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Pinellas STAR Center

Building 100 Area Remediation Technology Screening Report

August 2001

U.S. Department of Energy

GRAND JUNCTION OFFICE

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Pinellas STAR Center

Building 100 Area

Remediation Technology Screening Report

August 2001

Prepared by
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Acronyms and Abbreviations

bls	below land surface
CEARP	Comprehensive Environmental Assessment and Response Program
Center	Pinellas Science, Technology, and Research Center
CMIP	Corrective Measures Implementation Plan
CMS	Corrective Measures Study
COCs	contaminants of concern
CROW	contained recovery of oily wastes
DCE	dichloroethene
°C	degrees Celsius
DNAPL	dense non-aqueous phase liquid
DOE	U.S. Department of Energy
DPE	dual phase extraction
EPA	U.S. Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
FRTR	Federal Remediation Technologies Roundtable
ft	feet (foot)
GAC	granular activated carbon
HSWA	Hazardous and Solid Waste Amendments
ITRC	Interstate Technology and Regulatory Cooperation
ITRD	Innovative Treatment Remediation Demonstration
LNAPL	light non-aqueous phase liquid
MCLs	maximum contaminant levels
µg/L	micrograms per liter
mg/L	milligrams per liter
µmhos/cm	micromhos per centimeter
mV	millivolts
NAPL	non-aqueous phase liquid
NASA	National Aeronautics and Space Administration
NTU	nephelometric turbidity units
O&M	operation and maintenance
PCIC	Pinellas County Industry Council
POTW	publicly owned treatment works
PRB	permeable reactive barrier
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RTDF	Remediation Technologies Development Forum
SWMU	Solid Waste Management Unit
TCE	trichloroethene
VOCs	volatile organic compounds

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Executive Summary

MACTEC Environmental Restoration Services, LLC and the U.S. Department of Energy determined that a review of currently available remediation technologies and their applicability to remediation at the Building 100 Area is appropriate, based on the following issues: the dated Building 100 Corrective Measure Study, changes in regulatory setting and property ownership, recent data indicating a contaminant plume near the property boundary, and the identification of potential non-aqueous liquids.

Remediation at the Building 100 Area has been divided into three tasks.

1. Plume control near the property boundary at the southeast corner of the Center.
2. Treatment of potential contaminant source(s) under Building 100.
3. Treatment of dissolved phase contamination in the Building 100 Area.

The purpose of this document is to identify new remediation technologies, analyze and screen all available remediation technologies for their applicability to the three remediation tasks at the Building 100 Area, and to recommend technologies or groups of technologies that should be retained for detailed consideration at a later time. The results of the screening are summarized below, and the recommended technology types are discussed in detail in Sections 5.3, 6.3, and 7.3.

Summary of Recommended Technology Types

Plume Control	Source Treatment	Dissolved Phase Treatment
1) Enhanced bioremediation	1) Enhanced bioremediation	1) Enhanced bioremediation
2) Dual phase extraction	2) Chemical oxidation	2) Permeable reactive barrier walls
3) Permeable reactive barrier walls	3) Soil flushing/solubilization	3) Chemical oxidation
4) Groundwater pumping with ex situ treatment		4) Groundwater pumping with ex situ treatment
5) Vertical barriers		

A baseline sampling of soil and groundwater under the building, where feasible, and along the south and east property boundaries should be conducted prior to selection of the final remediation technologies. Without these additional data, broad assumptions would be necessary for remediation technology design. It is likely that these broad assumptions would result in significantly higher remediation costs relative to systems with designs based on more detailed data.

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1.0 Introduction

The Pinellas Science, Technology, and Research Center (Center) is a former U.S. Department of Energy (DOE) facility located in Largo, Florida. Two of the remaining four active Solid Waste Management Units (SWMUs) at the Center are PIN06, the Old Drum Storage Site, and PIN12, Industrial Drain Leaks-Building 100 Area (Figure 1). These two SWMUs are being remediated together because they are adjacent and have similar contaminants. Together, these two SWMUs are referred to as the Building 100 Area.

A series of Resource Conservation and Recovery Act (RCRA) Corrective Action documents have been written for the Building 100 Area; these documents are discussed in Section 1.2. Several years have passed since the Building 100 Area Corrective Measures Study (CMS) Report (DOE 1994), the Corrective Measures Implementation Plan (CMIP) (DOE 1996a), and the CMIP Addendum (DOE 1998a) were written. During this time, several changes have occurred, as listed below.

- Site-specific information, such as water quality data, has been updated.
- Changes in groundwater contaminant distribution and plume geometry have been observed.
- Potential non-aqueous phase liquids (NAPLs) have been identified.
- The regulatory setting has changed. In November 2000, Hazardous and Solid Waste Amendments (HSWA) authority was transferred from the U.S. Environmental Protection Agency (EPA) to the Florida Department of Environmental Protection (FDEP). A HSWA permit renewal application was submitted to the FDEP in July 2001.
- Property ownership has transferred from DOE to Pinellas County.
- Remediation schedule and priorities have been revised.
- Additional remediation technologies have emerged, and some methods of implementation for existing technologies may have changed.

Of particular importance is the remediation schedule. Currently, cleanup of the entire Building 100 Area is planned for completion by September 2010. Therefore, aggressive technologies may be necessary to meet cleanup goals by 2010. Typically, aggressive technologies are more expensive than relatively more passive technologies that take longer to achieve cleanup goals.

Remediation at the Building 100 Area has been divided into three tasks that are discussed in detail in Section 3.1.

1. Plume control near the property boundary at the southeast corner of the Center.
2. Treatment of potential contaminant source(s) under Building 100.
3. Treatment of dissolved phase contamination in the Building 100 Area.

1.1 Purpose

The purpose of this document is to identify new remediation technologies developed since the CMIP, analyze and screen all available technologies for applicability at the Building 100 Area, and recommend technologies or groups of technologies that should be retained for detailed consideration at a later time.

This document will not take the final step of recommending the specific technology that should be implemented for each of the three remediation tasks. Considerably more information about the technologies recommended in this document should be obtained to further evaluate effectiveness and costs prior to recommendation of the final technology. Also, additional soil and groundwater data may be required prior to specific remedy selection, as discussed in Section 2.3.5.

1.2 Building 100 Area Background and Operational History

The Pinellas Plant was constructed in the mid-1950s and primarily manufactured neutron generators for nuclear weapons. Additional products manufactured at the plant included radioisotopically-powered thermoelectric generators, thermal batteries, specialty capacitors, crystal resonators, neutron detectors, lightning arrester connectors, and vacuum switch tubes. On March 17, 1995, DOE sold the Pinellas Plant to the Pinellas County Industry Council (PCIC). The sales contract included clauses to ensure continued cleanup of the site by DOE. On July 1, 1999, the PCIC was dissolved and ownership of the Center changed to the Pinellas County government. The former Pinellas Plant is now known as the Pinellas Science, Technology, and Research Center.

1.2.1 Building 100

Building 100 is the most notable feature of the Center, covering approximately 11 acres in the southeastern corner of the Center (Figure 1). This structure housed the DOE Pinellas Area Office and the majority of former laboratory and production facilities located at the site. Building 100 has gone through a number of expansions during its history (Figure 2). A number of other former and current structures functioning as storage, utility, conveyance, and testing facilities are located around Building 100 and throughout the Center. One of the former structures, the Old Drum Storage Site, is discussed in Section 1.2.2.

