May-93	Nov-93	Dec-93	Feb-94	Jun-94	Aug-94	Jan-95
DCF92-01	16.0	22.8	19.7	14.8	11.1	17.4	16.5	14.9	14.7	18.0	15.6	12.4
DCF92-02	22.0	26.1	22.3	14.9	13.9	16.0	17.6	14.6	15.6	20.0	18.1	15.8
DCF92-03	20.0	NA	21.4	15.3	13.4	15.6	18.0	18.8	27.1	29.5	23.2	23.5
DCF92-04	NA	26.1	24.7	24.7	11.6	19.1	18.9	15.6	15.0	18.7	NA	NA
DCF92-05	20.0	17.5	18.7	18.7	12.7	17.9	16.8	16.0	23.7	22.0	17.4	19.2
DCF92-06	18.0	29.5	20.9	20.9	10.5	16.1	17.6	15.4	15.5	19.0	17.7	14.8
DCF93-08	NA	NA	NA	NA	NA	NA	NA	15.0	15.7	NA	NA	NA
DCF93-09	NA	NA	NA	NA	NA	NA	NA	14.2	13.9	18.9	18.0	NA
DCF93-10	NA	NA	NA	NA	NA	NA	NA	13.6	13.8	19.1	16.4	12.0
DCF93-11	NA	NA	NA	NA	NA	NA	NA	13.5	13.1	NA	NA	NA
DCF93-12	NA	NA	NA	NA	NA	NA	NA	14.0	13.0	NA	NA	NA
DCF93-13	NA	NA	NA	NA	NA	NA	NA	16.6	14.7	21.5	17.7	16.0
DCF93-14	NA	NA	NA	NA	NA	NA	NA	NA	14.1	NA	NA	NA
DCF93-15	NA	NA	NA	NA	NA	NA	NA	16.5	NA	NA	NA	NA
DCF93-16	NA	NA	NA	NA	NA	NA	NA	16.6	NA	NA	NA	NA
DCF93-17	NA	NA	NA	NA	NA	NA	NA	13.3	11.4	18.5	NA	NA
DCF93-18	NA	NA	NA	NA	NA	NA	NA	13.2	13.2	18.9	NA	NA
DCF93-19	NA	NA	NA	NA	NA	NA	NA	17.1	16.2	17.6	17.2	14.6
DCF93-20	NA	NA	NA	NA	NA	NA	NA	14.1	14.1	16.5	15.0	12.0
DCF94-22	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	17.0	11.9

Notes:

NA Temperature not collected from this well during this event

Data used to create this table was gathered during 1992 PA/SI and Quarterly Groudwater Sampling Events. This table was adapted from CEMRK, 1992b, 1993a, 1993b, 1994a, 1994b, 1994d, 1994e,1994f, 1994g, 1994i, 1995a.

TABLE 4-26
SUMMARY OF CHEMICAL DETECTIONS OF SOIL AND MANHOLE DEBRIS SAMPLES COLLECTED DURING THE SEWER LINE REPAIR
Dry Cleaning Facilities Area
Fort Riley, Kansas
May 1994

All results are shown in µg/kg unless otherwise noted.

Parameter	15747-002 (Excavated Soil)	DM-180-S (Manhole Debris)
Acetone	ND(4.0)	25.6
1,1-Dichloroethylene	ND(1.0)	12.3
1,2-Dichloroethylene (total)	ND(1.0)	36,400J
Trichloroethylene	ND(2.0)	3,760J
Tetrachloroethylene	25.1	34,600J
Xylenes (total)	ND(1.0)	ND(0.35)

<u>Notes</u>:

ND	Not Detected.
NA	Not Analyzed.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
J	Result is estimated.

This table is adapted from CEMRO (1994a) and has been modified to be consistent with other tables produced for this document.

TABLE 4-27
SUMMARY OF CHEMICAL DETECTIONS OF UST BOTTOMS SAMPLES COLLECTED DURING THE SEWER LINE REPAIR
Dry Cleaning Facilities Area
Fort Riley, Kansas
May 1994

All results are shown in μg/kg unless otherwise noted.

Parameter	Tank-002	15747UST (Top)	15747UST (Bottom)
1,2-Dichloroethylene (total)	218	ND(5,000)	ND(5,000)
Tetrachloroethylene	31.3	ND(2,200)	ND(2,200)
Xylenes (total)	94.2	171,000	34,500
TRPH[a]	13.4	974,000	2,350
Naphthalene	41.9J	226	797
2-Methylnaphthalene	ND(44.0)	ND(22.0)	106
4-Methylphenol	62.2J	ND(32.5)	ND(65.0)
Volatile TICs	1,500J	2,100,000J	380,000J
Semivolatile TICs	17,000J	2,700J	17,000J

Notes:

ND	Not Detected.
NA	Not Analyzed.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.
J	Result is estimated.
a	Results are shown in mg/l.

Samples Tank-002, 15747UST (Top and Bottom) were analyzed for Tentatively Identified Compounds (TICs) by EPA Methods 8240 and 8270.

This table is adapted from CEMRO (1994a) and has been modified to be consistent with other tables produced for this document.

TABLE 4-28
SUMMARY OF CHEMICAL DETECTIONS OF SOIL SAMPLES FROM UST LOCATIONS
Dry Cleaning Facilities Area
Fort Riley, Kansas
October 1994

All results shown in μg/kg unless otherwise noted, expressed as dry weight.

Analyte	DCFUST-3-3 9.5-10.5 feet	DCFUST-3-4 11.7 feet	DCFUST-4-2 13.5 feet	DCFUST-5-2 10.0-12.5 feet	DCFUST-5-3 16.0-17.0 feet	DCFUST-6-3 18.6-20.3 feet
m- and/or p-xylene	ND(27)	71	ND(5.5)	NA	NA	NA
Tetrachloroethylene	ND(27)	ND(30)	13	NA	NA	NA
TPH-GRO (mg/kg)	ND(0.1)	1800	170	ND(0.11)	5400	50[b]
TPH-DRO (mg/kg)	13	36	120	7	5100	68

<u>Notes</u>:

NA	Not Analyzed
ND	Not Detected
a	Sample collected from auger flights at refusal.
b	Compounds eluted in the boiling range of gasoline; however, the chromatogram was not characteristic of gasoline contamination.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

This table contains data from CEMRK (1994j).

TABLE 4-29
PCB ANALYSIS OF SOILS FROM FORMER SUBSTATIONS
Dry Cleaning Facilities Area
Fort Riley, Kansas
March 1994

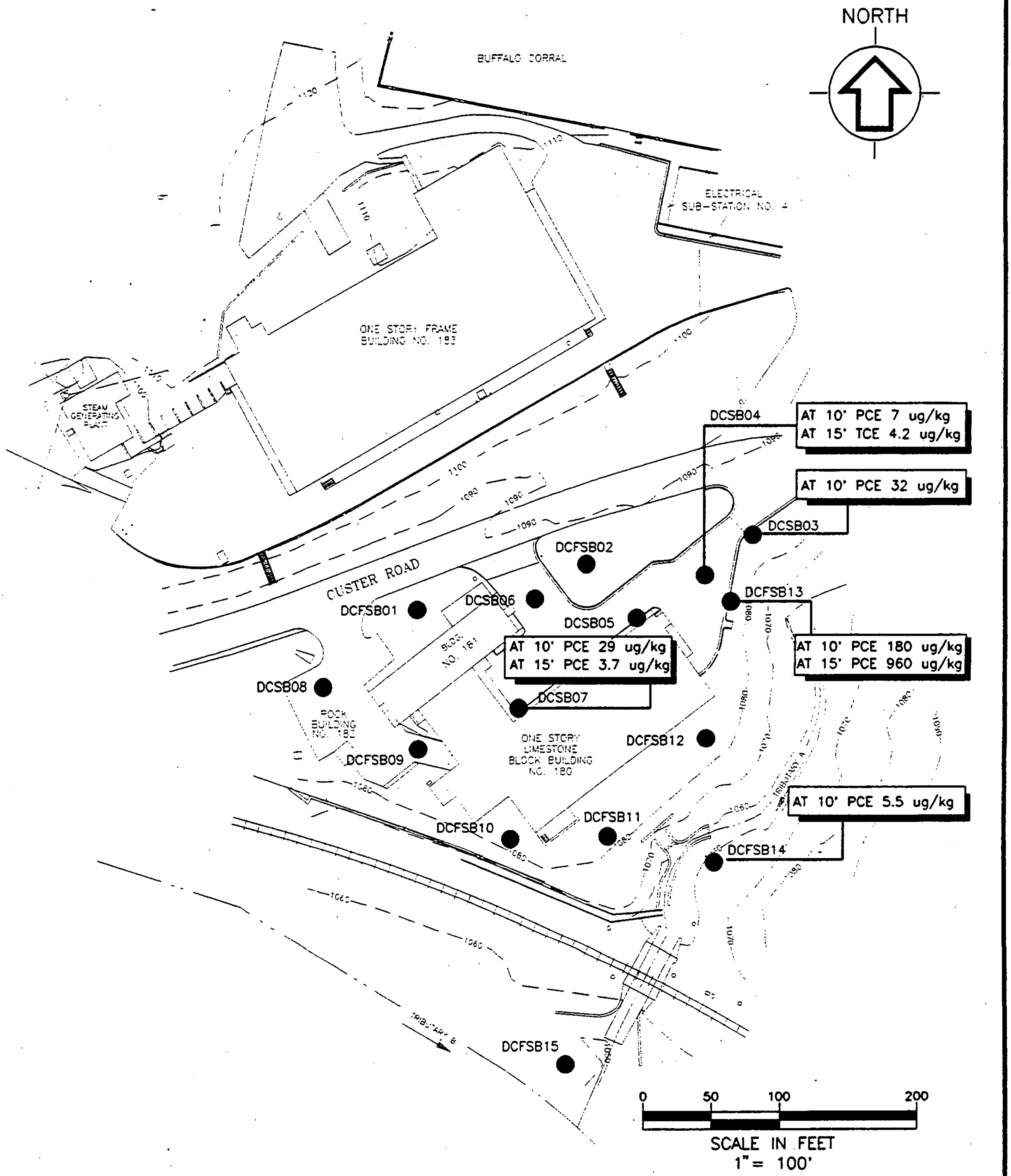
All results shown in µg/kg unless otherwise noted, expressed as dry weight.

Analyte	KPL SUB-9	KPL SUB-2	KPL SUB-5	KPL SUB-6MSD	KPL SUB-10	KPL SUB-6MS	KPL SUB-8	KPL SUB-6	KPL SUB-4	KPL SUB-7
Total Solids (%)	85.1	87.1	60.8	82.8	83.2	83.1	87.8	82.3	88.1	85.8
Aroclor-1254	ND(38.9)	ND(38.0)	ND(54.1)	ND(39.9)	60.6	ND(39.6)	ND(37.6)	ND(40.3)	ND(37.6)	ND(38.6)

Notes:

ND	Not Detected.
( )	Numbers in parentheses indicate Sample Quantitation Limits, or SQLs.

This table contains data from CEMRK (1994j).



LEGEND

DCFSB01 ● SOIL BORING, LOCATION; NO.

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992b.
3. SEE TABLE 4-1 FOR LIST OF CHEMICAL DETECTIONS.

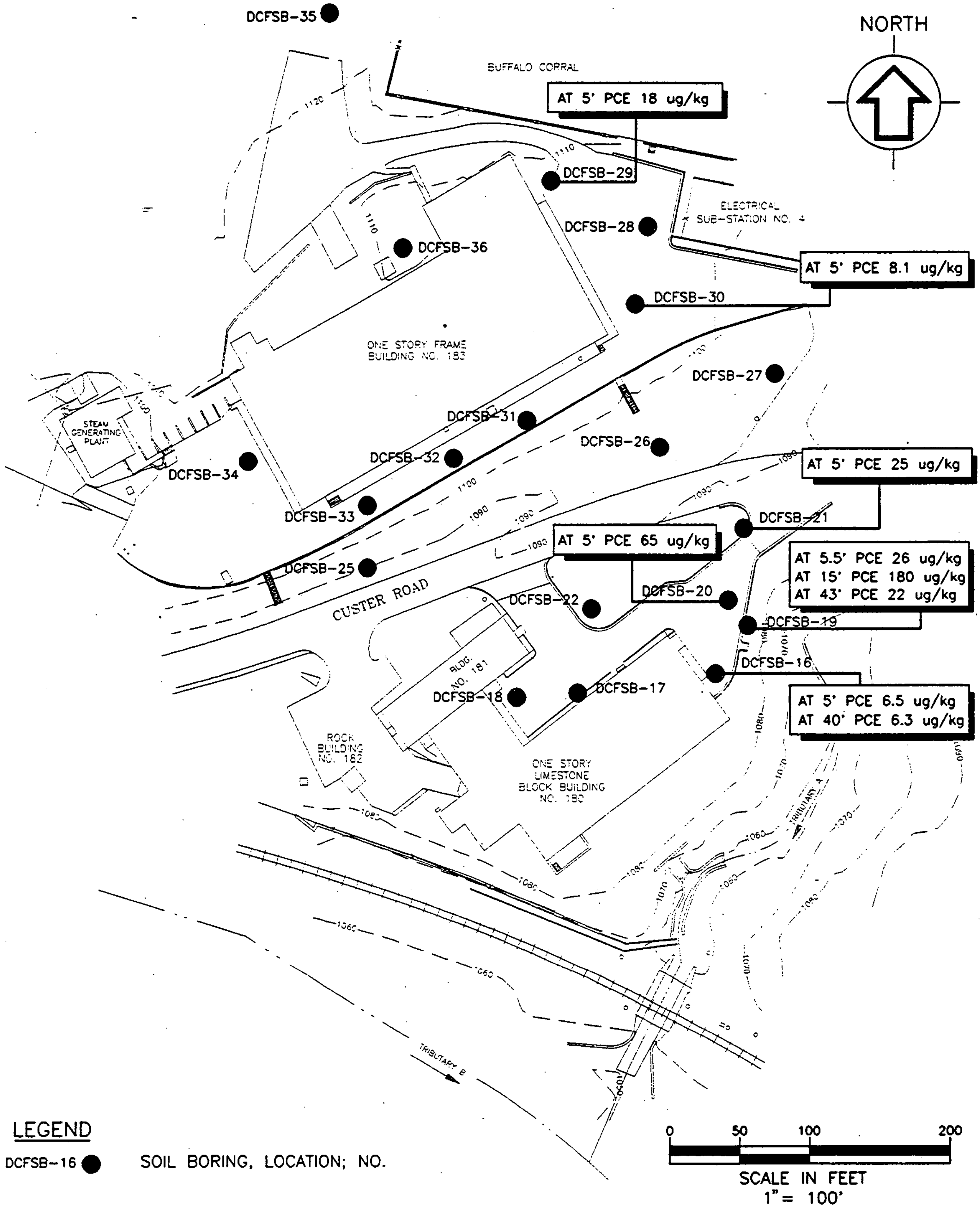
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN SOIL SAMPLES FROM SOIL BORINGS; 1992 PA/SI

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-1



LEGEND

DCFSB-16 ● SOIL BORING, LOCATION; NO.

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994b &1994e.
3. SEE TABLE 4-1 FOR LIST OF ALL CHEMICAL DETECTIONS.

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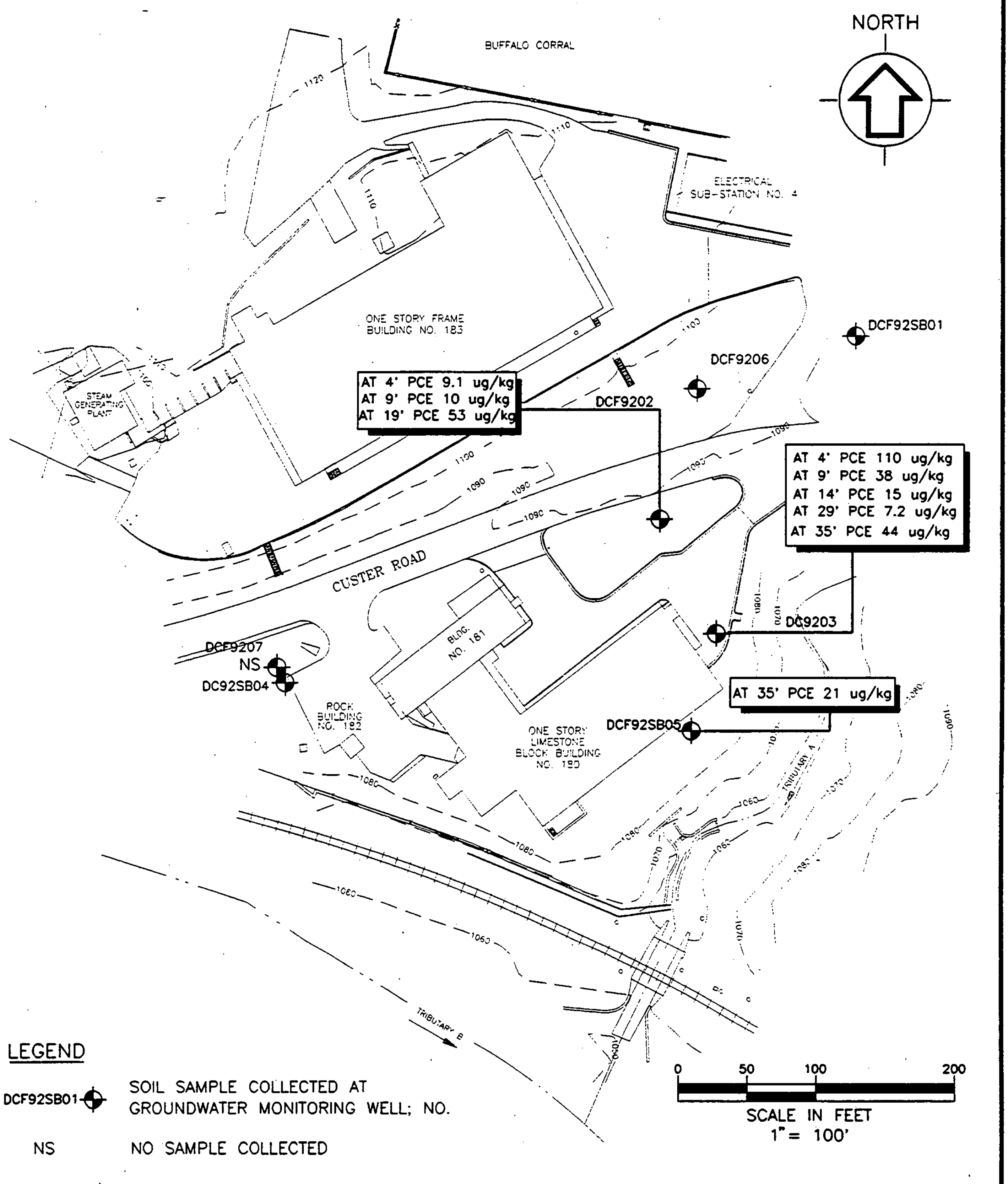
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN SAMPLES FROM SOIL BORINGS; 1993 RI

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-2



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992c.
3. SEE TABLE 4-2 FOR LIST OF ALL CHEMICAL DETECTIONS.

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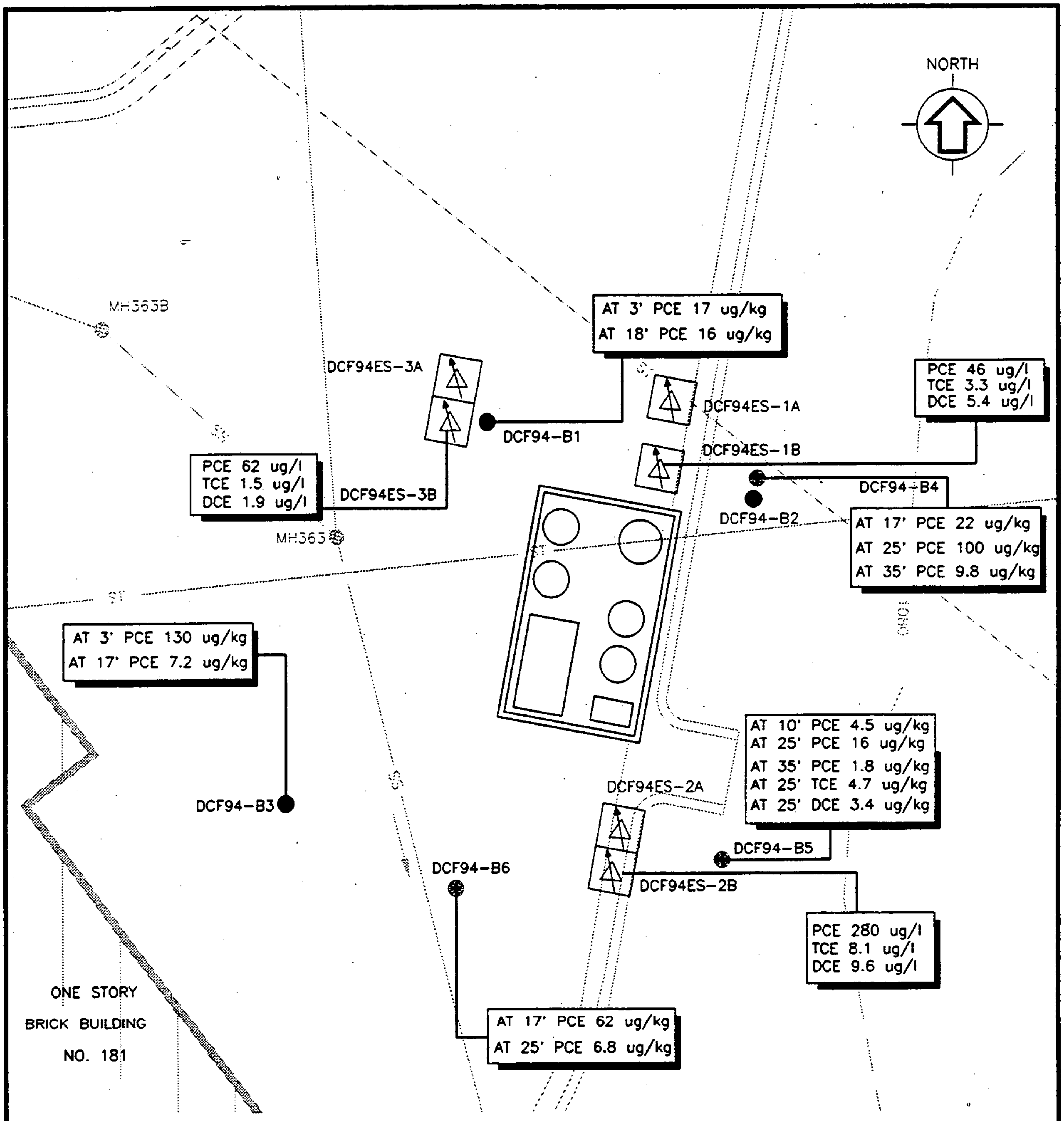
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN SAMPLES FROM MONITORING WELL BORINGS; 1992 PA/SI

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-3

4-5-0-10/30MAR95



LEGEND

DCF94-B3 ● SOIL BORING LOCATION; NO. 5/94

DCF94-B6 ⊕ SOIL BORING LOCATION; NO. 10/94

DCF94ES-1B △ EXTRACTION WELL

0 5 10 20

SCALE IN FEET
1"= 10'

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994k &1994m.
3. SEE TABLE 4-5 AND 4-24 FOR LIST OF ALL CHEMICAL DETECTIONS.
4. ug/l FOR GROUNDWATER SAMPLES, ug/kg FOR SOIL SAMPLES.
5. SAMPLE DEPTHS FOR WELLS DCF94-B4, B5 & B6 ARE ESTIMATED.
6. DCF94-B4 THROUGH DCF94-B6 ARE RESAMPLES OF DCF94-B1 THROUGH DCF94-B3.

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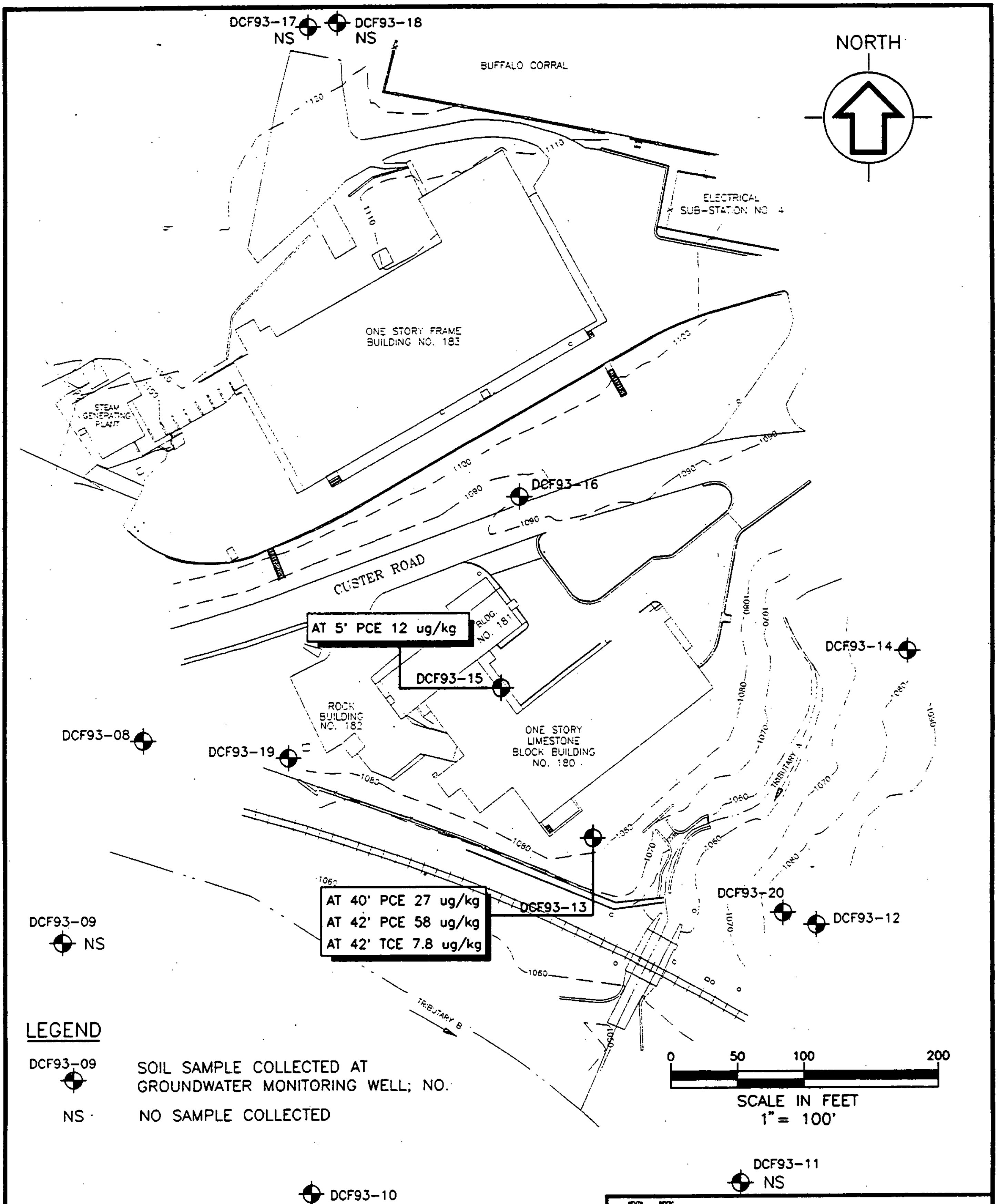
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN SOIL AND GROUNDWATER SAMPLES COLLECTED FROM SOIL BORINGS & EXTRACTION WELLS FOR THE PILOT TEST STUDY; 5/94 & 10/94

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-5

4-PP15, 30MAR95



LEGEND

DCF93-09 ⊕	SOIL SAMPLE COLLECTED AT GROUNDWATER MONITORING WELL; NO.
NS	NO SAMPLE COLLECTED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994b, 1994e.
3. SEE TABLE 4-3 FOR LIST OF ALL CHEMICAL DETECTIONS.

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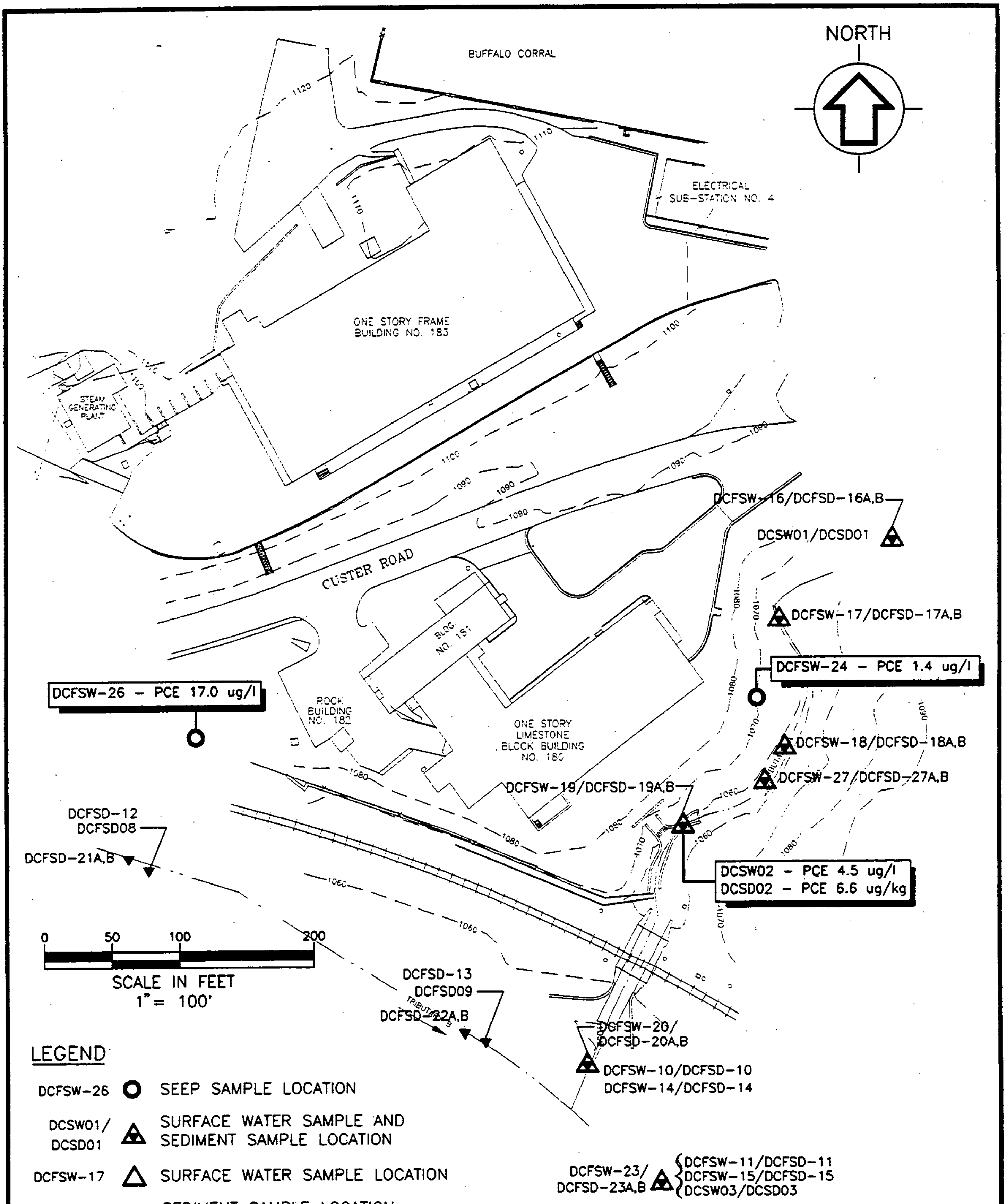
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED FROM SOIL SAMPLES FROM MONITORING WELL BORINGS; 1993 RI

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-4



LEGEND

DCFSW-26	○	SEEP SAMPLE LOCATION
DCSW01/ DCSD01	▲	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION
DCFSW-17	△	SURFACE WATER SAMPLE LOCATION
DCFSD-22A,B	▼	SEDIMENT SAMPLE LOCATION A = 0'-1' DEPTH SEDIMENT SAMPLES B = 1'-2' DEPTH SEDIMENT SAMPLES

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER - CEMRK 1992b, 1993a, 1993e, & 1995b.
3. SEE TABLE 4-6 AND 4-7 FOR LIST OF CHEMICAL DETECTIONS AND SAMPLE DATES.

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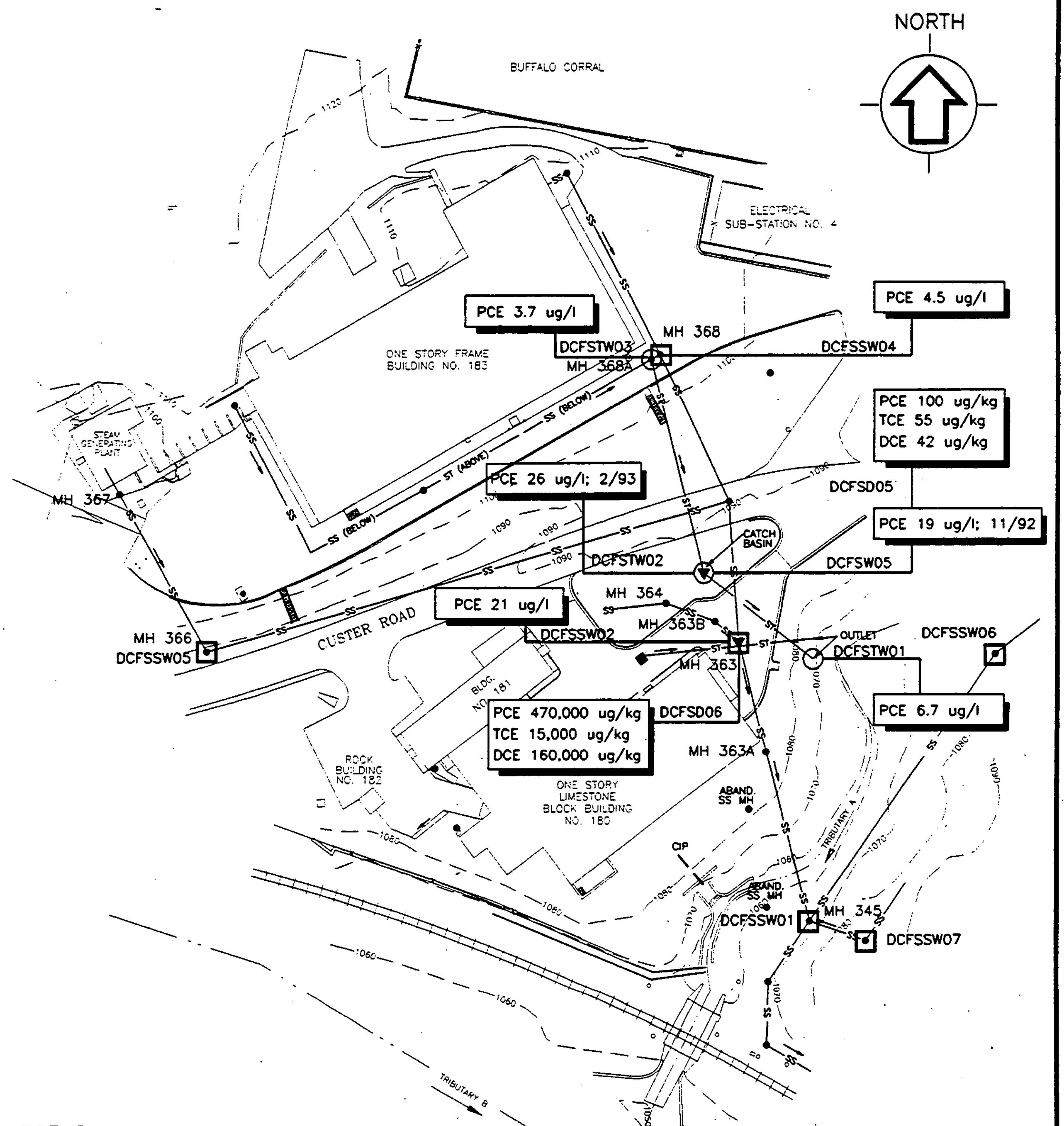
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN SEDIMENT, SURFACE WATER AND SEEP SAMPLES; 3/92, 7/92, 2/93, 11/93 & 1/95

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 4-6



LEGEND

DCFSSW05	☐	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW03	○	STORM SEWER WATER SAMPLE LOCATION
DCFSD06	▼	SANITARY/STORM SEWER SEDIMENT SAMPLE LOCATION

0 50 100 200

SCALE IN FEET
1" = 100'

NOTES:

1. SAMPLE DCFSD-06 WAS COLLECTED FROM WITHIN MH363B. DCFSD-05 AND DCFSW-05 WERE COLLECTED FROM WITHIN THE CATCH BASIN.
2. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
3. REFERENCE: AFTER - CEMRK 1993a & 1993b.
4. SEE TABLE 4-8 & 4-9 FOR LIST OF ALL CHEMICAL DETECTIONS.

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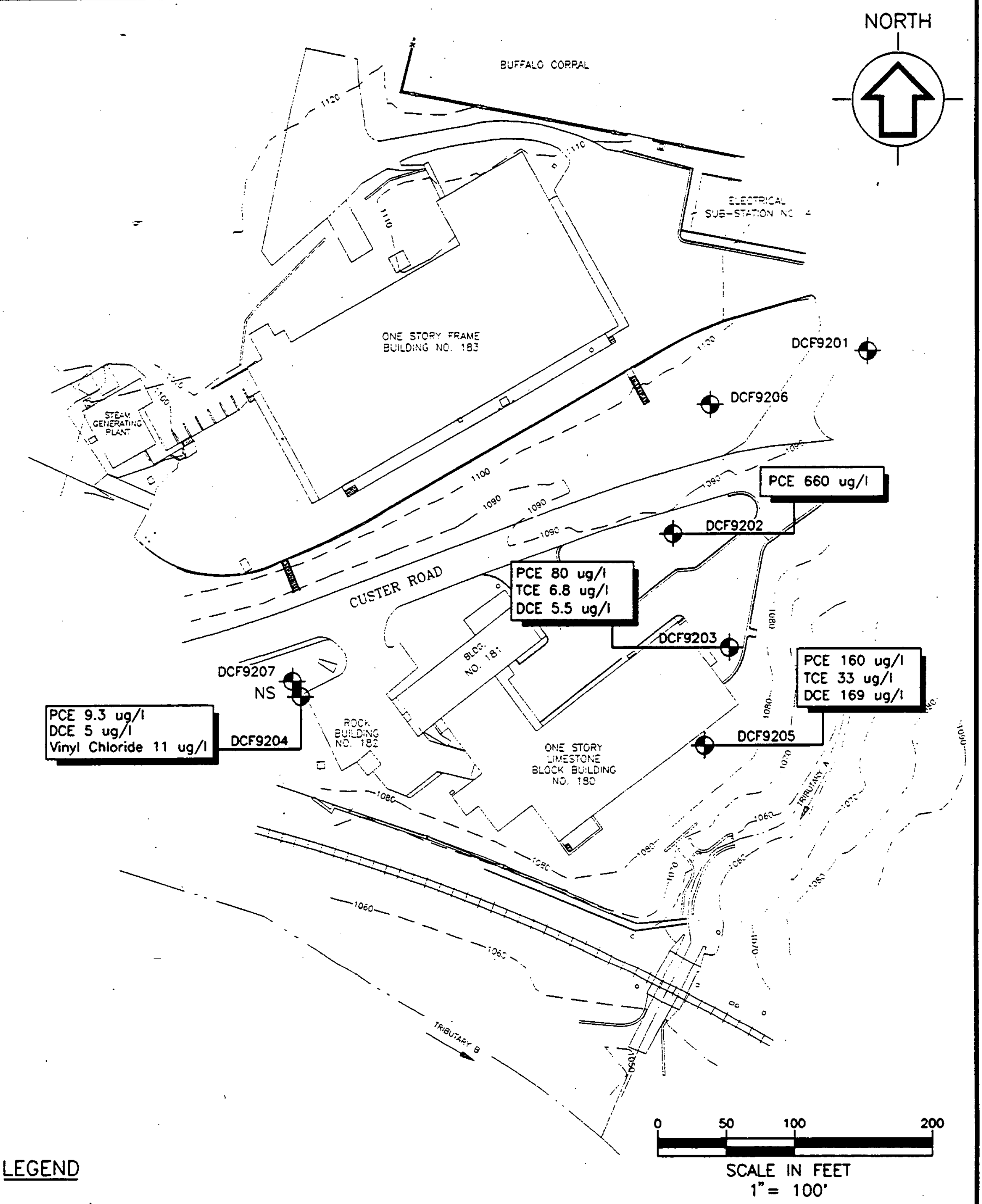
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN SANITARY/STORM WATER AND SEDIMENT SAMPLES; 11/92 & 2/93

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-7

4—SSW05/30MAR95



LEGEND

DCF9203 ⊕ GROUNDWATER MONITORING WELL; NO.

NS NO SAMPLE COLLECTED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1992b.
3. SEE TABLE 4-12 FOR LIST OF ALL CHEMICAL DETECTIONS.

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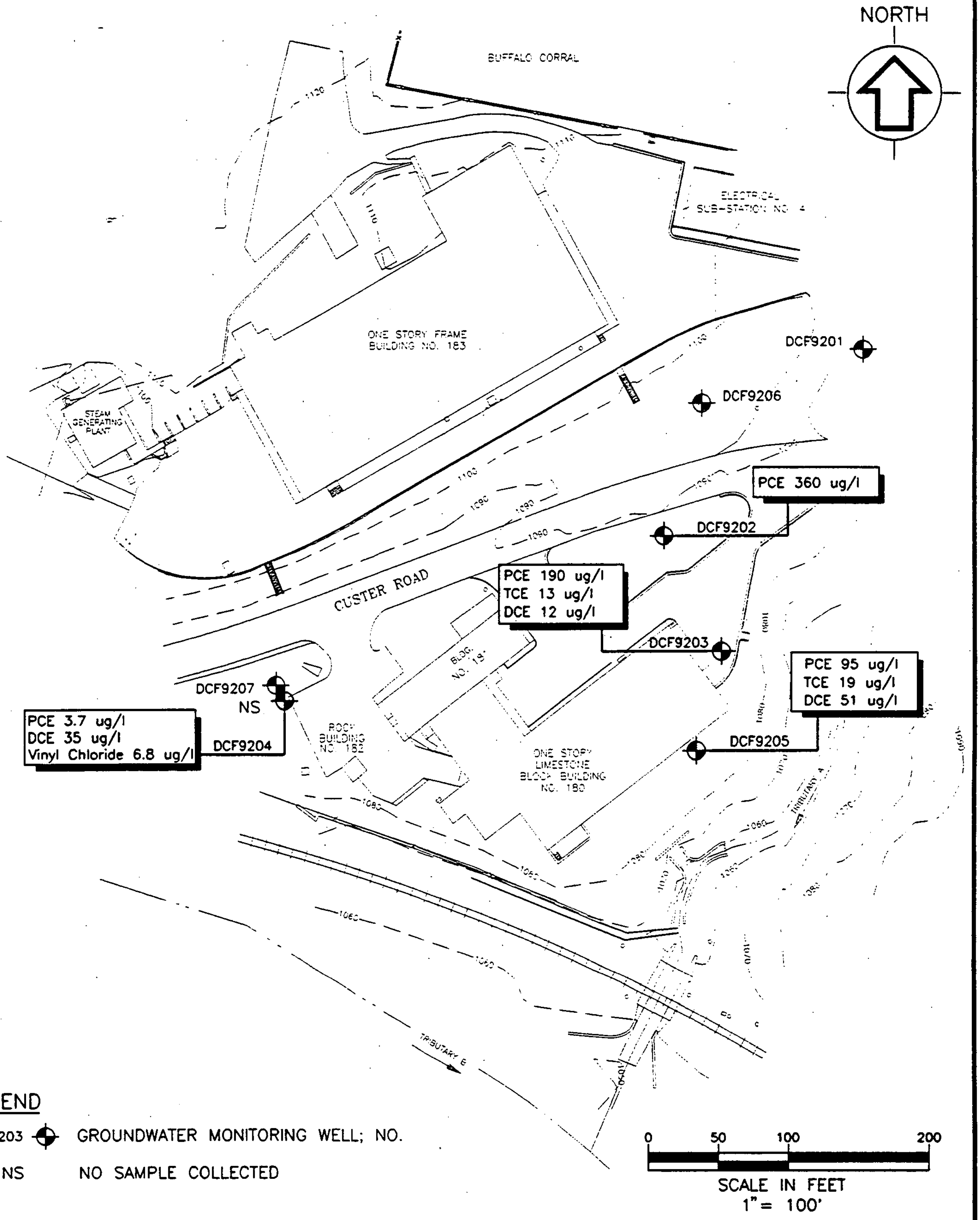
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 7/92

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-8



LEGEND

DCF9203 ⌖ GROUNDWATER MONITORING WELL; NO.

NS NO SAMPLE COLLECTED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993a.
4. SEE TABLE 4-13 FOR LIST OF ALL CHEMICAL DETECTIONS.

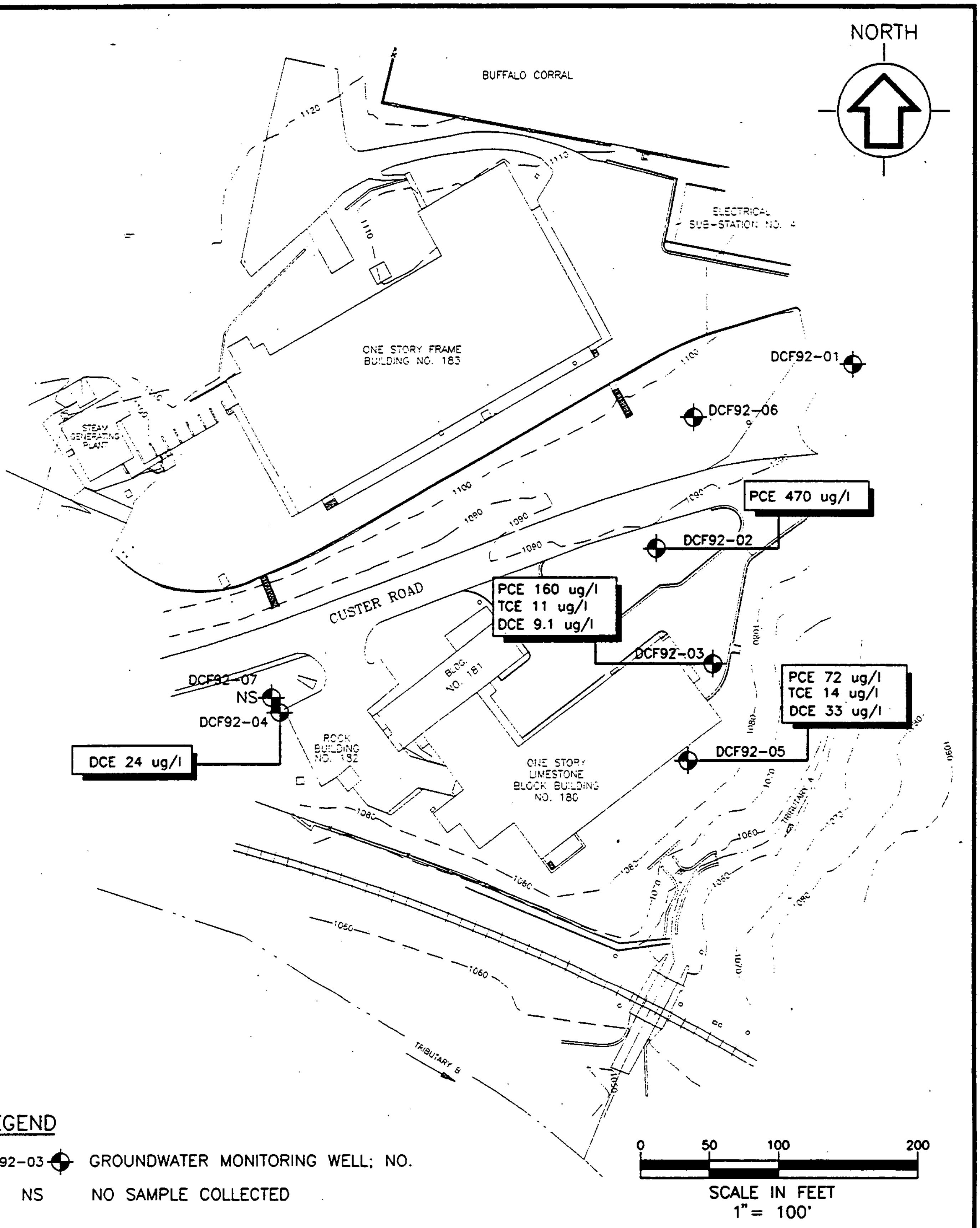
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 11/92

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-9



LEGEND

DCF92-03 ⊕ GROUNDWATER MONITORING WELL; NO.

