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GROUNDWATER INVESTIGATION REPORT
AND
FOCUSED FEASIBILITY STUDY
REVISION 1

CRAB ORCHARD NATIONAL WILDLIFE REFUGE
PCB OPERABLE UNIT
SITES 32/33
MARION, ILLINOIS

PREPARED BY
RMT, INC.
MADISON, WISCONSIN

January 2000

PART I – GROUNDWATER INVESTIGATION REPORT

VOLUME 1 OF 2

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PCB OPERABLE UNIT
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MADISON, WISCONSIN

January 2000

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Executive Summary

Background

The PCB Areas Operable Unit (PCBOU) consists of four of the original "study sites" defined in the remedial investigation for the Crab Orchard National Wildlife Refuge Superfund Site. Two of these sites, Site 32 (Area 9 Landfill) and Site 33 (Area 9 Building Complex), are addressed in this document.

As required in the Record of Decision (ROD) for the PCBOU issued by the United States Environmental Protection Agency (USEPA) in 1990, remedial action was performed at Sites 32/33 from late 1995 to June 1997. This action included several excavations of PCB-impacted soil near Building I-1-23 and near Building I-1-2, and from surface water drainage swales at the sites. PCB-impacted sediment was also dredged from the Crab Orchard Lake embayment. After removal and disposal of waste materials from the Area 9 Landfill, PCB-impacted soil beneath the landfill area was also excavated.

The PCB soil and sediment were treated using a temporary Thermal Treatment Unit (TTU) installed at Sites 32/33, or placed directly into a Repository constructed at the former Area 9 Landfill location, depending on concentrations of PCBs, lead, and cadmium in the materials compared with specified action levels. Ash from the TTU, above the action level for lead and cadmium, was stabilized with cement and transported for disposal at a RCRA Subtitle D landfill constructed as part of the remedial action at another location at the Superfund Site.

During the PCB remedial action, three of the PCB source areas at Sites 32/33 (Area 9 Repository, Building I-1-23, Building I-1-2) that were suspected of potentially contributing to contamination of groundwater and surface water were further characterized. During this additional sampling, volatile organic compounds (VOCs) were detected in groundwater. The VOC-contaminated groundwater was determined to warrant further characterization. An additional groundwater investigation was performed at the Sites in the 3rd quarter of 1997. The results from this work were issued in a report in March 1998, which indicated that at least three plumes of VOC-contaminated groundwater were present in the shallow aquifer. However, the nature and extent (horizontal and vertical) of the contamination, and knowledge of the site characteristics, were not sufficiently defined to allow selection of a remedial approach for groundwater. Therefore, a workplan proposing further groundwater investigation tasks and on-site pilot tests of preselected cleanup technologies was issued in March 1998; a May 1998 revision of the workplan was approved by the USEPA.

The work defined in the May 1998 workplan was performed during the summer of 1998. A sampling round that included confirmatory investigation sampling of monitoring wells and other sampling for Performance Standards Compliance Monitoring for the PCBOU under the Consent Decree was performed in December 1998.

Part I of this document presents a summary and analysis of the results of the summer 1998 groundwater investigation for Sites 32/33, and the December 1998 sampling for all sites within the PCBOU. Part II of the document includes a focused feasibility study that evaluates a number of alternatives for remediation of contaminated groundwater at Sites 32/33. The document was initially issued (Revision 0) to the USEPA and other recipients on the approved distribution list in July 1999. Written review comments on Revision 0 were issued by the USEPA, and written responses to these comments were submitted to the USEPA by Schlumberger. The comments and the responses were discussed by all involved parties. Revision 1 of this document was prepared to address the changes and additions to the Revision 0 document as agreed during those discussions.

Groundwater Investigation Results

A listing of the key findings and conclusions regarding the nature and extent of groundwater contamination and its sources is presented below.

- The primary contaminants of concern in groundwater are chlorinated volatile organic compounds (CVOCs); this finding is consistent with previous investigations. Trichloroethene (TCE) is more widely present and at higher concentrations than the other CVOCs. Only very low concentrations of PCBs, below MCLs, have been detected in groundwater in four of the monitoring wells at Sites 32/33.
- Five separate areas that are sources of the CVOC plumes have been identified. Three of these areas had been identified prior to the 1998 fieldwork (Area 9 Repository, Building I-1-23, and Building I-1-2); two additional source areas were identified from the 1998 investigation (Building I-1-36A, and an area south of the Repository).
- Three of the five source areas are coincident with areas where past releases of PCBs occurred: Buildings I-1-2 and I-1-23, and the Repository. The two recently discovered areas (Building I-1-36A and south of the Repository) appear to be sources of only CVOCs.
- The five CVOC source areas produce three separate groundwater plumes. The Building I-1-23 and I-1-2 sources each produce a separate plume. The contaminated groundwater emanating from the Repository, Building I-1-36A, and the area south of the Repository merges into a common plume. The plumes are believed to have existed for many years, possibly several decades, and are likely to be the result of relatively stable site conditions that existed until the time of the PCB remedial action from 1996 to mid-1997.
- The I-1-23 plume moves northward from I-1-23 and discharges into the West Swale and into the Crab Orchard Lake embayment. The I-1-2 plume moves westward toward Highway 148 and discharges into an intermittent stream and marsh area on the east side of

the highway; a portion of the I-1-2 plume moves a relatively short distance eastward into a groundwater stagnation zone contained within Site 33, and does not discharge to surface water. The plume formed from the sources at the Repository, I-1-36A, and south of the Repository moves northeastward and discharges into the East Swale.

- The discharges of contaminated groundwater to surface water have resulted in detectable concentrations of CVOCs in surface water at some groundwater/surface water interface locations, particularly at the I-1-23 plume discharge area, where relatively significant CVOC concentrations were observed in the West Swale in December 1998 samples.
- The vertical extent of groundwater contamination is limited to an Upper Clay unit in the CVOC source areas, and to a relatively thin (2 to 20 feet) Upper Sand unit that is present beneath the Upper Clay. The CVOCs move downward through the saturated Upper Clay at the source areas, into the higher permeability Upper Sand, where the plumes migrate horizontally to their surface water discharge areas. A thick (40 feet) Lower Clay unit that is continuous over the Sites provides a lower confining layer that helps prevent groundwater contaminants from moving downward and reaching the sandstone bedrock.
- It is likely that the locations of the past activities that caused the release of PCB-containing materials to the ground surface at the three primary source areas are coincident with the locations of the past activities that also released the CVOC-containing materials. Therefore, it is expected that a significant percentage of the total mass of CVOC-impacted soil that was originally present at the three source areas was removed during the PCB remedial action that was completed in 1997. However, due to the low rate of groundwater movement within the Upper Clay unit, insufficient time has elapsed since completion of the PCB remedial action to observe a decrease in CVOC concentrations in groundwater in the former PCB source areas.
- The CVOC source material remaining in the three primary source areas is expected to be mostly present in the saturated Upper Clay unit in the form of dispersed small blebs and ganglia of solvent residuals, located in areas and at depths outside of the limits of the excavations made during the PCB remedial action.
- The available soil and groundwater chemistry data used to calibrate a computer transport model developed for the Sites allows realistic simulations of current and future conditions in the aquifer to be made, and provides sufficient information to support development and evaluation of remedial alternatives for groundwater. Although the model simplifies the complexity of geologic units, such as the Upper Clay, it provides a useful tool for evaluating current and future site conditions.
- Biological degradation products of tetrachloroethene (PCE) and TCE are present in all groundwater plumes at the Sites. Moderately effective biodegradation by anaerobic reductive dechlorination is occurring in the CVOC source areas, but the degradation rate is low. Possible reasons for this low rate include marginally reducing chemical conditions in the groundwater, and/or lack of electron-donor compounds to sustain the metabolic processes of the soil microorganisms, as evidenced by low organic carbon content of the soil in several locations.

Pilot Tests Results

A listing of the key findings and conclusions from the remediation pilot tests performed at Sites 32/33 in 1998 is presented below. The pilot tests data and evaluation of the test results are presented in Part II of this document.

- Two types of remediation technologies were evaluated using pilot-scale tests: dual-phase extraction, and air sparging/soil vapor extraction. The tests were performed at the I-1-23, I-1-2, and Repository source areas.
- The results of these tests showed that none of these technologies by itself is feasible or would be effective at subsurface remediation of residual CVOCs at any of the source areas. Air sparging could result in a worsening of the groundwater contamination problem by spreading the plumes laterally within the Upper Sand unit and by decreasing the effectiveness of the existing natural biodegradation of the contaminants.
- Application of portions of these technologies as a component of a final remedial action for one or more of the CVOC source areas may be appropriate.

Feasibility Study Results

The key results from development and evaluation of alternatives for groundwater remediation at Sites 32/33 are presented below.

- Five "active" alternatives, in addition to a no-action alternative, were evaluated. A ranking of the five alternatives according to relative effectiveness, with respect to the lowest CVOC concentrations remaining in groundwater and the least remaining mass of CVOCs in the aquifer in the future, is as follows (from most effective to least effective):

    1.a. Multiple-phase extraction (MPE) with limited phytoremediation and monitored natural attenuation

    1.b. *In situ* soil thermal treatment with Mobile Injection Treatment Unit (MITU®), limited phytoremediation, monitored natural attenuation, and multiple-phase extraction at Repository (1.a. and 1.b. show comparable effectiveness)

    2. Enhanced *in situ* bioremediation with limited phytoremediation and monitored natural attenuation

    3. Phytoremediation and monitored natural attenuation

    4. Monitored natural attenuation

- Use of multiple-phase extraction (MPE) would offer overall effectiveness and permanence comparable to the MITU® technology, but at a significantly lower cost. MPE differs from dual-phase extraction (DPE) in that DPE uses a submersible pump in each well to create drawdown of the water table, while vacuum is induced at the well by separate vapor-only

piping that is manifolded to a medium- to low-range vacuum blower. The vacuum blowers used in DPE applications are typically not expected to extract groundwater by vacuum lift pumping, as are the high-range vacuum pumps used with MPE. MPE is therefore preferred over DPE in lower permeability formations, such as the Upper Clay at this site. Enhancements of MPE systems (e.g., *in situ* soil heating) could also be added if improvement of the rate or general efficiency of treatment of the initially installed MPE systems was determined to be necessary and cost-effective, based on actual performance of the installed MPE systems.

- A computer transport model that was calibrated to existing site conditions was used to simulate the approximate results expected from implementation of the various alternatives. The assumptions used for these model simulations are believed to be conservative with regard to the assumed mass of CVOC source material remaining following the PCB remedial action. The model simulates residual source material by using constant-concentration source nodes, which provides a conservative estimate of future plume concentrations by assuming the source concentrations do not decrease over time. The model simulations showed that, for any of the alternatives, the time required to attain the target Cleanup Standards for groundwater over all of Sites 32/33 will be lengthy (greater than 20 years) because some source material will remain. However, significant improvements in groundwater quality would be expected to occur over much shorter time periods.
- The likely presence of solvent residuals, dispersed in small blebs and ganglia, below the water table in the source zones represents a source of CVOCs to the groundwater that will persist as long as residual solvent remains. While the remedial alternatives that were evaluated would provide additional cleanup of the source areas to varying degrees, it is likely with any of the alternatives that some of the residual solvent will remain dispersed in limited areas of the aquifer, will represent a continuing source, and will impact the effectiveness of any remedial technology. This situation is typical of results encountered at essentially all sites where residual solvent is present (National Research Council, 1994).
- Remedial alternative simulations that assume some remaining concentrated CVOC residuals in the source areas following additional source treatment predict that significant reductions in both dissolved and adsorbed contaminant mass (by up to 95%) will occur in the aquifer over 20 years, with substantial reductions occurring in as little as 5 years.
- The apparent separate source of CVOC contamination of groundwater located south of the Repository is not associated with past PCB contamination or remedial activities. Notwithstanding this finding of the investigation, remediation of the CVOC source south of the Repository will be addressed with the remedial alternative selected for the CVOC source located beneath the Repository, due to the close proximity of this separate CVOC source to the Repository, and because of the likelihood that remediation of this CVOC source using the same approach that is selected for the source materials beneath the Repository will be feasible.
- The apparent separate source of CVOC contamination of groundwater located near Building I-1-36A is not associated with past PCB contamination or remedial activities. No information is available regarding the nature or extent of the CVOC source material that is

likely to be present in soil at this location. After a remedial alternative for groundwater has been selected, additional soil samples in the vicinity of Building I-1-36A will be collected and analyzed as part of a pre-design fieldwork program. The soil chemistry data from analysis of these samples will be used to define the nature and extent of the CVOC source materials and the appropriate remedial alternative to be used, if remediation of this source area is determined to be necessary.

- For all of the alternatives considered, some level of additional data and information is needed before final remedial design of the alternative can proceed. Therefore, a pre-design data acquisition step will be necessary to develop design information for the selected alternative.
- The alternatives evaluated have varying degrees of "cost sensitivity" on a per-cubic-yard of soil treated basis. The MITU®, with the highest cost per-cubic-yard treated, is most sensitive to the area and depth of soil that would be identified for treatment in the final design; this indicates that a fairly extensive pre-design source area delineation sampling program may be necessary to ensure cost-effective application of the MITU® alternative. The other alternatives, including multiple-phase extraction, have a much lower cost-per-cubic yard treated, and can be applied over a larger area and depth of soil at each of the source areas on a more cost-effective basis than the MITU®; a pre-design source delineation program may not be required for cost-effective application of these other alternatives.

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List of Acronyms and Abbreviations

[Note: All acronyms and abbreviations may not be used in this document.]

µg/L	micrograms per liter
AA	atomic absorption
ARARs	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
bgs	below ground surface
BNA	base-neutral-acid extractables
BOD	biochemical oxygen demand
CADD	computer-aided design and drafting
CCB	continuing calibration blank
CCC	calibration check compound
CCV	continuing calibration verification
CE	chloroethene (also known as vinyl chloride)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
cm/s	centimeter per second
COC	Chain of Custody
CONWR	Crab Orchard National Wildlife Refuge
COPC	constituent of potential concern
CRDL	Contract Required Detection Limits
CRL	Central Regional Laboratory
CRQL	Contract Required Quantitation Limits
1,2-DCE	1,2-dichloroethene
DCF	document control format
DO	dissolved oxygen
DOD	United States Department of Defense
DOI	United States Department of the Interior
DQO	Data Quality Objective

FCR	field change request
FERA	Final Effective Risk Assessment
FFA	Federal Facility Agreement
FID	flame ionization detector
FIT	field investigation team
FS	Feasibility Study
FSP	Field Sampling Plan
F&WS	United States Fish and Wildlife Service
GC/MS	gas chromatograph/mass spectrophotometer
gpm	gallons per minute
HSC	Health and Safety Coordinator
HSP	Health and Safety Plan
HSR	Health and Safety Representative
IAC	Illinois Administrative Code
ICB	initial calibration blank
ICP	inductively coupled plasma
ICS	interface check samples
ID	internal diameter
IDW	investigation-derived waste
IEPA	Illinois Environmental Protection Agency
IQAT	Independent Quality Assurance Team
kg	kilogram
L	liter
LCS	laboratory control sample
LRA	linear range analysis
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDL	Method Detection Limit
mg	milligram
mL	milliliter
MNA	monitored natural attenuation
MS	matrix spike
MS/MSD	matrix spike/matrix spike duplicate
MSD	matrix spike duplicate
M.S.L.	mean sea level

mV	millivolt
NCP	National Contingency Plan
ng	nanogram
NGVD	National Geodetic Vertical Datum, 1929
NIST	National Institute of Standards and Technology
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTU	nephelometric turbidity units
O&M	operation and maintenance
ORP	oxidation-reduction potential
OSC	On-site Coordinator
OSHA	Occupational Safety and Health Administration
OVA	organic vapor analyzer
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCBOU	PCB Operable Unit
PCDD	polychlorinated dibenzo(p)dioxin
PCDF	polychlorinated dibenzofuran
pg	picogram
pH	negative logarithm (base 10) of hydrogen ion activity
PID	photoionization detector
PLFA	phospholipid fatty acid
PM	Project Manager
ppb	parts per billion
PPE	personal protective equipment
ppm-v	parts per million - volume basis
PRP	Potentially Responsible Party
PVC	polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manual
QAMP	Quality Assurance Management Plan
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QC	quality control
RA	remedial action

RAGS	Risk Assessment Guidance for Superfund
RAS	routine analytical services
RCRA	Resource Conservation and Recovery Act
RD	remedial design
the Refuge	Crab Orchard National Wildlife Refuge
RF	response factor
RI	Remedial Investigation
ROD	Record of Decision
ROI	radius of influence
RPD	relative percent difference
RPM	Remedial Project Manager
RSD	relative standard deviation
RT	retention time
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SAS	special analytical services
SC	specific conductance
SHERP	Safety, Health, and Emergency Response Plan
SI	Supplemental Investigation
SII	Schlumberger Industries, Inc.
SMC	Sample Management Coordinator
SOP	standard operating procedure
SOW	Statement of Work
SPCC	system performance check compound
SRM	standard reference materials
S.U.	standard units
SVOC	semivolatile organic compound
SW846	Test Methods for Evaluating Solid Waste, 1986
TAL	Target Analyte List
TBD	to be determined
TCE	trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TEMP	temperature
TIC	Tentatively Identified Compound

TKN	total Kjeldahl nitrogen
TOC	total organic carbon
TSCA	Toxic Substance Control Act
TTU	Thermal Treatment Unit
USDOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOA	volatile organic analysis
VOC	volatile organic compound

Section 1
Introduction

1.1 Background

An investigation of groundwater occurrence and the nature and extent of groundwater contamination was performed at Sites 32/33 of the PCB Operable Unit at the Crab Orchard National Wildlife Refuge during the summer of 1998. The investigation was performed in accordance with a workplan (FDGTI, 1998b) that was conditionally approved by the USEPA in a letter to Schlumberger dated 29 September 1998. The objective of the groundwater investigation, as stated in the workplan, was "to define the breadth, depth, and downgradient extent of the CVOC plumes." In addition to groundwater investigation tasks, the fieldwork performed during the summer of 1998 included installation of various groundwater extraction and soil vapor extraction wells and monitoring well points at each of three identified groundwater contamination source areas, and pilot tests using these wells. The objective of the pilot tests, as stated in the workplan, was "to obtain hydraulic characteristics within [the] sand lens and to prove that vacuum extraction will be effective within the vadose zone at the areas of highest CVOC concentrations."

To supplement and confirm the groundwater chemistry data developed from groundwater investigation sampling performed during the summer 1998 fieldwork and from various earlier investigations, an additional round of groundwater sampling was performed in December 1998 at Sites 32/33. As part of the December 1998 sampling program, surface water at Sites 32/33 was also sampled, as required for Performance Standards Compliance Monitoring under the Consent Decree for the study sites comprising the PCB Operable Unit (Consent Decree, 1991). The December 1998 sampling round was performed in accordance with a workplan (RMT, 1998) that was approved by the USEPA in a letter to Schlumberger dated 7 December 1998.

Part I of this document (Groundwater Investigation Report) includes a description of the fieldwork tasks performed and the results from the groundwater investigation at Sites 32/33 during the summer of 1998, and from the additional groundwater and surface water sampling round performed in December 1998. The results from, and analysis of, aquifer pumping tests performed during the summer of 1998 are also included in this Groundwater Investigation Report.

Part II of this document (Focused Feasibility Study) includes an evaluation of a number of alternatives for possible remediation of contaminated groundwater. Part II also includes a

description of the facilities and results associated with the other pilot tests (air sparging/soil vapor extraction, dual-phase extraction) performed during summer 1998.

The document is being issued in this two-part format, rather than as two sequentially issued separate reports, to assist in expediting the review of remedial alternatives for groundwater at Sites 32/33.

1.2 Purposes of Report

The purposes of this Groundwater Investigation Report include the following:

- To present a description of the tasks performed as part of the groundwater investigation during the summer of 1998 and during the groundwater and surface water sampling round in December 1998.
- To document the results and data produced from the 1998 investigation.
- To incorporate the data and results of previous groundwater and surface water investigations performed prior to 1998 into the data summaries prepared for the 1998 investigation.
- To present a comprehensive evaluation of the groundwater/surface water flow system and the nature and extent of groundwater contamination at Sites 32/33, using data and information available from all investigations performed through 1998.

1.3 Scope of Report

Extensive activities have been completed at Sites 32/33 for remediation of PCBs, lead, and cadmium in soil at various source locations and in on-site drainage channels, and in sediment within the Crab Orchard Lake embayment at the north end of the Sites. Descriptions of these remediation activities for soil and sediment at Sites 32/33 and documentation of the cleanup results are reported in other documents. The fieldwork and results associated with the completed soil and sediment cleanup for PCBs and metals contamination are discussed in this Groundwater Investigation Report only to the extent that these cleanup actions relate to the potential for the continuing presence of residual sources of volatile organic compounds (VOCs) within the identified source areas for groundwater contamination at Sites 32/33.

This Groundwater Investigation Report focuses on the results of investigations of groundwater and surface water at Sites 32/33 performed in 1998, with an evaluation of the groundwater/surface water flow system and the nature and extent of groundwater contamination based on data and information available from all investigations performed through 1998. The scope of this report includes the following key components:

- A brief summary of the overall site background and a chronology of investigation programs and completed remedial action

- A description of the investigation tasks completed during summer 1998 and the groundwater and surface water sampling round performed in December 1998
- Presentation of data and results from the 1998 investigations
- An updated description of the site hydrogeology, including site stratigraphy and groundwater occurrence and flow
- A description of a groundwater numerical flow and contaminant transport model for the site with a summary of the modeling results
- A description of the locations and characteristics of, and the contaminants associated with, the source areas of groundwater contamination
- A discussion of the chemical and physical processes affecting the fate and transport of constituents of concern present within groundwater and surface water
- A conceptual model of the overall groundwater/surface water flow system and contaminant transport processes
- A discussion of the findings and conclusions from the comprehensive evaluation of groundwater and surface water

Section 2
Previous Site Investigations and Remedial Action

2.1 General

This section is intended to provide only a brief summary of the previous key environmental investigations and remedial actions that have been completed at Sites 32/33. Details of, and results from, these investigations and remedial actions are contained in reports and other documents previously issued for the PCB Operable Unit.

2.2 Site Investigations

Several field investigations have been performed at Sites 32/33 from 1983 through 1998. The majority of these investigations focused on evaluation of impacts of PCBs and metals on unsaturated soil and on sediment within the Crab Orchard Lake embayment and in the site drainage swales. Groundwater and surface water quality has also been evaluated during several of these investigation events. A chronology of the key fieldwork activities that have been performed through 1998 is shown in Table 2-1.

The groundwater investigations have included the installation of monitoring wells during several fieldwork events beginning in 1983 through the summer of 1998, with sampling and laboratory analysis of groundwater following each well installation event. A total of 38 monitoring wells currently exist at the site; 29 of these wells were installed in 1997 and 1998. Information on shallow groundwater quality obtained from sampling of monitoring wells was supplemented by installation of 72 Geoprobe® borings in 1998, with collection and analysis of groundwater samples from all the borings. Therefore, most of the existing data that define groundwater quality were collected since 1997, following completion of the PCB remedial action.

Surface water in the Crab Orchard Lake embayment and in on-site drainage swales has been sampled periodically since 1985, usually in conjunction with the groundwater sampling events.

2.3 Remedial Action

The field activities for remediation of PCBs and metals in soil and sediment began in December 1995, and were completed in June 1997 (FDGTI, 1998b). A total of approximately 112,000 cubic yards (*in-situ* volume) of contaminated soil and sediment were excavated from

the building complex area and from the East and West Swales during this action. An additional 44,000 cubic yards (*in-situ* volume) of sediment from the lake embayment were excavated.

Of the total volume of soil and sediment excavated from the building complex and swales, approximately 52,000 cubic yards were hauled and placed directly into the Area 9 Repository, and 60,000 cubic yards were treated in an on-site thermal treatment unit. All of the 44,000 cubic yards of sediment from the lake embayment were hauled and placed directly into the Repository.

Section 3
Scope of 1998 Groundwater Investigations

3.1 Summary of Work Performed

Two phases of investigation were conducted in 1998 to further identify the nature and extent of chlorinated volatile organic compounds (CVOCs) in groundwater and to conduct pilot testing of several potential remedial technologies at Sites 32/33. The first phase, performed in the summer of 1998 by Fluor Daniel GTI (FDGTI), included a direct-push groundwater sampling and analysis program, the installation and sampling of additional monitoring wells, and pilot tests of two potential remedial technologies. The scope of this first-phase of the investigation was in substantial conformance with the 1998 TCE Investigation, Work Plan, and Pilot Study prepared by FDGTI, dated May 1998 (FDGTI, 1998b).

The second phase, conducted in December 1998 by RMT, Inc. (RMT), included one comprehensive round of sampling and analysis of all existing groundwater monitoring wells and sampling and analysis at selected surface water locations. The scope of the second phase of the investigation was in substantial conformance with the Workplan for Performance Standards Compliance Monitoring and Additional Groundwater Investigation Sampling prepared by RMT, dated December 1998. Both phases of work were conducted in accordance with the Quality Assurance Project Plan (QAPP) prepared by Fluor Daniel Environmental Services, Inc. (FDES, 1995), and subsequent QAPP Addenda, except for specific modifications identified in the workplans. Summaries of both investigative programs are presented in the following sections.

3.2 Direct-push Sampling Program

A groundwater sampling program using direct-push technology was conducted to further identify the lateral, vertical, and longitudinal extent of the CVOC plumes. A Geoprobe®, operated by Innovative Probing Solutions (IPS) of Mount Vernon, Illinois, was used to bore through the upper silty clay/clayey silt unit and collect groundwater within the first significant permeable (sand) unit encountered. A total of 72 Geoprobe® borings were completed at the sites. The locations of the borings are shown on Figure 3-1.

Continuous soil samples were collected from each boring and were logged in the field by FDGTI geologists. The field logs were reviewed by RMT, edited to conform to the Unified Soil

Classification System (USCS), and finalized on Illinois Environmental Protection Agency (IEPA) standard boring log forms. Copies of the original field logs and finalized boring logs are included in Appendix A.

Groundwater samples were collected from each boring through a mill-slot screen pushed to the base of the boring after the drill rod was removed. The samples were withdrawn from the screen zone using an inertial pump with polyethylene tubing, and were collected directly into laboratory-supplied containers. The samples were placed on ice immediately, shipped to the laboratory, and analyzed for CVOCs on a rapid turnaround basis. This allowed for decisions to be made in the field as to the need for, and the location of, additional sampling points.

When sampling was completed, each boring was abandoned by tremie-grouting with a bentonite slurry. The location of each boring was marked, photographed, and surveyed. The Geoprobe® unit and all downhole equipment were decontaminated between sampling locations using a high-pressure, hot-water rinse at the decontamination pad that was constructed for use during the PCB remedial action.

3.3 Monitoring Well Installation

A total of 15 monitoring wells (33MWC-21 through 33MWC-24, 33MWC-27 through 33MWC-33, 33MWC-35, 33MWC-36, 33MWC-39, and 33MWC-41) were installed and sampled during this investigation to further define the nature and extent of constituents of concern at Sites 32/33. The locations of the monitoring wells are shown on Figure 3-1.

Approximately half (7) of the new wells were shallow and were screened in the Upper Sand unit. Three monitoring wells were screened in an intermediate sand unit that was subsequently determined to be discontinuous and absent in a number of locations. The remaining five monitoring wells were screened in a Lower Sand unit above the bedrock. A total of 38 monitoring wells are present at the site through the efforts of this investigation and those of previous investigations.

3.3.1 Drilling and Soil Sampling

The borings for the monitoring wells were advanced with 4 ¼-inch–ID hollow-stemmed augers, using a Diedrich D-120 rig operated by Mid America Drilling Services, Inc. Continuous soil samples were collected using either a 2-inch–diameter, 2.2-foot–long split-spoon sampler, or a 3.5-inch–diameter, 5-foot–long continuous core barrel sampler. The soil samples were logged in the field by FDGTI geologists. The field logs were reviewed by RMT, edited to conform to the Unified Soil Classification System (USCS), and finalized on IEPA standard boring log forms. Copies of the soil boring logs are included in Appendix B. The drilling and sampling equipment was decontaminated

between sampling locations using a high-pressure hot-water rinse at the decontamination pad.

3.3.2 Well Installation and Construction

Upon completion of each monitoring well boring, a 2-inch–diameter groundwater monitoring well constructed of Type 316 stainless-steel riser and screen was installed in each boring. The well screens were factory-slotted Type 316 stainless steel with 0.010-inch slots. The length of well screen installed at each drilling location was selected based on the thickness of the sand unit encountered. Five-foot well screens were installed across sand units approximately 6 feet or less in thickness, and 10-foot well screens were installed across sand units greater than 6 feet thick. A sand pack of 20- to 40-mesh washed silica was placed from approximately 6 inches below to 2 feet above the well screen. A minimum 2-foot–thick bentonite annular seal (slurry) was placed above the sand pack followed by a cement-bentonite grout to the surface. An 8-inch–diameter steel surface casing with lockable steel cap was placed over each well. A concrete pad, approximately 3 feet by 3 feet, was poured around the base of the surface casing. Copies of well construction diagrams that show the specific details of each monitoring well are included in Appendix B.

Monitoring wells constructed across sand layers below the upper permeable zone were double-cased to the base of the upper permeable zone to limit the downward migration of contaminants. To install these wells, a pilot hole was advanced with 10 ¼-inch hollow-stemmed augers to approximately 1 foot into the clay below the upper permeable zone. An 8-inch–I.D. flush-threaded stainless steel casing was seated into the clay and grouted in place. After the grout was allowed to set for at least 48 hours, the monitoring well borings were advanced through the outer casing with 4 ¼-inch hollow-stemmed augers.

3.3.3 Monitoring Well Development

Each monitoring well was developed within 2 weeks of installation to remove suspended fine material from the well and surrounding sand pack, to allow the well to yield relatively sediment-free water samples.

Wells were developed by pumping at a low flowrate using a small-diameter submersible pump with polyethylene tubing. Readings of pH, specific conductance, and temperature were taken at 15-minute intervals during development. Three successive parameter readings within 10 percent of each other, in conjunction with water clarity, were used as criteria for proper well development. Development time

was limited to 2 hours if the 10 percent criteria were not achieved. Copies of the well development documentation are included in Appendix C.

3.4 Pilot Testing Wells and Associated Monitoring Probes

Two remedial technologies were evaluated to address the dissolved-phase plumes and the VOC-impacted soil at the three previously identified source areas. The technologies include air sparging combined with soil vapor extraction (SVE), and dual-phase vacuum extraction (DPVE). Because of the differences in variables, such as site stratigraphy and soil properties, depth to groundwater, and variations in concentrations, separate pilot tests were conducted at each of the three previously identified source areas. These areas include an area to the east of Building I-1-2, an area to the west of Building I-1-23, and an area beneath the Area 9 Repository. Aquifer pumping tests were also conducted as the initial activity of the pilot testing phase to determine the hydraulic characteristics of the upper permeable zone.

3.4.1 Groundwater Pumping Wells

One groundwater pumping well, identified as the dual-phase extraction (DPE) well, was installed in each of the three source areas. The locations of the wells are described in Part II of this document.

Each pumping well boring was drilled with 4 ¼-inch-ID hollow-stemmed augers, using an ATV CME 750 rig operated by Geotechnology, Inc. Due to the proximity of well borings to other borings that were drilled, sampled, and logged previously, the borings were blind-drilled (no soil samples were collected) and no boring logs were prepared.

Each DPE well was constructed of 4-inch diameter threaded flush-joint Schedule 40 PVC, with a factory-cut 0.010-inch slotted screen. At the Building I-1-2 and Building I-1-23 source areas, the wells were screened from the base of the first permeable zone (the Upper Sand unit) to within 5 feet of the ground surface. At the Area 9 Repository source area, the well screen was installed within a low-permeability silt unit directly beneath the clay fill material in the Repository. The materials and methods of installation for the sand pack, bentonite seal, and annular seal for these wells are the same as those used for the monitoring wells as described in Subsection 3.3.2. Well construction diagrams showing the details of each DPE well are included in Appendix D. Well development was similar to monitoring well development described previously, and the results are included in Appendix C.

3.4.2 Soil Vapor Extraction Wells

Three SVE wells were installed in each of the three source areas. The locations of the wells are described in Part II of this document.

The borings for the SVE wells were blind-drilled using 4 ¼-inch–ID hollow-stemmed augers. No soil samples were collected, and no soil boring logs were prepared.

Each SVE well was constructed of 2-inch–ID threaded flush-joint Schedule 40 PVC riser and factory-cut 0.010-inch slotted screen. The screen interval extended from the water table to within 3 feet of ground surface. The materials and methods of installation for the sand pack, bentonite seal, and annular seal for these wells are the same as those used for the monitoring wells as described in Subsection 3.3.2. Well construction details for a typical SVE well from each of the three source areas are included in Appendix D.

3.4.3 Air Sparging Wells

One air sparging well was installed in each of the three source areas. The locations of the wells are described in Part II of this document.

Each air sparging well boring was blind-drilled with 4 ¼-inch–ID hollow-stemmed augers. No soil samples were collected, and no soil boring logs were prepared.

Each air sparging well was constructed of 4-inch–ID threaded flush-joint Schedule 40 PVC riser and factory-cut 0.010-inch slotted screen. Each screen was 5 feet long. At the Building I-1-2 and Building I-1-23 source areas, the well screen was installed to the base of the first saturated permeable zone. At the Area 9 Repository source area, the well screen was installed within a low-permeability silt unit directly beneath the clay fill material in the Repository. The materials and methods of installation for the sand pack, bentonite seal, and annular seal for these wells are the same as those used for the monitoring wells as described in Subsection 3.3.2. Air sparging well construction details are included in Appendix D.

3.4.4 Monitoring Probes

Monitoring probes were used as measurement devices for all pilot tests. Four probes were installed in each of the three source areas. The locations of the probes are described in Part II of this document.

Each monitoring probe was blind-drilled with 4 ¼-inch–ID hollow-stemmed augers. No soil samples were collected, and no soil boring logs were prepared.

Each monitoring probe was constructed of 2-inch-ID threaded flush-joint, Schedule 40 PVC riser and factory-cut 0.010-inch slotted screen. The screen zones generally extended from the base of the first permeable saturated zone to within 3 feet of ground surface. The materials and methods of installation for the sand pack, bentonite seal, and annular seal for these probes are the same as those used for the monitoring wells as described in Subsection 3.3.2. Typical monitoring probe construction details are included in Appendix D.

3.5 Surface Water Staff Gauge Installation

Four staff gauges (SG-01 through SG-04) were installed in several of the surface water drainageways at the site to aid in the interpretation of groundwater/surface water interaction. The gauges consisted of steel fence posts with wooden rulers attached and were driven into the stream sediment with a fence-post driver.

SG-01 and SG-02 were installed in the Center Swale channel originating near Building I-1-11 and extending northeasterly to Crab Orchard Lake. Staff gauge SG-03 was located in the West Swale just as it enters Crab Orchard Lake, and staff gauge SG-04 was located to the west of Highway 148 in an unnamed intermittent stream that originates to the west of Building I-1-1 (Figure 3-1).

3.6 Surveying

The elevations and locations of all monitoring wells, direct-push (Geoprobe®) borings, monitoring probes, and staff gauges were surveyed by Robert G. Sewell, Illinois Professional Land Surveyor #2347. The locations were surveyed relative to the State Plane Coordinate System, and were accurate to the nearest 0.01 foot. The elevations were surveyed relative to the National Geodetic Vertical Datum (NGVD), and were accurate to the nearest 0.01 foot. Surveying data are included in Appendix E.

3.7 Monitoring Well Groundwater Sampling

Groundwater samples were collected from site monitoring wells in two separate sampling rounds in 1998. The initial 1998 sampling round was conducted in June 1998 by FDGTI and included the 15 new monitoring wells installed during the 1998 groundwater investigation. Monitoring wells 33MWC-27 and 33MWC-28 were resampled by FDGTI in July 1998 due to a possible sample identification error. The wells were sampled in accordance with FDGTI's 1998 TCE Investigation Workplan (FDGTI, 1998b), the QAPP (FDES, 1995), and subsequent QAPP addenda.

The second round of groundwater sampling was performed in December 1998 by RMT, and included all 38 existing monitoring wells. This round of sampling was conducted in accordance with the workplan dated December 1998 (RMT, 1998) and the QAPP (FDES, 1995).

A groundwater and surface water sampling program was also performed in June 1999, in accordance with the requirements for semiannual Performance Standards Compliance Monitoring specified in the Consent Decree. The validated laboratory data from analysis of these samples are included in Appendix O.

Water levels representative of the static groundwater conditions were measured in all of the existing site monitoring wells in August 1998 after the wells had recovered from development. Static water levels were also recorded for all of the site monitoring wells prior to sampling in December 1998. These static water levels were used to establish water table and potentiometric surface maps. A summary of the water level readings is included in Table 3-1.

A summary of the 1998 sampling programs is presented below. Additional details are provided in the above-referenced workplans, the QAPP, and QAPP addenda.

3.7.1 Summer (June) 1998

Prior to sampling, each well was purged with a small-diameter submersible pump or a dedicated stainless steel bailer. Specific conductance, pH, E_H, and temperature were measured for every one-half well casing volume and recorded. Purging continued until the parameters stabilized within 10 percent or until five well casing volumes were removed. Well stabilization data for the FDGTI summer 1998 groundwater sampling are included in Appendix F.

Wells that purged dry prior to stabilizing were sampled when water levels recovered sufficiently to allow sampling, but always within 24 hours of purging, using the same equipment as that used for the wells that did not purge dry.

Following purging, samples were collected with a dedicated stainless steel bailer and poured directly into sample bottles provided by the laboratory.

3.7.2 Winter (December) 1998

Most of the shallow site monitoring wells were purged using a peristaltic pump and dedicated 3/8-inch-O.D. high-density polyethylene (HDPE) tubing. At wells where the depth to water was greater than 20 feet, or the total well depth was greater than 30 feet, a small-diameter submersible pump, dedicated stainless steel bailer, or disposable HDPE bailer was used instead of the peristaltic pump. Where a pump was used to

purge the well, the tubing (or submersible pump intake) was placed approximately 1 to 2 feet above the base of the well screen, and the well was pumped at a flowrate ranging from <0.5 liter/min to 1 liter/min. The pumping rate for each monitoring well was dependent on the hydraulic properties of the formation the well was screened across, and was determined in the field to be the highest flowrate attainable without creating drawdown greater than approximately 1 foot.

A YSI Model 3000 flow-through cell (or equivalent) equipped with temperature, specific electrical conductance, pH, and oxidation-reduction potential (redox) electrodes was connected to the discharge tubing from the peristaltic pump. In addition, dissolved oxygen (DO) measurements were taken at the pump discharge using Chemetrics colorimetric test kits. Each of these parameters were measured at each well during purging to evaluate stabilization. Groundwater chemistry was considered stable when the temperature change was ≤0.5 degrees C, the conductance change was ≤10 percent, the pH change was ≤0.1 pH unit, and the redox potential and DO change were ≤10 percent between three successive 1-liter sampling intervals. The wells were sampled immediately following stabilization, or after five casing volumes were removed. The samples were taken from the pump discharge after the flow-through cell had been disconnected. Sample collection flowrates were ≤100 mL/min.

When wells were purged with a bailer, a minimum of three well volumes to a maximum of five well volumes were removed prior to sampling, in conformance with the TCE Investigation Workplan and Pilot Study (FDGTI, 1998b). Wells that were purged dry were evacuated and allowed to recover prior to sampling, but for no more than 24 hours after purging. Field measurements of specific conductance, temperature, and pH were collected after every well volume. Measurements of DO and E_H were not collected at wells that were bailed or purged dry.