The need for remediation of environmental contamination at the Building 100 Area was first identified during investigations conducted under the DOE Comprehensive Environmental Assessment and Response Program (CEARP). The CEARP Phase I: Installation Assessment Pinellas Plant (DOE 1987b) identified the Old Drum Storage Site and the Industrial Drain Leaks at Building 100 as areas potentially requiring remediation based on past waste storage and handling activities.

SWMU PIN12 (Industrial Drain Leaks) consists of the liquid waste drain system that served Building 100. Four individual drainage systems were present within the building: health physics, chemical, sanitary, and storm systems. During the mid to late 1970s, drain lines associated with Building 100 deteriorated so that several leaks occurred under the building (DOE 1987a & b).

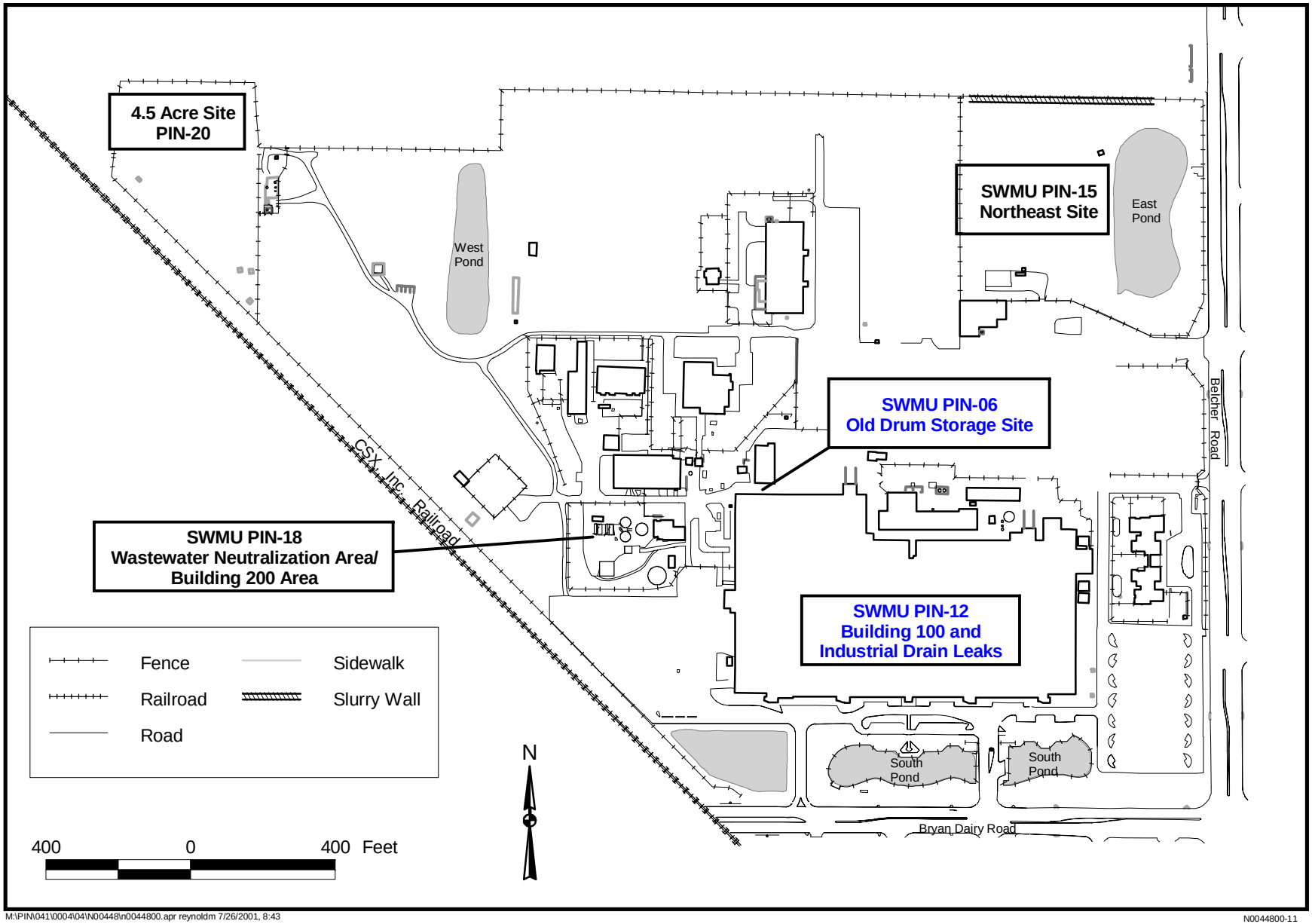

Figure 1. Location of PIN06 and PIN12

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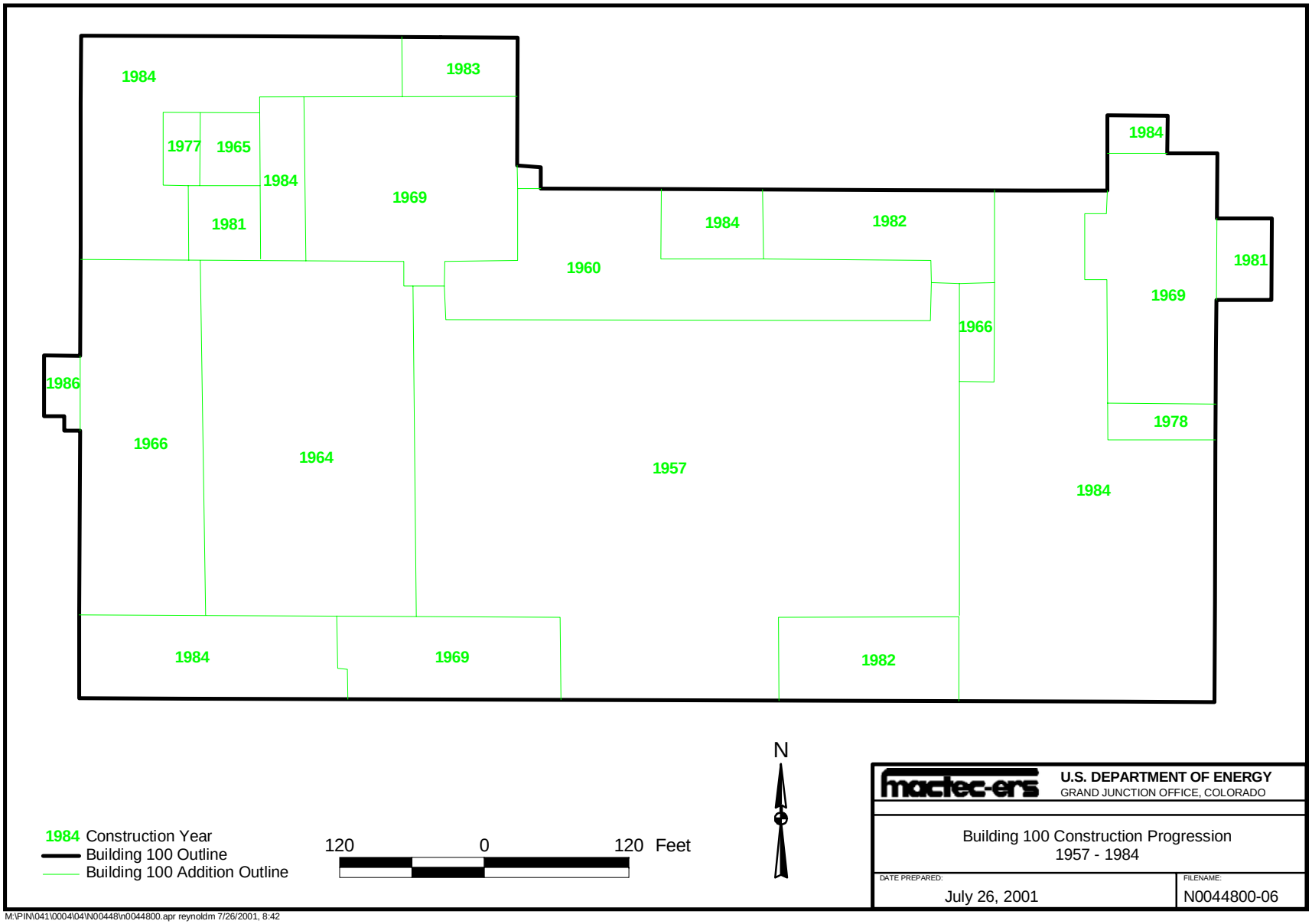