NS NO SAMPLE COLLECTED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1993b.
3. SEE TABLE 4-14 FOR LIST OF ALL CHEMICAL DETECTIONS.

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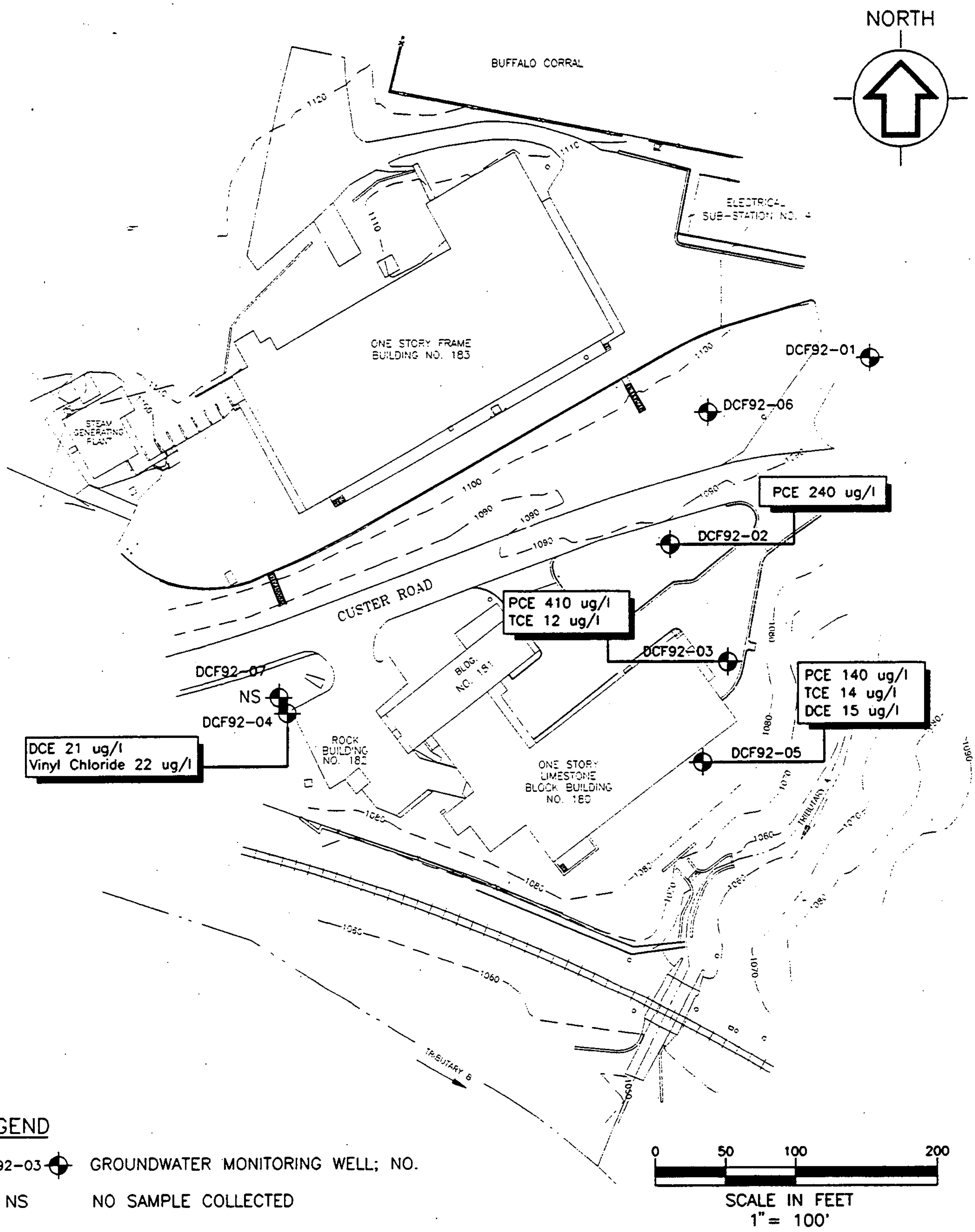
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 2/93

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-10



LEGEND

DCF92-03 ⊕ GROUNDWATER MONITORING WELL; NO.

NS NO SAMPLE COLLECTED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER - CEMRK 1993e.
3. SEE TABLE 4-15 FOR LIST OF ALL POSITIVE DETECTIONS.

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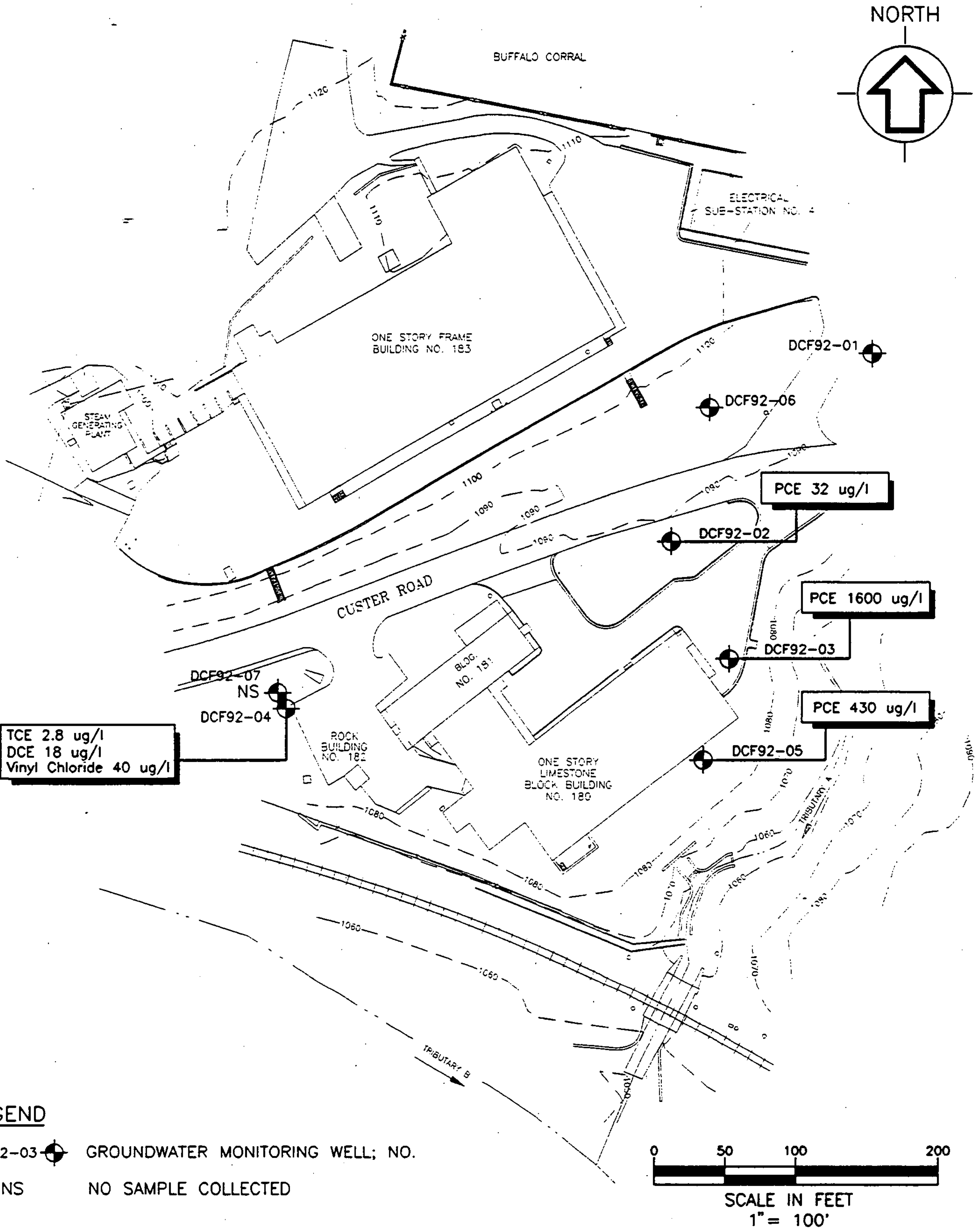
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 5/93

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-11



LEGEND

DCF92-03 ⌖ GROUNDWATER MONITORING WELL; NO.

NS NO SAMPLE COLLECTED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994a & 1994e.
3. SEE TABLE 4-19 FOR LIST OF ALL CHEMICAL DETECTIONS.

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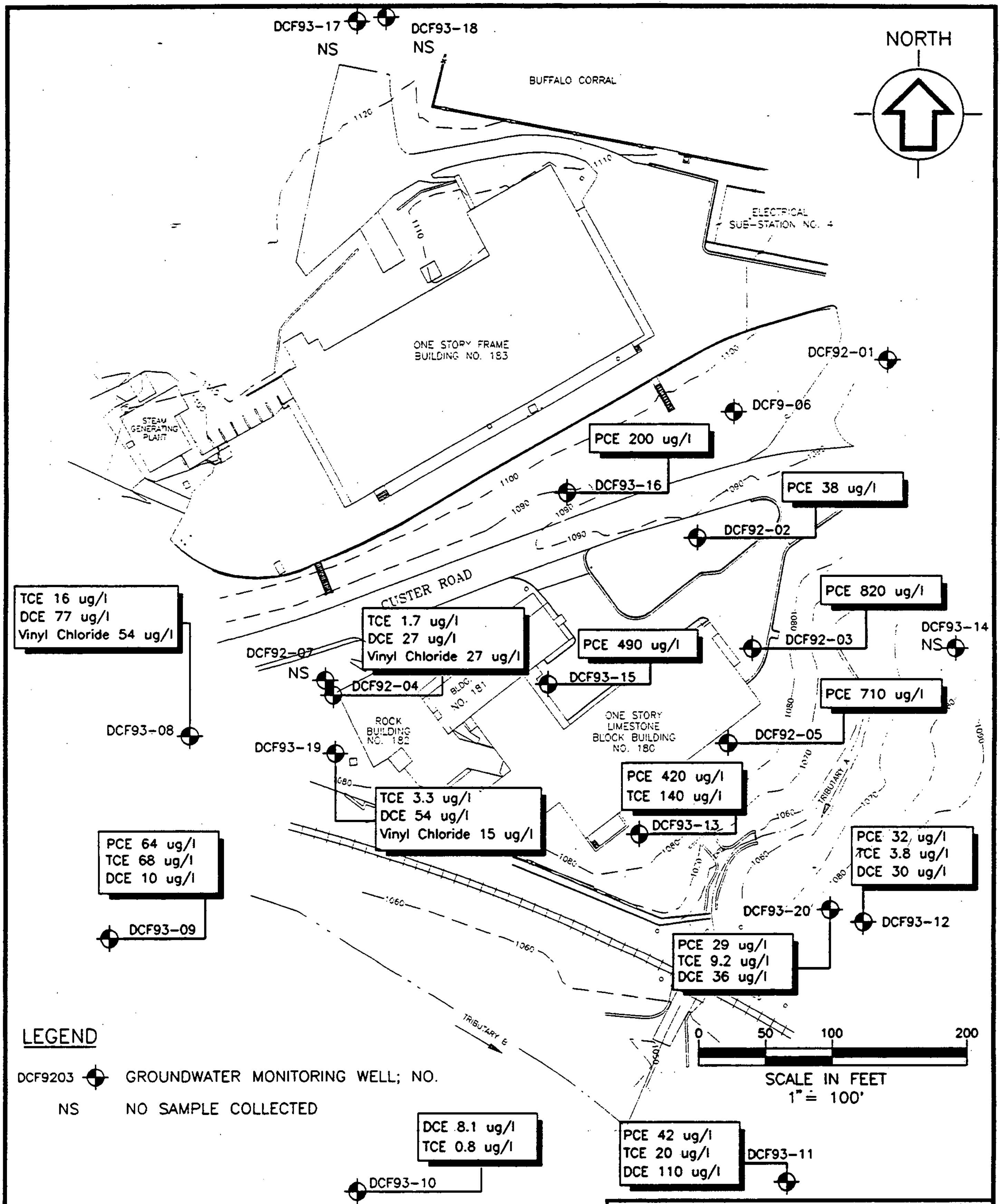
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 11/93

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-12



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FORT RILEY MILITARY RESERVATION (DCFA-RI)

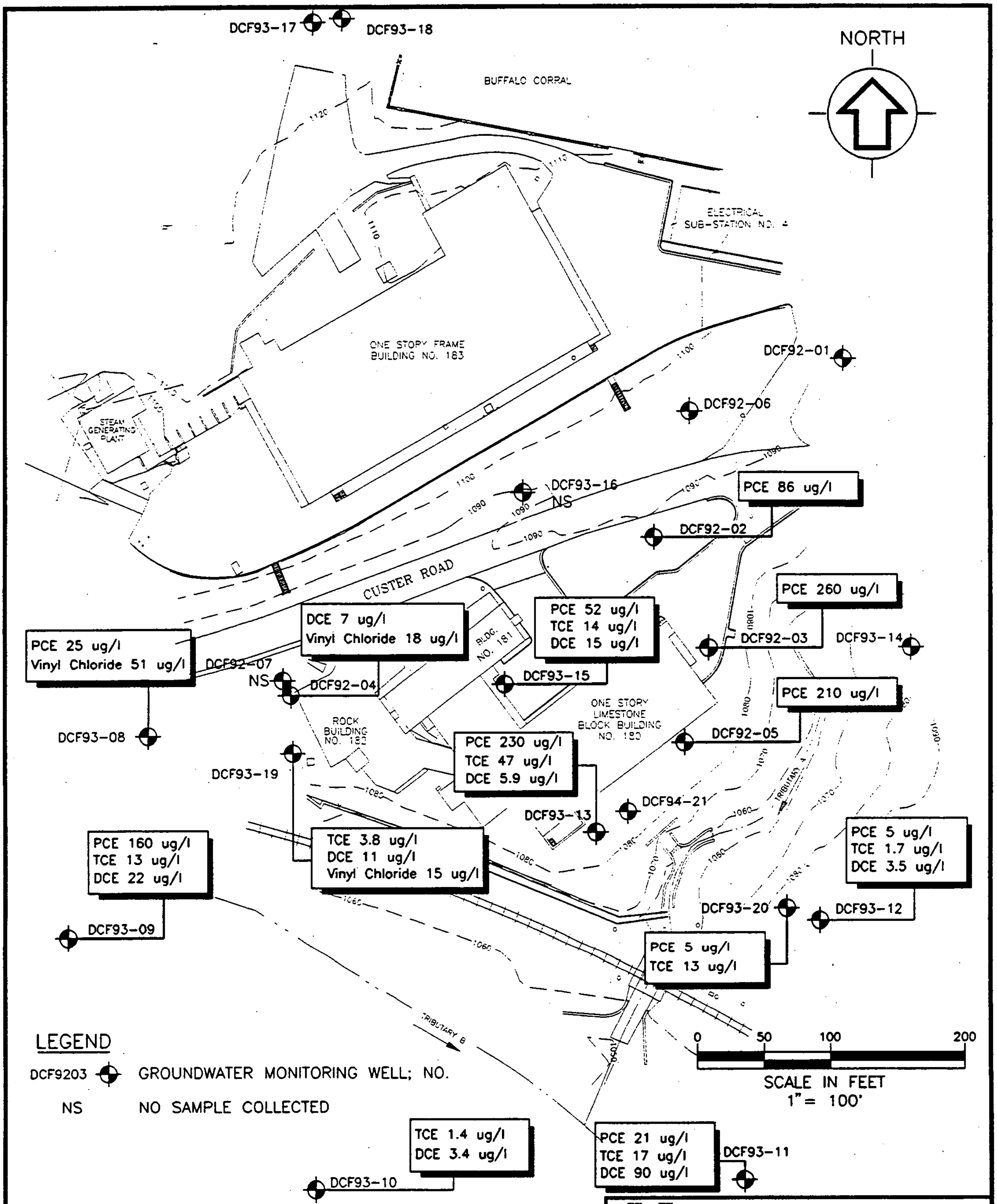
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 12/93

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-13

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994d &1994e.
3. SEE TABLE 4-4 FOR LIST OF ALL CHEMICAL DETECTIONS.

4-WC1293/30MAR95



LEGEND

DCF9203 ⊕ GROUNDWATER MONITORING WELL; NO.

NS NO SAMPLE COLLECTED

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994f.
3. SEE TABLE 4-20 FOR LIST OF ALL CHEMICAL DETECTIONS.

U.S. ARMY CORPS OF ENGINEERS

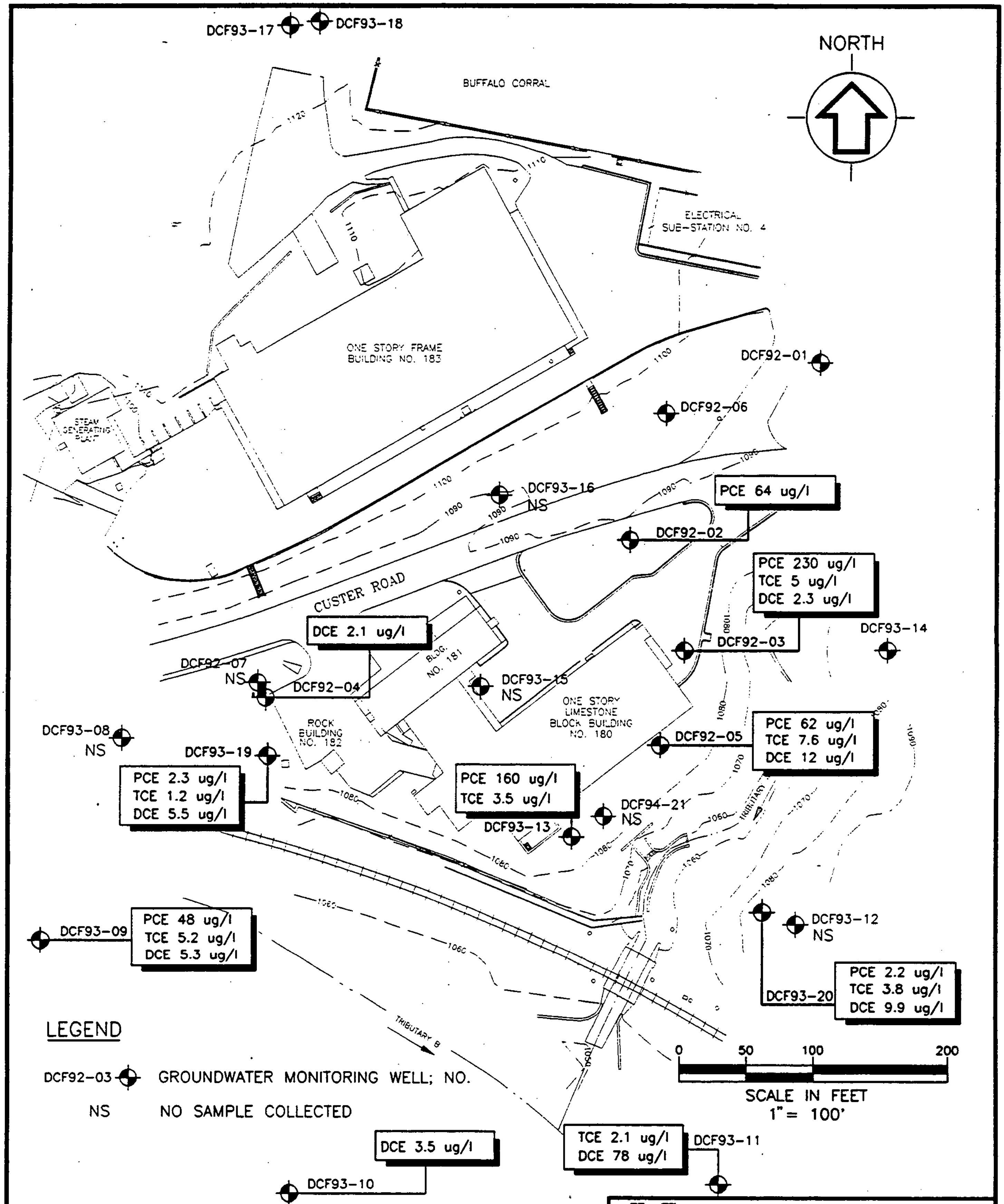
LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 2/94

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 4-14

I-WC294/30MAR95



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FORT RILEY MILITARY RESERVATION (DCFA-RI)

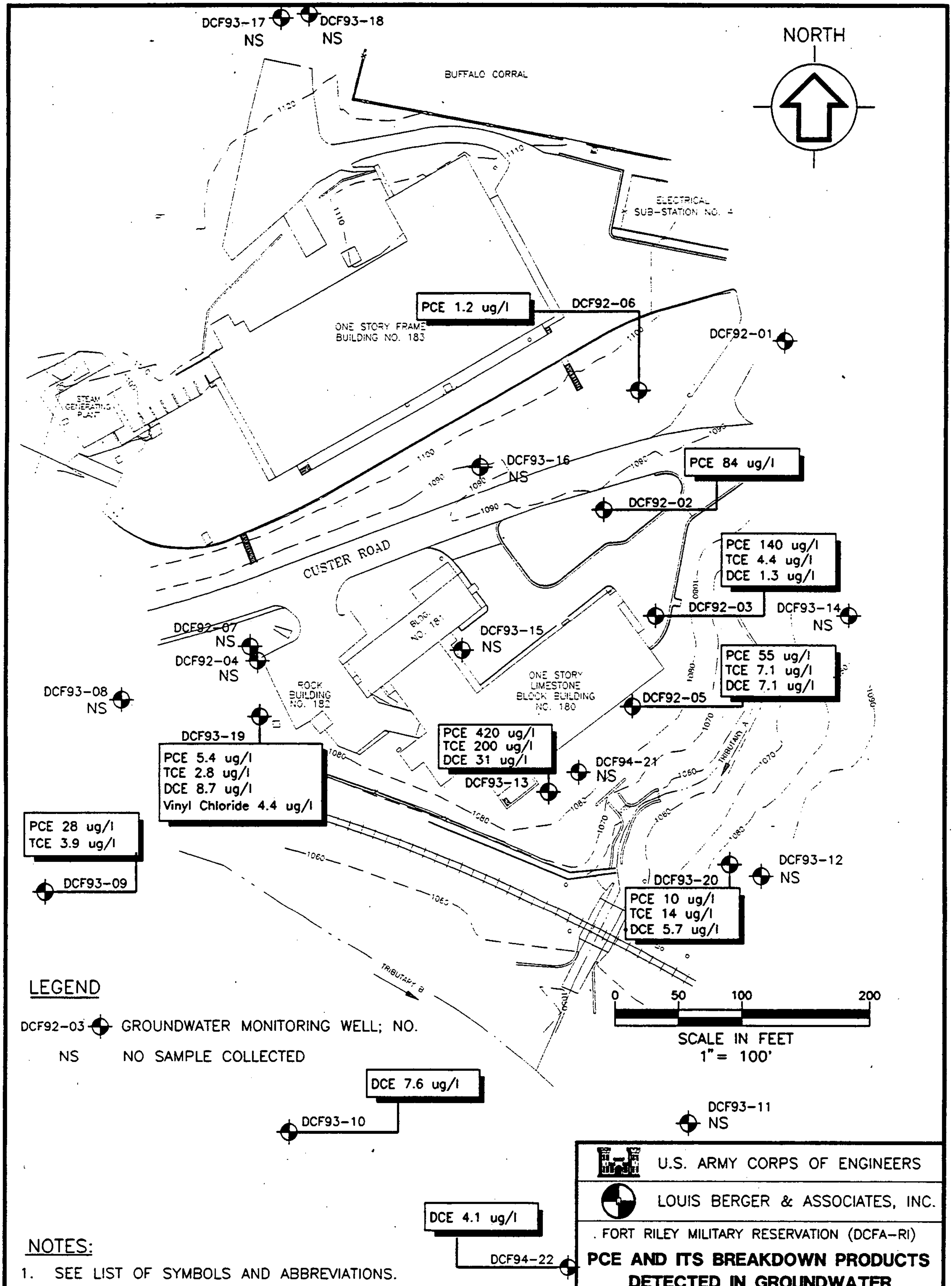
PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 6/94

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-15

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994j.
3. SEE TABLE 4-21 FOR LIST OF ALL CHEMICAL DETECTIONS.

1—WC694/30MAR95



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994I.
3. SEE TABLE 4-22 FOR LIST OF ALL CHEMICAL DETECTIONS.

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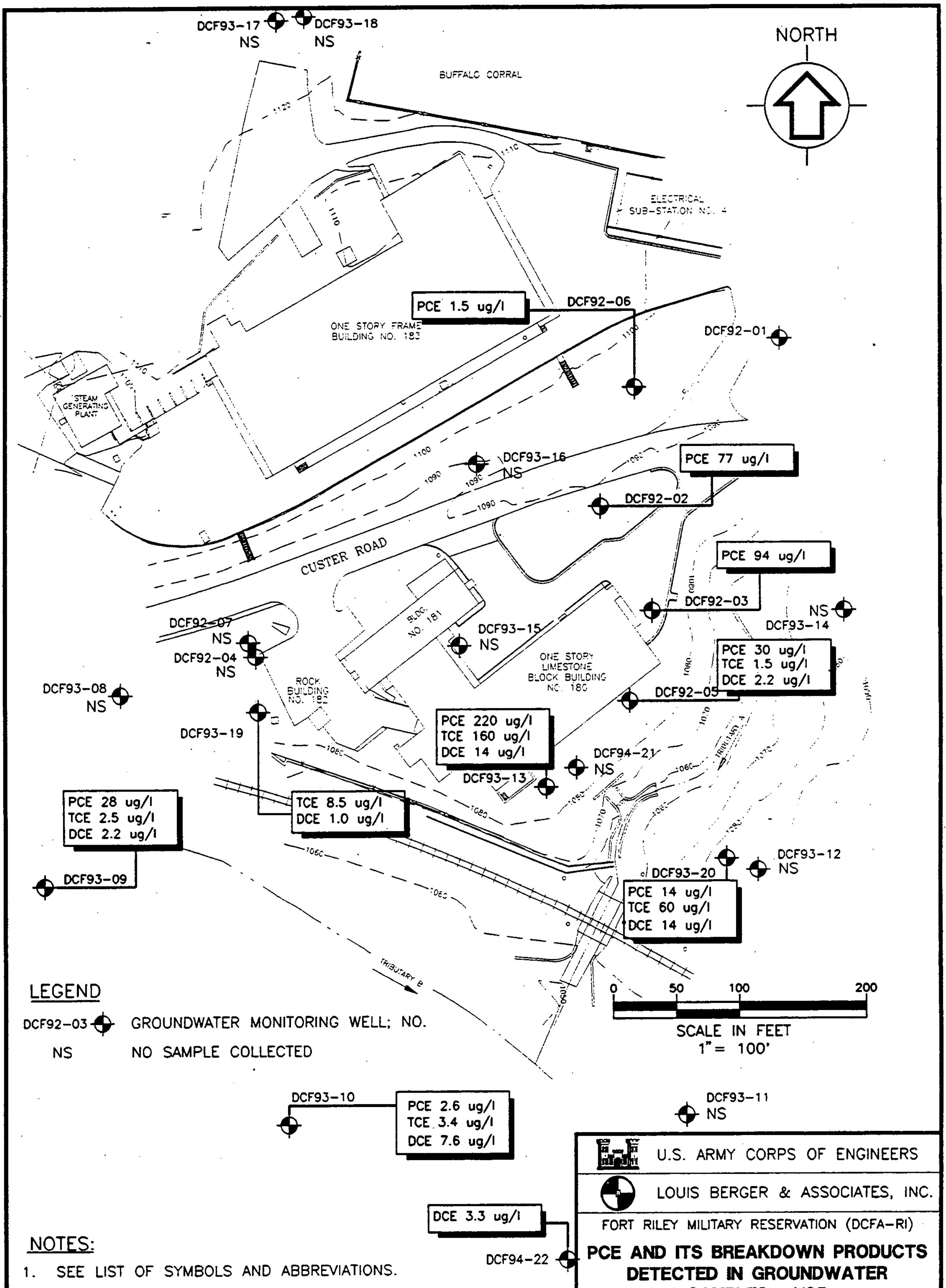
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 8/94

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-16

WC931 / SUMAP15



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1995a.
3. SEE TABLE 4-23 FOR LIST OF ALL CHEMICAL DETECTIONS.

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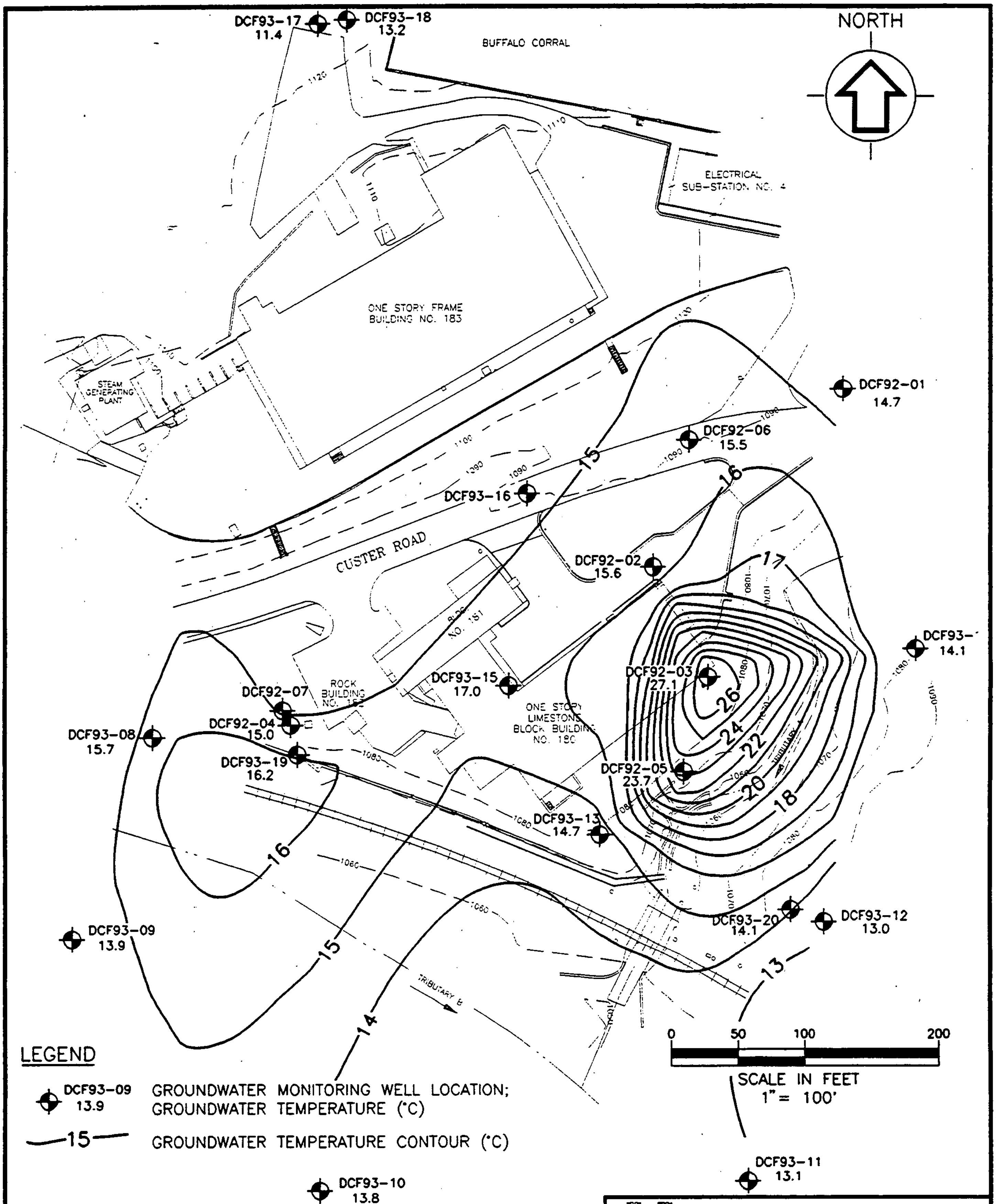
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE AND ITS BREAKDOWN PRODUCTS DETECTED IN GROUNDWATER SAMPLES; 1/95

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-17

4-WC195/30MAR95



LEGEND

DCF93-09 13.9	GROUNDWATER MONITORING WELL LOCATION; GROUNDWATER TEMPERATURE (°C)
—15—	GROUNDWATER TEMPERATURE CONTOUR (°C)

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. SEE TABLE 4-25 FOR FIELD NOTES CONTAINING TEMPERATURE COLLECTIONS.
3. REFERENCE: AFTER – CEMRK 1992b, 1993a, 1994a, b, d, e, f, g, i & 1995a.

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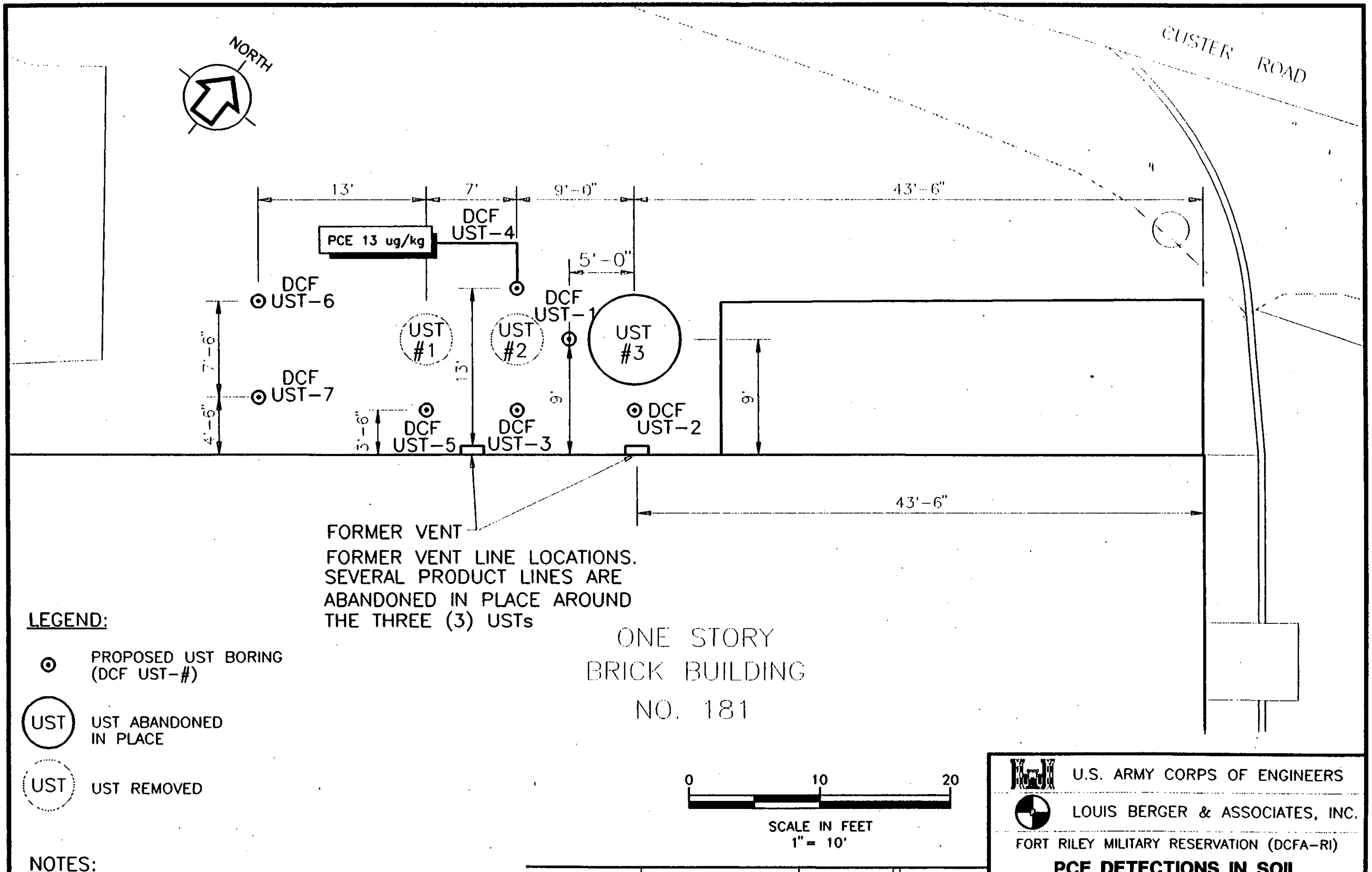
FORT RILEY MILITARY RESERVATION (DCFA-RI)

GROUNDWATER TEMPERATURE CONTOURS - 2/94

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-18

1--GWIM/30MAR95

4-PPUST/30MAR95



NOTES:
1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER – CEMRK 1994m.
3. SEE TABLE 4-28 FOR LIST OF ALL CHEMICAL DETECTIONS.

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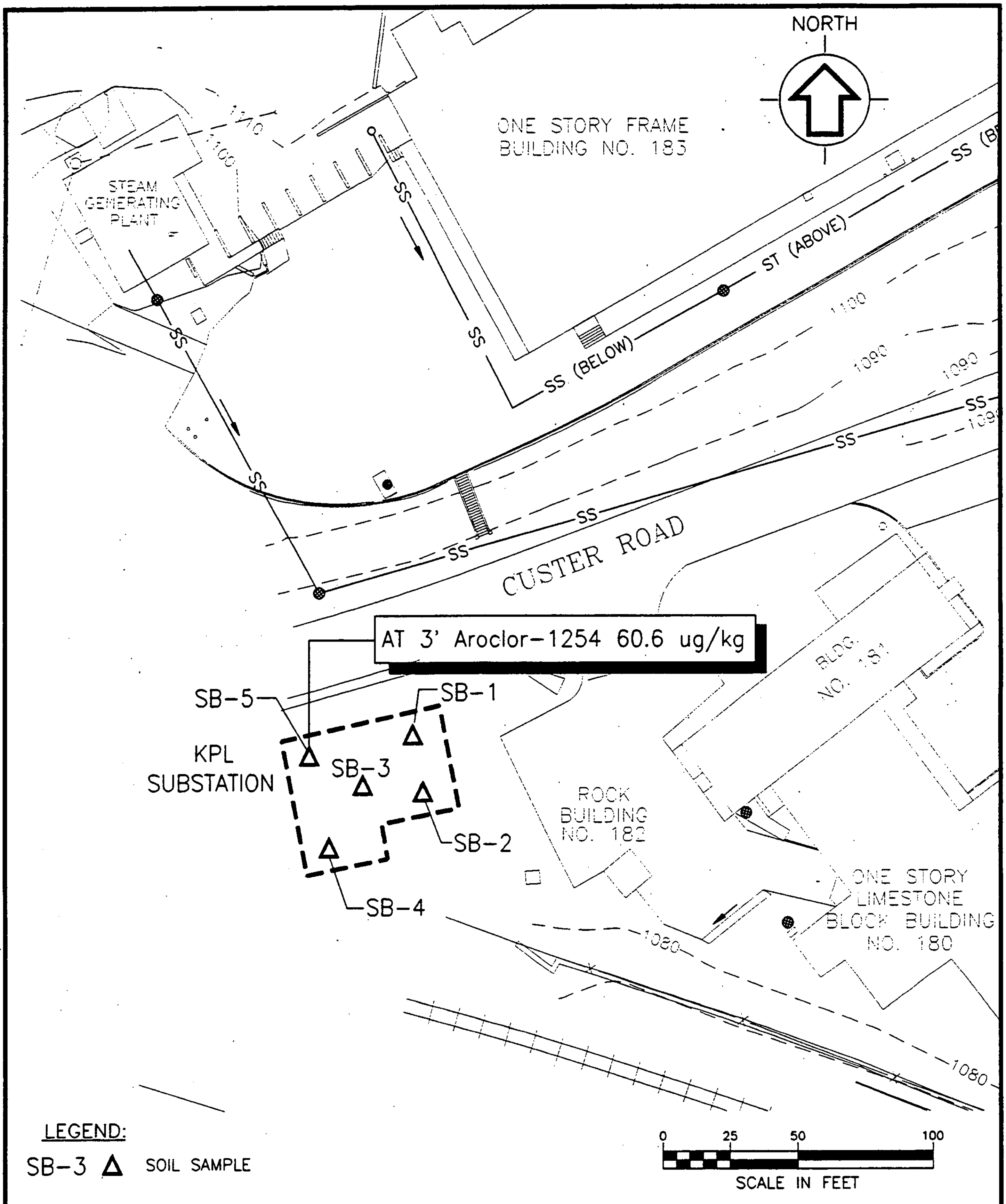
FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE DETECTIONS IN SOIL SAMPLES FROM UST REMOVAL/ ABANDONMENT ACTIVITIES; 10/94

SCALE:	DATE:	
AS SHOWN	MARCH 1995	FIG. 4-19



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LOUIS BERGER & ASSOCIATES, INC.

FORT RILEY MILITARY RESERVATION (DCFA-FS)

PCB DETECTIONS IN SOILS FROM FORMER SUBSTATION

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 4-20

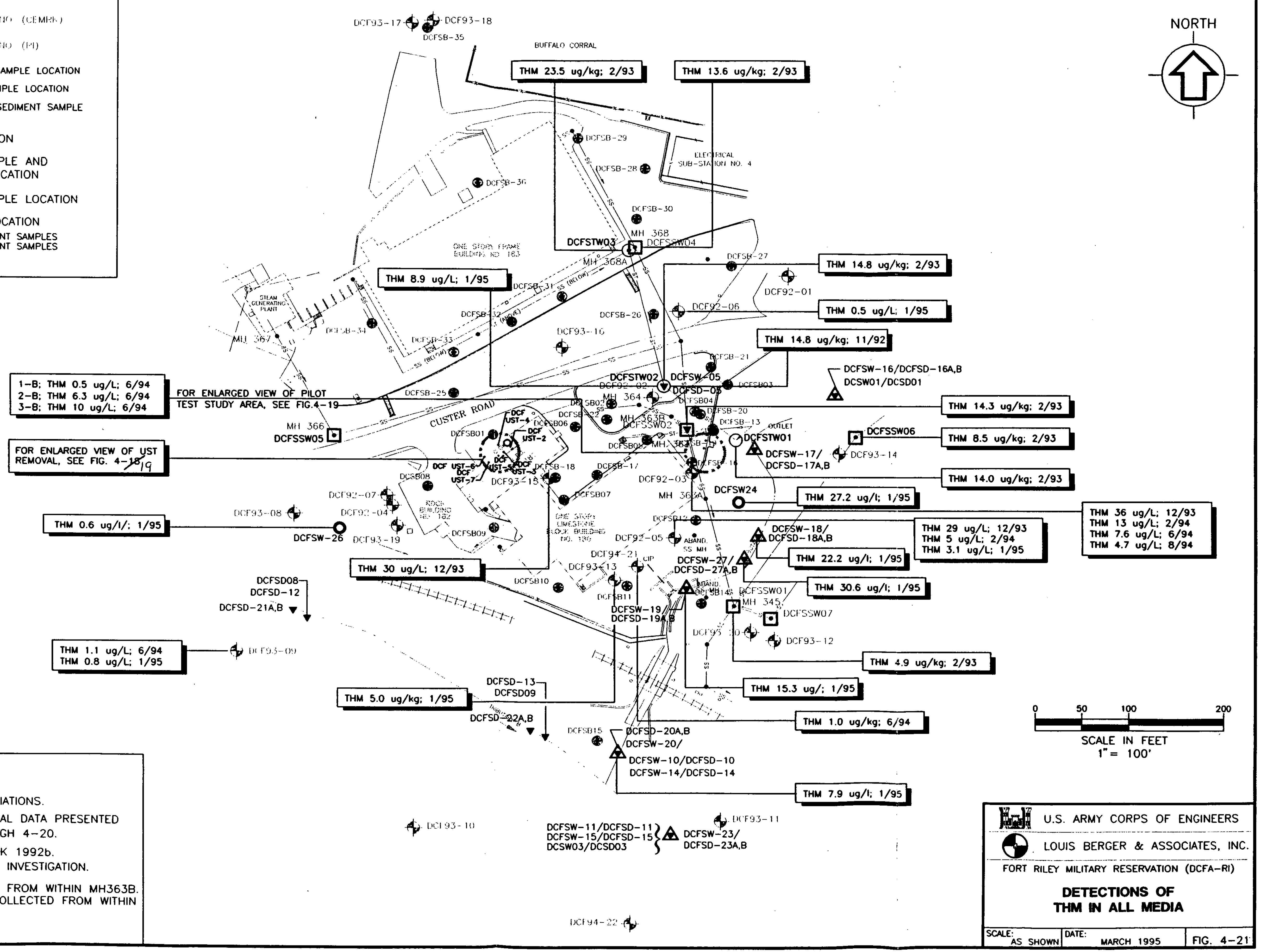
NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. REFERENCE: AFTER - CEMRK 1994i.
2. SEE TABLE 4-29 FOR LIST OF CHEMICAL DETECTIONS.

4-PCBFS/30MAR95

LEGEND

DCFSB05	◉	SOIL BORING LOCATION NO. (CEMRK)
DCFSB-16	◉	SOIL BORING LOCATION NO. (RI)
DCFSSW05	☐	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW03	○	STORM SEWER WATER SAMPLE LOCATION
DCFSD06	▼	SANITARY/STORM SEWER SEDIMENT SAMPLE LOCATION
DCFSW-26	○	SEEP SAMPLE LOCATION
DCSW01/ DCSD01	△	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION
DCFSW-17	△	SURFACE WATER SAMPLE LOCATION
DCFSD-22A,B	▼	SEDIMENT SAMPLE LOCATION A = 0'-1' DEPTH SEDIMENT SAMPLES B = 1'-2' DEPTH SEDIMENT SAMPLES



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. DATA CONSOLIDATED FROM ANALYTICAL DATA PRESENTED IN CHAPTER 4 TABLES; 4-1 THROUGH 4-20.
3. DCFSB01 THROUGH DCFSB15, CEMRK 1992b. DCFSB-16 THROUGH DCFSB-36, RI INVESTIGATION.
4. SAMPLE DCFSD-06 WAS COLLECTED FROM WITHIN MH363B. DCFSD-05 AND DCFSW-05 WERE COLLECTED FROM WITHIN THE CATCH BASIN.