Surface water samples were collected with an HDPE dipper, in accordance with the TCE Investigation Workplan and Pilot Study (FDGTI, 1998b).

Field Quality Assurance/Quality Control (QA/QC) samples were collected with the frequency and for the analytical program specified in the workplan (RMT, 1998).

3.8 Data Validation and Usability

3.8.1 Summer 1998 Data

The summer 1998 laboratory analytical data were validated by FDGTI. The data validations were conducted in accordance with the USEPA "Contract Laboratory

Program National Functional Guidelines for Organic Data Review" (February 1993, US EPA-540/R-94/012) and "Contract Laboratory Program National Functional Guidelines for Inorganic Data Review" (February 1994, US EPA-540/R-94/013); for parameters that are not specifically addressed by the USEPA's CLP or the validation guidelines, evaluation procedures similar to those referenced were followed. The criteria used for validation of these parameters were presented in the associated analytical Standard Operating Procedures (SOPs) in the QAPP. Reporting limits, surrogate recovery control limits, precision and accuracy control limits, etc., have been statistically established by the individual laboratories as required by the non-CLP methodologies. If the method-established criteria were used, the method employed was used in validation. Validation involved flagging of data, evaluation of blanks, evaluation of duplicates, and statistical evaluation of data.

Data validation tables and blank-corrected laboratory data summary tables for the summer 1998 samples were submitted to the USEPA by FDGTI on October 23, 1998. A summary or statement of the usability of the data with respect to the data quality objectives defined in the investigation workplan (FDGTI, 1998b) was not included with the submittal. A review of the data validation information by RMT, Inc., indicated that the data quality objectives for the summer 1998 fieldwork program were met, and the data were considered usable for the purposes defined in the workplan as approved by the USEPA.

3.8.2 Winter 1998 Data

A total of 53 water samples (47 groundwater, 5 surface water, and 1 leachate) were collected in December 1998 by RMT and analyzed by GPL Laboratories, LLLP (GPL), for target analyte list (TAL) metals and cyanide (SOW ILM01.1), target compound list (TCL) volatile organic compounds (SOW OLC2.0), TCL semivolatile organic compounds (SOW OLM03.2), and TCL organochlorine pesticides/PCBs (SOW OLM03.0 and OLM03.2). Inorganic indicator parameters were analyzed in accordance with EPA 600 Methods. Dissolved gas (ethane, ethene, and methane) analyses were performed using the GC/FID (gas chromatograph/flame ionization detector) method. Additionally, trip and field blanks, matrix spikes/matrix spike duplicates (MSs/MSDs), and blind field duplicates were collected and analyzed for quality control purposes.

Data validation was accomplished by RMT by comparing the quality assurance and quality control (QA/QC) results contained in the laboratory data packages with the requirements specified in the approved Quality Assurance Project Plan (FDES, 1995) (FDGTI, 1998c); the USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review (USEPA, 1994a); the USEPA Contract Laboratory

Program National Functional Guidelines for Organic Data Review Multi-Media, Multi-Concentration (OLMO 1.0) and Low Concentration Water (OLCO 1.0) (USEPA, 1994b); the National Functional Guidelines for Organic Data Review (USEPA, 1994c); and the general guidelines published in EPA 600, Methods for Chemical Analysis of Water and Waste, EPA 600/4-79-020 with revisions (USEPA, 1979), where appropriate. Particular attention was paid to raw data, chain-of-custody forms, initial and continuing calibrations, blanks, laboratory control samples (LCSs), spike and duplicate analyses, laboratory control samples (LCSs), and ICP serial dilution and ICP interference check sample results.

An evaluation of the laboratory data was submitted in a report to the USEPA by RMT on March 12, 1999 (RMT, 1999). The data quality objectives for the project were met, and the data are usable for the purposes as defined in the approved workplan. The procedures specified in the methods were implemented, and the data packages were found to contain all of the deliverables specified in the QAPP.

3.9 Variances from Workplans

FDGTI reported two minor variances from the approved workplan for the summer 1998 fieldwork. Copies of the variance reports are included in Appendix G.

The first variance, dated June 4, 1998, indicated that the pilot test wells should be considered short-term wells and should not have a concrete pad and a locking protective casing, as provided in construction of the monitoring wells.

The second variance, also dated June 4, 1998, indicated that, in areas of shallow bedrock where only one transmissive zone is present between ground surface and bedrock, only one monitoring well would be installed (in the transmissive zone) rather than the three wells indicated in the workplan.

Section 4
Investigation Results

4.1 Regional Physiography and Geology

The Crab Orchard National Wildlife Refuge is located in Southern Illinois, just south and west of the city of Marion. The refuge consists of approximately 42,620 acres of land primarily within Williamson County, extending west and south into Jackson, Union, and Johnson Counties. Crab Orchard Lake is the largest of 12 lakes within the Refuge. The western portion of the refuge around Crab Orchard Lake is open to public use for recreational purposes, while the eastern portion of the refuge is a wildlife sanctuary that is closed to general public access. Land around the eastern portions of Crab Orchard Lake is also used for industrial purposes (O'Brien and Gere, 1988).

The construction of Crab Orchard Lake was completed in 1940 as part of The Crab Orchard Project for Land Utilization. The dam that impounds the waters of Crab Orchard Creek and its tributaries, creating Crab Orchard Lake reservoir, is located at the extreme western end of the lake and has a spillway elevation of 405 feet M.S.L. Crab Orchard Lake is approximately 9 miles long, and varies in width from approximately 1.5 miles in the west near the dam to approximately 0.5 mile in the eastern end (Stall, et al., 1954). The resulting surface area of the lake is 6,965 acres, with a watershed drainage area of 72,525 acre-feet. Eastern portions of Crab Orchard Lake are approximately 2 to 3 feet deep. The average depth of the western part of the lake is 8 to 9 feet, with a maximum depth of 30 feet (Kelly and Hite, 1981, as cited in O'Brien and Gere, June 1988).

Crab Orchard Lake is located just north of the southern terminus of Illinoian continental glaciation. In pre-Illinoian time, river basins had eroded into Pennsylvanian sandstone, siltstone, and shale, resulting in topographically mature drainage basins. Illinoian glacial drift forms a thin (less than 25 feet thick), generally discontinuous mantle over the mature pre-Illinoian bedrock topography. The till generally ranges in composition from a very clayey, sandy silt, to a silty clay, and often does not exist on top of bedrock hills. Overlying the Illinoian till are Woodfordian outwash and slackwater lake deposits and Wisconsinan loess. The Woodfordian deposits are generally weakly bedded silty clay and clayey silt, locally interbedded with silt and sand with a lacustrine structure (Frye, et al., 1972).

4.2 Site Geology

Site geologic conditions were interpreted from soil boring logs from previous site investigations by O'Brien and Gere (1988), IT Corporation (1995b), Fluor Daniel (FDGTI, 1997), and the 1998 groundwater investigations performed by Fluor Daniel GTI (FDGTI, 1998b). A summary of the available well construction information for all monitoring wells installed at the site, including existing wells and wells that have been abandoned, is provided in Table 4-1. The available boring logs associated with these monitoring wells are included in Appendix B. Locations of all existing and abandoned monitoring wells are shown on Figure 3-1.

A total of 29 monitoring wells had been installed at the site prior to the 1998 groundwater investigations. A majority of these monitoring wells were installed near the groundwater table surface, at depths between 15 and 25 feet below ground surface (bgs). The bottom of one monitoring well, 32-110, was completed just above the bedrock surface near Crab Orchard Lake, at a depth of 82.5 feet bgs. Six of these monitoring wells, including 32-110, have subsequently been abandoned.

During the summer of 1998, FDGTI advanced a total of 72 Geoprobe® borings and installed 15 groundwater monitoring wells at the site. Table 4-2 summarizes the depths and approximate locations of all of the soil borings installed by FDGTI in 1998, and Table 4-1 includes a summary of the well construction information.

The Geoprobe® borings ranged from 12 feet to 58 feet in depth, with a majority of these borings advanced to depths of 15 to 30 feet bgs. The groundwater monitoring wells were generally installed in nests of two to three wells, with each screened interval targeting a specific sandy interval as defined by the geology described in the boring for monitoring well 32-110. The boring log for 32-110 is not available, however, the geology is described in text and cross-sections in the Remedial Investigation Report (O'Brien and Gere, 1988). The shallow monitoring wells installed in 1998 were completed at depths of approximately 25 to 35 feet bgs, the intermediate-depth wells were completed at approximately 45 to 50 feet bgs, and the deep wells were completed at 80 to 100 feet bgs.

The locations of the geologic cross-sections are shown on Figure 4-1. Cross-sections A-A' through D-D', depicting the geology of the site, are shown on Figures 4-2 and 4-3. Boring logs for monitoring wells and Geoprobe® borings installed by FDGTI in the summer of 1998, detailing the geologic conditions, are included in Appendices A and B.

4.2.1 Site Unconsolidated Sediment

The site is underlain by Recent and Quaternary unconsolidated deposits ranging from 30 to 100 feet thick (see Figures 4-2 and 4-3). The unconsolidated deposits consist of the following units:

Upper Clay

The Upper Clay occurs from the ground surface to depths of approximately 25 feet bgs beneath most of the site, but thins to approximately 15 feet in the north near Crab Orchard Lake. The Upper Clay consists of weakly bedded silty clays and clayey silts, with occasional silty sand seams and lenses. Many boring logs indicate structure within the Upper Clay, including laminar bedding or alternating 2- to 3-inch beds of finer and coarser material within the clay and silt, especially in the lower half of the unit (Appendix B). The calculated hydraulic conductivity of this unit is on the order of 10^{-4} to 10^{-5} cm/s, which is consistent with a silt or loess (Freeze and Cherry, 1979). The general composition and structure of the Upper Clay indicates that it is a weathered loess deposit, possibly underlain in some locations by slackwater lake deposits as described by Frye, et al., 1972.

Upper Sand

The Upper Sand occurs at elevations between approximately 380 feet and 400 feet above mean sea level (M.S.L.) and varies in thickness from 1 to 2 feet in the southern part of the site to approximately 20 feet in the western part, and 15 feet in the northwestern part. The Upper Sand is possibly absent in the southeastern portion of the site. Composition of the Upper Sand ranges from a clayey sand to a well-graded sand. In some locations, fine layering within the Upper Sand is noted in the boring logs, and there is a general coarsening downward sequence at most locations. This unit is consistent with either a glacio-lacustrine, or a glacial outwash, deposit.

Lower Clay

The Lower Clay occurs between elevations of approximately 340 feet M.S.L. and 380 feet M.S.L., and has a relatively constant thickness of approximately 40 feet. This unit ranges in composition from a silty clay to a clayey silt, and contains a trace to little fine sand and gravel. No depositional structures were noted within the Lower Clay. At some drilling locations, sandy interbedding was noted within the upper 20 feet of the Lower Clay. These sand lenses appear to be discontinuous and are not present beneath much of the site. The

Lower Clay is representative of Illinoian glacial till, as described by Frye, et al., 1972.

Lower Sand

The Lower Sand, where present, occurs immediately above the bedrock surface. The top of the Lower Sand occurs at approximately 340 to 350 feet M.S.L. This unit ranges from 10 to 20 feet thick in the northern portion of the site beneath Crab Orchard Lake to approximately 2 feet thick in the southwestern portion, and is not present in the southern and southeastern portions where the bedrock surface rises above approximately 350 feet M.S.L. The Lower Sand is consistently logged as a silty sand. Hydraulic conditions encountered during drilling in the Lower Sand caused sand to heave up inside the auger flights. As a result, few undisturbed soil samples were obtained from this unit. This unit is consistent with a glacial outwash deposit.

4.2.2 Site Bedrock

The bedrock surface below Williamson County consists of Pennsylvanian rocks. These rocks are dominantly weak shales, but include thin (less than 25 feet thick) limestones, sandstones, and coal beds. The Pennsylvanian rocks generally have low porosity and permeability, and yield small amounts of water through interconnected pores, fractures, and joints (Csallany, 1966).

Bedrock encountered during the 1998 groundwater investigations was described as a gray fine-grained micaceous sandstone, and drilling logs indicate that it is competent and well cemented. The sandstone has been identified as a part of the Carbondale Formation (AAPG 1965, as cited in O'Brien and Gere, 1988).

Topographically, the top of the bedrock surface slopes to the north and west toward Crab Orchard Lake (Figure 4-4). Bedrock elevations range from approximately 400 feet M.S.L. in the southern and southeastern portions of the site to approximately 320 to 340 feet M.S.L. in the northern and western portions of the site, respectively.

4.3 Groundwater

4.3.1 Regional Hydrogeology

Regionally, the shallowest groundwater occurs within the unconsolidated glacio-lacustrine deposits that mantle the bedrock surface throughout much of Southern Illinois. Groundwater is often encountered within 20 feet of the ground surface.

Shallow groundwater contours are a subdued reflection of the ground surface topography, with groundwater flowing from areas of high ground surface elevation, to discharge areas at lower elevations, such as streambeds or lakes.

Water-bearing sand and gravel units within the glacial and lacustrine deposits of Southern Illinois are common, but are generally thin. Groundwater yields from these units are not adequate for municipal supplies. In areas within the vicinity of the site, some thin scattered sand and gravel deposits provide adequate yield for farm and domestic water supplies (Frankie, et al., 1995).

The water-yielding characteristics of the Pennsylvanian bedrock are highly variable. In Williamson County, sandstone aquifer yields are adequate for domestic supplies throughout most of the county. The groundwater in these rocks becomes highly mineralized with depth, and production wells are rarely installed more than 200 to 300 feet into the bedrock. Domestic supplies from the sandstone aquifers are easily obtained at depths ranging from 50 to 80 feet (Csallany, 1966).

4.3.2 Monitoring Well Network

A total of 44 monitoring wells have been installed at Sites 32/33 of the Crab Orchard National Wildlife Refuge PCBOU. Five of these monitoring wells (32-061, 32-062, 32-109, 32-110, and 33MWC-04) were abandoned during the remediation and subsequent construction of the Area 9 Repository. Well COW-1 was destroyed and replaced by 32-063 prior to the Remedial Investigation in 1988 (O'Brien and Gere, 1988). Table 4-1 presents a summary of the available information for all monitoring wells ever installed at Sites 32/33, including installation dates and the consulting firm responsible for the work. Figure 3-1 shows all of the well locations.

A total of 38 monitoring wells currently exist at Sites 32/33. Of these, 23 monitoring wells (32-063, 33-340, 33-341, 33-342, and 33MWC-01 through 33MWC-20) are shallow water table wells. Most of these wells are screened across the lower portion of the Upper Clay unit and the upper portion of the Upper Sand unit. The remaining 15 monitoring wells (numbered 33MWC-21 through 33MWC-41) were installed at deeper intervals to monitor hydraulic head and groundwater chemistry in the Upper Sand and Lower Sand, and within sand seams in the Lower Clay.

4.3.3 Site Groundwater Occurrence and Flow

Groundwater levels at each of the 38 existing groundwater monitoring wells and surface water elevations at four staff gauges (Figure 3-1) were measured in August and December 1998. Previously, groundwater elevations at the site have been recorded at

variable intervals since December 1986. A summary of the available groundwater elevation data is presented in Table 3-1. Water table maps for the August and December 1998 monitoring events are presented on Figures 4-5 and 4-6. Potentiometric surface maps for the August and December 1998 monitoring events are presented on Figures 4-7 and 4-8, and Figure 4-9 depicts equipotential cross-sections A-A′ and D-D′ for the December 1998 monitoring event.

Generally, the water table at the site is a subdued reflection of the topography, with flow northward toward Crab Orchard Lake. As shown on Figure 4-9, groundwater flow within the clay units has a significant downward component, except in locations of groundwater discharge to surface water, while flow within the sand units is predominantly horizontal.

Upper Sand/Upper Clay

Groundwater is generally encountered between 1 foot to 15 feet below ground surface (bgs) in the Upper Clay unit at the site. The one exception is beneath the Area 9 Repository, where groundwater occurs approximately 22 feet below the top of the Repository. Groundwater elevations at most well locations fluctuate approximately 3 to 8 feet during the year (Table 3-1).

Figures 4-5 and 4-6 show the water table configurations for August 1998 and December 1998, respectively. The water table maps were constructed using the shallow water table well data where available. Water level data from piezometers constructed in the Upper Sand unit were used where water table well data were not available. This approximation appears to be generally valid based on a comparison of hydraulic head in adjacent wells completed in the two different units (e.g., 33MWC-13 and 33MWC-24). The water table configurations are generally consistent throughout the year, and consistent with previous investigations (e.g., IT Corp., 1995b). The additional wells installed during the summer 1998 field investigation allow a more detailed interpretation of the water table surface configuration than previously available.

Shallow groundwater beneath the site generally flows northward toward Crab Orchard Lake, but is affected locally by surface water drainageways and by the Area 9 Repository. In the Building I-1-2 Area, shallow groundwater flows radially away from a local groundwater high. A majority of the groundwater flow from this area is easterly, toward the East Swale, and westerly, toward the Heron Flats impoundment area located west of Highway 148. Horizontal

hydraulic gradients in the Building I-1-2 Area range from 0.003 to 0.006 (Table 4-3). Groundwater flow velocities in the Building I-1-2 Area ranged from approximately 80 ft/yr in August to 150 ft/yr in December. Horizontal hydraulic gradient and groundwater flow velocity calculations are included in Appendix H.

In the I-1-23 Area, groundwater flows primarily northward toward Crab Orchard Lake, with a lesser component of flow to the northeast toward the Area 9 Repository. A groundwater mound is present beneath the Area 9 Repository. This causes shallow groundwater to flow to the east toward the Center Swale (located immediately adjacent to the Repository) and to the north toward Crab Orchard Lake. During the summer of 1998, groundwater elevations at the Area 9 Repository were high enough to develop groundwater seeps along the base of the eastern side of the Repository. Horizontal hydraulic gradients in the Building I-1-23 Area range from 0.004 to 0.006, and the resulting groundwater flow velocity ranged from approximately 110 ft/yr in August to 70 ft/yr in December. Horizontal hydraulic gradients from the Area 9 Repository range from 0.01 to 0.02 (Table 4-3) with a groundwater flow velocity of approximately 10 ft/yr throughout the year.

The flow patterns shown on the two water table maps are similar, except that the water levels were generally 2 to 3 feet higher in August than in December 1998, and the December water table map indicates a mound associated with presumed recharge from the Center Swale.

Lower Sand Unit

Potentiometric surface maps for the Lower Sand unit for August 1998 and December 1998 are shown on Figures 4-7 and 4-8, respectively. Groundwater in the Lower Sand unit flows to the north toward Crab Orchard Lake. The horizontal hydraulic gradient in the Lower Sand ranges from 0.0004 to 0.0005 (Table 4-3). The calculated groundwater flow velocity in the lower sand is approximately 3 ft/yr (Appendix H).

Over most of the site, the head in the lower sand is generally 1 to 3 feet lower than the head in the Upper Sand indicating a downward potential. However, near Crab Orchard Lake, this is reversed, indicating an upward potential as groundwater discharges to the lake. This effect was previously exhibited by well 32-110, which was a flowing artesian well with a piezometric head elevation at least 3 feet above the lake elevation.

Slug Test Results

FDGTI performed slug tests at each of the 15 groundwater monitoring wells installed in 1998 after they were developed. Both rising head and falling head tests were performed at each of the monitoring wells. RMT analyzed the slug test data with AQTESOLV Version 2.0 for Windows, using the Bouwer-Rice Solution for a Slug Test in a Confined Aquifer (1976). Slug test data, and AQTESOLV input and output files, are included in Appendix I. The results from these tests and slug test results from previous investigations are summarized in Table 4-4.

A total of 22 slug tests have been performed at the site since the Remedial Investigation (O'Brien and Gere, 1988). Seven of the tests were conducted in wells completed within the Upper Clay, seven were conducted in wells completed in the Upper Sand, three were conducted in wells completed across sand seams in the Lower Clay, and five were conducted in wells completed in the Lower Sand.

The slug test results were generally consistent within each unit. In the Upper Clay, the calculated hydraulic conductivities ranged from 1.6×10^{-5} to 7.7×10^{-4} cm/s, with a geometric mean of 8.1×10^{-5} cm/s. These conductivity values are consistent with values reported for silt and loess of 10^{-7} to 10^{-3} cm/s (Freeze and Cherry, 1979).

In the Upper Sand, the calculated hydraulic conductivities ranged from 1.3×10^{-5} cm/s to 4.4×10^{-3} cm/s, with a geometric mean of 1.9×10^{-4} cm/s. These conductivity values are consistent with values reported for a silty sand or fine sand.

Slug test results from monitoring wells 33MWC-22, 33MWC-28, and 33MWC-31, which are screened across sand seams within the Lower Clay, were consistently on the order of 10^{-6} cm/s. The calculated hydraulic conductivity for these sand lenses is an order of magnitude below the range expected for a silty sand, and is generally more consistent with that of a glacial till (Freeze and Cherry, 1979). The apparent low hydraulic conductivity of these sand lenses may indicate the lack of continuity of the lenses, or may be the result of smearing clay within the borehole during drilling, and inadequate well development.

In the Lower Sand, calculated hydraulic conductivities generally ranged from 9.4×10^{-4} to 4.1×10^{-3} cm/s, with a geometric mean of 1.9×10^{-3} cm/s. These

values fall within the observed range for a silty sand of 10^{-5} to 10^{-2} cm/s documented in literature (Freeze and Cherry, 1979). Well 33MWC-35, which is screened completely within the Lower Sand unit, has a very low hydraulic conductivity of 6.3×10^{-6} cm/s, inconsistent with other wells in the same unit. This measurement, in conjunction with abnormally high pH and specific conductance measurements taken during sampling, indicates that this well may be affected by cement-bentonite grout.

Pumping Test Results

FDGTI conducted pumping tests in the Upper Sand at each of the three previously identified source areas. The locations of the extraction wells and associated monitoring points are described in Part II of this document. Construction information for these wells is summarized in Appendix D.

RMT analyzed the pumping test data with AQTESOLV Version 2.0 for Windows, using both the Theis (1935) and Cooper-Jacob (1946) solutions for pumping tests in confined aquifers. The results are summarized in Table 4-5, and the data files and AQTESOLV input and output files are included in Appendix J.

The pumping test results indicated a hydraulic conductivity for the Upper Sand ranging from 2.7×10^{-5} to 9.0×10^{-3} cm/s, with a geometric mean of approximately 2×10^{-3} cm/s. These values fall within the range of hydraulic conductivities reported for a silty sand of approximately 10^{-5} to 10^{-2} cm/s (Freeze and Cherry, 1979).

The hydraulic conductivity values calculated from the pumping tests are generally one order of magnitude higher than the hydraulic conductivity calculated from the slug test data. At the Building I-1-2 Area, the geometric mean of the pumping test results was 7.4×10^{-3} cm/s, while the hydraulic conductivity calculated from slug test data from adjacent monitoring well 33MWC-24, also completed within the Upper Sand, was 7.1×10^{-4} cm/s. Similarly, the hydraulic conductivity calculated from slug test data at 33MWC-21 (Building I-1-23) was 2.9×10^{-4} cm/s, compared with 5.3×10^{-3} cm/s calculated from the aquifer pumping test. The hydraulic conductivity calculated from slug test data from 33MWC-27 (Area 9 Repository) was 1.3×10^{-5} cm/s, compared with 1.5×10^{-4} cm/s calculated from the aquifer pumping test. The discrepancy between the hydraulic conductivity values calculated from the slug tests and the aquifer pumping tests is likely due to

incomplete monitoring well development, which resulted in poor hydraulic connection between the monitoring well screens and the aquifer at the time the slug tests were performed. Due to the nature of the test, the aquifer pumping tests results are considered a more accurate representation of the hydraulic characteristics because they represent much larger portions of the aquifer.

Vertical Flow

Vertical gradients were calculated using the August 1998 and December 1998 water level data for each of the well nests (Table 4-6). Vertical gradients are downward over most of the site, including each of the currently identified source areas. However, upward gradients are present near Crab Orchard Lake where groundwater discharge to the lake is occurring. There are also likely vertical upward gradients immediately below and adjacent to the lower reaches of the swales and intermittent streams (where the swales and streams approach larger surface water bodies), where groundwater is discharging to surface water.

Equipotential cross-section A-A′ on Figure 4-9 illustrates the vertical components of groundwater flow beneath the site. Groundwater beneath most of the site has a downward vertical component of flow through the Upper and Lower Clay units (e.g., 33MWC-21, -22, and -23), while flow within the Upper and Lower Sand units is generally horizontal. Near Crab Orchard Lake, well nest 33MWC-30, -31, and -32 show an upward gradient, indicating that groundwater from the Upper and Lower Sand units is discharging to the lake.

4.3.4 Groundwater Classification

As a part of this investigation, site groundwater occurring within unconsolidated sediment has been classified according to the Illinois Administrative Code, Title 35, Part 620, Subpart B. Water-bearing units at the site occur at depths greater than 10 feet bgs. Slug test and pumping test data from the Upper and Lower Sand units yield a hydraulic conductivity of $\geq 10^{-4}$ cm/s. Well development data for the Upper and Lower Sand units suggest that yields of greater than 150 gallons per day are obtainable from these units. On the basis of these findings, groundwater at the site is classified as Class I: Potable Resource Groundwater (Section 620.210).

4.4 Surface Water

4.4.1 Site Surface Water Occurrence and Flow

Surface water flow occurs at several locations at the site (Figure 3-1). In the southwestern portion of the site, an intermittent stream that appears to originate near monitoring well 33-342 flows westerly toward Highway 148, passes beneath Highway 148 through a culvert pipe, and discharges into the Heron Flats impoundment area on the western side of the highway. The Center Swale originates east of Building I-1-11 and runs northeasterly along the eastern and southern sides of the Area 9 Repository, before discharging to Crab Orchard Lake. The West Swale runs northward from the vicinity of Building I-1-23 and discharges to Crab Orchard Lake. The East Swale runs northward along the entire eastern boundary of Sites 32/33 and discharges to Crab Orchard Lake. The swales and the intermittent stream are often dry in their upper reaches, except following rainfall events. The lower reaches appear to be receiving groundwater inflow and are likely continuously flowing.

4.4.2 Staff Gauge Levels

FDGTI installed four staff gauges, SG-01 through SG-04, in surface water bodies at the site (Figure 3-1). Water levels were measured at the staff gauges in August 1998 and December 1998. The water level readings and calculated water elevations are summarized in Table 3-1.

4.5 Groundwater/Surface Water Relationship

During the August 1998 monitoring event, the Center Swale was dry at staff gauge SG-01, but water was present at staff gauge SG-02, located approximately 530 feet downstream from SG-01. The water elevation recorded at staff gauge SG-02 was lower than the groundwater elevation observed at nearby monitoring well 32-063 (Figure 4-5), indicating that groundwater begins to discharge to the swale between SG-01 and SG-02. In the December 1998 monitoring event, surface water elevations measured at the SG-01 and SG-02 locations were significantly higher than the groundwater elevations observed at either 32-063 or at 33MWC-09 (at the Repository). These data suggest that, during at least a portion of the year, surface water from this Center Swale serves to recharge the shallow groundwater system (Figure 4-6).

Rainfall data for 1998 were obtained from the F&WS for a weather station at the Refuge. A summary of the daily rainfall data and graphs of daily rainfall amounts for selected months are presented in Appendix M. These data indicate that significant amounts of rainfall occurred in the month prior to the December 1998 sampling event. In conjunction with the cooler

temperatures that time of the year, these rainfall events likely resulted in increased surface runoff that caused the higher water levels measured in the Center Swale at that time.

In both August 1998 and December 1998, groundwater elevations in well 33MWC-30 were higher than surface water at the adjacent staff gauge, SG-03, indicating that groundwater at this location is discharging to Crab Orchard Lake. The presence of water in the lower reaches of the swales and the intermittent stream throughout most of the year indicates that these are zones of groundwater discharge during most, if not all, of the year.

4.6 Site Conceptual Groundwater Flow

Equipotential cross-sections A-A′ and D-D′, depicting the site conceptual groundwater flow, are shown on Figure 4-9. Precipitation and surface water recharges groundwater in upgradient portions of the site. Groundwater flow in the low-permeability Upper Clay has a significant vertical downward component that discharges to the underlying Upper Sand. Groundwater flow within the Upper Sand is nearly horizontal. Also, because of the high hydraulic conductivities of the Upper Sand, the relative quantity of flow through this unit is high compared to the flow through the Upper Clay and Lower Clay units. Flow in the Lower Clay unit (below the Upper Sand) is generally downward, except adjacent to Crab Orchard Lake. Near the lake, strong upward gradients cause groundwater to flow upward and discharge into the lake and into the lower reaches of the swales and the intermittent stream.

Section 5
CVOC Source Area Locations and Descriptions

5.1 General Discussion

The existing data and descriptions of past manufacturing and on-site waste disposal operations indicate that the previously identified locations of sources of PCBs and metals contamination of soil near Building I-1-23 and Building I-1-2 and at the former Area 9 Landfill are also likely to be approximate locations of sources of the CVOC contamination of groundwater. The locations and extent of CVOC-contaminated groundwater at Sites 32/33 (discussed in Section 7) also provide evidence to support this hypothesis. Because the sources of PCB and CVOC contamination are believed to be generally coincident, it is expected that a significant percentage of the total mass of CVOC-impacted soil that was originally present at the primary source areas was removed during the PCB remedial action that was completed in 1997. However, some outlying zones of unsaturated and saturated soil at the former PCB source areas may contain dispersed CVOC residuals that lie outside the boundaries and/or the depth of the excavations made during the PCB remedial action.

The stated intent of the completed remedial action was that remediation of soil and sediment impacted by PCBs and metals would also address all of the other contaminants at the PCB Operable Unit (IT Corp., 1994a). However, only a limited amount of sampling and analysis of soil for VOCs at the PCB source areas was performed both prior to and immediately following the PCB remedial action. Therefore, VOC residuals may remain in unsaturated soil at the remediated PCB source areas. The soil excavations performed for the PCB remedial action extended only to the groundwater table at all areas, except possibly the Building I-1-23 source area. Therefore, VOC residuals that may have migrated into the saturated soil prior to the PCB remedial action would not have been affected by the PCB remedial action.

A general summary of information and data available from existing documents relevant to the past and current status of the sources of CVOC contamination of groundwater is presented in this section. Drawings prepared by Fluor Daniel GTI showing the locations and depths of PCB soil excavations at the Building I-1-2, Building I-1-23, and Repository source areas are included in Appendix N. The only post-excavation soil samples that were collected and analyzed for VOCs in these areas have been reported by Fluor Daniel GTI (FDGTI, 1998b).

5.2 CVOC Sources Associated With Former PCB Source Areas

Reports issued from 1988 to the present that contain information on the history of Sites 32/33 were reviewed to obtain data or descriptions that would assist in preparing a summary of the locations of sources of groundwater CVOC contamination and estimates of the quantity of remaining contaminant source material. Key documents reviewed included the Remedial Investigation Report (O'Brien & Gere, 1988), the Final Supplemental Investigation Report (IT Corp., 1995b), the Groundwater and Surface Water Monitoring Report (IT Corp., 1997), the Additional TCE Investigation Report (FDGTI, 1997), the Final Closeout Report (FDGTI, 1998a), and the Pre-1998 TCE Investigations Report (FDGTI, 1998b). Complete citations for these documents are included in Section 9. Most of the existing information focuses on the sources, nature, and extent of PCBs and metals contamination of unsaturated soil and sediment, with limited CVOC data. A compilation of existing CVOC chemistry data for soil samples collected in the vicinity of the groundwater contamination source areas will be included in the Pre-design Workplan that will be issued following selection of a preferred remedial alternative for groundwater.

5.2.1 Site 33 - Building Complex

The existing documents do not include discussions or data regarding the specific manufacturing operations or maintenance activities that were the direct causes of the releases of CVOCs at the two source areas within the building complex that were identified prior to the 1998 groundwater investigation. Only the general types of manufacturing or warehousing that were performed at the Site 33 building complex over long time periods are discussed in the documents. It is not known whether the raw materials containing the CVOCs were stored at the site in drums or in above-ground bulk storage tanks. There is very little information available that provides insight regarding the nature of the original sources of groundwater contamination by CVOCs.

On the basis of the information in the existing documents pertaining to Site 33, the approximate date(s) on which operations at the Site 33 building complex could have caused the releases of groundwater contaminants at the identified source areas cannot be determined. However, the information seems to imply that the level of manufacturing activity, and the corresponding potential for new or continuing contaminant releases, may have decreased significantly after 1962. The previously reported information also indicates that manufacturing operations that could have resulted in releases of CVOCs existed as early as 1946. On the basis of this information, and as indicated from the current nature and extent of groundwater contamination (as discussed in Section 7), it is likely that the current CVOC concentrations and plume locations observed in groundwater associated with the former PCB sources at the Site 33

buildings represent conditions that have existed for several decades. This condition is a result of the limited time since completion of the PCB remedial action to observe a trend of decreasing CVOC concentrations in groundwater that will result from that action, and the persistence of some residual CVOCs remaining following the PCB remedial action. Physical processes continue to transfer CVOCs from the remaining outlying sources to dissolved concentrations in groundwater, and to transport the dissolved CVOCs in the groundwater to surface water at various site locations.

The excavations made to remove the PCB- or metals-contaminated soil at Buildings I-1-2 and I-1-23 were reportedly backfilled to the ground surface using uncontaminated soil obtained from an off-site borrow location (FDGTI, 1998a).

Analysis of a soil sample collected by FDGTI in April 1997, following completion of the PCB remedial action, in the vicinity of well 33MWC-07 (Building I-1-23) from a depth of 9 to 11 feet indicated the following concentrations: 468 μg/kg acetone; 3 μg/kg tetrachloroethene; 122 μg/kg toluene; 345 μg/kg trichloroethene; 159 μg/kg 1,2-dichloroethene (total); 37,600 μg/kg 2-butanone; 54 μg/kg benzene; 10 μg/kg 4-methyl-2-pentanone; 1,070 μg/kg chlorobenzene; and 44 μg/kg diethylphthalate.

5.2.2 Site 32

Former Area 9 Landfill

The existing documents do not mention any solvents or VOC-containing wastes that were burned or disposed at the former landfill. Information regarding the type of disposal activities or nature of the waste that produced the groundwater plume emanating from the former landfill location has not been reported. The Final Closeout Report (FDGTI, 1998a) for the PCB remedial action does not mention removal of any drums from the former landfill. The specific locations where CVOC-containing wastes were disposed at the landfill area, if any, are not known. It is documented (Obrien & Gere, 1988) that use of the former Area 9 Landfill ceased in 1964. Therefore, it is expected that the CVOC plume originating at the former landfill location has been present for over 35 years.

Area 9 Repository

The Area 9 Repository contains Category 1 material from various excavations of the PCBOU, Category 2 ash from the Thermal Treatment Unit (TTU), and decontaminated equipment and debris from demolition of the Building I-1-23

annex. Category 1 material was defined as soil and sediment with PCBs $\leq$ 25 ppm and lead $\leq$ 450 ppm and/or cadmium $\leq$ 10 ppm. Category 2 ash was defined as material with a PCB concentration of < 25 ppm remaining from the thermal treatment of soil.

As noted previously in this section, it is likely that the previous "hot spots" of PCB-contaminated soil were also the locations with the higher concentrations of CVOC residuals. Therefore, a significant percentage of the total mass of CVOC-impacted soil would have been removed and treated in the TTU. The TTU would have destroyed CVOCs present in the soil, to non-detectable concentrations in the incinerator ash.

During stockpiling/staging, transporting, and placing the Category 1 material from Sites 32/33 in the Repository, some of the CVOCs would have been volatilized to the atmosphere. Soil from Site 17 and Site 28, and the Category 1 sediment from Sites 32/33, was not expected to have been contaminated with CVOCs. Therefore, it is expected that the Category 1 soil and sediment, and the Category 2 ash, that is currently contained in the Repository is not a substantial source of the residual CVOCs that are contributing to groundwater contamination at the former Area 9 Landfill location. However, it is likely that saturated Upper Clay soil beneath a portion of the Repository represents a continuing source of CVOCs, as evidenced by the observed nature and extent of the CVOC plume emanating from the former Area 9 Landfill location.

The excavations made to remove the PCB- or metals-contaminated soil at the former Area 9 Landfill were reportedly backfilled using Category 1 material (FDGTI, 1998a). From oral reports obtained from USEPA personnel, it is believed that, prior to placing the Category 1 backfill, an approximate 1-foot-thick layer of TTU ash (that passed the action levels that required ash fixation) was placed on the bottom of the excavations. It is not known whether the ash layer was also placed on the sideslopes of the excavations. After placing and compacting the Category 1 backfill, USEPA personnel report that the material was covered with a 1-foot layer of TTU ash. The ash was then covered with an approximate 1-foot-thick layer of uncontaminated soil from an off-site borrow location, which generally brought the grades back to pre-excavation elevations. The Repository waste materials were then placed on top of the backfilled excavations.

5.3 Additional CVOC Sources

In addition to the previously identified PCB source areas, two areas identified from the 1998 groundwater investigation appear to be additional sources of CVOC contamination of groundwater. These areas, one south of the Repository and one near Building I-1-36A, are believed to be unassociated with areas of former PCB/metals contamination, and are not the responsibility of Schlumberger. The areas can be identified on the CVOC isopleth maps on Figure 6-1.

5.3.1 Building I-1-36A

An apparent source of CVOC contamination of groundwater near Building I-1-36A was identified during the 1998 groundwater investigation. From observations of the existing condition of this building and its contents, it appears that the building currently has limited or no use. Analyses of groundwater samples collected in 1998 from two Geoprobe® borings on the eastern and western sides of the building indicate that the source of the groundwater contamination may be associated with a truck loading dock and a paved, depressed driveway from the road to the building, and with a concrete slab located behind (to the west of) the building. An empty, rusted drum was observed on this concrete slab as recently as July 1998. The type of manufacturing, maintenance, or storage activities that occurred at the building and adjacent areas in the past, and the type of chemicals or other materials that were used, are not known. There is no information indicating that Schlumberger or its predecessors used this building.

No data are available to identify the nature or amount of residual CVOCs that may be present in soil at this location. It is hypothesized that one or more past events resulted in a release of CVOC-containing liquid at the ground surface somewhere near Building I-1-36A, and that a sufficient quantity of the material remains in the unsaturated and/or saturated soil to create a continuing source of the existing groundwater plume emanating from the building area. The locations of five soil samples collected within a distance of 100 feet from Building I-1-36A were reported by IT Corporation (IT Corp., 1993). It is believed that the samples were collected in 1992, although the sampling dates are not reported by IT Corporation. Two of the samples (samples number 33R-019 and 33R-020) were collected from a depth of 0 to 1 foot, and were tested for PCBs and metals using field-screening methods. The test results for both of these samples were reported as "PCBs > 1 ppm." One sample (sample number 33R-177), collected from a depth of 0 to 1 foot, contained PCBs at a concentration of 105 mg/kg. No test data were reported for the remaining two samples collected in the vicinity of Building I-1-36A.

The limited amount of data for PCB concentrations in soil in the vicinity of Building I-1-36A does not provide any indication that PCBs are associated with the source of the CVOC contamination found in groundwater near this building.

5.3.2 South Side of Repository

A potential separate source of CVOC contamination of groundwater was identified during the 1998 groundwater investigation near a wooded area on the south side of the Repository. This location is in an area that would have been between the fence on the south side of the former landfill and a wooded area that begins on the south side of the Center Swale (Figure 6-1). This source is evidenced by the presence of tetrachloroethene (PCE) detected in groundwater samples collected in June 1998 from three Geoprobe® borings in this area (discussed further in Section 6). The groundwater flow system and the observed distribution of CVOCs in groundwater indicate that this source of CVOC contamination is not associated with the CVOC source identified at Building I-1-36A.