Figure 2. Building 100 Construction Progression

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The drain lines were repaired when the leaks were discovered, but an undetermined amount of wastewater escaped to the soil. These reports do not specify which drain systems leaked, or where the leaks occurred.

The health physics drain system in Building 100 was originally composed of two piping systems: health physics (standard) for fluids that were used in production processes involving the exclusive use of tritium, and health physics (chemical) for fluids that had potentially been in contact with either tritium or hazardous wastes (DOE 1991). These two piping systems were later tied together during building additions. The liquid within the health physics system was gravity-drained to a manhole near the southwest corner of Building 100, then continued to a lift station that pumped the liquid to one of three holding tanks (Figure 3). The composition of the health physics waste stream was primarily deionized water; however, any fluid that may have been contaminated with tritium entered the health physics system. These fluids may have included photographic developers and fixatives, cleaners, and acids (EMC 1989).

The chemical waste system in Building 100 (Figure 4) disposed of liquids such as acids, caustics, rinses, or other liquids that were not purely sanitary, such as condensate from air handling units (DOE 1991). In general, the chemical drains within Building 100 flowed to the east to be pumped west of the building to the main lift station. The chemical waste stream was generated by rinsing and diluting procedures in the laboratories and from condensate drains in the air-handling units. The composition of the chemical waste stream was primarily deionized water, photographic developers and fixatives, cleaners, and acids in dilute concentrations.

The sanitary drain system in Building 100 was composed of domestic wastewater drains. The drain lines in the building connected to mains that flow to the south to exit the building and were routed to various lift stations. The storm drain system in Building 100 was made up of several independent subsystems that were connected before the system exited the building. Roof drains in Building 100 were tied to headers that run through the ceiling level and then drain to underground mains, which then drain by gravity to the site storm drainage system (EMC 1989).

An investigation to determine the existing conditions of the Building 100 waste drainage systems was conducted by EMC Engineers, Inc. in 1989 (EMC 1989). All four drainage systems were investigated, including verification of system routing and the condition of underground and aboveground piping and ancillary equipment. Visual inspection, dye test tracing, excavation, ultrasonic testing, in-line video observation, and employee interviews were conducted. The investigation concluded that a portion of the health physics and chemical waste systems should be replaced, and that five possible leaks were identified as needing further investigation. Another important conclusion was that there were possible additional drain leaks beneath Building 100 that could contribute to the existing contaminant plume identified along the northwest corner of Building 100, or that could cause additional contaminant plumes at other locations beneath Building 100. Pinellas Plant facility personnel repaired the five identified drain leaks in Building 100 during maintenance operations (DOE 1994). Subsequently, the health physics and chemical drain systems were flushed, grouted, and abandoned, and some of the chemical drain systems were replaced by an above ground system that currently is in use (DOE 1997).

The RCRA Facility Assessment (RFA) Report (EPA 1988) recommended further assessment of two abandoned deep wells in the Floridan aquifer located under Building 100. One was believed to be located under the southwest corner of the building and was sealed with three yards of grout before being covered by the building (GE 1983). The other well was believed to be located under

Area 167 and was capped but not sealed before being covered by the building. However, the exact location of these wells is unknown. These wells are potential conduits for contamination to enter the Floridan aquifer. The presence of these wells needs to be considered during selection of the final remedial alternatives for the Building 100 Area.

1.2.2 Old Drum Storage Site

The Old Drum Storage Site (SWMU PIN06) is the former location of a concrete storage pad, equipped with a drain and containment system, used to store hazardous waste, including methylene chloride, ignitable liquids, arsenic, and calcium chromate solids (DOE 1987a). The concrete pad was located near the northwest corner of Building 100 (Figure 5). Empty drums containing residual waste solvents were also stored in this area (DOE 1987b). The pad was removed in October 1983 in accordance with an FDEP closure permit (DOE 1987a); a closure report was submitted to the FDEP in August 1986 (DOE 1986).

Employees interviewed indicated that, before 1960, drums were stored in an open area that is now under the northwest corner of Building 100 (DOE 1987b). These drums contained Epon 828 resin as bottoms (the small amount left in a drum after it has been used). According to employee interviews, in some cases drums were tipped over to drain the remaining contents. The resin itself is not a contaminant, but other potential contaminants may have been contained in the drums. This site may not have been fully cleaned up before the construction of Building 100.

1.2.3 Building 100 Area Documents

A RCRA Facility Investigation (RFI) was conducted in 1991 at the Pinellas Plant to fulfill requirements of the HSWA Permit, and an RFI Report was produced (DOE 1991). A subsequent RFI Report Addendum was completed in March 1992. Based on the findings in these two documents, in accordance with the HSWA Permit, EPA notified DOE of the requirement for a corrective measures study for the Old Drum Storage Site and the Industrial Drain Leaks - Building 100.

The CMS Report for the Building 100 Area and Old Drum Storage Site (DOE 1994) proposed remediation of these two SWMUs together (collectively referred to as the Building 100 Area). The report was submitted to the EPA and subsequently approved on June 9, 1994. The FDEP approved the CMS Report on January 18, 1995.

Based on the screening process in the CMS Report, three corrective measures actions were identified:

- pump-and-treat with an existing air stripping system;
- pump-and-treat with UV/oxidation; and
- pump-and-dispose to the Pinellas County publicly owned treatment works (POTW).

Pump-and-treat with the existing air stripping system was the preferred corrective measure for the Building 100 Area.