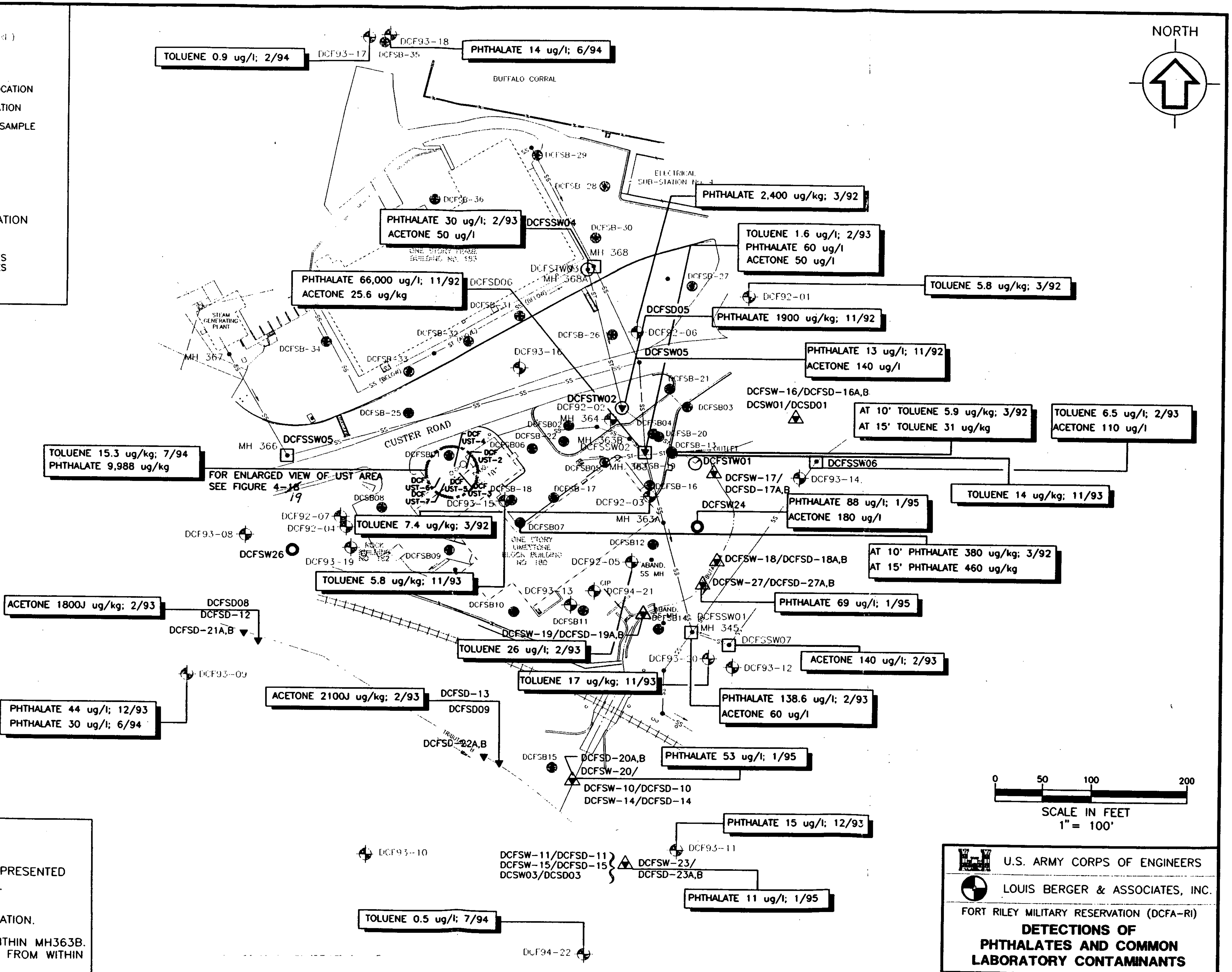
U.S. ARMY CORPS OF ENGINEERS
LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DETECTIONS OF THM IN ALL MEDIA

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 4-21

LEGEND

[illegible]	⊕	SOIL BORING, LOCATION; NO. (CEMRK)
DCFSB-16	●	SOIL BORING, LOCATION; NO. (RI)
DCFSSW05	□	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW03	○	STORM SEWER WATER SAMPLE LOCATION
DCFSD06	▼	SANITARY/STORM SEWER SEDIMENT SAMPLE LOCATION
DCFSW-26	●	SEEP SAMPLE LOCATION
DCSW01/ DCSD01	▲	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION
DCFSW-17	△	SURFACE WATER SAMPLE LOCATION
DCFSD-22A,B	▼	SEDIMENT SAMPLE LOCATION A = 0'-1' DEPTH SEDIMENT SAMPLES B = 1'-2' DEPTH SEDIMENT SAMPLES
J =		ESTIMATED CONCENTRATION



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. DATA CONSOLIDATED FROM ANALYTICAL DATA PRESENTED IN CHAPTER 4 TABLES; 4-1 THROUGH 4-20.
3. DCFSB01 THROUGH DCFSB15, CEMRK 1992b. DCFSB-16 THROUGH DCFSB-36, RI INVESTIGATION.
4. SAMPLE DCFSD-06 WAS COLLECTED FROM WITHIN MH363B. DCFSD-05 AND DCFSW-05 WERE COLLECTED FROM WITHIN THE CATCH BASIN.

U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

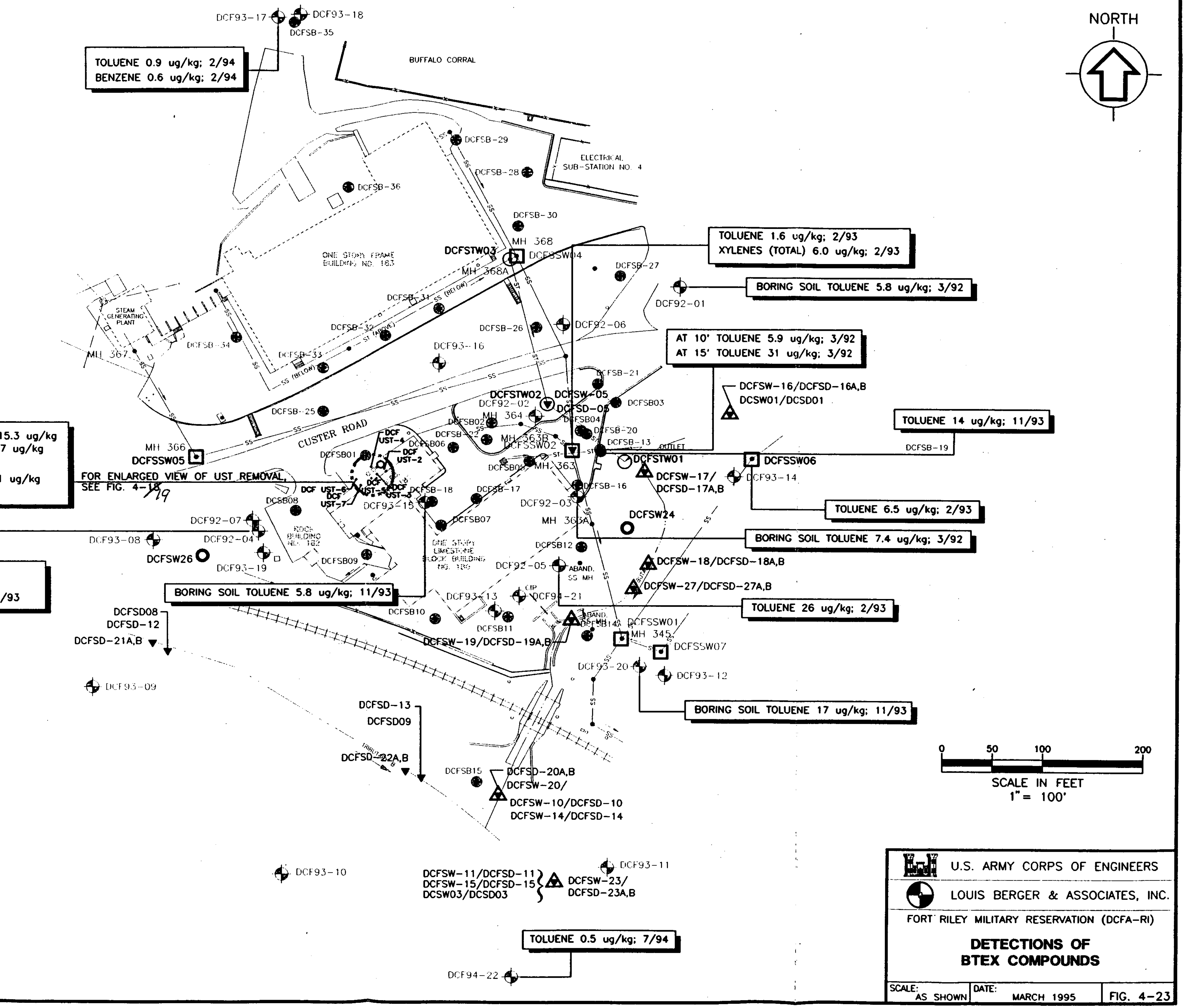
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DETECTIONS OF PHTHALATES AND COMMON LABORATORY CONTAMINANTS

SCALE: AS SHOWN | DATE: MARCH 1995 | FIG. 4-22

LEGEND

DCFSB15	●	SOIL BORING, LOCATION, NO. (CEMRK)
DCFSB-16	●	SOIL BORING, LOCATION, NO. (RI)
DCFSSW05	☐	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW03	○	STORM SEWER WATER SAMPLE LOCATION
DCFSD06	▼	SANITARY/STORM SEWER SEDIMENT SAMPLE LOCATION
DCFSW-26	**○**	SEEP SAMPLE LOCATION
DCSW01/ DCSD01	▲	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION
DCFSW-17	△	SURFACE WATER SAMPLE LOCATION
DCFSD-22A,B	▼	SEDIMENT SAMPLE LOCATION A = 0'-1' DEPTH SEDIMENT SAMPLES B = 1'-2' DEPTH SEDIMENT SAMPLES



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. DATA CONSOLIDATED FROM ANALYTICAL DATA PRESENTED IN CHAPTER 4 TABLES; 4-1 THROUGH 4-20.
3. DCFSB01 THROUGH DCFSB15, CEMRK 1992b. DCFSB-16 THROUGH DCFSB-36, RI INVESTIGATION.
4. SAMPLE DCFSD-06 WAS COLLECTED FROM WITHIN MH363B. DCFSD-05 AND DCFSW-05 WERE COLLECTED FROM WITHIN THE CATCH BASIN.

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LOUIS BERGER & ASSOCIATES, INC.

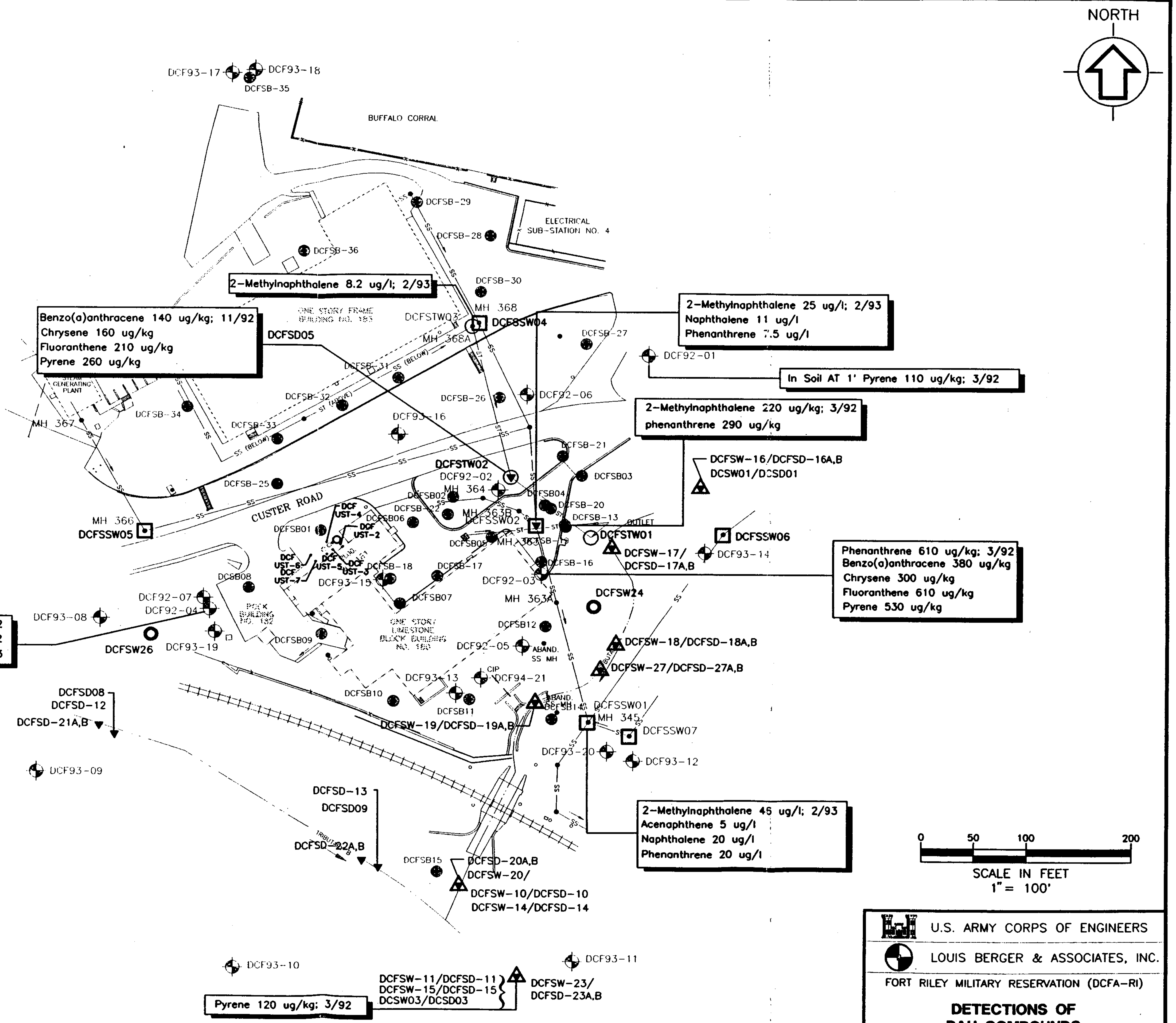
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DETECTIONS OF BTEX COMPOUNDS

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 4-23

LEGEND

DCFSB15	●	SOIL BORING, LOCATION, NO. (CEMRK)
DCFSB-16	●	SOIL BORING, LOCATION; NO. (RI)
DCFSSW05	☐	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW03	○	STORM SEWER WATER SAMPLE LOCATION
DCFSD06	▼	SANITARY/STORM SEWER SEDIMENT SAMPLE LOCATION
DCFSW-26	⭘	SEEP SAMPLE LOCATION
DCSW01/ DCSD01	▲	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION
DCFSW-17	△	SURFACE WATER SAMPLE LOCATION
DCFSD-22A,B	▼	SEDIMENT SAMPLE LOCATION A = 0'-1' DEPTH SEDIMENT SAMPLES B = 1'-2' DEPTH SEDIMENT SAMPLES



2-Methylnaphthalene 8.2 ug/l; 2/93

Benzo(a)anthracene 140 ug/kg; 11/92
Chrysene 160 ug/kg
Fluoranthene 210 ug/kg
Pyrene 260 ug/kg

2-Methylnaphthalene 25 ug/l; 2/93
Naphthalene 11 ug/l
Phenanthrene 7.5 ug/l

In Soil AT 1' Pyrene 110 ug/kg; 3/92

2-Methylnaphthalene 220 ug/kg; 3/92
phenanthrene 290 ug/kg

Phenanthrene 610 ug/kg; 3/92
Benzo(a)anthracene 380 ug/kg
Chrysene 300 ug/kg
Fluoranthene 610 ug/kg
Pyrene 530 ug/kg

Naphthalene 7.0 ug/l; 7/92
Naphthalene 5.4ug/l; 11/92
Naphthalene 6.7 ug/l; 5/93

2-Methylnaphthalene 45 ug/l; 2/93
Acenaphthene 5 ug/l
Naphthalene 20 ug/l
Phenanthrene 20 ug/l

Pyrene 120 ug/kg; 3/92

NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. DATA CONSOLIDATED FROM ANALYTICAL DATA PRESENTED IN CHAPTER 4 TABLES; 4-1 THROUGH 4-20.
3. DCFSB01 THROUGH DCFSB15, CEMRK 1992b. DCFSB-16 THROUGH DCFSB-36, RI INVESTIGATION.
4. SAMPLE DCFSD-06 WAS COLLECTED FROM WITHIN MH363B. DCFSD-05 AND DCFSW-05 WERE COLLECTED FROM WITHIN THE CATCH BASIN.

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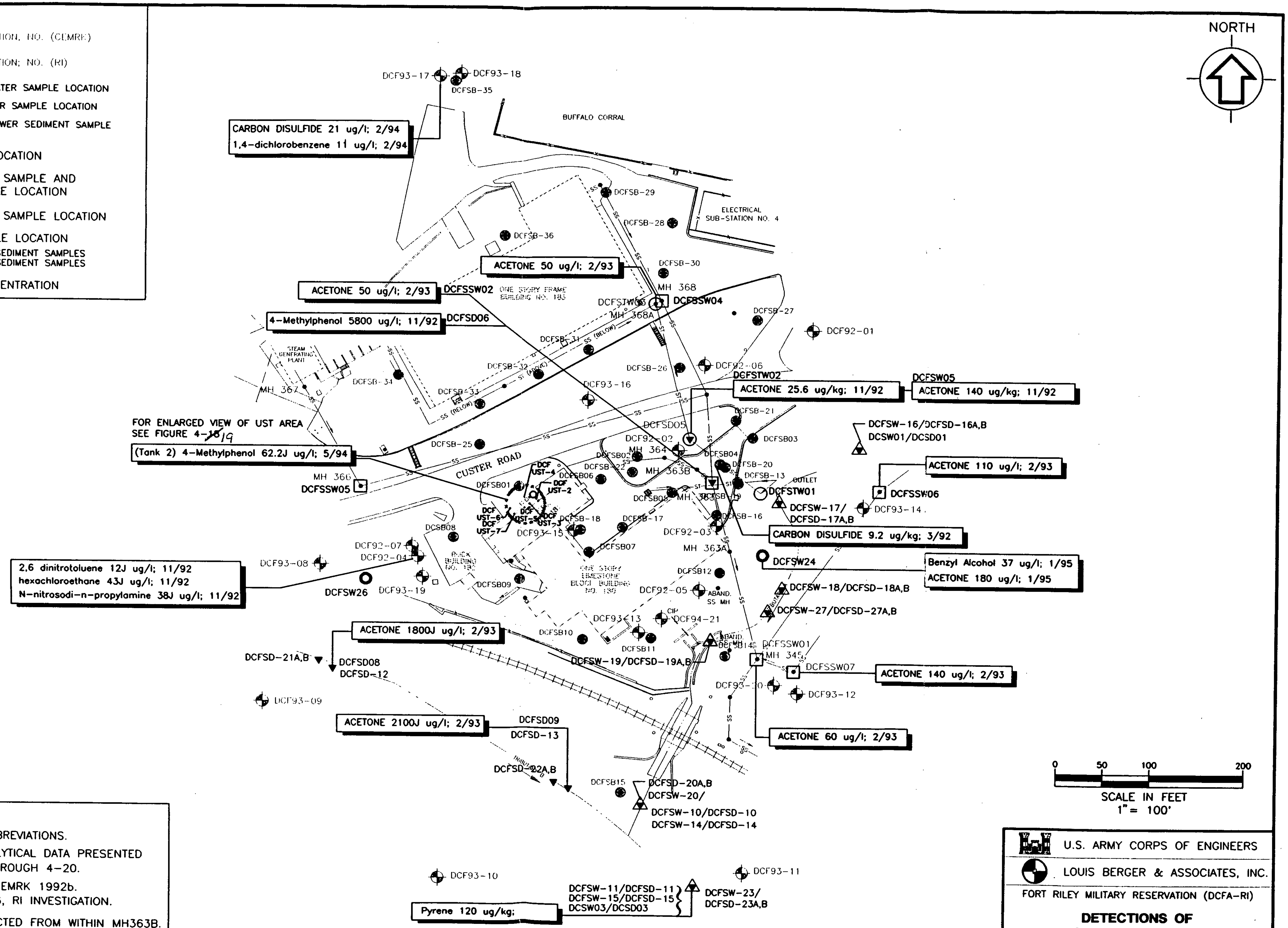
LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DETECTIONS OF PAH COMPOUNDS

SCALE: AS SHOWN
DATE: MARCH 1995
FIG. 4-24

LEGEND

DCFSB15	●	SOIL BORING, LOCATION, NO. (CEMRE)
DCFSB-16	●	SOIL BORING, LOCATION; NO. (RI)
DCFSSW05	☐	SANITARY SEWER WATER SAMPLE LOCATION
DCFSTW03	○	STORM SEWER WATER SAMPLE LOCATION
DCFSD06	▼	SANITARY/STORM SEWER SEDIMENT SAMPLE LOCATION
DCFSW-26	●	SEEP SAMPLE LOCATION
DCSW01/ DCSD01	▲	SURFACE WATER SAMPLE AND SEDIMENT SAMPLE LOCATION
DCFSW-17	△	SURFACE WATER SAMPLE LOCATION
DCFSD-22A,B	▼	SEDIMENT SAMPLE LOCATION A = 0'-1' DEPTH SEDIMENT SAMPLES B = 1'-2' DEPTH SEDIMENT SAMPLES
J =		ESTIMATED CONCENTRATION



NOTES:

1. SEE LIST OF SYMBOLS AND ABBREVIATIONS.
2. DATA CONSOLIDATED FROM ANALYTICAL DATA PRESENTED IN CHAPTER 4 TABLES; 4-1 THROUGH 4-20.
3. DCFSB01 THROUGH DCFSB15, CEMRK 1992b. DCFSB-16 THROUGH DCFSB-36, RI INVESTIGATION.
4. SAMPLE DCFSD-06 WAS COLLECTED FROM WITHIN MH363B. DCFSD-05 AND DCFSW-05 WERE COLLECTED FROM WITHIN THE CATCH BASIN.

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LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DETECTIONS OF OTHER CHEMICALS

SCALE: AS SHOWN
DATE: MARCH 1995
FIG. 4-25

TABLE OF CONTENTS

CHAPTER 5
FATE AND TRANSPORT OF CONTAMINANTS

Previous chapters have provided information on the environmental setting of the DCFA (Chapter 2), the investigation conducted (Chapter 3), and the nature and extent of contamination (Chapter 4) within the DCFA. This section describes the fate and transport of these contaminants via the various media: soils, groundwater, surface water/sediment, and air. To facilitate understanding of fate and transport, a review of physical and chemical properties of the contaminants is presented, and the potential routes of migration pathways within the various media are evaluated.

The transport assessment primarily addresses the potential subsurface migration pathways that are part of the Conceptual Site Model (CSM) (Chapter 2). A modeling approach is used to: (1) quantify the downward movement of contaminants (specifically PCE) from the unsaturated zone to groundwater; and (2) evaluate the migration of PCE and its breakdown products through the alluvial aquifer, and estimate the resulting concentrations in the Kansas River. The possible contribution through surface water flow for the tributaries into the river is included in this evaluation.

5.1 Physical and Chemical Properties

The physical and chemical properties of the analytes (or constituents) encountered during investigations at the DCFA are listed in Table 5-1. The properties listed are the molecular weight, vapor pressure, water solubility, Henry's law constant, and organic carbon partition coefficient (K_{oc}).

Both the vapor pressure and Henry's law constant express the fugacity of a compound when in contact with the atmosphere, i.e., its tendency to volatilize. The volatility of a pure compound is expressed by its vapor pressure; volatilization from water is expressed by Henry's law constant. The latter is a function of vapor pressure and water solubility (Howard, 1990). Chemicals with a vapor pressure less than 10^{-6} mm Hg mostly will be found associated with particulate matter (Howard, 1990). The Henry's law constant provides qualitative indication of the importance of volatilization from soil and water; for chemicals with values less than 10^{-7} atm-m^3/mole, the chemical is less volatile than water, and as water evaporates, the concentration will increase. This would apply to one of the PAHs found at the DCFA. For chemicals with Henry's law constant around 10^{-3} atm-m^3/mole or higher, volatilization will be rapid (Howard, 1990). For chemicals within the wide range of Henry's law constants between 10^{-7} atm-m^3/mole and 10^{-3} atm-m^3/mole, the degree of volatilization will follow the same trend; i.e., the higher the value, the faster the volatilization. This latter group includes all VOCs, except acetone, encountered at the DCFA (Table 5-1).

The K_{oc} value describes the tendency of a chemical to sorb onto organic matter. For undissociated, hydrophobic organic chemicals, sorption onto soil or sediment is often most strongly correlated with the organic carbon content of the medium. High K_{oc} values indicate stronger sorption and, consequently, less mobility of that compound in the environment.

Fifteen VOCs were detected in samples from the media collected within the DCFA: 10 halogenated compounds—tetrachloroethylene, 1,1,2-trichloroethane, trichloroethylene, DCE, dichloromethane, dibromochloromethane, bromodichloromethane, tribromomethane, trichloromethane, and vinyl chloride; and 5 nonhalogenated compounds—toluene, carbon disulfide, benzene, acetone, and ethylbenzene.

In general, VOCs exist in the vapor phase when released into the atmosphere and, because of water solubility characteristics, are subject to wet deposition (i.e., they are removed from the atmosphere by precipitation). If released to surface water, VOCs are subject to rapid volatilization to the air. The VOCs are degraded in the atmosphere by reaction with photochemically induced hydroxyl radicals. Bioconcentration and adsorption to sediments are not important removal processes. The VOCs released to subsurface soil tend to be transported to groundwater (Howard, 1990). VOCs do not exhibit strong sorption to soils or geologic materials when entrained as a dissolved constituent, such as might occur in sewage effluent, and will be transported through soils. Volatilization from soil (in limited effective areas) may occur in surface soils, as well as from subsurface soil, if the soil is exposed during utility repair or other excavation activities. Sampling within the DCFA suggests that the highest concentrations of VOCs are in the groundwater.

Semivolatile organic compounds (SVOCs) make up the remaining contaminants in the soil medium found within the DCFA. These include various PAHs: benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, 2-methylnaphthalene, phenanthrene, and pyrene. Other SVOCs encountered at the DCFA are bis(2-ethylhexyl)phthalate, di-n-octylphthalate, 2,6-dinitrotoluene, hexachloroethane, naphthalene, N-nitrosodi-n-propylamine and 1,4-dichlorobenzene. As a group, the SVOCs do not readily volatilize and are subject to much stronger adsorption onto soil and sediment than the VOCs. As a result, they are less mobile in the environment and are less likely to migrate to the groundwater. For this reason, SVOCs have been detected primarily during soil sampling and, with minor exceptions, not in groundwater monitoring wells within the DCFA (Table 4-25).

Degradation data, as expressed in half-life by environmental medium, are provided in Table 5-2. The first four columns in this table reflect removal due to various biochemical transformation processes; this table includes the volatilization half-life in surface water.

The range in values of the reported half-life for a given chemical in each medium reflects the dependence of biochemical transformations on site-specific conditions. These conditions include redox conditions, pH, temperature, and in the case of biodegradation, the presence or absence of microorganisms that can biodegrade the chemicals. The surface water volatilization rate will depend on the depth of the water body, rate of water flow, and presence or absence of waves. Therefore, the data provided in Table 5-2 should be used to compare the relative persistence of the different chemicals in the different media, rather than to predict their actual removal rates as part of the fate process.

5.2 Fate and Transport Processes

The following sections discuss the biochemical and transport processes that affect the ultimate fate and migration of the contaminants detected at the DCFA. The focus is on PCE and its breakdown products, TCE, DCE, and vinyl chloride, because PCE is the primary contaminant associated with the site.

5.2.1 Fate Processes

Chlorinated hydrocarbons, i.e., PCE and its breakdown products, are the primary contaminants encountered at the DCFA. This section describes the transformation pathways of chlorinated hydrocarbons in more detail. A chart showing the overall degradation pathways of chlorinated ethanes and ethylenes is presented (Figure 5-1). The time value indicated in this figure for each step in the transformation pathway is a relative measure of the rate of each transformation step, with higher values representing slower processes. The chart indicates that PCE may be formed as a result of the degradation of hexachlorethane and pentachloroethane. However, only a single detection of hexachloroethane has been made at the site, and no chlorinated ethanes are known to have been used at the DCF. Therefore, the general transformation pathways shown in Figure 5-1 can be simplified to:

PCE - TCE - 1,2-DCE - Vinyl chloride

Of the chlorinated solvents, only PCE has been used at the DCF. Therefore, the presence of TCE, DCE, and vinyl chloride at the site can be attributed to degradation of PCE. The degradation process is one of successive dehalogenation processes in an anaerobic, reducing environment. Conditions that favor degradation of PCE include water-logged conditions and high organic matter content. As indicated in Figure 5-1, the transformation of PCE into TCE and of TCE into DCE may occur rapidly if favorable conditions are present. The transformation of DCE into vinyl chloride occurs more slowly. This may help explain the observed small number of detections of vinyl chloride at the DCFA. Vinyl chloride degrades quite slowly, with a half-life on the order of years (Table 5-2). It is of interest to note that vinyl chloride has been detected consistently at only two of the monitoring wells at the site (DCF94-04 and DCF93-19). Analysis of metals during the PA/SI sampling found an elevated level of manganese at well DCF92-04, as well as high levels of TOCs (CEMRK, 1992a). All these factors indicate the existence of anaerobic reducing conditions, which would favor the breakdown of chlorinated solvents into vinyl chloride.

The VOCs encountered at the DCFA, with the possible exception of acetone and bromodichloromethane, have surface water volatilization half-lives on the order of hours (Table 5-2). Upon their introduction into surface water, i.e., the tributaries at the DCFA or the Kansas River, they are expected to disappear quickly by volatilization into the atmosphere. Dilling, et al. (1975) have experimentally measured the evaporation rates of a number of low-molecular-weight chlorinated hydrocarbons, including PCE and TCE, from water under ambient conditions. For a 1 μg/l initial concentration, they observed that 90 percent removal occurred in 63 minutes and 72 minutes for TCE and PCE, respectively.

5.2.2 Transport Processes and Potential Routes of Migration

All the contaminants encountered at the DCFA are present as water-dissolved constituents or are sorbed to soil and sediments. When introduced as a pure product, PCE may exist as a separate, dense non-aqueous phase liquid (DNAPL). In a U.S. EPA-funded review of DNAPLs in the environment, Cohen and Mercer (1991) concluded that the presence of a DNAPL is likely if groundwater concentrations exceed 1 percent of the aqueous solubility limit. The highest detected groundwater concentration of PCE at the DCFA is 1,600 μg/l; this corresponds to about 0.1 percent of the solubility of pure PCE. Therefore, the presence of DNAPL at the DCFA is not likely and will not be considered in the following discussion of contaminant transport processes.

1570

In the subsurface, the contaminants will migrate along with the water phase. The direction of movement is downward in the unsaturated zone and with the direction of groundwater flow in the saturated zone. Groundwater concentrations measured at the DCFA are low; therefore, density effects (sinking contaminants) are not of concern. In the saturated zone, the contaminants will also tend to spread out under the influence of hydrodynamic dispersion (Freeze and Cherry, 1979). The relative rate of movement of different chemicals will be largely controlled by their tendency to adsorb onto soil grains. Organics tend to adsorb most strongly onto natural organic matter. Therefore, the sorption of the various contaminants at the DCFA can be expressed as K_{oc} values (Table 5-1).

As a group, the VOCs have relatively low K_{oc} values. They are not subject to strong sorption, will leach readily from the soil, and will also migrate quickly in groundwater. The relative rate of migration of different chemicals can be expressed succinctly by the retardation factor (R), which is defined as follows (Freeze and Cherry, 1979):

$$R = 1 + \frac{\rho_b \cdot f_{oc} \cdot K_{oc}}{\theta} \qquad \textbf{(5.1)}$$

where:

ρ_b = Bulk density (g/ml),
f_{oc} = Fraction organic carbon,
K_{oc} = Organic carbon partition coefficient (ml/g),
θ = Volumetric water content.

An R value of 1.0 means that a compound is not sorbed at all and will move with the same velocity as water. A high R (K_{oc}) value, on the other hand, indicates strong sorption and slow migration in the water phase. Using as typical values: $f_{oc} = 0.002$, $\rho_b = 1.5$, and $\theta = 0.3$, an R value of 3 is obtained for PCE. In the case of vinyl chloride, the R value is 1.0. For vinyl chloride, sorption is negligible. Most of the SVOCs, with the exception of 2,6-dinitrotoluene and N-nitrosodi-n-propylamine, have high K_{oc} values. Therefore, they are much less mobile than the VOCs.

It should be noted that organic matter contents of soil and groundwater media may be quite variable, especially in alluvial deposits such as those encountered at the DCFA and along the Kansas River. Therefore, the calculation of a retardation factor as presented above is primarily for comparative purposes, to evaluate the relative mobility of different chemicals.

5.2.2.1 Soils

Soils are a complex of air, minerals, organic matter, and water, all of which affect the transportation of constituents. Surface soils are further complicated by diurnal and seasonal changes in temperature, which also affect the migration potential of constituents. The stratifications and relative permeability of the strata in the subsurface materials also add to the complexity of migration. In the DCFA, a large portion of the area is covered by impermeable roadways, parking lots, and building foundation materials, thus removing some of the effects of these variable factors. Infiltration of precipitation is reduced, as well as the potential for volatilization associated with temperature changes.

The frequency of detections of VOCs and SVOCs in soil and groundwater media is consistent with the different sorption behavior of the two groups of constituents. The source of contamination at the DCFA is the leaking sewer system, which has released constituents into the soil. In the case of the PAHs, they are likely to have been introduced through the existing fill material containing asphalt and other debris. The VOCs have migrated into the groundwater underneath the DCFA, as well as into the nearby alluvial aquifer. The SVOCs, on the other hand, remain in the soil and, with few exceptions, have not been detected in groundwater.

Over the longer term, the VOCs detected in the soil medium above the groundwater table may be expected to either biodegrade or leach into the groundwater under the influence of ambient recharge. The SVOCs in soil medium, on the other hand, are not expected to migrate significantly. Instead, they are expected to remain in the soil until they eventually degrade.

The estimates of PCE mass in soil and groundwater at the DCFA suggest that the greater amount of contaminant is in the soil. As such, there remains the possibility that leaching of PCE to the groundwater could occur.

An order-of-magnitude estimate of the potential rate of mass leaching from soils at the site into the groundwater can be developed as follows. In these calculations, the estimated average soil concentration and vertical extent of contamination, calculated in Chapter 4, are used. By assuming the soil column as a perfectly mixed batch reactor (Cushman and Ball, 1993), the rate of leaching can be estimated from the mass balance equation:

$$AD_s\rho_b\frac{dC_s}{dt} = -A\cdot I\cdot C_L \qquad (5.2)$$

where:

C_s = Soil concentration (mg/kg),
D_s = Thickness of contaminated soil zone (m),
A = Area of contamination (m^2),
I = Water infiltration (m/y),
C_L = Leaching concentration (mg/l),
t = Time (y), and
ρ_b = Soil bulk density (kg/l).

The above equation states that the rate of decrease of contaminant concentration in the soil is equal to the negative (decrease) of the contaminant concentration leaching into groundwater.

The relation between total soil concentration and leaching concentration can be estimated from the fraction organic carbon (f_{oc}) in the soil and the chemical's K_{oc} value as:

$$C_s = \left(f_{oc}K_{oc} + \frac{\theta}{\rho_b}\right)C_L \qquad (5.3)$$

where:

θ = Soil moisture content.

Using (5.3), the solution of (5.2) is:

$$C_L = C_L^0 e^{-\gamma t} \qquad (5.4)$$

where the coefficient γ is given by:

$$\gamma = \frac{I}{\rho_b D_S\left(f_{oc}K_{oc} + \frac{\theta}{\rho_b}\right)}, \qquad (5.5)$$

and C_L^0 is the initial leaching concentration.

The use of a partitioning equation (5.3) assumes that eventually all of the chemical in the soil medium will leach out. Equation (5.5) shows that for a given fraction of organic carbon in the soil, the leaching will proceed more quickly if the infiltration rate is high (larger I), the thickness of the contaminated soil zone is small (smaller D_s), and the K_{oc} is low. The infiltration rate, I, through soil at the DCFA is difficult to quantify and likely to be highly nonuniform. Where the soil surface has been paved over, the infiltration rate will be zero or very low. On the other hand, even though the sewer lines no longer act as a contamination source, any effluent released would cause a locally higher infiltration rate through the soil medium underneath leaking sewers.

Acknowledging this uncertainty as well as the simplifications in (5.2), it is still useful to estimate the rate of leaching from soils to assess the contribution of contaminants in the soil as a potential source to the groundwater system. As part of the RI at the Southwest Funston Landfill (CEMRK, 1994g), an infiltration rate of 2 inches/year (0.0508 meters/year) was estimated for silt loam soil. The calculations in Chapter 4 indicated that the higher percentage of PCE is in the 10- to 20-foot soil layer ($D_s = 3.1$ m), with an average concentration of $C_s = 200$ μg/kg. Using $f_{oc} = 0.002$, $\rho_b = 1.5$ g/ml, $\theta = 0.2$, and K_{oc} values from Table 5-1, the rate of leaching from soil can be calculated. Using (5.3) and the starting value of $C_s = 200$ μg/kg, the corresponding initial leaching concentration is $C_L^0 = 363$ μg/l. The result of these calculations for PCE is shown in Figure 5-2. This figure shows the concentration leaching from the soil as a function of time. The curve asymptotically approaches zero, which represents complete leaching of all the contaminant mass from the soil. Figure 5-2 indicates that this might take on the order of 100 years or more. As mentioned, this calculation ignores degradation of the contaminants. Depending on the rate of leaching as compared to in situ degradation, contaminants in soils may degrade more quickly than they can leach. The time-scale of the two processes can be compared in terms of their respective half-lives. Chemical degradation half-lives for soil are presented in Table 5-2. An equivalent half-life for physical removal due to leaching can be calculated from (5.5) as:

$$t^{1/2} = \frac{\ln(2)}{\gamma} \tag{5.6}$$

This leaching half-life represents the time required for the leaching concentration to be reduced to 50 percent of its original value. Alternatively, it also represents the time for half of the contaminant mass to be removed by leaching.

For PCE, with a K_{oc} value of 209 ml/g, the resulting value of the leaching half-life is:

$$\begin{aligned} t^{1/2} &= \frac{(0.6931)\,(1.5)\,(3.1)\left((0.002)\,(209) + \dfrac{0.2}{1.5}\right)}{0.0508} \\ &= 35y \end{aligned} \tag{5.7}$$

By comparison, Table 5-2 shows a chemical half-life for PCE in soils of 0.5 to 1 year. This indicates that under ambient infiltration conditions, the bulk of the PCE mass in soil will be removed by biochemical degradation rather than by leaching to groundwater. Volatilization and vapor-phase diffusion will also tend to reduce leaching.

5.2.2.2 Groundwater

This section evaluates the potential for migration of contaminants into and through groundwater in the alluvial aquifer that underlies the Kansas River floodplain.

Analytical data for samples collected from groundwater monitoring wells located on "The Island" south of the DCF (wells DCF93-09, DCF93-10, DCF93-11, and DCF94-22) indicate PCE and its breakdown products in the alluvial aquifer. The general groundwater flow direction in the alluvial aquifer is along the direction of flow in the Kansas River (Fader, 1974). Constituents released into the alluvial aquifer at the DCFA will migrate in an easterly direction. The U.S. Geological Survey (USGS) in Manhattan, Kansas has conducted extensive hydrogeological studies of the alluvial aquifer along the Kansas River and the Republican and Smoky Hill Rivers (Myers and Bigsby, 1989; Wolf and Helgesen, 1992). The interaction between the alluvial aquifer and the Kansas River has also been studied during the RI/FS of the Southwest Funston Landfill (CEMRK, 1994g). The groundwater-river interaction was discussed directly with the USGS (personal communication, USGS Hydrogeologist, 1994), specifically to evaluate the possibility of cross-flow underneath the river. The river is regarded by the USGS to act as a hydraulic boundary, with no groundwater cross-flow. During periods of high river stage, the river will recharge the groundwater, while during periods of low river stage, the groundwater will discharge to the Kansas River. Base flow in the river during extended periods of little or no precipitation is sustained by groundwater discharge. Because the river meanders, the floodplain pinches out approximately 500 meters east of the DCFA. Therefore, this location represents the likely groundwater discharge point. This also implies that further off-site migration of contaminated groundwater beyond this discharge location is unlikely.

Owing to the paucity of off-site groundwater monitoring data and river water quality data, a modeling approach was used to estimate alluvial groundwater concentrations away from the DCFA and to estimate potential contaminant loadings to the river.

Three-dimensional advective-dispersive transport of contaminants through the alluvial aquifer was simulated using a modified version of the U.S. EPA's Composite Model for Landfill (EPACML) leachate migration (U.S. EPA, 1990). The EPACML saturated zone transport model consists of an analytical three-dimensional solution for contaminant transport in a finite thickness aquifer under steady-state flow conditions. The contaminant source boundary condition is modeled as a vertical patch source with a Gaussian concentration distribution, described by a highest concentration at the center of the source and a standard deviation describing the width of the patch source. The assumptions associated with this analytical model include a uniform aquifer with a constant saturated thickness, and unidirectional and steady-state groundwater flow. Effects of recharge are ignored. A recent application of a two-dimensional version of this model for risk assessment is described by Cushman and Ball (1993). The modifications involve the extension of the model to accommodate multi-species transport with chained transformation relations (Sudicky, et al., 1991). This allows modeling of PCE and its breakdown products (TCE, DCE, and vinyl chloride).

Because the groundwater model considers only migration through the alluvial aquifer, the "source" location is not at the DCFA but, rather, the location where groundwater contaminants enter the alluvial aquifer adjacent to the DCFA. Because the simultaneous fate and transport of PCE, TCE, DCE, and vinyl chloride is modeled, source concentrations for all four compounds must be entered. The groundwater monitoring well with the highest detected concentrations was used to represent the source location. The selected well is DCF93-09, with a highest detected PCE concentration of 160 μg/l (Table 4-20) in the alluvium. The source concentrations for TCE and DCE were set to the highest detected level of these chemicals at this well. No vinyl chloride has been detected at this or any other groundwater monitoring well in the alluvium. This result is not inconsistent with detections of vinyl chloride in groundwater at the DCFA and groundwater flow from the DCFA into the alluvial aquifer. Because vinyl chloride is the breakdown product, its presence will lag behind PCE, TCE and DCE. Vinyl chloride was found at only three wells (DCF92-04, DCF93-08 and DCF93-19) at the DCFA, and the amount present at the DCFA may not be sufficient to cause detectable concentrations in the alluvium as a result of the mixing with ambient groundwater in the alluvial aquifer. Nevertheless, because the groundwater model accounts for the breakdown process, the model predicts the appearance of vinyl chloride as part of the transport simulation. For modeling purposes, it was assumed that the concentrations at well DCF93-09 would remain at their highest detected levels. This is a conservative assumption considering that the actual well monitoring data show a distinct decrease in concentration levels since February 1994 (Table 4-20). Retardation factors and transformation rates used in the modeling were obtained from the K_{oc} values and groundwater half-lives listed in Tables 5-1 and 5-2. To obtain conservative modeling results, i.e., high-end concentration estimates, the high value of the half-life shown in Table 5-2 was used, i.e., 2 years for PCE, 5 years for TCE, 8 years for DCE, and 8 years for vinyl chloride.

Table 5-3 presents estimated hydraulic conductivity values using various references (Schwab-Eaton, 1975; Myers and Bigsby, 1989; Wolf and Helgesen, 1992), the hydraulic gradients and computed flow rates. The model input parameters used in the calculations are summarized in Table 5-4. The average value of hydraulic conductivity and gradient = 5.5×10^4 m/y and 0.0012, respectively (Table 5-3) were used as input parameters. The saturated thickness of the alluvial aquifer is an average of values reported by Fader (1974). Dispersivity values were estimated from the travel distance to various receptor locations, using the relation suggested in U.S. EPA (1992e), but with maximum values imposed as shown in Table 5-4.

Results of the analysis are presented in Figure 5-3. The solid line in this figure depicts the steady-state groundwater concentrations of PCE along the concentration centerline as a function of downstream distance from the DCFA. The dashed lines represent the different breakdown products. The concentration profiles shown for the different chlorinated compounds reflect their respective persistence. Of the four compounds considered, PCE degrades most rapidly (shortest half-life). Although PCE has been detected at the highest concentrations at and near the DCFA, its concentration is reduced most rapidly with increasing distance. At distances of 150 meters (450 feet) or greater, the model predicts that the contaminants will be mainly in the form of TCE and DCE. At distances of 2,200 meters (1.4 miles) or greater, vinyl chloride is predicted to be the compound with the highest concentration. This is because vinyl chloride is the final breakdown product modeled, and it degrades quite slowly.

The source concentration values used in the model for both PCE (160 μg/l) and TCE (13 μg/l) exceed the maximum contaminant level (MCL) value (5 ppb for both chemicals). Nevertheless, the modeling results indicate that concentration values fall below the MCL within a relatively short distance, i.e., about 150 meters. DCE has a considerably higher MCL (70 ppb for the *cis*-isomer), and its concentrations always remain below the MCL. The model predicts that vinyl chloride concentrations actually increase with distance up to about 2,000 meters. The highest predicted vinyl chloride concentration is 0.6 μg/l as compared with an MCL of 2 μg/l.

The approximate distances of various locations of interest are marked on Figure 5-3. The first location denotes the discharge point into the Kansas River. This location is expected to be where discharge from the groundwater into the river might occur. The location "Irrigation Well" marks the distance to the private irrigation well located in the floodplain just south of Camp Funston. "Ogden" marks the distance to the wellfield in the town of Ogden.

The predicted concentrations depicted in Figure 5-3 represent a number of highly conservative assumptions:

- Continuous, steady-state release of contaminants;
- Source concentration at center of migration equal to maximum detected alluvial groundwater concentration; and
- No discharge of contaminants to the Kansas River, and no recharge of uncontaminated water from the river.

The results in Figure 5-3 show that even under these conservative assumptions, the concentrations of PCE or any of its breakdown products at the various marked locations are all well below federal MCLs. Under present conditions, residents in the town of Ogden represent the nearest off-site receptors for the groundwater pathway. The straight-line distance from the DCFA to the Ogden wellfield is about 5.5 miles (8,800 meters). The model-predicted maximum concentration at this distance is 0.1 μg/l for vinyl chloride and 0.02 μg/l for DCE (Figure 5-3). The average groundwater velocity in the alluvial aquifer is 180 meters/year; contaminants traveling at the same rate would require nearly 50 years to reach this distance. This implies also that chemicals would have to continue to be released at the modeled rate for at least 50 years.

The actual likelihood of any chemicals migrating via the groundwater pathway to the town of Ogden is extremely remote. As previously indicated, The Island floodplain pinches out against the Kansas River, approximately 500 meters east of the DCFA. Studies of the groundwater interaction with the river indicate that the Kansas River behaves as a boundary to groundwater flow (personal communication, USGS Hydrogeologist, 1994). Therefore, the expectation is that the contaminants in the alluvial groundwater will discharge to the river rather than migrate farther downstream via the groundwater pathway.

This conclusion is confirmed by available sampling data from the private irrigation well south of Camp Funston. This well was sampled during the RI of the Southwest Funston Landfill; no VOCs or SVOCs were detected in the alluvial groundwater at this location (CEMRK, 1994g).

5.2.2.3 Surface Water/Sediment

The occurrence of surface water and, thus, the potential for accumulation of sediments, is limited in the immediate area of the DCFA. Tributaries A and B are ephemeral-to-intermittent streams from which samples could not always be collected.

For those sampling events for which they were collected, few chemicals were detected. This may be because the contaminants are generally volatilized in the surface water and are likely volatilized from the sediments when the sediments are intermittently exposed. Another possible reason for the absence of contaminants in the sediments is that the flood of 1993 removed sediments containing contaminants. A small number of VOCs and SVOCs were detected in the sediments along Tributaries A and B during the initial sampling of the PA/SI, which was conducted prior to the flooding in the spring of 1993. Subsequent sampling of these sediments during the RI did not show any positive detections of SVOCs. VOCs were detected in the January 1995 RI sampling in the surface water; however, the chemicals are all trihalomethane (THM). The most important surface water body in the vicinity of the DCFA is the Kansas River. The significance of the surface water pathway for off-site migration of contaminants may be evaluated in terms of the water quality impact to the Kansas River.