The type of activities or events that caused this apparent contamination source is unknown. Soil in this area was not found to be impacted by PCBs during the PCB investigation and remedial action. Similar to the situation related to Building I-1-36A, no data are available to identify the nature or amount of residual CVOCs that may be present in soil at this location. It is hypothesized that one or more past events resulted in a release of CVOC-containing liquid at the ground surface somewhere in the vicinity of the 1998 Geoprobe® borings, and that a sufficient quantity of the material remains in the unsaturated and/or saturated soil to create a continuing source of the existing groundwater plume emanating from this area. No information or data are available that would indicate that PCBs or contaminants of any type other than CVOCs are associated with this apparent source of groundwater contamination. There is no information indicating that Schlumberger or its predecessors used this area. There are no existing data for CVOC concentrations in soil in this apparent source area. Therefore, the areal and vertical extent and mass of CVOC residuals at this location are uncertain.

Section 6
Nature and Extent of Groundwater Impacts

6.1 Background and Baseline Water Quality

Groundwater and surface water sampling to determine the background and baseline water quality, as defined in the Consent Decree Scope of Work (Consent Decree, 1991), was performed by IT Corporation in February 1995. This sampling program was performed to establish the background and baseline water quality at Sites 32/33 prior to start of the PCB remedial action in December 1995 to provide a basis for evaluating the effects of the remedial action for soil and sediment on the groundwater and surface water quality. For the background and baseline sampling, eight surface water samples (32SW-1, 32SW-2, 32SW-3, 32R-233, 32R-236, 32R-237, 32R-240, and 32R-242) and 14 groundwater samples (32-061, 32-062, 32-063, 32-109, 32-110, 33-340, 33-341, 33-342, and 33MWC-01 through 33MWC-06) were collected. Of these samples, three surface water samples (32SW-1, 32SW-2, and 32SW-3) and one groundwater sample (33MWC-01) were defined as background samples. The results from the analysis of the remaining samples were used to define "baseline" groundwater and surface water quality prior to the remedial action for PCBs at Sites 32/33. The surface water and groundwater samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), PCBs, pesticides, herbicides, total and dissolved Target Analyte List (TAL) metals, cyanide, dioxins, and furans. The results were reported in the Final Supplemental Investigation Report (IT Corp., 1995b).

6.1.1 Groundwater

The results of the background and baseline groundwater sampling are summarized in Tables 6-1 through 6-3. The data indicate that the constituents of concern in groundwater at the site are chlorinated VOCs (CVOCs). Elevated levels of several CVOCs were detected in groundwater from seven of the 10 monitoring wells, particularly in wells associated with the Building I-1-2 source area, where 290 µg/L, 390 µg/L, 1,400 µg/L, and 340 µg/L trichloroethene (TCE) was detected at wells 33-341, 33-342, 33MWC-02, and 33MWC-03, respectively.

Other constituents detected in the February 1995 groundwater samples included low concentrations of benzene, toluene, several SVOCs, most congeners of dioxins and furans, and several metals. The 2,3,7,8-TCDD congener was not detected in any

samples. Generally, the benzene, toluene, SVOCs, dioxins, and furans were detected at concentrations below the laboratory reporting limits, and were detected in background samples as well as baseline samples at the site.

Total aluminum, chromium, iron, manganese, and nickel concentrations were found to be elevated at the site relative to current Federal Drinking Water Standards; however, the uniform distribution of these metals in the site groundwater suggests that they are either naturally occurring, or that they are derived from well materials. Aluminum, chromium, manganese, iron, and nickel may be attributable to the degradation of stainless steel well screens or other materials used to construct the site monitoring wells. Reported concentrations of total metals were generally two times to as much as one order of magnitude higher than the corresponding dissolved metals concentrations. In many instances, dissolved metals concentrations were reported below detectable levels. The discrepancy between total and dissolved metals concentrations may be due to the mobilization of metals sorbed on soil particles during purging and sampling. Therefore, total metals concentrations are not necessarily representative of concentrations susceptible to transport by groundwater flow.

One PCB compound (Arochlor 1254) was detected at one well, 33-341, at a concentration of 15 μg/L. No pesticides, herbicides, or cyanide were detected in groundwater samples at the site.

6.1.2 Surface Water

The results of the baseline and background surface water sampling are summarized in Tables 6-1 through 6-3. Chlorinated VOCs at concentrations ranging from 2 μg/L to 60 μg/L were detected sporadically in both the background and baseline surface water samples from the site.

Other constituents detected in the February 1995 surface water samples included Arochlors 1254 and 1248, and several metals. Arochlors 1254 and 1248 were detected at concentrations of 2.9 μg/L and 1.9 μg/L, respectively, at surface water sampling point 32R-242 (in the West Swale, near the lake). Total aluminum, iron, and manganese concentrations were found to be elevated at the site relative to current Federal Drinking Water Standards; however, the distribution of these metals in the site surface water appears to be uniform. Therefore, the presence of these metals in surface water is not attributed to past or current activities at the site. Low concentrations of most congeners of dioxins and furans were detected. The 2,3,7,8-TCDD congener was *not* detected in any samples. Most of these parameters were detected at concentrations below the

reporting limits and were detected in background samples as well as baseline samples at the site.

No SVOCs, pesticides, herbicides, or cyanide was detected in site surface water samples.

6.2 Overview of Groundwater Contaminant Occurrence

The groundwater chemistry data for all groundwater samples collected during 1998 are presented in Appendix L. Summaries of the constituents detected in these samples are presented in Tables 6-4 through 6-8.

The results confirm the earlier findings that the primary constituents of concern in groundwater are volatile organic compounds (VOCs). Chlorinated VOCs (CVOCs), particularly tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2 dichloroethene (DCE), and vinyl chloride, make up the majority of the constituents detected in groundwater; however, petroleum-related VOCs (e.g., benzene and toluene) were detected sporadically across the site. The chemistry data indicate that groundwater is not significantly impacted by SVOCs, PCBs, pesticides, or metals.

The results also show that groundwater impacts are restricted to the Upper Clay and Upper Sand units. Concentrations of VOCs in intermediate-depth sand lenses within the Lower Clay unit and in the Lower Sand were very low to nondetectable (Tables 6-4 through 6-8). The limited vertical migration is attributed to the continuous layer of low-permeability silty clay (the Lower Clay unit) between the Upper and Lower Sand units that, in conjunction with biodegradation, prevents vertical transport of significant concentrations of contaminants. The low concentrations of VOCs observed in a small number of intermediate and deep monitoring wells (0.5 μg/L to approximately 200 μg/L) are likely due to cross-contamination during drilling. When the monitoring wells were installed, steel casings were installed through the Upper Clay and Upper Sand units to prevent the downward migration of contaminants during drilling. However, impacted water from these upper zones that remained in the casings after their installation was not removed prior to drilling deeper. The contaminants detected in the deep and intermediate wells are expected to decrease in concentration over a relatively short time as unimpacted groundwater flows past the wells and as groundwater is removed during future purging and sampling of the wells. Further evidence of this expected effect is provided by the reductions in concentrations observed between the initial sampling round following installation and development of the wells (June/July 1998) and the next sampling round in December 1998. At intermediate-depth wells 33MWC-31, 33MWC-22, and 33MWC-28, CVOCs at concentrations of several hundred μg/L were detected in the June/July 1998 sampling event. Similarly, a trace to 10's of μg/L CVOCs were detected in each of the deep monitoring wells at the site during this same sampling round. However, CVOC concentrations in each of these

wells decreased significantly in the December 1998 sampling round. For example, water samples from intermediate-depth monitoring wells 33MWC-22, 33MWC-28, and 33MWC-31 contained 228 μg/L, 239 μg/L, and 151 μg/L total VOCs in June/July 1998, respectively. In December 1998, total VOC concentrations at these locations dropped to 0.5 μg/L (33MWC-22), 0.6 μg/L (33MWC-28), and 37.8 μg/L (33MWC-31). These three wells will be included in a groundwater monitoring program that will be developed and implemented as part of the remedial design/remedial action for groundwater, to determine whether the expected downward trend in VOC concentrations has continued.

6.3 Groundwater Contaminant Sources and Plumes

To illustrate the areal distribution of CVOCs (the primary contaminants) in groundwater at the site, a chemical isopleth map was prepared. Figure 5-1 shows the distribution of total CVOCs in the Upper Clay and the Upper Sand units. Figure 6-1 shows the distribution of individual CVOC compounds at the site.

The results indicate that there are five apparently separate CVOC source areas, rather than the three previously identified (at Buildings I-1-2 and I-1-23 and at the Area 9 Repository). Concentrations of PCE and other CVOCs were detected in a plume that appears to originate in the vicinity of Building I-1-36A, and in an additional apparent plume source located near the south side of the Area 9 Repository. CVOC plumes within the Upper Sand unit extend from 500 feet to over 1,000 feet downgradient from each of the source areas. The term "source area" as used in this discussion refers to an approximate area of soil containing significant concentrations of VOCs that are causing or contributing to the contaminated groundwater plumes at the site.

In the source areas, total CVOC concentrations in groundwater generally are an order of magnitude higher in the Upper Clay than in the Upper Sand (Figure 5-1). This indicates that much of the remaining CVOCs, following completion of the PCB remedial action, are contained in the fine-grained shallow saturated soil in the former PCB source areas, and leach slowly into the underlying sand. However, deeper wells in the source areas have very low to nondetectable CVOC concentrations. This indicates that contaminants are transported laterally within the Upper Sand with little or no downward migration through the underlying low-permeability clay.

In downgradient locations, shallow wells and Geoprobe® borings that penetrate only the Upper Clay and the uppermost portion of the Upper Sand (the shallow saturated zone) show low CVOC concentrations relative to adjacent, deeper wells completed across the entire thickness of the Upper Sand (Figure 5-1). This finding demonstrates the importance of the Upper Sand (rather than Upper Clay) as the primary horizontal transport medium for contaminants. It also

points out the effects of recharge into the Upper Sand on the distribution of contaminants within that unit. In the source areas, contaminants infiltrating from the Upper Clay will cause the highest concentrations within the Upper Sand to occur near the top of the unit, with lower concentrations near the bottom. As water and contaminants move laterally through the Upper Sand, recharge of relatively clean water from the overlying clay outside the source areas will result in the highest concentrations of contaminants in the Upper Sand in the middle and lower portions of the unit, and much lower concentrations near the top. This would explain the discrepancy noted between some Geoprobe® sample results and nearby monitoring well results.

The transport of CVOCs from the source areas is dependent on the geology as well as on the hydraulic gradient. In areas where the Upper Sand is not present or is discontinuous, CVOCs have been transported shorter distances than in areas where the Upper Sand is continuous.

6.4 Contaminant Biodegradation

Figure 6-1 shows the distribution of PCE and its biodegradation breakdown products TCE, DCE, and vinyl chloride in the Upper Clay and Upper Sand units. In the Upper Sand, the ratio of PCE to its degradation products TCE, DCE, and vinyl chloride decreases within the plumes with distance from the source areas, while the concentrations of TCE, DCE, and vinyl chloride initially increase. This indicates that natural biodegradation of PCE is occurring as it is transported laterally downgradient within the Upper Sand. The presence of TCE, DCE, and vinyl chloride in the shallow groundwater within the source areas indicates that biodegradation of residual PCE is also occurring in the fine-grained shallow source area soil (Upper Clay).

Evidence of CVOC biodegradation at the site is provided from the results of the field measurements of the primary biodegradation indicator parameters, including dissolved oxygen, dissolved iron, oxidation-reduction (redox) potential, pH, temperature, and specific conductance, and the laboratory results for nitrogen, sulfate, alkalinity, chloride, methane, ethane, and ethene. Field measurements are summarized in Table 6-9, and laboratory results are summarized in Tables 6-4, 6-6, and 6-7.

Field measurements of dissolved oxygen (DO), dissolved iron, redox potential, and specific conductance are plotted on Figure 6-2. Zones of low DO, negative redox potential, high specific conductance, and high dissolved iron generally correspond to the areas of high concentrations of CVOCs in groundwater, indicating anaerobic conditions in those areas. Elevated methane concentrations were also detected within the plumes of CVOC-impacted groundwater (Figure 6-3). Methane is commonly produced as an anaerobic degradation product of petroleum-related VOCs, such as toluene, and also indicates conditions favorable for reductive

dechlorination. The methane can be used by microorganisms to cometabolize CVOCs under aerobic conditions. These results show that conditions favorable to anaerobic degradation are present near the source areas of the plumes.

Other laboratory data that are sometimes useful in identifying biodegradation processes were less conclusive. Nitrogen, sulfate, and alkalinity concentrations do not show any consistent trends along flow lines within the contaminant plumes. Chloride concentrations are highly inconsistent and fluctuate over three orders of magnitude across the site, with no correlation to CVOC concentrations. There appear to be other, significant sources of chloride at the site that are unrelated to the CVOC contamination. Therefore, chloride is not a good indicator of CVOC biodegradation at this site. Ethene was not detected in any of the site groundwater monitoring wells, and ethane was detected only at well 33MWC-35. Because these data are inconclusive throughout the site, they will not be discussed in the context of the individual source areas.

The following subsections present a summary of groundwater chemistry data within the groundwater plumes associated with each identified CVOC source area. Because the groundwater impacts do not extend into the underlying Lower Clay or Lower Sand units, the following discussion involves only the Upper Clay and Upper Sand units.

6.5 Descriptions of Individual Plumes

6.5.1 Building I-1-2

VOCs

Two plumes of CVOCs extend downgradient to the east and west of the Building I-1-2 source area (Figures 5-1 and 6-1). The orientations of these plumes are consistent with the previously identified source area and the groundwater flow pattern in that area (Figures 4-5 and 4-6). Transport of contaminants to the north and south appears to be very limited in extent, as evidenced by nondetectable CVOC concentrations at wells 33MWC-01 (the background well), 33MWC-10, and Geoprobe® borings GP-03D and GP-06D. While these locations are technically downgradient of the Building I-1-2 source area, a groundwater divide effectively splits the groundwater flow at the source area to the east and west (Figures 4-5 and 4-6). This results in very little groundwater flow from the Building I-1-2 source area to the north or south.

Groundwater from source area well 33MWC-13, completed in the Upper Clay, contains a total CVOC concentration one order of magnitude higher than that from adjacent source area well 33MWC-24, which is completed across the

Upper Sand. This illustrates the importance of the Upper Clay as the primary source of VOCs leaching downward into the Upper Sand unit. Downgradient to the west, groundwater from wells and Geoprobe® borings completed in the Upper Clay (e.g., 33MWC-12 and GP-06C) contained low to nondetectable CVOC concentrations, while groundwater from an adjacent well in the Upper Sand (33MWC-33) contained over 2,000 ppb CVOCs. These data indicate that, while the highest CVOC concentrations occur within the shallow fine-grained sediment (Upper Clay) in the source area, lateral transport of CVOCs occurs primarily within the Upper Sand, and downgradient areas of the Upper Clay are not impacted.

The CVOC plume to the west of Building I-1-2 is of a greater extent, and contains higher CVOC concentrations, than the plume to the east. The difference in CVOC distribution is explained by the geology depicted in Cross Section D-D′ (Figure 4-3). The Upper Sand thickens to the west which allows significant transport of contaminants, but appears to be discontinuous to the east, which limits lateral transport in that direction. As a result, the CVOC plume to the east extends approximately 800 feet downgradient toward the East Swale, while to the west, total CVOC concentrations on the order of 2,000 μg/L persist more than 1,300 feet downgradient of the source area. Transport of CVOCs to the west is toward the intermittent stream and marsh area on the east side of Highway 148.

A comparison of CVOC concentrations with the respective Primary Drinking Water Standards defined as the Federal Maximum Contaminant Levels (MCLs) (Table 6-4) indicates that concentrations of PCE and TCE commonly exceed MCLs within the contaminant plumes. DCE and vinyl chloride also exceed MCLs within the shallow source area and downgradient locations.

SVOCs

Groundwater samples collected in June 1998 from monitoring wells 33MWC-24, 33MWC-33, 33MWC-35, and 33MWC-36 were analyzed for SVOCs, and groundwater samples collected in December 1998 from all of the Building I-1-2 Area wells were analyzed for SVOCs. Several phthalates, diethylphthalate, bis (2-ethylhexyl) phthalate, di-n-butylphthalate, diethylphthalate, and dimethylphthalate, were detected sporadically in the Building I-1-2 area wells at concentrations below the Contract Required Quantitation Limit (CRQL). Phthalates that were detected in the June groundwater sampling event were not confirmed in the December round.

Likewise, those phthalates detected in the December event were not detected in June. Bis (2-ethylhexyl) phthalate exceeded the Federal Maximum Contaminant Level (MCL) of 6 μg/L at monitoring wells 33MWC-13 (8 μg/L) and 33MWC-14 (7 μg/L) in December 1998. No MCLs have been established for the remaining phthalates. Phthalates are plasticizers found in laboratory and sampling equipment. It is well documented that low levels of phthalates are frequently detected in most groundwater investigations and are usually attributed to these nonenvironmental sources.

At well 33MWC-35, 4-chloro-3-methylphenol was detected in the June (130 μg/L) and December (22 μg/L) rounds. In December, 6 μg/L phenol was detected at this well. These compounds are not present in groundwater at the source areas, and the origin of their occurrence is unknown. The MCL for phenol is 100 μg/L. No MCL has been established for 4-chloro-3-methylphenol. Phenol and 4-chloro-3-methylphenol are common constituents of antiseptics and disinfectants for septic systems. Phenol is also a reagent used in chemical analysis and is a common laboratory contaminant.

PCBs/Pesticides

Groundwater samples collected in June 1998 from monitoring wells 33MWC-24, 33MWC-33, 33MWC-35, and 33MWC-36 were analyzed for PCBs, and groundwater samples collected in December 1998 from each of the Building I-1-2 Area monitoring wells were analyzed for PCBs. Two PCBs, Arochlor 1248 (1.1 μg/L) and Arochlor 1254 (0.63 μg/L), were detected at concentrations above the MCL of 0.5 μg/L (for PCBs as decachlorobiphenyl) at monitoring well 33-341 in the December 1998 sample. This well is located in the source area immediately adjacent to the northern excavation, and is screened within the Upper Clay. The PCBs detected in the groundwater sample could be sorbed onto soil particles that are mobilized during purging and sampling, or may be present in a dissolved phase due to the presence of significant concentrations of CVOCs in groundwater at this location, which increases the solubility of the PCBs. The PCBs do not appear to have migrated downgradient from the source area.

Groundwater samples collected in December 1998 from wells 33MWC-01 through 33MWC-03 associated with the Building I-1-2 Area were analyzed for pesticides. No pesticides were detected in these samples.

Metals

In December 1998, groundwater samples from monitoring wells 33MWC-01, 33MWC-02, and 33MWC-03 were collected and analyzed for Target Analyte List (TAL) dissolved metals, plus total cadmium and total lead. No cadmium or lead was detected in the samples. No primary MCLs were exceeded for metals. An aluminum concentration of 218 μg/L exceeded the Secondary Maximum Contaminant Level (SMCL) of 50 μg/L at 33MWC-02, and a manganese concentration of 66.3 μg/L exceeded the SMCL of 50 μg/L at 33MWC-03. There were no clear patterns to the metals concentrations and no apparent correlation to CVOC concentrations. The metals concentrations observed during this sampling event are similar to those detected during the background and baseline groundwater monitoring in February 1995.

6.5.2 Building I-1-23

VOCs

Concentrations of CVOCs on the order of 3,000 ppb extend from the Building I-1-23 source area northward (downgradient) to Crab Orchard Lake (Figures 5-1 and 6-1). The vertical distribution of CVOCs within the source area saturated zone is very similar to that observed in the Building I-1-2 source area. Groundwater from shallow (Upper Clay) source area well 33MWC-07 contained a total CVOC concentration one order of magnitude higher than adjacent source area well 33MWC-21, completed across the Upper Sand. Unlike the Building I-1-2 Area, however, total CVOC concentrations in the Upper Sand and the Upper Clay in the extreme downgradient monitoring wells and Geoprobe® borings near Crab Orchard Lake (33MWC-30 and GP-01B) are very similar. This is the result of upward vertical gradients in the immediate vicinity of Crab Orchard Lake that cause upward movement of impacted groundwater from the Upper Sand, through the Upper Clay, and discharge to the West Swale and to Crab Orchard Lake.

SVOCs

Groundwater samples collected in June 1998 from wells 33MWC-21 through 33MWC-23, and from 33MWC-30 through 33MWC-32, were analyzed for SVOCs, and groundwater samples collected in December 1998 from all Building I-1-23 Area wells were analyzed for SVOCs. Several phthalates, bis (2-ethylhexyl) phthalate, di-n-butylphthalate, and dimethylphthalate, were detected sporadically in the Building I-1-23 Area wells, mostly at

concentrations below the CRQL. Phthalates that were detected in the June groundwater sampling event were generally not confirmed in the December round. Bis (2-ethylhexyl) phthalate exceeded the MCL of 6 μg/L at 33MWC-23 (8 μg/L) in the June sample. No MCLs have been established for the other phthalates.

At monitoring well 33MWC-07, 2-chlorophenol (43 μg/L), 2-methylphenol (4 μg/L), 4-methylphenol (3 μg/L), phenol (8 μg/L), and naphthalene (33 μg/L) were detected in the December 1998 sample. The MCL for phenol is 100 μg/L. No MCLs have been established for 2-chlorophenol, 2-methylphenol, 4-methylphenol, or naphthalene.

4-Chloro-3-methylphenol was detected in a sample collected in June 1998 from intermediate-depth monitoring wells 33MWC-22 and 33MWC-31, and in a sample collected in December 1998 from 33MWC-22. This compound has not been detected in any of the shallow source area monitoring wells, and the origin of its presence is unknown. No MCL has been established for 4-chloro-3-methylphenol.

Naphthalene is often associated with petroleum-related VOCs (PVOCs), and the detection of naphthalene at 33MWC-07 is consistent with the detection of other PVOCs, including benzene and toluene, at this location. Phenols, including chloro- and methyl-phenols, are common constituents of antiseptics and disinfectants for septic systems; in addition, methylphenols are used in the manufacture of some synthetic resins. Phenol is also a reagent in laboratory analysis, and can be a laboratory contaminant.

PCBs/Pesticides

Groundwater samples collected in June 1998 from monitoring wells 33MWC-21, 33MWC-22, 33MWC-23, 33MWC-30, 33MWC-31, and 33MWC-32 were analyzed for PCBs, and groundwater samples collected in December 1998 from each of the Building I-1-23 Area monitoring wells were analyzed for PCBs. At 33MWC-07, completed in the Upper Clay in the Building I-1-23 source area, 5.4 μg/L Arochlor 1016 was detected in the December 1998 groundwater sample. Arochlor 1016 (39 μg/L) and Arochlor 1254 (3.4 μg/L) were detected in the December 1998 sample from 33MWC-16, which is screened in the Upper Clay near the Building I-1-23 source area. The PCBs detected in these groundwater samples may have been sorbed onto soil particles and mobilized during purging and sampling, or may be present as a

dissolved phase due to the high concentrations of CVOCs at these locations, which increases the solubility of the PCBs. Concentrations of each of the PCBs exceed the MCL of 0.5 µg/L; however, it does not appear that PCBs have migrated significantly downgradient from the Building I-1-23 source area.

A groundwater sample collected in December 1998 from well 33MWC-06 was analyzed for pesticides. No pesticides were detected in this sample.

Metals

In December 1998, groundwater samples from monitoring wells 33MWC-05 and 33MWC-06 were collected and analyzed for TAL dissolved metals, plus total cadmium and total lead. No cadmium or lead was detected in the samples. No MCLs or SMCLs were exceeded for metals.

6.5.3 Area 9 Repository

VOCs

A plume of CVOCs extends eastward from the Area 9 Repository toward the Center and East Swales, and some migration of CVOCs has occurred to the north toward Crab Orchard Lake. The distribution of contaminants emanating from soil beneath the Area 9 Repository is explained by the water table configurations shown on Figures 4-5 and 4-6, and by the geology depicted on cross-section B-B′ (Figure 4-2). During periods of high groundwater levels (e.g., August 1998), the highest groundwater gradients are easterly toward the Center and East Swales. At lower groundwater elevations, groundwater passing beneath the Repository flows in a more northerly direction, with a slightly lower gradient. The thin and clay-rich nature of the Upper Sand beneath the Repository greatly reduces (by adsorption) the transport of CVOCs away from the source area, particularly to the north where the deposit becomes very clayey. The transport of CVOCs that does occur is primarily to the east, where the Upper Sand is thicker and of lower clay content. Therefore, it is believed that the Area 9 Repository plume discharges to the East Swale.

Because of the composition and configuration of the Upper Sand beneath the Area 9 Repository, the CVOC concentrations measured at shallow saturated zone well 33MWC-09 (screened completely within the Upper Clay) and Upper Sand well 33MWC-27 are very similar. Concentrations of PCE and its degradation products are highest within the one identified source area. TCE,

DCE, and vinyl chloride are transported downgradient of this source area, but unlike the other CVOC plumes, the concentrations of these species generally decrease in downgradient locations. The decrease of biodegradation products in the downgradient areas of the plume is the result of relatively low groundwater flow velocities in the vicinity of the Area 9 Repository. Low flow velocity limits the transport of PCE source material downgradient, thus reducing concentrations of biodegradation products in these areas.

No CVOCs were detected at 33MWC-39, located to the northeast of the Repository, in the December 1998 sample. A concentration of 63 μg/L total CVOCs was detected in a sample collected at this location in June 1998. Variations in groundwater chemistry at this location appear to be the result of variations in the groundwater flow direction and possibly seasonal water table fluctuations.

SVOCs

Groundwater samples collected in June 1998 from wells 33MWC-27 through 33MWC-29, 33MWC-39, and 33MWC-41 were analyzed for SVOCs; and groundwater samples collected in December 1998 from all the Area 9 Repository wells were analyzed for SVOCs. Additional samples were collected from 33MWC-27 and 33MWC-28 in July 1998 because of a sample identification problem. No SVOCs were detected in monitoring wells 33MWC-17 through 33MWC-20. Several phthalates, bis (2-ethylhexyl) phthalate, di-n-butylphthalate, diethylphthalate, and dimethylphthalate, were detected sporadically in the new Repository wells. Bis (2-ethylhexyl) phthalate exceeded the MCL of 6 μg/L in June and July at 33MWC-27 (48 μg/L), 33MWC-28 (180 μg/L), and 33MWC-29 (6 μg/L). No MCLs have been established for the other phthalates.

4-Chloro-3-methylphenol was detected in samples collected in June, July, and December 1998 at intermediate-depth monitoring well 33MWC-28. Phenol was detected at this well in a July 1998 sample. These compounds have not been detected in any of the shallow source area monitoring wells, and the origin of their presence is unknown. No MCL has been established for 4-chloro-3-methylphenol. The MCL for phenol is 100 μg/L.

PCBs/Pesticides

Groundwater samples from all of the Area 9 Repository wells were collected in December 1998 and analyzed for PCBs, and samples collected in June 1998

from wells 33MWC-27, 33MWC-28, 33MWC-29, 33MWC-39, and 33MWC-41 were analyzed for PCBs. No PCBs were detected in groundwater samples from any wells at the Area 9 Repository.

No groundwater samples collected in 1998 were analyzed for pesticides.

Metals

No groundwater samples collected in 1998 from wells at the Area 9 Repository were analyzed for metals.

6.5.4 Building I-1-36A

VOCs

CVOCs in groundwater originating in the area of Building I-1-36A form a plume, which extends first easterly toward the Center Swale where it merges with a plume originating south of the Area 9 Repository, and then north and eastward toward the East Swale and Crab Orchard Lake (Figures 5-1 and 6-1). Here, the CVOC plume from Building I-1-36A merges with the Area 9 Repository plume to the east of the Repository. Eastward transport of CVOCs from the Building I-1-36A Area is aided by intermittent recharge from the Center Swale. Near Building I-1-36A, there is also a northerly component to the flow system that causes low CVOC concentrations at the perimeter of the I-1-36A plume to merge with the Building I-1-23 plume.

SVOCs

A groundwater sample collected in December 1998 from monitoring well 32-063 was analyzed for SVOCs. No SVOCs were detected in this sample.

PCBs/Pesticides

During the December 1998 sampling event, only one groundwater sample (from 32-063) was analyzed for PCBs; no PCBs were detected in this sample. No groundwater samples collected in December 1998 were analyzed for pesticides.

Metals

No groundwater samples were collected in 1998 for metals analysis from wells in the Building I-1-36A Area.

6.5.5 South Side, Area 9 Repository

VOCs

A plume, designated the South Side plume, appears to originate from a separate source area located to the south of the Area 9 Repository and to the east of the Center Swale (Figures 5-1 and 6-1). The nature and extent of the South Side CVOC plume was defined by the FDGTI Geoprobe® investigation in 1998. Groundwater samples collected from the Geoprobe® borings were analyzed only for VOCs. No monitoring wells have been installed in this area.

The South Side plume merges with the Building I-1-36A plume (from the west), and extends to the northeast toward the eastern side of the Area 9 Repository, following the trend of the Center Swale. Here, it merges with the Area 9 Repository plume. The combined CVOC plume is then transported to the east and north where it emerges as surface water in the East Swale, which then flows into Crab Orchard Lake.

6.6 Surface Water

In December 1998, surface water samples were collected from the East Swale (32R-233), the Center Swale (32R-236 and 32R-237), the West Swale (32R-242), and the Crab Orchard Lake embayment near the West Swale (32R-240/241). Each of the samples was analyzed for VOCs, SVOCs, pesticides, PCBs, TAL total metals, total and amenable cyanide, total alkalinity, chloride, nitrogen, and sulfate. The results of these analyses are summarized in Tables 6-4, 6-10 and 6-11, and complete validated data reports are included in Appendix L.

6.6.1 VOCs

The December 1998 samples showed that CVOCs in groundwater were discharging to surface water in the West Swale and Crab Orchard Lake downgradient of the Building I-1-23 Area. Surface water from 32R-242 in the West Swale contained a total CVOC concentration of 1,322 µg/L (primarily TCE, at 1,038.5 µg/L). Approximately 100 feet north of 32R-242, along the shore of the Crab Orchard Lake embayment (32R-240/241), the total CVOC concentration dropped to 18 µg/L, probably due to a combination of volatilization, biodegradation, dilution, and dispersion.

TCE was detected at 1 µg/L in the Center Swale, near the eastern perimeter of the Area 9 Repository (32R-236). 1,2-Dichlorobenzene was detected at 1.1 µg/L in the intermittent stream in the southwestern portion of the site. No other CVOCs were detected in surface water samples.

6.6.2 SVOCs

Low levels of two phthalates, bis (2-ethylhexyl) phthalate and di-n-butylphthalate, were detected in the Center Swale, north of the Repository (32R-237). Bis (2-ethylhexyl) phthalate was also detected in the intermittent stream (32R-250) in the southwestern portion of the site. All of the detected concentrations were below the CRQL and the MCL for bis(2-ethyl hexyl)phthalate was not exceeded. No MCL has been established for di-n-butylphthalate.

6.6.3 Pesticides/PCBs

No pesticides were detected in any of the December 1998 surface water samples. Arochlor 1254 was detected at 32R-233 in the East Swale (0.54 μg/L). This concentration exceeds the MCL for PCBs of 0.5 μg/L. The samples were not filtered; therefore, it is uncertain whether this concentration was in a dissolved phase or was adhered to suspended sediment in the water sample.

6.6.4 Metals/Cyanide

No cadmium was detected in the December 1998 surface water samples. Low levels of total lead were detected at concentrations below the CRQL in three surface water samples, 32R-233 (1.8 μg/L), 32R-240/241 (2.6 μg/L), and 32R-250 (2.4 μg/L). All of the lead concentrations were below the MCL of 15 μg/L.

No MCLs for metals were exceeded. SMCLs for aluminum, iron, and manganese were exceeded in each of the surface water samples. These results are consistent across the site, and are consistent with baseline and background surface water samples collected in February 1995.

A total cyanide concentration of 0.0088 mg/L associated with the I-1-23 source area plume was detected in the surface water sample from the intermittent stream (32R-250). This concentration is well below the MCL for cyanide of 0.2 mg/L. Cyanide was not detected in any other surface water or groundwater samples collected in December 1998.

Section 7
Groundwater Flow and Transport Model of Existing Conditions

This section presents the results of the calibration of a groundwater flow and transport model that was constructed to evaluate the relative effectiveness of site-specific remedial alternatives that are developed and evaluated in Part II of this document. The model documentation is presented in detail in Appendix K. The results of the predictive modeling of the effects of the remedial alternatives are presented in the Focused Feasibility Study.

7.1 Conceptual Model of Groundwater Flow

The groundwater flow system has been described in detail in Section 4, and is summarized briefly here. Figure 4-2 (Cross-sections A and B) shows the major geologic strata of importance at the site. Further description is presented in Appendix K.

Figures 4-5, 4-6, 4-7, and 4-8 show that shallow groundwater flow is generally toward Crab Orchard Lake and the swales and surface water discharge zones that occur over the site. Groundwater flow is primarily downward from the Upper Clay to the Upper Sand layer over much of the area, based on the measured heads in these units. Downward hydraulic gradients as high as 0.3 ft/ft characterize the upland areas (most of the site), and upward gradients of lesser magnitude occur near the lake and surface water discharge zones (the swales and wetland areas).

The conceptual model for transport of contaminants at the site, illustrated on Figures 7-1 and 7-2 and discussed in Section 8, is that dissolved contaminants migrate vertically downward from the source areas, through the Upper Clay into the Upper Sand unit. The permeable Upper Sand unit is the primary pathway for lateral contaminant migration in the groundwater at the site. The absence of contaminants in the Lower Sand unit indicates that, despite the existence of relatively strong downward gradients over portions of the site, contaminants have not reached the Lower Sand. Although the process responsible for this attenuation has not been investigated in detail, the presence of daughter products of biodegradation of the chlorinated solvents within the upper strata indicates that biodegradation is likely occurring at the site, and may be limiting the migration of contaminants into the Lower Clay and the Lower Sand units.

7.2 Model Setup

The Modflow code (McDonald and Harbaugh, 1984) was used to simulate the groundwater flow system. The transport and fate of contaminants at the site were simulated using the MT3D code (Zheng, 1990). The Visual Modflow platform (Guigier and Franz, 1995) was used to set up the model parameters and evaluate the model results. The Visual Modflow program integrates the flow and transport codes, and allows for the use of a map-based graphical interface to enter spatially correct hydraulic data.

The model domain measures 15,000 feet (north-south) by 13,000 feet (east-west) and extends beyond the site boundaries by several thousand feet, so that model boundaries could be set at existing groundwater divides. A five-layer model was constructed to represent the important geologic strata at the site for contaminant transport. The five layers of the model represent the following hydrostratigraphic units:

- Layer 1: Upper Clay
- Layer 2: Upper Sand
- Layer 3: Upper Portion of Lower Clay
- Layer 4: Lower Portion of Lower Clay
- Layer 5: Lower Sand

7.3 Boundary Conditions and Model Parameters

Boundary conditions of the flow model were set to represent actual hydraulic boundaries at the site, based on available site data. Boundary conditions and model parameters are described in detail in Appendix K.

Early in the process of calibrating the contaminant transport model, it became evident that a continuing source of CVOC contamination was needed in the I-1-23, I-1-2, and Repository areas to represent "source" concentrations that have been an ongoing source of contaminants to the aquifer prior to completion of the PCB remedial action in 1997, and that are associated with some CVOC residuals since then. The existing long CVOC plumes could not be simulated accurately in the transport model without the presence of continuing source (constant concentration) nodes at the three locations mentioned above, at least through 1997. The source areas around Buildings I-1-23 and I-1-2, and the Repository, have yielded groundwater samples with concentrations well over 10,000 μg/L TCE. The persistence of these high concentrations measured at the source locations, years after the release of contaminants to the soil is believed to have ceased, indicates that a concentrated source of CVOC residuals likely existed at these locations, at least until completion of the PCB remedial action in 1997.

Insufficient time has elapsed to detect changes in the concentration of CVOCs in the groundwater as a result of the PCB soil removal in 1996/1997, due to the slow movement of groundwater. However, the source areas have been simulated using a conservative assumption that source concentrations do not decrease over time in the source areas. This approach, simulating continuing sources of CVOCs to the groundwater using constant-concentration nodes, allows a conservative estimate of future concentrations in the groundwater to be made with the model and also avoids the necessity of defining the exact mass of CVOCs in the aquifer. Further discussion of this approach is presented in Appendix K (Volume II of this report).

Processes that were included in the contaminant transport model include the following: advection, dispersion, sorption, and biodegradation. During calibration of the transport model, the half-life of TCE biodegradation was varied in order to represent the observed distribution and concentration of TCE in the groundwater. Slow rates of biodegradation, with a TCE half-life of 24 years, were necessary for the model to reproduce the long plumes that exist at the site in the Upper Sand unit. These processes, and the approach to simulating each of them, are discussed in more detail in Appendix K.

7.4 Calibration

Figure 7-3 shows the calibrated model head distribution for the water table. A comparison of the model-derived head values with those measured during August 1998 shows a reasonably good fit of the model to the observed heads. Most of the model-generated contours agree to the measured points to within 1 foot, especially in the Upper Clay and Upper Sand (model layers 1 and 2). Although there are fewer measured points for calibration, the model-derived heads in the Lower Sand unit are generally within 1 to 2 feet of the measured values. Using reasonable values of hydraulic parameters, the model has produced a hydraulic head distribution that is a reasonable match to measured hydraulic head values, and to the direction and magnitude of the hydraulic gradient, especially in the upper geologic strata where the contaminant migration occurs. For this reason, the flow model is considered to be calibrated sufficiently to test the remedial alternatives that are being considered.

The transport portion of the model was also calibrated to the existing contaminant plume concentrations. TCE was chosen as the representative contaminant for calibration, because TCE is the primary (i.e., most abundant) contaminant of concern, and because the distribution of the TCE plume is generally coincident with, and more extensive than, other contaminant distributions in the groundwater.

The TCE plume generated by the model for the Upper Sand unit is shown on Figure 7-4. This figure shows the I-1-23 plume and the Repository plume; a similar figure illustrating the

Building I-1-2 plume is presented in Appendix K. A comparison of Figure 7-4 with Figure 6-1 shows that the extent and concentrations of the model-generated map are approximately the same as those that are observed at the site, based on the data that are available. The model also successfully simulates the absence of TCE in the Lower Sand unit. There are areas where the model-generated concentrations do not match the measured values very closely (e.g., near Crab Orchard Lake, where predicted concentrations are lower than measured values). Although the observed plume has some measured concentrations that are higher or lower than the model-predicted values, the extent, shape, and concentrations provide a reasonable approximation of the observed plumes that is useful for the purpose of comparing the effectiveness of remedial alternatives. The results of these predictive simulations are presented in the accompanying Feasibility Study, Section 6. The results of sensitivity testing of the model to various parameters, assumptions, and boundary conditions are presented in Appendix K.

7.5 Implications from Calibrated Model

Two major conclusions from calibration of the transport model that have broad implications for site remediation are the following:

- The size of the plumes and the persistence of high concentrations of TCE in the vicinity of Buildings I-1-23 and I-1-2 and the Repository years after releases occurred indicate that a significant mass of TCE was present at these locations, at least until completion of the PCB remedial action, and that TCE residuals that remain represent a continuing source of TCE to the groundwater.
- The length of the TCE plumes and the relatively slowly decreasing concentrations over distance indicate that the rate of biodegradation in the Upper Sand unit (the primary pathway) must be very slow.