As detailed in the Building 100 Area CMIP (DOE 1996a), implementation of corrective measures at the Building 100 Area included installation of two groundwater recovery wells near the northwest corner of Building 100. These wells pump extracted groundwater through

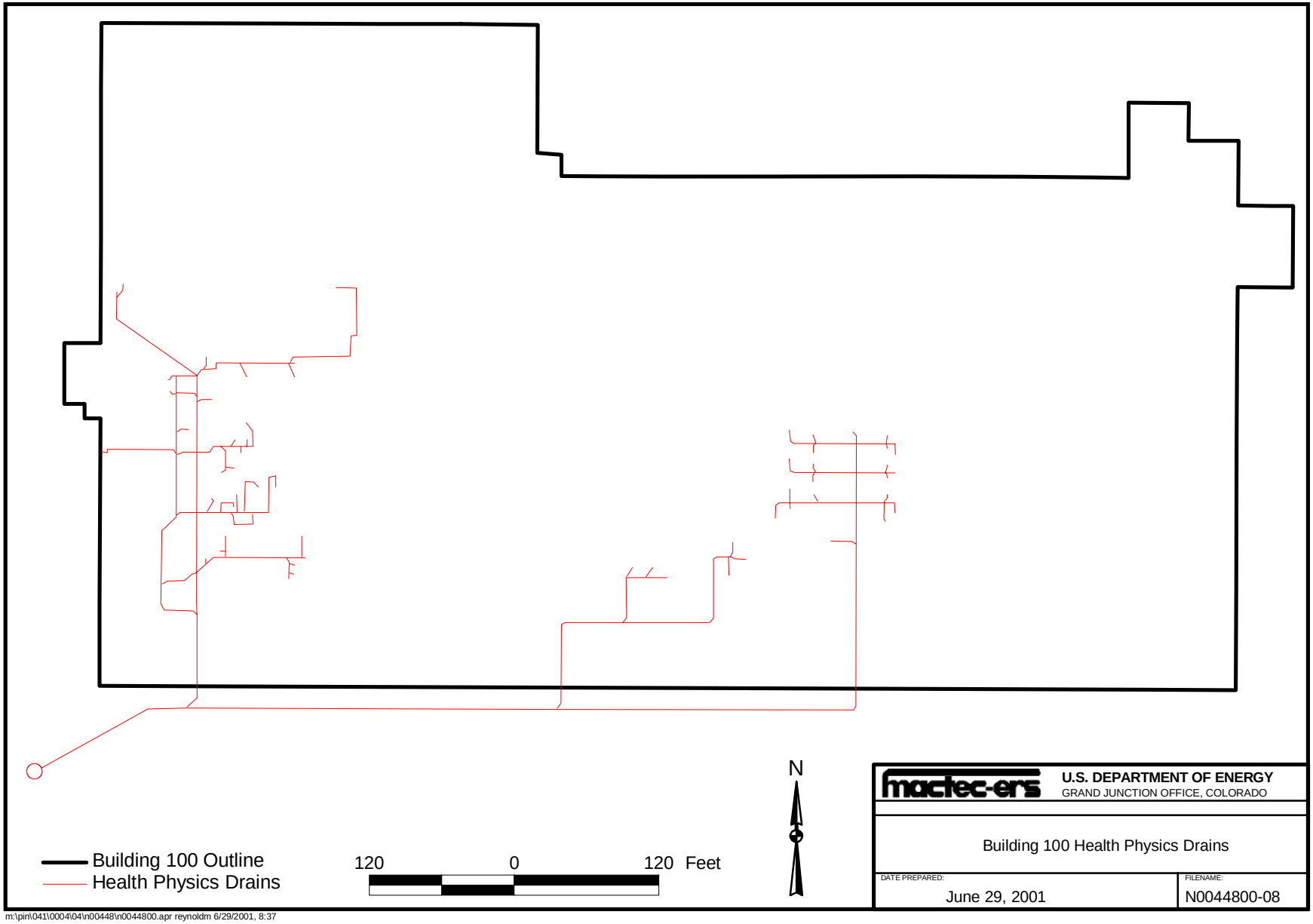

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Figure 3. Building 100 Health Physics Drain System

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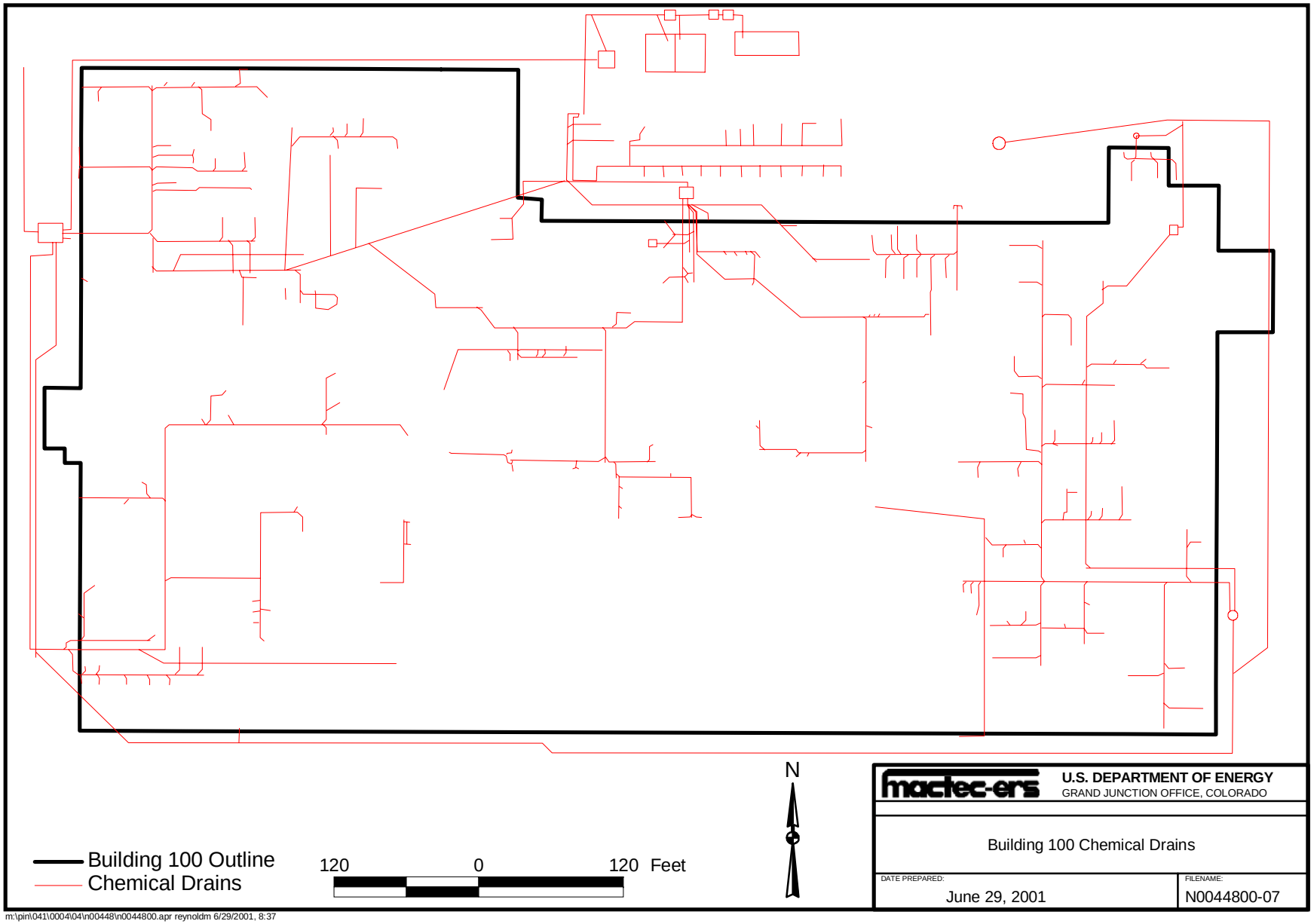

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Figure 4. Building 100 Chemical Drain System