Chemicals may reach the river by one of two pathways: groundwater discharge or surface water inflow via Tributaries A and B. Tributary B is a small ephemeral stream that picks up flow primarily from

Tributary A, and to a limited extent from upstream of the DCFA, and empties into the river east of the DCFA (Figure ES-2). River concentrations due to surface water inflow can be estimated from concentrations detected in Tributary A adjacent to DCFA. Under the conservative assumption that there are no losses of chemicals en route, i.e., no volatilization, and using a simple dilution approach, concentrations can be estimated. Fader (1974) reported the baseflow in the Kansas River to be about 700 cubic feet per second (cfs). For an average flow in Tributary B of 0.5 cfs (225 gpm), the dilution of chemicals after mixing with the ambient river water would be:

$$DF_{sw} = \frac{700}{0.5} = 1400, \tag{5.8}$$

where DF_{sw} is the surface water dilution factor; i.e., the expected concentration in the river due to surface water inflow would be $\frac{1}{1400}$-th of the concentration in the tributary adjacent to the DCFA. In the case of PCE, the maximum detected concentration in Tributary A is 4.5 μg/l; the resulting concentration in the Kansas River would be:

$$C_{river} = \frac{4.5}{1400} = 3.2\ 10^{-3}\ \mu g/l. \tag{5.9}$$

In the case of contaminated groundwater discharging to the river, a similar dilution factor can be estimated from the ratio between the volumetric rate of contaminated groundwater discharge and the ambient flow in the river.

The concentration in the alluvial groundwater, at the shortest distance to the river, is about 0.4 μg/l for PCE (Figure 5-3). The concentration in the river resulting from discharge of contaminated groundwater can be estimated from the ratio between the volumetric rate of groundwater recharge and the ambient flow in the river. Assuming spreading of the groundwater concentration by dispersive mixing, the width of the zone of groundwater contamination at its intersection with the river would be:

$$Y_{contaminant} = 2(3\sigma + 3\sqrt{2\ \alpha_T\ \chi}), \tag{5.10}$$

where:

σ = Contaminant standard deviation at the contaminant origin,
α_T = Transverse dispersivity, and
χ = Travel distance from the contaminant origin.

The parameter σ has a value of 15.2 meters, and the distance to the potential discharge point into the river is about 480 meters (1,575 feet); a corresponding value for α_T is (U.S. EPA, 1992f):

$$\begin{aligned} \alpha_T &= 0.02\chi \\ &= 9.6\ m \end{aligned} \tag{5.11}$$

Therefore, the resulting value for $Y_{contaminant}$ is:

$$\begin{aligned} Y_{contaminant} &= 2(45.6 + 3\sqrt{2\times9.6\times480}) \\ &= 667.2\ m \end{aligned} \tag{5.12}$$

The rate of groundwater discharge to the river reportedly varies between 2.2 and 4.3 cfs/mile (Fader, 1974). Using the higher of the two values, and the estimated width of the contaminated groundwater zone, the rate of contaminated groundwater inflow is approximately:

$$\frac{667.2}{1609} * 4.3 = 1.8\ cfs \tag{5.13}$$

where the constant 1609 converts meters to miles. Defining the river dilution factor as the rate of river baseflow to groundwater inflow and assuming that the average inflow concentration is half the contaminant center line concentration, or 0.2 μg/l, the predicted river concentration is:

$$C_{river} = \frac{1.8}{700} * 0.2 = 5.1 * 10^{-4}\ \mu g/L.$$

Adding the contributions of surface water inflow and groundwater discharge, the maximum PCE concentration in the river would be about $3.2\times10^{-3} + 5.1\times10^{-4} = 3.7\times10^{-3}$ μg/l. This concentration is more than 200 times below the Federal Ambient Water Quality Criteria level of 0.8 μg/l for consumption of water and fish.

The simulated groundwater concentrations at the discharge location to the river for the PCE breakdown product are 2.0 μg/l for TCE, 2.1 μg/l for DCE, and 0.5 μg/l for vinyl chloride. Using a similar dilution calculation for these compounds as described above, the estimated concentrations in the Kansas River are as follows:

- TCE: 2.6×10^{-3} μg/l
- DCE: 2.7×10^{-3} μg/l
- Vinyl chloride: 6.4×10^{-4} μg/l

These calculations represent a high-end estimate of the expected concentrations in the Kansas River. For instance, in the case of PCE, the calculations indicate that inflow from Tributaries A and B would be the main contribution to contamination of the river. This calculation is based on a one-time detected maximum concentration in Tributary A and disregards the fact that VOCs will likely volatilize completely before reaching the river.

In the case of TCE, DCE, and vinyl chloride, groundwater is the only pathway that contributes to discharge of contaminants to the river. Although biodegradation of the chlorinated compounds is included in the groundwater pathway modeling, volatilization from the river is ignored as a removal mechanism in calculating the river concentrations.

Detection limits for PCE and its breakdown products in water are on the order of 0.5 to 1 μg/l. The predicted concentrations are all at least 2 orders of magnitude below detection limits. This result is consistent with available sampling data from the Kansas River. During the RI of the Southwest Funston Landfill, a background surface water quality sample was collected from the Kansas River upstream of the discharge point from the Main Post Wastewater Treatment Plant (CEMRK, 1994g). The only organic constituent detected was dichloromethane. The level was less than 10 times the blank level, which indicates sample or laboratory contamination.

5.2.2.4 Air

The fate and transport of chemicals found within the DCFA in air is of concern to the extent that soils and/or groundwater containing chemicals are brought to the surface. Because the contaminants are predominantly volatile compounds, areas within the immediate vicinity of any exposure would be most affected. Prevailing wind direction at the time of bringing any contaminated soils to the surface would dictate the direction of transport. Because of their vapor pressure, VOCs would readily volatilize to the atmosphere from a surface (Table 5-1). Degradation in the atmosphere would proceed through either photochemical reaction, oxidation, or reductive dehalogenation. The degradation half-life of PCE is on the order of 16 to 160 days, depending on atmospheric physical and chemical conditions. Values for degradation products of PCE are similar (Table 5-2).

During repair of the sanitary sewer line, air monitoring was conducted at several locations around the site. No detections of VOCs were recorded in early May 1994 during the course of this work. These detection limits were 22.8 ppb for PCE, 34.5 ppb for dichloromethane, and 5.3 ppb for 1,1,1-trichloroethane (U.S. EPA, 1994b).

5.3 Summary

The evaluation of fate and transport in this chapter provides information on the factors influencing the movement and persistence of VOCs and SVOCs detected at the site. VOCs are characterized by low sorption onto soils or sediments and, therefore, relatively rapid migration along with water movement. They will tend to volatilize rapidly when exposed to the atmosphere, and/or released to surface water. The detections of TCE, DCE and vinyl chloride are consistent with the breakdown of PCE. The occurrence of PCE in both soils and groundwater, and of the PCE breakdown products predominantly in groundwater at the DCFA and the adjacent alluvial aquifer, is consistent with the dominant migration pathways identified in the CSM, and the fate and transport characteristics of the chlorinated solvents.

The evaluation of leaching from soil indicates that, under natural recharge conditions, little downward movement of contaminants is expected to occur. Therefore, the detections of PCE and its breakdown products in groundwater and the concentration levels found imply a source of increased infiltration, which points to the leaking sewers as a primary source of PCE contamination in the subsurface.

The groundwater transport modeling analysis of the migration of PCE and its breakdown products through the alluvial aquifer (Figure 5-3) shows a rapid drop-off of PCE, TCE and DCE concentrations with distance as a result of dispersive mixing and degradation. The concentration of vinyl chloride first increases and then gradually decreases, but never exceeds 0.6 μg/l. Model-predicted concentrations of PCE and TCE are reduced to below MCLs within approximately 150 m (500 ft) from well DCF93-09 which was taken as the "source" location in the groundwater model.

Calculations of river water concentrations were made considering discharge into the river from the alluvial aquifer and inflow via Tributaries A and B. The predicted concentration of PCE is on the order of 10^{-3} μg/l; values for the PCE breakdown products are similar. The calculations did not consider volatilization, which will be a dominant removal mechanism in surface water. Even so, the predicted values are very low. This result is consistent with the absence of detections of PCE or any of the other chemicals associated with the DCFA in the river reported in the Southwest Funston Landfill RI report (CEMRK, 1994g).

TABLE 5-1
PHYSICAL AND CHEMICAL PROPERTIES OF ANALYTES ENCOUNTERED DURING INVESTIGATIONS AT THE DCFA
Dry Cleaning Facilities Area
Fort Riley, Kansas

VOCs	Mol. (1) Weight (g/mole)	Vapor Pressure (1) (mm Hg)^a	Water (1) Solubility (mg/l)^a	Henry's Law (4) Constant (atm-m^3/mole)	K_{oc}^{b} (4) (ml/g)
Acetone	58.1	231	NAv	3.67×10^{-5}	NAv
Benzene	78.1	95.19	1791	0.00543	31-143
Bromodichloromethane	163.8	50@20°C	4700@22°C	0.0016	53-251
Carbon disulfide	76.1	297@20°C	2100@20°C	0.0014	63
Trichloromethane	119.4	246	7950	0.00435	34
Dibromochloromethane	208.3(2)	15@10.5°C	4000(3)	0.060	NAv
1,2-Dichloroethylene	96.9	340	600	0.0067	36
Ethylbenzene	106.2	9.53	161	8.44×10^{-3}	164
Dichloromethane	84.9	434.9	13,000	0.00268	1.7
Tetrachloroethylene	165.8	18.49	1503	0.0149	209
Toluene	92.1	28.4	534.8	0.00594	37-178
Tribromomethane	252.8	5.6mm@25°C	3,190@30°C	5.6×10^{-4}	282
Trichloroethylene	131.4	69.0	1100	0.0103	87-150
1,1,2-Trichloroethane	133.4	30.3@20°C	4420@20°C	1.2×10^{-3}@20°C	70
Vinyl chloride	62.5	2660	2763	0.0107	0.40
SVOCs					
Benzo(a)anthracene	228.3	1.1×10^{-7}	0.009	2.3×10^{-8}	1.3×10^{6}
Benzo(a)pyrene	252.3	5.5×10^{-9}	0.004	2.4×10^{-6}	8.9×10^{5}
Bis(2-ethylhexyl)phthalate	390.0	6.2×10^{-8}	0.4	1.1×10^{-5}	1.0×10^{5}
Chrysene	228.3(2)	6.3×10^{-9} (4)	1.8×10^{-3} (3)	1.05×10^{-6}(3)	2.0×10^{5}(3)
Di-n-octyl phthalate	390.6	1.2@200°C	0.285@24°C	1.41×10^{-12}@25°C	977×10^{6}
2,6-Dinitrotoluene	182.1	0.02	1320.0	3.3×10^{-7}	91.2
Fluoranthene	202.3(2)	5.0×10^{-6}(3)	2.65×10^{-1}(1)	6.5×10^{-6}(3)	3.8×10^{4}(3)
Hexachloroethane	237.0	0.79	50.0	2.5×10^{-3}	1.9×10^{4}
2-Methylnaphthalene	142.2(2)	6.8(2)	2.7×10^{1} (3)	4.1×10^{-4}(2)	2511(2)
Naphthalene	128.2	0.23	30.0	4.6×10^{-4}	1290
N-nitrosodi-n-propylamine	130.2	NAv	9900.0	NAv	10
Phenanthrene	178.2(1)	9.6×10^{-4} (3)	0.816(1)	2.26×10^{-4}(3)	1.4×10^{4}(3)
Pyrene	202.3(1)	2.5×10^{-6}(3)	0.160(1)	5.1×10^{-6}(3)	3.8×10^{4}(3)

Notes:

Data from Howard (1989, 1990) unless otherwise indicated.

(1) Verschueren, K. (1983). Handbook of Environmental Data on Organic Chemicals, 2nd Edition, Van Nostrand Reinhold, New York.

(2) Mackey, D., Shiu, W.Y., Ma, K.C. (1992). Illustrated Handbook of Physical-Chemical Properties and Environmental Fate for Organic Chemicals, Lewis Publishers, Boca Raton, FL.

(3) EPA, December 1979. Water-Related Rate of 129 Priority Pollutants, EPA/440/4-79/029, Washington, DC.

(4) Montgomery, J. H., Welkom, L. M., Groundwater Chemicals Desk Reference, Lewis Publishers, 1990 Chelsea, MI
At 25°C unless otherwise indicated.

° Soil organic carbon/water partition coefficient.

NAv Not Available.

TABLE 5-2
DEGRADATION DATA FOR ANALYTES ENCOUNTERED WITHIN THE DCFA
Dry Cleaning Facilities Area
Fort Riley, Kansas

VOCs	Chemical Half-Life				
	Soil	Surface Water	Air	Ground Water	Volatilization Half-Life (hrs)
Acetone	NAv	NAv	NAv	NAv	20
Benzene	5-16d	5-16d	2-20d	10d-2y	2.7
Bromodichloromethane	0.5-12d	0.5-12d	4m	ND	35
Carbon disulfide	3m-1y	3h-9d	9d	3m-1.1y	2.6
Trichloromethane	4w-6m	4w-6m	26-260d	8w-5y	4
1,2-Dichloroethylene	4w-6m	4w-6m	1-12d	8w-8y	NAv
Dibromochloromethane	28d-6m	28d-6m	6.1w-1.2y	14d-6m	3-3.1
Ethylbenzene	3-10d	3-10d	0.24-24h	6d-7.5m	NAv
Dichloromethane	7-28d	7-28d	19-190d	14d-8w	3-5.6
Tetrachloroethylene	6m-1y	6m-1y	16-160d	1-2y	Minutes-several hrs
Toluene	4-22d	4-22d	10h-4.3d	7-28d	2.9-5.7
Tribromomethane	4w-6m	4w-6m	54d-541d	8w-12m	NAv
Trichloroethylene	0.5-1y	0.5-1y	1.1-11d	1-5y	Minutes-several hrs
1,1,2-Trichloroethane	4.5m-1y	4.5m-1y	8.1d-11.6w	4.5m-13.4y	0.3
Vinyl chloride	4w-6m	4w-6m	10-97h	8w-8y	0.8
SVOCs					
Benzo(a)anthracene	100d-1.9y	1-3h	1-3h	200d-3.8y	180 @ 25°C (4)
Benzo(a)pyrene	57d-1.5y	0.4-1.1h	0.4-1h	114d-3y	600 @ 25°C (4)
Bis(2-ethylhexyl)phthalate	5-23d	5-23d	2.9-29h	10-389d	NAv
Chrysene	1-2.7y	4.4-13h	0.8-8h	2-5.5y	NAv
Di-n-octyl phthalate	7d-4w	7d-4w	1.9d	14d-1y	NAv
2,6-Dinitrotoluene	4w-6m	2h-1d	1d	2d-1y	NAv
Fluoranthene	4.6-14.4m	21-63h	2-20h	9m-2.4y	NAv
Hexachloroethane	4w-6m	4w-6m	8-80y	8w-1y	15
2-Methylnaphthalene	NAv	2.4-2.6w(1)	NAv	NAv	NAv
Naphthalene	17-48d	12h-20d	3-30h	1-258d	4.1-5
N-nitrosodi-n-propylamine	3w-6m	0.2-1h	0.2-1h	6w-1y	NAv
Phenanthrene	16d-6.5m	3-25h	2-20h	32h-1y	NAv
Pyrene	30w-5.2y	0.7-2h	0.7-2h	60d-10.4y	NAv

Notes:

(1) Zepp, R.G., Scholtzhauer, P.F. (1979). Photoreactivity of selected aromatic hydrocarbons in water. In: Polynuclear Aromatic Hydrocarbons. Jones, P.W., Leber, P., Editors, Ann Arbor Sci. Publ. Inc., Ann Arbor, MI, pp.141-58.

min:	minute	w:	week	d:	day
h:	hour	m:	month	y:	year

Source (unless otherwise indicated): Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M., Michalenko, E.M., Editors (1991). Handbook of Environmental Degradation Rates, Lewis Publishers, Inc., Chelsea, MI.

TABLE 5-3
GROUNDWATER FLOW RATES IN ALLUVIAL AQUIFER
Dry Cleaning Facilities Area
Fort Riley, Kansas

Reference	Hydraulic Conductivity (m/y)	Gradient	Flow Rate (m/y)
Schwab-Eaton, 1975	7.4×10^4	0.0010	74.0
Myers and Bigsby, 1989	1.7×10^4	0.0012	20.0
Wolf and Helgesen, 1992	7.5×10^4	0.0013	97.6
Average	5.5×10^4	0.0012	63.9

TABLE 5-4
EPACML MODEL INPUT PARAMETERS
Dry Cleaning Facilities Area
Fort Riley, Kansas

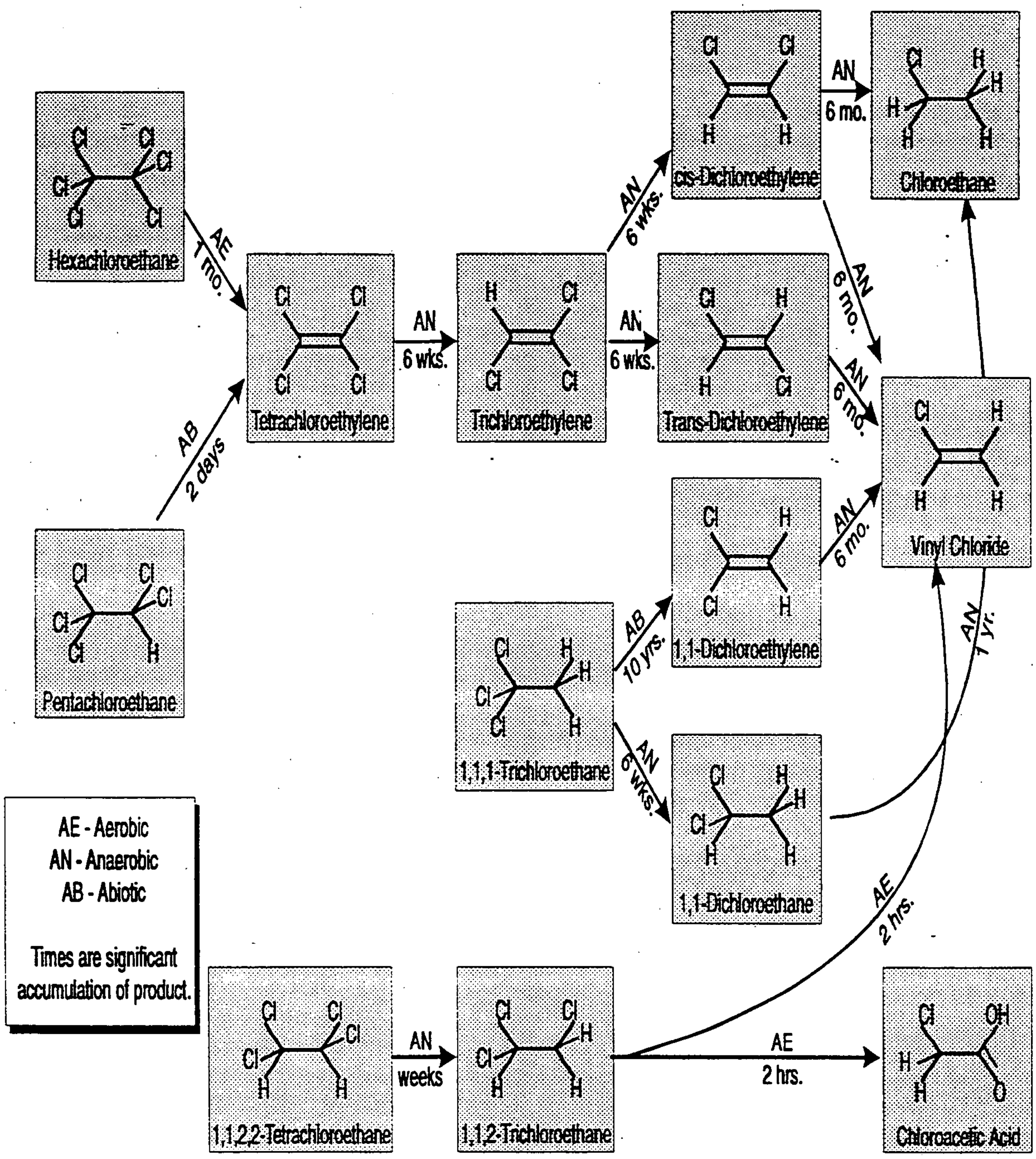
Parameter	Units	Value
Source spread, σ	m[a]	15.24
Initial mixing depth, h	m	1.52
Source concentration, C_o	μg/l	160 (PCE) 13 (TCE) 68 (DCE) 0.0 (VC)
Hydraulic conductivity, K	m/y	5.5×10^4
Hydraulic gradient (dh/dl), i	unitless	0.001
Porosity, n	unitless	0.3
Saturated thickness, b	m	12.2
Longitudinal dispersivity, α_L[b]	m	19.5-50.0
Transverse dispersivity, α_T[b]	m	3.9-10.0
Vertical dispersivity, α_V[b]	m	2.0-5.0
Retardation factor, R	unitless	3.0 (PCE) 2.2 (TCE) 1.4 (DCE) 1.0 (VC)
Degradation coefficient, λ	1/4	0.35 (PCE) 0.14 (TCE) 0.09 (DCE) 0.09 (VC)
Receptor well transverse position, y	m	0.0
Well depth below water table	m	0.0

Notes:

a To convert from meters to feet, note that 1 meter (m) ÷ 3.28 feet.

b Dispersivities evaluated as a function of travel distance to receptor point, with $\alpha_L = 0.1 \times$ distance, $\alpha_T = 0.02 \times$ distance, $\alpha_V = 0.01 \times$ distance. Maximum values set corresponding to travel distance of 500 m.

Degradation Pathways of Chlorinated Hydrocarbons



AE - Aerobic
AN - Anaerobic
AB - Abiotic

Times are significant accumulation of product.

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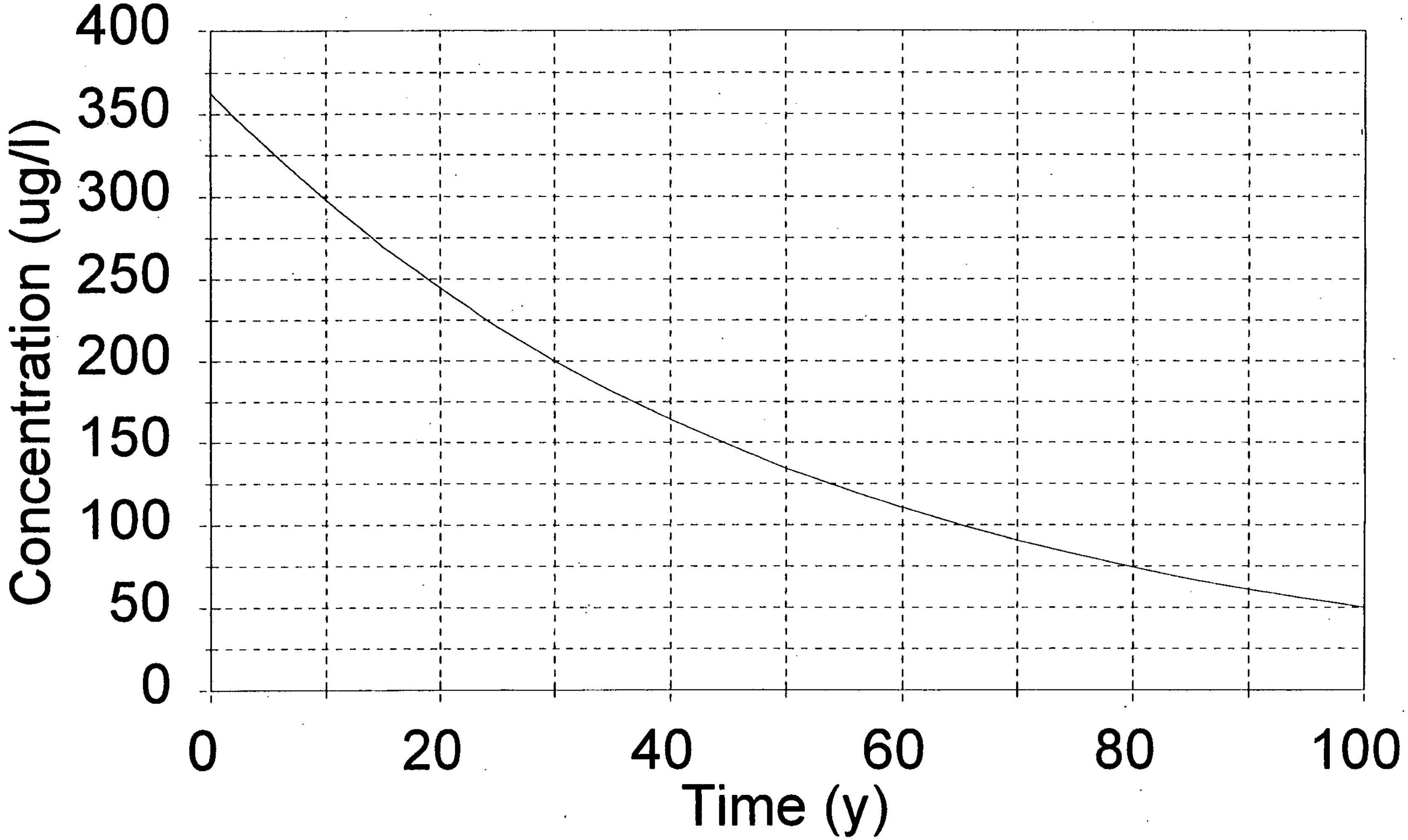
FORT RILEY MILITARY RESERVATION (DCFA-RI)

DEGRADATION PATHWAYS OF CHLORINATED HYDROCARBONS

SCALE: NONE	DATE: MARCH 1995	FIG. 5-1

5-DPCH/30MAR95



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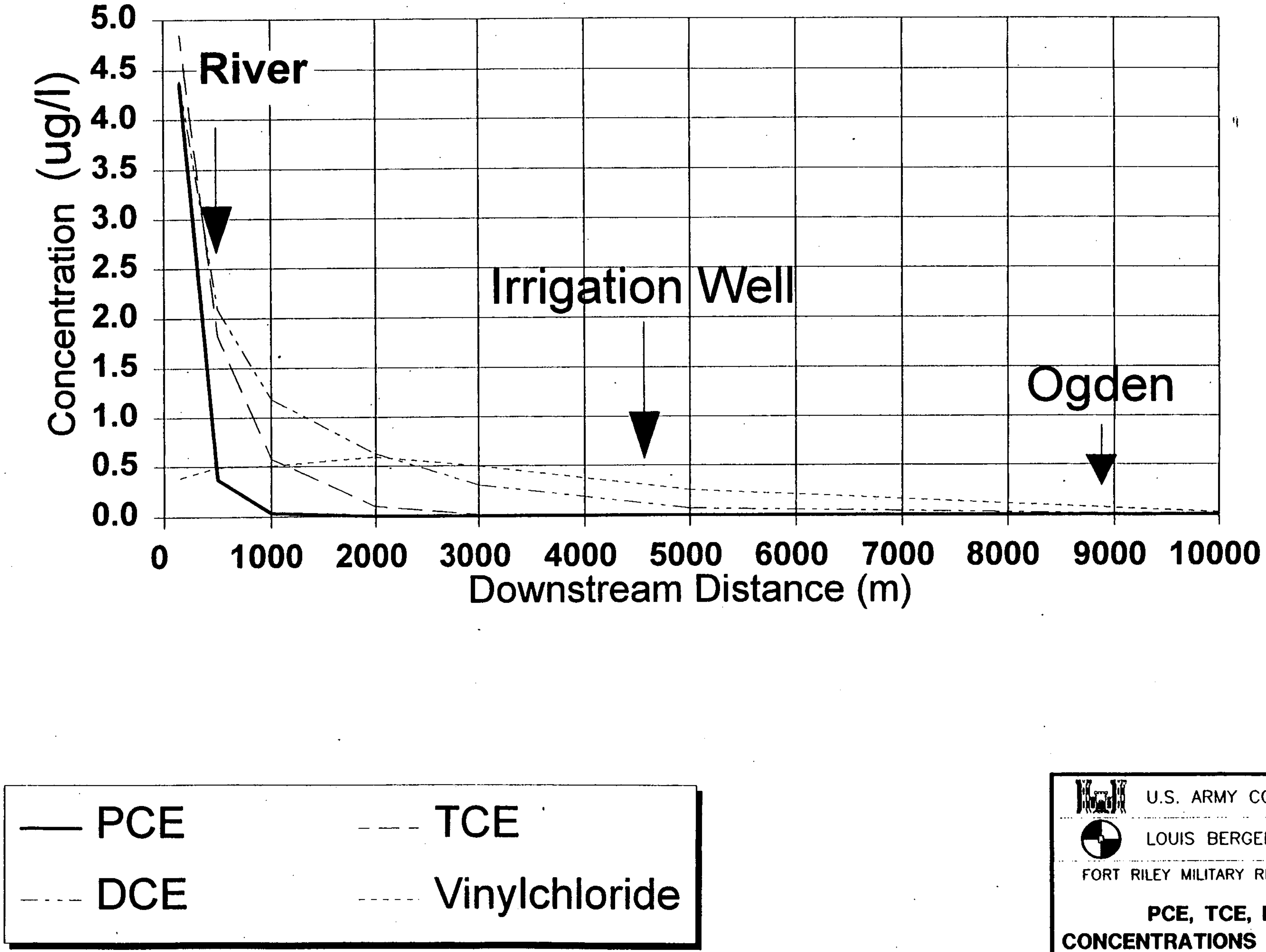
FORT RILEY MILITARY RESERVATION (DCFA-RI)

SOIL LEACHING
CONCENTRATION vs. TIME

SCALE:	DATE:	
NONE	MARCH 1995	FIG. 5-2

5-CIIGW/30MAR95



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FORT RILEY MILITARY RESERVATION (DCFA-RI)

PCE, TCE, DCE, & VC CONCENTRATIONS IN GROUNDWATER

SCALE: NONE	DATE: MARCH 1995	FIG. 5-3

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CHAPTER 6
BASELINE RISK ASSESSMENT

■ Summary

A Baseline Risk Assessment (BLRA) was performed to evaluate the impact of chemical contamination at the DCFA, and to assess whether releases of hazardous substances associated with the site pose potential risks to human health and the environment under current or possible future exposure circumstances. The BLRA was performed following U.S. EPA Risk Assessment Guidance for Superfund (RAGS). The human health evaluation considered the universe of potentially exposed populations; however, only utility workers and recreational children were retained as receptors for both current and future site conditions. Potential exposure pathways for the utility worker are the following:

- Ingestion of, and dermal contact with, subsurface soil;
- Inhalation of volatiles and fugitive dust;
- Ingestion of, and dermal contact with, sediment; and
- Dermal contact with surface water.

Potential exposure pathways for recreational children are as follows:

- Ingestion of, and dermal contact with, sediment; and
- Dermal contact with surface water.

Exposure calculations were performed based on the 95 percent Upper Confidence Limit (UCL) of the contaminants in soils, surface water, and sediment. The calculated Hazard Index and carcinogenic risk for the utility worker were less than 0.1 and 1×10^{-7}, respectively. The primary contribution to the risk for both receptors was from dermal contact with surface water containing PCE. For the recreational child, the values were less than 0.1, and 3×10^{-8}, respectively. This pathway accounted for over 99.5 percent of the health risk. The BLRA indicated that exposure levels are below acceptable levels as defined in the National Contingency Plan (NCP; Federal Register, 1990b). For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper-bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}. For systemic (non-carcinogenic) toxicants, acceptable exposure levels represent concentrations to which humans may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety. A Hazard Index of less than 1.0 is generally used as the acceptable level for non-carcinogenic effects (U.S. EPA, 1989a).

Based on an evaluation of current and potential future land use conditions, ingestion of groundwater was excluded as a reasonable exposure scenario and is not part of the BLRA. For information purposes only, health risks were also evaluated for a scenario that assumes ingestion of on-site groundwater by a hypothetical future worker. These risks were evaluated assuming ingestion of water with 95 percent UCL concentration values of all contaminants in groundwater. For this scenario, the Hazard Index and carcinogenic risk were 0.4 and 1×10^{-4}, respectively. PCE and vinyl chloride in groundwater would each contribute approximately 50 percent of the cancer risk.

The ecological assessment considered risk to vegetation and to terrestrial and aquatic animal life at, and adjacent to, the DCFA. Ecological Effects Quotients (EEQs) were calculated for surface water and sediment exposures. The results of the ecological assessment did not indicate a risk to ecological receptors.

Methodology

The risk assessment follows U.S. EPA guidance for risk assessments in general and for Superfund sites in particular as set forth in the following documents:

- Risk Assessment Guidance for Superfund, Vol. 1 - Human Health Evaluation Manual Part A (U.S. EPA, 1989a);
- Risk Assessment Guidance for Superfund, Vol. II - Environmental Evaluation Manual (U.S. EPA, 1989b);
- Exposure Factors Handbook (U.S. EPA, 1989c);
- Risk Assessment Guidance for Superfund, Vol. 1 - Human Health Evaluation Manual Supplemental Guidance, Standard Default Exposure Factors (U.S. EPA, 1991a);
- Supplemental Guidance to RAGS: Calculating the Concentration Term (1992a);
- Guidance for Data Usability in Risk Assessment - Part A (U.S. EPA, 1992b);
- Dermal Exposure Assessment: Principles and Applications (U.S. EPA, 1992c);
- Framework for Ecological Risk Assessment (U.S. EPA, 1992d);
- ECO Updates, U.S. EPA Supplementary Guidance Bulletins for Ecological Assessment (U.S. EPA, 1991 and 1992); and
- Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons (U.S. EPA, 1993b).

The risk assessment is based on data generated during the PA/SI and RI as summarized in previous sections of this report. Pathway-specific models are used to characterize contaminant release and transport mechanisms, behavior patterns, and processes leading to potential contaminant exposure. Standard U.S. EPA risk characterization models and toxicological parameters are used to develop quantitative estimates of risk for each exposure pathway and potentially exposed populations.

The risk assessment is based on the most reasonable future use of the DCFA site under continued military use of the Fort Riley Military Installation. The risk assessment estimates the potential for adverse human health and ecological impacts at the site. Information on the distribution of contamination, the toxicity of the compounds detected in the various media, and a site-specific estimate of chemical intake via assumed exposure routes is combined to estimate potential adverse impacts. The environmental media considered are soil, air, groundwater, surface water, and sediment. A number of samples have been collected from the sanitary and storm sewers. These results were presented in Chapter 3 but were not used in the BLRA.

The result of the assessment for human receptors is expressed in terms of risk for carcinogenic contaminants and hazard quotients for non-carcinogenic contaminants. The results of the ecological assessment are expressed in terms of ecological effects quotients. The risk assessment incorporates conservative assumptions about contaminant exposures, intakes, and contaminant toxicity. Consequently, the calculated health and ecological risks represent high-end estimates for the human health and ecological hazards associated with the site; the actual risk, although unknown, is not expected to exceed that calculated in the Baseline Risk Assessment.

6.1 Human Health Risk Assessment

This chapter is organized in two parts: the human health risk assessment and the ecological risk assessment. The human health risk assessment is presented in Sections 6.1.1 through 6.1.4 and consists of four components: (1) Data Evaluation; (2) Exposure Assessment; (3) Toxicity Assessment; and (4) Risk Characterization. Each of these components is briefly discussed below.

- ***The Data Evaluation*** (Section 6.1.1) is primarily concerned with the selection of chemicals of concern representative of the type and magnitude of potential human health effects. Contaminant concentrations relative to background levels, contaminant release, and environmental transport mechanisms, exposure routes, and toxicity are considered when developing a list of contaminants used to define the site-associated risks. This section concludes with the selection of chemicals of concern for various environmental media. These chemicals are then used for the quantitative risk assessment.

- ***The Exposure Assessment*** (Section 6.1.2) identifies potential human health or environmental exposures either at the source area or off site. Exposure routes are developed from information on the source area concentrations, contaminant release mechanisms, patterns of human activity, and other pertinent information. The pathway-specific models used to calculate the intake of contaminants are also described.

- ***The Toxicity Assessment*** (Section 6.1.3) presents available human health and environmental criteria for all the contaminants. Quantitative toxicity indices are presented where they are available, including any applicable regulatory standards and criteria. Enforceable standards such as Maximum Contaminant Levels (MCLs), regulatory guidelines such as Ambient Water Quality Criteria (AWQC) and Health Advisories, and dose-response parameters such as Reference Doses (RfDs) and Cancer Slope Factors (CSFs) are presented for each chemical of concern. A brief discussion of the toxicological properties of the chemicals of concern is presented in Appendix C-IV.

- ***The Risk Characterization*** (Section 6.1.4) defines the risks associated with threshold (non-carcinogenic) and non-threshold (carcinogenic) effects of the contaminants through the use of estimated intakes and the RfDs/CSFs. The uncertainties associated with the quantitative risk estimates are also identified.

Potential impacts on non-human receptors and the environment resulting from the chemicals of concern present in various environmental media are evaluated in the ecological risk assessment, which is presented in Section 6.2.

6.1.1 Data Evaluation

This task uses analytical data and regulatory criteria to select a list of chemicals of concern for each medium analyzed. The BLRA is based upon and utilizes combined data from the PA/SI, IFI and RI collected between March 1992 and January 1995. This section focuses on chemicals of concern from the perspective of human health. The primary chemicals of concern for the DCFA consist of PCE and its degradation products (TCE, DCE, and vinyl chloride), detected in all media samples (soil, groundwater, surface water, and sediment), except surface soil. The rationale for the selection of chemicals of concern follows.

The procedure used to select chemicals of concern is designed to identify the DCFA operations-related chemicals that may represent a human health risk. In general, the chemicals of potential concern should include chemicals in the following classifications (U.S. EPA, 1989a):

- Positively detected in at least one sample in a given medium, including (1) chemicals with no qualifiers attached (excluding samples with unusually high detection limits), and (2) chemicals with qualifiers attached that indicate known identities but unknown concentrations;
- Detected at levels significantly greater than in associated blank samples (i.e., 5 times the levels in blank samples for chemicals not considered to be common laboratory contaminants and 10 times the levels in blank samples for those that are);
- Only tentatively identified but either may be associated with the site based on historical information or may have been confirmed by Special Analytical Services (SAS), i.e., non-standardized analyses conducted under the Contract Laboratory Program (CLP); and/or
- Transformation products of chemicals demonstrated to be present.

The U.S. EPA Risk Assessment Guidance for Superfund (RAGS) allows the number of chemicals carried through the risk assessment to be reduced by eliminating infrequently detected chemicals (U.S. EPA, 1989a). Most sites will show detections of some toxic chemicals from anthropogenic or natural sources that are not site-operations-related. If these compounds occur only infrequently, they may not be found in background samples but show up occasionally in the (larger number of) samples collected from the site. A detection frequency of less than 5 percent is often used as a practical guideline for screening out non-site-operations-related chemicals. It is, however, not appropriate to use an arbitrary cutoff level on the detection frequency as the only criterion. Chemicals that have been detected only a few times but that are known to be associated with DCFA operations, as well as chemicals that are breakdown products of other DCFA operations-related chemicals, should be retained. A constituent that is detected only a few times in groundwater should be left in if it is found more frequently in soil, because groundwater is a receiving medium for soil contaminants. On the other hand, chemicals which are common laboratory contaminants might be eliminated even though they have been detected with a significant frequency. A high number of detections may indicate poor housekeeping practices by the laboratory.

Metals are not chemicals of concern at the DCFA and are not considered in the Baseline Risk Assessment (BLRA). As documented in the work plans for the PA/SI (CEMRK, 1991, 1992c) and for the RI/FS (CEMRK, 1993d,h), only volatile and semivolatile analytes were included. Metals analyses of groundwater samples were only conducted in the November 1992 sampling event. The purpose of the metals analysis in this event was to provide data for evaluation of treatment technologies in the Feasibility Study. All work plans have been reviewed and approved by state and federal regulators. In November 1992, three metals — iron, manganese and magnesium — were added along with inorganic compounds to provide information on levels of these metals in the groundwater at the DCFA for the development of groundwater remedial technologies. This limited sampling showed an elevated level of manganese (990 μg/l), exceeding the federal Maximum Contaminant Level Goal (MCLG) of 200 μg/l in well DCF92-04. However, the levels detected are within the range of background levels (personal communication, KGS Geochemist, 1993). A further discussion is provided in Section 6.1.1.2.

Data were summarized for each environmental medium by determining frequencies of detection, concentration ranges of detected values, and representative concentrations. The extent of contamination in the areas sampled, the identification of DCFA operations-related chemicals by medium sampled, and selection of chemicals of concern for the BLRA are presented in the following subsections.

6.1.1.1 Summary of Contamination

The analytical results for subsurface soils, groundwater, sediment, and surface water used in the BLRA are summarized in Tables 6-1 through 6-4. Chemical names printed in boldface (e.g., **tetrachloroethylene**) represent the contaminants of concern for the baseline risk assessment; chemical names printed in italics (e.g., *dichloromethane*) represent common laboratory contaminants or trihalomethanes. Sediment and surface water results pertain to samples collected from Tributaries A and B. Analytical results for surface soils are not included in these tables because no contaminants were detected in surface soil samples. Included in the tables is information on the concentration in background samples, frequency of detection, sample quantitation limits, range of detected concentrations, average concentration, and upper 95 percent confidence limit on the average concentration. Non-detects were assigned a value of half the Sample Quantitation Limit (SQL) in the calculation of average and 95 percent UCL concentration values (U.S. EPA, 1992a). The range of quantitation limits for the same chemical reflects differences in sample and laboratory conditions for analyzing the samples from each of the sampling rounds.

Because the number of samples collected from each medium during the field investigation is always finite, and the data may not follow a Gaussian (normal) frequency distribution, the arithmetic average calculated from the sampling data may not provide an accurate estimate of the expected concentration to which a receptor might be exposed. To guard against the possibility that exposure concentrations are underestimated, U.S. EPA Risk Assessment Guidance for Superfund (U.S. EPA, 1989a; 1992a) recommends that the 95 percent UCL of the mean concentration, rather than the sample mean should be used in the risk assessment. The 95 percent UCL is a statistical upper bound estimate of the true mean concentration, which provides a 95 percent likelihood that the true mean is less than or equal to the calculated UCL value. It should be noted that the arithmetic averages and 95 percent UCL values are not directly comparable. The arithmetic average is calculated directly from the sampling data, whereas the UCL value is based on log-transformed data. As a consequence, the average value may sometimes exceed the 95 percent UCL.

The calculated UCL value may exceed the maximum detected concentration. This situation reflects a large uncertainty in the mean concentration value, which may be due to a small sample number, a large variation in detected concentration values, and/or values assigned to non-detects that are higher than actually detected values. The 95 percent UCL values were used in the exposure calculations for the DCFA, except when this value exceeded the maximum detected concentration. In those cases, the latter value was used.

Upper confidence limits were calculated following procedures in the Supplemental Guidance to RAGS (U.S. EPA, 1992a), ~~assuming a log-normal distribution for each chemical.~~ For non-detected concentrations, half the sample quantitation limit was used in the UCL calculation. If a chemical was present at a concentration less than 5 times the level in the associated blank, it was treated as a non-detected concentration. For chemicals that are common laboratory contaminants (dichloromethane, toluene, acetone, and phthalate esters), only sample concentrations exceeding 10 times the blank level were counted as positive detections. Details on the calculation procedure are provided in Appendix C.

Table 6-1 presents a summary of contaminants in subsurface soils to a depth of 25 feet. The 25-foot depth was selected because the maximum depth of utilities in the area of identified contamination is 25 feet. The data in Table 6-1 was obtained from the PA/SI and RI soil borings and monitoring well borings (Tables 4-1 through 4-3). Sample locations are depicted in Figures 4-1 through 4-4. Workers might be exposed to contaminants in soil down to this depth. In the subsurface soil samples, only tetrachloroethylene, dichloromethane, toluene, and bis(2-ethylhexyl)phthalate were detected in more than one or two samples. Dichloromethane, toluene, and phthalates are all considered common laboratory contaminants (U.S. EPA, 1989a). The number of positive detections of these chemicals reflects the number of samples in which the detected level was 10 times or more above the blank level.

In the case of dichloromethane, nearly all soil samples collected during the PA/SI from both soil borings and monitoring well borings (including blanks) contained this chemical. In contrast, none of the RI soil samples showed any detections of dichloromethane. This difference between PA/SI and RI results strongly suggests that laboratory procedures during the PA/SI may account for most if not all of the detections of dichloromethane in soils.

Other than PCE, dichloromethane, and toluene, the detected concentrations in soil were very localized. All SVOCs detected only once were found at the same location (boring for well DCF92-03) at a depth of 4 feet. The boring log records the presence of debris in the fill materials at this location (CEMRK, 1992a). The reported debris was observed to include asphalt chunks and other paving and construction materials (personal communication, Fort Riley DES IR Program Manager, 1994). PAHs (e.g., benzo(a)pyrene benzo(a)anthracene, and chrysene) detected at this sampling location are common constituents of asphalt. This sampling location is near the northeast corner of Building 180 in an area that is presently paved, indicating that the contamination likely occurred at some time in the past.

Table 6-2 presents the summary of chemicals detected in groundwater. This table summarizes all groundwater sampling data (Table 4-18). Locations of the groundwater monitoring wells are depicted in Figure 3-22. The most frequently detected chemicals in groundwater samples are PCE, TCE, and DCE, detected in 60, 46, and 53 samples, respectively, of 103 samples collected. The highest PCE concentrations were found in wells DCF92-02, DCF92-03, and DCF92-05 near known sewer lines. This result is consistent with the role of the sewers from Building 183 as the main source of contaminants at the DCFA. Sewer water contaminated with PCE leaking from the sewers will tend to infiltrate vertically downward through the soil and consequently leads to the highest concentrations in groundwater at locations below, or near, the sewer lines. The detections of TCE and DCE are consistent with the breakdown of PCE (see Chapter 5). The final toxic breakdown product of PCE is vinyl chloride. There are relatively few detections of vinyl chloride in groundwater (Table 6-2), consistent with the fact that the breakdown of DCE into vinyl chloride occurs more slowly than the breakdown of PCE into TCE, and TCE into DCE (see Chapter 5).

It may be noted also that several chemicals detected only a few times in groundwater, including benzene, 2,6-dinitrotoluene, hexachloroethane, naphthalene, n-nitrosodi-n-propylamine, and ethylbenzene, were detected together in monitoring well DCF92-04 during the initial sampling rounds of July and November 1992 (Tables 4-12, 4-13 and 4-18).

A fingerprint analysis of a water sample collected during the installation of well DCF92-04 indicated 243 μg/l of petroleum hydrocarbons, identified as highly weathered gasoline or mineral spirits (Stoddard solvent) residues (Appendix I, CEMRK, 1992c). The type of number of chemicals found at well DCF92-04 indicates an origin other than the leaking sewers emanating from Building 183. The contaminants may be associated with spills of Stoddard solvent used in the past at the DCFA and/or releases associated with the underground storage tanks, which were discovered on the north side of Building 181. The fact that most of these referenced chemicals were only detected at this well, and only during the initial sampling rounds, indicates a very limited extent of these non-PCE-related contaminants. Although somewhat speculative, an argument can be made that the (petroleum) hydrocarbons detected at well DCF94-02, e.g., by acting as a source of substrate, may have promoted the breakdown of PCE and TCE at this location, thus explaining the consistent detections of DCE and vinyl chloride in this well and the nearby wells DCF93-19 and DCF93-08.