Section 8
Contaminant Fate and Transport

The existing groundwater chemistry data show that some amount of natural biological degradation of the chlorinated solvent plumes is occurring at Sites 32/33. As outlined in Wiedemeier et al. (1996) and RTDF (1996), the several "lines of evidence" that can build a case that biodegradation is occurring include the following:

- The degradation products are present
- Geochemical indicators of microbial activity are present
- A reduction of mass is occurring spatially and temporally
- The actual distance of contaminant migration is less than would be expected based on advective (migration) processes alone
- Direct evidence for the presence of microbial activity exists

The discussion presented below is organized according to these lines of evidence.

8.1 Degradation Products

The major biotic degradation pathway for PCE is through sequential reductive dechlorination to TCE, then to cis-1,2-DCE, which degrades to vinyl chloride, which further degrades to ethene (Figure 8-1). This biological degradation pathway only occurs in an anaerobic environment, and redox potentials (E_H) generally need to be below -100 mV for optimum degradation. The rate of dechlorination typically slows as the degree of chlorination decreases. Since vinyl chloride is the most reduced compound, the thermodynamic equilibrium tends to stabilize vinyl chloride as the end product in aquifers that have stronger negative redox potentials. However, under aerobic conditions, many soil microorganisms can oxidize vinyl chloride, ultimately mineralizing the aliphatic compound to carbon dioxide and water (Cookson, 1995). In addition, some researchers have data that indicate that vinyl chloride can mineralize under iron-reducing conditions (Chappell, 1996). The relative rate of these processes at the site cannot be determined. Abiotic pathways for PCE and TCE degradation are not confirmed in the literature (Weidemeier et al., 1996). Recent investigations (University of Wisconsin, 1998) have shown that the conversion of cis-1,2-DCE to vinyl chloride, rather than vinyl chloride to ethene, may be the rate-limiting step in the sequential anaerobic degradation pathway shown on Figure 8-1.

The isoconcentration contours for CVOCs present in the groundwater at Sites 32/33 as of December 1998 presented on Figure 6-1 indicate that the breakdown products of PCE and TCE

(cis-1,2-DCE and vinyl chloride) are present within each of the separate plumes at significant concentrations. These findings indicate that reductive dechlorination of the CVOCs has occurred, and is likely to still be occurring, at the site. However, the extent and concentrations of the various chlorinated compounds, as shown on Figure 6-1, indicate that the rate and efficiency of the degradation are low, and have not sufficiently reduced or eliminated the CVOCs in the elapsed time since the initial release of the CVOC source materials, possibly several decades ago. The persistence of the CVOCs is the result of decreased biodegradation efficiency caused by one or more conditions within the aquifer that are inhibitory to the microorganisms capable of mediating the reductive dechlorination process, such as depletion of electron donor substrate (microorganism food source), neutral to positive redox potential, lack of preferential electron acceptor substances, or other trace nutrient deficiencies. The persistence of CVOCs in the separate plumes is also likely to be attributable to the continuing replenishment of CVOC mass into the groundwater in the Upper Sand from residual source materials remaining in the silty clay soil following completion of remedial action at the PCB source areas.

8.2 Geochemical Indicators

Geochemical data can provide indirect evidence for the presence of microorganisms that are producing the apparent degradation described in the previous subsection. Microorganisms utilize naturally occurring or anthropogenic (manmade) organic carbon as a food (electron) source, and also utilize a variety of electron acceptors for respiration. Oxygen, nitrogen, iron, sulfate, and carbon dioxide can all potentially be used as the electron acceptor based on availability and redox condition. These electron acceptors are utilized by the microorganisms in order of highest to lowest energy acquisition. The order of use is oxygen (aerobic environment), nitrogen (aerobic or anaerobic environment), ferric iron (anaerobic environment), sulfate (anaerobic environment), and carbon dioxide (anaerobic environment). The carbon dioxide is used by microorganisms known as methanogens (methane producers) in a process known as methanogenesis (Wiedemeier et al., 1996). Reductive dechlorination, where biodegradation of the more highly chlorinated compounds occurs, is most effective in the sulfate-reducing and methanogenic environments, but may occur in all but aerobic environments where more than 0.5 mg/L oxygen is present.

Measured pH values in groundwater across the site are typically between 6.5 and 8.0, well within the ideal range for microbial populations (Wiedemeier et al., 1996). Specific conductance measurements in groundwater indicate moderately elevated zones of conductance associated with the CVOC plumes (see Figure 6-2). These zones may be attributable to dissolved solids concentrations that were constituents of various waste liquids released to the soil in the source areas with the CVOCs. Groundwater temperature measurements at the site

typically range from 55 to 65 degrees F, reflecting seasonal variations. These temperatures are well within the optimal functioning range for microbial populations (Wiedemeier et al., 1996).

Total organic carbon (TOC) content of the groundwater sampled at several wells during 1998 shows that TOC is highly variable over the site. Samples from several wells showed TOC in the range of 1 to 10 mg/L, while samples from several other wells contained TOC in the range of 60 to 95 mg/L. These results show that, while the chlorinated contaminants make up a portion of the organic carbon present in the groundwater, naturally occurring sources of organic carbon are present to support biological dechlorination. Bacteria can also utilize particulate organic carbon in the aquifer as the primary substrate supporting reductive dechlorination. However, measured values of particulate organic carbon in the sediments at the site are low (typically in the range of 0.05 percent), and thus may be limited as a "food" source for bacteria.

Dissolved oxygen (DO) data (see Figure 6-2) show that an anoxic or anaerobic environment (DO between 0 and 1 mg/L) in the groundwater is generally coincident with the CVOC plume locations. A DO concentration of 2 mg/L was measured at the designated site background well 33MWC-01, indicating marginally aerobic conditions outside of the plume. The redox potential data are less conclusive (see Figure 6-2). Redox potentials typically between 0 and -200 millivolts are indicative of reducing conditions. Positive redox potentials indicate oxidizing (aerobic) conditions. The data show that redox potentials within the I-1-2 and I-1-23 source areas (-41 and -131 millivolts, respectively) are sufficient to promote anaerobic activity. However, a limited amount of redox data is available, and further conclusions are not possible. It is also important to note, and it has been well documented in the literature, that DO concentrations and redox potential are two of the most difficult parameters to measure accurately, particularly in low-yielding wells, such as are generally present at this site.

As discussed in Section 6, nitrogen, sulfate, and alkalinity concentrations do not show any consistent trends along flow lines within the plumes, and chloride was not detected in many of the site monitoring wells. The nitrate concentrations in the contaminated portion of the aquifer are generally below the 1.0 mg/L threshold value for reductive dechlorination to occur (Wiedemeier et al., 1996). Sulfate concentrations are highly variable (< 10 to > 1,000 mg/L), but are generally in the 100's of mg/L, which could cause competitive exclusion of dechlorination through sulfate reduction reactions (Wiedemeier et al., 1996). This could slow the rate of dechlorination in the aquifer. The lack of a trend in alkalinity is not surprising, and it is the least useful of the parameters analyzed in the groundwater samples.

Methane concentrations in groundwater indicate that methanogenesis, an anaerobic biological process, has occurred, and is likely continuing, in the vicinity of the CVOC source areas. The presence of methane in groundwater is indicative of strongly reducing conditions that favor

reductive dechlorination. The observed elevated concentrations of methane across the site coincide with the locations of the CVOC plumes.

8.3 Reduction of CVOC Mass

At sites with CVOC plumes where significant biodegradation is occurring, a reduction in contaminant mass typically is observed both temporally and spatially along the length of the plume, sometimes until concentrations are not detectable. A qualitative assessment of the groundwater chemistry data for Sites 32/33 shows that some reduction of CVOC mass is occurring in the general location of the sources. However, the data also show that, as the plumes leave the I-1-2 and I-1-23 source areas, the total CVOC mass is relatively conserved to a distance of several hundred feet from the source areas. For the plume originating from beneath the Repository, it appears that a greater amount of mass reduction is occurring within a much smaller distance from the source area(s). This is likely to be the result of a higher rate of biological degradation in this plume due to more conducive conditions, possibly including higher organic carbon concentrations. Alternately, more available time for degradation due to slower groundwater flow in the Repository area may be the reason for the apparent greater degree of biodegradation.

A more detailed examination of the I-1-23 plume shows that, although the total CVOC mass is only moderately reduced from the source area to the groundwater discharge point at the West Swale and the lake, dechlorination of the individual compounds via biological breakdown is occurring along the flow line of the plume. A plot of estimated groundwater concentrations of the individual chlorinated compounds in the upper sand (not in the upper clay) vs. distance from the I-1-23 source area to the lake along the estimated flow line of the plume center-of-mass is shown on Figure 8-2. This plot shows concentration trends that are consistent with the expected sequential reductive dechlorination process described throughout the technical literature and as observed at various sites with CVOC plumes. All of the breakdown products of PCE are found in the source area (see Figure 6-1). This could be due to a variety of reducing conditions in the shallow system, or possibly due to cometabolic processes occurring in the source areas.

As the plume moves through the Upper Sand aquifer a short distance from the source area, vinyl chloride disappears and the production of vinyl chloride apparently stops. This may indicate that less favorable anaerobic conditions are present in this zone. In the proximal half of the plume, the breakdown of PCE to TCE, and TCE to DCE, continues to occur. However, conditions suitable for breakdown of DCE to vinyl chloride are not present. The vinyl chloride that was produced from the anaerobic activity nearer the source area is likely to have been oxidized to carbon dioxide and water by other aerobic microorganisms that were initially encountered within the Upper Sand that is slightly oxidizing (aerobic) as it moves into the

source area, but becomes increasingly anaerobic downgradient of the source due to the effect of the contaminants. In the distal half of the plume, the PCE drops gradually to nondetectable levels, while TCE and DCE concentrations also begin to drop, and vinyl chloride re-appears.

Interpretations of reduction in CVOC mass based on the groundwater chemistry data and on conclusions from calibration of the contaminant transport model provide a further line of evidence that biodegradation is occurring, albeit slowly, and that it can contribute to the natural attenuation of CVOC contamination at the site.

8.4 Distance of Contaminant Migration

At any site, contaminant migration over a shorter distance than would be expected based on advective processes alone provides evidence that other attenuative processes, such as biodegradation, are occurring. Organic contaminant advection in groundwater is retarded, or slowed, by the presence of organic matter in aquifers. This organic matter causes continuous sorption/desorption of organic contaminants as contaminated groundwater migrates through the aquifer. This sorption/desorption effectively slows (retards) the migration of the organic contaminants, and the reduction in contaminant migration velocity in the groundwater is represented by a calculated retardation factor that is specific for each chlorinated compound. Parameters included in the calculated retardation factor include the dry bulk density of the soil, the organic carbon content of the soil, the octanol/water partitioning factor for the chlorinated compound, and the porosity of the soil.

Samples of water-saturated soil collected at various locations across Sites 32/33 in August 1997 showed consistently low organic carbon content of the soil, ranging from 0.026 percent to 0.27 percent (weight of organic carbon/weight of saturated soil), with an arithmetic average value of 0.07 percent. Using this average organic carbon value and other parameters obtained from physical analyses of Sites 32/33 soil samples and literature data, the calculated retardation factor for TCE is only 1.31. This low value indicates that sorption of TCE and the other CVOCs onto soil within the area of the plumes would not be expected to greatly slow or retard the movement of the dissolved CVOCs in the groundwater flow. In the absence of biological degradation, the physical processes of advection and dispersion alone will be the primary factors influencing the movement and shape of the CVOC plumes.

As mentioned above, it is often helpful to make a comparison of the expected longitudinal extent of a CVOC plume without the effects of biodegradation (assuming only physical processes and sorption affect CVOC movement) vs. the observed actual extent of the plume. This type of comparison often provides a line-of-evidence that biodegradation is occurring at a site. Because the age of the plumes (date or dates of CVOC releases) at Sites 32/33 is not

known, and because each of the plumes discharges to surface water at the site within a few hundred feet from the source areas, this type of direct comparison cannot be made.

8.5 Direct Evidence of Microbial Activity

A final line-of-evidence for biodegradation that is employed at some sites is laboratory analysis of volatile fatty acids in groundwater in impacted areas. Fatty acids contain microbial "biomarkers" that provide information on the health, condition, type, and activity of the microbial populations present. The volatile fatty acids, produced under methanogenic conditions, effectively enhance dehalogenation (Cookson, 1995).

Groundwater samples collected from site wells in 1997 were analyzed for volatile fatty acids. Proper interpretation and assessment of laboratory results for fatty acids typically require the assistance of an experienced environmental microbiologist. This type of analysis of the volatile fatty acids results from the 1997 groundwater samples is not available; no discussion of these results was included in the summary report issued for the 1997 groundwater sampling round (FDGTI, 1998b). Therefore, an evaluation of possible direct evidence of microbial activity in the Sites 32/33 plumes is not available.

8.6 Computer Modeling

Groundwater flow and contaminant transport modeling was performed to simulate the effects of existing naturally occurring processes on the distribution and migration of groundwater contamination over Sites 32/33. The transport model was prepared for the following purposes:

- To provide insights into the nature of residual CVOCs at the source areas, and estimates of the remaining source mass.
- To provide estimates of the rate and effectiveness of biological degradation of CVOCs that is currently occurring within the separate plumes.
- To be used in the Focused Feasibility Study (Part II of this document) to make projections of the expected effects of CVOC source removal resulting from implementation of the various remedial alternatives on the extent of the groundwater plumes over time.

The modeling approach was developed to enable simulation of the decay of the main CVOC source area compound (TCE), as well as to incorporate physical attenuation processes such as advection, dispersion, and sorption. The three-dimensional numerical groundwater flow model (MODFLOW; McDonald & Harbaugh, 1988) and numerical, three-dimensional transport code (MT3D; Zheng, 1990) were calibrated to the site conditions existing in December 1998 (i.e., groundwater flow system and locations and concentrations of CVOC plumes). Descriptions of the model parameters and the calibration processes are included in Section 7.

TCE is the primary CVOC present in the contaminated groundwater. Therefore, the transport model was calibrated to the existing TCE plume conditions. The calibrated model confirmed several observations and assumptions regarding the fate and transport processes affecting CVOCs as gleaned from the data that define the nature and extent of groundwater contamination and from the "lines-of-evidence" for the existence of biodegradation, as discussed in this section. Specifically, the model results indicate that biodegradation of TCE occurs at a slow rate in the Upper Clay and Upper Sand units (half-life of 24 years). This estimated rate is consistent with the long, persistent CVOC plumes in the Upper Sand that exist over the site.

8.7 Findings and Conclusions Regarding CVOC Fate and Transport

The key findings and conclusions regarding CVOC fate and transport derived from use of the groundwater flow and contaminant transport models, from the groundwater chemistry data, and from information contained in previous site documents, include the following:

- ***Biodegradation***
  - Biological degradation products of PCE and TCE are present in all groundwater plumes at the site.
  - Moderately effective biodegradation of CVOCs by anaerobic reductive dechlorination is occurring in the general areas of the separate CVOC sources. The biodegradation rate in the Upper Clay and Upper Sand units is low and the rate is relatively rapid in the Lower Clay unit.
  - The estimated field half-life of TCE in the Upper Clay and Upper Sand units, as determined from calibration of the contaminant transport model, is 24 years. Typical half-life values of 0.3 to 3 years are reported in technical literature at sites where significant anaerobic biodegradation is occurring; however, it is much longer at other sites where biodegradation is insignificant due to unfavorable conditions.
- ***CVOC Transfer and Transport***
  - The organic carbon content of the site soil (below the topsoil layer) is very low, resulting in minimal capacity of the soil to adsorb CVOCs or to retard the transport of CVOCs in the groundwater plumes. This may also be a rate-limiting factor for biodegradation at the site, since microorganisms are incapable of growth using PCE and TCE as a primary substrate (electron donor), and need an alternate source of organic carbon for cell growth.
  - The primary mechanisms for continuing migration of CVOCs from the Upper Clay to the Upper Sand unit at the source areas are 1) slow downward leaching of CVOCs through the clay resulting from surface water infiltration (groundwater recharge), and 2) the annual groundwater table elevation changes at the source areas, which may re-contact groundwater during high-water table conditions with CVOC residuals retained in the significant volume of voids within the capillary zone of the clay. As the water table drops during the dryer seasons, the dissolved

CVOCs are pulled deeper into the clay, thus moving closer to the point of "breakthrough" from the saturated clay into the more permeable Upper Sand unit.

- The horizontal migration of concentrated CVOCs in the water-saturated clay from their original point of release at ground surface is expected to be minimal, due to the low horizontal hydraulic conductivity of the Upper Clay (8×10^{-5} cm/s) and the presence of downward vertical gradients in the clay. If released as a DNAPL (e.g., concentrated waste solvent), the CVOCs would tend to migrate vertically through the unsaturated clay, potentially spreading laterally somewhat at the capillary fringe zone of the clay above the groundwater table. However, the overall pattern of CVOC movement downward through the clay from the release point at ground surface is expected to have been over a relatively limited lateral extent, unless the sinking DNAPL encountered one of the discontinuous silty sand lenses or other discontinuities in the clay that would have provided preferential routes for lateral vs. vertical DNAPL movement.

- *Remaining CVOC Sources*
  - The locations of the original CVOC releases appear to be generally coincident with the locations of the former PCB sources, at three of the identified general source areas: Building I-1-2 (eastern side), Building I-1-23 (northwestern side), and the former Area 9 Landfill. However, two other CVOC source areas do not appear to be associated with past PCB sources: Building I-1-36A and an area south of the Area 9 Repository.
  - Lack of information describing the specific dates, quantities, locations, and types of the original releases of CVOCs to the soil hinders efforts to estimate the likelihood that concentrated nonaqueous-phase solvents are present or previously existed in soil at the source areas. Information provided in previous reports indicates the activities that created the CVOC plumes may have occurred as much as several decades ago.
  - CVOC residuals that remain in the vicinity of former PCB source areas are expected to be present primarily in the saturated Upper Clay unit. The CVOCs are likely to have displaced water from a portion of the high-porosity clay, possibly as small blebs and ganglia of residual solvent dispersed within the small soil pores. An indication of this source material distribution pattern is provided at the Building I-1-23 area where concentrations of TCE, DCE, and vinyl chloride are approximately one order of magnitude higher in the shallow saturated zone Upper Clay (33MWC-07) than in the Upper Sand (33MWC-21) located only 20 feet apart. A similar pattern is evidenced at the Building I-1-2 area in wells 33MWC-13 (Upper Clay) and 33MWC-24 (Upper Sand).
  - The actual CVOC concentrations in groundwater at the source areas, and the significant extent and likely age of the plumes, provide an indication that a relatively significant mass of concentrated CVOC residuals was present in the soil at the source areas, at least until the time of the PCB remedial action in 1996-1997. The calibrated transport model indicates that TCE concentrations in groundwater up to 100 mg/L (roughly 10 percent of pure TCE solubility in water) are likely to

have been present in one or more "hot spot" at the source areas, up to the time of the PCB remedial action. It is recognized that, although a substantial amount of contaminants is likely to have been removed in the soil excavations, it is also possible that elevated concentrations may still exist in soil at some locations. To account for this possibility, constant-concentration source nodes were included in the contaminant transport model for all of the simulations.

- The mass of CVOCs present in the waste materials placed in the Area 9 Repository is uncertain, since these materials were not analyzed for CVOCs. However, the CVOC mass in this material is expected to be limited (as described in Section 5). Leaching of surface water through the Repository waste is a potential mass transfer/transport mechanism for CVOCs, if present, to enter the groundwater beneath the Repository. Estimates of the leaching rate through the waste have not been calculated, due to the limited CVOC mass expected to be present in the waste, and lack of information regarding the characteristics of the cover material placed on the Repository.
- Laboratory data that could be used to make reliable estimates of the CVOC mass that may have been removed with excavated soil during the PCB remedial action do not exist, since soil samples were not analyzed for CVOCs as part of the PCB remedial action. Under these circumstances, use of constant-concentration nodes in the calibrated contaminant transport model allows a realistic, conservative simulation of current conditions at the site to be made, without requiring that the exact mass of CVOCs in the aquifer be known. This approach allows a conservative simulation of future concentrations in the aquifer to be made, by assuming that the source concentrations do not decrease over time.
- Due to the low rate of groundwater movement within the Upper Clay unit, it is likely that insufficient time has elapsed since completion of the PCB remedial action in 1997 to observe a clear trend of decreasing CVOC concentrations in groundwater in the former PCB source areas that will result from that action. In addition, the pilot tests that were performed in the summer of 1998 caused source area disturbances of the groundwater flow system, the CVOC distribution patterns, and possibly the natural conditions that were conducive to biodegradation of CVOCs, thus making evaluation of groundwater quality improvements in the source areas based on subsequent groundwater sampling data from monitoring wells at the source areas difficult to determine, until the original equilibrium conditions within the source areas have been re-established.

Section 9
References

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Part I
Tables

Table 2-1
Chronology of Key Fieldwork Activities
Sites 32/33

DATE	DESCRIPTION OF EVENT OR ACTIVITY	PERFORMED BY
1983	Initial groundwater investigation at Area 9 Landfill	Ecology & Environment, Inc.
August 1985	Remedial investigation, Phase I	O'Brien & Gere
December 1986	Remedial investigation, Phase II	O'Brien & Gere
July to September 1992	Predesign data collection for PCB remedial action	IT Corporation
March 1993	Predesign data collection for PCB remedial action	IT Corporation
January 1994	Predesign data collection for PCB remedial action	IT Corporation
February 1995	Supplemental investigation	IT Corporation
December 1995 to June 1997	PCB remedial action	Fluor Daniel GTI and Maxymillian Technologies, Inc.
April 1996	Compliance monitoring during PCB remedial action	IT Corporation
April 1997	Pre-1998 TCE investigation	Fluor Daniel GTI
September 1997	Pre-1998 TCE investigation	Fluor Daniel GTI
May to August 1998	1998 TCE investigation and pilot study	Fluor Daniel GTI
December 1998	Groundwater investigation sampling and compliance monitoring	RMT, Inc.
June 1999	Compliance monitoring	RMT, Inc.

Notes:
1. Record of Decision—effective date 1 August 1990.
2. Consent Decree—date of entry 27 August 1992.

Table 3-1
Summary of Groundwater and Surface Water Elevation Data
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
Monitoring Wells						
32-063	415.9	415.9 [1]	17-Dec-86	2.9 [1]	413.0	Upper Clay(?)
			21-Jan-87	2.0 [1]	413.9	
		418.93	19-Jun-87	9.56	409.37	
			17-Sep-92	11.32	407.61	
			26-Mar-93	3.81	415.12	
			13-Jul-93	8.87	410.06	
			13-Sep-93	10.21	408.72	
			29-Jan-94	3.55	415.38	
			28-Feb-94	3.91	415.02	
			29-Mar-94	3.79	415.14	
			5-May-94	4.11	414.82	
			2-Jun-94	7.45	411.48	
			11-Jul-94	10.42	408.51	
			17-Aug-94	3.48	415.45	
			12-Sep-94	6.68	412.25	
			3-Oct-94	11.42	407.51	
			1-Nov-94	6.78	412.15	
			3-Jan-95	4.12	414.81	
			9-Feb-95	4.35	414.58	
			9-Apr-96	4.28	414.65	
			19-Apr-96	4.31	414.62	
			16-Sep-97	8.80	410.13	
			Aug-98	5.95	412.98	
			6-Dec-98	8.44	410.49	

Table 3-1
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Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33-340	424.9	424.9 [1]	17-Dec-86	6.9 [1]	418.0	Upper Clay(?)
			21-Jan-87	8.3 [1]	416.6	
		428.17	19-Jun-87	14.08	414.09	
			24-Mar-93	8.74	419.43	
			13-Jul-93	12.17	416.00	
			15-Sep-93	13.92	414.25	
			27-Jan-94	8.50	419.67	
			28-Feb-94	8.51	419.66	
			29-Mar-94	8.76	419.41	
			5-May-94	8.28	419.89	
			2-Jun-94	8.51	419.66	
			11-Jul-94	13.83	414.34	
			17-Aug-94	15.62	412.55	
			12-Sep-94	16.00	412.17	
			3-Oct-94	16.32	411.85	
			1-Nov-94	12.41	415.76	
			3-Jan-95	10.20	417.97	
			9-Feb-95	10.32	417.85	
			9-Apr-96	10.30[3]	417.99[3]	
			19-Apr-96	11.12	417.05	
			16-Sep-97	16.20	411.97	
		(2)	Aug-98	NM	NM	
		426.86 [2]	6-Dec-98	15.22	411.64	

Table 3-1
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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33-341	425.9	425.9 [1]	15-Dec-86	1.2 [1]	424.7	Upper Clay(?)
			21-Jan-87	0.8 [1]	425.1	
		429.31	19-Jun-87	6.23	423.08	
			24-Mar-93	3.15	426.16	
			13-Jul-93	5.30	424.01	
			15-Sep-93	7.02	422.29	
			27-Jan-94	3.41	425.90	
			28-Feb-94	3.51	425.80	
			29-Mar-94	3.47	425.84	
			5-May-94	3.47	425.84	
			2-Jun-94	4.49	424.82	
			11-Jul-94	6.70	422.61	
			17-Aug-94	6.64	422.67	
			12-Sep-94	6.12	423.19	
			3-Oct-94	9.64	419.67	
			1-Nov-94	5.54	423.77	
			3-Jan-95	3.64	425.67	
			9-Feb-95	3.69	425.62	
			9-Apr-96	3.88	425.43	
			19-Apr-96	3.88	425.43	
			16-Sep-97	10.10	419.21	
			Aug-98	7.90	421.41	
			6-Dec-98	11.32	417.99	

Table 3-1
Summary of Groundwater and Surface Water Elevation Data
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[4] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33-342	429.6	429.6 [1]	15-Dec-86	6.6 [1]	423.0	Upper Clay(?)
			21-Jan-87	6.4 [1]	423.2	
		432.81	19-Jun-87	12.42	420.39	
			24-Mar-93	8.59	424.22	
			13-Jul-93	7.78	425.03	
			15-Sep-93	11.74	421.07	
			27-Jan-94	7.79	425.02	
			28-Feb-94	8.38	424.43	
			29-Mar-94	8.36	424.45	
			5-May-94	8.27	424.54	
			2-Jun-94	11.00	421.81	
			11-Jul-94	13.27	419.54	
			17-Aug-94	14.96	417.85	
			12-Sep-94	15.90	416.91	
			3-Oct-94	16.28	416.53	
			1-Nov-94	10.42	422.39	
			3-Jan-95	9.03	423.78	
			9-Feb-95	9.15	423.66	
			9-Apr-96	9.17[3]	422.85[3]	
			19-Apr-96	9.22[3]	422.80[3]	
			16-Sep-97	14.25	418.56	
			Aug-98	11.70	421.11	
			6-Dec-98	14.15	418.66	

Table 3-1
Summary of Groundwater and Surface Water Elevation Data
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33MWC-01	NA	432.02	3-Jan-95	8.41	423.61	Upper Clay
			9-Feb-95	8.40	423.62	
			9-Apr-96	6.54	425.48	
			19-Apr-96	8.15	423.87	
			16-Sep-97	13.20	418.82	
			Aug-98	10.16	421.86	
			6-Dec-98	13.10	418.92	
33MWC-02	NA	424.86	3-Jan-95	3.03	421.83	Upper Clay
			9-Feb-95	3.16	421.70	
			9-Apr-96	3.88	420.98	
			19-Apr-96	3.73	421.13	
			16-Sep-97	10.75	414.11	
			Aug-98	3.84	421.02	
			6-Dec-98	9.78	415.08	
33MWC-03	NA	429.50	3-Jan-95	10.32	419.18	Upper Clay/ Upper Sand
			9-Feb-95	10.37	419.13	
			9-Apr-96	9.61	419.89	
			19-Apr-96	9.64	419.86	
			16-Sep-97	15.30	414.20	
			Aug-98	12.30	417.20	
			6-Dec-98	15.58	413.92	

Table 3-1
Summary of Groundwater and Surface Water Elevation Data
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SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[9] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33MWC-05	NA	424.39	3-Jan-95	6.77	417.62	Upper Clay
			9-Feb-95	3.81	420.58	
			9-Apr-96	5.95	418.44	
			19-Apr-96	5.96	418.43	
			16-Sep-97	13.20	411.19	
			Aug-98	9.25	415.14	
			6-Dec-98	12.38	412.01	
33MWC-06	NA	421.70	3-Jan-95	7.96	413.74	Upper Clay
			9-Feb-95	8.16	413.54	
			9-Apr-96	8.48	413.22	
			19-Apr-96	8.76	412.94	
			16-Sep-97	14.80	406.90	
			Aug-98	12.49	409.21	
			6-Dec-98	13.03	408.67	
33MWC-07	422.72	424.69	16-Sep-97	13.70	410.99	Upper Clay/ Upper Sand
			Aug-98	10.40	414.29	
			6-Dec-98	13.49	411.20	
33MWC-08	415.27	417.27	16-Sep-97	9.45	407.82	Upper Clay/ Upper Sand
			Aug-98	6.91	410.36	
			6-Dec-98	8.46	408.81	
33MWC-09	432.58	435.13	16-Sep-97	23.25	411.88	Upper Clay/ Upper Sand
			Aug-98	22.79	412.34	
			6-Dec-98	24.80	410.33	

Table 3-1
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Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33MWC-10	424.21	426.26	16-Sep-97	15.40	410.86	Upper Clay/ Upper Sand
			Aug-98	6.80	419.46	
			6-Dec-98	14.55	411.71	
33MWC-11	424.03	425.95	16-Sep-97	13.10	412.85	Upper Clay/ Upper Sand
			Aug-98	10.13	415.82	
			6-Dec-98	13.07	412.88	
33MWC-12	428.05	429.91	16-Sep-97	17.00	412.91	Upper Clay/ Upper Sand
			Aug-98	14.50	415.41	
			6-Dec-98	17.18	412.73	
33MWC-13	427.68	429.68	16-Sep-97	9.40	420.28	Upper Clay
			Aug-98	7.30	422.38	
			6-Dec-98	10.38	419.30	
33MWC-14	427.58	429.67	16-Sep-97	9.70	419.97	Upper Clay/ Upper Sand
			Aug-98	7.30	422.37	
			6-Dec-98	10.37	419.30	
33MWC-15	416.32	417.59	16-Sep-97	7.60	409.99	Upper Clay/ Upper Sand
			Aug-98	4.60[4]	412.89[4]	
			6-Dec-98	6.30	411.29	
33MWC-16	422.14	424.12	16-Sep-97	13.85	410.27	Upper Clay/ Upper Sand
			Aug-98	10.50	413.62	
			6-Dec-98	13.39	410.73	
33MWC-17	416.39	418.43	16-Sep-97	12.15	406.28	Upper Clay
			Aug-98	10.10	408.33	
			6-Dec-98	7.55	410.88	

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Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33MWC-18	406.91	408.96	16-Sep-97	4.58	404.38	Upper Clay/ Upper Sand
			Aug-98	1.51	407.45	
			6-Dec-98	4.05	404.91	
33MWC-19	407.38	409.43	16-Sep-97	2.75	406.68	Upper Clay
			Aug-98	1.33	408.10	
			6-Dec-98	4.80	404.63	
33MWC-20	416.45	418.55	16-Sep-97	9.70	408.85	Upper Clay/ Upper Sand
			Aug-98	7.61	410.94	
			6-Dec-98	12.81	405.74	
33MWC-21	422.51	425.11	Aug-98	10.70	414.41	Upper Sand
			6-Dec-98	13.53	411.58	
33MWC-22	422.56	425.26	Aug-98	10.80	414.46	Lower Clay
			6-Dec-98	13.90	411.36	
33MWC-23	422.51	424.68	Aug-98	13.50	411.18	Lower Sand
			6-Dec-98	15.04	409.64	
33MWC-24	427.56	429.65	Aug-98	7.10	422.55	Upper Sand
			6-Dec-98	10.21	419.44	
33MWC-27	432.00	434.45	Aug-98	22.20	412.25	Upper Sand
			6-Dec-98	24.15	410.30	
33MWC-28	432.13	434.59	Aug-98	26.40	408.19	Lower Clay
			6-Dec-98	24.33	410.26	
33MWC-29	432.22	434.15	Aug-98	23.30	410.85	Lower Sand
			6-Dec-98	24.56	409.59	
33MWC-30	407.44	409.69	Aug-98	2.85	406.84	Upper Sand
			6-Dec-98	3.16	406.53	

Table 3-1
Summary of Groundwater and Surface Water Elevation Data
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Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	GROUNDWATER ELEVATION (ft, MSL)	UNIT SCREENED
33MWC-31	407.38	409.86	Aug-98	2.85	407.01	Lower Clay
			6-Dec-98	3.15	406.71	
33MWC-32	407.36	409.91	Aug-98	-0.50 (artesian)	410.41	Lower Sand
			6-Dec-98	0.36	409.55	
33MWC-33	427.41	429.55	Aug-98	14.10	415.45	Upper Sand
			6-Dec-98	16.85	412.70	
33MWC-35	427.25	429.78	Aug-98	17.40	412.38	Lower Sand
			6-Dec-98	19.22	410.56	
33MWC-36	421.79	424.13	Aug-98	6.85	417.28	Upper Sand
			6-Dec-98	9.09	415.04	
33MWC-39	414.77	417.12	Aug-98	10.40	406.72	Upper Sand
			6-Dec-98	10.39	406.73	
33MWC-41	414.61	417.24	Aug-98	6.20	411.04	Deep Sand
			6-Dec-98	7.86	409.38	

Table 3-1
Summary of Groundwater and Surface Water Elevation Data
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	GROUND SURFACE ELEVATION (ft, MSL)	REFERENCE ELEVATION (ft, MSL)	DATE	DEPTH TO WATER[6] (ft)	SURFACE WATER ELEVATION (ft, MSL)	UNIT SCREENED
Surface Water						
33SG-01	NA	413.97 [5]	Aug-98	DRY	DRY	NA
			6-Dec-98	0.38	414.35	
33SG-02	NA	411.01 [5]	Aug-98	0.41	411.42	NA
			6-Dec-98	0.56	411.57	
33SG-03	NA	405.23 [5]	Aug-98	0.07	405.30	NA
			6-Dec-98	0.23	405.46	
33SG-04	NA	407.89 [5]	Aug-98	1.17	409.06	NA
			6-Dec-98	NM	NM	

Notes:

[1] Water levels were reported relative to the ground surface elevation.

[2] 33-340 was found damaged in August 1998. The well was repaired and resurveyed in August 1998.

[3] Depth to water and groundwater elevation are inconsistent, but are reprinted as reported by IT (September 1995).

[4] Depth to water and groundwater elevation are inconsistent, but are reprinted as reported to RMT by FDGTI (August 1998).

[5] The staff gauge reference elevation represents the 0-foot mark on the staff gauge. The "Depth to Water" measurement is the water level on the staff gauge.

[6] Measured from top of interior well casing.

NA = not applicable.

NM = no measurement.