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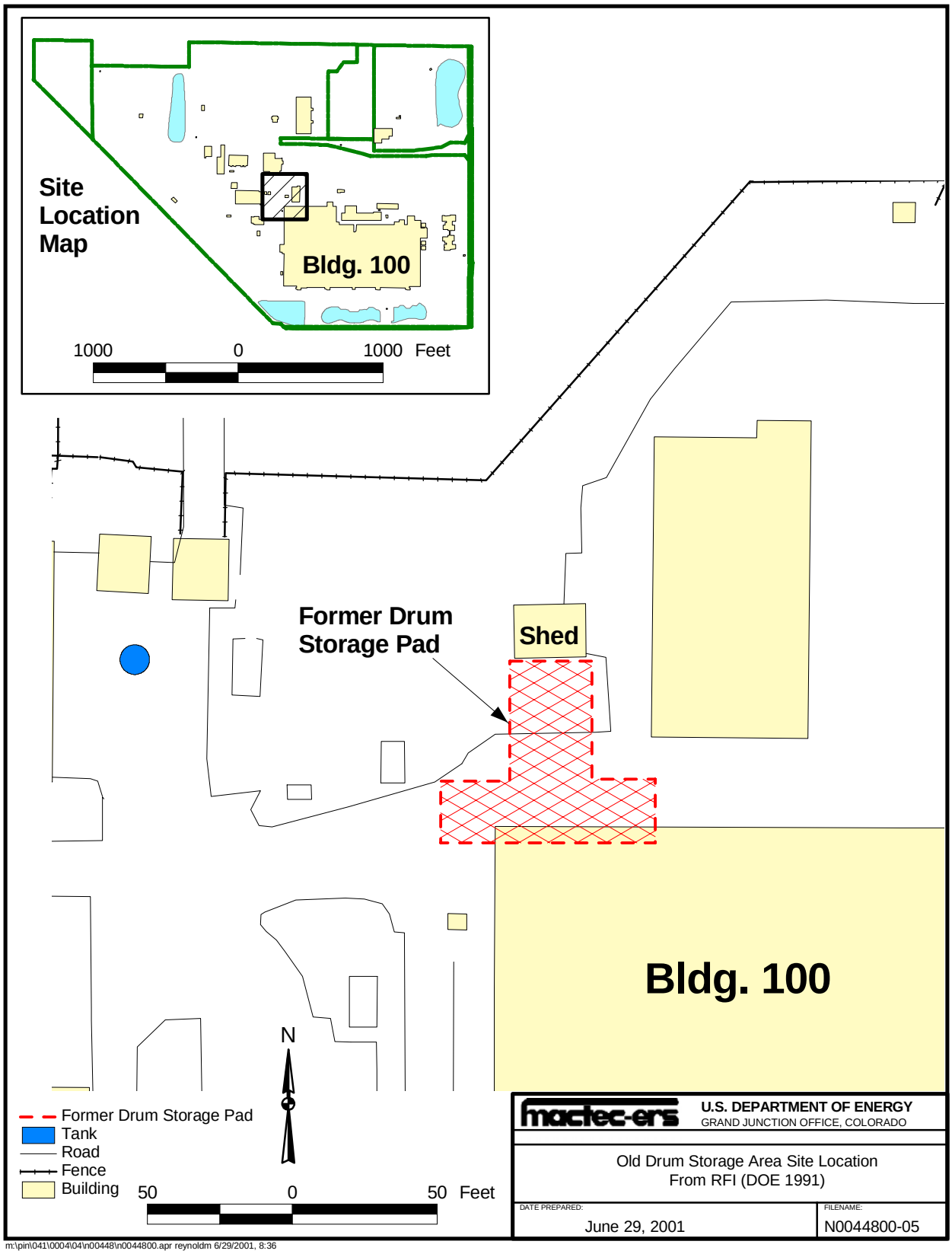

Figure 5. Location of the Old Drum Storage Area

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secondary containment piping to the Northeast Site treatment system for pretreatment, air stripping, and discharge to the Center industrial wastewater neutralization facility prior to transfer to the POTW.

The location of these two recovery wells was based on modeling done in the CMS Report (DOE 1994). This modeling was based on data collected during the RFI from PIN06 and PIN12 monitoring wells located near the northwest corner and around the periphery of Building 100. These monitoring wells were screened from 3 to 13 feet (ft) below land surface (bls); no deeper wells existed at this time. The results from four sampling events in 1990 and 1991 showed that contamination was limited to relatively low levels at the northwest corner of Building 100. Based on these data, the modeling demonstrated that two recovery wells would be sufficient to clean up the contamination in this area.

Subsequently, additional investigations were conducted by installing wells at multiple depths both outside the building and through the floor of the building. These investigations are summarized in the Building 100 Subsurface Investigation (DOE 1996b) and the Building 100 Area Data Report (DOE 1996c). Results of these investigations indicated that significant contaminant concentrations were present at medium and deep depths under the building, and that low levels of contamination were present at the south and east sides of the building. The Building 100 Area Data Report (DOE 1996c) recommended that:

- the two recovery wells installed under the CMIP continue operation,
- additional characterization under the building and east of the building was necessary,
- additional contaminant transport modeling was necessary, and
- the potential for occurrence of dense non-aqueous phase liquids (DNAPLs) be evaluated.

The recommendations were addressed in the Building 100 Area CMIP Addendum (DOE 1998a). Several different pumping scenarios were modeled, and it was recommended that the installation of two additional recovery wells at the southeast corner of Building 100 be implemented as the supplemental alternative.

In June 1998, the FDEP responded to the CMIP Addendum with comments regarding the possible presence of a more permeable zone near the base of the surficial aquifer, the apparent deepening of the surficial deposits/Hawthorn contact to the southeast of Building 100, and the suggestion of additional deep wells into the Floridan aquifer. FDEP went on to state that until an additional hydrogeologic assessment is completed, installation of the new recovery systems should be delayed.

DOE provided a response to FDEP's comments in a December 1998 letter. The content of this letter was of sufficient detail to satisfy the FDEP with one exception, the need for additional monitoring wells into the Floridan aquifer. In April 1999, DOE proposed, and FDEP approved, two Floridan aquifer well locations adjacent to Building 100. The two Floridan aquifer wells were installed in August 1999 and May 2000.

In October 1999, DOE sent the FDEP a letter that contained a proposal to evaluate the potential installation of a permeable reactive barrier (PRB) wall and further evaluate other treatment technologies for remediation of the contaminant plume beneath Building 100. Specifically, DOE proposed to evaluate the results from the 4.5 Acre Site biosparge system to see if this type of

remediation might be effective beneath Building 100. FDEP approved DOE's recommendation in a November 1999 letter.

The first part of the DOE proposal was accomplished in December 1999 with the completion of a bench-scale treatability report for treatment of dissolved volatile organic compounds (VOCs) present in groundwater at the Building 100 Area. The results from this study indicated that a reactive wall would degrade the chlorinated VOCs to maximum contaminant levels (MCLs) using iron metal as the reactive medium. This treatability study report was included in a document that evaluated the suitability of a PRB wall at the Building 100 Area (DOE 2000b). DOE continues to evaluate the 4.5 Acre Site biosparge system to assess the effectiveness of VOCs removal and applicability to Building 100 Area remediation.

1.3 Report Organization

Section 1.0 contains the introduction, purpose, and site background. Section 2.0 discusses the current conditions at Building 100, including hydrogeology, nature and extent of contamination, identification of contaminants of concern (COCs) and media cleanup goals, and affected environmental pathways. Section 3.0 presents the remediation tasks and objectives. Section 4.0 contains the identification and categorization of remediation alternatives. Sections 5.0, 6.0, and 7.0 present the screening of plume control technologies, source treatment technologies, and dissolved phase treatment technologies, respectively. Section 8.0 presents the recommendations and conclusions. Section 9.0 contains a list of references cited within this document.