Analytical results for surface water and sediments are summarized in Table 6-3 and Table 6-4, respectively. These results pertain to samples collected from Tributaries A and B. Sediment data and sampling locations are presented in Table 4-6 and Figure 4-6, respectively. Surface water data and sampling locations are presented in Table 4-7 and Figure 4-6. Water and sediment samples collected from the sanitary and storm sewer system are not included. As a result of the sewer repair and manhole cleanout in May 1994, and the elimination of PCE in the wastewater discharged through the sewer system, no residual contaminant concentrations are likely to be present in the sewer system. Moreover, during sewer repair or replacement, sewer pipes are lifted out using machinery, and workers will not be in direct contact with any material in the pipes.

During the January 1995 sampling of the tributaries, two seep locations were observed and sampled (DCFSW-24 and DCFSW-26; see Table 4-7). These two seeps are not included for the BLRA. The seeps were observed during only one sampling event, which indicates a very infrequent occurrence. Any contaminants will tend to volatilize quickly from seeps. Therefore, the seeps do not appear to be a source of chronic exposures. PCE was detected in a single sample out of 14 surface water samples collected from the tributaries. The surface water samples show a relatively high number of detections of trihalomethanes (THMs), including bromodichloromethane, dibromochloromethane, trichloromethane, and tribromomethane. THMs may be formed in the environment as the result of reactions between chlorine from chlorinated water and natural organic matter. THMs have been detected in a number of the Fort Riley drinking water wells located along the Kansas River, upgradient from the DCFA, indicating that these compounds occur commonly. All positive detections in sediment were made during the PA/SI sampling rounds. Dichloromethane was found in three of three sediment samples collected during the baseline PA/SI, and once during the subsequent PA/SI sampling. Considering that for the soil medium the incidence of dichloromethane detections was also very high during the initial sampling, and that dichloromethane is a common laboratory contaminant, laboratory procedures may be suspected to be the cause of at least part of the detections of dichloromethane in sediment. Acetone was detected twice; PCE and pyrene were detected only once in sediment.

The lack of positive detections in sediment during the RI sampling is likely a result of the flooding of 1993. The flood may have eroded sediment in the tributaries and washed out contaminants. An additional 18 sediment samples were collected from the streambed of Tributaries A and B during January 1995. Samples were taken both from the surface sediments (upper 1 foot) and from a 2- to 3-foot depth. None of these samples showed detections of either VOCs or SVOCs. This result confirms that the sediments along the tributaries do not act as a long-term source of contaminants.

6.1.1.2 Evaluation of Analytical Data

Historical data from the PA/SI and IFI, and current data from the RI, collected during a time period from March 1992 to January 1995, were combined for the risk assessment. All samples were analyzed through a U.S. Army Corps of Engineers, Missouri River Division, certified laboratory and were validated in accordance with U.S. EPA protocols. The sampling and analysis protocols and techniques and quality assurance/quality control (QA/QC) procedures followed for the data collected during the PA/SI (CEMRK, 1992b) were evaluated using U.S. EPA data evaluation procedures as discussed below, and were judged to be of sufficient quality to be usable for a quantitative risk assessment. Combining the PA/SI data with RI data assumes that both data sets are representative of site conditions. A detailed data quality evaluation is presented in Chapter 4 of this report.

Analytical methods used were U.S. EPA Methods 8260/8240 for VOCs, and U.S. EPA Methods 3550/8270 for the SVOCs (U.S. EPA, 1986a). The methods for analyses were selected to identify the presence or absence of the analyte of interest, achieve detection limits at or below ARARs, and provide qualitative as well as quantitative data.

The QC samples collected during the sampling efforts included field blanks (rinsates and trip blanks), split and duplicate samples, laboratory blanks (method blanks), and matrix spike/matrix spike duplicate (MS/MSD) samples. Upgradient samples were collected to establish background conditions for each medium of potential concern. Locations for sampling performed during the PA/SI and the RI have been presented in previous sections of this report.

The analytical data were evaluated according to the data evaluation procedures specified in the U.S. EPA's "Risk Assessment Guidance for Superfund" (U.S. EPA, 1989a) and the U.S. EPA's "Guidance for Data Useability in Risk Assessment" (U.S. EPA, 1992b). These procedures outline specific aspects of data quality that must be addressed in compiling a data set to be used in quantitative risk assessment. The following aspects are addressed in evaluating the data set: analytical methods, quantitation limits, use of qualified data, contamination of blank samples, and comparison of site samples with background.

The analytical methods used were appropriate for the quantitative risk assessment. The quality of the data produced was scientifically correct and legally defensible, as U.S. EPA-approved methods with known limits of precision and accuracy were used. Practical Quantitation Limits (PQLs) and Method Detection Limits (MDLs) were compared to regulatory criteria, such as Maximum Contaminant Levels (MCLs), to determine whether the methods used were sufficiently sensitive for regulatory review. The MDL is the minimum amount of analyte that can be routinely identified using a specific method, under conditions of 100 percent analyte recovery. The PQL as used here represents levels that a laboratory should routinely and reliably detect and quantitate in a variety of sample matrices. As such, it provides a measure of the sensitivity of a laboratory method. In most cases, the PQLs provided by the laboratory were less than, or equal to, the relevant health-based standards for the constituents detected at the site. Exceptions for groundwater constituents include the following: PCE (PQL = 1.1 μg/l and Kansas Notification Level = 0.7 μg/l); TCE (PQL = 0.6 μg/l and Kansas Notification Level = 0.5 μg/l); vinyl chloride (PQL = 10 μg/l and Kansas Notification Level = 0.2 μg/l); 2,6-dinitrotoluene (PQL = 10 μg/l, Kansas Action Level = 0.04 μg/l, and Kansas Notification Level = 0.004 μg/l); and bis(2-ethylhexyl)phthalate (PQL = 10 μg/l, MCL = 6 μg/l, and Alternate Kansas Notification Level = 3 μg/l).

Exceptions also occurred for some surface water constituents. The PQLs for bromodichloromethane (5 μg/l), dibromochloromethane (5 μg/l), and tetrachloroethylene (5 μg/l) did not meet the AWQC for the protection of human health via ingestion of water and fish (0.27 μg/l, 0.41 μg/l, and 0.8 μg/l, respectively).

For soils, there are no promulgated standards with which to compare laboratory PQL values. In the absence of applicable soil criteria, proposed RCRA Corrective Action Levels (CALs) and Risk-Based Concentrations (RBCs) developed by U.S. EPA Region III were used to evaluate the adequacy of analytical techniques for detecting contaminants at levels of concern. RCRA CALs and RBC values are presented in Table 6-14 for the chemicals detected in soils at the DCFA. Because of the commercial/light industrial nature of the DCFA, the RBC values in this table are for industrial soil. The RCRA CALs were proposed in 1990 and are somewhat dated, as they represent information on the toxicity of different chemicals that may since have been revised. The RBC values in this table are for the First Quarter 1994 update and represent current data. PQLs for soils are 5 μg/kg for most of the VOCs, and 660 μg/kg for most of the SVOCs detected at the site. The PQLs for soils were all below RCRA CALs. Only in the case of benzo(a)pyrene does the PQL (= 660 μg/kg) exceed the corresponding RBC value (= 390 μg/kg; note that Table 6-14 presents concentrations in mg/kg).

Although in these cases, the PQLs for the analytical method used exceeded regulatory standards, this does not necessarily mean that the methods employed were inadequate, or that health and environmental risks will be underestimated. The PQL represents a quantitation level that a laboratory should be able to meet on a routine basis. The actual quantitation level achieved in the sample analysis is represented by the Sample Quantitation Limit (SQL). SQLs are reported in Tables 6-1 through 6-4. Sample quantitation limit, the value reported by the analytical laboratory, is dependent on sample size, percent moisture (for soil and sediment), and the nature and extent of any matrix interferences. In many cases, the SQL values reported by the laboratory are below the PQL values. Moreover, the methodology for treating non-detects in the risk calculations is designed to account for the fact that low concentration levels of contaminants of concern may be missed because of the finite precision of analytical procedures. Non-detects of chemicals of concern are not ignored; instead they are assigned a value of one-half of the SQL (U.S. EPA, 1992b). If the SQL is raised, the concentration value used in the risk calculations for non-detects is also raised.

- **Qualified Data**

To assess the quality of the analytical procedures utilized, method blank results, MS/MSD results, surrogate recoveries, and holding time adherence were evaluated. The results of these evaluations were noted with qualifiers or flags. Based on this evaluation, all data collected from this site were usable for the BLRA, with the exception of results flagged with a "B" or "T" qualifier. The concentrations of these results as well as all of the non-detects, were treated similarly and, therefore, replaced with one-half the sample quantitation limit in calculation of the UCL values.

All detections of semivolatile contaminants in subsurface soils, except for one detection of bis(2-ethylhexyl)phthalate at 2,400 μg/kg, were at levels below the PQL. These detections are indicated in Table 6-1 with a "J" qualifier. This qualifier indicates a degree of uncertainty in the measured concentration level because a laboratory may not be able to consistently measure concentrations below the PQL in a consistently reproducible manner accurately. The "J" qualified data however, is suitable for use in a quantitative risk assessment. The qualifiers used are as follows (see Appendix C):

B - Indicates sample results associated with a method blank that contains the analyte. The "B" flag indicates that the analyte was detected at a concentration less than 10 times that of the method blank. These results may have a positive bias or may run the risk of being false positives owing to laboratory contamination.

E - Estimated result, quantitation uncertain due to MS/MSD relative percent difference (RPD) result.

F - Estimated result, quantitation uncertain due to field duplicate results.

I - Estimated quantitation based on internal standard recoveries exceeding control limits. Results may be biased high.

I2 - Estimated result based on low internal standard recoveries and high surrogate recoveries. Results may be biased high.

J - Numerical value is an estimated quantity.

M - Quantitation limit higher than normal due to matrix interference.

S - Estimated result, possible false positive, or biased high results based on matrix interference from a high surrogate recovery.

T - Estimated result, possible cross-contamination during shipping based on trip blank results.

- **Background Samples**

Samples were collected for each medium of concern from a location upgradient of the suspected area of contamination. These samples were used to evaluate background conditions (i.e., background concentrations of constituents) at the site. Dichloromethane was detected in two soil samples (DCF92SB01A and DCF92SB01B) collected during the installation of background monitoring well DCF92-01. Pyrene was also detected in one of these samples (DCF92SB01A). The presence of dichloromethane is likely a false positive due to laboratory contamination.

Iron, magnesium and manganese were detected in the groundwater at a number of wells, including the upgradient monitoring well (DCF92-01) during the PA/SI. The concentration levels of iron, manganese and magnesium were discussed by telephone with a Kansas Geological Survey chemist (personal communication, KGS Chemist, 1993). The levels detected are consistent with natural background concentrations. Additional information of background levels of metals has been obtained from published reports. The USGS has published a statewide summary of groundwater quality in Kansas (USGS, 1983). This publication delineated different groundwater regions in the state and provided a summary of groundwater quality in each region. In the region including Riley County, 18 percent of the wells were reported to have manganese concentrations exceeding the MCL of 50 μg/l. An aquifer evaluation study was conducted in 1974-75 of the Republican Flats area south of Camp Forsyth to determine the suitability of the groundwater to serve as an alternative supply source to the existing Fort Riley supply wells which "yield a variable quality water, many times containing excessive amounts of manganese" (Schwab-Eaton, 1975). Manganese concentrations in these existing wells were reported to range from 50 μg/l to 750 μg/l. Iron concentrations ranged from 10 μg/l to 1,700 μg/l. Twelve test wells were installed and analyzed for iron, manganese and total hardness. Detected concentrations were ND to 1,800 μg/l for manganese (mean = 388 μg/l) and 140 to 2,800 μg/l for iron (mean = 1,274 μg/l).

Samples from well DCF92-01 have also shown detections of dichloromethane (5 and 11 μg/l). Wells DCF93-17 and DCF93-18 were installed as background wells during the RI. Benzene (0.6 μg/l), toluene (0.9 μg/l), carbon disulfide (21 μg/l), and 1,4-dichlorobenzene (11 μg/l) have been detected at well DCF93-17. Bis(2-ethylhexyl)phthalate (14 μg/l) was detected in well DCF93-18.

A background surface water (DCFSW01) and sediment (DCFSD01) sample were collected from Tributary A upstream from the DCFA during the PA/SI. No VOCs or SVOCs were detected in either surface water or sediment at this location. Samples were collected from the same location in January 1995 (samples DCFSW-16 and DCFSD-16A,B). As before, no VOCs and SVOCs were detected at this background sampling location. As mentioned in Section 6.1.1.1, several trihalomethanes (THMs) were detected in surface water samples from Tributary A during the January 1995 sampling round. The occurrence of these compounds may be attributed to reactions between chlorinated water and natural organic matter.

Only trichloromethane was found in groundwater at the DCFA, but other THMs have been found in drinking water wells in the vicinity of the Main Post. A letter report which summarizes the results of groundwater sampling at Fort Riley conducted by the U.S. Army Environmental Hygiene Agency (USAEHA, 1992) documents the following levels of THMs in the Camp Forsyth wells (located approximately 3 miles upgradient from the DCFA): bromodichloromethane = 2.2 µg/l; dibromochloromethane = 1.0 µg/l; trichloromethane = 1.9 µg/l. The reference does not provide details on sample collection and analytical methods, but the samples for organic chemical analyses are usually taken at the wellhead before any treatment.

6.1.1.3 Chemicals of Potential Concern

The summary and evaluation of analytical and background data presented in the preceding sections provide the basis for identifying the chemicals of potential concern to be included in the Baseline Risk Assessment. The objective is to identify the DCFA operations-related chemicals that may represent a health risk. The primary DCFA operations-related chemicals are PCE and its breakdown products, TCE, DCE, and vinyl chloride. As discussed in the preceding sections, many of the other VOCs and SVOCs detected at the site were found in only a small number of samples, including some found (only) in background samples. Some of the more frequently detected chemicals at the site are U.S. EPA-recognized common laboratory contaminants (U.S. EPA, 1989a).

The data evaluation procedure is designed to screen out anomalous detections caused by sample or laboratory contamination by comparing detected concentration levels to levels detected in blanks, and applying the fivefold to tenfold rules to decide whether a detection should be counted as a "positive." It should be recognized that these are empirical rules that may not guarantee that all such anomalous detections are correctly identified. Several examples in the DCFA sampling data likely represent laboratory contamination but pass the tenfold rule. A specific example is dichloromethane, which was detected in virtually all of the PA/SI soil and sediment samples, but in none of the RI soil or sediment samples. Other chemicals, such as bis(2-ethylhexyl)phthalate, also a common laboratory contaminant as well as a common plasticizing agent for PVC, are so ubiquitous in the environment that their presence can also be regarded as not DCFA operations-related. The same applies to detections of trihalomethanes (THMs) in groundwater and surface water.

Only chemicals detected at 5 percent or greater frequency and that are not common laboratory contaminants, or THMs, are retained for the baseline risk assessment. In situations where chemicals are detected at greater than 5 percent frequency, but their presence is not related to (historical) operations at the DCFA, the risks are calculated also for the case in which these chemicals are included. This situation pertains to THMs and to chemicals suspected to represent laboratory contamination, e.g., dichloromethane in soils. This additional risk calculation was performed to verify that the omission of these chemicals from the BLRA does not significantly alter the overall assessment of health risks.

A discussion of chemicals of concern, by environmental medium, follows.

- **Soils**

Chemicals of concern in soils are PCE and TCE. Of the other VOCs and SVOCs detected in soils, only dichloromethane, toluene, and bis(2-ethylhexyl)phthalate were detected at 5 percent or greater frequency. All three of these chemicals are recognized common laboratory contaminants. Only dichloromethane (28 percent) was detected at a significantly greater than 5 percent frequency. As discussed before, this is in all likelihood attributable to PA/SI laboratory procedures. Of the remaining chemicals, only phenanthrene and pyrene were detected more than once. In the case of pyrene, however, one of the two detections was in a background soil sample.

- **Groundwater**

Chemicals of concern for groundwater are PCE, TCE, DCE, vinyl chloride, and naphthalene. PCE and its breakdown products were all detected at greater than 5 percent frequency and are all directly DCFA operations-related. Naphthalene was detected in only 3 out of 68 samples analyzed for SVOCs. The presence of naphthalene may be related to the past use of Stoddard solvent as the dry cleaning fluid at the DCF and, therefore, it cannot be discounted as possibly DCFA operations-related. The only other chemicals detected at greater than 5 percent frequency are trichloromethane (a THM) and bis(2-ethylhexyl)phthalate.

- **Surface Water**

The only chemical of concern detected in water samples from the tributaries is PCE, which was detected once during the baseline PA/SI sampling. The surface water sampling in January 1995 showed detections of a number of trihalomethanes (bromodichloromethane, tribromomethane, dibromochloromethane, and trichloromethane). Bis(2-ethylhexyl)phthalate and di-n-octylphthalate have also been detected in the tributary. None of the THMs or phthalates are related to known or suspected leaks or spills or with DCFA operations. For information purposes, risk calculations including the THMs and phthalates were also made for surface water exposures.

- **Sediment**

The chemical of concern for sediment is PCE, which as was the case in surface water, was detected once during the PA/SI baseline sampling of the streambed sediment of Tributaries A and B. Acetone and dichloromethane were also detected at greater than 5 percent frequency. Both are common laboratory contaminants. In the case of acetone, there are also reported detections of this compound in the sewer sampling of February 1993, as well as a detection in the seep in the bank of Tributary A in January 1995. This might indicate a separate source of acetone in the sewer system, unrelated to the DCF. Risk calculations including acetone and dichloromethane are presented, for information purposes only, along with the BLRA results. The only other chemical detected in sediment is pyrene, with one detection during the PA/SI baseline sampling.

6.1.2 Exposure Assessment

The purpose of this section is to evaluate the potential for human exposure to the hazardous chemicals in the environmental media within the DCFA. This section characterizes the potentially exposed populations, identifies actual or potential exposure routes, and provides exposure estimates. The receptors considered in the Baseline Risk Assessment are utility workers and recreational children. The pathways considered are as follows:

- Ingestion of, and dermal contact with, subsurface soil;
- Inhalation of volatiles and fugitive dust;
- Dermal contact with sediment;

- Ingestion of sediment; and
- Dermal contact with surface water.

The utility worker may be exposed to contaminants in subsurface soil, sediment, and surface water during installation or repair of utility lines. The recreational child may be exposed to contaminants in sediment and surface water while playing near the tributaries.

The utility worker represents the Reasonable Maximum Exposure (RME) for each of those pathways, and consequently also for the combined pathways. The RME is defined (U.S. EPA, 1989a) as the highest exposure reasonably expected to occur at a site.

The remainder of this section presents the rationale for selecting the exposure scenarios for the Baseline Risk Assessment and identifies the corresponding exposure parameters.

The selection of exposure scenarios begins by considering a wide universe of hypothetical receptors and both present and potential future land use conditions. A conceptual exposure model that relates contamination sources, migration pathways, and exposure routes to potential receptors is presented in Figure 6-2. To determine whether an actual or potential exposure exists at the site, the most likely pathways of contaminant release and transport as well as the human and environmental activity patterns at the site must be considered. A complete exposure pathway has three components: (1) a source of chemicals that can be released to the environment; (2) a route of contaminant transport through an environmental medium; and (3) an exposure or contact point for a human or ecological receptor. The exposure pathway is considered to be "complete" if all of the above elements are present. If one or more elements are not present, exposure does not occur. Following this procedure, infeasible exposure scenarios are identified and eliminated from further consideration.

A key result of the exposure assessment is determination of the RME expected to occur under both current and future land use conditions. In accordance with U.S. EPA's RAGS, RMEs are estimated for individual pathways. If a population is exposed via more than one pathway, the combination of exposures across pathways also must represent an RME (U.S. EPA, 1989a). The intent of the RME is to estimate a conservative exposure case. This is achieved by selecting generally high-end values for the individual parameters in the exposure equations.

6.1.2.1 Exposed Populations and Exposure Pathways

The evaluation of exposed populations and exposure pathways for current and future land use conditions is based on continued Army control over the site. Land use conditions at the site and nearby parts of the Main Post have remained stable since the beginning of this century. Fort Riley is not presently considered for base closure. There is no realistic expectation that future land use and human populations will be appreciably different from historical and present conditions. Evaluations involving other than military control are not pertinent at the present. Alternative future land use and reuse are properly addressed under the Base Realignment and Closure (BRAC) Act. Even if the site remains under Army control, any proposed action potentially impacting land use at the installation would be subject to the National Environmental Policy Act (NEPA), the Council on Environmental Quality (CEQ) regulations implementing NEPA (40 CFR Parts 1500-1508), and Department of Defense (DoD) Directive 6050.1, Environmental Effects in the United States of DoD Actions. This action would be assessed in accordance with Army Regulation (AR) 200-2, Environmental Effects of Army Actions, which implements the CEQ regulations and DoD 6050.1. AR 200-2 requires an assessment of projects and activities which potentially impact land use and land use plans, as well as an assessment of "the direct impacts on human health and welfare and on other forms of life and related ecosystems."

The universe of hypothetically exposed populations that might be exposed to chemicals of concern consists of the following:

- Office and laundry/dry cleaning workers;
- Groundskeepers;
- Utility workers;
- Nearby residents;
- Recreational children;
- Future site workers; and
- Future residents.

The hypothetical receptors include the groups of individuals who might be exposed to DCFA operations-related chemicals through either nearby residence or occupational activities.

Individuals may be exposed to DCFA operations-related contaminants via three primary routes: ingestion, inhalation, and dermal absorption. The following sections describe the receptors in relationship to these exposure routes to determine whether a potential for actual exposure exists.

Potential on-site receptors under current conditions are office and dry cleaning personnel working in Buildings 180/181 and 183, utility workers, and groundskeepers. Information on personnel at the former and current laundry and dry cleaning facilities was obtained through the Fort Riley Directorate of Engineering and Housing. Workers in Building 180/181 include 20 office personnel. The current laundry and dry cleaning facilities employ 25 to 30 personnel, including 4 office workers; the remainder are laundry and dry cleaning workers (personal communication, DEH, 1994a). Potential exposure of on-site receptors would be primarily via the air pathway; on-site utility workers conducting soil excavation activities may also be exposed via direct dermal contact and ingestion of contaminated soil.

Information on groundskeeping activities at the DCFA was provided by the Building Supervisor at the former DCF and by the on-site contractor at the current DCF. These activities consist of mowing the grass once every two weeks during the growing season. Mowing around Building 180/181 is done by DEH personnel and requires about 2 hours for a 2-person crew. Mowing around Building 183 is done by the contractor who operates the dry cleaning facility. The mowing is usually done by a 1- or 2-person crew and, according to the contractor, takes 5-6 hours (First Lieutenant Fort Riley DEH, January 1994). The only other reported regular groundskeeping activity is the spreading of fertilizer, which is done once a year in the spring, using a tractor-mounted spreader which goes around different buildings at Fort Riley. The total time for this activity is less than 1 hour per year.

Various underground utility lines are present within the DCFA. These include sanitary and storm sewers, as well as water, natural gas, and telecommunications lines which run along Custer Road. Repair work of sewer lines at or near locations of known sewer breaks might expose utility workers to elevated contaminant levels in soil. The reported frequency of underground utility work is on the order of several days per year by 2- to 3-person crews. A more detailed discussion is provided in Section 6.1.2.2.

The "Residents" category comprises several different populations, including residents inside and outside of the Fort Riley facility boundary. Residents closest to the DCFA are military personnel and dependents living along Brick Row, a housing development located approximately 350 yards to the northeast of the DCFA. According to 1992 housing data (DEH, 1992), there are 26 residences along Brick Row with a total of 76 residents. Assuming that the first dependent in each residence is a spouse and any additional dependents are children, the total number of children is estimated as 24. Residences along Brick Row are designated as family residences for Company Grade officers. These are junior officers with a rank of Captain and lower (personal communication, DEH, 1994a). Therefore, it is expected that the children include infants and young children. These residents are potentially exposed to contaminants at the DCFA via the air pathway. Children may also be exposed through ingestion of water and sediment, as well as dermal contact when playing in and near Tributary A. Military personnel normally have a 3-year tour of duty. Therefore, the expected maximum exposure duration of the children is also 3 years.

Other potential exposure pathways for residential receptors are the surface water pathways, i.e., exposure associated with recreational activities (fishing, boating), along and in the Kansas River, and the groundwater pathway for residents who use groundwater from the alluvial aquifer along the Kansas River. Figure 6-1 depicts the locations of known wells along the Kansas River in the vicinity of the DCFA.

The figure shows that all existing wells up to five miles downstream of the DCFA are placed along the Republican and Kansas Rivers, and tap the alluvial aquifer which exists under the river floodplain. The direction of groundwater flow in the alluvial aquifer generally follows the direction of flow in the river, which is toward the east in the vicinity of the DCFA (Fader, 1974). The Fort Riley Main Post wells and Junction City wells are all located upgradient from the DCFA and, therefore, will not be impacted by any contaminants originating from the DCFA. The well at Marshall Airfield is located across the Kansas River from the DCFA and is not downgradient from the DCFA. The river acts as a hydraulic boundary to groundwater flow. Even if cross-channel flow were to be considered as a theoretical possibility, the effects of dilution and volatilization in the river (see Chapter 5) will prevent any contaminants from actually reaching this well location. Therefore, the Marshall Airfield well will not be impacted by groundwater contaminants from the site.

According to information provided by the DEH Master Planner (personal communication, DEH, 1994d), laundry and dry cleaning operations in Building 183 will cease by October 1995. There are no current plans for future use of this building. The building structure, which was erected in the 1940s as a temporary building, will be demolished and the area converted to green space. There is no other planned use for the site according to the Fort Riley Land Use Master Plan (CEMRK, 1987).

Presently there are no on-site residents at the DCFA. Exposure to on-site residents can occur only if the site, or The Island floodplain directly south of the DCFA, were to be developed for residential use in the future. The floodplain is included here because contaminants have been detected in the alluvial groundwater as well as in the tributary. The possibility of future development has been evaluated. Considering the various pertinent characteristics and limitations of the site, residential use is not realistic. Therefore, future residents are not considered in the Baseline Risk Assessment. The site is unsuitable for residential development for the following reasons:

- The potentially buildable land immediately around Buildings 180/181 and 183 is small in area and bisected by Custer Road, one of the main roads on Post. The site is bordered by a buffalo corral to the north, a historic cemetery to the west, the Union Pacific Railroad right-of-way to the south, and a steep ravine of Tributary A to the east (see Figure ES-2). According to the Fort Riley Buildable Area Map for Main Post and Marshall Airfield (CEMRK, 1987), the area surrounding the DCFA is marked with a designation of "soils least suitable for development." The only exception is the area immediately north of the DCFA which includes the present buffalo corral.

- The DCFA lies within the Main Post historic district and, therefore, is subject to certain restrictions and architectural requirements for building construction (personal communication, DEH, 1993). These requirements do not preclude the construction of new buildings but make them more costly.

- The floodplain adjacent to the DCFA is an ecologically sensitive area and an important wintering habitat for bald eagles (U.S. Fish and Wildlife Service, 1992); it is unsuitable for development because of restrictions of the Endangered Species Act and restrictions on floodplain development due to its location within a 10-year floodplain (FEMA, 1988).

The restrictions and limitations of the site for future residential development exist regardless of whether the site remains under Army control. Should Fort Riley be designated for BRAC and the DCFA be designated for sale or transfer in the future the site may need to be re-evaluated and decisions made based on the site conditions existing at that time relative to the potential disposition and land use under consideration. In either case, there is no reasonable expectation that future land use will be substantially different from the historical and present-day use.

This assessment is based on the specific conditions at the DCFA and Fort Riley. Use of the area as green space or continued office/light industrial use under Army control is the only reasonable and foreseeable future use of the site. Therefore, on-site residents are not included as a potentially exposed population.

6.1.2.2 Evaluation of Potential Exposure Pathways

This section evaluates the exposure pathways for each of the receptor groups. The most important pathways are: inhalation of volatiles and fugitive dust by on-site workers and nearby residents; ingestion of, and dermal contact with, soil, sediment, and surface water by workers and nearby residents; and ingestion of, and dermal contact with, sediment and surface water by recreational children. Based on a careful review of present and future site conditions, ingestion of groundwater is not a feasible exposure pathway. A discussion of each of the pathways follows.

- **Air Pathway**

Two potential scenarios can be identified for exposure via the air pathway of on-site occupational and nearby residential receptors. The first scenario is exposure due to inhalation of volatiles and particulates released from the surface soils at the site, and ingestion of contaminated surface soil. The second scenario is exposure associated with soil excavation activities during installation and/or repair of underground utilities (sewer, water, gas, electric, telephone).

Exposure under the first scenario can occur only if contaminants are present in the surface soil. The potential for exposure under this scenario is considered negligible. Approximately 85 percent of the site is paved (either roadway or parking lot). Surface soil samples collected from unpaved areas during the RI did not show detectable levels of any of the contaminants of potential concern. Based on the absence of positive detections in surface soil samples, the inhalation and ingestion pathway for surface soil contaminants is not considered in the BLRA.

Exposure to on-site receptors is expected to be most significant during on-site activities involving soil excavation, particularly installation or repair of underground utilities in locations of existing soil contamination. These activities may increase air emission due to enhanced volatilization, and generation of airborne particulates by mechanical action and wind erosion of exposed soil. Receptors who might conceivably be affected under this exposure scenario are utility workers, office and laundry/dry cleaning workers, groundskeepers, and nearby residents and future site workers. Except for the utility workers, exposure would be via the air pathway only. Utility workers may be exposed by inhalation as well as direct dermal contact and ingestion of contaminated soil. The exposure of utility workers will always be higher than that of other on-site workers and nearby residents. Based on this consideration and the absence of positive contaminant detections in surface soils on site, several of the potential receptors discussed previously can be omitted from the BLRA. These receptors are present and future workers at the former (Building 181) and current (Building 183) DCF, groundskeepers, and nearby residents. Consequently, only utility workers will be considered in the BLRA for this pathway.

- **Groundwater Pathway**

A thin saturated zone exists underneath the DCFA at a depth of approximately 40 feet below ground surface. Contaminants of concern detected in groundwater at the site were shown in Table 6-2. Groundwater underneath the site discharges into the adjacent alluvial aquifer located south of the DCFA. Groundwater sampling of the alluvial aquifer immediately south of the DCFA has shown the presence of contaminants of concern. The maximum detected alluvial groundwater concentration (off site) of PCE was 160 μg/l (well DCF93-09, February 1994), compared to an on-site maximum groundwater concentration of 1600 μg/l (well DCF93-03, November 1993). The significance of the groundwater pathway is evaluated for both current and future land use conditions.

Present Land Use Conditions. There are no on-site irrigation or drinking water wells within the DCFA. The alluvial aquifer along the Kansas River is used to provide both irrigation and drinking water (Figure 6-1). Contaminants have been detected in the alluvial groundwater in the immediate vicinity of the site. The groundwater flow direction in the alluvial aquifer generally follows the direction of flow in the river, i.e., toward the east. Potential downgradient groundwater receptors are residents connected to the town of Ogden water supply system, and residents living along the Kansas River to the east and northeast of the DCFA who have or might have private drinking water wells. Along the western side of the Kansas River, the nearest downgradient wells are in the town of Ogden. Residents with domestic wells downgradient from the DCFA, but across the Kansas River, will not be impacted by contaminants emanating from the DCFA because the river acts as a hydraulic barrier.

Under present land and groundwater use conditions, users of the Ogden well system and any private wells in the Ogden area represent the nearest downgradient population for the groundwater pathway. As discussed in Chapter 5, the expected fate of contaminants released into the alluvial groundwater is discharge into the river and eventual loss to the atmosphere by volatilization. Even if the presence of the river on groundwater movement is ignored, the calculations presented in Chapter 5 show that, under highly conservative assumptions (steady-state source), the concentrations of PCE or any of its breakdown products reaching the town of Ogden would be 20 times or more below the MCL.

Under present land use conditions, therefore, the groundwater pathway does not represent a significant exposure pathway.

Future Land Use Conditions. Based on measured groundwater concentrations and the fate and transport calculations in Chapter 5, exposure via the groundwater pathway can only be potentially significant if groundwater wells are placed either directly in the shallow groundwater underneath the DCFA or in the alluvial aquifer immediately south of the DCFA.

The DCFA is presently supplied by the Fort Riley water system. According to the *Emergency Expansion Capability Report and Environmental/Analytical Assessment — Ft. Riley* (CEMRK, 1994h) the safe available yield of water from the aquifer serving Fort Riley is estimated at 50 million gallons per day, which exceeds the combined requirements of Fort Riley and the surrounding communities. Fort Riley is currently served by a total of 8 wells with a combined total well capacity of 8,400,000 gallons per day, which is reduced to approximately 7,900,000 gallons per day when adjusted for fire fighting requirements. In comparison, the actual daily consumption is approximately 3,400,000 gallons per day, or approximately 42 percent of the available capacity. Based on this, installation of new water supply wells is neither reasonable nor foreseeable. There are no records to indicate that water supply wells for either drinking water or other purposes have ever been installed at the site. The likelihood that water supply wells might be installed in the future depends in part on the future land use of the site, as well as on the suitability of the water-bearing formation to provide a sufficient supply of water. Monitoring wells installed during the PA/SI and RI have shown that the saturated thickness is only approximately 5 feet or less. Several of the wells installed during the RI (DCF93-14, 16, 17, and 18) were found to be "dry" wells; i.e., not enough water was encountered to allow purging of the wells during sampling events. While not dry during installation, during the June 1994 sampling event all of the above-mentioned wells were "dry." The sustained yield test conducted in August 1994 gave a combined yield for 3 wells of only 0.73 gpm. Installation of on-site wells is also infeasible from an economic point of view. The site is already connected to the Fort Riley water system. According to information provided by the Fort Riley Public Utilities Specialist, the cost of providing drinking water is presently $1.12 per 1000 gallons. By comparison, the cost of providing water to future workers from an on-site well which is operated for a 25-year period would be approximately $6.50 per 1000 gallons. The basis for this cost estimate is provided at the end of Appendix C-V.

In general, the alluvial aquifer that underlies the Kansas River floodplain is highly productive. This aquifer is used as the water supply for Fort Riley and the towns of Junction City and Ogden. Installing a drinking water well in the alluvial aquifer immediately next to the DCFA is technically feasible; however, it is not a reasonable, practical, or economically viable option.

Cost considerations would be similar to an on-site well. Moreover, the alluvial area immediately to the south, designated as The Island, is an undeveloped and ecologically important buffer zone between the river and the Main Post. This area lies within a 10-year flood zone and is presently inaccessible by road. Because of its low topographic elevation, extensive flood control measures would be needed in order to meet state requirements for a public well location, construction, and disinfection (KDHE, 1979). These requirements in turn, would increase costs and conflict with restrictions imposed by Executive Order No. 111988 on floodplain management, as well as with the Endangered Species Act. The latter applies because The Island is a wintering habitat for Bald Eagles (U.S. Fish and Wildlife Service, 1992).

Because the ingestion of on-site groundwater does not meet the requirement of representing a reasonable exposure scenario, it is not included in the BLRA; consequently, there is no RME for this pathway. For information purposes only, the health risks associated with ingestion of groundwater by a hypothetical on-site occupational receptor are presented in Section 6.1.4.4.

- **Surface Water and Sediment**

Current and future utility workers at the DCFA may be exposed to contaminants in surface water and sediments along Tributary A, while performing activities such as repairing the sanitary sewer line that crosses the tributary and/or cleaning out the tributary that represents a surface drainageway. Children playing along Tributary A and/or B may also be exposed to contaminants in the surface water and sediments. Because the tributaries are minor streams which are intermittently dry, they are not used for fishing or other recreational activities, such as boating or swimming.

As discussed in Section 6.1.1.1, sediment samples collected from Tributaries A and B in January 1995 did not show positive detections for any of the VOCs or SVOCs. The flooding during the spring of 1993 has likely removed any of the contaminants detected in sediment during the PA/SI sampling. This implies also that contaminants would no longer act as a source of contamination. However, for completeness and to ensure a conservative assessment, the sediment exposure pathway is still carried through the risk assessment.

The major surface waterbody that might be affected by contaminants originating from the DCFA is the Kansas River. Information on recreational activities along and in the Kansas River was provided by the Director of the Riley County Parks Department (personal communication, Riley Co. Parks Dept., 1994). The river is used for a variety of recreational activities, including boating and fishing. No public boat ramps, beaches, or campgrounds exist along the Kansas River between Junction City and Ogden. Fishing may occur from riverbanks where accessible from roads, and from boats in the river. Both motorboats and canoes have been observed in the river in the vicinity of the DCFA.

The potential exposure of humans and fish to contaminants in the river has been evaluated by performing screening-level calculations of potential contaminant discharges to the Kansas River. This analysis was presented in Chapter 5. Considering both discharge of contaminated groundwater and inflow of contaminants from Tributary B into the river, the sample calculations for PCE show that, even under extremely conservative assumptions, projected concentration values are more than 50 times below the federal Ambient Water Quality Criteria (AWQC) for ingestion of water and fish.

Therefore, exposure to surface water and sediments will be eliminated from the Baseline Risk Assessment for all potential receptors, except utility workers and recreational children. Because expected concentration levels in the Kansas River are more than 200 times below AWQC values, and bioaccumulation is not a concern for the chemicals encountered at the site, ingestion of fish is eliminated from the BLRA.

6.1.2.3 Selected Exposure Scenarios

Based on the evaluation presented in Section 6.1.2.2, the following receptors and exposure routes have been selected for inclusion in the BLRA:

- Utility worker (current and future)
  - Ingestion of soil and sediment
  - Dermal contact with soil, sediment, and surface water
  - Inhalation of volatiles and particulates
- Recreational child (current and future)
  - Ingestion of sediment
  - Dermal contact with sediment and surface water

The utility workers represent the RME as it pertains to the soil, sediment, and surface water pathways. Recreational children will not have a direct exposure to contaminated soil, and any exposure due to airborne contaminants will not exceed that experienced by on-site workers.

■ Exposure Patterns

The following two sections present the exposure parameters for the two receptor groups, utility workers and recreational children. Because future land use conditions at and surrounding the DCFA are not expected to be appreciably different from present conditions, no explicit distinction is made between present and future conditions in determining the health risks to the two receptor groups. Whenever future conditions might result in a greater exposure, conservative values are assigned to the appropriate exposure parameters. For instance, present utility work, such as the April 1994 sewer repair, is conducted by personnel using OSHA protective gear. In the exposure assessment, it is assumed that hands and forearms are unprotected and will directly contact contaminated media. Similarly, the exposure duration of recreational children at present is limited by the 3-year rotation of military personnel. Consequently, in the exposure assessment, a value of 3 years is used for recreational children.

▸ Utility Workers (Current and Future Scenarios)

Information regarding the frequency and duration of underground utility work at the DCFA was obtained from the Fort Riley DEH Chief of Utilities and the Outside Plant Branch Manager. The reported typical frequency of utility work is 2 person-days per year for sewer, water, and gas work, and 1 person-day per year for telephone work. Both types of work are typically performed by 3-person crews. A record of maintenance and repair activities obtained from the DEH for the DCFA, covering a 2.5-year period from 6/1/91 through 11/29/93, shows that a total of 77 labor hours were expended on sewer work. This corresponds to an average exposure of 3.85 8-hour days per year. Including 1 day per year for telephone work, and assuming that the work is performed by 2-person crews, the average exposure frequency is $(3.85+1)/2 = 2.5$ days/year/person. Based on interviews with the DEH Cables Supply Service Leader, two different frequencies for underground utility work, 12 days per year and 2-3 days per year, respectively, have also been reported (CEMRK, 1993d). For the risk assessment, the higher estimate of 12 days/year will be used, although no interview record for this reference was found. Reported crew sizes are from 2-3 persons. OSHA safety rules (i.e., the "buddy system") would not permit a single worker to conduct all the work. Two-person crews will be assumed, resulting in an exposure frequency of 12/2 = 6 days/year/person.

▸ Recreational Children (Current and Future Scenarios)

A default exposure frequency of 2.6 hours per day, 7 days/year/child (U.S. EPA, 1989c) will be used for the recreational child playing along Tributary A or B. Duration of the exposure for recreational children is assumed to be 3 years (between the ages of 6 and 15). Because of the relative inaccessibility of Tributaries A and B, recreational children under age 6 will not be considered.

■ Exposure Parameters

Probability distributions for body weights are derived from the data contained in the Exposure Factor Handbook (U.S. EPA, 1989c). The body weights selected correspond to the 50th percentile for each age group. The weights 70 kilograms (kg) and 37 kg are those for adults and children 6-15 years old. Specific exposure parameters selected for the different pathways are shown in Table 6-5. Discussion of these parameters is as follows:

▸ Fugitive Dust Inhalation Pathway Parameters

The inhalation rate of 2.5 m^3/h, which is for an adult performing moderate activity (U.S. EPA, 1989c), is used for the utility workers. A maximum inhalation bioavailability factor of 100 percent is used.

- **Incidental Ingestion of Soil Pathway Parameters**

Utility workers are expected to be in repeated contact with soils. Therefore, an upper-bound value of 480 mg/d is used for incidental ingestion of soil (U.S. EPA, 1989c).

- **Dermal Contact with Soil Pathway Parameters**

A probability distribution of skin surface area exposed to soil is derived from age-group-specific data provided in the Exposure Factors Handbook (U.S. EPA, 1989c). For the utility worker, hands, forearms, and face are assumed to come in contact with soil. The 95th percentile of the exposed skin surface area is 4,260 cm^2 for adults. A soil adherence factor of 1.0 mg/cm^2 is used (U.S. EPA, 1989c). In the absence of chemical-specific data on dermal absorption, 100 percent absorption is used.

- **Dermal Contact with Surface Water and Sediments Pathways Parameters**

It is assumed that workers hands, forearms, and face may come in contact with surface water and sediments. The 95th percentile of the exposed skin surface area is 4,260 cm^2 for adults (U.S. EPA, 1989c). For children, it is assumed that their lower legs and feet may also be in contact with surface water and sediment. The estimated 95 percent value is 5,060 cm^2. A dermal adherence factor of 1.0 mg/cm^2 and a dermal absorption rate of 100 percent are assumed for sediments. Chemical specific permeability constants are used for surface water exposure, obtained from the U.S. EPA Dermal Exposure Assessment Manual (U.S. EPA, 1992c).

- **Incidental Ingestion of Sediment Pathway Parameter**

Similar to soil ingestion, 480 mg/kg is used for incidental ingestion by utility workers. The gastrointestinal bioavailability factor used for all chemicals, which represents the fraction of ingested chemical that is actually absorbed into the body, is assumed to be 100 percent.

6.1.2.4 Exposure Estimates

Exposure estimates associated with each exposure route are presented in this section. The quantification of exposure consists of two steps:

1) Determination of exposure point concentration; and
2) Calculation of chemical intakes.

- **Exposure Point Concentrations**

The 95 percent Upper Confidence Limit (UCL) concentrations in each medium (Tables 6-1 through 6-4) are used to provide the exposure point concentrations. The concentration values used in the exposure calculations are intended to represent a conservative estimate of the concentrations to which a receptor might be exposed during repeated contact with a medium. The U.S. EPA's RAGS (U.S. EPA 1989a; U.S. EPA, 1992a) suggests to use the 95 percent UCL as a reasonable upper-bound estimate of the average exposure concentration. If the calculated UCL value exceeds the maximum detected value, the latter is to be used.

The exposure calculations in this BLRA are based on the 95 percent UCL values as presented in Tables 6-1 through 6-4.

In the case of air exposures during utility work, limited data are available. Air monitoring was conducted during the April 1994 sewer repair (see Section 3.3.1) using Open Path Fourier Transform Infrared Spectroscopy (OP-FTIR). This monitoring was conducted by the U.S. EPA Region VII Environmental Services Division, at the request of the CEMRK, specifically to detect low levels of VOCs in the air. The primary compound of interest was PCE. Based on the results of the soil gas survey during the PA/SI, dichloromethane, trichloroethane, and 1,1,2-trichloroethane were also targeted for laboratory qualification. OP-FTIR field detection limits for the target compounds were as follows (U.S. EPA, 1994b):

▸	PCE	22.8 ppb
▸	Dichloromethane	34.5 ppb
▸	1,1,1-Trichloroethane	5.3 ppb

None of the target compounds were detected during the one-day monitoring event.

The absence of detections during this one-time monitoring event does not guarantee that air emissions will never be of concern. Therefore, for the BLRA, air exposure point concentrations were estimated from the 95 percent UCL subsurface soil concentrations using U.S. EPA emission models. The calculations are presented in Appendix C-I, and take into account both generation of fugitive dust and volatilization of chemicals. The results of these calculations are summarized in Table 6-6, which presents the predicted on-site air concentrations for a "typical" underground utility repair activity. It may be noted that the predicted ambient air concentrations are low (e.g., PCE $= 2.5\times10^{-5}$ mg/m^3 $= 2.5\times10^{-5}$ ppb). These low predicted concentrations are consistent with the absence of detections during the 1994 sewer repair activity.

■ Calculation of Chemical Intakes

Chemical intakes for each receptor and exposure pathway are presented in this section. The intake equations use the exposure parameter values and exposure rates for each receptor as summarized in Table 6-5.

All equations and calculation methods used in estimating exposures are consistent with U.S. EPA risk assessment guidance (U.S. EPA, 1989a, 1991). For carcinogenic contaminants, the risks are calculated as an incremental lifetime risk. The exposure in this case is calculated as a lifetime (70 years) average. For non-carcinogenic contaminants, the exposures are calculated as an average over the actual duration of the exposure period, e.g., 25 years for an adult occupational receptor.

Health risks from chronic exposures are quantified in terms of the total amount of chemical with which a receptor comes into contact or which is absorbed by the receptor, per unit body weight, and averaged either over the length of the exposure period for non-carcinogenic effects or over the receptor's expected lifetime (70 years) for carcinogenic effects. Equations for calculating intakes have been developed by the U.S. EPA (U.S. EPA, 1989a).

The equations for the pertinent exposure pathways at the DCFA are summarized below. Parameter values used in the calculations have been summarized in Table 6-5. The actual calculations of chemical intakes and associated health risks are presented in spreadsheet format in Appendix C-III.

▸ Dermal Contact with Chemicals in Soil or Sediment

The intake of chemicals through dermal contact with soil or sediment by utility workers and dermal contact with sediment by recreational children is given by:

$$\text{Intake (mg/kg - d)} = \frac{CS \cdot SA \cdot ABS \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \qquad \textbf{(6.1)}$$

where:

CS = Chemical concentration in soil or sediment (mg/kg)
SA = Surface area of exposed skin (cm^2/event)
AF = Skin adherence factor (mg/cm^2)
ABS = Absorption factor (dimensionless)
ET = Exposure time (h/d)
EF = Exposure frequency (events/y)
ED = Exposure duration (y)
CF = Conversion factor ($=10^{-6}$ kg/mg)
BW = Body weight (kg)
AT = Averaging time (d)

This equation does not contain chemical-specific permeability constants because they are not currently available for constituents detected in soil and sediment media. Dermal intakes have been calculated using the very conservative assumption that 100 percent of the chemicals in the soil that comes in contact with the skin are absorbed into the body. While highly lipid-soluble non-volatile compounds may well be absorbed by the skin, this assumption is overly conservative for the volatile chemicals of potential concern. Volatile chemicals are likely to volatilize to air rather than being completely absorbed through the skin. This is demonstrated in a model that estimates dermal absorption from soil using chemical-specific octanol-water partition coefficients and Henry's law constants (McKone, 1990). The results of this model indicate that 3 percent or less of the VOCs would be absorbed through the skin. Therefore, the assumption of complete uptake of chemicals from the soil matrix leads to a substantial overestimate of risk.