Prepared by: PR 1/22/99

Checked by: MLW 1/25/99

Table 4-1
Groundwater Monitoring Well Information
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

WELL NAME	WELL LOCATION	N	S	E	W	DATE ESTABLISHED	WELL CASING DIAM.	WELL CASING TYPE	ELEVATIONS TOP OF WELL CASING	ELEVATIONS GROUND SURFACE	REFERENCE M.S.L. (x)	REFERENCE SITE DATUM (x)	SCREEN LENGTH & TYPE (ft)	WELL DEPTH[1] (ft bgs)	TYPE OF WELL PZ	TYPE OF WELL OW	TYPE OF WELL OTHER	ABAN-DONED (Y/N)	INSTALLED BY
32-61	ORIG. ID = "COW-3"					LATE 1983	2"	PVC	414.94	412.8	X		5'	30.5				Y	Ecology & Environment, Inc.
32-62	ORIG. ID = "COW-2"					LATE 1983	2"	PVC	410.49	408.5	X		5'	35.5				Y	Ecology & Environment, Inc.
COW-01						LATE 1983	2"	PVC					5' 316 SS	29				Y	Ecology & Environment, Inc.
32-63							2"	PVC	418.93	415.9	X		5' 316 SS	15		X		N	O'Brien & Gere
32-109							2"	PVC	411.01	407.8	X		5' 316 SS	15		X		Y	O'Brien & Gere
32-110							2"	PVC	410.89	407.6	X		5' 316 SS	82.5	X			Y	O'Brien & Gere
33-340	373825.04 786403.55	X		X			2"	PVC	426.86*	424.9 425.04*	X		5' 316 SS	15		X		N	O'Brien & Gere
33-341							2"	PVC	429.31	425.9	X		5' 316 SS	14		X		N	O'Brien & Gere
33-342							2"	PVC	432.81	429.6	X		5' 316 SS	20		X		N	O'Brien & Gere
33MWC-01	370582.65 787787.59	X		X		01/19/95	2"	PVC	432.02	NA	X		15' SS	19 (20)		X		N	IT Corp
33MWC-02	372016.14 787850.85	X		X		01/21/95	2"	PVC	424.86	NA	X		15' SS	19 (20)		X		N	IT Corp
33MWC-03	371559.27 786496.74	X		X		01/20/95	2"	PVC	429.50	NA	X		15' SS	20.5 (23)		X		N	IT Corp
33MWC-04	373897.67 787557.74	X		X		01/22/95	2"	PVC	423.11	NA	X		15' SS	19 (23)		X		Y	IT Corp
33MWC-05	373308.11 785513.25	X		X		01/20/95	2"	PVC	424.39	NA	X		15' SS	19 (22)		X		N	IT Corp
33MWC-06	374547.94 785838.99	X		X		01/21/95	2"	PVC	421.70	NA	X		15' SS	19 (20)		X		N	IT Corp

Table 4-1
Groundwater Monitoring Well Information
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

WELL NAME	WELL LOCATION	N	S	E	W	DATE ESTABLISHED	WELL CASING DIAM.	WELL CASING TYPE	ELEVATIONS TOP OF WELL CASING	ELEVATIONS GROUND SURFACE	REFERENCE M.S.L. (x)	REFERENCE SITE DATUM (x)	SCREEN LENGTH & TYPE (ft)	WELL DEPTH[1] (ft bgs)	TYPE OF WELL PZ	TYPE OF WELL OW	TYPE OF WELL OTHER	ABAN-DONED (Y/N)	INSTALLED BY
33MWC-07	374000.20	X				08/25/97	2"	316 SS	424.69	422.72**	X		15'	24.5		X		N	FDGTI
	786399.81			X									316 SS	(25)					
33MWC-08	374814.08	X				08/13/97	2"	316 SS	417.27	415.27**	X		10'	20.8		X		N	FDGTI
	786151.41			X									316 SS	(24)					
33MWC-09	374284.58	X				08/23/97	2"	316 SS	435.13	432.58**	X		15'	42.2		X		N	FDGTI
	787250.09			X									316 SS	(45)					
33MWC-10	372585.03	X				08/14/97	2"	316 SS	426.26	424.21**	X		15'	24.2		X		N	FDGTI
	787368.15			X									316 SS	(26)					
33MWC-11	370880.87	X				08/19/97	2"	316 SS	425.95	424.03**	X		15'	19		X		N	FDGTI
	786550.14			X									316 SS	(21)					
33MWC-12	371714.46	X				08/18/97	2"	316 SS	429.91	428.05**	X		15'	19.9		X		N	FDGTI
	786255.20			X									316 SS	(21)					
33MWC-13	371380.44	X				08/22/97	2"	316 SS	429.68	427.68**	X		15'	19.9		X		N	FDGTI
	787486.39			X									316 SS	(21)					
33MWC-14	371604.30	X				08/21/97	2"	316 SS	429.67	427.58**	X		15'	24.7		X		N	FDGTI
	787324.75			X									316 SS	(25.2)					
33MWC-15	373115.13	X				08/15/97	2"	316 SS	417.59	416.32**	X		15'	28		X		N	FDGTI
	787899.35			X									316 SS	(29)					
33MWC-16	374096.09	X				08/25/97	2"	316 SS	424.12	422.14**	X		15'	24.5		X		N	FDGTI
	786264.68			X									316 SS	(25)					
33MWC-17	374288.50	X				09/10/97	2"	316 SS	418.43	416.39**	X		15'	20.2		X		N	FDGTI
	787478.09			X									316 SS	(21)					
33MWC-18	374568.35	X				09/09/97	2"	316 SS	408.96	406.91**	X		15'	20		X		N	FDGTI
	787313.87			X									316 SS	(21)					
33MWC-19	374772.98	X				09/09/97	2"	316 SS	409.43	407.38**	X		15'	20		X		N	FDGTI
	787149.94			X									316 SS	(21)					
33MWC-20	374805.81	X				09/10/97	2"	316 SS	418.55	416.45**	X		15'	20		X		N	FDGTI
	786824.56			X									316 SS	(21)					
33MWC-21	374012.59	X				06/09/98	2"	316 SS	425.11	422.51**	X		10'	38	X		Upper	N	FDGTI
	786378.69			X									316 SS	(39.5)			sand		

Table 4-1
Groundwater Monitoring Well Information
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

WELL NAME	WELL LOCATION	N	S	E	W	DATE ESTABLISHED	WELL CASING		ELEVATIONS		REFERENCE		SCREEN LENGTH & TYPE (ft)	WELL DEPTH[1] (ft bgs)	TYPE OF WELL			ABAN-DONED (Y/N)	INSTALLED BY
							DIAM.	TYPE	TOP OF WELL CASING	GROUND SURFACE	M.S.L. (x)	SITE DATUM (x)			PZ	OW	OTHER		
33MWC-22	374003.83	X				06/16/98	2"	316 SS	425.26	422.56**	X		5' 316 SS	49	X		Lower clay	N	FDGTI
	786383.42			X															
33MWC-23	373995.02	X				06/12/98	2"	316 SS	424.68	422.51**	X		10' 316 SS	102 (103)	X		Lower sand	N	FDGTI
	786388.95			X															
33MWC-24	371399.72	X				06/04/98	2"	316 SS	429.65	427.56**	X		5' 316 SS	28 (35)	X		Upper sand	N	FDGTI
	787484.37			X															
33MWC-27	374305.42	X				06/17/98	2"	316 SS	434.45	432.00**	X		5' 316 SS	48	X		Upper sand	N	FDGTI
	787254.09			X															
33MWC-28	374297.24	X				06/18/98	2"	316 SS	434.59	432.13**	X		5' 316 SS	60.5	X		Lower clay	N	FDGTI
	787258.14			X															
33MWC-29	374288.26	X				06/04/98	2"	316 SS	434.15	432.22**	X		10' 316 SS	104	X		Lower sand	N	FDGTI
	787262.71			X															
33MWC-30	375163.57	X				06/09/98	2"	316 SS	409.69	407.44**	X		10' 316 SS	25.5 (26.5)	X		Upper sand	N	FDGTI
	786004.73			X															
33MWC-31	375162.42	X				06/16/98	2"	316 SS	409.86	407.38**	X		10' 316 SS	45	X		Lower clay	N	FDGTI
	785995.11			X															
33MWC-32	375160.99	X				06/15/98	2"	316 SS	409.91	407.36**	X		10' 316 SS	81 (82)	X		Lower sand	N	FDGTI
	785985.26			X															
33MWC-33	371755.55	X				06/10/98	2"	316 SS	429.55	427.41**	X		10' 316 SS	39.5 (41)	X		Upper sand	N	FDGTI
	786218.09			X															
33MWC-35	371742.29	X				06/17/98	2"	316 SS	429.78	427.25**	X		5' 316 SS	80	X		Lower sand	N	FDGTI
	786197.18			X															
33MWC-36	371968.31	X				06/16/98	2"	316 SS	424.13	421.79** 421.2	X		5' 316 SS	30 (30.5)	X		Upper sand	N	FDGTI
	787973.28			X															
33MWC-39	374526.33	X				06/11/98	2"	316 SS	417.12	414.77**	X		10' 316 SS	31 (32)	X		Upper sand	N	FDGTI
	787543.38			X															
33MWC-41	374546.64	X				06/14/98	2"	316 SS	417.24	414.61**	X		10' 316 SS	95	X		Lower sand	N	FDGTI
	787539.12			X															

Table 4-1
Groundwater Monitoring Well Information
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

WELL NAME	WELL LOCATION	N	S	E	W	DATE ESTABLISHED	WELL CASING		ELEVATIONS		REFERENCE		SCREEN LENGTH & TYPE (ft)	WELL DEPTH[1] (ft bgs)	TYPE OF WELL			ABAN-DONED (Y/N)	INSTALLED BY
							DIAM.	TYPE	TOP OF WELL CASING	GROUND SURFACE	M.S.L. (x)	SITE DATUM (x)			PZ	OW	OTHER		
33SG-01	373400.72	X				07/16/98	NA	NA	413.97***	NA	X		NA	NA			Staff Gauge	N	FDGTI
	786980.31			X															
33SG-02	373884.01	X				07/16/98	NA	NA	411.01***	NA	X		NA	NA			Staff Gauge	N	FDGTI
	787215.29			X															
33SG-03	375222.02	X				07/16/98	NA	NA	405.23***	NA	X		NA	NA			Staff Gauge	N	FDGTI
	785991.26			X															
33SG-04	371559.91	X				07/16/98	NA	NA	407.89***	NA	X		NA	NA			Staff Gauge	N	FDGTI
	784981.07			X															

Notes:

(1) Value in parentheses is the total boring depth.

* 33-340 was resurveyed in August 1998. 1st GS elevation listed is original survey. 2nd elevation is the elevation of the brass monument in the concrete pad.

** Elevation of brass monument in concrete pad.

*** Staff Gauge reference elevations represent the elevation of the 0-foot mark on the staff gauge.

NA = Not applicable

A total of 38 monitoring wells exist at sites 32/33 as of December 1998.

No entry indicates information not available or does not exist.

Prepared by: MLW 10/30/98
Checked by: PMC 1/27/99

Table 4-2
Summary of Soil Borings Installed Summer 1998
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

BORING I.D.	DATE INSTALLED	GROUND SURFACE ELEVATION (ft, MSL)	BORING DEPTH (ft bgs)	ELEVATION OF GROUNDWATER SAMPLE COLLECTION INTERVAL (ft, MSL)*	AREA OF INVESTIGATION
Geoprobe Borings					
GP-1A	6/1/1998	417.1	20.0	397.1 - 399.1	AREA 9 REPOSITORY
GP-2A	6/1/1998	407.8	34.0	373.8 - 375.8	AREA 9 REPOSITORY
GP-3A	6/1/1998	413.3	12.0	401.3 - 403.3	AREA 9 REPOSITORY
GP-4A	5/29/1998	413.2	22.0	391.2 - 393.2	AREA 9 REPOSITORY
GP-5A	6/4/1998	406.7	20.0	386.7 - 388.7	AREA 9 REPOSITORY
GP-6A	6/4/1998	415.4	28.0	387.4 - 389.4	AREA 9 REPOSITORY
GP-7A	6/4/1998	411.9	16.0	395.9 - 397.9	AREA 9 REPOSITORY
GP-8A	6/5/1998	417.8	18.0	399.8 - 401.8	AREA 9 REPOSITORY
GP-9A	6/5/1998	417.5	20.0	397.5 - 399.5	AREA 9 REPOSITORY
GP-10A	6/8/1998	418.4	20.0	398.4 - 400.4	AREA 9 REPOSITORY
GP-11A	6/8/1998	417.1	20.0	397.1 - 399.1	AREA 9 REPOSITORY
GP-12A	6/8/1998	410.5	16.0	394.5 - 396.5	AREA 9 REPOSITORY
GP-13A	6/8/1998	413.6	20.0	393.6 - 395.6	I-1-36A/AREA 9 REPOSITORY
GP-14A	6/11/1998	416.0	20.0	396 - 398	AREA 9 REPOSITORY
GP-15A	6/12/1998	420.1	28.0	392.1 - 394.1	I-1-36A/AREA 9 REPOSITORY
GP-16A	6/12/1998	418.8	20.0	398.8 - 400.8	BUILDING I-1-36A
GP-17A	6/12/1998	419.3	28.0	391.3 - 393.3	I-1-36A/AREA 9 REPOSITORY
GP-18A	6/18/1998	419.5	27.0	392.5 - 394.5	I-1-36A/AREA 9 REPOSITORY
GP-19A	6/18/1998	419.1	29.0	390.1 - 392.1	I-1-36A/AREA 9 REPOSITORY
GP-20A	6/18/1998	421.1	28.0	393.1 - 395.1	BUILDING I-1-36A
GP-21A	6/18/1998	422.2	32.0	390.2 - 392.2	BUILDING I-1-36A
GP-1B	5/27/1998	406.5	22.0	384.5 - 386.5	BUILDING I-1-23
GP-2B	6/1/1998	418.7	28.0	387.7 - 390.7	BUILDING I-1-23
GP-3B	5/27/1998	422.6	27.5	395.1 - 397.1	BUILDING I-1-23
GP-4B	5/27/1998	418.8	28.0	390.8 - 392.8	BUILDING I-1-23
GP-5B	5/27/1998	413.0	24.0	389 - 391	BUILDING I-1-23
GP-6B	6/3/1998	409.3	16.0	393.3 - 395.3	BUILDING I-1-23

Table 4-2
Summary of Soil Borings Installed Summer 1998
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

BORING I.D.	DATE INSTALLED	GROUND SURFACE ELEVATION (ft, MSL)	BORING DEPTH (ft bgs)	ELEVATION OF GROUNDWATER SAMPLE COLLECTION INTERVAL (ft, MSL)*	AREA OF INVESTIGATION
GP-7B	6/1/1998	410.2	24.0	386.2 - 388.2	BUILDING I-1-23
GP-8B	6/2/1998	420.4	28.0	392.4 - 394.4	BUILDING I-1-23
GP-9B	6/8/1998	411.0	12.0	399 - 401	BUILDING I-1-23
GP-10B	6/11/1998	408.0	18.0	390 - 392	BUILDING I-1-23
GP-11B	7/10/1998	408.1	12.0	396.1 - 398.1	BUILDING I-1-23
GP-1C	5/29/1998	426.7	24.0	402.7 - 404.7	BUILDING I-1-2 WEST
GP-2C	5/29/1998	426.2	24.0	402.2 - 404.2	BUILDING I-1-2 WEST
GP-3C	5/29/1998	425.8	24.0	399.8 - 402.8	BUILDING I-1-2 WEST
GP-4C	5/29/1998	426.4	28.0	398.4 - 400.4	BUILDING I-1-2 WEST
GP-5C	6/2/1998	420.3	16.0	404.3 - 406.3	BUILDING I-1-2 WEST
GP-6C	6/2/1998	426.7	20.0	405.7 - 408.7	BUILDING I-1-2 WEST
GP-7C	6/3/1998	428.4	28.0	400.4 - 402.4	BUILDING I-1-2 WEST
GP-8C	6/3/1998	428.0	27.0	401 - 403	BUILDING I-1-2 WEST
GP-9C	6/3/1998	426.5	20.0	406.5 - 408.5	BUILDING I-1-2 WEST
GP-1D	5/28/1998	424.3	32.5	396.3 - 398.3	BUILDING I-1-2 EAST
GP-2D	5/28/1998	425.3	34.0	391.3 - 393.3	BUILDING I-1-2 EAST
GP-3D	5/28/1998	424.7	37.0	387.7 - 389.7	BUILDING I-1-2 EAST
GP-4D	5/28/1998	423.6	24.0	399.6 - 401.6	BUILDING I-1-2 EAST
GP-5D	6/1/1998	427.9	28.5	399.4 - 401.4	BUILDING I-1-2 EAST
GP-6D	6/1/1998	425.4	58.0	397.4 - 399.4	BUILDING I-1-2 EAST
GP-7D	6/2/1998	421.8	16.0	405.7 - 407.7	BUILDING I-1-2 EAST
GP-8D	6/5/1998	421.1	16.0	405.1 - 407.1	BUILDING I-1-2 EAST
GP-9D	6/5/1998	423.1	31.5	391.6 - 393.6	BUILDING I-1-2 EAST
GP-10D	6/9/1998	420.8	16.0	404.8 - 406.8	BUILDING I-1-2 EAST
GP-11D	6/9/1998	421.8	20.0	401.8 - 403.8	BUILDING I-1-2 EAST
GP-12D	6/9/1998	421.2	26.0	395.2 - 397.2	BUILDING I-1-2 EAST
GP-13D	6/11/1998	423.4	24.0	399.4 - 401.4	BUILDING I-1-2 EAST
GP-14D	6/12/1998	423.7	27.5	396.2 - 398.2	BUILDING I-1-2 EAST
GP-1E	7/8/1998	424.7	20.0	404.7 - 406.7	BUILDING I-1-36A

Table 4-2
Summary of Soil Borings Installed Summer 1998
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

BORING I.D.	DATE INSTALLED	GROUND SURFACE ELEVATION (ft, MSL)	BORING DEPTH (ft bgs)	ELEVATION OF GROUNDWATER SAMPLE COLLECTION INTERVAL (ft, MSL)*	AREA OF INVESTIGATION
GP-2E	7/7/1998	423.1	24.0	399.1 - 401.1	BUILDING I-1-36A
GP-3E	7/7/1998	418.5	24.0	394.5 - 396.5	BUILDING I-1-36A
GP-4E	7/8/1998	417.9	24.0	393.9 - 395.9	BUILDING I-1-36A
GP-5E	7/8/1998	421.1	24.0	397.1 - 399.1	BUILDING I-1-36A
GP-6E	7/7/1998	421.4	28.0	392.4 - 394.4	BUILDING I-1-36A
GP-7E	7/8/1998	417.4	24.0	393.4 - 395.4	BUILDING I-1-36A
GP-8E	7/8/1998	422.8	32.0	390.8 - 392.8	BUILDING I-1-36A
GP-9E	7/10/1998	423.1	24.0	399.1 - 401.1	BUILDING I-1-36A
GP-10E	7/10/1998	415.7	28.0	387.7 - 389.7	BUILDING I-1-36A
GP-11E	7/10/1998	422.0	12.0	410 - 412	BUILDING I-1-36A
GP-12E	7/14/1998	411.9	28.0	383.9 - 385.9	BUILDING I-1-36A
GP-13E	7/13/1998	415.4	24.0	391.4 - 393.4	BUILDING I-1-36A
GP-14E	7/13/1998	421.8	32.0	389.8 - 391.8	BUILDING I-1-36A
GP-15E	7/13/1998	416.2	36.0	380.2 - 382.2	BUILDING I-1-36A
GP-16E	7/14/1998	421.8	32.0	389.8 - 391.8	BUILDING I-1-36A
GP-17E	7/14/1998	418.4	16.0	402.4 - 404.4	BUILDING I-1-36A
Monitoring Wells					
33MWC-21	6/9/1998	422.51	39.5	384.5 - 394.5	BUILDING I-1-23
33MWC-22	6/16/1998	422.56	49	373.6 - 378.6	BUILDING I-1-23
33MWC-23	6/12/1998	422.51	103	320.5 - 330.5	BUILDING I-1-23
33MWC-24	6/1/1998	427.56	28	399.6 - 404.6	BUILDING I-1-2
33MWC-26	6/1/1998	427.56	35	NA	BUILDING I-1-2
33MWC-27	6/17/1998	432.00	48	384.0 - 389.0	AREA 9 REPOSITORY
33MWC-28	6/18/1998	432.13	60.5	371.6 - 376.6	AREA 9 REPOSITORY
33MWC-29	6/4/1998	432.22	104	328.2 - 338.2	AREA 9 REPOSITORY
33MWC-30	6/9/1998	407.44	26.5	381.9 - 391.9	BUILDING I-1-23
33MWC-31	6/16/1998	407.38	45	362.4 - 372.4	BUILDING I-1-23
33MWC-32	6/15/1998	407.36	82	326.4 - 336.4	BUILDING I-1-23

Table 4-2
Summary of Soil Borings Installed Summer 1998
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

BORING I.D.	DATE INSTALLED	GROUND SURFACE ELEVATION (ft, MSL)	BORING DEPTH (ft bgs)	ELEVATION OF GROUNDWATER SAMPLE COLLECTION INTERVAL (ft, MSL)*	AREA OF INVESTIGATION
33MWC-33	6/18/1998	427.41	41	387.9 - 397.9	BUILDING I-1-2
33MWC-35	6/17/1998	427.25	80	347.3 - 352.3	BUILDING I-1-2
33MWC-36	6/16/1998	421.79	30.5	391.8 - 396.8	BUILDING I-1-2
33MWC-39	6/11/1998	414.77	32	383.8 - 393.8	AREA 9 REPOSITORY
33MWC-41	6/14/1998	414.61	95	319.6 - 329.6	AREA 9 REPOSITORY

Notes:
All borings installed by FDGTI.

* For Geoprobe borings, assumes water sample was collected in the last two feet of the boring, unless otherwise indicated on the field logs.
Monitoring well sample collection intervals correspond to the screened interval.
Total of 72 Geoprobe soil borings installed.

NA = Not Available

Prepared by: MLW 1/21/99
Checked by: PMC 1/26/99

Table 4-3
Summary of Horizontal Gradient Calculations
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

LOCATION	AUGUST 1998	DECEMBER 1998
Horizontal Hydraulic Gradient - Upper Sand		
Building I-1-2 Area	0.003	0.006
Building I-1-23 Area	0.006	0.004
Area 9 Repository	0.01	0.02
Horizontal Hydraulic Gradient - Lower Sand		
Whole Site	0.0005	0.0004

Notes:

Hydraulic Gradient Calculations are included in Appendix H.

Prepared by: MLW 1/28/99

Checked by: BAB 1/28/99

Table 4-4
Summary of Slug Test Results
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

WELL I.D.	GEOLOGIC UNIT	K (cm/s)
32-63[2]	Upper clay	7.2×10^{-5}
32-109[2]	Upper clay	1.2×10^{-4}
33-341[2]	Upper clay	2.9×10^{-5}
33-342[2]	Upper clay	7.7×10^{-4}
33MWC-02[3]	Upper clay	3.9×10^{-5}
32-61[2]	Upper clay??	1.9×10^{-4}
32-62[2]	Upper clay??	1.6×10^{-5}
	GEOMETRIC MEAN =	8.1×10^{-5}
33MWC-21[4]	Upper sand	2.9×10^{-4}
33MWC-24[4]	Upper sand	7.1×10^{-4}
33MWC-27[4]	Upper sand	1.3×10^{-5}
33MWC-30[4]	Upper sand	4.4×10^{-3}
33MWC-33[4]	Upper sand	9.6×10^{-5}
33MWC-36[4]	Upper sand	4.5×10^{-5}
33MWC-39[4]	Upper sand	1.5×10^{-4}
	GEOMETRIC MEAN =	1.9×10^{-4}
33MWC-22[4]	Lower clay	1.1×10^{-6}
33MWC-28[4]	Lower clay	1.5×10^{-6}
33MWC-31[4]	Lower clay	5.0×10^{-6}
	GEOMETRIC MEAN =	2.0×10^{-6}
33MWC-23[4]	Lower sand	1.5×10^{-3}
33MWC-29[4]	Lower sand	9.4×10^{-4}
33MWC-32[4]	Lower sand	4.1×10^{-3}
33MWC-35[4]	Lower sand	6.3×10^{-6}
33MWC-41[4]	Lower sand	2.1×10^{-3}
	GEOMETRIC MEAN =	1.9×10^{-3}[5]

Notes:
(1) Reported hydraulic conductivity is geometric mean of available results.
(2) Hydraulic conductivity data taken from O'Brien and Gere RI report, July 1988.
(3) Hydraulic conductivity data taken from IT Corp. Final Supplemental Investigation Report, September 1995.
(4) Hydraulic conductivity data collected by FDGTI, summer 1998, analyzed by RMT, Inc.
(5) The geometric mean for the lower sand does not include data from 33MWC-35, as this well may be influenced by cement grout.

Data files and analytical results are included in Appendix I.

Prepared by: MLW 12/29/98

Checked by: TSS 1/22/99

Table 4-5
Summary of Aquifer Pumping Test Results
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

	TRANSMISSIVITY (FT^2/MIN)		STORATIVITY		K (cm/s)	
	THEIS	COOPER-JACOB	THEIS	COOPER-JACOB	THEIS	COOPER-JACOB
Building I-1-2						
EXT. WELL	2.0E-02	2.0E-02	NA	NA	7.8E-03	7.8E-03
MP-1	1.8E-02	2.3E-02	1.1E-03	8.7E-04	7.0E-03	9.0E-03
MP-2	2.0E-02	2.0E-02	1.0E-03	8.7E-04	7.7E-03	7.8E-03
MP-3	1.8E-02	1.8E-02	5.9E-04	5.9E-04	7.0E-03	7.0E-03
MP-4	1.6E-02	1.8E-02	5.0E-04	3.8E-04	6.4E-03	7.2E-03
				GEOM. MEAN	7.1E-03	7.7E-03
				VARIANCE	3.6E-07	6.3E-07
Building I-1-23*						
MP-1	8.3E-02	1.0E-01	1.2E-02	8.6E-03	3.3E-03	4.0E-03
MP-2	1.9E-01	1.9E-01	5.7E-03	5.7E-03	7.5E-03	7.5E-03
MP-3	1.3E-01	8.9E-02	1.5E-02	1.5E-02	5.0E-03	3.6E-03
MP-4	1.8E-01	1.5E-01	4.6E-03	4.5E-03	7.4E-03	6.2E-03
				GEOM. MEAN	5.5E-03	5.1E-03
				VARIANCE	4.0E-06	3.5E-06
Area 9 Repository						
EXT. WELL	4.1E-04	4.2E-04	NA	NA	2.7E-05	2.8E-05
MP-1	9.7E-03	1.7E-02	6.8E-03	4.8E-03	6.5E-04	1.1E-03
MP-2	2.8E-03	3.7E-03	9.9E-03	6.0E-03	1.9E-04	2.5E-04
MP-3	1.5E-03	1.8E-03	8.4E-03	5.9E-03	9.7E-05	1.2E-04
MP-4	2.1E-03	2.6E-03	9.3E-03	6.3E-03	1.4E-04	1.7E-04
				GEOM. MEAN	1.4E-04	1.7E-04
				VARIANCE	6.1E-08	2.0E-07

Notes:
Data collected by FDGTI and analyzed by RMT.
NA = Not Applicable
Data files and analytical results are included in Appendix J.
* No available data for extraction well in Building I-1-23 area.
Prepared by: MLW 1/19/99
Checked by: TSS 1/22/99

Table 4-6
Summary of Vertical Gradient Calculations
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

WELL NUMBER	WELL TYPE	AUGUST 1998 GROUNDWATER ELEVATION (h) (ft-MSL)	AUGUST 1998 REFERENCE POINT (L) (ft-MSL)	AUGUST 1998 DELTA h (ft)	AUGUST 1998 DELTA L (ft)	AUGUST 1998 VERTICAL GRADIENT (i) (ft/ft)	DECEMBER 1998 GROUNDWATER ELEVATION (h) (ft-MSL)	DECEMBER 1998 REFERENCE POINT (L) (ft-MSL)	DECEMBER 1998 DELTA h (ft)	DECEMBER 1998 DELTA L (ft)	DECEMBER 1998 VERTICAL GRADIENT (i) (ft/ft)
Building I-1-23											
Source Area											
33MWC-21	Upper Sand	414.41	389.76				411.58	389.76			
33MWC-22	Lower Clay	414.46	377.06	-0.05	12.70	-0.004	411.36	377.06	0.22	12.70	0.017
33MWC-22	Lower Clay	414.46	377.06				411.36	377.06			
33MWC-23	Lower Sand	411.18	326.01	3.28	51.05	0.064	409.64	326.01	1.72	51.05	0.034
33MWC-21	Upper Sand	414.41	389.76				411.58	389.76			
33MWC-23	Lower Sand	411.18	326.01	3.23	63.75	0.051	409.64	326.01	1.94	63.75	0.030
Downgradient											
33MWC-30	Upper Sand	406.84	387.44				406.53	387.44			
33MWC-31	Lower Clay	407.01	368.38	-0.17	19.06	-0.009	406.71	368.38	-0.18	19.06	-0.009
33MWC-31	Lower Clay	407.01	368.38				406.71	368.38			
33MWC-32	Lower Sand	410.41	331.86	-3.40	36.52	-0.093	409.55	331.86	-2.84	36.52	-0.078
33MWC-30	Upper Sand	406.84	387.44				406.53	387.44			
33MWC-32	Lower Sand	410.41	331.86	-3.57	55.58	-0.064	409.55	331.86	-3.02	55.58	-0.054

Table 4-6
Summary of Vertical Gradient Calculations
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

WELL NUMBER	WELL TYPE	AUGUST 1998 GROUNDWATER ELEVATION (h) (ft-MSL)	AUGUST 1998 REFERENCE POINT (L) (ft-MSL)	AUGUST 1998 DELTA h (ft)	AUGUST 1998 DELTA L (ft)	AUGUST 1998 VERTICAL GRADIENT (i) (ft/ft)	DECEMBER 1998 GROUNDWATER ELEVATION (h) (ft-MSL)	DECEMBER 1998 REFERENCE POINT (L) (ft-MSL)	DECEMBER 1998 DELTA h (ft)	DECEMBER 1998 DELTA L (ft)	DECEMBER 1998 VERTICAL GRADIENT (i) (ft/ft)
Area 9 Repository											
Source Area											
33MWC-27	Upper Sand	412.25	387.50				410.30	387.50			
33MWC-28	Lower Clay	408.19	375.13	4.06	12.37	0.328	410.26	375.13	0.04	12.37	0.003
33MWC-28	Lower Clay	408.19	375.13				410.26	375.13			
33MWC-29	Lower Sand	410.85	334.97	-2.66	40.16	-0.066	409.59	334.97	0.67	40.16	0.017
33MWC-27	Upper Sand	412.25	387.50				410.30	387.50			
33MWC-29	Lower Sand	410.85	334.97	1.40	52.53	0.027	409.59	334.97	0.71	52.53	0.014
Downgradient											
33MWC-39	Upper Sand	406.72	389.27				406.73	389.27			
33MWC-41	Lower Sand	411.04	325.61	-4.32	63.66	-0.068	409.38	325.61	-2.65	63.66	-0.042
Building I-1-2											
Downgradient											
33MWC-33	Upper Sand	415.45	393.91				412.70	393.91			
33MWC-35	Lower Sand	412.38	350.75	3.07	43.16	0.071	410.56	350.75	2.14	43.16	0.050

Notes:

Vertical Gradient (i) = Delta h / Delta L; Positive values indicate downward groundwater flow.

Reference Point (L) for head measurements (h) is the water table for water table wells and the midpoint of the screened interval for piezometers including the sand filter pack.

Delta h = the distance between head measurements

Delta L = the distance between reference points

Prepared by: MLW 1/27/99

Checked by: SSM 1/27/99

Table 6-1
Crab Orchard National Wildlife Refuge-PCB Operable Unit-Laboratory Qualifiers

INORGANIC DATA	
B	Analyte value is below the Quantitation Limit.
D	Analyte value is from a diluted analysis.
H	Analysis was performed past holding time.
E	ICP serial dilution exceeded the control limits.
J	Reported value is less than the reporting limit but greater than zero.
U	Analyte was tested for but was not detected; value indicates the detection limit.
ORGANIC DATA	
B	Analyte was present in the method blank.
D	Analyte value is from a diluted analysis.
E	Reported concentration exceeded the calibration range of the instrument.
J	Reported value is less than the reporting limit but greater than zero.
P	The difference for detected pesticide/Aroclor result between the two GC columns is greater than 25 percent.
U	The compound was analyzed for but not detected, the value indicates the detection limit.

Data Validation Qualifiers

b	Analyte was present in the trip blank.
f	Analyte was present in the field blank.
h	Analyte was present in the laboratory holding/storage blank.
u	Analyte was present at less than 10 times the concentration in the associated method (B), trip (b), field (f), and/or laboratory storage blank for common laboratory contaminants, or at less than 5 times the blank concentration of other analytes, and is therefore qualified as nondetectable (u) according to USEPA data validation procedures (USEPA, 1994a and 1994b). The reports of 4,4'-DDT, 4,4'-DDE, and 4,4'DDD below the Quantitation Limits are believed to be false-positives representing baseline interference and/or Aroclor peaks. Therefore, u-qualifiers indicate that the results should be considered nondetected.
j	When specific QC criteria are outside the established control limits, the reported concentration or the Quantitation Limit is approximate.
R	*(Pre-1997 data)** Unreliable result. Analyte may or may not be present in the sample. Supporting data necessary to confirm result. *QC criteria for calibration were not met and/or reported concentration exceeded calibration range of instrument.*

* Qualifier description is taken from the Final Supplemental Investigation Report, Revision 2 (IT Corp., 9/95b). Text in italics added by RMT, 2/99.

No entry in the summary analytical tables indicates that the analysis was either not performed, or the parameter was not detected in the sample.

Table 6-2

Summary of Volatile and Semivolatile Organic Compounds and PCBs

Detected in Baseline and Background Groundwater and Surface Water Samples - February 1995

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	32-061 02/07/1995	32-063 02/07/1995	33-341 02/06/1995	33-342 02/06/1995	33MWC-01 02/05/1995	33MWC-02 02/07/1995	33MWC-03 02/05/1995	33MWC-04 02/08/1995	33MWC-05 02/06/1995	33MWC-06 02/06/1995	32SW-01 02/02/1995	33SW-03 02/03/1995	SW32R-236 02/07/1995	SW32R-240 02/06/1995	SW32R-242 02/06/1995
VOCs																
1,1-DICHLOROETHENE	µg/L			0.6	0.1 J		0.5									
1,3-DICHLOROBENZENE	µg/L			0.2 J												
1,4-DICHLOROBENZENE	µg/L			0.5												
BENZENE	µg/L	0.2 J														
CIS-1,2-DICHLOROETHENE	µg/L			180 R	47		47 R	16					19	8	2	
METHYLENE CHLORIDE	µg/L											0.4 J				
TOLUENE	µg/L					0.2 J										
TRANS-1,2-DICHLOROETHENE	µg/L			2			0.5									
TRICHLOROETHENE	µg/L		4	290 R	390 R		1400 R	340					60 r	16	0.5	
SVOCs																
BENZO(A)ANTHRACENE	µg/L					0.7 J										
BENZO(A)PYRENE	µg/L					0.2 J										
CHRYSENE	µg/L					0.6 J										
FLUORANTHENE	µg/L					1 J			1 J		0.7 J					
PHENANTHRENE	µg/L					0.7 J			1 J	0.8 J						
PYRENE	µg/L					5 J		0.9 J	2 J	0.9 J						
PCBs																
AROCLOR-1248	µg/L															1.9 J
AROCLOR-1254	µg/L			15												2.9 J

Notes:

No entry indicates that the parameter was not detected in the sample.

Table 6-3
Summary of Metals Detected in Baseline and Background
Groundwater and Surface Water Samples - February 1995
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL[5]	32-061 02/07/1995	32-062 02/06/1995	32-063 02/07/1995	32-109 02/05/1995	32-110 02/05/1995	33-340 02/07/1995	33-341 02/06/1995	33-342 02/06/1995	33MWC-01 02/05/1995	33MWC-02 02/07/1995	33MWC-03 02/05/1995
ALUMINUM, DISSOLVED	µg/L	NS								19500			
ALUMINUM, TOTAL	µg/L	NS		27500	7380	7670		2510 R	17700		34500	53700	109000
ANTIMONY, DISSOLVED	µg/L	6										2.3 B	
ANTIMONY, TOTAL	µg/L	6							2.1 J			7 B	15.3 J
ARSENIC, TOTAL	µg/L	50[1]										35.6	38.5 J
BARIUM, DISSOLVED	µg/L	2,000	85.7 J				89.7 J				88.9 J	166 J	
BARIUM, TOTAL	µg/L	2,000	102 J	176 J	100 J	133 J	100 J		294	102 J	412	536	809
BERYLLIUM, TOTAL	µg/L	4											
CADMIUM, DISSOLVED	µg/L	5				1.1 J							
CADMIUM, TOTAL	µg/L	5		1.5 J	1.9 J	1.3 J		1.2 J	1.6 J	1.1 J	1.5 J		
CALCIUM, DISSOLVED	µg/L	NS				162000						3020000	
CALCIUM, TOTAL	µg/L	NS				157000						352000	
CHROMIUM, DISSOLVED	µg/L	100											
CHROMIUM, TOTAL	µg/L	100	26 J	60.8	1330 J	155		56.7 J	324 J	40.1	63.9	98.4 B	208
COBALT, TOTAL	µg/L	NS		19.3 J		21.2 J			18.7 J		29.1 J	38.4 J	83.9 J
COPPER, DISSOLVED	µg/L	[2]											
COPPER, TOTAL	µg/L	[2]											143
IRON, DISSOLVED	µg/L	NS											457
IRON, TOTAL	µg/L	NS	1550	43100		12400	759	3360	20200	16500	58200	85500	107000
LEAD, TOTAL	µg/L	[3]		15.8	2.4 J			2.5 J	17.9	5.3 J	27.1	74	124
MAGNESIUM, DISSOLVED	µg/L	NS	36000 R	35800		86200				48800		144000	39200
MAGNESIUM, TOTAL	µg/L	NS	38800	39400		81100				47500		146000	53000
MANGANESE, DISSOLVED	µg/L	NS	741	111		2040			254		717	1120	1570
MANGANESE, TOTAL	µg/L	NS	946	628	347	4560		246	794	233	1700	3610	2630
MERCURY, TOTAL	µg/L	2											0.33
NICKEL, DISSOLVED	µg/L	NS							99.9			30.2 J	179
NICKEL, TOTAL	µg/L	NS		54.2	463	64.2		84.6	212	34.8 J	88.5	129	
POTASSIUM, DISSOLVED	µg/L	NS											
POTASSIUM, TOTAL	µg/L	NS											
SELENIUM, DISSOLVED	µg/L	50						9.4					
SELENIUM, TOTAL	µg/L	50						7					
SILVER, TOTAL	µg/L	NS											
SODIUM, DISSOLVED	µg/L	NS	139000 R			208000 J	201000	187000 R				226000 R	
SODIUM, TOTAL	µg/L	NS	144000 R	134000		202000	191000	187000 R		172000		247000 R	136000
VANADIUM, TOTAL	µg/L	NS		51.3	21 J				33.6 J	38.3 J	68.6	111	190
ZINC, DISSOLVED	µg/L	NS											
ZINC, TOTAL	µg/L	NS		133					150		213	215	743

Notes:
No entry indicates that the parameter was not detected in the sample.
(1) Under review.
(2) Copper action level = 1,300 µg/L.
(3) Standard applied at tap. Lead action level = 15 µg/L.
(4) Refer to Table 6-12 for the Illinois General Use Water Quality Standards for Crab Orchard Lake.
(5) Federal Maximum Contaminant Level.
NS = no standard.

Table 6-3
Summary of Metals Detected in Baseline and Background
Groundwater and Surface Water Samples - February 1995
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL[5]	33MWC-04 02/06/1995	33MWC-05 02/06/1995	33MWC-06 02/06/1995	32SW-01 02/02/1995	32SW-02 02/03/1995	33SW-03 02/03/1995	SW32R-103 02/07/1995	SW32R-236 02/07/1995	SW32R-237 02/07/1995	SW32R-240 02/08/1995	SW32R-242 02/08/1995
ALUMINUM, DISSOLVED	µg/L	NS				87.8 J	79.5 J	67.7 J					
ALUMINUM, TOTAL	µg/L	NS	36300	86400	79400	2990	4250	1690	2710 R			4690	5890
ANTIMONY, DISSOLVED	µg/L	6					2.3 J	2.5 J					
ANTIMONY, TOTAL	µg/L	6	5.6 B						2.1 J	4.1 J			
ARSENIC, TOTAL	µg/L	50[1]	32.3		40.1								
BARIUM, DISSOLVED	µg/L	2,000				29.3 J	27.2 J	51.1 J					
BARIUM, TOTAL	µg/L	2,000	421	505	725	47.2 J	51.5 K	55.5 J					
BERYLLIUM, TOTAL	µg/L	4		2.2 J	2.3 J								
CADMIUM, DISSOLVED	µg/L	5											
CADMIUM, TOTAL	µg/L	5											
CALCIUM, DISSOLVED	µg/L	NS				40100	40200	90400					126000 R
CALCIUM, TOTAL	µg/L	NS				35100	41000	95300					126000 R
CHROMIUM, DISSOLVED	µg/L	100				1 J			6.2 B				
CHROMIUM, TOTAL	µg/L	100	55.6 B	123	137	1 J	2.3 J		13.7 J			3.5 J	3.3 J
COBALT, TOTAL	µg/L	NS	29 J	55.8 J	57.2 J								
COPPER, DISSOLVED	µg/L	[2]				4.5 J	6.1 J	6.5 J					
COPPER, TOTAL	µg/L	[2]				6.6 J	7.1 J	4.3 J					
IRON, DISSOLVED	µg/L	NS			1350	49.9 J	48.5 J						
IRON, TOTAL	µg/L	NS	55000	81400	132000	3060	4050	966		391	2280	4600	6010
LEAD, TOTAL	µg/L	[3]	23.4	61.6	58.2				2.5 J			2.9 J	5
MAGNESIUM, DISSOLVED	µg/L	NS				16000	14700	59900					52400 R
MAGNESIUM, TOTAL	µg/L	NS		36400		14200	15300	58400					55500 R
MANGANESE, DISSOLVED	µg/L	NS		231	104	153	111	302		105 R	170 R	207	191 R
MANGANESE, TOTAL	µg/L	NS	921	1410	2740	330	308	317	146 R	115 R	264	353	307
MERCURY, TOTAL	µg/L	2			0.27								
NICKEL, DISSOLVED	µg/L	NS											
NICKEL, TOTAL	µg/L	NS	59.7	119	143		4.5 J						
POTASSIUM, DISSOLVED	µg/L	NS				3870 J	3670 J	2070 J					
POTASSIUM, TOTAL	µg/L	NS				3960 J	4210 J	2120 J					
SELENIUM, DISSOLVED	µg/L	50	5.3										
SELENIUM, TOTAL	µg/L	50	8.9										
SILVER, TOTAL	µg/L	NS									1.1 J		
SODIUM, DISSOLVED	µg/L	NS				24200 J	23100 J	110000 J					139000 R
SODIUM, TOTAL	µg/L	NS				24000	24600	108000					147000 R
VANADIUM, TOTAL	µg/L	NS	75.3	151	165		7.7 J						
ZINC, DISSOLVED	µg/L	NS				7.8 J	7.5 J	10.3 J					
ZINC, TOTAL	µg/L	NS	232	328	363	33.7	34.4	9.8 J					

Notes:
No entry indicates that the parameter was not detected in the sample.
(1) Under review.
(2) Copper action level = 1,300 µg/L.
(3) Standard applied at tap. Lead action level = 15 µg/L.
(4) Refer to Table 6-12 for the Illinois General Use Water Quality Standards for Crab Orchard Lake.
(5) Federal Maximum Contaminant Level.
NS = no standard.