2.0 Current Conditions

This section describes the current conditions at the Building 100 Area as they relate to the screening of remediation alternatives. The relevant items are hydrogeologic conditions, COCs, cleanup goals, nature and extent of contamination, and affected environmental pathways.

2.1 Site Hydrogeology

The Center is located in Pinellas County, which sits on the western flank of the Florida Platform, within the Atlantic Coastal Plain Geologic Province. The Florida Platform is composed predominantly of thick sequences of carbonate rocks deposited in a shallow marine environment, and capped by a thin, siliciclastic, sediment-rich sequence (Scott et al. 1991). The following formations, from shallowest to deepest, are present beneath the Center: surficial deposits, Hawthorn Group, Tampa Limestone, Suwannee Limestone, Ocala Limestone, and Avon Park Formation (Figure 6). The topography at the Center is generally flat.

2.1.1 Surficial Aquifer

The uppermost sediments compose the surficial aquifer, and consist of silty-to-shelly, fine-grained sands. Currently, no municipal water supplies are derived from the surficial aquifer due to the poor quality and limited availability of the groundwater (DOE 1991). However, due to recent drought conditions, interest in the surficial aquifer as a water source has increased.

Based on lithologic logs from drilling activities around the perimeter of Building 100 in May 1995, the surficial aquifer around the building generally ranges in thickness from approximately 35 ft to 40 ft. A series of grain-size analyses was run on sediments collected from two boreholes advanced just outside the northwest corner of Building 100 during the referenced drilling activities. The results of these analyses are summarized in Table 1.

Table 1. Building 100 Area Surficial Sediments Description

Well	Sample interval (ft bls)	USCS Classification	Description
PIN12–0520	10–12	SP	Shelly SAND
PIN12–0520	15–17	SP	Shelly SAND
PIN12–0520	20–22	SP-SM	Silty SAND
PIN12–0520	25–27	SP-SM	Silty SAND
PIN12–0520	30–32	SP	Shelly SAND
PIN12–0520	35–37	SP	SAND
PIN12–0520	40–42	SP	SAND
PIN12–0520	45–47	SC	Clayey SAND
PIN12–0520	47–49	SC	Clayey SAND
PIN12–0522	40–42	SP-SC	Clayey SAND
PIN12–0522	42–44	SP-SC	Clayey SAND
PIN12–0522	44–46	CL	Sandy CLAY

In May 1995, specific-capacity tests were performed on monitoring wells PIN12–0520, PIN12–0521, PIN12–0522, and PIN12–0523, which are located outside the northwest corner of Building 100. The purpose of these tests was to estimate the horizontal hydraulic conductivity of the surficial aquifer in the immediate vicinity of the tested wells, based on the Theis equation for

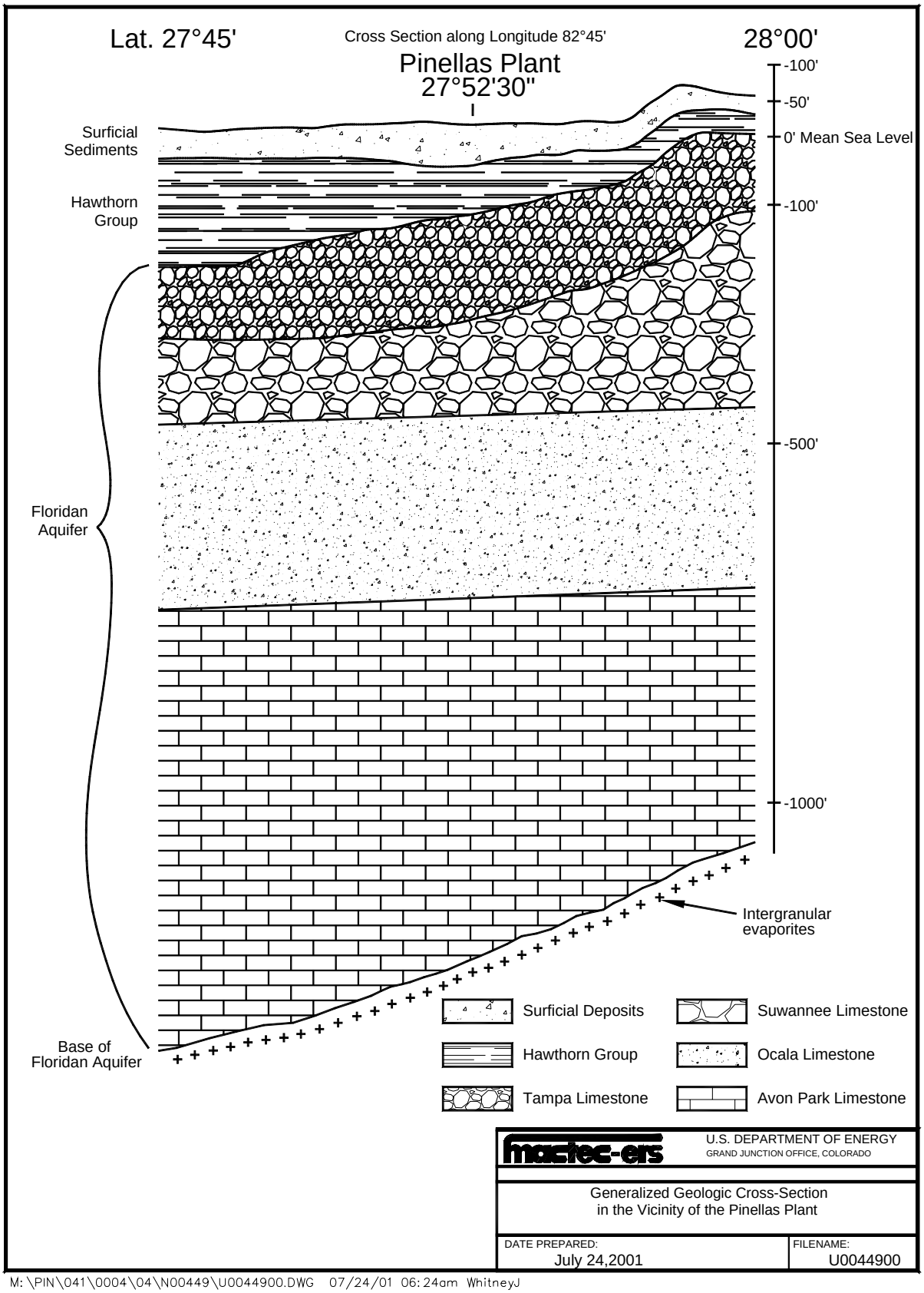

Figure 6. General Geologic Cross Section of the Center Area

non-equilibrium, horizontal flow (Butler 1957; Walton 1962). Estimated hydraulic conductivity values are summarized in Table 2.

Table 2. Estimated Hydraulic Conductivity at the Building 100 Area

Well	Screened Interval (ft bls)	Estimated Horizontal Hydraulic Conductivity (ft/day)
PIN12–0520	36–46	0.47
PIN12–0521	19.5–29.5	1.35
PIN12–0522	32–42	0.59
PIN12–0523	18–28	2.06

These hydraulic conductivity values for the surficial aquifer are in agreement with previous estimates, based on slug tests around Building 100, of 0.17 to 1.3 ft/day (DOE 1991). In addition, estimates of hydraulic conductivity for the surficial aquifer at the Center using data from a hydrocone field program, slug tests, and an aquifer test conducted at the 4.5 Acre Site, ranged from 0.1 to 3 ft/day. These hydraulic conductivity estimates were made from one-ft intervals at 15.5 ft and 25.5 ft bls. The data show that, in general, the hydraulic conductivity decreases with depth, as seen at Building 100. Vertical hydraulic conductivity values were estimated from aquifer test data and ranged from 0.42 to 1 ft/day, values that are in the same range as the estimates of horizontal hydraulic conductivities.