▸ Ingestion of Soil or Sediment

The intake of chemicals through incidental ingestion of soil or sediment by utility workers and ingestion of sediment by recreational children is given by:

$$\text{Intake (mg/kg - d)} = \frac{CS \cdot IR \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \qquad \textbf{(6.2)}$$

where:

CS = Concentration of chemical in soil or sediment (mg/kg)
IR = Ingestion rate (mg soil/d)
EF = Exposure frequency (d/y)
ED = Exposure duration (y)
BW = Body weight (kg)
AT = Averaging time (d)

- **Dermal Contact with Surface Water**

The intake of chemicals through dermal contact with surface water by utility workers or by recreational children is given by:

$$\text{Intake (mg/kg - d)} = \frac{CW \cdot SA \cdot PC \cdot ET \cdot EF \cdot ED \cdot CF}{BW \cdot AT} \tag{6.3}$$

where:

CW = Chemical concentration in surface water (mg/l)
SA = Surface area of exposed skin (cm^2)
PC = Chemical-specific permeability constant (cm/h)
ET = Exposure time (h/d)
EF = Exposure frequency (d/y)
ED = Exposure duration (y)
CF = Conversion factor ($=10^{-3}$ l/cm^3)
BW = Body weight (kg)
AT = Averaging time (d)

The U.S. EPA's Dermal Exposure Assessment guidance document (U.S. EPA, 1992c) presents an alternative methodology to determine intake through dermal contact with surface water. Exposure to contaminants via this pathway involves assessing a dose absorbed per event, which is then used to estimated total absorbed dose. However, this document also states that the new model may produce results that seem counterintuitive and that the model may be overly conservative. Therefore, for the present risk assessment, the equation given above (U.S. EPA, 1989a) was used.

Dermal intakes associated with surface water exposure were adjusted to absorbed dose estimates by assuming that the contaminants permeate skin at chemical-specific permeability rates (U.S. EPA, 1992c). Permeability constants for constituents detected in aqueous media are listed in the Risk Characterization Tables in Appendix C. These values were obtained from the U.S. EPA's Dermal Exposure Assessment guidance document (U.S. EPA, 1992c).

- **Inhalation of Fugitive Dust and Volatiles**

The intake of chemicals through inhalation of fugitive dust and volatiles by utility workers and future on-site workers is given by:

$$\text{Intake (mg/kg - d)} = \frac{CA \cdot IR \cdot ET \cdot EF \cdot ED}{BW \cdot AT} \qquad \textbf{(6.4)}$$

where:

CA = Chemical concentration in air (mg/m^3)
IR = Inhalation rate (m^3/h)
ET = Exposure time (h/d)
EF = Exposure frequency (d/y)
ED = Exposure duration (y)
BW = Body weight (kg)
AT = Averaging time (d)

6.1.3 Toxicity Assessment

The purpose of this section is to identify the potential health hazards associated with exposure to each of the chemicals of concern. Information on the toxicity of each of the chemicals of concern was obtained from standard U.S. EPA data sources, primarily the U.S. EPA's Integrated Risk Information System (IRIS) database. A toxicological evaluation characterizes the inherent toxicity of a compound. The literature indicates that the chemicals of concern cause carcinogenic and/or non-carcinogenic health effects in humans. In addition, many of the chemicals have adverse effects on ecological receptors. Although the chemicals of concern may cause adverse health effects, dose-response relationships and the potential for exposure must be evaluated before the risks to receptors can be determined. Dose-response relationships correlate the magnitude of the intake with the probability of toxic effects, and are discussed below.

6.1.3.1 Health Effects

An important component of the risk assessment process is the relationship between the intake of a chemical (the amount of a chemical that is absorbed by a receptor) and the potential for adverse health effects resulting from that intake. Dose-response relationships provide a means by which potential public health impacts may be quantified. The published information of doses and responses is used in conjunction with information on the nature and magnitude of human exposure to develop an estimate of potential health risks.

Standard Reference Doses (RfDs) and/or Cancer Slope Factors (CSFs) have been developed by the U.S. EPA for the organic and inorganic contaminants. This section provides a brief description of these parameters. Brief toxicological profiles of the chemicals of concern are provided in Appendix C.

- **Reference Doses (RfDs)**

The RfD is developed by the U.S. EPA for chronic and/or subchronic human exposure to hazardous chemicals and is solely based on the non-carcinogenic health effects imparted by a chemical. The RfD is usually expressed as a dose (mg) per unit body weight (kg) per unit time (d). For the inhalation pathway, the toxicity value is expressed as a reference concentration (RfC), with units of mg/m^3. It is generally derived by dividing a no-observed-(adverse)-effect-level (NOEL or NOAEL) or a lowest-observed-adverse-effect-level (LOAEL) by an appropriate uncertainty factor. NOAELs, etc., are determined from laboratory or epidemiological toxicity studies. The uncertainty factor is based on the availability of toxicity data.

Various types of RfDs/RfCs are available, depending on the exposure route of concern (e.g., oral or inhalation), the critical effect of the chemical (e.g., developmental or other), and the length of exposure being evaluated (e.g., chronic or subchronic).

A chronic RfD/RfC is defined as an estimate of a daily exposure level for the human population that is likely to be without appreciable risk of deleterious effects during a lifetime. Chronic RfDs/RfCs are specifically developed to be protective for long-term exposures, i.e., 7 years to a lifetime (70 years). All exposures except childhood exposures in this preliminary risk evaluation are assumed to be long-term.

RfDs for the dermal exposure route are not generally available. Oral RfD values have been used as dermal RfDs. The chemicals of potential concern are generally well-absorbed in the gut and, therefore, do not require adjustment to an absorbed-dose basis.

The chronic RfDs/RfCs for the chemicals of concern at this site are presented in Tables 6-8 and 6-9. These tables correspond to oral and inhalation exposure routes, respectively. Values are provided for the chemicals of concern, i.e., PCE, TCE, DCE, and vinyl chloride, as well as other organic compounds detected at greater than 5 percent frequency at the DCFA. This latter category includes the suspected laboratory contaminants as well as trihalomethanes. As stated earlier, non-carcinogenic toxicity values for the inhalation route are often expressed as RfCs, in units of mg/m^3. RfDs for the inhalation pathway were obtained from Health Effects Assessment Summary Tables (HEAST) and the IRIS database (U.S. EPA, 1993a and 1994b). For chemicals for which RfC rather than RfD values were provided, the RfCs were converted to RfDs using body weight and inhalation rate as follows:

$$\text{RfD (mg/kg-d)} = \frac{RfC\,(mg/m^3) \cdot 20(m^3/d)}{70(kg)} \tag{6.5}$$

In making this conversion, a 100 percent absorption factor is assumed. The body weight of 70 kg is a U.S. EPA standard default value for an average adult male (U.S. EPA, 1989a and 1991a). The inhalation rate of 20 m^3/d is consistent with an inhalation rate of 2.5 m^3/h for the utility worker, because the entire daily exposure is assumed to occur during an 8-hour work day (2.5 m^3/h × 8 h/d = 20 m^3/d). U.S. EPA guidance (U.S. EPA, 1993a) warns that the conversion from RfC to RfD may be technically incorrect, but also suggests that it may not add significant uncertainty to the risk assessment process and, therefore, be a reasonable use of the data.

Uncertainty factors are generally applied as multiples of 10 to represent specific areas of uncertainty in the available data. A factor of 10 is used: to account for variations in the general population in order to protect sensitive subpopulations; when extrapolating test results from animals to humans, to account for interspecies variability; when a NOAEL derived from a subchronic study, instead of a chronic study, is used to develop the RfD; and when a LOAEL is used instead of a NOAEL. In addition, the U.S. EPA reserves the use of a modifying factor of up to 10 for professional judgement of uncertainties in the database not already accounted for. The default value of the modifying factor is 1.

The RfD incorporates the surety of the evidence for chronic human health effects. Even if applicable human data exists, the RfD as diminished by the uncertainty factor still maintains a margin of safety so that chronic human health effects are not underestimated. Thus, the RfD is an acceptable guideline for evaluation of non-carcinogenic risk, although the associated uncertainties preclude its use for precise risk quantitation.

- **Cancer Slope Factor (CSF)**

CSFs are applicable for estimating the lifetime probability (assuming a 70-year lifetime) of human receptors developing cancer as a result of exposure to known or potential carcinogens. This factor is generally reported by the U.S. EPA in units of $(mg/kg/d)^{-1}$ and is derived through an assumed low-dosage linear relationship and an extrapolation from high- to low-dose responses determined from animal studies. The value used in reporting the CSF is the 95 percent UCL. CSFs for the oral and inhalation routes are presented in Table 6-10 and Table 6-11, respectively. Values are provided for the chemicals of concern, i.e., PCE, TCE, DCE, and vinyl chloride, as well as other organic compounds detected at greater than 5 percent frequency at the DCFA. This latter category includes the suspected laboratory contaminants and trihalomethanes.

CSFs for the dermal exposure route are not generally available. Consistent with the handling of dermal exposures for non-carcinogens (see above), oral CSFs have been used as dermal CSFs in this risk assessment.

- **Weight of Evidence**

To evaluate carcinogenic effects, the U.S. EPA uses a two-part evaluation in which the chemical is first assigned a weight-of-evidence classification, and then a Cancer Slope Factor (CSF) is calculated. These indices can be derived for either oral or inhalation exposures. The weight-of-evidence classification is based on an evaluation of the available data to determine the likelihood that the chemical is a human carcinogen.

The classification is as follows:

A - Known human carcinogen

B - Potential human carcinogen. B1 indicates that limited human data are available. B2 indicates that there is sufficient evidence of carcinogenicity in animals, but inadequate or no evidence in humans.

C - Possible human carcinogen

D - Not classifiable as to human carcinogenicity

E - No evidence of carcinogenicity in humans

6.1.3.2 Applicable or Relevant and Appropriate Requirements (ARARs)

Chemical-specific ARARs are health- or risk-based numerical values that represent an acceptable amount or concentration of a chemical. By comparing detected concentration levels of chemicals in each medium to ARARs, an initial indication is obtained of whether that chemical is likely to pose a health risk. Even if a concentration is below the ARAR level, a receptor may still be subject to unacceptable risks due to the effects of exposure to multiple chemicals and across multiple exposure pathways.

This section presents the available federal regulatory standards or guidelines for all of the chemicals of concern within the DCFA. Currently, the only potentially enforceable federal regulatory standards for exposures to groundwater contamination are the Maximum Contaminant Levels (MCLs) to the extent that groundwater might reasonably be used as a drinking water source currently or in the foreseeable future. MCLs have not been specified for many of the chemicals of concern; therefore, other regulatory guidelines may be used for comparative purposes to infer health risks and environmental impacts. Relevant federal regulatory guidelines included the AWQC, non-zero Maximum Contaminant Level Goals (MCLGs), and Health Advisories.

Regulatory air quality criteria are not included here. Because of the absence of detections during air quality monitoring and exceedingly low modeled air emissions, air quality is not a concern at the site.

6.1.3.3 To Be Considered (TBC) Requirements

The TBCs are non-promulgated advisories or guidance issued by the state or federal government that are not legally binding and do not have the status of potential ARARs. However, the TBCs are used in conjunction with site risk assessment to aid in the determination of cleanup levels necessary to protect human health and the environment. Examples of TBCs include Health Advisories, RfDs, guidance policy documents developed to implement regulations, and calculated risk-based remediation goals (Tables 6-12 through 6-14).

6.1.3.4 ARARs and TBCs

The media of concern at the site and potentially associated ARARs are as follows:

- **Groundwater**

The National Primary Drinking Water Regulations established by the U.S. EPA provide MCLs and MCLGs for a number of constituents. By definition, the MCLGs equal to zero are non-enforceable health goals, while the MCLs are the enforceable standards for drinking water which must be set as close at the MCLGs as feasible. Non-zero MCLGs are also to be considered as potential ARARs. Applicable state and federal MCLs for the chemicals of potential concern detected in groundwater are provided in Table 6-12.

In addition to federal MCLs, the state of Kansas has developed Kansas Action Levels (KALs), Kansas Notification Levels (KNLs), Alternate Kansas Action Levels (AKALs), and Alternate Kansas Notification Levels (AKNLs). These levels are unpromulgated and are considered as potential guidance when their application is appropriate based on site-specific conditions. The KNL or AKNL is used to constitute administrative confirmation that groundwater contamination exists. The KAL or AKAL represents the level at which long-term exposure to contaminant concentrations is unacceptable.

Under the NCP, and as applied to the specific site conditions, MCLs and non-zero MCLGs are potentially relevant and appropriate in that they should only be used as cleanup standards if the groundwater or surface water at or near the DCFA is reasonably expected to be used as drinking water in the future.

- **Surface Water**

The U.S. EPA has developed AWQC for constituents in surface water. The AWQC for the protection of aquatic organisms are derived based on two criteria: (1) acute criterion representing the maximum concentrations permissible at any time, and (2) chronic criterion representing the maximum permissible concentration averaged over a 24-hour time period. Surface water criteria adopted by the state of Kansas (Kansas Administrative Regulations [KAR], 1994) generally follow the federal AWQC. Table 6-13 presents the federal and state AWQC for the constituents detected in the site's surface water.

The AWQC for the protection of human health are based on the ingestion of contaminated water and/or the ingestion of contaminated organisms from surface water (U.S. EPA, 1987). The federal AWQC are not applicable to surface water in the two tributaries (A and B) immediately adjacent to the site because the intermittent nature of flow in these tributaries does not support recreational activities or fish populations. They are applicable to the Kansas River.

- **Soils and Sediments**

Under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) regulations, no guidelines exist for allowable soil concentrations. The proposed Resource Conservation and Recovery Act (RCRA) Subpart S Regulations (Federal Register, 1990a) have developed Corrective Action Levels (CALs), which are health-based criteria serving as an indication of whether a corrective measure is required. The concentrations of constituents detected in the site's surface soil samples are compared to the proposed RCRA CALs in Table 6-14. This table also lists Risk-Based Concentrations (RBCs) for industrial soil, developed by U.S. EPA Region III (U.S. EPA, 1994a). Both RBCs and RCRA CALs are TBCs for soils, although RBCs are more widely accepted as they are calculated using standard risk assessment techniques.

The RCRA CALs are based on the ingestion of contaminated soil. The U.S. EPA Region III RBCs are based on dermal contact and ingestion of soil. The RCRA CALs were proposed in 1990 and are somewhat dated, as they represent information on the toxicity of different chemicals that may since have been revised. The RBC values in this table are for the First Quarter 1994 update and represent current data. RBC values for industrial, rather than residential, soil are compared in Table 6-14 to measured soil levels at the DCFA. Because of the industrial/commercial nature of the DCFA, comparison with a typical industrial scenario as incorporated in the RBCs is considered to be the most appropriate.

6.1.4 Risk Characterization

This section characterizes, on a quantitative basis, potential human health risks resulting from the exposures outlined in the preceding sections. Quantitative risk estimates are generated based on risk assessment methods outlined in current U.S. EPA guidance (U.S. EPA, 1989a). Results of the risk characterization show that carcinogenic risks are on the order of 10^{-6} or lower, and hazard indices are less than 0.1 for both the utility worker, who represents the RME, and the recreational child.

Non-carcinogenic risk estimates are presented in the form of Hazard Quotients and Hazard Indices, which are determined through comparison of estimated intakes with published Reference Doses (RfDs). Incremental cancer risk estimates are provided in the form of dimensionless probabilities based on Cancer Slope Factors (CSFs).

Estimated human intakes were developed for each of the specific exposure routes discussed in the preceding sections. Both carcinogenic and non-carcinogenic risks are summarized for each exposure route on a series of tables in this section. Detailed calculations are provided in Appendix C-III.

The Hazard Quotient is the ratio of the estimated intake and the RfD for a selected chemical of concern, as follows:

$$\text{Hazard Quotient} = \text{Intake} / \text{RfD} \tag{6.6}$$

If a Hazard Quotient for an individual chemical is less than 1, adverse health effects are not likely.

A Hazard Index is generated by summing the individual Hazard Quotients for the chemicals of concern. If the value of the Hazard Index exceeds unity (1.0), there is a potential non-carcinogenic health risk associated with exposure to that particular chemical mixture. The Hazard Index is not a mathematical prediction of the severity of toxic effects; it is simply a numerical indicator of the possibility of the occurrence of non-carcinogenic (threshold) effects.

Incremental cancer risk estimates are generated for each of the exposure pathways using the estimated intakes and published CSFs as follows:

$$\text{Risk} = \text{Intake} \times \text{CSF} \tag{6.7}$$

If the above equation results in a risk greater than 0.01, the following equation is used:

$$\text{Risk} = 1 - [\exp(\text{Intake} \times \text{CSF})] \tag{6.8}$$

The risk determined using these equations is a unitless expression of an individual's likelihood of developing cancer as a result of exposure to carcinogenic chemicals. An incremental cancer risk of 1×10^{-6} indicates that the exposed receptor has no greater than 1 in 1 million chance of developing cancer under the defined exposure scenario. Alternatively, such a risk may be interpreted as representing no more than one additional case of cancer in an exposed population of 1 million persons. The calculated cancer risks should be recognized as upper-limit estimates. CSFs are the 95 percent UCL of a dose-response curve generally derived from animal studies. Actual human risk, while not identifiable, is not expected to exceed the UCL based on the CSFs and, in fact, may be lower.

The U.S. EPA has generally defined risks in the range of 10^{-4} to 10^{-6} as being acceptable for most hazardous waste sites addressed under CERCLA. For CERCLA activities, residual risks on the order of 10^{-6} or less are the primary goal, but are often modified by such regulatory requirements as MCLs or chemical-specific cleanup goals.

Carcinogenic and non-carcinogenic health risks are estimated using several different assumptions; therefore, the values presented in this section contain an inherent amount of uncertainty. The extent to which health risks can be characterized is primarily dependent upon the accuracy with which the toxicity of a chemical can be estimated and the accuracy of the exposure scenario assumptions.

The following sections summarize the results of the risk calculations for the two receptors examined: utility workers and recreational children. The non-carcinogenic and carcinogenic health risks for each receptor group are presented in Sections 6.1.4.1 and 6.1.4.2, respectively. The detailed calculations of Hazard Quotients and cancer risks associated with individual chemicals are provided in spreadsheet format in Appendix C. Note that the calculations presented in Appendix C include both the chemicals of concern, as well as suspected laboratory contaminants and non-DCFA-operations-related trihalomethanes.

6.1.4.1 Non-Carcinogenic Effects Characterization

Calculated Hazard Indices for non-carcinogenic effects of exposures to contaminants in soil, sediment, surface water, dust, and groundwater for the two receptor groups are summarized in Table 6-15. The Hazard Indices for exposure to the chemicals of concern in all media considered are much less than 0.1. The total Hazard Index, summed across pathways, is 0.0005 for the utility worker and 0.0004 for the recreational child. It should be noted that none of the chemicals of concern detected in soils (PCE and TCE) have chronic RfDs for inhalation exposure. Consequently, there is no Hazard Index for this pathway. Hazard Indices for the recreational child's exposure to soil contaminants were not calculated because this receptor does not have a direct exposure to contaminated soil.

Non-carcinogenic effects were also calculated for the case in which contaminants which are common laboratory contaminants, as well as trihalomethanes in surface water, were included in the exposure and risk calculations. In this case, the total Hazard Index for utility workers and recreational children increases to 0.0028 and 0.0024, respectively (see Appendix C-III).

For information purposes, hazard indices were calculated also using the arithmetic average concentration of chemicals detected in each medium, instead of the 95 percent UCL values (Tables 6-1 through 6-4). The results of these calculations are presented in Table 6-16. As expected, the hazard quotients for the individual chemicals in this case are somewhat lower than if the 95 percent UCL values were used. The total Hazard Index is 0.00035 for the utility worker and 0.0003 for the recreational child.

6.1.4.2 Carcinogenic Risk Characterization

Table 6-15 presents a summary of the carcinogenic health risks by receptor and exposure pathway. The cumulative cancer risk for the utility worker is calculated to be 1×10^{-7}. The primary contribution to the cancer risk is from dermal contact with PCE in surface water. The risk for this pathway is 1×10^{-7}. Ingestion of, and dermal contact with, soil, inhalation of fugitive dust and volatiles, and ingestion and dermal contact with sediment do not produce risks in excess of 2×10^{-10}.

Cancer risks for the recreational child for each separate exposure pathway calculated are 3×10^{-8} or less; the estimated cumulative cancer risk for the recreational child is calculated as 3×10^{-8}. Dermal contact with PCE in surface water accounts for most of the risk. For both the utility worker and the recreational child, PCE in surface water accounts for over 99.5 percent of the carcinogenic risk. It may be noted that this is based on a one-time detection of PCE in Tributary A.

Overall, the carcinogenic risks to either receptor are well below the 10^{-6} threshold.

Carcinogenic risks were also calculated for the case in which contaminants which are common laboratory contaminants, as well as trihalomethanes in surface water, were included in the exposure and risk calculations. In this case, the total carcinogenic risk increases to 2×10^{-7} for the utility worker and to 5×10^{-8} for the recreational child. The primary contribution to the risk is still from dermal contact with surface water. This pathway accounts for over 90 percent of the risk for both the utility worker and the recreational child. Even when the additional suspected laboratory contaminants are included in the calculations, the risks for the individual soil and sediment exposure pathways remain below 2×10^{-9} for the utility worker and below 2×10^{-10} for the recreational child.

When phthalates and THMs are included in the calculations of surface water risk, the calculated risk is approximately doubled as compared to the baseline case. The calculations are found in Appendix C. PCE is still the largest contributor to the risk for this pathway (56 percent); the next largest contributions are from trichloromethane (26 percent) and bis(2-ethylhexyl)phthalate (15 percent).

Table 6-16 presents a summary of carcinogenic risks for the case where the average rather than 95 percent UCL concentration values are used in the exposure calculations. In this case, the overall calculated risks for the utility worker and recreational child are reduced. The carcinogenic risk is 7×10^{-8} for the utility worker and 2×10^{-8} for the recreational child.

6.1.4.3 Uncertainties of the Health Risk Assessment

This section presents and evaluates the various sources of uncertainty in the BLRA. The risk values obtained, e.g., incremental cancer risk, are not fully probabilistic estimates of risk, but conditional estimates given a considerable number of assumptions about exposure and toxicity. There are several categories of uncertainties. One is the completeness of the site characterization, including identification of contaminants and determination of concentration values. A second category of uncertainty is the selection of receptors, including assumptions about future land use and the determination of exposure parameters, such as exposure frequency and duration and chemical uptake parameters. Other sources of uncertainty are inherent in the toxicity values for each chemical.

Specific uncertainties that apply to the risk evaluation of all the identified exposure scenarios are identified below. An order of magnitude is provided for each source of uncertainty. This order of magnitude represents a best professional estimate of the impact of various assumptions that were used.

- The risk assessment is based on the present understanding of the site characteristics. Conditions at the site may change in unanticipated ways, resulting in either an increase or a decrease in the risk associated with the site. This factor is considered to have a relatively minor contribution to uncertainties. The major impact in terms of risk would be if on-site groundwater were to be used for drinking water. This is not a realistic scenario for the DCFA.

- The characterization of contaminant levels and potential migration routes in the BLRA may not be complete, resulting in an underestimate of risk associated with the site.

- The use of high-end (95 percent UCL) concentrations to estimate exposure and the assumption that these concentrations will remain constant over the entire exposure period of up to 25 years may be very conservative. This tacitly assumes that there is a continuing source of contaminants, and that the organic contaminants do not degrade. In reality, there is no evidence of a continuing source, and all chemicals of concern at the site are subject to biochemical degradation, with half-lives on the order of days to several years (see Table 5-2).

- The assumptions regarding body weight, average lifetime exposure, intake of contaminants, population characteristics, and lifestyle may not be representative for the actual exposed population, resulting in an underestimate or overestimate of risk. This risk assessment utilized U.S. EPA-established parameters where possible (e.g., for body weight, lifetime, daily water ingestion rate, daily inhalation rate, etc.). In those instances where there was no established standard, conservative values quoted in the literature or a conservative assumption based upon knowledge of the site or professional judgement was utilized. The expected uncertainty in each of the individual exposure parameters is relatively minor. However, the multiplicative effect of all parameters combined may add considerably to the overall uncertainty. Because several of the exposure parameters are conservative (e.g., all utility work over a 25-year period performed by the same individuals, 100 percent absorption rate), the combined effect may be to overestimate risks by more than an order of magnitude.

- Cancer slope factors (CSFs) are primarily derived using laboratory animal studies and, when available, human studies. This is one of the main sources of uncertainty in the risk assessment. Extrapolation of data from high to low doses, from one species to another, and from one exposure route to another introduces uncertainty in the values of CSFs. The application of uncertainty factors as multiples of 10 may introduce a considerable degree of conservatism in the values of the CSFs and the estimated risks.

- The slope factor for a chemical is based on the upper 95th percentile estimate of cancer potency. The upper 95th percentiles of probability distributions are not strictly additive; hence, the estimated total cancer risk may become artificially more conservative as risks from several different carcinogens are summed. Because the number of chemicals of concern at the DCFA was small, the contribution of this factor to the overall uncertainty is probably also minor.

- The total cancer risk for multiple substances sums all carcinogens equally, giving as much weight to Class B or Class C carcinogens as Class A carcinogens. The only Class A carcinogen detected at the DCFA is vinyl chloride, which was detected one or more times in three of the groundwater wells. The effect of treating all carcinogens the same will be to add to the degree of conservatism in the assessment.

- The action of two different chemicals might not be independent. The assumption that there are no synergistic or antagonistic effects of different organic and inorganic chemicals may not be true. In the absence of clear-cut scientific evidence of synergistic or antagonistic health effects of chemicals in mixtures, the relative contribution of this source of uncertainty is considered minor.

- Toxicity values are not available for all constituents of concern. Thus, the non-carcinogenic and carcinogenic risks calculated for the pathways of interest at the site may be reduced or increased.

This risk assessment should not be viewed as an absolute quantitative measure of the risk to public health presented by site-specific contaminants. The assumptions and inherent uncertainties in the risk assessment process do not allow this level of confidence. The risk assessment provides a reasonable indication of the potential for risk due to exposure to site-specific chemicals. This information should help guide the management of the site and contribute to the remedial decision-making process.

6.1.4.4 Hypothetical Industrial Worker Scenario (Future Only)

The following section presents the health risks associated with a hypothetical future industrial worker scenario. This scenario is presented for information only and does not represent the Army's view of a realistic future scenario. This scenario is based on a "default" industrial worker, as defined in the U.S. EPA's Standard Default Exposure Factors guidance document (U.S. EPA, 1991a). This default scenario (using the hypothetical future industrial worker) considers ingestion of potable water, incidental ingestion of soil and dust, and inhalation of contaminated air (U.S. EPA, 1991a). Because no contaminants were detected in surface soils and inhalation of contaminants via the air was shown for the utility worker to have only a small contribution to the health risk (cancer risk of 10^{-10}, see Table 6-15), only the groundwater ingestion pathway is considered. The intake of chemicals through ingestion of drinking water by the hypothetical site worker is given by:

$$\text{Intake (mg/kg - d)} = \frac{CW \cdot IR \cdot EF \cdot ED}{BW \cdot AT} \quad (6.9)$$

where:

CW = Chemical concentration in water (mg/l)
IR = Ingestion rate (l/d)
EF = Exposure frequency (d/y)
ED = Exposure duration (y)
BW = Body weight (kg)
AT = Averaging time (d)

The pertinent exposure parameter values for the industrial worker are as follows:

- Exposure frequency (EF): 5 days/week, 250 days/year;
- Exposure duration (ED): 25 years;
- Ingestion of contaminated water (IR): 1 liter/day
- Body weight (BW): 70 kg.
- Averaging time (AT): 70 years carcinogens; 25 years non-carcinogens.

This scenario assumes that on-site groundwater provides the potable water source even though the site hydrogeology is not capable of yielding sufficient groundwater for use (Section 3.2.4). To determine exposure concentrations for this receptor, 95 percent UCL values of the chemicals of concern in groundwater were used. Results of the risk calculations are presented in Table 6-17. This table summarizes the non-carcinogenic health effects, and carcinogenic risks to the future utility worker.

The non-carcinogenic Hazard Index for this scenario is 0.4. The primary contribution (85 percent) is from PCE. The carcinogenic health risk from ingestion of groundwater is 1×10^{-4}. PCE and vinyl chloride represent the major contributions to the risk. PCE accounts for 51 percent of the risk and vinyl chloride for 48 percent. Together these two chemicals would account for 99 percent of the cancer risk.

Because a well is installed in a fixed location, a receptor will be exposed to the concentrations at that location, rather than to an average concentration from multiple wells. For completeness, therefore, a number of additional hypothetical groundwater ingestion scenarios were evaluated. These were: (1) well with highest PCE concentration; (2) well with highest vinyl chloride concentration; and (3) well with highest PCE concentration in alluvium. Exposure point concentrations for each of the three scenarios are presented in Table 6-6 and results of the risk calculations are presented in Table 6-17. Assuming ingestion from the well with highest PCE or highest vinyl chloride concentration would produce comparable cancer risks: 3×10^{-4} and 4×10^{-4}, respectively. Ingestion from the highest PCE alluvial well would result in an approximately tenfold reduction in cancer risk (3×10^{-5}).

6.1.4.5 Summary of Human Health Assessment

The results of the human health evaluation of current receptors at the DCFA do not indicate a concern for potential risk to public health, for either systemic (non-carcinogenic) or carcinogenic endpoints. Utility workers performing installation or repair of underground utilities at the DCFA, and/or performing work in or along Tributary A, and recreational children playing along Tributary A or B, were identified as potential receptors. Of these two groups, the utility worker appears to be more at risk (carcinogenic risk = 1×10^{-7}, Hazard Index < 0.1). The risks associated with this worker's exposures are well below acceptable risk ranges (cancer risk = 1×10^{-4} to 1×10^{-6}, and Hazard Index = 1.0). Children playing at or near the DCFA do not appear to be at risk based on the surface water and sediment exposure scenarios used in the Baseline Risk Assessment.

In addition to the above exposure scenarios of the BLRA, exposure and risk calculations were performed for a "default" industrial/commercial worker as a worst-case scenario. Default exposure assumptions (U.S. EPA, 1991a) for this receptor include ingestion of 1 liter of water from the contaminated drinking water source per day. Using the maximum detected groundwater concentrations from the hottest well, the risk calculations show significant health risks associated with the ingestion of on-site groundwater. The Hazard Index for non-carcinogenic health effects is 0.4; the carcinogenic risk is 1×10^{-4}. PCE and vinyl chloride would contribute approximately equally (close to 50 percent each) to the carcinogenic risk in this hypothetical scenario.

6.2 Ecological Risk Assessment

6.2.1 Objectives and Approach

An ecological risk assessment was conducted to evaluate the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors (U.S. EPA, 1992d). The Ecological Risk Assessment for the DCFA was conducted in accordance with the guidance provided in the Risk Assessment Guidance for Superfund, Vol. II - Environmental Evaluation Manual (U.S. EPA, 1989b) and other U.S. EPA guidance documents, including Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (U.S. EPA, 1989d), Framework for Ecological Risk Assessment (U.S. EPA, 1992d), Ecological Techniques for the Assessment of Terrestrial Superfund Sites (U.S. EPA, 1992e), and the U.S. EPA's ECO Updates Supplementary Guidance Bulletins (U.S. EPA, 1991-92).

In accordance with U.S. EPA definitions (U.S. EPA, 1992d), an ecological risk does not exist unless (1) the stressor has the inherent ability to cause one or more adverse effects, and (2) it co-occurs with or contacts an ecological component (i.e., organisms, populations, communities, or ecosystems) long enough and at a sufficient intensity to elicit the identified adverse effect.

In the ecological risk assessment of the DCFA, only chemical stressors, i.e., chemical contaminants associated with the DCFA, are considered. The identification of the ecological components potentially at risk is based on the ecological site description and ecological habitats delineated at and near the site, as presented in Section 2.8, together with the knowledge of the nature and extent of contamination associated with the DCFA (Chapter 4).

The approach for the ecological risk assessment further involves the selection of appropriate ecological endpoints that are relevant to decisions made protecting the environment (U.S. EPA, 1992d). These endpoints consist of assessment endpoints which are explicit expressions of the actual environmental value that is to be protected and measurement endpoints which are measurable responses to a stressor that are related to the characteristics chosen as the assessment endpoints.

Primary assessment endpoints for the ecological risk assessment of the DCFA are (1) adverse impacts on plant and animal species in and along the two tributaries where DCFA operations-related chemicals have been detected in sediment and surface water, and (2) adverse impacts on the Kansas River, and especially on the Bald Eagle population which uses The Island as a winter roosting location, and the Kansas River as a winter feeding location.

The ecological risk assessment was designed during the planning stage of the RI as a qualitative rather than a quantitative assessment. Consequently, there is no direct quantitative data for the ecological measurement endpoints.

In the absence of this quantitative data, an indirect approach is used, which uses measured concentrations in the various media (water, sediment), in combination with data on the bioconcentration and bioaccumulation potential of chemicals of concern to evaluate exposure. Environmental Effects Quotients (EEQs) are calculated as an indication of whether sufficient contaminants are present in exposure media pathways to pose a potential ecological threat.

The ecological risk assessment consists of four primary components: source and receptor characterization, identification of chemicals of concern, exposure assessment, and risk characterization. Each component is summarized below and discussed more extensively in the remainder of this section.

- ***The Source and Receptor Characterization*** (Section 6.2.2) summarizes the extent of contamination in the various environmental media (soil, groundwater, sediment, and surface water) which may serve as sources to ecological receptors. It also briefly describes the major plant and animal species that were observed or expected to inhabit or use the site area.

- ***The Identification of Chemicals of Concern*** (Section 6.2.3) is based on criteria selected to provide an appropriate level of conservatism at this stage of the risk assessment. Chemicals of concern were selected based primarily on comparisons to toxic or potentially hazardous concentrations or the potential of a contaminant to bioaccumulate.

- ***The Exposure Assessment*** (Section 6.2.4) evaluates the potential exposures to chemicals in each medium of concern. It also addresses the potential for secondary exposures via the food chain. However, because no biological samples were analyzed for chemical composition, contaminated biota could not be considered to be a direct medium of concern. Therefore, the potential impacts associated with the ingestion of contaminated biota are addressed qualitatively in this risk assessment, as a function of potential bioconcentration/bioaccumulation.

- ***Risk Characterization*** (Section 6.2.5) involves comparing EEQs for chemicals to toxic or hazardous concentration (benchmark values). Although several methods have been developed to accomplish the integration of toxicity and exposure evaluation, the "quotient method" is the most frequently used and accepted approach. This method, which provides the basis for this study's risk calculations, divides the exposure concentration by the selected toxicity benchmark value. The resulting quotient enables the evaluation of relative toxicity between individual chemicals; higher quotients are associated with greater potential toxicity.

6.2.2 Source and Receptor Characterization

Site characterization activities during the PA/SI and RI have detected contaminants in shallow subsurface soils, groundwater, and surface water and sediments of Tributaries A and B. Each of these media may, in principle, act as a source of contaminants for ecological receptors. The Conceptual Site Model (CSM), as developed from the PA/SI and RI activities, is that contaminants have been initially released to soils, primarily through leaking sewers, and to a lesser extent through surface spills or dumping of still bottoms. The more mobile volatile organic constituents have migrated downward to the groundwater underneath the site, and subsequently into the adjacent alluvial aquifer that underlies The Island. Contaminants have also been detected in some of the samples collected from the tributaries. To the extent that these contaminants are DCFA operations-related, they may have migrated into the tributaries as a result of overland flow due to sewer overflows, and/or through seeps in the bank of the tributary. Groundwater and the tributaries may act as a source of contaminants to the Kansas River, through discharge of contaminated groundwater into the river.

An ecological site description is provided in Section 2.8 of this report. The following overview of ecological receptors is based on the information presented in Chapter 2, in relation to the contaminant sources summarized above.

The DCFA, i.e., the cleared and partially paved area surrounding the buildings, does not support significant ecological receptors. Vegetation consists of lawn-type grasses which are regularly mowed during the growing season. This area is designated a "Highly Disturbed" or "Commercial" in Section 2.8. Although a variety of animal species (birds, mammals) may pass through the area during hunting/foraging activities, they are not expected to inhabit the area immediately around the DCF (Buildings 180/181 and 183) in significant numbers.

Plant and animal receptors along the tributary and on The Island are described in Sections 2.8.1 and 2.8.2 of this report. Vegetation typically noted in riverine and densely vegetated drainage habitats in the Fort Riley area include cottonwood *(Populus deltoides)*, sycamore *(Platanus occidentalis)*, box elder (*Acer negundo*), and hackberry *(Celtis accidentalis)* as canopy cover, and is dominated by redbud *(Cencis canadensis)*, dogwood *(Cornus* sp.), greenbrier *(Similax* sp.), poison ivy *(Rhus radicans)*, Virginia creeper *(Panthenocissis quinquefolia)*, and seedling overstory species.

Animal species expected in or near the vicinity of the tributaries include benthic organisms, amphibians, (frogs, salamanders), and reptiles. It should be noted that because of their intermittent nature, the tributaries do not support fish life. A variety of small mammals, deer, and birds (primarily songbirds) live on The Island and may also potentially be impacted by contaminants in the tributary, either directly or through the food chain.

Potential ecological receptors in the Kansas River are fish and predator species, especially the Bald Eagle (see below).

6.2.2.1 Endangered Species Considerations

An overview of threatened and endangered species which may be encountered at or near the DCFA has been provided in the ecological site description in Section 2.8. A summary listing of the threatened and endangered species known to occur in the Fort Riley area, along with their typical habitats, is provided in Table 6-18 (U.S. Fish and Wildlife Service, 1992).

As indicated in the table, the only endangered species that is expected to be present on a regular basis in the riparian floodplain immediately south of the DCF is the Bald Eagle. This area provides an important roosting location for Bald Eagles who are wintering in the Fort Riley area. The U.S. Fish and Wildlife Service (USFWS) survey noted that the confluence of the Republican and Smokey Hill Rivers is one of the main areas of concentration of Bald Eagles at Fort-Riley. According to information provided by the Fort Riley Endangered and Threatened Species biologist, this area serves as an important roosting location because it is protected from northerly winds by the river bluff and the trees. At least 65 Bald Eagles have been observed at the same time roosting overnight in the trees near the DCFA in the period between mid-December and February. The eagles come to the area when nighttime weather is most severe because open, unfrozen water and fish are available at the outlets to the Milford Reservoir, one to two miles upstream. Eagles have been observed since 1986 at this location.

The eagles forage along Milford Lake, the Republican River, the Smoky Hill River, and downstream from The Island, along the Kansas River. The Kansas River, downstream from The Island, is the only portion of the foraging habitat which could be affected by contaminants issuing from the DCFA. A single observation of a Peregrine Falcon flying above the Kansas River, near The Island (personal communication, Wildlife Specialist, Fort Riley) had been reported. Peregrine Falcons might potentially feed on ducks in the river. Tributaries A and B on The Island do not support any fish and could not be used by the eagle population.

6.2.3 Chemicals of Concern

The primary chemicals of concern for the ecological risk assessment are the same as those selected for the human health evaluation. They consist of PCE and its breakdown products, i.e., TCE, DCE, and vinyl chloride. A number of additional, non-DCFA-operations-related VOCs and SVOCs have also been detected at the site. Other VOCs that have been detected are either common laboratory contaminants, especially dichloromethane, or trihalomethanes which were detected mostly in surface water samples in Tributary A. SVOCs detected include a number of PAHs (benzo(a)pyrene, benzo(a)anthracene, chrysene) which were detected in a single soil sample, and bis(2-ethylhexyl)phthalate which has been detected sporadically in all media except sediments.

The 95 percent UCL value of concentrations detected is used as representative of ecological exposure concentrations. In the case of exposures to receptors in the Kansas River (fish, Bald Eagles), estimated concentration values obtained from the model calculations presented in Chapter 5 are used.

6.2.4 Exposure Assessment

This section presents and discusses the potential for exposure to ecological receptors. The following discussion is based upon and summarized in the conceptual exposure model for ecological receptors, which is depicted graphically in Figure 6-3. The left-hand side of this figure shows the relationships between the contaminated media (soil, groundwater, sediment, and surface water). The right-hand side of this figure depicts the potential exposure pathways by which ecological receptors may be impacted. They can be either (1) direct exposure to contaminated media, or (2) secondary exposure via the food chain. The potential for exposure via direct contact is discussed first, followed by an evaluation of the potential for exposure through bioaccumulation.

It may be noted that the PA/SI and RI sampling was focused on potential human exposures, and not designed to measure representative exposures to ecological receptors. This means, for instance, in the case of surface water and sediments, that sampling locations were concentrated near the DCFA. No attempt was made to collect samples along the entire length of Tributary B as it traverses The Island. By concentrating the measurements close to the source of contamination, the resulting estimates of exposure to ecological receptors are likely to be high.

6.2.4.1 Direct Exposure Pathways

- **Soils**

Direct contact with contaminants in soils does not present a significant exposure pathway for ecological receptors. Contaminants in soils are of concern only at the DCFA site, i.e., the area immediately surrounding the buildings. Contaminants have been detected only in subsurface soil; no contaminants have been detected in surface soils. The shallowest detections of contaminants in soil have been of PCE at a depth of about 4 feet, at a number of sampling locations, and a single detection of a number of PAHs, also at a depth of 4 feet, at the location of monitoring well DCF92-03 (Table 4-2). These contaminants are not DCFA operations-related and, moreover, this detection was at a location which is covered by pavement. Approximately 85 percent of the ground surface is paved over, which, except possibly for deep-burrowing earthworms (Russell, 1973), effectively eliminates the possibility of contact with plants or animals. No signs of either animal burrows or vegetation stress have been visually evident during site visits.

- **Groundwater**

Contact with contaminants in groundwater does not represent a feasible exposure pathway for ecological receptors at or near the DCFA. On-site groundwater is at a depth of approximately 40 feet below ground surface. The groundwater beneath The Island was found at approximately 10 feet below ground surface during installation of monitoring wells. Although some tree roots may reach this deep (Russell, 1973), this depth is well below the rooting depth of most plant species.

Groundwater may potentially contribute to exposure of ecological receptors through discharge of contaminants into the Kansas River. The resulting river water concentrations have been quantitatively evaluated in Chapter 5 and are discussed here as part of the surface water pathway (see below).

- **Sediments**

A small number of contaminants have been detected in the streambed sediments of Tributaries A and B during the PA/SI sampling. These detections are summarized in Table 6-4. The chemicals detected are PCE (0.0066 mg/kg), the primary DCFA operations-related contaminant, acetone (1.8-2.1 mg/kg) and dichloromethane (0.8-1.1 mg/kg), both of which are common laboratory contaminants, and a single detection of pyrene (0.12 mg/kg), which is not a DCFA operations-related chemical. All detections in sediment were made during the PA/SI and the Initial Field Investigation part of the RI. No VOCs or SVOCs were detected in sediments of the tributaries during the actual RI sampling. This sampling followed the extensive flooding during the spring of 1993. This also points out why accumulation of contaminants in these sediments is unlikely. Volatile compounds will tend to disappear by volatilization during dry periods. Semivolatiles, which are more strongly sorbed to sediments, will be removed together with the sediment during periods of high rainfall and flooding when the sediments are eroded and washed out to the river. This erosion will occur only during periods of high river flow. The resulting greatly increased dilution of any contaminants in sediment entering the river means that this erosion will have a negligible small impact on concentration levels in the river.

- **Surface Water**

Exposure to contaminants in surface water may occur in the tributaries as well as in the Kansas River. Results of the surface water sampling in the tributaries adjacent to the DCFA are summarized in Table 6-3. The contaminants detected in Tributary A are PCE (4.5 μg/l), a number of trihalomethanes (bromodichloromethane, bromoform, dibromochloromethane, and trichloromethane) with a highest detected concentration of 27 μg/l for trichloromethane, and two SVOCs, bis(2-ethylhexyl)phthalate (11.5-69 μg/l) and di-n-octylphthalate (19μg/l). Of these chemicals, only PCE is DCFA operations-related. The trihalomethanes are formed by the reaction of chlorinated drinking water and natural organic matter, and the phthalates are common laboratory contaminants.

Aquatic organisms may be exposed to chemicals in surface waters and sediments. Surface water flow in Tributaries A and B is ephemeral and does not readily support aquatic life. Although fish are unlikely to reside in the surface waters adjacent to the site, other aquatic life forms present in the surface water (benthic organisms, amphibians) may potentially be exposed to contaminants in the tributaries.

Theoretically, discharge of contaminants from the tributaries and discharge of contaminated groundwater may have an impact on fish in the Kansas River, and possibly on Bald Eagles who prey on fish. Sampling of the Kansas River as part of the Southwest Funston Landfill RI (CEMRK, 1994g) did not show detections of any of the chemicals associated with the DCFA. Information on the availability of fish tissue analysis data was solicited from the USFWS (personal communication, USFWS, 1994). According to information provided by a USFWS biologist, no tissue analysis data of fish in the Kansas River in the vicinity of the DCFA is available.

In the absence of direct data, the exposure to species in the river may be evaluated based upon the calculations of river concentrations presented in Chapter 5. These calculations were performed for all constituents detected either in the surface water of Tributary A or in the alluvial groundwater sampling, under the assumption that these chemicals may eventually discharge to the river. The results of these calculations are presented in Table 6-19. It can be seen that the projected concentration levels in the river are all extremely low, even without considering the effects of volatilization, which will reduce actual concentrations even more (see Chapter 5). The calculated concentration values are at least one or two orders of magnitude below detection levels, which is consistent with the absence of detections in river sampling during the Southwest Funston Landfill RI.

6.2.4.2 Secondary Exposure Pathways

Secondary exposures may result from the accumulation and transfer of chemicals through the food chain. The importance of this exposure pathway is a function of both the tendency of a chemical for bioconcentration and bioaccumulation, and the sensitivity of the exposed organism. Bioconcentration refers to the concentration of a contaminant in the organism relative to the concentration in the immediate environment (soil, water, sediment). Bioaccumulation refers to the increase of concentration in organisms with increasing trophic levels in the food chain (U.S. EPA, 1989d). Bioconcentration is especially important for aquatic organisms and for terrestrial plants and animals (e.g., earthworms) in direct contact with soils. Predators (e.g., Bald Eagles) and other species near the top of the food chain are potentially the most vulnerable to effects of bioaccumulation. Based on the evaluation of direct exposure pathways in the preceding sections, exposure to soils is not a concern for this ecological risk assessment.

The potential for bioconcentration via organisms in surface water and/or sediment can be evaluated in terms of the aquatic bioconcentration factor (BCF) of chemicals detected in surface water and sediment. The BCF is the dimensionless ratio of the concentration of a contaminant in the organism to the concentration in the immediate environment (water, sediment). Aquatic BCFs are listed in Table 6-20. Included are BCFs for constituents that were detected in surface water or sediment in the tributaries, or in the alluvial groundwater based on the possibility of eventual migration to the Kansas River. The VOCs all have low BCFs, while only di-n-octylphthalate has a very high BCF. Aquatic BCFs of 300 or less are generally considered not significant (U.S. EPA, 1989b); this includes all of the VOCs. Only bis(2-ethylhexyl)phthalate and di-n-octylphthalate have BCFs exceeding 300. Neither of these constituents is DCFA operations-related, but both are considered common laboratory contaminants. Di-n-octylphthalate was detected in only one out of all the samples collected during the PA/SI and RI.

The tendency of chemicals to bioaccumulate through the food chain is correlated with the octanol-water coefficient of a compound (K_{ow}), which is a predictor of bioaccumulation in the oils of fish and the fat of animals (U.S. EPA, 1989b). The K_{ow} is also closely correlated to the BCF (Lyman, et al., 1991). In other words, although bioconcentration and bioaccumulation refer to distinctly different processes, the BCF can also be interpreted as a surrogate measure of a chemical's potential for bioaccumulation.

The primary contaminants at the DCFA, i.e., PCE and its breakdown products, all have low to negligible potential for bioaccumulation. Considering also the exceedingly low concentrations predicted to occur in the Kansas River and the propensity of VOCs to volatilize, it is unlikely that contaminants in surface water present a significant exposure to Bald Eagles or other higher species in the food chain.