Table 6-4
Summary of Dioxins and Furans Detected in Baseline and Background
Groundwater and Surface Water Samples - February 1995
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	32-061 02/07/1995	32-062 02/06/1995	32-063 02/07/1995	32-109 02/05/1995	33-340 02/07/1995	33-341 02/06/1995	33-342 02/06/1995	33MWC-01 02/05/1995	33MWC-02 02/07/1995	33MWC-03 02/05/1995	33MWC-04 02/08/1995	33MWC-05 02/06/1995	33MWC-06 02/06/1995
Groundwater Samples														
1,2,3,4,6,7,8-HPCDD	ng/L	0.082	0.0146 J	0.303	0.0582	0.0672	0.0415	0.0355 J	0.0046 B	0.0151 J	0.0139 B		0.0179 J	0.0142 J
1,2,3,4,6,7,8-HPCDF	ng/L	0.0555	0.0032 B	0.0429 J	0.0101 J	0.0337 J	0.026 J	0.0065 B		0.0032 J				
1,2,3,4,7,8,9-HPCDF	ng/L	0.0035 J		0.0043 J			0.0112 J							
1,2,3,4,7,8-HXCDD	ng/L			0.0012 J										
1,2,3,4,7,8-HXCDF	ng/L	0.0213 J		0.0142 J	0.0045 J	0.0177 J	0.0345 J							
1,2,3,6,7,8-HXCDD	ng/L	0.0059 J		0.0253 J	0.0036 J	0.0052 J		0.0029 J						
1,2,3,6,7,8-HXCDF	ng/L	0.0126 J		0.0098 J	0.0026 J	0.0068 J	0.0142 J	0.0013 J						
1,2,3,7,8,9-HXCDD	ng/L			0.0039 J		0.0043 J		0.0022 J						
1,2,3,7,8,9-HXCDF	ng/L						0.0012 J							
1,2,3,7,8-PECDF	ng/L	0.0048 J		0.0068 J	0.0023 J	0.0036 J	0.0037 J							
2,3,4,7,8-PECDF	ng/L	0.007 J		0.0046 J	0.0022 J	0.0066 J	0.0075 J							
2,3,7,8-TCDF	ng/L	0.0118	0.0014 J	0.0058 J	0.0022 J	0.003 J	0.0218							
OCDD	ng/L	1.11 B	0.259 B	2.43 B	0.986 J	1.22 B	1.04 B	0.443 J	0.434 B	0.426 B	0.537 B	0.355 B	3.63 B	0.756 B
OCDF	ng/L	0.0639 B	0.0062 J	0.0785 B	0.0238 J	0.0397 B	0.0672 B	0.0198 B						
TOTAL HPCDD	ng/L	0.161	0.0262 J	0.492	0.1	0.125	0.13	0.0717 J	0.0046 B	0.0276 J	0.0365 B		0.0465 J	0.0299 J
TOTAL HPCDF	ng/L	0.0853	0.0081 B	0.14	0.0255 J	0.0571 J	0.0665 J	0.0196 J		0.0095 J				0.0081 B
TOTAL HXCDD	ng/L	0.0278 J		0.0679	0.0036 J	0.0274 J	0.028 J	0.011 J			0.012 J		0.0158 J	
TOTAL HXCDF	ng/L	0.121 B		0.192 B	0.0376 J	0.0847 B	0.131 B	0.0204 J		0.0105 B				0.0159 BJQ
TOTAL PECDD	ng/L	0.0052 J											0.0051 J	
TOTAL PECDF	ng/L	0.139	0.002 J	0.104	0.0265 J	0.0771	0.142 J	0.0035 J						
TOTAL TCDD	ng/L	0.0149		0.0055 J	0.0033 J	0.0044 J	0.0109				0.006 J		0.0249	
TOTAL TCDF	ng/L	0.225		0.0609	0.0063 J	0.0684	0.208							

Notes:
No entry indicates that the parameter was not detected in the sample.

Table 6-4
Summary of Dioxins and Furans Detected in Baseline and Background
Groundwater and Surface Water Samples - February 1995
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	32SW-1 (02/02/1995)	32SW-2 (02/03/1995)	33SW-3 (02/03/1995)	32R-103 (02/07/1995)	32R-236 (02/07/1995)	32R-237 (02/07/1995)	32R-240 (02/08/1995)	32R-242 (02/08/1995)
Surface Water Samples									
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	ng/L	0.034 J	0.0379 J	0.011 J	0.027 J		0.105	0.105	0.225
1,2,3,4,6,7,8-Heptachlorodibenzofuran	ng/L		0.0028 J	0.004 J	0.002 J	0.0014 J	0.0081 J	0.0048 J	0.229 J
1,2,3,4,7,8,9-Heptachlorodibenzofuran	ng/L								0.0468 J
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	ng/L								0.006 J
1,2,3,4,7,8-Hexachlorodibenzofuran	ng/L					0.002 J	0.0069 J	0.0036 J	0.281
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	ng/L						0.0041 J		0.0106 J
1,2,3,6,7,8-Hexachlorodibenzofuran	ng/L				0.001 J		0.0036 J	0.0026 J	0.120
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	ng/L						0.005 J		0.0093 J
1,2,3,7,8-Pentachlorodibenzofuran	ng/L								0.024 B
2,3,4,6,7,8-Hexachlorodibenzofuran	ng/L	0.0017 B	0.002 B	0.0022 B			0.0077 J	0.0036 J	0.0226 J
2,3,4,6,7,8-Pentachlorodibenzofuran	ng/L						0.0102 J	0.0049 J	0.0897
2,3,7,8-TCDF	ng/L	0.0025 J			0.0054 J	0.0023 J	0.0485	0.0168	0.248
Heptachlorodibenzo-p-dioxin	ng/L	0.0844	0.0929	0.0213 J	0.0684 J		0.272	0.278	0.452
Heptachlorodibenzofuran	ng/L	0.002 J	0.0053 J	0.0071 J	0.0038 J	0.0014 J	0.0125 J	0.009 J	0.435 J
Hexachlorodibenzo-p-dioxin	ng/L	0.007 J	0.0083 J	0.0031 J	0.0079 J		0.0281 J	0.0141 J	0.0501 J
Hexachlorodibenzofuran	ng/L	0.0065 B	0.0083 B	0.0037 B			0.0349 J	0.0247 J	0.916 B
Octachlorodibenzo-p-dioxin	ng/L	1.25 B	1.63 B	0.27 B	1.12 B	0.141 B	5.15 B	5.15 B	7.79 B
Octachlorodibenzofuran	ng/L	0.0049 J	0.0055 J	0.0115 J			0.0086 B	0.0078 B	0.179 B
Pentachlorodibenzo-p-dioxin	ng/L						0.0055 J		
Pentachlorodibenzofuran	ng/L		0.0019 J		0.0115 J	0.0043 J	0.115	0.0591	1.37
Tetrachlorodibenzo-p-dioxin	ng/L						0.0031 J		
Total TCDF	ng/L				0.0494 J	0.0169 J	0.344	0.153	2.48

Notes:
No entry indicates that the parameter was not detected in the sample.

Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	32-061	32-063			32-109	33-340	33-341		
				04/17/1996	04/18/1996	09/04/1997	12/16/1998	04/16/1996	9/4/1997	04/18/1996	9/4/1997	12/16/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7				1			0.8		0.8 J
1,2,4-TRICHLOROBENZENE	µg/L	70	70							0.4 J		
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170								180	
1,3-DICHLOROBENZENE	µg/L	NE	NS							0.2 J		
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS									
BENZENE	µg/L	5	5[3]									
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS									
CARBON TETRACHLORIDE	µg/L	5	5									
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS									
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70				1.1	1		140		238.5 D
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]									
METHANE	µg/L	NE	NS								3.1	
METHYLENE CHLORIDE	µg/L	5	NS			3 J			1 JB		2 JB	
TETRACHLOROETHENE	µg/L	5	5									
TOLUENE	µg/L	1000	1,000[3]									
TRANS-1,2-DICHLOROETHENE	µg/L	100	100							2		4.2
TRICHLOROETHENE	µg/L	5	5		4	6 J	11.4 bf			760	350	388.5 Dbf
VINYL CHLORIDE	µg/L	2	2									0.8 J
XYLENE, M + P	µg/L	NE	NS	0.2 J								
XYLENE, TOTAL	µg/L	10,000	10,000[3]									

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.

(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.

(4) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
NS = no standard.

Indicates an MCL exceedance

Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33-342			33MWC-01	33MWC-02		
				04/18/1996	9/4/1997	12/11/1998	9/4/1997	04/18/1996	9/4/1997	12/09/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS							
1,1,2-TRICHLOROETHANE	µg/L	5	5			2.4				1.6
1,1-DICHLOROETHANE	µg/L	NE	NS							
1,1-DICHLOROETHENE	µg/L	7	7					0.5		0.6 J
1,2,4-TRICHLOROBENZENE	µg/L	70	70							
1,2-DICHLOROBENZENE	µg/L	600	600							
1,2-DICHLOROETHANE	µg/L	5	5							
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170		49				**74**	
1,3-DICHLOROBENZENE	µg/L	NE	NS							
1,4-DICHLOROBENZENE	µg/L	75	75							
2-BUTANONE	µg/L	NE	NS							
4-METHYL-2-PENTANONE	µg/L	NE	NS							
ACETONE	µg/L	NE	NS							
BENZENE	µg/L	5	5[3]							
BROMODICHLOROMETHANE	µg/L	80[2]	NS							
CARBON DISULFIDE	µg/L	NE	NS							
CARBON TETRACHLORIDE	µg/L	5	5							
CHLOROBENZENE	µg/L	100	NS							1.4
CHLOROFORM	µg/L	80[2]	NS	0.1 J						
CHLOROMETHANE	µg/L	NE	NS							
CIS-1,2-DICHLOROETHENE	µg/L	70	70	66		**306 D**		38		65 JDf
ETHANE	µg/L	NE	NS							
ETHYLBENZENE	µg/L	700	NS[3]							
METHANE	µg/L	NE	NS		12 B	30.6 Bf	2.5		2.4	
METHYLENE CHLORIDE	µg/L	5	NS		2 JB		3 JB		2 JB	
TETRACHLOROETHENE	µg/L	5	5	0.3 J						
TOLUENE	µg/L	1000	1,000[3]							
TRANS-1,2-DICHLOROETHENE	µg/L	100	100			3.1				
TRICHLOROETHENE	µg/L	5	5	**720**	**450**	**1789 Dbf**		**760**	**780**	**881 Dbf**
VINYL CHLORIDE	µg/L	2	2	**2**		**4.4**		0.2 J		
XYLENE, M + P	µg/L	NE	NS							
XYLENE, TOTAL	µg/L	10,000	10,000[3]							

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.

(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.

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Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33MWC-03			33MWC-05	33MWC-06	33MWC-07		33MWC-08	
				04/14/1996	9/4/1997	12/15/1998	9/4/1997	9/4/1997	09/09/1997	12/09/1998	09/09/1997	12/08/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5						38	26.4 Ej		
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7						20	11.1	2 J	2
1,2,4-TRICHLOROBENZENE	µg/L	70	70						2 J	3 J		
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170		17				12000 D		390 D	
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS						19000 D			
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS						200 E			
BENZENE	µg/L	5	5[3]						2200 D	994.8 Ej		
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS									
CARBON TETRACHLORIDE	µg/L	5	5							1.6		
CHLOROBENZENE	µg/L	100	NS						39000 D	9375 D		1.2
CHLOROFORM	µg/L	80[2]	NS	0.2 J					28			
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70	21		21.2				4850 D		1639 D
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]						4 J			
METHANE	µg/L	NE	NS		7.5		2.4	2.5	12.4	13.2 Bf		
METHYLENE CHLORIDE	µg/L	5	NS		2 JB		2 JB	3 JB	120 B		3 JB	
TETRACHLOROETHENE	µg/L	5	5	10	9 J	8.6			640 D	375.2 Ej	46	13.9
TOLUENE	µg/L	1000	1,000[3]						2000 D	548.3 Ej		
TRANS-1,2-DICHLOROETHENE	µg/L	100	100			0.6 J				26.5 Ej		14.9
TRICHLOROETHENE	µg/L	5	5	520	260	430 Dbf			66000 D	28600 Dbf	4400 D	1117 Dbf
VINYL CHLORIDE	µg/L	2	2						23	8.7	2 J	0.7 J
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]						18			

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.
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Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33MWC-09		33MWC-10	33MWC-11		33MWC-12	33MWC-13	
				9/4/1997	12/11/1998	09/08/1997	09/08/1997	12/07/1998	09/09/1997	09/09/1997	12/11/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS								
1,1,2-TRICHLOROETHANE	µg/L	5	5	59	33.7 Ej					13	7.3
1,1-DICHLOROETHANE	µg/L	NE	NS		0.9 J						
1,1-DICHLOROETHENE	µg/L	7	7	19							
1,2,4-TRICHLOROBENZENE	µg/L	70	70								
1,2-DICHLOROBENZENE	µg/L	600	600					2.2			1.2
1,2-DICHLOROETHANE	µg/L	5	5		1.2						
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170	6900						1600 D	
1,3-DICHLOROBENZENE	µg/L	NE	NS								
1,4-DICHLOROBENZENE	µg/L	75	75								
2-BUTANONE	µg/L	NE	NS								
4-METHYL-2-PENTANONE	µg/L	NE	NS								
ACETONE	µg/L	NE	NS								
BENZENE	µg/L	5	5[3]	4 J	3.4						
BROMODICHLOROMETHANE	µg/L	80[2]	NS						1 J		
CARBON DISULFIDE	µg/L	NE	NS								
CARBON TETRACHLORIDE	µg/L	5	5								
CHLOROBENZENE	µg/L	100	NS								
CHLOROFORM	µg/L	80[2]	NS	21 B					11	11	
CHLOROMETHANE	µg/L	NE	NS								
CIS-1,2-DICHLOROETHENE	µg/L	70	70		2400 D						1400 D
ETHANE	µg/L	NE	NS								
ETHYLBENZENE	µg/L	700	NS[3]								
METHANE	µg/L	NE	NS		542 Df	3.5				15.7	57.8 Df
METHYLENE CHLORIDE	µg/L	5	NS	2 JB		1 JB	3 JB		6 JB	3 JB	
TETRACHLOROETHENE	µg/L	5	5	260	174 Ej					36	24.4
TOLUENE	µg/L	1000	1,000[3]								
TRANS-1,2-DICHLOROETHENE	µg/L	100	100		57.4 Ej						7.2
TRICHLOROETHENE	µg/L	5	5	40000	32600 Dbf				6 J	26000 D	27300 Dbf
VINYL CHLORIDE	µg/L	2	2	23	13.8					18	9.1
XYLENE, M + P	µg/L	NE	NS								
XYLENE, TOTAL	µg/L	10,000	10,000[3]								

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.

(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.

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Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33MWC-14		33MWC-15	33MWC-16		33MWC-17		33MWC-18
				09/09/1997	12/11/1998	09/08/1997	9/4/1997	12/14/1998	9/4/1997	12/09/1998	9/4/1997
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS								4 J
1,1,2-TRICHLOROETHANE	µg/L	5	5								
1,1-DICHLOROETHANE	µg/L	NE	NS								
1,1-DICHLOROETHENE	µg/L	7	7					1.4			
1,2,4-TRICHLOROBENZENE	µg/L	70	70	50	**95 D**		**170**	**87**			
1,2-DICHLOROBENZENE	µg/L	600	600	3 J	4.3		5 J	2.3			
1,2-DICHLOROETHANE	µg/L	5	5								
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170	16			**110**		4 J		
1,3-DICHLOROBENZENE	µg/L	NE	NS	6 J	10						
1,4-DICHLOROBENZENE	µg/L	75	75	5 J	7.1		8 J	3			
2-BUTANONE	µg/L	NE	NS								
4-METHYL-2-PENTANONE	µg/L	NE	NS								
ACETONE	µg/L	NE	NS								
BENZENE	µg/L	5	5[3]				1 J				
BROMODICHLOROMETHANE	µg/L	80[2]	NS						1 J		
CARBON DISULFIDE	µg/L	NE	NS								
CARBON TETRACHLORIDE	µg/L	5	5								
CHLOROBENZENE	µg/L	100	NS		1.6		18	9.3			
CHLOROFORM	µg/L	80[2]	NS	4 J			13 B		9 JB		4 JB
CHLOROMETHANE	µg/L	NE	NS					2.2			
CIS-1,2-DICHLOROETHENE	µg/L	70	70		10.4			**258 D**		2.4 f	
ETHANE	µg/L	NE	NS								
ETHYLBENZENE	µg/L	700	NS[3]								
METHANE	µg/L	NE	NS	13.5	15.1 Bf			224.5 BDf	3.8		3.7
METHYLENE CHLORIDE	µg/L	5	NS	**5 JB**		2 JB	2 JB		2 JB		3 JB
TETRACHLOROETHENE	µg/L	5	5	**40**	**20.9**		**100**	**25.7 Ej**			1 J
TOLUENE	µg/L	1000	1,000[3]								
TRANS-1,2-DICHLOROETHENE	µg/L	100	100					3.7			
TRICHLOROETHENE	µg/L	5	5	**97**	**11.8 Dbf**		**3200**	**695 Dbf**	**11**	**10.9 bf**	
VINYL CHLORIDE	µg/L	2	2							0.6 J	
XYLENE, M + P	µg/L	NE	NS								
XYLENE, TOTAL	µg/L	10,000	10,000[3]								3 J

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.
(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.
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Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33MWC-19		33MWC-20	33MWC-21		33MWC-22		33MWC-23
				9/4/1997	12/09/1998	9/4/1997	06/25/1998	12/14/1998	06/25/1998	12/15/1998	06/25/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS								
1,1,2-TRICHLOROETHANE	µg/L	5	5					3.6			
1,1-DICHLOROETHANE	µg/L	NE	NS								
1,1-DICHLOROETHENE	µg/L	7	7					1.5			
1,2,4-TRICHLOROBENZENE	µg/L	70	70					0.7 J			
1,2-DICHLOROBENZENE	µg/L	600	600							0.5 J	
1,2-DICHLOROETHANE	µg/L	5	5								
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170								
1,3-DICHLOROBENZENE	µg/L	NE	NS								
1,4-DICHLOROBENZENE	µg/L	75	75								
2-BUTANONE	µg/L	NE	NS								
4-METHYL-2-PENTANONE	µg/L	NE	NS								
ACETONE	µg/L	NE	NS					11			
BENZENE	µg/L	5	5[3]				1 J	4			
BROMODICHLOROMETHANE	µg/L	80[2]	NS			3 J					
CARBON DISULFIDE	µg/L	NE	NS								
CARBON TETRACHLORIDE	µg/L	5	5					0.8 J			
CHLOROBENZENE	µg/L	100	NS				21	12.8			
CHLOROFORM	µg/L	80[2]	NS	4 JB		20 B			9 J		
CHLOROMETHANE	µg/L	NE	NS								
CIS-1,2-DICHLOROETHENE	µg/L	70	70				33	226 D	1 J		
ETHANE	µg/L	NE	NS								
ETHYLBENZENE	µg/L	700	NS[3]								
METHANE	µg/L	NE	NS	3.5		1.7					
METHYLENE CHLORIDE	µg/L	5	NS	2 JB			4 JB		4 JB		4 JB
TETRACHLOROETHENE	µg/L	5	5				5 J	246 D			
TOLUENE	µg/L	1000	1,000[3]		2				210 E		
TRANS-1,2-DICHLOROETHENE	µg/L	100	100				3 J	2			
TRICHLOROETHENE	µg/L	5	5				490 D	2624 Dbf	4 J		
VINYL CHLORIDE	µg/L	2	2								
XYLENE, M + P	µg/L	NE	NS								
XYLENE, TOTAL	µg/L	10,000	10,000[3]								

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.

(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.

(4) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

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MCL = Federal Maximum Contaminant Level
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Indicates an MCL exceedance

Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33MWC-24		33MWC-27			33MWC-28		
				06/26/1998	12/11/1998	06/25/1998	07/09/1998	12/11/1998	06/25/1998	07/09/1998	12/11/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS								
1,1,2-TRICHLOROETHANE	µg/L	5	5				24 J	19.6	25		
1,1-DICHLOROETHANE	µg/L	NE	NS								
1,1-DICHLOROETHENE	µg/L	7	7				5 J	6.1	4 J		
1,2,4-TRICHLOROBENZENE	µg/L	70	70								
1,2-DICHLOROBENZENE	µg/L	600	600	37	62 D						
1,2-DICHLOROETHANE	µg/L	5	5				1 J	1.1			
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170								
1,3-DICHLOROBENZENE	µg/L	NE	NS								
1,4-DICHLOROBENZENE	µg/L	75	75	2 J	2 J						
2-BUTANONE	µg/L	NE	NS				81			190	
4-METHYL-2-PENTANONE	µg/L	NE	NS								
ACETONE	µg/L	NE	NS							41	
BENZENE	µg/L	5	5[3]				1 J	1.3	1 J		
BROMODICHLOROMETHANE	µg/L	80[2]	NS								
CARBON DISULFIDE	µg/L	NE	NS								
CARBON TETRACHLORIDE	µg/L	5	5								
CHLOROBENZENE	µg/L	100	NS								
CHLOROFORM	µg/L	80[2]	NS								
CHLOROMETHANE	µg/L	NE	NS								
CIS-1,2-DICHLOROETHENE	µg/L	70	70	84	101 D	1 J	850 E	2270 D	1400 D	1 J	0.6 J
ETHANE	µg/L	NE	NS								
ETHYLBENZENE	µg/L	700	NS[3]								
METHANE	µg/L	NE	NS		350 BDf			9.3 Bf			977 BDf
METHYLENE CHLORIDE	µg/L	5	NS						1 JB		
TETRACHLOROETHENE	µg/L	5	5	34	34.1 Ej		39	48.1 Ej	38		
TOLUENE	µg/L	1000	1,000[3]				8 J			5 J	
TRANS-1,2-DICHLOROETHENE	µg/L	100	100				14	25.4 Ej	15		
TRICHLOROETHENE	µg/L	5	5	830 D	1063 Dbf	7 J	3300 E	16770 Dbf	14000 D	2 J	
VINYL CHLORIDE	µg/L	2	2	6 J	6		7 J	5.5	4 J		
XYLENE, M + P	µg/L	NE	NS								
XYLENE, TOTAL	µg/L	10,000	10,000[3]								

Notes:

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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33MWC-29		33MWC-30		33MWC-31		33MWC-32	
				06/25/1998	12/10/1998	06/26/1998	12/15/1998	06/26/1998	12/16/1998	06/26/1998	12/14/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS								
1,1,2-TRICHLOROETHANE	µg/L	5	5								
1,1-DICHLOROETHANE	µg/L	NE	NS								
1,1-DICHLOROETHENE	µg/L	7	7			6 J	5.3				
1,2,4-TRICHLOROBENZENE	µg/L	70	70								1.1
1,2-DICHLOROBENZENE	µg/L	600	600								
1,2-DICHLOROETHANE	µg/L	5	5								
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170								
1,3-DICHLOROBENZENE	µg/L	NE	NS								
1,4-DICHLOROBENZENE	µg/L	75	75								
2-BUTANONE	µg/L	NE	NS								
4-METHYL-2-PENTANONE	µg/L	NE	NS								
ACETONE	µg/L	NE	NS								
BENZENE	µg/L	5	5[3]								
BROMODICHLOROMETHANE	µg/L	80[2]	NS								
CARBON DISULFIDE	µg/L	NE	NS								
CARBON TETRACHLORIDE	µg/L	5	5								
CHLOROBENZENE	µg/L	100	NS								
CHLOROFORM	µg/L	80[2]	NS								
CHLOROMETHANE	µg/L	NE	NS								
CIS-1,2-DICHLOROETHENE	µg/L	70	70	1 J	0.6 J	**400 D**	**530 D**	35	13.2		
ETHANE	µg/L	NE	NS								
ETHYLBENZENE	µg/L	700	NS[3]								
METHANE	µg/L	NE	NS				22.1 Bf		1248 BDf		
METHYLENE CHLORIDE	µg/L	5	NS	3 JB		3 JB		4 JB		3 JB	
TETRACHLOROETHENE	µg/L	5	5								
TOLUENE	µg/L	1000	1,000[3]								
TRANS-1,2-DICHLOROETHENE	µg/L	100	100			25	27.7 Ej	2 J	0.5 J		
TRICHLOROETHENE	µg/L	5	5	**18**	1.3	**2100 D**	**3060 Dbf**	**110**	**24.1 Dbf**		
VINYL CHLORIDE	µg/L	2	2			**2 J**	1.6				
XYLENE, M + P	µg/L	NE	NS								
XYLENE, TOTAL	µg/L	10,000	10,000[3]								

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
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Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	33MWC-33		33MWC-35		33MWC-36		33MWC-39		33MWC-41
				06/30/1998	12/08/1998	06/30/1998	12/09/1998	06/29/1998	12/10/1998	06/29/1998	12/10/1998	06/29/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7		1.8							
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600						1			
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS			11		14				
BENZENE	µg/L	5	5[3]									
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS									
CARBON TETRACHLORIDE	µg/L	5	5									
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS			4 J						
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70	**160**	**284 D**	9 J				3 J		
ETHANE	µg/L	NE	NS		2.9 J							
ETHYLBENZENE	µg/L	700	NS[3]									
METHANE	µg/L	NE	NS		16.4 Bf		13.9 Bf				23.1 B	
METHYLENE CHLORIDE	µg/L	5	NS	4 JB		4 JB				3 JB		3 JB
TETRACHLOROETHENE	µg/L	5	5	**65**	**42.4 Ej**	**6 J**	0.8 J					
TOLUENE	µg/L	1000	1,000[3]									
TRANS-1,2-DICHLOROETHENE	µg/L	100	100	**120**	**200 D**	4 J						
TRICHLOROETHENE	µg/L	5	5	**1100 D**	**2200 Dbf**	**56**		**6 J**	**8.2**	**60**		2 J
VINYL CHLORIDE	µg/L	2	2	**7 J**	**13.7**							
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]									

Notes:

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Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-1A 06/01/1998	GP-2A 06/01/1998	GP-3A 06/01/1998	GP-4A 05/29/1998	GP-5A 06/04/1998	GP-6A 06/04/1998	GP-7A 06/04/1998	GP-8A 06/05/1998	GP-9A 06/05/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7									
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS									
BENZENE	µg/L	5	5[3]									
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS									
CARBON TETRACHLORIDE	µg/L	5	5									
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS									
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70	7 J	21	3 J	6 J					
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]									
METHANE	µg/L	NE	NS									
METHYLENE CHLORIDE	µg/L	5	NS	6 JB	7 JB	6 JB	2 JB	9 JB	1 JB	4 JB	2 JB	2 JB
TETRACHLOROETHENE	µg/L	5	5									
TOLUENE	µg/L	1000	1,000[3]									
TRANS-1,2-DICHLOROETHENE	µg/L	100	100									
TRICHLOROETHENE	µg/L	5	5	1100 D		10 J	7 J			19		2 J
VINYL CHLORIDE	µg/L	2	2				1 J					
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]									

Notes:

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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-10A 06/08/1998	GP-11A 06/08/1998	GP-12A 06/08/1998	GP-13A 06/09/1998	GP-14A 06/11/1998	GP-15A 06/12/1998	GP-16A 06/12/1998	GP-17A 06/12/1998	GP-18A 06/18/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5					29				
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7				3 J	2 J				
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5								2 J	
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS									
BENZENE	µg/L	5	5[3]				2 J					
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS				2 J					
CARBON TETRACHLORIDE	µg/L	5	5								14	
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS					7 J			31	
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70				39	83	2 J		3 J	10 J
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]				2 J					
METHANE	µg/L	NE	NS									
METHYLENE CHLORIDE	µg/L	5	NS	3 JB	3 JB	4 JB		3 JB	3 JB	3 JB	3 JB	10 JB
TETRACHLOROETHENE	µg/L	5	5				210 E	5 J	3 J	3 J	85	
TOLUENE	µg/L	1000	1,000[3]									
TRANS-1,2-DICHLOROETHENE	µg/L	100	100				2 J	1 J				
TRICHLOROETHENE	µg/L	5	5	6 J		1 J	73	6600 E	26	85	22	
VINYL CHLORIDE	µg/L	2	2				4 J					
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]				7 J					

Notes:
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Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-19A 06/18/1998	GP-20A 06/18/1998	GP-21A 06/18/1998	GP-1B 05/27/1998	GP-2B 06/01/1998	GP-3B 05/27/1998	GP-4B 05/27/1998	GP-5B 05/27/1998	GP-6B 06/03/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7	2 J			7 J				2 J	
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS								20	
BENZENE	µg/L	5	5[3]									
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS									
CARBON TETRACHLORIDE	µg/L	5	5	160 D								
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS	71 B								
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70	23	2 J	100	660 D	2 J		1 J	130	4 J
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]									
METHANE	µg/L	NE	NS									
METHYLENE CHLORIDE	µg/L	5	NS	3 JB	3 JB	3 JB	6 JB		1 J		7 JB	3 JB
TETRACHLOROETHENE	µg/L	5	5	290 D	32	9 J					1 J	
TOLUENE	µg/L	1000	1,000[3]								3 J	
TRANS-1,2-DICHLOROETHENE	µg/L	100	100	1 J		4 J						
TRICHLOROETHENE	µg/L	5	5	150	19	28	2300 D	2 J	1 J	6 J	1900 D	
VINYL CHLORIDE	µg/L	2	2	17		11	4 J					
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]									

Notes:

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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-7B 06/01/1998	GP-8B 06/02/1998	GP-9B 06/08/1998	GP-10B 06/11/1998	GP-1C 05/29/1998	GP-2C 05/29/1998	GP-3C 05/29/1998	GP-4C 05/29/1998	GP-5C 06/02/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7									
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS		7 J							10 J
BENZENE	µg/L	5	5[3]									
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS				1 J					
CARBON TETRACHLORIDE	µg/L	5	5									
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS									
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70				67	3 J		**110**	67	
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]									
METHANE	µg/L	NE	NS									
METHYLENE CHLORIDE	µg/L	5	NS	**8 JB**	**25 B**	3 JB		2 JB	1 J B	1 JB	1 JB	**25 B**
TETRACHLOROETHENE	µg/L	5	5							**19**	**5 J**	
TOLUENE	µg/L	1000	1,000[3]									
TRANS-1,2-DICHLOROETHENE	µg/L	100	100				17			2 J		
TRICHLOROETHENE	µg/L	5	5				**93**	**12**		**250 E**	**79**	3 J
VINYL CHLORIDE	µg/L	2	2							**12**		
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]									

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.
(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.
(4) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
NS = no standard.

Indicates an MCL exceedance

Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-6C 06/02/1998	GP-7C 06/03/1998	GP-8C 06/03/1998	GP-9C 06/03/1998	GP-1D 05/28/1998	GP-2D 05/28/1998	GP-3D 05/28/1998	GP-4D 05/28/1998	GP-5D 06/02/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7									
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS	10 J								13
BENZENE	µg/L	5	5[3]									
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS									
CARBON TETRACHLORIDE	µg/L	5	5									
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS									
CHLOROMETHANE	µg/L	NE	NS	8 J								
CIS-1,2-DICHLOROETHENE	µg/L	70	70	2 J					2 J		1 J	11
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]									
METHANE	µg/L	NE	NS									
METHYLENE CHLORIDE	µg/L	5	NS	40 B	3 JB	3 JB	3 JB	4 JB	2 JB	2 JB	3 JB	26 B
TETRACHLOROETHENE	µg/L	5	5	1 J								
TOLUENE	µg/L	1000	1,000[3]					2 J	2 J			
TRANS-1,2-DICHLOROETHENE	µg/L	100	100									
TRICHLOROETHENE	µg/L	5	5	10 J							4 J	1 J
VINYL CHLORIDE	µg/L	2	2									
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]									

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.

(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.

(4) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
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Indicates an MCL exceedance

Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-6D 06/01/1998	GP-7D 06/02/1998	GP-8D 06/05/1998	GP-9D 06/05/1998	GP-10D 06/09/1998	GP-11D 06/10/1998	GP-12D 06/09/1998	GP-13D 06/11/1998	GP-14D 06/12/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7							1 J		
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS		9 J	7 J						
BENZENE	µg/L	5	5[3]								1 J	
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS							1 J		
CARBON TETRACHLORIDE	µg/L	5	5									
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS									
CHLOROMETHANE	µg/L	NE	NS							2 J		
CIS-1,2-DICHLOROETHENE	µg/L	70	70						37	1 J	2 J	
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]							1 J		
METHANE	µg/L	NE	NS									
METHYLENE CHLORIDE	µg/L	5	NS	7 JB	23 B	5 JB	8 JB		2 JB		3 JB	3 JB
TETRACHLOROETHENE	µg/L	5	5							2 J		
TOLUENE	µg/L	1000	1,000[3]								2 J	
TRANS-1,2-DICHLOROETHENE	µg/L	100	100									
TRICHLOROETHENE	µg/L	5	5					3 J	580 D	62	10 J	
VINYL CHLORIDE	µg/L	2	2							1 J		
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]							4 J		

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.
(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.
(4) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

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Indicates an MCL exceedance

Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]

Groundwater Investigation Report and Focused Feasibility Study

Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-1E 07/08/1998	GP-2E 07/07/1998	GP-3E 07/07/1998	GP-4E 07/08/1998	GP-5E 07/08/1998	GP-6E 07/07/1998	GP-7E 07/08/1998	GP-8E 07/08/1998	GP-9E 07/10/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS									
1,1,2-TRICHLOROETHANE	µg/L	5	5									
1,1-DICHLOROETHANE	µg/L	NE	NS									
1,1-DICHLOROETHENE	µg/L	7	7									
1,2,4-TRICHLOROBENZENE	µg/L	70	70									
1,2-DICHLOROBENZENE	µg/L	600	600									
1,2-DICHLOROETHANE	µg/L	5	5									
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170									
1,3-DICHLOROBENZENE	µg/L	NE	NS									
1,4-DICHLOROBENZENE	µg/L	75	75									
2-BUTANONE	µg/L	NE	NS									
4-METHYL-2-PENTANONE	µg/L	NE	NS									
ACETONE	µg/L	NE	NS									
BENZENE	µg/L	5	5[3]									
BROMODICHLOROMETHANE	µg/L	80[2]	NS									
CARBON DISULFIDE	µg/L	NE	NS									
CARBON TETRACHLORIDE	µg/L	5	5									
CHLOROBENZENE	µg/L	100	NS									
CHLOROFORM	µg/L	80[2]	NS									
CHLOROMETHANE	µg/L	NE	NS									
CIS-1,2-DICHLOROETHENE	µg/L	70	70					1 J		5 J		
ETHANE	µg/L	NE	NS									
ETHYLBENZENE	µg/L	700	NS[3]									
METHANE	µg/L	NE	NS									
METHYLENE CHLORIDE	µg/L	5	NS	2 JB	2 JB	2 JB	2 JB	1 JB	2 JB	1 JB	1 JB	
TETRACHLOROETHENE	µg/L	5	5									
TOLUENE	µg/L	1000	1,000[3]									
TRANS-1,2-DICHLOROETHENE	µg/L	100	100									
TRICHLOROETHENE	µg/L	5	5					44		30		4 J
VINYL CHLORIDE	µg/L	2	2							2 J		
XYLENE, M + P	µg/L	NE	NS									
XYLENE, TOTAL	µg/L	10,000	10,000[3]									

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.

(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.

(4) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
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Indicates an MCL exceedence

Table 6-5

Summary of Volatile Organic Compounds Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[4]	GP-10E 07/10/1998	GP-11E 07/10/1998	GP-12E 07/14/1998	GP-13E 07/13/1998	GP-14E 07/13/1998	GP-15E 07/13/1998	GP-16E 07/14/1998	GP-17E 07/14/1998
1,1,2,2-TETRACHLOROETHANE	µg/L	NE	NS								
1,1,2-TRICHLOROETHANE	µg/L	5	5								
1,1-DICHLOROETHANE	µg/L	NE	NS								
1,1-DICHLOROETHENE	µg/L	7	7					5 J			
1,2,4-TRICHLOROBENZENE	µg/L	70	70								
1,2-DICHLOROBENZENE	µg/L	600	600								
1,2-DICHLOROETHANE	µg/L	5	5								
1,2-DICHLOROETHENE, TOTAL	µg/L	70	170								
1,3-DICHLOROBENZENE	µg/L	NE	NS								
1,4-DICHLOROBENZENE	µg/L	75	75								
2-BUTANONE	µg/L	NE	NS								
4-METHYL-2-PENTANONE	µg/L	NE	NS								
ACETONE	µg/L	NE	NS								
BENZENE	µg/L	5	5[3]					2 J			
BROMODICHLOROMETHANE	µg/L	80[2]	NS								
CARBON DISULFIDE	µg/L	NE	NS								
CARBON TETRACHLORIDE	µg/L	5	5								
CHLOROBENZENE	µg/L	100	NS								
CHLOROFORM	µg/L	80[2]	NS								
CHLOROMETHANE	µg/L	NE	NS								
CIS-1,2-DICHLOROETHENE	µg/L	70	70	**310 E**		1 J	25	**850 E**	18	32	
ETHANE	µg/L	NE	NS								
ETHYLBENZENE	µg/L	700	NS[3]								
METHANE	µg/L	NE	NS								
METHYLENE CHLORIDE	µg/L	5	NS							1 JB	
TETRACHLOROETHENE	µg/L	5	5	2 J				**220 E**		**310 D**	1 J
TOLUENE	µg/L	1000	1,000[3]				2 J	2 J			
TRANS-1,2-DICHLOROETHENE	µg/L	100	100	5 J				8 J	1 J		
TRICHLOROETHENE	µg/L	5	5	**130**	2 J	**10 J**	**9 J**	**190**	**13**	**58**	1 J
VINYL CHLORIDE	µg/L	2	2	**9 J**			**2 J**	**670 E**	**5 J**	**7 J**	
XYLENE, M + P	µg/L	NE	NS								
XYLENE, TOTAL	µg/L	10,000	10,000[3]								

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Total for combined trihalomethanes (THM) cannot exceed 80 µg/L. THMs include bromodichloromethane and chloroform.
(3) Standard for sum of benzene, ethylbenzene, toluene, and xylene (BTEX) is 11,705 µg/L.
(4) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
NS = no standard.

Indicates an MCL exceedance

Table 6-6

Summary of Semivolatile Organic Compounds and PCBs Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	32-063	32-109	32-110	33-340	33-341		
				09/04/1997	04/16/1996	04/16/1996	9/4/1997	04/18/1996	9/4/1997	12/16/1998
SVOCs										
2-CHLOROPHENOL	µg/L	NE	NS							
2-METHYLPHENOL	µg/L	NE	NS							
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS							
4-METHYLPHENOL	µg/L	NE	NS							
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6	2 J	3	6	2 JB	3 J		
BUTYLBENZYLPHTHALATE	µg/L	NE	NS							
DI-N-BUTYLPHTHALATE	µg/L	NE	NS				5 JB		8 JB	
DIETHYLPHTHALATE	µg/L	NE	NS							
DIMETHYLPHTHALATE	µg/L	NE	NS							
NAPHTHALENE	µg/L	NE	NS							
PHENOL	µg/L	NE	100							
PCBs			0.5[3]							
AROCLOR-1016	µg/L	0.5	NS							
AROCLOR-1248	µg/L	0.5	NS							1.1 P
AROCLOR-1254	µg/L	0.5	NS					4.3		0.63 J

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

(3) Standard for sum of all Aroclors is 0.5 µg/L.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
NS = no standard.

Indicates an MCL exceedance

Table 6-6

Summary of Semivolatile Organic Compounds and PCBs Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	33-342		33MWC-02		33MWC-03		33MWC-04
				04/18/1996	9/4/1997	04/18/1996	9/4/1997	9/4/1997	12/15/1998	04/18/1996
SVOCs										
2-CHLOROPHENOL	µg/L	NE	NS							
2-METHYLPHENOL	µg/L	NE	NS							
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS							
4-METHYLPHENOL	µg/L	NE	NS							
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6	2 J		4 J	1 JB	2 JB		5 J
BUTYLBENZYLPHTHALATE	µg/L	NE	NS	0.5 J						
DI-N-BUTYLPHTHALATE	µg/L	NE	NS		4 JB					
DIETHYLPHTHALATE	µg/L	NE	NS						1 J	
DIMETHYLPHTHALATE	µg/L	NE	NS							
NAPHTHALENE	µg/L	NE	NS							
PHENOL	µg/L	NE	100							
PCBs			0.5[3]							
AROCLOR-1016	µg/L	0.5	NS							
AROCLOR-1248	µg/L	0.5	NS							
AROCLOR-1254	µg/L	0.5	NS							

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.
(3) Standard for sum of all Aroclors is 0.5 µg/L.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
NS = no standard.