In the Building 100 Area, depth-to-water ranges from about one to five ft bls, depending on the season and recent rainfall. Current groundwater elevations and contours for the shallow and deep surficial aquifers in the Building 100 Area are shown on Figures 7 and 8, respectively. Flow in the surficial aquifer is influenced by groundwater withdrawals from recovery wells in the northwest corner of Building 100. Shallow groundwater beneath Building 100 flows out laterally to the north (recovery well influence), and to the east, southeast, and south (natural groundwater flow). Groundwater in the deeper surficial aquifer flows to the northwest (recovery well influence) and southeast (natural groundwater flow).

In the shallow surficial aquifer beneath the west side of the building, the hydraulic gradient beyond the influence of pumping was approximately 0.005 ft/ft in April 2001. Using Darcy's Law, along with approximations of one ft/day for hydraulic conductivity and 0.3 for effective porosity, groundwater velocity in the shallow surficial aquifer in this area is approximately six ft/year. A reasonable hydraulic gradient cannot be estimated for the area beneath the center of the building. In the deeper surficial aquifer beneath the southeast corner of the building, a rough hydraulic gradient of 0.002 ft/ft was estimated. Horizontal groundwater movement in the deeper surficial aquifer in this area would be about two to three ft/year.

2.1.2 Hawthorn Group

Underlying the surficial aquifer is the Hawthorn Group, which is composed of sand, clay, limestone, and dolomite, and forms a widespread dividing layer between the surficial aquifer and the Tampa Limestone (Figure 6). The Hawthorn Group ranges from 55 to 78 ft in thickness in the area of the Center (DOE 1991). Depth to the top of the Hawthorn Group in the Building 100 Area generally ranges from about 35 to 40 ft bls, but has been logged as deep as 46 ft bls at the

location of well PIN12–0520. The upper portion of the Hawthorn Group consists of sandy clay with weathered limestone or other carbonate lenses.

Aquifer tests to estimate the hydraulic properties of this formation were conducted as part of the sitewide RFI. Results indicated that the Hawthorn Group has an average vertical hydraulic conductivity of 0.0011 ft/day. The estimated vertical travel time for groundwater movement through the formation is 629 years (DOE 1991). Thus, in the vicinity of the Center, the Hawthorn Group is considered an aquitard (i.e., a semi-confining geologic unit that restricts vertical groundwater flow). Results from these aquifer tests indicate that it is unlikely that contamination in the surficial aquifer will travel through the Hawthorn and affect the underlying Floridan aquifer (DOE 1991).

2.1.3 Floridan Aquifer

Underlying the Hawthorn Group is the Tampa Limestone, which is the uppermost unit of the Floridan aquifer (Figure 6). The Tampa Limestone consists of clayey, weathered limestone with varying amounts of quartz sand, phosphate, and fossils. Beneath the Tampa Limestone is the Suwanee Limestone, which consists of hard, micritic, yellow-to-cream colored, fossiliferous limestone that may contain interbeds of quartz sand and chert. The underlying Ocala Limestone is considered a semi-confining unit and is composed of cream-to-tan colored, granular, porous, foraminiferal limestone. The Avon Park Formation, the major water-bearing zone of the upper Floridan aquifer, is characterized by hard, brown, microcrystalline, vuggy dolomite, and gray, soft, fossiliferous, porous limestone.

Groundwater flow in the Floridan aquifer is most affected by the presence of dissolution cavities (i.e., preferential pathways) in the carbonate rocks. Aquifer tests performed on three Floridan aquifer wells in Pinellas County yielded estimates of transmissivity ranging from 9×10^5 to 1.2×10^6 ft^2/day (Southwest Florida Water Management District 1988). The Floridan aquifer is the main source of drinking water in the area.

2.2 Contaminants of Concern and Cleanup Goals

COCs are discussed in Sections 2.2.1 and 2.2.2, and cleanup goals are presented in Section 2.2.3.

2.2.1 Contaminants of Concern for Soil

RFI data collection activities at the Old Drum Storage Site addressed the potential for soil contamination resulting from spills that may have occurred at the site in the past. Soil samples were collected in 1990 and 1991 and a number of compounds were identified. However, using an EPA methodology based on magnitude of concentration and toxicological properties, it was determined that none of these compounds were applicable as soil COCs.

During the RFI, soil sampling directly beneath Building 100 was not possible due to the difficulty of this operation, the lack of information on utility locations, and the interruption of operational activities that would have resulted (DOE 1991).