6.2.5 Risk Characterization

This section will address the Applicable or Relevant and Appropriate Requirements (ARARs) which are used as a basis to determine which contaminants detected in sediment and surface water may pose a risk to ecological receptors. Currently, there is no available guidance that describes criteria for quantifying risks to ecological receptors. Following the ecological risk assessment guidance (U.S. EPA, 1989b), professional judgement is generally used. A chemical's Ecological Effects Quotient (EEQ) may be calculated in order to quantify the risk. The EEQ is the ratio of a substance exposure level over a specified time period to a reference exposure concentration derived from a similar exposure period. Calculations are done according to the following equation:

$$EEQ = \frac{\text{Environmental Concentration}}{\text{Chronic Concentration}} \tag{6.10}$$

All chemicals with EEQs greater than 1.0 pose potential ecological risk. However, chemicals with EEQ > 0.3 are considered of potential concern because they may contribute to chronic effects resulting from additivity or synergism.

6.2.5.1 Sediments

The National Oceanic and Atmospheric Administration (NOAA) has developed Effects Range Concentrations, which are nonenforceable guidance criteria for sediments. These concentrations were derived from data on the potential of these chemicals to cause adverse biological effects in coastal marine and estuarine environments. Effects-threshold-range-concentrations are defined as those concentrations at which effects may be perceived in an organism due to exposure to the constituent of concern. These values are presented in Table 6-21 and are used as a basis for the ecological risk evaluation.

As shown in Table 6-21, two effects-based values, the Effects Range - Low (ER-L) and the Effects Range - Median (ER-M), are usually determined for a given constituent, using a method similar to that used in establishing marine quality standards for the state of California (NOAA, 1990). This method involves a three-step approach. First, currently available information (i.e., studies and reports) containing estimates of chemical sediment concentrations associated with adverse biological effects is assembled and reviewed. Second, a range is established for a particular constituent, based upon a preponderance of evidence, which reflects the concentrations at which biological effects are noted. Third, this range is evaluated relative to the sediment chemical data available from the National Status and Trends (NS&T) Program. The ER-L and ER-M values are generated as a result of this process. The ER-L is the 10th percentile of this effects range, while the ER-M is the 50th percentile of the reported range of concentrations associated with biological effects.

A description of the relative degree of confidence associated with the ER-L and ER-M values is also provided by NOAA. The ER-L and ER-M values associated with a high degree of confidence were supported by clusters of data with similar concentrations, by data from multiple geographic locations, by data sets that included more than results from an approach, and for chemicals for which the overall apparent effects threshold was similar to or within the range of the ER-L and ER-M values (NOAA, 1990). Values associated with a low degree of confidence were based on data sets without these qualities.

The NOAA sediment criteria pertain to coastal and estuarine sediments, rather than directly to riverine sediments as encountered along the tributaries. The New York State Department of Environmental Conservation (NYSDEC) has recently published sediment criteria (NYSDEC, 1994). These also have been reviewed for use in the present ecological assessment. The NYSDEC guidance lists sediment criteria for a number of hazardous chemicals and also presents a methodology for calculating these criteria based on a chemical's Water Quality Criteria and K_{ow} value. None of the chemicals in Table 6-21 are listed in the NYSDEC guidance document; Ambient Water Quality Criteria (AWQC) are available for PCE only. The NYSDEC sediment criterion derived for PCE is included in Table 6-21.

Calculation of EEQs is possible only for PCE and pyrene. The EEQ value for PCE is 0.006/10 = 0.0006. The value for pyrene (a non-DCFA-operations-related chemical) is 0.337/1000 = 0.0003. No EEQs could be calculated for acetone and dichloromethane. However, both of these are non-DCFA-operations-related chemicals, and the presence of dichloromethane, in particular, can be attributed to laboratory contamination. The low EEQ values indicate an absence of risk to ecological receptors due to sediment exposure. Again, it is noted that contaminants were detected in sediments only during the PA/SI. No contamination was found during the RI, indicating that sediments along the tributary do not serve as a continuing source of contaminants.

6.2.5.2 Surface Water

Potential ARARs for protection of aquatic life in surface water include AWQC and State of Kansas Ambient Water Criteria. AWQC for protection of aquatic life were established under the Clean Water Act (CWA). These criteria represent guidance on the environmental effects of pollutants, which can be used to derive regulatory requirements.

Relevant state and federal surface water criteria for the protection of aquatic life were compared with contaminant levels detected in Tributaries A and B, as well as predicted Kansas River concentrations, in Table 6-13. Water quality criteria are used for comparison with surface water data, even though they are not strictly applicable for the tributaries present at the DCFA. These criteria are used because the surface water from the site discharges into nearby surface waters (i.e., Tributaries A and B eventually empty into the Kansas River).

None of the chemicals detected in surface water samples collected on and around this site exceeded the AWQC for the protection of aquatic life. As surface water flow is ephemeral in Tributaries A and B and aquatic life is scarce or non-existent, the impact of an exceedance in ARARs would still be expected to be limited under current conditions.

In addition to the comparison provided in Table 6-13, an evaluation of projected contaminant levels in the Kansas River was made by comparing these contaminant levels to federal and state AWQC. This information is provided in Table 6-19. This table lists the contaminants which have been detected in either groundwater or surface water at the DCFA, and which might eventually migrate to the river. The concentration levels represent projected values based on the fate and transport calculations presented in Chapter 5. It should be noted that these represent conservative (high-end) estimates. Inspection of the concentration values indicates that the calculated values are all low: orders of magnitude below the federal and state AWQC.

Comparison of the values in Table 6-19 with the chronic concentrations for protection of aquatic life shows that none of the concentrations result in an EEQ approaching unity. The highest value is $3.8 \times 10^{-6}/0.84 = 4.6 \times 10^{-6}$ for tetrachloroethylene. If non-DCFA-operations-related chemicals are included in the evaluation, this conclusion does not change. Including bis(2-ethylhexyl)phthalate, the highest EEQ value becomes $1.4 \times 10^{-5}/0.36 = 3.9 \times 10^{-5}$.

Even if the concentration in surface water in the tributaries (Tables 6-3 and 6-13) is used instead of the projected concentration value in the Kansas River, the calculation of the EEQ indicates negligible ecological risk to aquatic organisms. This would result in an EEQ value for PCE of 0.0016/0.84 = 0.002. If bis(2-ethylhexyl)phthalate is included, this value becomes 0.05. This is still below values of potential concern.

6.2.6 Uncertainties

Uncertainties can arise from many sources in any qualitative risk assessment. These sources include the following:

- Confidence that all key contaminants were identified and quantified accurately.
- Confidence that sensitive habitats and receptors were adequately characterized.
- Confidence that contaminant migration pathways and exposure routes are known.
- Uncertainty in the comparison of site concentrations to generic environmental criteria that may not be truly applicable to site conditions.

Qualitative risk assessments that rely on a comparison to background concentrations and chemical-specific ARARs are somewhat limited in that they cannot account for cumulative toxic effects from several chemicals or several exposure routes.

Additional uncertainties in the present assessment of risk to environmental receptors are derived in part from the imprecision of present scientific data on exactly what constituent concentrations pose a hazard to environmental receptors. For example, NOAA guidance defined with respect to coastal and estuarine sediments was employed for an evaluation of the possible hazards associated with the presence of constituents in riverine sediments in the absence of suitable reference criteria for freshwater sediments.

6.2.7 Conclusions

There are no known negative impacts on flora and fauna by contaminants detected in the soils, groundwater, sediments, and surface water collected as part of these investigations. Based on this qualitative risk assessment, the site does not appear to have a negative impact on the aquatic life in the area of the tributaries. In addition, the natural character of the tributaries does not readily support aquatic life. Terrestrial and riparian communities periodically utilizing these ephemeral streams for a water source or habitat might possibly be exposed to chemical concentrations in surface waters and sediments. However, based on the detected concentration levels, the level of exposure to aquatic, terrestrial, and riparian ecological receptors is expected to be small. Calculated EEQs indicate that direct exposures do not pose a significant risk. The evaluation of bioaccumulation potential indicates that secondary exposures do not pose a significant concern either. Based on the projected concentration levels of various contaminants in the Kansas River and the absence of significant bioaccumulation, impacts on aquatic life in the river, as well as on higher species in the food chain (i.e., Bald Eagles), are expected to be minimal or non-existent.

TABLE 6-1
CHEMICALS DETECTED IN SHALLOW SUBSURFACE SOIL SAMPLES (≤25 FEET)
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in μg/kg unless otherwise noted, expressed as dry weight.

Parameter	Frequency of Detection[a]	Quantitation Limit[b]	Range of Detected Concentration[c]	Average Soil Concentration[d]	95% Upper Confidence Limit[e]
VOLATILE ORGANICS:					
Carbon disulfide	1/101	3.2 - 25	9.2	2.6	2.7
Dibromochloromethane	1/101	2.4 - 25	190(I2)	4.8	3.7
Dichloromethane	28/101	5 - 25	22 - 180	19.0	23.0
Tetrachloroethylene	22/101	3.2 - 15	3.7(J) - 960	20.6	11.2
1,1,2-Trichloroethane	1/101	5.0 - 25	8.6(I2)	3.1	3.2
Toluene	6/101	5.2 - 29	5.8 - 31	3.8	3.8
Trichloroethylene	1/101	3.2 - 29	4.2(J)	2.7	2.9
SEMIVOLATILE ORGANICS:					
Benzo(a)anthracene	1/58	100 - 900	380(J)	136.9	214.1
Benzo(a)pyrene	1/58	240 - 900	270(J)	194.9	214.8
Chrysene	1/58	100 - 900	300(J)	135.5	155.2
bis(2-Ethylhexyl)phthalate	3/58	330 - 900	380(J) - 2400	283.7	300.2
Fluoranthene	1/58	140 - 900	610(J)	155.3	176.7
2-Methylnaphthalene	1/58	140 - 900	220(J)	149.1	168.4
Phenanthrene	2/58	140 - 900	290(J) - 610(J)	159.6	183.0
Pyrene	2/58	100 - 900	110(J) - 530(J)	140.4	161.8

Notes:

Tetrachloroethylene: DCFA operations-related chemical of concern, retained for BLRA.
Toluene: Common laboratory contaminant, not DCFA operations-related.

a Number of samples in which the chemical was positively detected divided by the number of samples available.
b Range reflects variation in sample quantitation limits (SQLs) between different sampling and analytical rounds.
c Only one value is noted when there was a single detection in the medium.
d The average soil concentration was calculated using all detected values of the chemical plus half the sample quantitation limit for the soil samples in which the chemical was not detected.
e The 95 percent Upper Confidence Limit (UCL) is calculated using statistical procedures appropriate for characterizing lognormal populations (Gilbert 1987). The UCL may exceed the maximum detected concentration because of the small sample number and the large standard deviation of the data set.

(J) Sample quantitation is estimated.
(I2) Low internal standard response and high surrogate recovery. Result is biased high.

TABLE 6-2
CHEMICALS DETECTED IN GROUNDWATER SAMPLES
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in μg/l unless otherwise noted.

Parameter	Frequency of Detection[a]	Quantitation Limit[b]	Range of Detected Concentrations[c]	Arithmetic Average Groundwater Concentration[d]	95% Upper Confidence Limit[e]
VOLATILE ORGANICS:					
Benzene	3/103	0.4-20	0.5(J)-0.6	1.3	1.3
Trichloromethane (THM)	14/103	0.5-25	0.5(J)-36	2.5	2.6
1,2-Dichloroethylene	53/103	0.5-25	4.1-110	12.6	29.9
Ethylbenzene	1/103	0.7-35	1.1	2.0	2.2
Dichloromethane	3/103	0.9-45	5-13	3.1	3.5
Tetrachloroethylene	60/103	1.1-5.5	1.5(J)-1600	93.8	341.8
Toluene	3/103	0.4-100	0.5-26	2.0	5.6
Trichloroethylene	46/103	0.6-30	0.8-160	9.2	13.2
Vinyl Chloride	11/103	0.8-40	11-54	5.6	8.0
Carbon disulfide	1/103	3-250	21	9.7	8.6

TABLE 6-2 (CONTINUED)
CHEMICALS DETECTED IN GROUNDWATER SAMPLES

Parameter	Frequency of Detection[a]	Quantitation Limit[b]	Range of Detected Concentrations[c]	Arithmetic Average Groundwater Concentration[d]	95% Upper Confidence Limit[e]
SEMIVOLATILE ORGANICS:					
2,6-Dinitrotoluene	1/68	4-26	12(S)	3.1	5.5
bis(2-Ethylhexyl)phthalate	5/68	6-26	10-44	4.1	6.6
Hexachloroethane	1/68	5-26	43(S)	3.5	5.5
Naphthalene	3/68	3-26	5.4(S)-7	2.9	5.4
N-Nitrosodi-n-propylamine	1/68	5-26	38(S)	3.4	5.5
1,4-Dichlorobenzene	1/68	4-26	11	2.8	5.1

Notes:

Naphthalene: DCFA operations-related chemical retained for BLRA.
bis(2-Ethylhexyl)phthalate: Common laboratory contaminant, not DCFA operations-related.

a Number of samples in which the chemical was positively detected, divided by the number of samples available.

b Range reflects variation in sample quantitation limits (SQLs) between different sampling and analytical rounds.

c Only one value is noted when there was a single detection in the medium.

d The average groundwater concentration was calculated using all detected values of the chemical plus half the sample quantitation limit for the groundwater samples in which the chemical was not detected.

e The 95 percent Upper Confidence Limit (UCL) is calculated using statistical procedures appropriate for characterizing lognormal populations (Gilbert, 1987). The UCL may exceed the maximum detected concentration because of the small sample number and the large standard deviation of the data set.

(J) Sample quantitation is estimated.

(S) Estimated result, may be biased high.

TABLE 6-3
CHEMICALS DETECTED IN SURFACE WATER SAMPLES FROM TRIBUTARIES A AND B
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in μg/l unless otherwise noted.

Parameter	Frequency of Detection[a]	Quantitation Limit[b]	Range of Detected Concentrations[c]	Average Concentration[d]	95% Upper Confidence Limit[e]
VOLATILE ORGANICS:					
Bromodichloromethane (THM)	3/14	0.6 - 0.9	0.5 - 5.8	0.8	1.2
Bromoform (THM)	2/14	1.6 - 1.8	1.6 - 4.6	1.1	1.4
Dibromochloromethane (THM)	4/14	0.6 - 2.0	1.4 - 6.7	1.3	2.3
Tetrachloroethylene	1/14	1.1 - 3.0	4.5	1.1	1.6
Trichloromethane (THM)	5/14	0.6 - 0.9	3.1 - 27.0	4.2	25.4
SEMIVOLATILE ORGANICS:					
bis(2-Ethylhexyl)phthalate	3/14	6.0 - 10.0	11.5 - 69.0	11.6	19.7
Di-n-octylphthalate	1/14	6.0 - 10.0	19.0	5.6	7.0

Notes:

Tetrachloroethylene: DCFA operations-related chemical of concern, retained for BLRA.
Trichloromethane (THM): Trihalomethane, not DCFA operations-related.

a Number of samples in which the chemical was positively detected, divided by the number of samples available.
b Range reflects variation in sample quantitation limits (SQLs) between different sampling and analytical rounds.
c Only one value is noted when there was a single detection in the medium.
d The average groundwater concentration was calculated using all detected values of the chemical plus half the sample quantitation limit for the groundwater samples in which the chemical was not detected.
e The 95 percent Upper Confidence Limit (UCL) is calculated using statistical procedures appropriate for characterizing lognormal populations (Gilbert, 1987). The UCL may exceed the maximum detected concentration because of the small sample number and the large standard deviation of the data set.

TABLE 6-4
CHEMICALS DETECTED IN SEDIMENT SAMPLES FROM TRIBUTARIES A AND B
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in μg/kg unless otherwise noted.

Parameter	Frequency of Detection[a]	Quantitation Limit[b]	Range of Detected Concentrations[c]	Average Concentration[d]	95% Upper Confidence Limit[e]
VOLATILE ORGANICS:					
Acetone	2/29	120 - 130	1800(E) - 2100(E)	204.8	197.9
Dichloromethane	4/29	5 - 14	80.0(B) - 1100	51.1	40.0
Tetrachloroethylene	1/29	3 - 14	6.6	3.3	6.1
SEMIVOLATILE ORGANICS:					
Pyrene	1/25	940	120(J)	280.5	336.9

Notes:

Tetrachloroethylene: DCFA operations-related chemical of concern, retained for BLRA.
Dichloromethane: Common laboratory contaminant, not DCFA operations-related.

a Number of samples in which the chemical was positively detected, divided by the number of samples available.
b Range reflects variation in sample quantitation limits (SQLs) between different sampling and analytical rounds.
c Only one value is noted when there was a single detection in the medium.
d The average groundwater concentration was calculated using all detected values of the chemical plus half the sample quantitation limit for the groundwater samples in which the chemical was not detected.
e The 95 percent Upper Confidence Limit (UCL) is calculated using statistical procedures appropriate for characterizing lognormal populations (Gilbert, 1987). The UCL may exceed the maximum detected concentration because of the small sample number and the large standard deviation of the data set.

(E) Estimated result, quantitation uncertain based on exceeded calibration range.
(J) Sample quantitation is estimated.

TABLE 6-5
EXPOSURE PARAMETERS
Dry Cleaning Facilities Area
Fort Riley, Kansas

Pathway/Receptor	Exposure Time (h/d)	Exposure Frequency (d/y)	Exposure Duration (y)	Body Weight (kg)	Body Surface Area (cm^2)	Rate	Bio Factor
1- Fugitive Dust Inhalation							
• Utility Worker	8	6	25	70	NAp	2.5 m^3/h	1.0
2- Incidental Ingestion of Soil							
• Utility Worker	NAp	6	25	70	NAp	480 mg/d	1.0
3- Dermal Contact with Soil							
• Utility Worker	8	6	25	70	4,260	1 mg/cm^2	1.0
4- Dermal Contact with Sediment							
• Utility Worker	8	6	25	70	4,260	1 mg/cm^2	1.0
• Recreational Child	2.6	7	3	37	5,060	1 mg/cm^2	1.0
5- Dermal Contact with Surface Water							
• Utility Worker	8	6	25	70	4,260	chemical-	1.0
• Recreational Child	2.6	7	3	37	5,060	specific	1.0
6- Incidental Ingestion of Sediment							
• Utility Worker	NAp	6	25	70	NAp	480 mg/d	1.0
• Recreational Child	NAp	7	3	37	NAp	200 mg/d	1.0

Note:

NAp	Not Applicable

TABLE 6-6
GROUNDWATER EXPOSURE CONCENTRATIONS FOR HYPOTHETICAL FUTURE INDUSTRIAL WORKER
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in μg/l unless otherwise noted.

Chemical	Exposure Concentration[a]
1) HIGHEST PCE WELL (DCF92-03)	
1,2-Dichloroethylene	12
Dichloromethane	13
Tetrachloroethylene	1600
Trichloroethylene	13
Trichloromethane	36
2) HIGHEST VINYL CHLORIDE WELL (DCF93-08)	
1,2-Dichloroethylene	77
Trichloroethylene	16
Vinyl Chloride	54
3) HIGHEST ALLUVIAL PCE WELL (DCF93-09)	
1,2-Dichloroethylene	68
Tetrachloroethylene	160
Trichloroethylene	13
bis(2-ethylhexyl)phthalate	44

Note:

[a] Maximum detected concentrations in each well.

TABLE 6-7
ESTIMATED ATMOSPHERIC EXPOSURE CONCENTRATIONS FOR INHALATION PATHWAY
Dry Cleaning Facilities Area
Fort Riley, Kansas

Chemical	**95% UCL Soil Concentration (mg/kg)**	**Air Concentration (mg/m³)**
bis(2-Ethylhexyl)phthalate	0.30	9.8×10^{-7}
Dichloromethane	0.023	4.7×10^{-5}
Tetrachloroethylene	0.011	2.5×10^{-5}
Toluene	0.004	7.0×10^{-6}
Trichloroethylene	0.003	6.8×10^{-6}

TABLE 6-8
TOXICITY VALUES FOR CHRONIC NON-CARCINOGENIC EFFECTS
ORAL ROUTE
Dry Cleaning Facilities Area
Fort Riley, Kansas

Parameter	Chronic RfD (kg-d/mg)	Confidence Level*	Critical Effect	Uncertainty Factor**	Source
Acetone	1.0×10^{-1}	Low	Nephrotoxicity	1000	IRIS
Bromodichloromethane	2.0×10^{-2}	Medium	Renal cytomegaly	1000	IRIS
Bromoform	2.0×10^{-2}	Medium	Hepatic Lesions	1000	IRIS
Trichloromethane	1.0×10^{-2}	Medium	Fatty cyst formation in liver	1000	IRIS
Dibromochloromethane	2.0×10^{-2}	Medium	Liver lesions (rats)	1000	IRIS
1,2-Dichloroethylene	9.0×10^{-3}	Low	Increased serum alkaline phosphatase (male mice)	1000	HEAST
bis(2-Ethylhexyl)phthalate	2.0×10^{-2}	Medium	Incr. relative liver wt. (guinea pig)	1000	IRIS
Dichloromethane	6.0×10^{-2}	Medium	Liver toxicity	100	IRIS
Naphthalene	4.0×10^{-2}	Low	Decreased body weight	1000	U.S. EPA
Tetrachloroethylene	1.0×10^{-2}	Medium	Hepatoxicity (mice, et. gain) (rats)	1000	IRIS
Toluene	2.0×10^{-1}	Medium	Changes in liver and kidney weights	1000	IRIS
Trichloroethylene	6.0×10^{-3}	Low	Liver and kidney toxicity	3000	U.S. EPA

Notes:

NAv Not Available.
* Confidence Level - Rating given in RfD/RfC indicating quality of the given value, expressed as Low, Medium, or High.
** Uncertainty Factor - Tenfold factors used in operationally deriving the RfD/RfC from experimental data.
They are intended to account for:
(1) the variation in sensitivity among the members of the human population;
(2) the uncertainty in extrapolating animal data to the case of humans;
(3) the uncertainty in extrapolating from data obtained in a study that is of less than lifetime exposure; and
(4) the uncertainty in using LOEL data rather than NOEL data.

Sources: IRIS = Integrated Risk Information System (10/94) (U.S. EPA, 1994b); HEAST = Health Effects Assessment Summary Tables (FY 1993 Annual) (U.S. EPA, 1993a); U.S. EPA = Superfund Health Risk Technical Support Center, Cincinnati, Telephone: (513) 569-7300.

TABLE 6-9
TOXICITY VALUE FOR CHRONIC NON-CARCINOGENIC EFFECTS
INHALATION ROUTE
Dry Cleaning Facilities Area
Fort Riley, Kansas

Parameter	Chronic RfD (kg-d/mg)	Confidence Level*	Critical Effect	Uncertainty Factor**	Source
Dibromochloromethane	NAv	NAv	NAv	NAv	IRIS
bis(2-Ethylhexyl)phthalate	NAv	NAv	NAv	NAv	IRIS
Dichloromethane	8.6×10^{-1}	NAv	NAv	100	HEAST
Tetrachloroethylene	NAv	NAv	NAv	NAv	IRIS
Toluene	1.1×10^{-1}	Medium	Neurological effects	300	IRIS
Trichloroethylene	Pending	NAv	NAv	Nav	IRIS

Notes:

NAv Not Available - No value listed in reference.
* Confidence Level - Rating given in RfD/RfC indicating quality of the given value, expressed as Low, Medium, or High.
** Uncertainty Factor - Tenfold factors used in operationally deriving the RfD/RfC from experimental data.
They are intended to account for:
(1) the variation in sensitivity aming the members of the human population;
(2) the uncertainty in extrapolating animal data to the case of humans;
(3) the uncertainty in extrapolating from data obtained in a study that is of less than lifetime exposure; and
(4) the uncertainty in using LOEL data rather than NOEL data.

Sources: IRIS = Integrated Risk Information System (10/94) (U.S. EPA, 1994b); HEAST = Health Effects Assessment Summary Tables (FY 1993 Annual) (U.S. EPA, 1993a).

TABLE 6-10
TOXICITY VALUES FOR CHRONIC CARCINOGENIC EFFECTS
ORAL ROUTE
Dry Cleaning Facilities Area
Fort Riley, Kansas

Parameter	Cancer Slope Factor (kg-d/mg)	Weight of Evidence Classification*	Type of Cancer	Source
Bromodichloromethane	6.2×10^{-2}	B2	Tumors in kidneys and large intestines (rats and male mice), liver tumor (female mice), mononuclear cell leukemia (female rats)	IRIS
Bromoform	7.9×10^{-3}	B2	Neoplastic lesions in large intestines (rats)	IRIS
Trichloromethane	6.1×10^{-3}	B2	Several tumor types in rats and mice	IRIS
Dibromochloromethane	8.4×10^{-2}	C	Hepatocellular adenoma	IRIS
1,2-Dichloroethylene	NAv	B2	NAv	IRIS
bis(2-Ethylhexyl)phthalate	1.4×10^{-2}	B2	Liver tumors in rats/mice orally	IRIS
Dichloromethane	7.5×10^{-3}	B2	Hepatocellular neoplasms	IRIS
Naphthalene	NAv	D	NAv	IRIS
Tetrachloroethylene	5.2×10^{-2}	Pending	NAv	U.S. EPA
Toluene	NAv	D	NAv	IRIS
Trichloroethylene	1.1×10^{-2}	Pending	Hepatocellular carcinomas in mice	U.S. EPA
Vinyl Chloride	1.9	A	Lung and liver tumors in rats	HEAST

Notes:

NAv Not Available - No value listed in reference.

* Weight of Evidence Classification:

A	Human carcinogen
B1	Probable human carcinogen; limited human data available
B2	Probable human carcinogen; inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenity

Sources: IRIS = Integrated Risk Information System (10/94) (U.S. EPA, 1994b); HEAST = Health Effects Assessment Summary Tables (FY 1993 Annual) (U.S. EPA, 1993a); U.S. EPA = Superfund Health Risk Technical Support Center, Cincinnati, Telephone: (513) 569-7300.

TABLE 6-11
TOXICITY VALUES FOR CHRONIC CARCINOGENIC EFFECTS
INHALATION ROUTE
Dry Cleaning Facilities Area
Fort Riley, Kansas

Parameter	Cancer Slope Factor (kg-d/mg)	Weight of Evidence Classification*	Type of Cancer	Source
Dibromochloromethane	NAv	C	NAv	IRIS/HEAST
bis(2-Ethylhexyl)phthalate	NAv	B2	NAv	IRIS/HEAST
Dichloromethane	1.6×10^{-3}	B2	Combined adenomas and carcinomas	IRIS
Tetrachloroethylene	2.0×10^{-3}	B2	Leukemia, liver tumors (mice)	U.S.EPA
Toluene	NAv	D	NAv	IRIS
Trichloroethylene	6.0×10^{-3}	B2	Lung tumors (mice)	U.S.EPA

Notes:

NAv Not Available - No value listed in reference.
* Weight of Evidence Classification:

A	Human carcinogen
B1	Probable human carcinogen; limited human data available
B2	Probable human carcinogen; inadequate or no evidence in humans
C	Possible human carcinogen
D	Not classifiable as to human carcinogenity

Sources: IRIS = Integrated Risk Information System (10/94) (U.S. EPA, 1994b); HEAST = Health Effects Assessment Summary Tables (FY 1993 Annual) (U.S. EPA, 1993a); U.S. EPA = Superfund Health Risk Technical Support Center, Cincinnati, Telephone: (513) 569-7300.

TABLE 6-12
EXPOSURE POINT CONCENTRATION AND STATE AND FEDERAL MCLs FOR GROUNDWATER
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in mg/l unless otherwise noted.

Parameter	Exposure Concentration[a]	Federal Maximum Contaminant Level[b]	Federal Maximum Contaminant Level Goal[b]	Kansas Action Level[c]	Kansas Notification Level[c]	Alternate Kansas Action Level[c]	Alternate Kansas Notification Level[c]
VOLATILE ORGANICS:							
Benzene	0.0013	0.005	0	0.005	0.0005	NAv	NAv
Trichloromethane	0.0026	NAv	NAv	0.1	0.0005	NAv	NAv
1,2-Dichloroethylene	0.0299	0.07 (cis) 0.1 (trans)	0.07 (cis) 0.1 (trans)	0.07 (cis) 0.07 (trans)	0.007 (cis) 0.007 (trans)	NAv	NAv
Toluene	0.0056	1.0	1.0	2.0	0.2	NAv	NAv
Dichloromethane	0.0035	0.005	0[P]	0.05	0.005	NAv	NAv
Tetrachoroethylene	0.342	0.005	0	0.007	0.0007	NAv	NAv
Ethylbenzene	0.0022	0.7	0.07	0.68	0.068	NAv	NAv
Trichloroethylene	0.013	0.005	0	0.002	0.0002	NAv	NAv
Vinyl Chloride	0.008	0.002	0	0.002	0.0002	NAv	NAv

TABLE 6-12 (CONTINUED)
EXPOSURE POINT CONCENTRATION AND STATE AND FEDERAL MCLs FOR GROUNDWATER

Parameter	Exposure Concentration[a]	Federal Maximum Contaminant Level[b]	Federal Maximum Contaminant Level Goal[b]	Kansas Action Level[c]	Kansas Notification Level[c]	Alternate Kansas Action Level[c]	Alternate Kansas Notification Level[c]
SEMIVOLATILE ORGANICS:							
2.6-Dinitrotoluene	0.0055	NAv	NAv	0.00004	0.000004	NAv	NAv
bis(2-ethylhexyl) phthalate	0.0066	0.006[d]	0[d]	4.2	0.420	0.940	0.003
Hexachloroethane	0.0055	NAv	NAv	0.0019	0.00019	NAv	NAv
Naphthalene	0.0054	NAv	NAv	0.143	0.143	NAv	NAv
n-Nitrosodi-n-propylamine	0.0055	NAv	NAv	0.01	0.001	5.85	0.585

Notes:

Tetrachloroethylene: DCFA operations-related chemical of concern, retained for BLRA.

P	Proposed MCL/MCLG
NAv	Not Available (constituent has been listed for regulation)
a	Lower of 95 percent UCL and maximum detected concentration.
b	Maximum Contaminant Levels and Maximum Contaminant Goal (40 CFR 141 Subpart B)
c	KDHE Memorandum, dated December 5, 1988; Revised Groundwater Contaminant Cleanup Target Concentrations for Aluminum and Selenium.
d	Drinking Water Regulations and Health Advisories, U.S. EPA Office of Water, December 1992.

TABLE 6-13
EXPOSURE POINT CONCENTRATION AND REGULATORY AND GUIDANCE CRITERIA FOR SURFACE WATER
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in mg/l unless otherwise noted.

Parameter	95% UCL Concentration (Tributary)	Estimated Kansas River Concentration[1]	Federal Ambient Water Quality Criteria* (mg/l)				Kansas State Water Quality Standards*** For the Protection Of Public Health
			For the Protection of Aquatic Life:		For the Protection of Human Health (consumption of):		
			Acute	Chronic	Water & Fish	Fish Only	
Bromodichloromethane	0.0012	8.6×10^{-7}	11	NAv	0.00027**[b]	0.022**[b]	0.1
Trichloromethane	0.025	1.8×10^{-5}	28.9	1.24	0.0057**[b]	0.470**[b]	0.1
Dibromochloromethane	0.023	1.6×10^{-5}	11	NAv	0.00041**[b]	0.034**[b]	NAv
bis(2-Ethylhexyl)-phthalate	0.020	1.4×10^{-5}	NAv	NAv	0.0018**[b]	0.0059**	0.004
Di-n-octylphthalate	0.007	5.0×10^{-6}	NAv	NAv	NAv	NAv	NAv
Tetrachloroethylene	0.0016	3.7×10^{-6}	5.28[a]	0.84[a]	0.0008**[b]	0.00885**[b]	0.005

Notes:

Tetrachloroethylene: DCFA operations-related chemical, retained for BLRA.

NAv Not Available.

1 Predicted concentration in Kansas River after mixing with ambient river water.

a Insufficient data to develop criteria. Value presented is lowest observed effect level.

b Human health criteria for carcinogens reported for three risk levels. Value presented in this table is the 10^{-6} risk level.

Sources: *Quality Criteria for Water - 1986. EPA 440/5-86.001, 1 May, 1987.
**40 CFR 131.36 - Toxic Criteria for states not complying with Clean Water Act Section 303(c)(2)(B).
***Kansas Surface Water Quality Standards (KAR 28.16.28), July 14,1994; Domestic Water Supply Criteria.

TABLE 6-14
COMPARISON OF CONSTITUENTS DETECTED IN SHALLOW SUBSURFACE SOILS (≤25 FEET) SAMPLES TO RCRA CORRECTIVE ACTION LEVELS,[A] AND REGION III RBCs[c]
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in mg/kg unless otherwise noted.

Parameter	95% UCL Exposure Concentration	RCRA Corrective Action Level[a]	EPA Region III RBCs[b]
VOLATILE ORGANICS:			
Carbon disulfide	0.003	8000	100,000
Dibromochloromethane	0.004	NAv	34
Dichloromethane	0.023	90	380
Tetrachloroethylene	0.011	10	55
Toluene	0.004	20,000	200,000
Trichloroethylene	0.003	NAv	260
1,1,2-Trichloroethane	0.003	100	50
SEMIVOLATILE ORGANICS:			
Benzo(a)anthracene	0.21	NAv	3.9
Benzo(a)pyrene	0.21	NAv	0.39
Chrysene	0.16	NAv	390
bis(2-Ethylhexyl)phthalate	0.3	60,000	200
Fluoranthene	0.18	NAv	41,000
2-Methylnaphthalene	0.17	NAv	NAv
Phenanthrene	0.18	NAv	NAv
Pyrene	0.16	NAv	31,000

Notes:

Tetrachloroethylene: DCFA operations-related chemical, retained for BLRA.

NAv Not Available.

a RCRA Corrective Action Levels - Federal Register, Vol.55, No. 145, 27 July, 1990. pp. 30798-30884. Corrective Action for Solid Waste Management Facilities, Proposed Rule.

b Risk Based Concentration values for industrial soil (U.S. EPA, 1994a).

TABLE 6-15
SUMMARY OF HEALTH RISKS FOR UTILITY WORKER AND RECREATIONAL CHILD FOR REASONABLE MAXIMUM EXPOSURE SCENARIO
Dry Cleaning Facilities Area
Fort Riley, Kansas

UTILITY WORKER

Contribution by Chemical	Shallow Subsurface Soil Exposures			Surface Water Exposures	Sediment Exposures		Total For Each Receptor
	Ingestion	Inhalation	Dermal		Ingestion	Dermal	
NON-CARCINOGENIC EFFECTS:							
PCE	0.00000012	NAv	0.00000110	0.00051	0.00000007	0.00000061	
TCE	0.00000005	NAv	0.00000048	NAv	NAv	NAv	
Pathway Total	**0.00000017**	**NAv**	**0.00000158**	**0.00051**	**0.00000007**	**0.00000061**	**0.00051**
CARCINOGENIC RISKS:							
PCE	2.3E-11	8.4E-11	2E-10	9.5E-08	1.3E-11	1.1E-10	
TCE	1.3E-12	6.8E-11	1.1E-11	NAv	NAv	NAv	
Pathway Total	**2.4E-11**	**1.5E-10**	**2.1E-10**	**9.5E-08**	**1.3E-11**	**1.1E-10**	**1E-07**

TABLE 6-15 (CONTINUED)
SUMMARY OF HEALTH RISKS FOR UTILITY WORKER AND RECREATIONAL CHILD FOR REASONABLE MAXIMUM EXPOSURE SCENARIO
Dry Cleaning Facilities Area
Fort Riley, Kansas

RECREATIONAL CHILD

Contribution by Chemical	Shallow Subsurface Soil Exposures			Surface Water Exposures	Sediment Exposures		Total For Each Receptor
	Ingestion	Inhalation	Dermal		Ingestion	Dermal	
NON-CARCINOGENIC EFFECTS:							
PCE	NAp	NAp	NAp	0.00044	0.00000006	0.00000016	
TCE	NAp	NAp	NAp	NAv	NAv	NAv	
Pathway Total	**NAp**	**NAp**	**NAp**	**0.00044**	**0.00000006**	**0.00000016**	**0.00044**
CARCINOGENIC RISKS:							
PCE	NAp	NAp	NAp	2.9E-08	2.7E-12	1.1E-10	
TCE	NAp	NAp	NAp	NAv	NAv	NAv	
Pathway Total	**NAp**	**NAp**	**NAp**	**2.9E-08**	**2.7E-12**	**1.1E-10**	**3E-08**

Notes:

NAp	Not applicable; chemical does not contribute to risk.
NAv	Not available; pathway not evaluated.

TABLE 6-16
SUMMARY OF HEALTH RISKS FOR UTILITY WORKER AND RECREATIONAL CHILD FOR AVERAGE CONCENTRATION EXPOSURE SCENARIO
Dry Cleaning Facilities Area
Fort Riley, Kansas

UTILITY WORKER

Contribution by Chemical	Shallow Subsurface Soil Exposures			Surface Water Exposures	Sediment Exposures		Total For Each Receptor
	Ingestion	Inhalation	Dermal		Ingestion	Dermal	
NON-CARCINOGENIC EFFECTS:							
PCE	0.00000022	0.00000055	0.00000202	0.00035	0.00000013	0.00000033	
TCE	0.00000005	NAv	0.00000045	NAv	NAv	NAv	
Pathway Total	**0.00000027**	**0.00000055**	**0.00000247**	**0.00035**	**0.00000013**	**0.00000033**	**0.00035**
CARCINOGENIC RISKS:							
PCE	4.2E-11	1.6E-10	3.7E-10	6.5E-08	7.0E-12	6.0E-11	
TCE	1.2E-12	6.3E-11	1.0E-11	NAv	NAv	NAv	
Pathway Total	**4.4E-11**	**2.2E-10**	**3.8E-10**	**6.5E-08**	**7.0E-12**	**6.0E-11**	**7E-08**

TABLE 6-16 (CONTINUED)
SUMMARY OF HEALTH RISKS FOR UTILITY WORKER AND RECREATIONAL CHILD FOR AVERAGE CONCENTRATION EXPOSURE SCENARIO
Dry Cleaning Facilities Area
Fort Riley, Kansas

RECREATIONAL CHILD

Contribution by Chemical	Shallow Subsurface Soil Exposures			Surface Water Exposures	Sediment Exposures		Total For Each Receptor
	Ingestion	Inhalation	Dermal		Ingestion	Dermal	
NON-CARCINOGENIC EFFECTS:							
PCE	NAp	NAp	NAp	0.0003	0.00000003	0.0000009	
TCE	NAp	NAp	NAp	NAv	NAv	NAv	
Pathway Total	**NAp**	**NAp**	**NAp**	**0.0003**	**0.00000003**	**0.0000009**	**0.0003**
CARCINOGENIC RISKS:							
PCE	NAp	NAp	NAp	2.0E-08	1.5E-12	6.0E-11	
TCE	NAp	NAp	NAp	NAv	NAv	NAv	
Pathway Total	**NAp**	**NAp**	**NAp**	**2.0E-08**	**1.5E-12**	**6.0E-11**	**2E-08**

Notes:

NAp	Not applicable; chemical does not contribute to risk.
NAv	Not available; pathway not evaluated.

TABLE 6-17
SUMMARY OF HEALTH EFFECTS—NON-CARCINOGENIC AND CARCINOGENIC CHARACTERIZATION FOR HYPOTHETICAL INDUSTRIAL WORKER
Dry Cleaning Facilities Area
Fort Riley, Kansas

Scenario	Health Effects
95% UCL ALL WELLS:	
Non-Carcinogenic Hazard Index	0.4
Carcinogenic Risk	1×10^{-4}
HOTTEST PCE WELL (DCF92-03):	
Non-Carcinogenic Hazard Index	1.6
Carcinogenic Risk	3×10^{-4}
HOTTEST VINYL CHLORIDE WELL (DCF93-08):	
Non-Carcinogenic Hazard Index	0.1
Carcinogenic Risk	4×10^{-4}
HOTTEST ALLUVIAL WELL (DCF93-09):	
Non-Carcinogenic Hazard Index	0.3
Carcinogenic Risk	3×10^{-5}

TABLE 6-18
PROTECTED ANIMAL AND PLANT SPECIES OCCURRING WITHIN FORT RILEY, KANSAS AND ADJACENT COUNTIES
Dry Cleaning Facilities Area
Fort Riley, Kansas

Species Name	Federal Status	State Status	Preferred Habitat	On-Site Habitat
MAMMALS:				
Eastern Spotted Skunk *(Spilogale putorius)*	C2	ST	Open level cultivated farmland upland sites with preference for fallen logs and brush piles.	No
BIRDS:				
Bald Eagle *(Haliaeetus leucocephalus)*	FT	SE	Near water bodies (rivers, lakes, etc.) utilizing riparian forest.	Wood floodplain south of DCF is significant wintering habitat.
Black Tern *(Chlidonias niger)*	C2		Wetlands with persistent emergent vegetation and open water.	No
Eskimo Curlew *(Numenius borealis)*	FE	SE	Wet meadows, fields, pastures, drier parts of salt and brackish marshes.	No
Henslow's Sparrow *(Ammodramus henslowii)*	C2		Mesic grasslands with tall herbaceous vegetation.	No
Least Tern *(Sterna antillarum)*	FE	SE	Sparsely vegetated sandbars in a wide channel with good visibility.	Yes
Loggerhead Shrike *(Lanius ludovicianus)*	C2		Grassland areas with scattered woody vegetation.	No
Peregrine Falcon *(Falco peregrinus)*	FE	SE	Large river or water fowl management areas, cropland, meadow and prairies, river bottoms, marshes and lakes.	Yes
Piping Plover *(Charadrius melodus)*	FT	ST	Open unvegetated beach or sandbar	Yes

TABLE 6-18 (CONTINUED)
PROTECTED ANIMAL AND PLANT SPECIES OCCURRING WITHIN FORT RILEY, KANSAS AND ADJACENT COUNTIES

Species Name	Federal Status	State Status	Preferred Habitat	On-Site Habitat
Quachita Map Turtle	C2		Riverine and Lacustrine Habitats	Yes
Western Snowy Plover *(Charadrius alexandrinus nivosus)*	C3	ST	Unvegetated riverain.	Yes
White-faced ibis *(Plegadis chihi)*	C2	ST	Small ponds with stands of cattails or bulrush.	No
Whooping Crane *(Grus americana)*	FE	SE	Wetland, riverain base sandbars, shallow water, slow river flow.	No
REPTILES:				
Texas Horned Lizard *(Phrynosoma cornutum)*	C2		Dry-flat areas with sandy, loamy, or rocky surface with little vegetation.	No
FISHES:				
Topeka shiner *(Notropls tristis)*	C1		Large quiet pools near headwaters of small streams.	No
Sturgeon chub *(Hybopsis gelida)*	C1 PT		Areas of shallow strong currents and gravel bottoms, and turbulent areas where water flows across sandbars.	Yes

TABLE 6-18 (CONTINUED)
PROTECTED ANIMAL AND PLANT SPECIES OCCURRING WITHIN FORT RILEY, KANSAS AND ADJACENT COUNTIES

Species Name	Federal Status	State Status	Preferred Habitat	On-Site Habitat
INSECTS:				
American burying beetle *(Nicrophorus americanus)*	FE	SE	Areas with suitable humus and topsoil suitable for burying carrion.	Unknown
Prairie mole cricket *(Gryllotaipe major)*	C2		Tall-grass prairie, ungrazed or unmowed native tall-grass with silt-sandy loam soils.	No
Regal fritillary butterfly *(Speyeria idalia)*	C2		Prairie meadows (wet), moist tall-grass prairie, virgin grassland where violets *(Viola spp.)* act as host plants.	No
PLANTS:				
Western prairie fringed orchid *(Platanthera praeclara)*	FT		Tall-grass prairie and sedge meadow (fire adapted).	No

Notes:

Listed by the U.S. Fish and Wildlife Service, Region #6 and Kansas Department of Wildlife Parks.
FE = Federal Endangered Species
FT = Federal Threatened Species
C2 = Federal Candidate Species
SE = State Endangered Species
ST = State Threatened Species
PT = Proposed Threatened Species

Source: U.S. Fish and Wildlife Service (USFWS), 1992. A Survey of Threatened and Endangered Species on Fort Riley Military Reservation, Kansas.

TABLE 6-19
ESTIMATED CONTAMINANT CONCENTRATIONS IN KANSAS RIVER AND AMBIENT WATER QUALITY CRITERIA
Dry Cleaning Facilities Area
Fort Riley, Kansas

All results shown in mg/l unless otherwise noted.

Parameter	Estimated Concentration	AWQC for Protection of Aquatic Life*		Kansas Water Quality Standards for Protection of Aquatic Life***	
		Acute	Chronic	Acute	Chronic
VOLATILE ORGANICS:					
Bromodichloromethane	$8.5\ 10^{-7}$	11	NAv	11	NAv
Bromoform	$1.0\ 10^{-6}$	11	NAv	11	NAv
Dibromochloromethane	$1.6\ 10^{-6}$	11	NAv	11	NAv
1,2-Dichloroethylene	$2.7\ 10^{-6}$	11.6	NAv	11.6	NAv
Dichloromethane	$1.8\ 10^{-8}$	NAv	NAv	NAv	NAv
Tetrachloroethylene	$3.8\ 10^{-6}$	5.28	0.84	5.2	0.84
Trichloroethylene	$2.6\ 10^{-6}$	45	21.9**	45	21.9
Trichloromethane	$1.8\ 10^{-5}$	28.9	1.24	28.9	1.24
Vinyl chloride	$6.4\ 10^{-7}$	NAv	NAv	NAv	NAv
SEMIVOLATILE ORGANICS:					
Bis(2-Ethylhexyl)phthalate	$1.4\ 10^{-5}$	0.4	0.36	0.4	0.36
Di-n-Octylphthalate	$5.0\ 10^{-6}$	NAv	NAv	NAv	NAv

Notes:

NAv Not Available.

Sources:
* U.S. Federal Register Vol. 45, No. 231, November 28, 1980, pp. 79318-79341.
** U.S. EPA (1994b).
*** Kansas Surface Water Quality Standards (KA 28.16.28), July 14, 1994.

TABLE 6-20
BIOCONCENTRATION FACTORS FOR CHEMICALS DETECTED AT DCFA
Dry Cleaning Facilities Area
Fort Riley, Kansas

Constituent	Aquatic BCF	Ref.
VOLATILE ORGANICS:		
Acetone	0.7	3
Bromodichloromethane	5.2-23	3
Bromoform	33	5
Trichloromethane	6	4
Dibromochloromethane	22	5
trans-1,2-Dichloroethene	1.6	1
Dichloromethane	5	3
Tetrachloroethylene	49	4
Trichloroethylene	17-39	4
Vinyl Chloride	1.17	1
SEMIVOLATILE ORGANICS:		
bis(2-Ethylhexyl)phthalate	850	4
Di-n-octylphthalate	5.8×10^6	5

Notes:

1. U.S. EPA (1986b).
2. Verschueren (1983).
3. Howard (1989; 1990).
4. Lyman, Reehl, Rosenblatt (1990).
5. Values calculated using K_{ow} (equation from Lyman, Reehl, Rosenblatt, 1990 and K_{ow} values from Montgomery, Welkom, 1990).

TABLE 6-21
SEDIMENT CONCENTRATIONS VERSUS ECOLOGICAL CRITERIA
Dry Cleaning Facilities Area
Fort Riley, Kansas

All values are in mg/kg unless otherwise noted.