Indicates an MCL exceedance

Table 6-6

Summary of Semivolatile Organic Compounds and PCBs Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	33MWC-05 9/4/1997	33MWC-06 9/4/1997	33MWC-07 09/09/1997	33MWC-07 12/09/1998	33MWC-08 09/09/1997	33MWC-09 9/4/1997	33MWC-10 09/08/1997
SVOCs										
2-CHLOROPHENOL	µg/L	NE	NS				43			
2-METHYLPHENOL	µg/L	NE	NS				4 J			
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS							
4-METHYLPHENOL	µg/L	NE	NS				3 J			
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6	1 JB	1 JB	2 J		2 J	2 JB	2 J
BUTYLBENZYLPHTHALATE	µg/L	NE	NS							
DI-N-BUTYLPHTHALATE	µg/L	NE	NS	3 JB		2 J		1 J		
DIETHYLPHTHALATE	µg/L	NE	NS							
DIMETHYLPHTHALATE	µg/L	NE	NS							
NAPHTHALENE	µg/L	NE	NS				33			
PHENOL	µg/L	NE	100				8 J		240	
PCBs			0.5[3]							
AROCLOR-1016	µg/L	0.5	NS				5.4			
AROCLOR-1248	µg/L	0.5	NS							
AROCLOR-1254	µg/L	0.5	NS							

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

(3) Standard for sum of all Aroclors is 0.5 µg/L.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter. Appendix L summarizes the associated detection limits, where available.

NE = not established.
MCL = Federal Maximum Contaminant Level
NS = no standard.

Indicates an MCL exceedance

Table 6-6

Summary of Semivolatile Organic Compounds and PCBs Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	33MWC-11		33MWC-12	33MWC-13	33MWC-14	33MWC-15
				09/08/1997	12/07/1998	09/09/1997	09/09/1997	09/09/1997	09/08/1997
SVOCs									
2-CHLOROPHENOL	µg/L	NE	NS						
2-METHYLPHENOL	µg/L	NE	NS						
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS						
4-METHYLPHENOL	µg/L	NE	NS						
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6	1 J		2 J	8 J	7 J	2 J
BUTYLBENZYLPHTHALATE	µg/L	NE	NS						
DI-N-BUTYLPHTHALATE	µg/L	NE	NS			3 J	17		
DIETHYLPHTHALATE	µg/L	NE	NS		3 J	4 J	2 J		
DIMETHYLPHTHALATE	µg/L	NE	NS						
NAPHTHALENE	µg/L	NE	NS						
PHENOL	µg/L	NE	100						
PCBs			0.5[3]						
AROCLOR-1016	µg/L	0.5	NS						
AROCLOR-1248	µg/L	0.5	NS						
AROCLOR-1254	µg/L	0.5	NS						

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

(3) Standard for sum of all Aroclors is 0.5 µg/L.

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NE = not established.
MCL = Federal Maximum Contaminant Level
NS = no standard.

Indicates an MCL Exceedance

Table 6-6

Summary of Semivolatile Organic Compounds and PCBs Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	33MWC-16 9/4/1997	33MWC-16 12/14/1998	33MWC-18 9/4/1997	33MWC-19 9/4/1997	33MWC-20 9/4/1997	33MWC-21 06/25/1998
SVOCs									
2-CHLOROPHENOL	µg/L	NE	NS						
2-METHYLPHENOL	µg/L	NE	NS						
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS						
4-METHYLPHENOL	µg/L	NE	NS						
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6	**6 JB**		**8 JB**	**8 JB**	2 JB	1 J
BUTYLBENZYLPHTHALATE	µg/L	NE	NS						
DI-N-BUTYLPHTHALATE	µg/L	NE	NS	6 JB					11 B
DIETHYLPHTHALATE	µg/L	NE	NS						
DIMETHYLPHTHALATE	µg/L	NE	NS						
NAPHTHALENE	µg/L	NE	NS						
PHENOL	µg/L	NE	100						
PCBs			0.5[3]						
AROCLOR-1016	µg/L	0.5	NS		**39 DP**				
AROCLOR-1248	µg/L	0.5	NS						
AROCLOR-1254	µg/L	0.5	NS		**3.4 P**				

Notes:

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Summary of Semivolatile Organic Compounds and PCBs Detected in Groundwater[1]
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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	33MWC-22		33MWC-23	33MWC-24	33MWC-27		
				06/25/1998	12/15/1998	06/25/1998	06/26/1998	06/25/1998	07/09/1998	12/11/1998
SVOCs										
2-CHLOROPHENOL	µg/L	NE	NS							
2-METHYLPHENOL	µg/L	NE	NS							
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS	37	6 J			110 D		
4-METHYLPHENOL	µg/L	NE	NS							
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6	1 J	3 J	**8 J**	2 J	3 J	**48 B**	2 J
BUTYLBENZYLPHTHALATE	µg/L	NE	NS							
DI-N-BUTYLPHTHALATE	µg/L	NE	NS	8 JB		17 B		19 B		
DIETHYLPHTHALATE	µg/L	NE	NS							
DIMETHYLPHTHALATE	µg/L	NE	NS			96 D	2 J			
NAPHTHALENE	µg/L	NE	NS							
PHENOL	µg/L	NE	100							
PCBs			0.5[3]							
AROCLOR-1016	µg/L	0.5	NS							
AROCLOR-1248	µg/L	0.5	NS							
AROCLOR-1254	µg/L	0.5	NS	0.1 J						

Notes:
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(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.
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Table 6-6
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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	33MWC-28			33MWC-29		33MWC-31	
				06/25/1998	07/09/1998	12/11/1998	06/25/1998	12/10/1998	06/26/1998	12/16/1998
SVOCs										
2-CHLOROPHENOL	µg/L	NE	NS							
2-METHYLPHENOL	µg/L	NE	NS							
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS		26	4 J			14	
4-METHYLPHENOL	µg/L	NE	NS							
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6	**14**	**180 D**		**6 J**	1 J	2 J	
BUTYLBENZYLPHTHALATE	µg/L	NE	NS							
DI-N-BUTYLPHTHALATE	µg/L	NE	NS	11 B			16 B		7 J	
DIETHYLPHTHALATE	µg/L	NE	NS			2 J				
DIMETHYLPHTHALATE	µg/L	NE	NS				1 J			
NAPHTHALENE	µg/L	NE	NS							
PHENOL	µg/L	NE	100		4J					6 J
PCBs			0.5[3]							
AROCLOR-1016	µg/L	0.5	NS							
AROCLOR-1248	µg/L	0.5	NS							
AROCLOR-1254	µg/L	0.5	NS							

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.
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Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	33MWC-32 06/26/1998	33MWC-33 06/30/1998	33MWC-35 06/30/1998	33MWC-35 12/09/1998	33MWC-36 06/29/1998	33MWC-39 06/29/1998
SVOCs									
2-CHLOROPHENOL	µg/L	NE	NS						
2-METHYLPHENOL	µg/L	NE	NS						
4-CHLORO-3-METHYLPHENOL	µg/L	NE	NS			130 D	22		
4-METHYLPHENOL	µg/L	NE	NS						
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	6		2 J	19		1 J	1 J
BUTYLBENZYLPHTHALATE	µg/L	NE	NS						
DI-N-BUTYLPHTHALATE	µg/L	NE	NS		8 J	19		10 J	17
DIETHYLPHTHALATE	µg/L	NE	NS						1 J
DIMETHYLPHTHALATE	µg/L	NE	NS	67	4 J			1 J	340 D
NAPHTHALENE	µg/L	NE	NS						
PHENOL	µg/L	NE	100				6 J		
PCBs			0.5[3]						
AROCLOR-1016	µg/L	0.5	NS						
AROCLOR-1248	µg/L	0.5	NS						
AROCLOR-1254	µg/L	0.5	NS						

Notes:

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Table 6-7

Summary of Metals Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	BACKGROUND[3]	SMCL	32-061 04/17/1996	32-062 04/16/1996	32-063 04/18/1996	32-063 09/04/1997	32-109 04/16/1996	32-110 04/16/1996	33-340 04/19/1996
ALUMINUM, DISSOLVED	µg/L	NE	NS		50							
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50	**810**	**33500**	**4370 J**		**2150**	**169 J**	**1760 J**
ANTIMONY, TOTAL	µg/L	6	6		NE		2.8 J					
ARSENIC, TOTAL	µg/L	50	50		NE	3.3 J	22.4					
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE	83.9 J	59.9 J	30.6 J		25.8 J	79.4 J	38.2 J
BARIUM, TOTAL	µg/L	2000	2,000	412	NE	96.3 J	229	69.9 J		44.5 J	95.3 J	50.6 J
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE	1.2 J						
CALCIUM, DISSOLVED	µg/L	NE	NS		NE	79700	88400	39600		170000	22600	47000
CALCIUM, TOTAL	µg/L	NE	NS		NE	79800	113000	41200		175000	23300	45100
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE	26.8	63.6	72.7		39.2		**123**
COBALT, DISSOLVED	µg/L	NE	NS		NE					2.4 J		
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE		29.2 J	4.9 J		4.9 J		2.6 J
COPPER, DISSOLVED	µg/L	1300	NS		NE					3.5 J		2.6 J
COPPER, TOTAL	µg/L	1300	650		NE	5 J	49.3	12.4 J		5.4 J		12.4 J
IRON, DISSOLVED	µg/L	NE	NS		300	271 J						
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3							
IRON, TOTAL	µg/L	NE	5,000	58,200	300	**4110 J**	**62900 J**	**5940**	**358**	**2280 J**	**715 J**	**2140**
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE		30.9	2.8 J				
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE	37900	40900	20500		79300	9260	24900
MAGNESIUM, TOTAL	µg/L	NE	NS		NE	37500	52300	21400		81300	9480	23900
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50	**758**	**259**	5.3 J		**991**	18	2.8 J
MANGANESE, TOTAL	µg/L	NE	150	1,700	50	**834**	**1500**	**179**		**1230**	20.2	**95.1**
MERCURY, TOTAL	µg/L	2	2		NE							
NICKEL, DISSOLVED	µg/L	NE	NS		NE	2.7 J	2.5 J			14.8 J		3.8 J
NICKEL, TOTAL	µg/L	NE	100	88.5	NE	16.5 J	78.7	69.8		31.4 J	2.6 J	91.5
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE	1960 J					3220 J	558 J
POTASSIUM, TOTAL	µg/L	NE	NS		NE	1870 J	6890	800 J			3310 J	750 J
SELENIUM, DISSOLVED	µg/L	50	NS		NE							8.9
SELENIUM, TOTAL	µg/L	50	50		NE		3.9 J					9
SODIUM, DISSOLVED	µg/L	NE	NS		NE	158000	165000	70200		213000	208000	176000
SODIUM, TOTAL	µg/L	NE	NS		NE	155000	170000	71500		219000	213000	173000
VANADIUM, DISSOLVED	µg/L	NE	NS		NE							
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE	1.4 J	71.2	9.4 J		2.9 J		3.8 J
ZINC, DISSOLVED	µg/L	NE	NS		5000			88.5				
ZINC, TOTAL	µg/L	NE	5,000	213	5000	54.8	210	51				25.9

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Table 6-7

Summary of Metals Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS [2]	BACKGROUND [3]	SMCL	33-341			33-342		33MWC-01		
						04/18/1996	9/4/1997	12/16/1998	04/18/1996	9/4/1997	04/17/1996	9/4/1997	12/07/1998
ALUMINUM, DISSOLVED	µg/L	NE	NS		50								
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50	**622 J**			**6240 J**		**4780**		
ANTIMONY, TOTAL	µg/L	6	6		NE								
ARSENIC, TOTAL	µg/L	50	50		NE				3.8 J				
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE	71.7 J			31.2 J		68 J		47.7Bf
BARIUM, TOTAL	µg/L	2000	2,000	412	NE	84.5 J			57.6 J		96.8 J		
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE	1.1 J							
CALCIUM, DISSOLVED	µg/L	NE	NS		NE	34800			83200		49800		54000 f
CALCIUM, TOTAL	µg/L	NE	NS		NE	35100			78800		59400		
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE	**107**			35.8		22.1		
COBALT, DISSOLVED	µg/L	NE	NS		NE	4.1 J							
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE	5.8 J			3.5 J		3.9 J		
COPPER, DISSOLVED	µg/L	1300	NS		NE	4.7 J			2.8 J		2.7 J		
COPPER, TOTAL	µg/L	1300	650		NE	28.7			9 J		15.3 J		
IRON, DISSOLVED	µg/L	NE	NS		300								
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3			0.2					
IRON, TOTAL	µg/L	NE	5,000	58,200	300	**1620**	**458**		**5990**	**18100**	**6580 J**	**417**	
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE				2 J		3.6		
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE	18100			56800		20100		21700 f
MAGNESIUM, TOTAL	µg/L	NE	NS		NE	18200			53600		24200		
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50	**102**			27.3		41.6		48 f
MANGANESE, TOTAL	µg/L	NE	150	1,700	50	**136**			**112**		**268**		
MERCURY, TOTAL	µg/L	2	2		NE								
NICKEL, DISSOLVED	µg/L	NE	NS		NE	474					5.3 J		
NICKEL, TOTAL	µg/L	NE	100	88.5	NE	498			28.8 J		22.2 J		
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE				632 J		829 J		643Bf
POTASSIUM, TOTAL	µg/L	NE	NS		NE				1190 J		1640 J		
SELENIUM, DISSOLVED	µg/L	50	NS		NE								
SELENIUM, TOTAL	µg/L	50	50		NE								
SODIUM, DISSOLVED	µg/L	NE	NS		NE	94400			163000		51600		50200 Ef
SODIUM, TOTAL	µg/L	NE	NS		NE	95300			156000		51900		
VANADIUM, DISSOLVED	µg/L	NE	NS		NE				1.5 J				
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE	1.4 J			14 J		7.9 J		
ZINC, DISSOLVED	µg/L	NE	NS		5000								
ZINC, TOTAL	µg/L	NE	5,000	213	5000	41.3			66.6				

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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	BACKGROUND[3]	SMCL	33MWC-02			33MWC-03			33MWC-04
						04/18/1996	9/4/1997	12/09/1998	04/14/1996	9/4/1997	12/15/1998	04/18/1996
ALUMINUM, DISSOLVED	µg/L	NE	NS		50			218 f				
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50	3950 J			332			5390 J
ANTIMONY, TOTAL	µg/L	6	6		NE							
ARSENIC, TOTAL	µg/L	50	50		NE							4.9 J
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE	109 J		52.1Bf	107 J		131Bf	36.8 J
BARIUM, TOTAL	µg/L	2000	2,000	412	NE	141 J			109 J			88.5 J
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE							
CALCIUM, DISSOLVED	µg/L	NE	NS		NE	358000		328000 f	70800		63800 f	22300
CALCIUM, TOTAL	µg/L	NE	NS		NE	347000			72000			24500
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE	1070						84.9
COBALT, DISSOLVED	µg/L	NE	NS		NE	14.6 J						
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE	18.1 J						3.5 J
COPPER, DISSOLVED	µg/L	1300	NS		NE	2.3 J			2.3 J			
COPPER, TOTAL	µg/L	1300	650		NE	29			3.1 J			16.6 J
IRON, DISSOLVED	µg/L	NE	NS		300					280		
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3			0.1				
IRON, TOTAL	µg/L	NE	5,000	58,200	300	10600	1980		210 J	190		8110
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE	2.6 J						3.4
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE	152000		131000 f	42500		37700 f	8400
MAGNESIUM, TOTAL	µg/L	NE	NS		NE	146000			43100			9600
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50	468		174 f	77		66.3 f	6.8 J
MANGANESE, TOTAL	µg/L	NE	150	1,700	50	556			79.2			128
MERCURY, TOTAL	µg/L	2	2		NE							
NICKEL, DISSOLVED	µg/L	NE	NS		NE	1420		895 f	6.5 J			
NICKEL, TOTAL	µg/L	NE	100	88.5	NE	1540			6.8 J			62.2
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE	1050 J		723Bf	525 J		441Bf	439 J
POTASSIUM, TOTAL	µg/L	NE	NS		NE	1430 J			554 J			1270 J
SELENIUM, DISSOLVED	µg/L	50	NS		NE							7.5
SELENIUM, TOTAL	µg/L	50	50		NE							9.4
SODIUM, DISSOLVED	µg/L	NE	NS		NE	236000		224000 Ef	132000		118000 f	55000
SODIUM, TOTAL	µg/L	NE	NS		NE	235000			136000			57900
VANADIUM, DISSOLVED	µg/L	NE	NS		NE							
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE	9.2 J						10.2 J
ZINC, DISSOLVED	µg/L	NE	NS		5000	56.1						
ZINC, TOTAL	µg/L	NE	5,000	213	5000	318						68.7

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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	BACKGROUND[3]	SMCL	33MWC-05 04/14/1996	33MWC-05 9/4/1997	33MWC-05 12/15/1998	33MWC-06 04/17/1996	33MWC-06 9/4/1997	33MWC-06 12/15/1998	33MWC-07 09/09/1997
ALUMINUM, DISSOLVED	µg/L	NE	NS		50							
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50	**1190**			**13600**			
ANTIMONY, TOTAL	µg/L	6	6		NE							
ARSENIC, TOTAL	µg/L	50	50		NE				5.3 J			
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE	38.3 J		0.72Bf	55.6 J		62.6Bf	
BARIUM, TOTAL	µg/L	2000	2,000	412	NE	44.1 J			176 J			
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE							
CALCIUM, DISSOLVED	µg/L	NE	NS		NE	60600		180Bf	21300		24800 f	
CALCIUM, TOTAL	µg/L	NE	NS		NE	59900			22300			
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE				69.5			
COBALT, DISSOLVED	µg/L	NE	NS		NE							
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE				9.2 J			
COPPER, DISSOLVED	µg/L	1300	NS		NE				2.1 J			
COPPER, TOTAL	µg/L	1300	650		NE	3.9 J			31.1			
IRON, DISSOLVED	µg/L	NE	NS		300		74.7			**5960**		
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3							
IRON, TOTAL	µg/L	NE	5,000	58,200	300	**815 J**	129		**20300 J**	25		**8660**
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE				10.2			
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE	28800			8130		9280 f	
MAGNESIUM, TOTAL	µg/L	NE	NS		NE	28300			9740			
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50	1.6 J			6 J			
MANGANESE, TOTAL	µg/L	NE	150	1,700	50	11.3 J			**418**			
MERCURY, TOTAL	µg/L	2	2		NE				0.1 J			
NICKEL, DISSOLVED	µg/L	NE	NS		NE				4.7 J			
NICKEL, TOTAL	µg/L	NE	100	88.5	NE				58.3			
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE	478 J		65.2Bf	339 J		291Bf	
POTASSIUM, TOTAL	µg/L	NE	NS		NE	643 J			2290 J			
SELENIUM, DISSOLVED	µg/L	50	NS		NE						1.9B	
SELENIUM, TOTAL	µg/L	50	50		NE	3.4 J						
SODIUM, DISSOLVED	µg/L	NE	NS		NE	137000			19800		23500 f	
SODIUM, TOTAL	µg/L	NE	NS		NE	132000			20000			
VANADIUM, DISSOLVED	µg/L	NE	NS		NE							
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE	2 J			26.7 J			
ZINC, DISSOLVED	µg/L	NE	NS		5000							
ZINC, TOTAL	µg/L	NE	5,000	213	5000				69.9			

Notes:
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(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.
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Table 6-7

Summary of Metals Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	BACKGROUND[3]	SMCL	33MWC-08		33MWC-09		33MWC-10	33MWC-11	
						09/09/1997	12/08/1998	9/4/1997	12/11/1998	09/08/1997	09/08/1997	12/07/1998
ALUMINUM, DISSOLVED	µg/L	NE	NS		50							
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50							
ANTIMONY, TOTAL	µg/L	6	6		NE							
ARSENIC, TOTAL	µg/L	50	50		NE							
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE							
BARIUM, TOTAL	µg/L	2000	2,000	412	NE							
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE							
CALCIUM, DISSOLVED	µg/L	NE	NS		NE							
CALCIUM, TOTAL	µg/L	NE	NS		NE							
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE							
COBALT, DISSOLVED	µg/L	NE	NS		NE							
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE							
COPPER, DISSOLVED	µg/L	1300	NS		NE							
COPPER, TOTAL	µg/L	1300	650		NE							
IRON, DISSOLVED	µg/L	NE	NS		300							
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3		0.1		0.1			0.1
IRON, TOTAL	µg/L	NE	5,000	58,200	300	**10200**		**140000**		**32600**	**75200**	
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE							
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE							
MAGNESIUM, TOTAL	µg/L	NE	NS		NE							
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50							
MANGANESE, TOTAL	µg/L	NE	150	1,700	50							
MERCURY, TOTAL	µg/L	2	2		NE							
NICKEL, DISSOLVED	µg/L	NE	NS		NE							
NICKEL, TOTAL	µg/L	NE	100	88.5	NE							
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE							
POTASSIUM, TOTAL	µg/L	NE	NS		NE							
SELENIUM, DISSOLVED	µg/L	50	NS		NE							
SELENIUM, TOTAL	µg/L	50	50		NE							
SODIUM, DISSOLVED	µg/L	NE	NS		NE							
SODIUM, TOTAL	µg/L	NE	NS		NE							
VANADIUM, DISSOLVED	µg/L	NE	NS		NE							
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE							
ZINC, DISSOLVED	µg/L	NE	NS		5000							
ZINC, TOTAL	µg/L	NE	5,000	213	5000							

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						09/09/1997	12/08/1998	09/09/1997		09/09/1997	09/08/1997	9/4/1997	9/4/1997
ALUMINUM, DISSOLVED	µg/L	NE	NS		50								
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50								
ANTIMONY, TOTAL	µg/L	6	6		NE								
ARSENIC, TOTAL	µg/L	50	50		NE								
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE								
BARIUM, TOTAL	µg/L	2000	2,000	412	NE								
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE								
CALCIUM, DISSOLVED	µg/L	NE	NS		NE								
CALCIUM, TOTAL	µg/L	NE	NS		NE								
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE								
COBALT, DISSOLVED	µg/L	NE	NS		NE								
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE								
COPPER, DISSOLVED	µg/L	1300	NS		NE								
COPPER, TOTAL	µg/L	1300	650		NE								
IRON, DISSOLVED	µg/L	NE	NS		300	**1820**				118			
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3		0.1		**0.4**				
IRON, TOTAL	µg/L	NE	5,000	58,200	300	**50400**		**38700**		**3420**	**57000**	**56500**	**23800**
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE								
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE								
MAGNESIUM, TOTAL	µg/L	NE	NS		NE								
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50								
MANGANESE, TOTAL	µg/L	NE	150	1,700	50								
MERCURY, TOTAL	µg/L	2	2		NE								
NICKEL, DISSOLVED	µg/L	NE	NS		NE								
NICKEL, TOTAL	µg/L	NE	100	88.5	NE								
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE								
POTASSIUM, TOTAL	µg/L	NE	NS		NE								
SELENIUM, DISSOLVED	µg/L	50	NS		NE								
SELENIUM, TOTAL	µg/L	50	50		NE								
SODIUM, DISSOLVED	µg/L	NE	NS		NE								
SODIUM, TOTAL	µg/L	NE	NS		NE								
VANADIUM, DISSOLVED	µg/L	NE	NS		NE								
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE								
ZINC, DISSOLVED	µg/L	NE	NS		5000								
ZINC, TOTAL	µg/L	NE	5,000	213	5000								

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PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	BACKGROUND[3]	SMCL	33MWC-18	33MWC-19		33MWC-20		33MWC-24	33MWC-27	33MWC-30	33MWC-31
						9/4/1997	9/4/1997	12/09/1998	9/4/1997	12/09/1998	12/11/1998	12/11/1998	12/15/1998	12/16/1998
ALUMINUM, DISSOLVED	µg/L	NE	NS		50									
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50									
ANTIMONY, TOTAL	µg/L	6	6		NE									
ARSENIC, TOTAL	µg/L	50	50		NE									
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE									
BARIUM, TOTAL	µg/L	2000	2,000	412	NE									
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE									
CALCIUM, DISSOLVED	µg/L	NE	NS		NE									
CALCIUM, TOTAL	µg/L	NE	NS		NE									
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE									
COBALT, DISSOLVED	µg/L	NE	NS		NE									
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE									
COPPER, DISSOLVED	µg/L	1300	NS		NE									
COPPER, TOTAL	µg/L	1300	650		NE									
IRON, DISSOLVED	µg/L	NE	NS		300									
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3			0.1		**0.3**	0.1	0.1	**0.6**	**2**
IRON, TOTAL	µg/L	NE	5,000	58,200	300	**53500**	**46400**		**49200**					
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE									
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE									
MAGNESIUM, TOTAL	µg/L	NE	NS		NE									
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50									
MANGANESE, TOTAL	µg/L	NE	150	1,700	50									
MERCURY, TOTAL	µg/L	2	2		NE									
NICKEL, DISSOLVED	µg/L	NE	NS		NE									
NICKEL, TOTAL	µg/L	NE	100	88.5	NE									
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE									
POTASSIUM, TOTAL	µg/L	NE	NS		NE									
SELENIUM, DISSOLVED	µg/L	50	NS		NE									
SELENIUM, TOTAL	µg/L	50	50		NE									
SODIUM, DISSOLVED	µg/L	NE	NS		NE									
SODIUM, TOTAL	µg/L	NE	NS		NE									
VANADIUM, DISSOLVED	µg/L	NE	NS		NE									
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE									
ZINC, DISSOLVED	µg/L	NE	NS		5000									
ZINC, TOTAL	µg/L	NE	5,000	213	5000									

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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	BACKGROUND[3]	SMCL	33MWC-32 12/14/1998	33MWC-33 12/08/1998	33MWC-35 12/09/1998	33MWC-36 12/10/1998	33MWC-39 12/10/1998	33MWC-41 12/10/1998
ALUMINUM, DISSOLVED	µg/L	NE	NS		50						
ALUMINUM, TOTAL	µg/L	NE	NS	34,500	50						
ANTIMONY, TOTAL	µg/L	6	6		NE						
ARSENIC, TOTAL	µg/L	50	50		NE						
BARIUM, DISSOLVED	µg/L	2000	NS	88.9 J	NE						
BARIUM, TOTAL	µg/L	2000	2,000	412	NE						
CADMIUM, TOTAL	µg/L	5	5	1.5 J	NE						
CALCIUM, DISSOLVED	µg/L	NE	NS		NE						
CALCIUM, TOTAL	µg/L	NE	NS		NE						
CHROMIUM, TOTAL	µg/L	100	100	63.9	NE						
COBALT, DISSOLVED	µg/L	NE	NS		NE						
COBALT, TOTAL	µg/L	NE	1,000	29.1 J	NE						
COPPER, DISSOLVED	µg/L	1300	NS		NE						
COPPER, TOTAL	µg/L	1300	650		NE						
IRON, DISSOLVED	µg/L	NE	NS		300						
IRON, DISSOLVED FIELD	mg/L	NE	NS		0.3	1	3	0.2	0.1	0.1	0.2
IRON, TOTAL	µg/L	NE	5,000	58,200	300						
LEAD, TOTAL	µg/L	NE	7.5	27.1	NE						
MAGNESIUM, DISSOLVED	µg/L	NE	NS		NE						
MAGNESIUM, TOTAL	µg/L	NE	NS		NE						
MANGANESE, DISSOLVED	µg/L	NE	NS	717	50						
MANGANESE, TOTAL	µg/L	NE	150	1,700	50						
MERCURY, TOTAL	µg/L	2	2		NE						
NICKEL, DISSOLVED	µg/L	NE	NS		NE						
NICKEL, TOTAL	µg/L	NE	100	88.5	NE						
POTASSIUM, DISSOLVED	µg/L	NE	NS		NE						
POTASSIUM, TOTAL	µg/L	NE	NS		NE						
SELENIUM, DISSOLVED	µg/L	50	NS		NE						
SELENIUM, TOTAL	µg/L	50	50		NE						
SODIUM, DISSOLVED	µg/L	NE	NS		NE						
SODIUM, TOTAL	µg/L	NE	NS		NE						
VANADIUM, DISSOLVED	µg/L	NE	NS		NE						
VANADIUM, TOTAL	µg/L	NE	NS	68.6	NE						
ZINC, DISSOLVED	µg/L	NE	NS		5000						
ZINC, TOTAL	µg/L	NE	5,000	213	5000						

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Table 6-8

Summary of Inorganic Indicator Parameters Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	32-063		33-341		33-342		33MWC-01	
					09/04/1997	12/16/1998	9/4/1997	12/16/1998	9/4/1997	12/11/1998	9/4/1997	12/07/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE	191		125		404		269	225
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE	191		125		404	482	269	
ALKALINITY, CARBONATE	mg/L	NE	NS	NE								
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE	3.42							
CHLORIDE	mg/L	NE	200	250	13.9	1.43 j	178	11.9 j	82.9		9.6	
COD	mg/L	NE	NS	NE					5.54			
NITROGEN, AMMONIA	mg/L	NE	NS	NE	0.169	0.191		0.305	4.56	0.292	1.34	
NITROGEN, NITRATE	mg/L	10	10	NE	1.35		0.05					
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE		2.94						
NITROGEN, NITRITE	mg/L	1	NS	NE	0.04		0.029		0.052			
PHOSPHORUS	mg/L	NE	NS	NE	0.385		0.04		0.233		0.17	
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE	0.043		0.03		0.186		0.14	
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500				**516**		**1280**		343
SULFATE	mg/L	NE	400	250	126	90.5	91	98	50	**377**	71.4	50.4
SULFIDE, TOTAL	mg/L	NE	NS	NE	9.6							
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE	3.47			1	1.74			68.9
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE	177		272		179		208	

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PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	33MWC-02		33MWC-03		33MWC-05	
					9/4/1997	12/09/1998	9/4/1997	12/15/1998	9/4/1997	12/15/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE	433	375	317	364	404	
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE	433		317		404	
ALKALINITY, CARBONATE	mg/L	NE	NS	NE						
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE	5.36		2.92			
CHLORIDE	mg/L	NE	200	250	81.1	**1110 D**	24.4		15.3	0.18
COD	mg/L	NE	NS	NE	16		11.5		8.52	
NITROGEN, AMMONIA	mg/L	NE	NS	NE	10.6	0.331	5.01		1.88	
NITROGEN, NITRATE	mg/L	10	10	NE			0.17		0.82	
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE				0.321		0.067
NITROGEN, NITRITE	mg/L	1	NS	NE	0.046					
PHOSPHORUS	mg/L	NE	NS	NE	0.2		0.46		0.35	
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE	0.019		0.31		0.321	
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500		**2560**				
SULFATE	mg/L	NE	400	250	**335**	**440**	94.5	54	163	3.76
SULFIDE, TOTAL	mg/L	NE	NS	NE	1		1			
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE	5.27	1.94	4.68			
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE	306				186	

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PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	33MWC-06		33MWC-07		33MWC-08	
					9/4/1997	12/15/1998	09/09/1997	12/09/1998	09/09/1997	12/08/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE	94.2	106	446		328	
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE	94.2		446	333	328	254
ALKALINITY, CARBONATE	mg/L	NE	NS	NE						
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE						
CHLORIDE	mg/L	NE	200	250	1.72		54.5		148	1.36
COD	mg/L	NE	NS	NE					12.6	
NITROGEN, AMMONIA	mg/L	NE	NS	NE	4.02		2.85		1.65	
NITROGEN, NITRATE	mg/L	10	10	NE	6.8		0.02		0.17	
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE		7.15		0.151		
NITROGEN, NITRITE	mg/L	1	NS	NE			0.03		0.04	
PHOSPHORUS	mg/L	NE	NS	NE	0.49		0.185		0.081	
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE	0.353		0.3		0.05	
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500				**562**		**1110**
SULFATE	mg/L	NE	400	250	23.8	6.16	229	**297**	**572**	**369**
SULFIDE, TOTAL	mg/L	NE	NS	NE			11		6.8	
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE				1.79		63.3
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE			107		58.9	

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Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	33MWC-09		33MWC-10		33MWC-11		33MWC-12	
					9/4/1997	12/11/1998	09/08/1997	12/07/1998	09/08/1997	12/07/1998	09/09/1997	12/08/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE	425		280		351		148	
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE	425	445	280	468 j	351	369 j	148	235
ALKALINITY, CARBONATE	mg/L	NE	NS	NE								
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE	2.25				1.27			
CHLORIDE	mg/L	NE	200	250	19.1	3.05	15.4		62.1		33.4	2.27
COD	mg/L	NE	NS	NE								
NITROGEN, AMMONIA	mg/L	NE	NS	NE		0.41	10.2		13.1		12.9	
NITROGEN, NITRATE	mg/L	10	10	NE	0.71				4.15		0.29	
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE		0.459				2.22		0.177
NITROGEN, NITRITE	mg/L	1	NS	NE	0.065		0.02		0.03			
PHOSPHORUS	mg/L	NE	NS	NE	2.31		6.59		7.66		2.82	
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE			0.278		0.343		0.35	
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500		**1330**		**547**		**1500**		452
SULFATE	mg/L	NE	400	250	169	236	**432**	96	**600**	**737**	31.5	83.9
SULFIDE, TOTAL	mg/L	NE	NS	NE			6		11		6	
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE	4.52	4.3	4.26	91.9	5.66	73.7	2.5	62.6
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE	28.5		381					

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1988.

(2) Illinois Class I Groundwater Standards. 35 IAC Part 620 - Groundwater Quality, Subpart D, Section 620.410.

No entry indicates that the parameter was either not detected in the groundwater sample, or the water sample was not analyzed for that parameter.
Appendix L summarizes the associated detection limits, where available.