		NYSDEC Criteria[b]	**NOAA Criteria**[c]			
Chemical	**Exposure Concentration**[a]	**Concentration**	**ER-L Concentration**	**ER-M Concentration**	**Overall Apparent Effects Threshold**	**Degree of Confidence**
VOLATILE ORGANICS:						
Acetone	0.2	NAv	NAv	NAv	NAv	NAv
Dichloromethane	0.04	NAv	NAv	NAv	NAv	NAv
Tetrachloroethylene	0.006	10	NAv	NAv	NAv	NAv
SEMIVOLATILE ORGANICS:						
Pyrene	0.337	NAv	350	2200	1000	Moderate/ Moderate

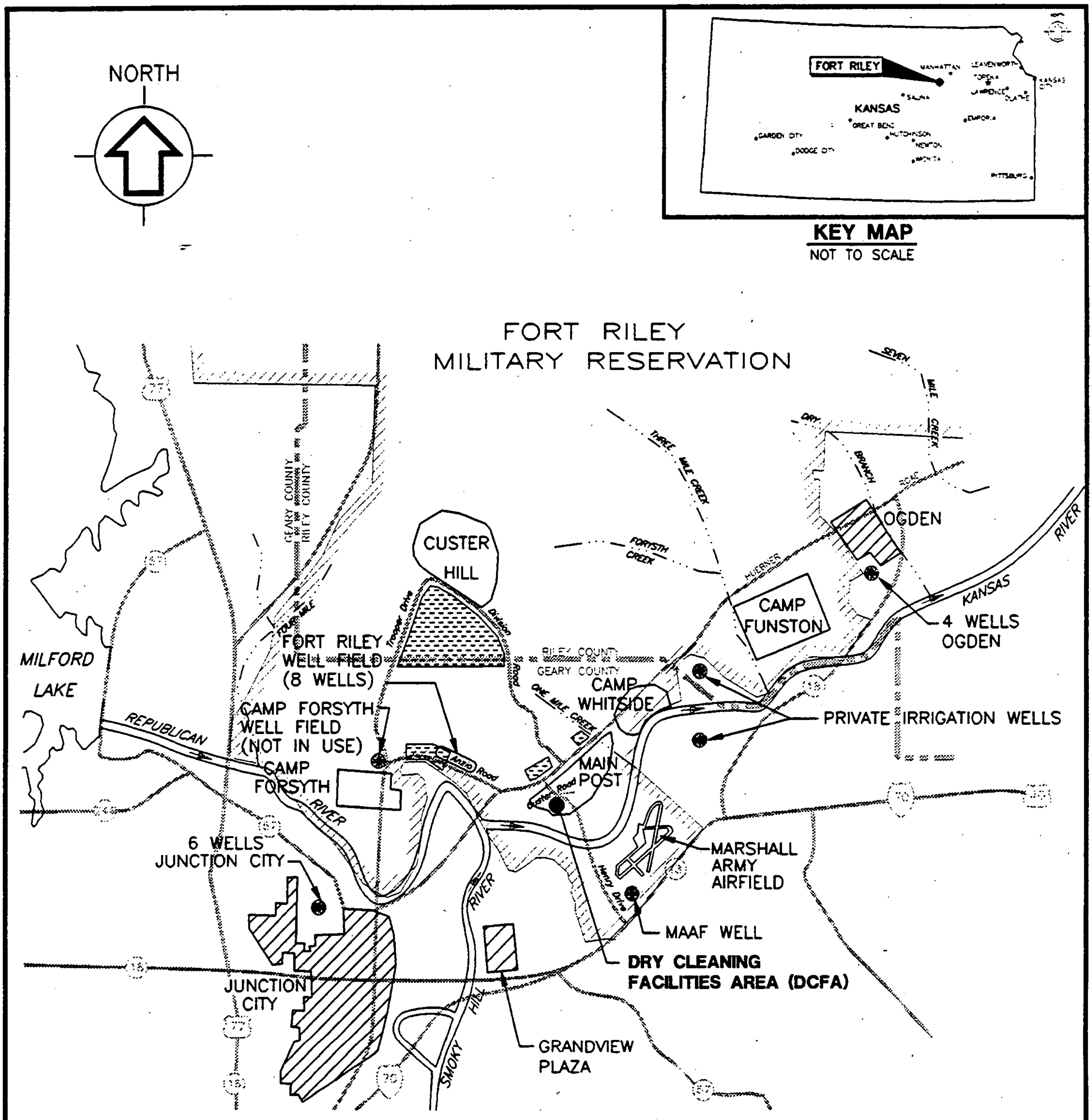
Notes:

NAv Not available.

[a] Lower of 95 percent UCL and maximum detected concentration.

[b] Calculated from Technical Guidance for Screening Contaminated Sediments, NYSDEC, November 1993, using $K_{ow} = 400$, AWQC = 0.84 mg/l and fraction organic carbon = 3 percent.

[c] National Oceanic and Atmospheric Administration, Technical Memorandum, NOS OMA 52, 1990.



LEGEND:

▒ MILITARY HOUSING

☐ CANTONMENT AREA

▨ MUNICIPALITY

MILITARY RESERVATION BOUNDARY

NOTE:

BIG BLUE RIVER (NOT SHOWN) IS APPROX. 8km TO THE NE OF MAIN POST

U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER & ASSOCIATES, INC.

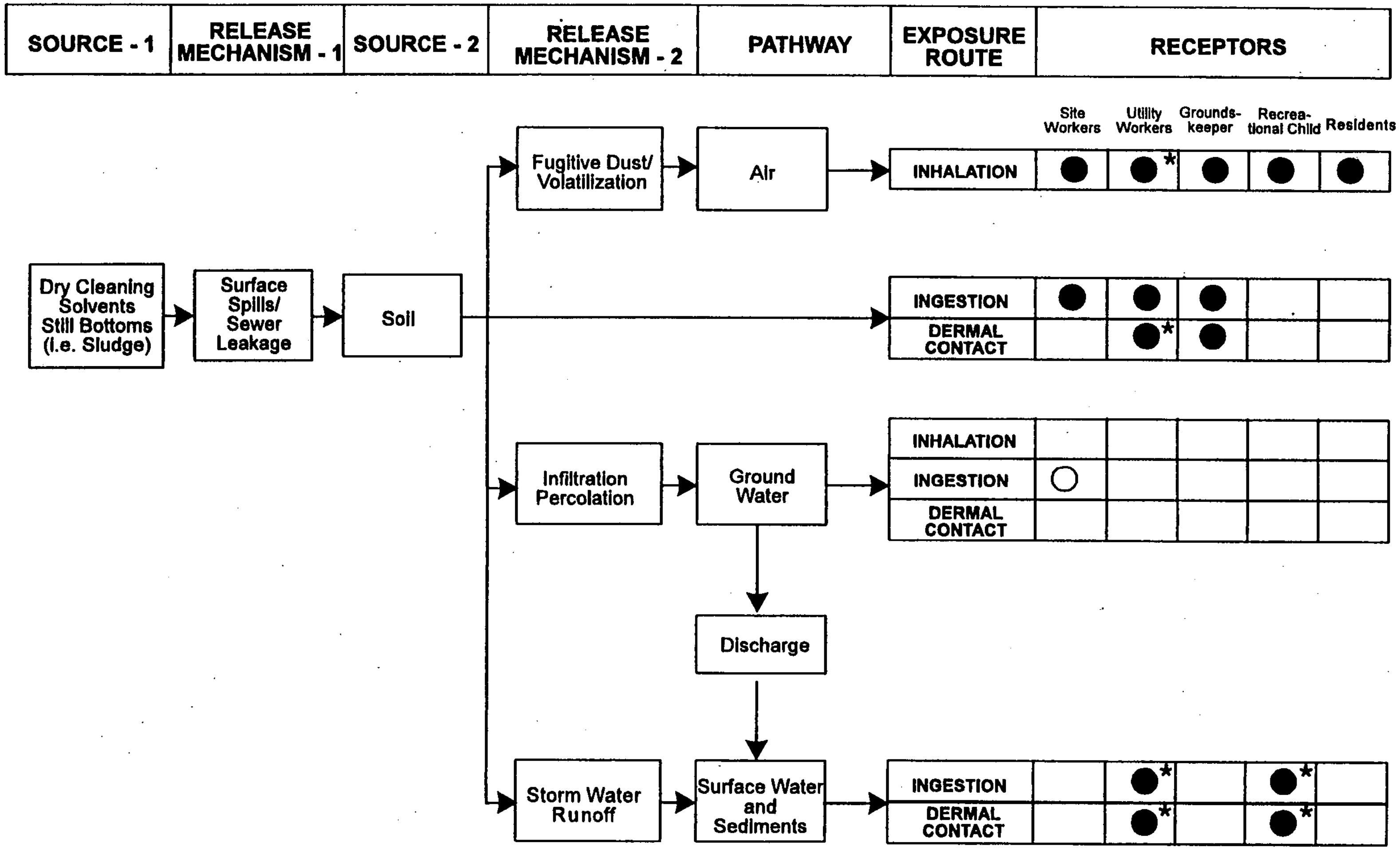
FORT RILEY MILITARY RESERVATION (DCFA-RI)

POPULATION CENTERS AND KNOWN WELL LOCATIONS IN THE DCFA VICINITY

SCALE: AS SHOWN	DATE: MARCH 1995	FIG. 6-1

6-PCWELL/30MAR95

6-EM/30MAR95



Pathway	Exposure Route	Site Workers	Utility Workers	Grounds-keeper	Recrea-tional Child	Residents
Air	INHALATION	●	●*	●	●	●
Soil	INGESTION	●	●	●		
	DERMAL CONTACT		●*	●		
Ground Water	INHALATION					
	INGESTION	○				
	DERMAL CONTACT					
Surface Water and Sediments	INGESTION		●*		●*	
	DERMAL CONTACT		●*		●*	

○ Indicates potential future pathway

* Included in Baseline Risk Assessment

U.S. ARMY CORPS OF ENGINEERS

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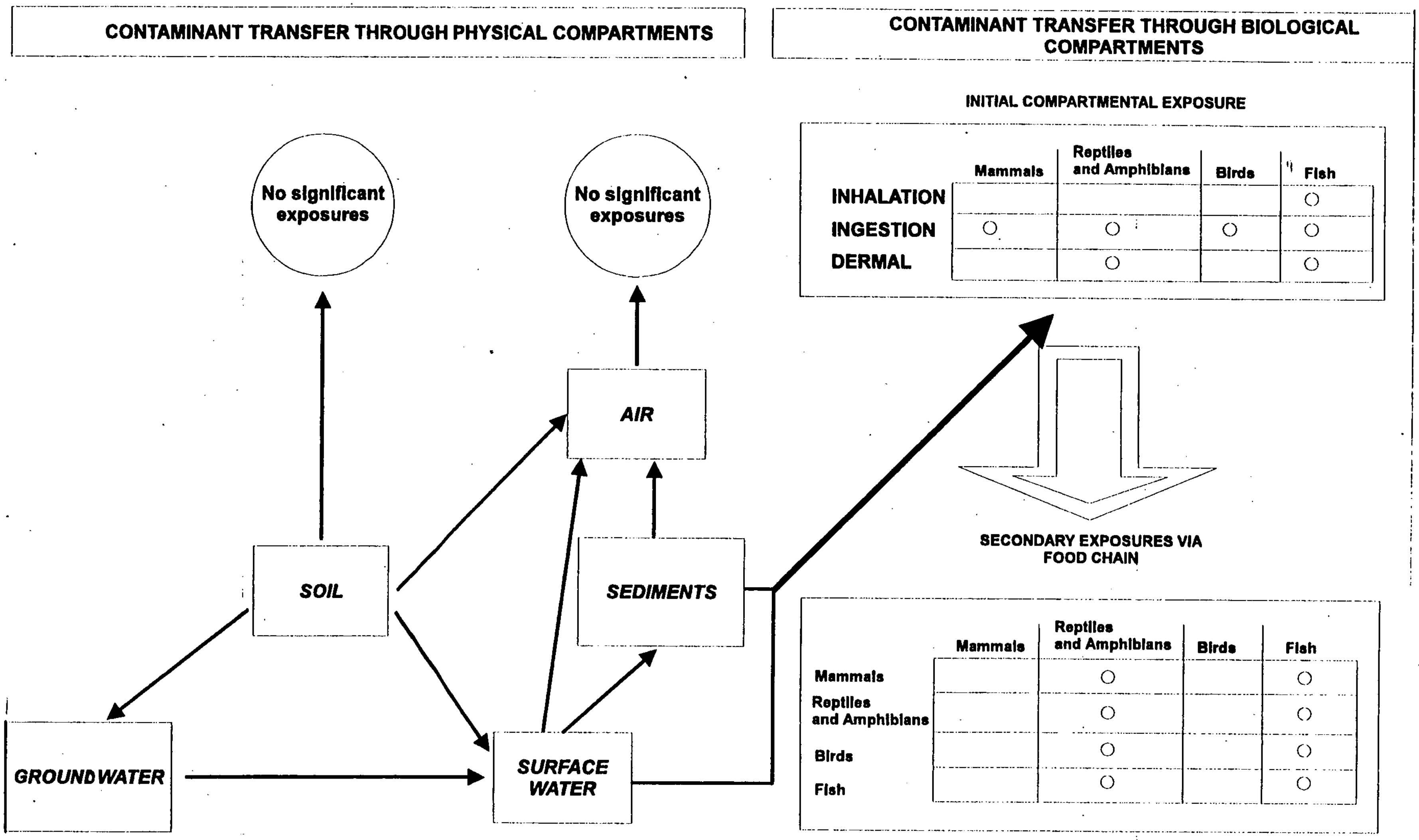
FORT RILEY MILITARY RESERVATION (DCFA-RI)

EXPOSURE MODEL

SCALE: NONE | DATE: MARCH 1995 | FIG. 6-2



INITIAL COMPARTMENTAL EXPOSURE

	Mammals	Reptiles and Amphibians	Birds	Fish
INHALATION				○
INGESTION	○	○	○	○
DERMAL		○		○

SECONDARY EXPOSURES VIA FOOD CHAIN

	Mammals	Reptiles and Amphibians	Birds	Fish
Mammals		○		○
Reptiles and Amphibians		○		○
Birds		○		○
Fish		○		○

○ CONTAMINANT CONCENTRATIONS, AS PRESENTLY MEASURED, BELOW LEVEL PRODUCING SIGNIFICANT EXPOSURES.

U.S. ARMY CORPS OF ENGINEERS
LOUIS BERGER & ASSOCIATES, INC.
FORT RILEY MILITARY RESERVATION (DCFA-RI)

EXPOSURE MODEL FOR ECOLOGICAL RECEPTORS

SCALE: NONE | DATE: MARCH 1995 | FIG. 6-3

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CHAPTER 7
SUMMARY AND CONCLUSIONS

The adequacy of the study area characterization is a result of the integration of pre-RI investigations and this comprehensive RI. This RI work included a systematic development and implementation of the investigations including:

Initial Field Investigations (IFI)
- soil gas survey
- sewer water sampling
- surface water and sediment sampling

Supplemental IFI
- video survey of sanitary and storm sewers
- smoke test
- dye trace

RI field investigations
- soil borings
- surface soil sampling
- surface water and sediment sampling
- monitoring well installation
- geophysics

Periodic groundwater sampling

Aquifer tests

Supplemental sewer investigations
- temperature and conductivity monitoring
- hydraulic integrity test
- groundwater elevation monitoring

The RI also incorporated data from three other DCFA related activities which, while not elements of the RI have, nevertheless, played a key role in the performance of the study and the characterization of the site:

Sanitary sewer line repair

Cleaning contaminated sediment from an abandoned manhole

Pilot test studies
- soil vapor extraction (ongoing)
- groundwater extraction (unsuccessful, terminated)

Underground storage tanks
- testing of contents
- 2 removed, 1 abandoned in-place
- soil sampling at time of removal
- soil borings

In addition to conducting the RI work to reasonably characterize the study area, additional activities were conducted to reduce the potential for future releases, such as, enhanced waste management practices at the current laundry and dry cleaning facilities, repair of a sanitary sewer segment (MH 363B to MH 365) and clean out of a sanitary sewer manhole (MH 363B). Additional activities that will minimize potential future chemical migration to the environment include removal and abandonment of USTs and a pilot study (still ongoing) which has removed VOCs from the unsaturated zone. These activities have resulted in reducing potential future releases of chemicals to the environment.

Trends in analytical data show that chemical concentrations in the study area are continuing to decline. This indicates that chemicals in the environment are attenuating and that there are no ongoing sources in the study area. Presented below is a summary of this RI and the conceptual site model.

7.1 Scope of Investigations

The CERCLA study began with a review of data from previous investigations conducted by various government agencies, such as USATHAMA (AEC) and USAEHA (CHPPM), and concluded with a series of field investigations that are reported in the PA/SI, the RI/FS Work Plan (IFI activities) and this RI document. Field work associated with the RI included sampling of surface water, groundwater, soils, and sediment for analyses of VOCs and SVOCs. In addition, data derived from studies conducted in conjunction with a pilot study and other activities noted above were utilized.

Results from all of these activities allowed for study area characterization that provided the basis for an assessment of the nature and extent of contamination, fate and transport and human health and ecological risk. A summary of these investigations is provided below, followed by a conceptual site model developed to facilitate presentation of key site conditions to aid in reaching conclusions from the RI and to develop remedial action objectives and remedial alternatives for the Feasibility Study.

7.2 Environmental Setting

The DCFA on Fort Riley is located on a promontory approximately 1,500 feet downstream from the confluence of the Smoky Hill and Republican Rivers. Fort Riley lies within the Osage Plains section of the Central Lowlands physiographic province. The topography around Fort Riley consists of plains incised by steep drainage features. Surface elevations range from 1,025 to 1,356 feet above mean sea level.

The DCFA covers approximately 7 acres at the southwest corner of the Main Post. Figure 1-2 shows the DCFA and its boundaries. For the purposes of this report, the "DCFA," "Study Area," and "Site" are defined as follows:

- DCFA: Area of current and former laundry and dry cleaning operations and related facilities;
- Study Area: DCFA and the limits of other areas associated with the RI (i.e., Tributaries A and B and The Island); and
- Site: As used in this RI, "site" is the same as the DCFA.

The units of interest with regard to the study area including the DCFA include the Havensville shale and the Threemile limestone of the Chase Group, and the Speiser shale, Funston limestone, Blue Rapids shale, Crouse limestone, Easly Creek shale, and Bader limestone of the Council Grove Group. The unconsolidated materials overlying these rock units consist of clays, silts, sands, and fill material. All these materials occur adjacent to the alluvial deposits of the Kansas River.

Groundwater occurs to a limited extent in preferential permeability zones within the limestones that underlie the study area. None of the underlying limestone units yields sufficient water to be considered an aquifer. Alluvial materials within the Kansas River flood plain typically yield sufficient water on a sustained basis to be considered as aquifers, and are so utilized.

Land use within the DCFA has remained relatively constant as commercial/light industrial from the early 1900s to the present for dry cleaning and laundry operations. The population groups currently or potentially associated with the DCFA include the employees of the respective buildings; the patrons of services provided at those buildings, maintenance workers, and, to a lesser extent, the residents of a family housing area to the northeast of the DCFA. Land use in the Main Post area has, over the last 30 - 40 years, transitioned from mixed residential, light industrial, commercial and office use to almost exclusively residential and office. This continuing trend is illustrated by the move of the Post Exchange to Custer Hill, the near future move of the Commissary to Camp Forsyth, planned closure of the Laundry & Dry Cleaning facility (Building 183 & 184), and the anticipated move of the Installation Consolidated Property Book Office to Custer Hill. No significant new construction has occurred on Main Post since it's designation as a Historic District. Historic District considerations now control land use. No new housing has been built on Main Post in many, many years, since before the Historic District designation. All new housing has been in the Forsyth and Custer Hill areas. Construction of additional housing on Main Post would be prohibitively expensive, since new construction, if allowed at all, would have to be masonry so as to not detract from the Historic District.

Ecologically the DCFA is a mostly paved area with two operating facilities. There are grassy areas and trees adjacent to the buildings, but these represent a small percentage of the ecological environment within the study area. The area immediately to the south, the island, supports the greater percentage of vegetation and wildlife. Cottonwood, Sycamore, Box Elder, Dogwood and other species of trees and plants occur in this area. Wildlife is also concentrated primarily on the Island with transient use and habitat in the area to the north between the DCFA and the cemetery as shown on Figure 2-1. The study area is divided into four basic habitat types: highly disturbed or commercial, wooded upland, wooded riverine, and river aquatic. Two listed species, the threatened bald eagle and the endangered peregrine falcon, have been confirmed to occur in the vicinity of Fort Riley. The bald eagle frequently uses The Island area as a nighttime roosting spot while wintering in the area. The peregrine falcon is considered an "uncommon transient" which has been sited on Fort Riley on only a couple of occasions. Surveys have documented bald eagles wintering in mature trees and large snags along the Republican and Kansas Rivers, in addition to the Farnum and Madison Creek coves at Milford Reservoir.

Groundwater in the study area is strongly influenced by the Kansas River. Regional hydrology is dominated by the Republican, Smoky Hill and Kansas Rivers. The Kansas River is formed as a result of the confluence of the Republican and Smoky Hill Rivers, approximately ¼ mile west of the DCFA. The average annual flow in the Kansas River for the period from 1964 to 1992 at the Fort Riley gaging station located on the Henry Road Bridge is 2,436 cubic feet per second (cfs) (USGS, 1992). The gage height for this station during this period fluctuated from 10 to 24 feet. Over a 10-year period (1978-1988), river stage fluctuations ranged from 3.7 feet, (or 1,038.4 feet mean sea level m.s.l., to 16.97 feet (or 1,051.66 feet m.s.l.). The corresponding stage elevations at the study area are estimated to be lower by approximately 3.0 feet than the gaged stage elevations.

The relationship between the DCFA monitoring wells and the Kansas River water levels (including flood stages) are illustrated in Figures 2-6 and 3-33. In November 1992, the Kansas River water level was approximately six feet below the elevation of the DCFA wells (1042 feet MSL compared to elevation 1048 feet MSL). Conversely, in June 1993, the Kansas River water level was 3 feet higher than the elevation of the DCFA wells (1053 feet MSL compared to 1050 feet MSL). In August 1994, following the recession of the summer 1993 flood, the Kansas River elevation was approximately 10 feet below the elevation of the DCFA wells (1038 feet MSL compared to 1048 feet MSL). Wells in the alluvium show much more drastic effects and closer correlation to the Kansas River water levels as may be expected because of their proximity to the river and the high permeability of the alluvial materials.

Two tributaries adjacent to the DCFA, identified as A and B, are the only other surface water features associated with the study area. Both tributaries are ephemeral streams. Tributary A joins with Tributary B south of the DCFA. Tributary B tends to be dry upstream of the confluence with Tributary A and also downstream of the confluence when there is no flow in Tributary A.

7.3 Study Area Characterization

A summary of the study area characterization is included below to provide a basis for understanding the nature and extent, fate and transport and risk assessment summaries presented later in this chapter.

7.3.1 Geology

The DCFA is underlain by a series of limestones and shales above the alluvial flood plain of the Kansas River. These rock units are noted in Figure 2-2. Beginning at about the level of Custer Road and proceeding downward, the rock units consists of the following formation: Speiser Shale, Funston limestone, Blue Rapids shale, Crouse limestone and Easly Creek Shale. Alternating layers of limestone and shale continue below the Easly Creek , but the Easly Creek represents the base of the units of interest with respect to contamination concerns at the DCFA. This shale is 30 feet thick and is very dense, unfractured and is very likely a confining formation (extremely low permeability).

These rock units are overlain by soils, generally referred to in this report as overburden or unconsolidated materials, that vary in thickness from 3 feet in the area west of Building 183, to 42 feet thick in the area south of building 180/181. In the area east and south of Building 180/181 a large portion of the rock units have been eroded and replaced over geologic time with materials of variable texture, see Figure 3-24. These materials range from slightly organic plastic silty sands (SM) to the plastic clays (CH). Adjacent to and continuous with this upland rock area and unconsolidated materials, are the alluvial silts and sands of the Kansas River floodplain. This area to the south of the DCFA, The Island, is of limited areal extent and narrows to the east of the study area where the river is very close to the northern escarpment.

7.3.2 Hydrogeology

Three potential water-bearing units are identified beneath the DCFA. These are the upper and lower limestone units of the Crouse formation; and the unconsolidated materials in an area east of Building 180/181 where the upper Crouse limestone unit and part of the shale underlying this unit have been eroded and replaced with the unconsolidated materials. (The Funston formation lies approximately 20 feet above the saturated zone, and as such, does not contain nor yield sufficient water to be considered aquifer.) None of these units yield sufficient water on a sustained basis to be regarded as an aquifer.

These three units are recharged to a limited extent by infiltration of precipitation, but primarily by the Kansas River via the adjoining alluvial deposits during high flow in the river. The unconsolidated materials, the Crouse formation, and the alluvial deposits are hydraulically connected to the river. This is illustrated on Figure 2-6, which shows a geologic cross-section of the study area and water levels in the river and the aquifer below the river.

Groundwater flow direction is primarily to the south-southwest in the DCFA. The flow direction gradually changes to easterly, parallel to the Kansas River flow direction, in the floodplain alluvial deposits. See Figure 3-31. The hydraulic conductivity of the unconsolidated materials ranges from 10^{-4} to 10^{-7} cm/sec based on slug tests and correlations with grain size distribution.

Vertical movement of groundwater potentially exists between the unconsolidated materials and the underlying lower Crouse limestone in the area where the upper Crouse has been eroded away, but further movement would be restricted by the Easly Creek shale beneath the lower Crouse limestone. Likewise vertical movement of groundwater from the upper Crouse limestone to the lower Crouse limestone could potentially exist (where both units are present), but water levels in the lower Crouse are above the top of that unit (see Figure 3-30) indicating a confined situation. This means that downward movement of groundwater from the upper Crouse to the lower Crouse (or deeper) is highly unlikely.

The groundwater level data indicated that there is only one sustainable aquifer in the study area: the unconfined Kansas River alluvium in The Island. These data also show that the lower Crouse limestone unit is a confined water bearing zone and is hydraulic connected with the upper Crouse limestone only in the localized erosion area at the DCFA. Unconsolidated materials and the Crouse formations are connected with the groundwater in the alluvium in the Island. The alluvium , in turn, is hydraulically connected with the Kansas River.

Groundwater is apparently also influenced by recharge from leaks from aged storm and sanitary sewers within the DCFA. Flow studies indicate an average 10% loss from a reach of sanitary sewer to the southeast of Building 180. It is unknown if this value is representative of all reaches. The measured leakage is apparently responsible for the seep(s) along Tributary A. Leakage of the sanitary sewer line beneath Custer Road may well be the source of the seep along the embankment southwest of 180/181, above the railroad tracks. Water line breaks also occur in the area. Water level data may be indicative of a groundwater mound in the general area of the sanitary sewer along Custer Road.

7.3.3 Chemical

The analytical parameters, VOCs and SVOCs, determined in the course of the field investigations commencing with the PA/SI through to the conclusion of the RI as enumerated in this report, provided sufficient data to conclude that chemical compounds are present in the media sampled. Both the data assessment and the data evaluation process supports the conclusion that the data generated in the course of these investigations is of sufficient and known quality to meet the objective of characterizing the site conditions and for inclusion in the evaluation of risk assessment. The specifics of the chemicals detected need to be viewed in the context of the medium, location, frequency of detection and consistency of detection over time. By viewing detected chemicals from this perspective, an understanding can be gained of which chemicals are attributable to operations, practices and potential sources at the DCFA and which chemicals are attributable to other causes such as common laboratory contamination or the chlorination of potable water.

The classes of chemicals analyzed and subsequently detected at any time, can be categorized as follows - PCE and its breakdown products; polyaromatic hydrocarbons (PAHs); benzene, toluene, ethylbenzene and xylenes (BTEX) (these compounds were not detected as a group but rather individually and sporadically); trihalomethanes; and a general category of compounds, both non specific to site operations and infrequent, if not, one time detections. Included in the latter class are such chemicals as carbon disulfide, 2,6-dinitrotoluene, hexachloroethane, and N-nitrosodi-n-dipropylamine.

The PCE and its breakdown products have the direct link to site operations and were carried through to the evaluation of nature and extent, fate and transport and baseline risk assessment, a discussion of which follows.

BTEX compounds and PAHs were found inconsistently and relatively infrequently. As seen in Figures 4-23 and 4-24, the cross media representation of detections, no conclusion regarding a single source can be drawn. However, it is possible that the isolated detection of the PAHs can be attributable to the previous usage of Stoddard solvent at the facility. As demonstrated by the analytical results from the USTs sampled, the analytical results reported as a TPH (gasoline or diesel range) may, in fact, be mineral spirits or Stoddard solvents, since there was no reason for motor gasoline to have ever been at the facility. The most important consideration of this point for these chemical classes is, however, that both the infrequency, as well as the concentration found of these analytes, would support the conclusion that these compounds resulted from incidental spills, rather than an ongoing or more pervasive source. Additionally, the leaking sewers carrying discharge water from the washing machine, particularly those laundering rags from the Consolidated Maintenance Facility may have contributed compounds consistent with oils and similar products.

The detections of THMs and the common laboratory contaminants including phthalates, acetone and toluene, are explained by the fact that they are infrequently detected, the result of common laboratory contamination or occur in the environment as a result of other practices. THMs are known to occur as a byproduct of the chlorinated process for potable water systems. Phthalates are common plasticizers and found in a variety of products, including the gloves used both for sample collection and analysis. Acetone is a common laboratory contaminant which has also been found to be naturally formed from the natural decay of vegetation. Toluene may be attributable to laboratory contamination, the past use of Stoddard solvent or to the laundering of rags from vehicle maintenance.

7.4 Nature and Extent of Contamination

The nature of contaminants encountered within the DCFA consists of VOCs and infrequent detections of SVOCs. The most frequently detected VOCs were tetrachloroethylene (PCE), trichloroethylene (TCE) and dichloroethylene (DCE). The most frequently detected SVOCs were phthalates.

PCE is the primary site-related contaminant of concern. TCE and DCE are breakdown products of PCE. The final toxic breakdown product of PCE, vinyl chloride, has been detected in three of the on-site monitoring wells but not in the alluvium or any of the other media sampled. PCE has apparently entered the environment through leaky storm and sanitary sewers, and possibly through accidental spills and discharges directly to the ground on the west side of Building 180/181. PCE introduced to the soil has migrated downward to the thin saturated zone underneath the site. From here it has moved laterally into the alluvium of The Island which underlies the Kansas River floodplain to the south of the DCFA. With the exception of a single detection of TCE in soils, the breakdown products of PCE have been only detected in groundwater. One-time detections of PCE have been made in the surface water and sediment sampled at Tributary A and in seeps sampled on Tributary A and the embankment on the southwest side DCFA.

Other VOCs and SVOCs have also been detected during the field investigation efforts. A summary of all chemicals detected, by medium, including frequency, is provided in Tables 6-1 through 6-4. With the exception of dichloromethane and bis(2-ethylhexyl)phthalate, the additionally detected compounds have been detected only sporadically, and typically in only one of the media sampled. Dichloromethane and bis(2-ethylhexyl)phthalate are both recognized as common laboratory contaminants. Bis(2-ethylhexyl)phthalate is also widely used as a plasticizing agent, and may have been introduced in a number of different ways, some as mundane as discarded plastic materials (bottles, bags, etc.).

Sampling and analysis tasks completed in soils and groundwater indicate that these media have the highest concentrations centered primarily in two areas: the northeast corner of Building 180/181, and immediately west of Building 180/181. The concentrations adjacent to the northeast corner may be attributable to the leaking sewer, and the concentrations to the west of Building 180/181 may be a result of spills and discharges that reportedly occurred in that location with some contribution related to underground storage tanks (USTs) that were located at the northwest corner of the building.

The analyses of groundwater samples taken from the northeast side of the building for various sampling events showed concentrations of PCE that ranged from 1,600 μg/l to 32 μg/l. Analyses of groundwater on the west side ranged from 9.3 μg/l to nondetect.

Soil concentrations in these same areas ranged from 960 μg/kg to nondetect for soil borings on the northeast. Analyses of soils on the west showed nondetects for the soils that are generally less than 10 feet thick. No detections were recorded for samples from surface soils.

7.5 Fate and Transport of Contaminants

The evaluation of fate and transport in this chapter provides information on the factors influencing the movement and persistence of VOCs and SVOCs detected at the site. VOCs are characterized by low sorption onto soils or sediments and, therefore, relatively rapid migration along with water movement. They will tend to volatilize rapidly when exposed to the atmosphere, and/or released to surface water. The detections of TCE, DCE and vinyl chloride are consistent with the breakdown of PCE. The occurrence of PCE in both soils and groundwater, and of the PCE breakdown products predominantly in groundwater at the DCFA and the adjacent alluvial aquifer (Chapter 4), is consistent with the dominant migration pathways identified in the CSM, and the fate and transport characteristics of the chlorinated solvents.

The evaluation of leaching from soil indicates that, under natural recharge conditions, little downward movement of contaminants is expected to occur. Chapter 4 and Appendix D-I present the results of mass calculation in soils and groundwater. Therefore, the detections of PCE and its breakdown products in groundwater and the concentration levels found imply a source of increased infiltration, which points to the leaking sewers as a primary source or transport mechanism of PCE contamination in the subsurface.

The groundwater transport modeling analysis of the migration of PCE and its breakdown products through the alluvial aquifer (Figure 5-3) shows a rapid drop-off of PCE, TCE and DCE concentrations with distance as a result of dispersive mixing and degradation. The concentration of vinyl chloride first increases and then gradually decreases, but never exceeds 0.6 μg/l. Model-predicted concentrations of PCE and TCE are reduced to below MCLs within approximately 150 m (500 ft) from well DCF93-09 which was taken as the "source" location in the groundwater model.

Calculations of river water concentrations were made considering discharge into the river from the alluvial aquifer and inflow via Tributaries A and B. The predicted concentration of PCE is on the order of 10^{-3} μg/l; values for the PCE breakdown products are similar. The calculations did not consider volatilization, which will be a dominant removal mechanism in surface water. Even so, the predicted values are very low. This result is consistent with the absence of detections of PCE or any of the other chemicals associated with the DCFA in the Kansas River, downstream of the study area as reported in the Southwest Funston Landfill RI report (CEMRK, 1994g).

7.6 Risk Assessment

Risks were evaluated for both potential human and ecological receptors based on the data collected during the PA/SI and the RI. Two groups were identified as potential receptors of concern: (1) utility workers performing installation or repair of underground utilities at the DCFA, and/or performing work in or along Tributary A; and (2) recreational children who may play along Tributary A or B. Exposure pathways considered for the utility worker were inhalation of volatiles and fugitive dust, and dermal contact with and ingestion of soil, sediment and surface water. Exposure pathways considered for the recreational child were dermal contact with and ingestion of sediment and surface water.

The results of the human health evaluation of current receptors at the DCFA do not indicate a concern for potential risk to public health for either systemic (non-carcinogenic) or carcinogenic endpoints. Of the two receptor groups, the calculated risk to the utility worker is slightly higher (carcinogenic risk = 1×10^{-7}; hazard quotient $\leq$ 0.1). The risks associated with this worker's exposures are within acceptable risk ranges as defined in the NCP (cancer risk $\leq 1\times10^{-4}$ to 1×10^{-6}; hazard index $\leq$ 1.0) and, therefore, represents the Reasonable Maximum Exposure (RME) for the site. Children playing at or near the DCFA do not appear to be at risk based on the surface water and sediment exposure scenarios used in the Baseline Risk Assessment (BLRA). Because future land use conditions at and surrounding the DCFA are not expected to be appreciably different from present conditions, no explicit distinction is made between present and future conditions in determining the health risks to the two receptor groups.

In addition to the risk characterization performed as part of the BLRA, the health risks were evaluated for a scenario involving a hypothetical future industrial worker. Exposure assumptions (U.S. EPA, 1991) for this receptor include ingestion of 1 liter of water from the contaminated drinking water source per day. Using the 95% UCL groundwater concentrations, the risk calculations show significant health risks associated with the ingestion of on-site groundwater. The hazard quotient for non-carcinogenic health effects is 0.4; the carcinogenic risk is 1×10^{-4}.

The calculated health risk associated with ingestion of groundwater is controlled by PCE and vinyl chloride. PCE accounts for 51 percent of the risk and vinyl chloride for 48 percent. None of the other contaminants in groundwater have cancer risks greater than 10^{-6} or hazard quotients greater than 0.01.

An ecological risk assessment was performed to evaluate the potential exposure and risk to ecological receptors caused by chemicals associated with the DCFA. The ecological assessment focused on risk caused by exposure to contaminated surface water and sediments in Tributary A. The assessment also evaluated the risks to receptors in the Kansas River and floodplain, specifically aquatic species and Bald Eagles. Bald Eagles are only known to be at the study area for 3-4 months of the year and, therefore, their exposure is limited. Based on a comparison of concentrations detected in the tributaries to surface water and sediment criteria, there is no unacceptable risk due to direct contact with these media. Because the calculated concentrations that might occur in the Kansas River are extremely low and the contaminants have little or no tendency to bioaccumulate, risks to species in the river as well as to Bald Eagles via secondary exposures will be minimal to non-existent.

7.7 Conceptual Site Model

A Conceptual Site Model (CSM) has been developed for the DCFA and is presented below. In order to gain an understanding of the nature and extent of contamination at the DCFA, data was collected to determine contaminants of concern, sources of contaminants, release mechanisms, transformation processes, fate and transport of contaminants (including migration pathways), and potential receptors.

The purpose of a CSM is to facilitate an overall understanding of the primary site characteristics. This understanding is essential for the conclusions of the RI, as well as for the development of appropriate remedial action objectives and alternatives as part of the DCFA Feasibility Study (FS).

This CSM is a narrative description supported by figures that presents key information and conclusions regarding:

- assessment of contaminant sources;
- release mechanisms;
- physical-chemical-biological processes affecting contaminant migration;
- transport pathways;
- contaminant fate; and,
- receptors

The CSM continues to evolve as additional environmental information is obtained and evaluated as part of the periodic sampling events at the DCFA. Future confirmation or revision of the current understanding will continue following expected closure of the laundry and dry cleaning facilities in the fall of 1995 when the impact of eliminating sewer leakage on groundwater will become evident.

Identification of the Potential Contaminant Source(s)

There are essentially two sources believed to be potentially responsible for the contaminants present at the DCFA:

- the release of contaminated effluent from leaky sanitary sewers and storm sewers; and,
- disposal/spills of still bottoms behind Building 180/181.

The relative contribution of each of these sources cannot be ascertained due to a lack of quantitative records. A third possible source of contaminants was the three underground storage tanks located outside of Building 180/181. However, these tanks were removed in 1994, were in good condition, and no significant releases of contaminants have been associated with the tanks. The infrequency and the low concentrations detected of TPH (gasoline or diesel range) in groundwater supports the conclusion that these compounds resulted from incidental spills rather than from leakage.

The first source is associated with the past practices and activities at the former DCF (Building 180/181) and the current dry cleaning and laundry facilities (Building 183) that apparently resulted in a few sporadic releases of PCE to the storm and/or sanitary sewers servicing the DCFA. Two past activities in particular are suspected as being associated with these releases. The first activity was associated with inadvertent spills of PCE on the floor of the laundry facilities that were washed into floor drains, resulting in PCE entering the sewer lines. The second activity was associated with the use of blankets, mattress pads, and/or other fabrics to clean-up spills of PCE, followed by rinsing and/or laundering these fabrics such that PCE-contaminated rinseate was conveyed to the sewer system. Once in the sewer system, wastewater containing PCE appears to have entered the subsurface environment through leaks in the sanitary and/or storm sewers.

In addition, blockages in various parts of the sewers may have reduced flow capacity which caused sewer backups and occasional overflows from manholes and/or increased hydraulic pressure which would have resulted in greater leakage though joints, cracks or breaks. Contaminated effluent thus entered either the unsaturated zone through surface infiltration, or the nearby tributaries through seeps.

The second potential source is associated with reported disposal of still bottoms or PCE behind Building 180/181. There is little information known regarding these spills. This practice was reported in the Installation Assessment of Fort Riley, Kansas (USATHAMA, 1984) but was not supported with documentation. Subsequent communications with past and current employees could not confirm this practice. Investigative data is not indicative of a significant release to the environment in this area. Through leaching and infiltration, this may have resulted in the migration of contaminants to the unsaturated zone and ultimately to the groundwater.

The potential for future accidental releases of contaminants to the environment at the DCFA has been reduced through the sealing of floor drains and enforcement of enhanced waste management practices at the current DCF.

The major source areas in the vicinity of the DCFA (as well as the dominant migration pathways) are shown in Figure 2-11.

Hydrogeologic Setting and Migration Pathways

Figure 2-1 presents the surface water features and drainage basin in the vicinity of the DCFA and the site stratigraphy is illustrated in Figures 2-4 and 2-5. Figure 2-11 identifies the primary migration pathways at the DCFA.

There are essentially two dominant migration pathways associated with the DCFA as follows:

- Subsurface leakage from sewers that migrate through preferential paths in the unsaturated zone that resulted in surface seeps along the embankment behind Building 180/181 and the embankment adjacent to Tributary A. These seeps subsequently entered the nearby ephemeral stream (Tributaries A) and eventually flowed to the Kansas River. Analytical data indicates that contamination from the seeps attenuates quickly in the surface water; and,

- Downward migration of contaminants through the unsaturated zone, into the underlying groundwater, then laterally to the southwest and eventually into the alluvium parallel with, and discharging to the Kansas River at the eastern end of The Island.

These two pathways are considered to be independent of each other since the groundwater elevations down-gradient of the DCFA are below the stream bed elevations in the tributaries, and flow in the tributaries is ephemeral occurring only during/after storm events.

The following factors are also important to a proper understanding of the CSM and potential migration pathways in the vicinity of the DCFA:

- The Funston limestone is more than 20 feet above the saturated zone and, therefore, is not a water-bearing formation;
- The upper and lower Crouse limestone are potentially interconnected through common lateral connections as a result of being exposed in the unconsolidated materials within the subsurface erosional/trough feature in the bedrock located adjacent to and beneath Building 180/181. This is as opposed to vertical interconnection through the intervening shale (Crouse shale);
- Vertical movement of groundwater from the upper Crouse limestone to the lower Crouse limestone, although possible, is unlikely because the lower Crouse formation is in a confined condition (i.e., water level is above the top of the formation).
- Vertical downward groundwater movement is limited by the confining Easly Creek shale.
- Detections of PCE and its breakdown products in the lower Crouse formation (DCF93-19 and DCF93-20) are attributable to lateral movement of groundwater from the unconsolidated materials to the lower Crouse and lateral groundwater movement from the alluvium to the lower Crouse;
- Groundwater flow in the saturated soils overlying bedrock is generally in the south-southwest direction in the erosional/trough feature, and then turns in a southeasterly direction once it reaches The Island (see Figure 3-31).
- Groundwater flow in the bedrock units is not considered to be a significant pathway and appears to be very limited - it is characterized as a diffuse-flow system with flow occurring intermittently along horizontal bedding planes and fractures;
- Preferential pathways exist in the unsaturated zone due to the presence of trenches of buried utilities/pipelines, steam line tunnel, and naturally occurring seams or layers of increased permeability soils.
- During periods of flood, groundwater flow is from the river to the alluvium and the DCFA, and during periods of low river flows, groundwater flow direction is reversed.
- The mean annual water level in the Kansas River above the elevation of the lower Crouse limestone. This provides the head in the lower Crouse and along with the Crouse and Easly Creek shales (above and below the lower Crouse respectively) results in the confined condition of the lower Crouse.

Processes Affecting Contaminant Release, Migration, and Fate

Dissolution, dispersion, degradation and the adsorption/desorption of contaminants in the soil matrix are the most significant processes which affect the release, migration, and environmental distribution of contaminants at the DCFA. These processes are generally controlled by the character of the water, soils, and rocks in which the contamination exists; and more specifically, solubility characteristics, partition/adsorption coefficients, pH, and temperature.

Dissolution is a significant factor in the nature of the contaminants released at the DCFA because the contaminants are believed to have been in a diluted state prior to discharge (i.e., contaminants were not released in a concentrated state). Subsequent laundry wastewater sewer leakage caused further dilution in the environment. Biological degradation (decay/half-life of contaminants due to consumption by naturally occurring microorganisms) and/or volatilization are often dominant mechanisms affecting levels of organic contaminants in the environment. Dispersion/dilution also can significantly modify the behavior and distribution of contaminants in surface water, sediments and groundwater by spreading a given amount of contaminant over a larger area/volume.

The naturally occurring combination of biological degradation, volatilization, and dilution/dispersion is often referred to as "natural attenuation." In combination with the factors described previously, the effect of natural attenuation is integral to a comprehensive understanding of the past, present and future nature and extent of the contamination at the DCFA; especially the decreases in contaminant concentrations associated with the DCFA.

Trends in the Data

Results from the most recent sampling event substantiate the general trend towards reductions in contaminant levels at or near the DCFA. Table 4-18 is presented as an illustration of this, and indicates that concentrations of PCE, DCE, TCE, and vinyl chloride in the groundwater are currently at levels substantially below their past/maximum concentrations. The most recent groundwater level data also indicates that water table elevations have significantly decreased (approximately three to five feet) over the past two years primarily due to climatological variations.

This general decrease in contaminant levels will likely continue and is believed to be due to several factors, including:

- Enhanced management/housekeeping practices at the laundry and dry cleaning facility: the floor drains at the DCF have been plugged; spill control equipment is used to clean spills; and, if blankets or mattress pads are used to clean spills, they are dry cleaned as opposed to laundering;
- The sanitary sewer repairs;
- Cleaning of sediments from an abandoned manhole;
- Removal of 2 USTs and abandonment of 1 in place (including removal of UST contents);
- Planned closure of Building 183 will result in a substantial decrease in wastewater leakage from sewers and, thus, reduce presence of subsurface water and possible driving force for mobilizing residual contamination;
- Most of the site (over 80 percent) is paved, which minimizes potential surface water infiltration and subsequent leaching of residual contaminants in soils; and
- Natural attenuation of the contaminants.

Identification of Receptors

Based on the identified site conditions and the current and reasonably foreseeable land uses in the vicinity of the DCFA, the following statements are made as part of the CSM:

- The air pathway is not of concern for fugitive releases or volatilization from surface soils because there were no contaminants of concern detected in surface soils;
- Groundwater in the vicinity of the DCFA and on The Island will not be used as a drinking water source. Fort Riley's current actual daily consumption is approximately 42 percent of its available capacity. Based on this, installation of new water supply wells is not likely;
- The ephemeral nature of Tributaries A and B is such that, for purposes of surface water and/or fish consumption, only the Kansas River must be considered; and,
- The current or less intensive types of site activities and non-residential land use will persist.
- The ecological assessment considered risk to vegetation and to terrestrial and aquatic animal life at, and adjacent to, the DCFA. The results of the ecological assessment did not indicate a risk to ecological receptors.

As a result, the primary media-specific receptor types and locations identified for the DCFA are:

- Air – Inhalation of volatiles and particulates by utility workers during subsurface repairs;
- Surface water/sediments – utility workers performing repair activities and children playing along Tributary A and/or B;
- Subsurface soils -- shallow subsurface soils at the DCFA to which site/utility workers might reasonably be exposed.

CONCLUSION

Based on a review of the data and analyses presented in previous referenced studies and this RI Report, the following statements can be made:

- ▲ The fate and transport analysis shows that concentration of chemicals of concern, namely PCE and its breakdown products, attenuate to levels below MCLs within the study area; this has been confirmed by the periodic groundwater monitoring which shows decreasing concentrations for chemicals of concern;
- ▲ The results of the baseline risk assessment show that based on the selected receptors and the associated potential exposure pathways at the study area there is no unacceptable risk for either human or ecological receptors.

According to the NCP, Section 300.430, the purpose of the RI/FS is to *"assess site conditions and evaluate alternatives to the extent necessary to select a remedy"*. Also, in accordance with *EPA's Guidance* *for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (EPA 1988), "the objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to gather information sufficient to support an informed risk management decision regarding which remedy appears to be the most appropriate for a given site".*

The goals of this RI have been met and there is sufficient information and understanding of the study area for proceeding to the FS and the process of evaluating remedial alternatives and selecting an appropriate remedy for the DCFA.

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