NE = not established.
SMCL = Secondary Maximum Contaminant Level
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Indicates an SMCL exceedence
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Table 6-8

Summary of Inorganic Indicator Parameters Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	33MWC-13		33MWC-14		33MWC-15		33MWC-16	
					09/09/1997		09/09/1997	12/11/1998	09/08/1997	12/07/1998	9/4/1997	12/14/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE	293		229		311		395	
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE	293	429	229	244	311	469 j	395	
ALKALINITY, CARBONATE	mg/L	NE	NS	NE								
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE	3.74		1.13		1.58		7.98	
CHLORIDE	mg/L	NE	200	250	35.2		59.8		26.6	1.36	4.13	0.31
COD	mg/L	NE	NS	NE								
NITROGEN, AMMONIA	mg/L	NE	NS	NE	16	0.247	2.15		12.9	0.107	3.06	0.2
NITROGEN, NITRATE	mg/L	10	10	NE	0.07				0.19			
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE						0.152		
NITROGEN, NITRITE	mg/L	1	NS	NE	0.05		0.03		0.05			
PHOSPHORUS	mg/L	NE	NS	NE	4.77		0.067		8.4		2.46	
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE	0.17		0.03		0.3			
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500		**731**		316		**4770**		**816**
SULFATE	mg/L	NE	400	250	66	174	37	45.3	**678**	**2890**	204	187
SULFIDE, TOTAL	mg/L	NE	NS	NE			8		1			
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE	5.26	2.53	1.93		6.85	95.1	13.2	3.1
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE	583		7.19		34			

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Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	33MWC-17		33MWC-18		33MWC-19		33MWC-20		33MWC-21
					9/4/1997	12/09/1998	9/4/1997	12/09/1998	9/4/1997	12/09/1998	9/4/1997	12/09/1998	12/14/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE	285		376		474		380		
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE	285	295	376	277	474	509	380	364	
ALKALINITY, CARBONATE	mg/L	NE	NS	NE									
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE					1.8		1.3		
CHLORIDE	mg/L	NE	200	250	2.4		2.5		1.4		5		1.31
COD	mg/L	NE	NS	NE	7		17.4		42.1				
NITROGEN, AMMONIA	mg/L	NE	NS	NE	0.17	0.106	0.44		0.76	0.148	0.24	0.142	
NITROGEN, NITRATE	mg/L	10	10	NE	0.21		0.13		0.13		1.57		
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE		0.108		0.079				1	0.224
NITROGEN, NITRITE	mg/L	1	NS	NE	0.062						0.047		
PHOSPHORUS	mg/L	NE	NS	NE	9.43		8.64		7.21		9.08		
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE	0.131		0.079		0.068		0.061		
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500		**543**		**1330**		**1500**		**2430**	**1000**
SULFATE	mg/L	NE	400	250	159	102	**253**	**457**	492	**253**	87	132	**355**
SULFIDE, TOTAL	mg/L	NE	NS	NE	1						5.6		
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE	1.17		4.7	1.87	8.6	2.52	2	1.62	2.96
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE					107		206		

Notes:

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Table 6-8

Summary of Inorganic Indicator Parameters Detected in Groundwater[1]
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	33MWC-22 12/15/1998	33MWC-23 12/14/1998	33MWC-24 12/11/1998	33MWC-27 12/11/1998	33MWC-28 12/11/1998	33MWC-29 12/10/1998	33MWC-30 12/15/1998	33MWC-31 12/16/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE								
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE		238	443	501	420	343		
ALKALINITY, CARBONATE	mg/L	NE	NS	NE		83.5						37.6
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE								
CHLORIDE	mg/L	NE	200	250	3.65	4.79		0.87		2.18	2.18	173 j
COD	mg/L	NE	NS	NE								
NITROGEN, AMMONIA	mg/L	NE	NS	NE	1.73	0.916		0.428	2.53	1.96	0.377	7.6
NITROGEN, NITRATE	mg/L	10	10	NE								
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE		0.062						
NITROGEN, NITRITE	mg/L	1	NS	NE								
PHOSPHORUS	mg/L	NE	NS	NE								
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE								
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500	**2360**	**638**	**816**	**1140**	**732**	**690**	**1200**	**722**
SULFATE	mg/L	NE	400	250	207	19.5	211	**261**	33.3	18.6	181	4.51
SULFIDE, TOTAL	mg/L	NE	NS	NE								
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE	10.9		4.94	3.35	6.38		1.63	5.06
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE								

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Marion, Illinois

PARAMETER	UNITS	MCL	ILLINOIS CLASS I GW STDS.[2]	SMCL	33MWC-32 12/14/1998	33MWC-33 12/08/1998	33MWC-35 12/09/1998	33MWC-36 12/10/1998	33MWC-39 12/10/1998	33MWC-41 12/10/1998
ALKALINITY AS $CaCO_3$	mg/L	NE	NS	NE						
ALKALINITY, BICARBONATE	mg/L	NE	NS	NE		394		377	306	320
ALKALINITY, CARBONATE	mg/L	NE	NS	NE			60.4			
CARBON, DISSOLVED ORGANIC	mg/L	NE	NS	NE						
CHLORIDE	mg/L	NE	200	250	1.31	3.18				2.18
COD	mg/L	NE	NS	NE						
NITROGEN, AMMONIA	mg/L	NE	NS	NE	1.28	0.122	3	0.292	0.318	1.46
NITROGEN, NITRATE	mg/L	10	10	NE						
NITROGEN, NITRATE + NITRITE	mg/L	10	NS	NE						
NITROGEN, NITRITE	mg/L	1	NS	NE						
PHOSPHORUS	mg/L	NE	NS	NE						
PHOSPHORUS, ORTHO	mg/L	NE	NS	NE						
SOLIDS, TOTAL DISSOLVED	mg/L	NE	1,200	500	**730**	**2220**	**617**	484	**534**	**692**
SULFATE	mg/L	NE	400	250	26.2	**1160**	11	69.8	124	21.7
SULFIDE, TOTAL	mg/L	NE	NS	NE						
TOTAL ORGANIC CARBON AS NPOC	mg/L	NE	NS	NE		92.4	6.14	8.54		
VOLATILE FATTY ACIDS	mg/L	NE	NS	NE						

Notes:

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Table 6-9
Summary of Field Parameter Measurements
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	SAMPLE DATE[1]	pH (s.u.)	TEMPERATURE (deg. C/deg. F)	SPECIFIC CONDUCTANCE (@25 deg. C)	DISSOLVED OXYGEN (ppm)	DISSOLVED IRON (ppm)	E_H (mV)	TOTAL CVOCs (µg/L)	PURGE/ SAMPLE METHOD	COMMENTS
SHALLOW MONITORING WELLS										
Upgradient and Sidegradient										
33-340	12/15/1998	9.1	14.8/58.6	168	NM	NM	NM	ND	Peristaltic Pump	Well purged dry prior to sampling
33MWC-01	12/7/1998	6.5	13.4/56.1	74	2	<0.1	147	ND	Peristaltic Pump	
33MWC-05	12/15/1998	6.8	15.1/59.2	155	1	<0.1	46	ND	Peristaltic Pump	
33MWC-15	12/7/1998	6.6	13.0/55.4	731	0.8	<0.1	179	ND	Peristaltic Pump	
Building I-1-2										
Source Area										
33MWC-13	12/11/1998	7.2	12.7/54.9	1291	0.9[2]	0.4	19[2]	28749	Peristaltic Pump	Well purged dry prior to sampling
33MWC-24	6/26/1998	NM	NM	NM	NM	NM	NM	993	Pump?	
	12/11/1998	6.8	16.7/62.1	1265	0.1	0.1	-49	1268	Whale Pump	
Downgradient - East										
33MWC-02	12/9/1998	6.7	13.9/57.0	4100	0.6	0.1	45	950	Peristaltic Pump	
33MWC-36	6/29/1998	7.0	16/60	820	NM	NM	277	6	Pump	Well purged dry prior to sampling
	12/10/1998	7.0	14.8/58.6	840	0.3	0.1	20	9	Whale Pump	
Downgradient - North										
33MWC-14	12/11/1998	7.5	15.6/60.1	80	0.6	NR	-37	161	Peristaltic Pump	
33-341	12/16/1998	11.5	15.0/59.0	994	NM	0.2	27[2]	633	Peristaltic Pump	Well purged dry prior to sampling
33MWC-10	12/7/1998	7.0	15.2/59.4	992	1	<2.5	65	ND	Peristaltic Pump	
Downgradient - West										
33-342	12/11/1998	7.0	16.1/61.0	2000	0.2	<0.1	-15	2105	Peristaltic Pump	
33MWC-03	12/15/1998	7.4	15.3/59.5	224	0.6	NR	15	460	Peristaltic Pump	
33MWC-11	12/7/1998	7.1	13.7/56.7	261	0.7	0.1	160	2.2	Peristaltic Pump	
33MWC-12	12/8/1998	7.5	14.0/57.2	119	2	0.1	119	ND	Peristaltic Pump	
33MWC-33	6/30/1998	NM	NM	NM	NM	NM	NM	1452	Pump/SS Bailer	Well purged dry prior to sampling
	12/8/1998	7.1	12.7/54.9	425	0.8	3	-78	2742	Peristaltic Pump	

Table 6-9
Summary of Field Parameter Measurements
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Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	SAMPLE DATE[1]	pH (s.u.)	TEMPERATURE (deg. C/deg. F)	SPECIFIC CONDUCTANCE (@25 deg. C)	DISSOLVED OXYGEN (ppm)	DISSOLVED IRON (ppm)	E_H (mV)	TOTAL CVOCs (µg/L)	PURGE/ SAMPLE METHOD	COMMENTS
Building I-1-23										
Source Area										
33MWC-07	12/9/1998	8.0	17.5/63.5	1435	0.2	>10	-131	43286	Peristaltic Pump	
33MWC-21	6/25/1998	7.3	18/64	1680	NM	NM	0.0	552	Pump	
	12/14/1998	6.8	15.0/59.0	900	0.8	<0.1	105	3117	Peristaltic Pump	
33MWC-16	12/14/1998	6.0	15.4/59.7	150	1	<0.1	37	1088	Peristaltic Pump	
Downgradient - North										
33MWC-06	12/15/1998	6.3	14.9/58.8	303	1	<0.1	31	ND	Whale Pump	
33MWC-08	12/8/1998	7.2	13.0/55.4	104	2	0.1	167	2789	Peristaltic Pump	
33MWC-30	6/26/1998	NM	NM	NM	NM	NM	NM	2533	Pump?	
	12/15/1998	7.4	14.4/57.9	450	0.6	0.6	94	3625	Peristaltic Pump	
Building I-1-36A										
Downgradient - Northeast										
32-063	12/15/1998	7.0	14.8/58.6	619	NM	<0.1	28[2]	13.5	Peristaltic Pump	Well purged dry prior to sampling
Area 9 Repository										
Source Area										
33MWC-09	12/11/1998	6.8	14.7/58.5	2180	1.5[2]	0.1	97[2]	35281	Bailed	Well purged dry prior to sampling
33MWC-27	6/25/98[3]	NM	NM	NM	NM	NM	NM	8[3]	Pump/SS Bailer	Well purged dry prior to sampling
	7/9/1998	NM	NM	NM	NM	NM	NM	4240	Pump	Well purged dry prior to sampling
	12/11/1998	6.6	11.9/53.4	1908	2[2]	0.1	134[2]	19146	Bailed	Well purged dry prior to sampling
Downgradient - East										
33MWC-17	12/9/1998	7.2	16.9/62.4	94	2	NR	17	14	Peristaltic Pump	
33MWC-39	6/29/1998	7.2	17/62	760	NM	NM	55	63	Pump	
	12/10/1998	7.0	15.4/59.7	930	0.6	0.1	3	ND	Whale Pump	

Table 6-9
Summary of Field Parameter Measurements
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	SAMPLE DATE[1]	pH (s.u.)	TEMPERATURE (deg. C/deg. F)	SPECIFIC CONDUCTANCE (@25 deg. C)	DISSOLVED OXYGEN (ppm)	DISSOLVED IRON (ppm)	E_H (mV)	TOTAL CVOCs (µg/L)	PURGE/ SAMPLE METHOD	COMMENTS
Downgradient - North										
33MWC-18	12/9/1998	6.8	13.8/56.8	1850	1	<0.1	53	ND	Peristaltic Pump	
33MWC-19	12/9/1998	6.8	9.6/49.3	2080	1.5[2]	0.1	122[2]	ND	Peristaltic Pump	Well purged dry prior to sampling
33MWC-20	12/9/1998	5.3	12.5/54.5	1230	1.0[2]	0.3	188[2]	ND	Peristaltic Pump	
LOWER CLAY										
Building I-1-23										
Source Area										
33MWC-22	6/25/1998	NM	NM	NM	NM	NM	NM	14	Pump?	Well purged dry prior to sampling
	12/15/1998	8.7	13.3/55.9	3070	NM	NM	NM	0.5	Whale Pump/SS Bailer	Well purged dry prior to sampling
Downgradient - North										
33MWC-31	6/26/1998	NM	NM	NM	NM	NM	NM	147	Pump	Well purged dry prior to sampling
	12/16/1998	10.1	13.9/57.0	2700	NM	2	NM	38	Bailed	Well purged dry prior to sampling
Area 9 Repository										
Source Area										
33MWC-28	6/25/98[3]	NM	NM	NM	NM	NM	NM	15486[3]	SS Bailer	Well purged dry prior to sampling
	7/9/1998	NM	NM	NM	NM	NM	NM	3	Pump	Well purged dry prior to sampling
	12/11/1998	8.6	14.5/58.1	1350	NM	<0.1	NM	0.6	Bailed	Well purged dry prior to sampling
LOWER SAND										
Building I-1-2										
Downgradient - West										
33MWC-35	6/30/1998	NM	NM	NM	NM	NM	NM	79	Pump/SS Bailer	Well purged dry prior to sampling
	12/9/1998	8.6	14.4/57.9	113	0.6[2]	0.2	-255[2]	1	Keck Pump/SS Bailer	Well purged dry prior to sampling

Table 6-9
Summary of Field Parameter Measurements
Groundwater Investigation Report and Focused Feasibility Study
Crab Orchard National Wildlife Refuge, PCBOU Sites 32/33
Marion, Illinois

SAMPLE LOCATION	SAMPLE DATE[1]	pH (s.u.)	TEMPERATURE (deg. C/deg. F)	SPECIFIC CONDUCTANCE (@25 deg. C)	DISSOLVED OXYGEN (ppm)	DISSOLVED IRON (ppm)	E_H (mV)	TOTAL CVOCs (µg/L)	PURGE/ SAMPLE METHOD	COMMENTS
Building I-1-23										
Source Area										
33MWC-23	6/25/1998	7.8	17/62	860	NM	NM	0.0	ND	Pump	
	12/14/1998	9.4	15.7/60.3	250	0.1	<0.1	-152	ND	Whale Pump	
Downgradient - North										
33MWC-32	6/26/1998	NM	NM	NM	NM	NM	NM	ND	Pump	
	12/14/1998	7.4	14.4/57.9	1305	0.1	1	-158	1.1	Peristaltic Pump	
Area 9 Repository										
Source Area										
33MWC-29	6/25/1998	7.4	16/61	1040	NM	NM	350	19	Pump	
	12/10/1998	8.1	15.3/59.5	1248	0.2	<0.1	-192	1.9	Whale Pump	
Downgradient - Northeast										
33MWC-41	6/29/1998	7.4	18/64	1200	NM	NM	NM	2	Pump	
	12/10/1998	7.5	14.3/57.7	1263	0.2	0.2	63	ND	Whale Pump	

Notes:
NM = No measurement
NR = Not recorded
(1) June 1998 and July 1998 data collected by FDGTI. December 1998 data collected by RMT.
(2) Dissolved oxygen and E_H measurements may not be representative of groundwater conditions because the well was either purged dry prior to sampling, or the well was purged and/or sampled with a bailer.
(3) June 1998 groundwater samples from monitoring wells 33MWC-27 and 33MWC-28 appear to have been switched. Wells were resampled in July 1998.

Prepared by: MLW 1/21/99
Checked by: PMC 1/26/99

Table 6-10

Summary of Volatile and Semivolatile Organic Compounds and PCBs Detected in Surface Water[1]

Groundwater Investigation Report and Focused Feasibility Study

PCBOU Sites 32/33

Marion, Illinois

PARAMETER	UNITS	MCL[2]	32SW-01 04/10/1996	32SW-02 04/10/1996	33SW-03 04/09/1996	SW32R-103 04/09/1996	SW32R-233 12/10/1998	SW32R-236 12/10/1998	SW32R-237 04/09/1996
VOCs									
1,1-DICHLOROETHENE	µg/L	7							
1,2,4-TRICHLOROBENZENE	µg/L	70				0.1 J			0.4 J
1,2-DICHLOROBENZENE	µg/L	600							
ACETONE	µg/L	NE					12.4		
CIS-1,2-DICHLOROETHENE	µg/L	70			6				
METHYLENE CHLORIDE	µg/L	5	0.4 J	0.4 J	0.8 J				
TRANS-1,2-DICHLOROETHENE	µg/L	100							
TRICHLOROETHENE	µg/L	5			53			1	
SVOCs									
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6							
DI-N-BUTYLPHTHALATE	µg/L	NE			2				
PCBs									
AROCLOR-1254	µg/L	0.5					0.53 J		

Notes:

(1) Data presented in table represent the available data from April 1996 through December 1998.

(2) Federal Maximum Contaminant Level.

Refer to Table 6-12 for pertinent Illinois General Use Water Quality Standards for Crab Orchard Lake.

No entry indicates that the parameter was not detected in the water sample, or that the water sample was not analyzed for that parameter.

NE = not established.

Table 6-10

Summary of Volatile and Semivolatile Organic Compounds and PCBs Detected in Surface Water[1]
Groundwater Investigation Report and Focused Feasibility Study
PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	MCL[2]	SW32R-237 12/10/1998	SW32R-240 04/10/1996	SW32R-240/241 12/10/1998	SW32R-242 12/10/1998	SW32R-250 12/11/1998
VOCs							
1,1-DICHLOROETHENE	µg/L	7				1.2	
1,2,4-TRICHLOROBENZENE	µg/L	70					
1,2-DICHLOROBENZENE	µg/L	600					1.1
ACETONE	µg/L	NE			2.8 J		
CIS-1,2-DICHLOROETHENE	µg/L	70		0.7	8.9	272 D	
METHYLENE CHLORIDE	µg/L	5					
TRANS-1,2-DICHLOROETHENE	µg/L	100				10.3	
TRICHLOROETHENE	µg/L	5		0.2 J	8.9	1038.5 D	
SVOCs							
BIS(2-ETHYLHEXYL)PHTHALATE	µg/L	6	2 J				1 J
DI-N-BUTYLPHTHALATE	µg/L	NE	1 J				
PCBs							
AROCLOR-1254	µg/L	0.5					

Notes:
(1) Data presented in table represent the available data from April 1996 through December 1998.
(2) Federal Maximum Contaminant Level.

Refer to Table 6-12 for pertinent Illinois General Use Water Quality Standards for Crab Orchard Lake.

No entry indicates that the parameter was not detected in the water sample, or that the water sample was not analyzed for that parameter.

NE = not established.

Table 6-11

Summary of Metals and Inorganic Indicator Parameters Detected in Surface Water [1]
Groundwater Investigation Report and Focused Feasibility Study
PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	32SW-01 04/10/1996	32SW-02 04/10/1996	33SW-03 04/09/1996	SW32R-103 04/09/1996	SW32R-233 12/10/1998	SW32R-236 12/10/1998	SW32R-237 04/09/1996
METALS								
ALUMINUM, TOTAL	µg/L	1140 J	1440 J	1070 J	8720 J	697	601	5430 J
ARSENIC, TOTAL	µg/L				5 J			4.2 J
BARIUM, DISSOLVED	µg/L	24 J	22.7 J	54.7 J	29.1			25.95
BARIUM, TOTAL	µg/L	33.3 J	36.2 J	59.1 J	81.6 J	56.4 B	121 B	69.9 J
CADMIUM, DISSOLVED	µg/L							2.8 J
CALCIUM, DISSOLVED	µg/L	48800	47500	124000	44300			42100
CALCIUM, TOTAL	µg/L	46100	46800	120000	44000	118000	241000	44200
CHROMIUM, TOTAL	µg/L				8 J	0.8 B	0.91 B	4.5 J
COBALT, TOTAL	µg/L						2 B	
COPPER, DISSOLVED	µg/L	4.8 J	3.4 J	4.7 J	3.4 J			4.2 J
COPPER, TOTAL	µg/L					6.5 B	9.4 B	
IRON, TOTAL	µg/L	1140 J	1630 J	702 J	8360 J	615	685	5370 J
LEAD, TOTAL	µg/L				4.8	1.8 B		3.8
MAGNESIUM, DISSOLVED	µg/L	18500	17800	55200	16300			15600
MAGNESIUM, TOTAL	µg/L	17300	17500	53300	16800	38600	47900	16500
MANGANESE, DISSOLVED	µg/L	6.7 J	3 J	2140	66.5			122
MANGANESE, TOTAL	µg/L	230	272	2100	488	67.6	3770	495
NICKEL, TOTAL	µg/L					2.4 B	3.9 B	
POTASSIUM, DISSOLVED	µg/L	3720 J	3540 J	1820 J	3350 J			3830 J
POTASSIUM, TOTAL	µg/L	3760 J	3850 J	1900 J	4480 J	5440	5120	4520 J
SODIUM, DISSOLVED	µg/L	37900	36800	106000	37600			36100
SODIUM, TOTAL	µg/L	35600	36200	103000	35600	93300 Ej	64800 Ej	34500
VANADIUM, TOTAL	µg/L				16.2 J	1.4 B	1.3 B	10.2 J
ZINC, TOTAL	µg/L				35.9	14.3 B	45.9	

Notes:

[1] Data presented in table represent the available data from April 1996 through December 1998.

Refer to Table 6-12 for pertinent Illinois General Use Water Quality Standards for Crab Orchard Lake.

No entry indicates that the parameter was not detected in the water sample, or that the water sample was not analyzed for that parameter.

Table 6-11

Summary of Metals and Inorganic Indicator Parameters Detected in Surface Water [1]
Groundwater Investigation Report and Focused Feasibility Study
PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	32SW-01 04/10/1996	32SW-02 04/10/1996	33SW-03 04/09/1996	SW32R-103 04/09/1996	SW32R-233 12/10/1998	SW32R-236 12/10/1998	SW32R-237 04/09/1996
INDICATOR PARAMETERS								
ALKALINITY AS $CaCO_3$	mg/L					130	297	
CHLORIDE	mg/L					0.87		
CYANIDE, AMENABLE	mg/L							
CYANIDE, TOTAL	mg/L							
NITROGEN, NITRATE + NITRITE	mg/L					0.115	0.057	
SULFATE	mg/L					337	386	

Notes:
[1] Data presented in table represent the available data from April 1996 through December 1998.

Refer to Table 6-12 for pertinent Illinois General Use Water Quality Standards for Crab Orchard Lake.

No entry indicates that the parameter was not detected in the water sample, or that the water sample was not analyzed for that parameter.

Table 6-11

Summary of Metals and Inorganic Indicator Parameters Detected in Surface Water [1]
Groundwater Investigation Report and Focused Feasibility Study
PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	12/10/1998	SW32R-240 04/10/1996	SW32R-240/241 12/10/1998	SW32R-242 12/10/1998	SW32R-250 12/11/1998
METALS						
ALUMINUM, TOTAL	µg/L	552	1930 J	623	235	1070
ARSENIC, TOTAL	µg/L					
BARIUM, DISSOLVED	µg/L		28.4 J			
BARIUM, TOTAL	µg/L	59.3 B	43 J	45.1 B	54.4 B	27.4 B
CADMIUM, DISSOLVED	µg/L					
CALCIUM, DISSOLVED	µg/L		48400			
CALCIUM, TOTAL	µg/L	24800	49400	106000	215000	34100
CHROMIUM, TOTAL	µg/L	0.96 B		0.79 B		2.3 B
COBALT, TOTAL	µg/L			1.4 B	0.67 B	
COPPER, DISSOLVED	µg/L		2.8 J			
COPPER, TOTAL	µg/L	8.4 B		11.6 B	8.3 B	7.9 B
IRON, TOTAL	µg/L	416	2070 J	967	99.7 B	1000
LEAD, TOTAL	µg/L			2.6 B		2.4 B
MAGNESIUM, DISSOLVED	µg/L		18400			
MAGNESIUM, TOTAL	µg/L	14600	10000	39000	70800	9300
MANGANESE, DISSOLVED	µg/L		273			
MANGANESE, TOTAL	µg/L	47.4	537	547	550	25.4
NICKEL, TOTAL	µg/L	5.2 B		2.6 B	3.5 B	1.8 B
POTASSIUM, DISSOLVED	µg/L		3230 J			
POTASSIUM, TOTAL	µg/L	1980 B	3580 J	4360 B	3920 B	3470 B
SODIUM, DISSOLVED	µg/L		46400			
SODIUM, TOTAL	µg/L	48000 Ej	45800	116000 Ej	212000 Ej	9550
VANADIUM, TOTAL	µg/L	1.2 B		2.6 B		1.9 B
ZINC, TOTAL	µg/L	18.7 B		31.6	27.3	16.8 B

Notes:
[1] Data presented in table represent the availab
data from April 1996 through December 199

Refer to Table 6-12 for pertinent Illinois General Use Water Quality Standards for Crab Orchard Lake.

No entry indicates that the parameter was not detected in the water sample, or that the water sample was not analyzed for that parameter.

Table 6-11

Summary of Metals and Inorganic Indicator Parameters Detected in Surface Water [1]
Groundwater Investigation Report and Focused Feasibility Study
PCBOU Sites 32/33
Marion, Illinois

PARAMETER	UNITS	12/10/1998	SW32R-240 04/10/1996	SW32R-240/241 12/10/1998	SW32R-242 12/10/1998	SW32R-250 12/11/1998
INDICATOR PARAMETERS						
ALKALINITY AS $CaCO_3$	mg/L	27.8		151	153	128
CHLORIDE	mg/L	37.9		0.87	3.48	
CYANIDE, AMENABLE	mg/L					0.0088 B
CYANIDE, TOTAL	mg/L					0.0088
NITROGEN, NITRATE + NITRITE	mg/L	0.129				0.05
SULFATE	mg/L	119		362	662	28.8

Notes:
[1] Data presented in table represent the availab
data from April 1996 through December 199

Refer to Table 6-12 for pertinent Illinois General Use Water Quality Standards for Crab Orchard Lake.

No entry indicates that the parameter was not detected in the water sample, or that the water sample was not analyzed for that parameter.

Table 6-12
Illinois General Use Water Quality Standards for Crab Orchard Lake

CONSTITUENT	ILLINOIS GENERAL USE WATER QUALITY STANDARDS[1][2] FOR CRAB ORCHARD LAKE		
	AATC[3][4]	CATC[3][4]	HH[3]
1,2-Dichloroethene	(14,000)	(1,100)	NC
1,2-Dichlorobenzene	210	170	5,500
trans-1,2-Dichloroethene	NC	NC	34,000
cis-1,2-Dichloroethene	NC	NC	NC
Tetrachloroethene	1,200	150	2.8
Trichloroethene	12,000	940	25
Toluene	1,300	110	62,000
Vinyl chloride	(40,000)	(4,000)	120
Xylenes	1,500	120	62,000
2-Chlorophenol	510	41	130
3-Methyl-4-chlorophenol	310	25	NC
2,4-Dimethylphenol	740	220	740
Chlorinated p-dioxins	NC	NC	NC
Chlorinated dibenzofurans	NC	NC	NC
Phenol	100	NC	NC
Naphthalene	510	68	NC
PCBs	NC	NC	0.000015
Cadmium (total)	9.7	1.1	NC
Chromium (+3) (total)	1.7	0.21	NC
Chromium (+6) (total)	16	11	NC
Copper (total)	18	12	NC
Iron (dissolved)	1,000	NC	NC
Lead (total)	96	20	NC

Notes:

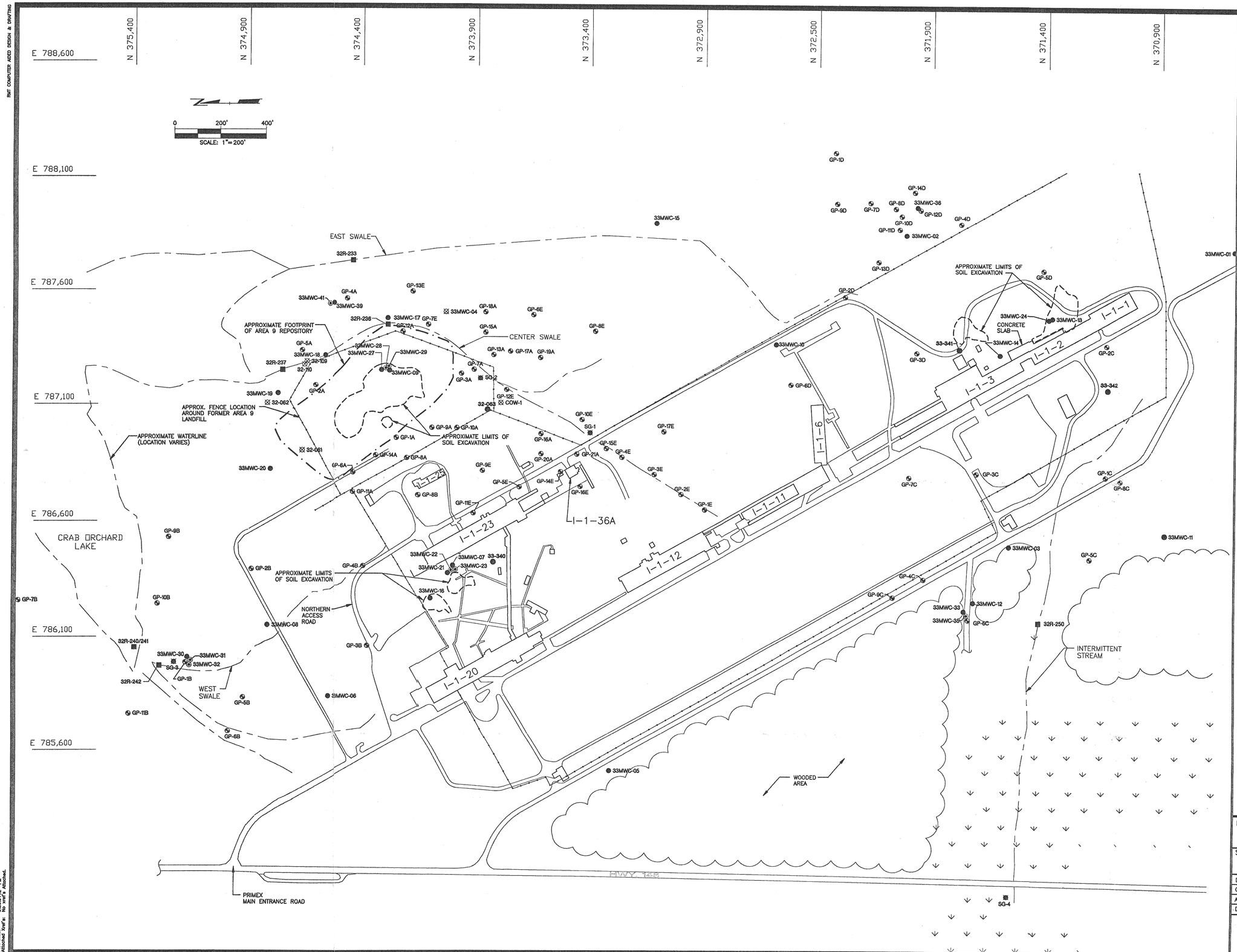
(1) 35 IAC Part 302, Subpart B: General Use Water Quality Standards
Part 302.208: Numeric Standards for Chemical Constituents
Part 302.210: Other Toxic Substances
Concentrations shown for constituents classified as "Other Toxic Substances" were calculated by IEPA – Bureau of Water, for Crab Orchard Lake.

(2) All concentrations are in micrograms per liter (µg/L).

(3) AATC = Acute Standard or Acute Aquatic Toxicity Criterion.
CATC = Chronic Aquatic Toxicity Criterion.
HH = Human Health Criterion.
NC = no criterion.

(4) Parentheses indicate calculated concentration is considered a provisional criterion to be applied as a guidance or screening value.

Part I
Figures



LEGEND

33MWC-30	SHALLOW MONITORING WELL
33MWC-22	PIEZOMETER
SG-4	STAFF GAUGE
32R-242	SURFACE WATER SAMPLING LOCATION
GP-1A	GEOPROBE SAMPLE LOCATION
32-061	MONITORING WELL, ABANDONED (APPROXIMATE LOCATION)
	APPROXIMATE CENTERLINE OF SURFACE DRAINAGE CHANNEL/SWALE
	FENCE
	APPROXIMATE LIMITS OF SOIL EXCAVATION FOR PCB REMEDIAL ACTION
	APPROXIMATE FOOTPRINT OF AREA 9 REPOSITORY
	MARSH/WETLAND
	APPROXIMATE LOCATION OF WOODED AREAS WEST OF SITE 32/33

NOTES

1. SOURCE: BASE MAP FROM "1998 TCE INVESTIGATION, WORKPLAN AND PILOT STUDY FOR THE PCB OPERABLE UNIT AT THE CRAB ORCHARD NATIONAL WILDLIFE REFUGE SUPERFUND SITE, MARION, ILLINOIS" REV. 1, MAY 1998, PREPARED BY FLUOR DANIEL GTI.
2. ALL EXISTING BUILDINGS, ROADS, AND SITE FEATURES ARE NOT SHOWN.
3. APPROXIMATE EXTENT OF MARSH/WETLANDS ESTIMATED FROM SITE TOPOGRAPHIC MAP.
4. LOCATION OF ALL WOODED AREAS NOT SHOWN.
5. EXCAVATION BOUNDARIES REPRESENT ONLY THOSE EXCAVATIONS LOCATED NEAR THE ORIGINS OF THE SEPARATE GROUNDWATER CVOC PLUMES.

PROJECT: CRAB ORCHARD NWR - PCB O.U.
GROUNDWATER INVESTIGATION REPORT AND FOCUSED FEASIBILITY STUDY

SHEET TITLE: SITE PLAN SITES 32/33

DRAWN BY: SIEWERTD	SCALE: 1"=200'	PROJ. NO. 4781.03
CHECKED BY: SLM		FILE NO. 47810318.DWG
APPROVED BY: TEG	DATE PRINTED: JAN 13 2000	FIGURE 3-1
DATE: JANUARY 2000		

RMT, INC.
744 Heartland Trail
Madison, WI 53717-1934
P.O. Box 8923
Madison, WI 53708-8923
Phone: 608/831-4444

RMT COMPUTER AIDED DESIGN & DRAFTING

RMT Data
Drawing Name: u:\47810\03\47810318.dwg
Operator Name: SIEWERTD
Drawing Size: 630/750 Bytes
Plot Date: Thursday, February 11, 1999
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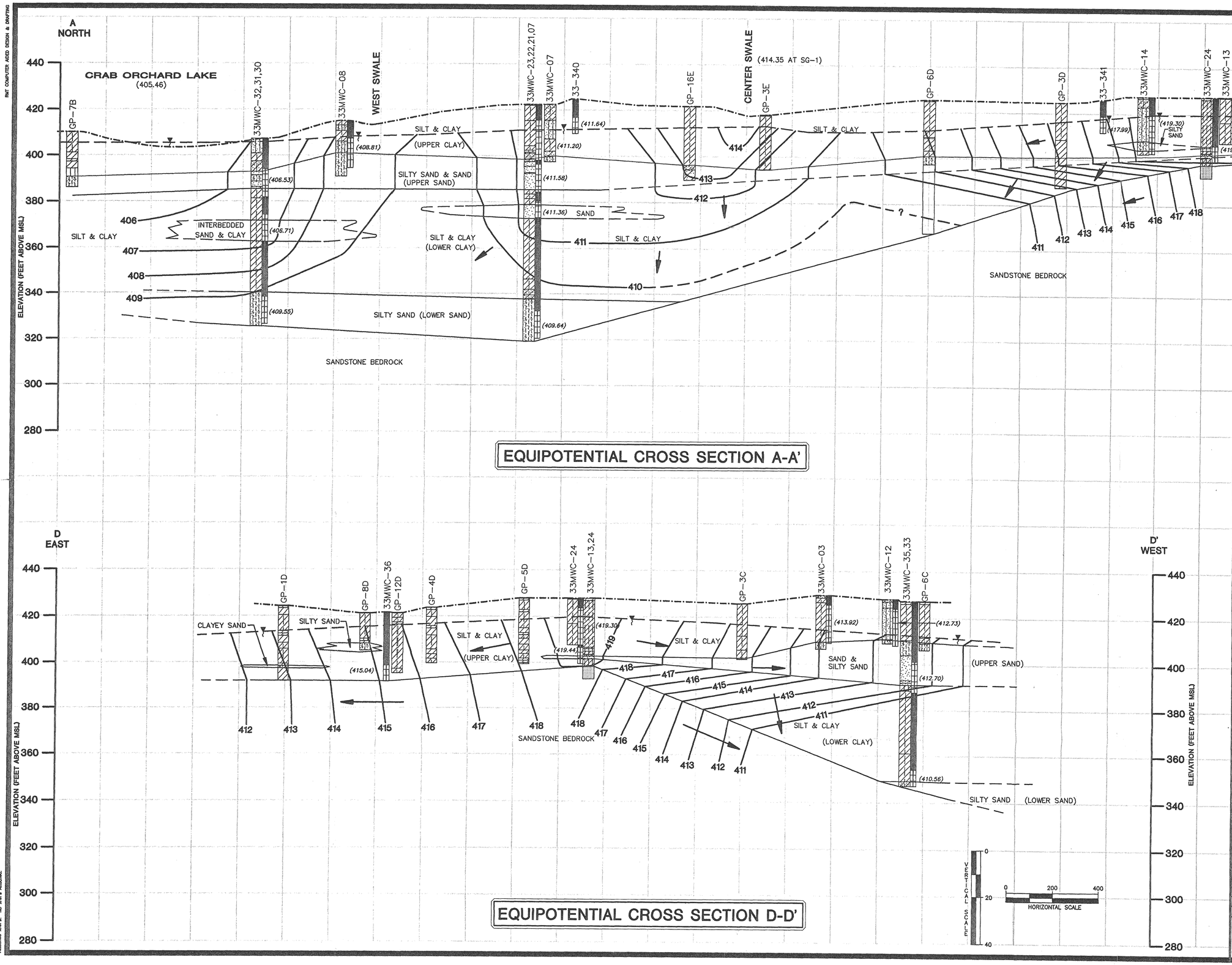


EQUIPOTENTIAL CROSS SECTION A-A'

EQUIPOTENTIAL CROSS SECTION D-D'

LEGEND

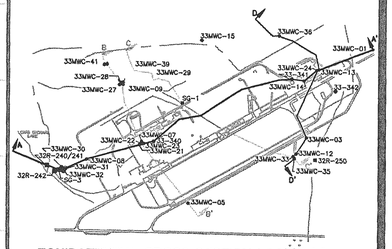
- STRATIGRAPHIC BOUNDARY (DASHED WHERE INFERRED)
- WATER TABLE SURFACE (12-6-98)
- EXISTING GROUND SURFACE
- (411.58) GROUNDWATER HEAD ELEVATION (FEET, MSL) (12-6-98)
- EQUIPOTENTIAL LINE (CONTOUR = 1.0 FT.)

STRATIGRAPHIC UNITS

- SAND
- SILTY SAND
- CLAYEY SAND
- SANDY SILT
- SILT
- SILTY, SANDY CLAY
- SILTY CLAY/CLAYEY SILT
- CLAY
- ASH FILL
- SANDSTONE BEDROCK

WELL CONSTRUCTION DETAIL

- WELL SEAL
- WELL SCREEN & SAND PACK



EQUIPOTENTIAL CROSS SECTION LOCATION MAP

PROJECT: CRAB ORCHARD NWR - PCB O.U.
GROUNDWATER INVESTIGATION REPORT AND
FOCUSED FEASIBILITY STUDY

SHEET TITLE:
EQUIPOTENTIAL CROSS SECTIONS A-A' & D-D'
SITES 32/33, DECEMBER 1998

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CHECKED BY: SLM		FILE NO. 47810317.DWG
APPROVED BY: TEG	DATE PRINTED: JAN 13 2000	FIGURE 4-9
DATE: JANUARY 2000		

RMT, INC.
744 Heartland Trail
Madison, WI 53717-1934
P.O. Box 8923
Madison, WI 53708-8923
Phone: 608/831-4444

RMT COMPUTER AIDED DESIGN & DRAFTING
PLOT DATA
Drawing Name: A:\047810\320\47810317.dwg
Operator Name: SIEWERTD
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Plot Time: 3:00:07pm PM
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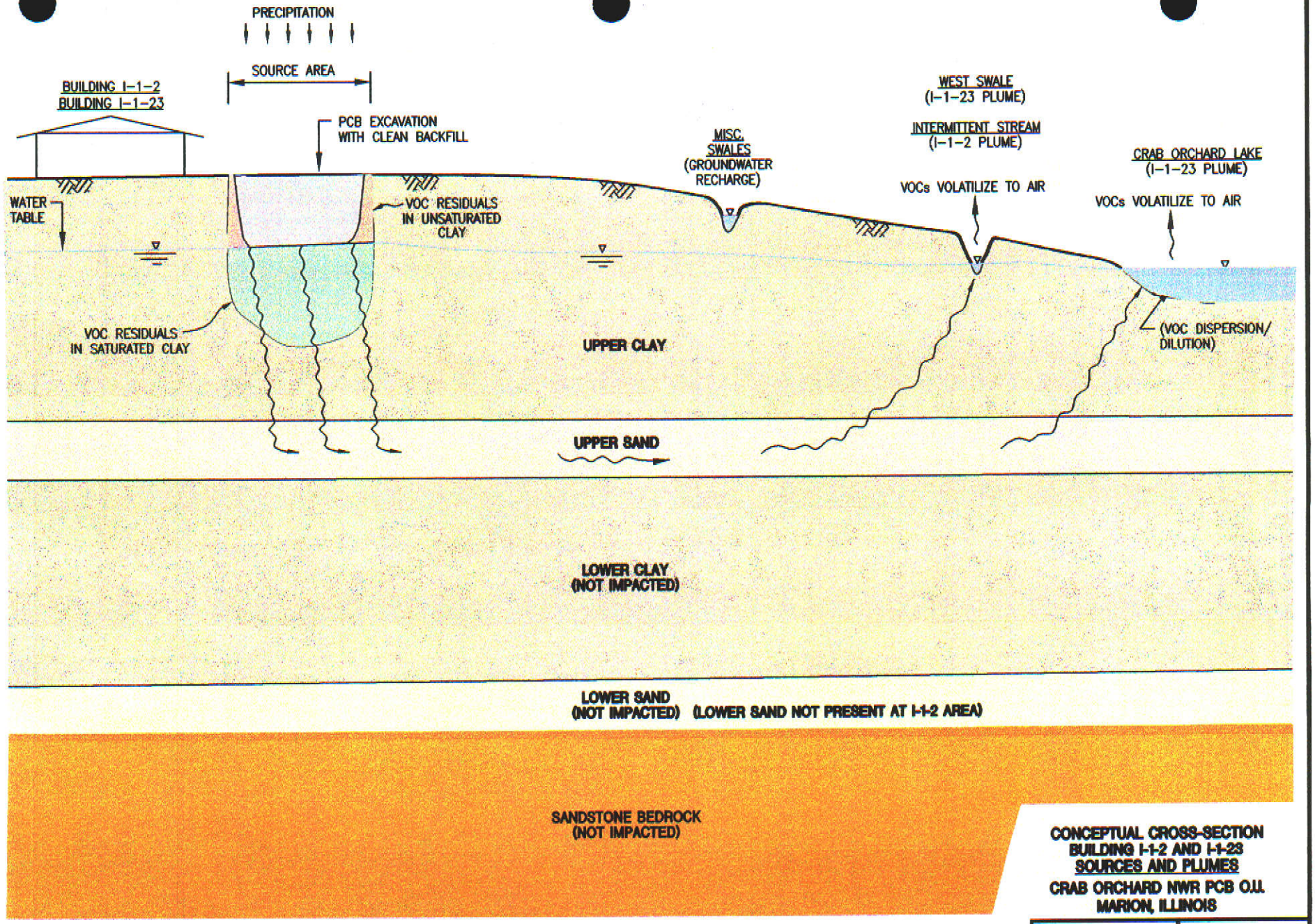

NOTES

1. VOC DEGREDATION THAT IS OCCURRING ALONG TRANSPORT PATH IS NOT SHOWN ON THIS CONCEPTUAL DRAWING.

LEGEND

PREDOMINANT VOC TRANSPORT PATH

NOT TO SCALE

CONCEPTUAL CROSS-SECTION
BUILDING I-1-2 AND I-1-23
SOURCES AND PLUMES
CRAB ORCHARD NWR PCB O.U.
MARION, ILLINOIS

RMT

DWN. BY:	BREWSTEK
APPROVED BY:	TEG
DATE:	JANUARY 2000
PROJ. #	4781.03
FILE #	8X110327.DWG

FIGURE 7-1

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Plot Time: 2:42:23 PM
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