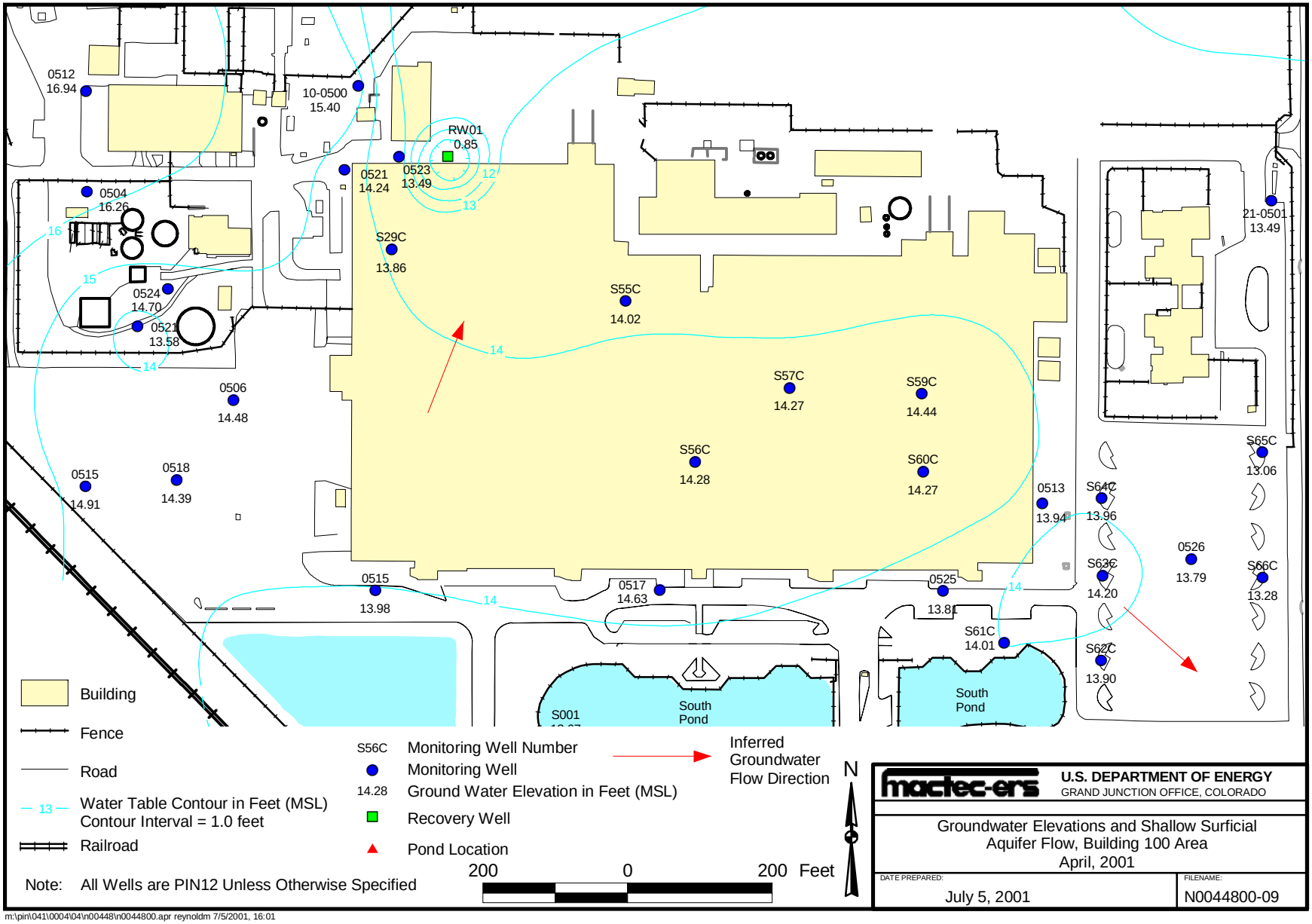

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Figure 7. Groundwater Elevations and Flow Direction in the Shallow Surficial Aquifer at the Building 100 Area in April 2001

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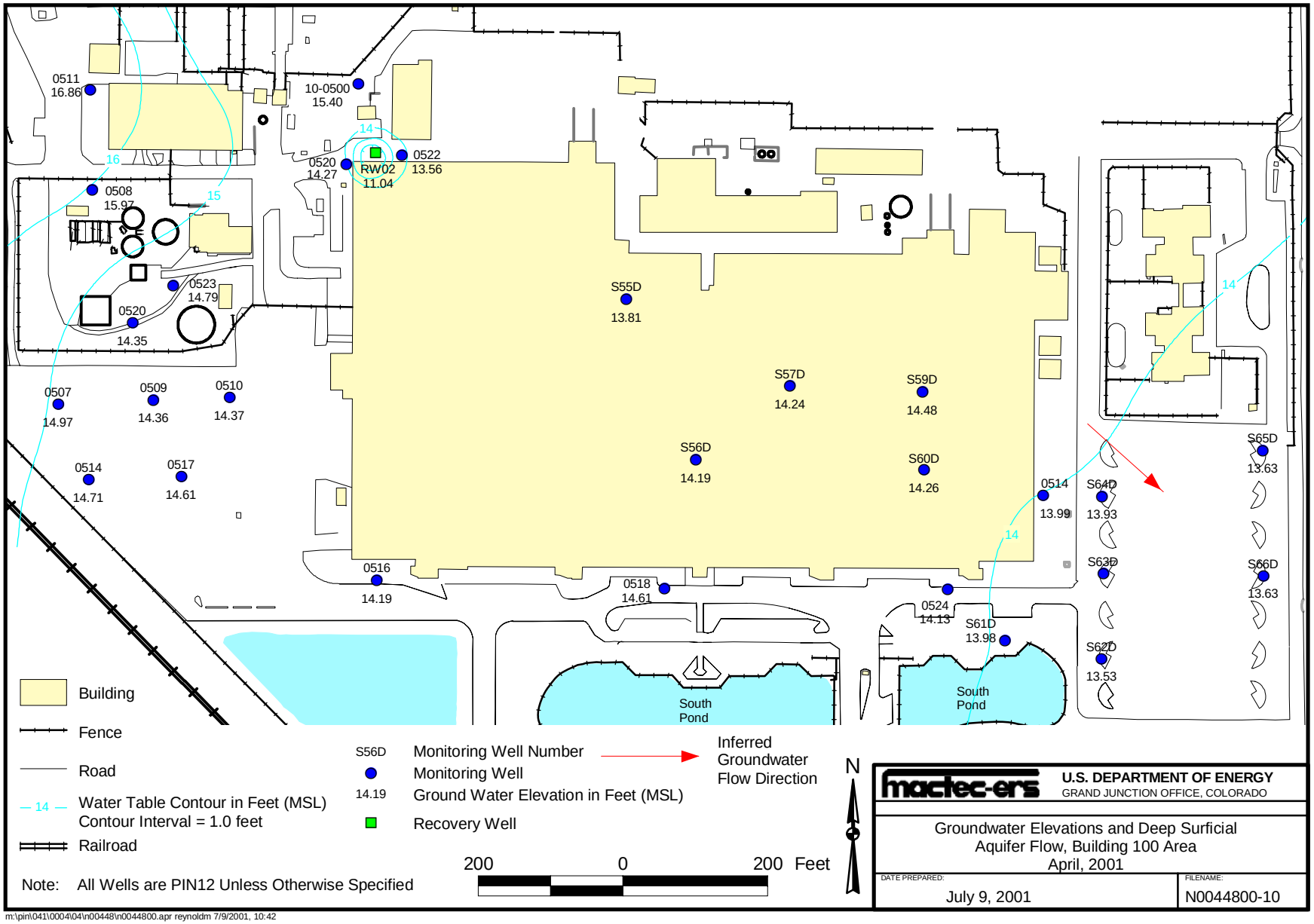

Figure 8. Groundwater Elevations and Flow Direction in the Deep Surficial Aquifer at the Building 100 Area in April 2001

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In 1995, during the DOE cleanup of the facility prior to transfer to the new owner, three phases of soil sampling, in conjunction with the installation of monitoring wells, were conducted beneath vacated areas of Building 100. Sampling locations were selected based on proximity to existing floor drains, proximity to existing monitoring wells located along the perimeter of the building, location of radiological material management areas, and Building 100 room vacancy. Soil samples were collected only from the unsaturated zone within approximately 3 or 4 ft beneath the floor slab; no soil samples were collected from below the water table. Analytical results demonstrated that VOCs and metals in these soil samples were below the EPA soil screening levels, except for arsenic at five locations along the northern edge of Building 100. Based on these results, soil COCs were not reevaluated at the time.

Because the RFI Report (DOE 1991) determined that the only medium of concern at the Building 100 Area was groundwater and that soil remediation was not required, no soil COCs were identified for the Building 100 Area. This determination has been consistent through subsequent reports (DOE 1994, 1996a, and 1998a). Based on this determination, the scope of this document does not include soil remediation.

2.2.2 Contaminants of Concern for Groundwater

Currently, the list of groundwater COCs for the Building 100 Area (Table 3) is a combination of the COCs identified for the Old Drum Storage Site and Building 100 Industrial Drain Leaks in the RFI Report (DOE 1991). This COCs list is the same list that has been included in the CMS Report (DOE 1994), the CMIP (DOE 1996a), and the CMIP Addendum (DOE 1998a). Total 1,2-dichloroethene (DCE) was listed on the original COCs list in the RFI Report; however, now that cis- and trans-1,2-DCE can be analyzed separately, the individual compounds are listed here.

Table 3. Groundwater COCs and Cleanup Goals for the Building 100 Area

COC	Cleanup Goals (FDEP Drinking Water Standards) (µg/L)[a]
Tetrachloroethene	3
Trichloroethene (TCE)	3
cis-1,2-Dichloroethene (DCE)	70
trans-1,2-DCE	100
1,1-DCE	7
Vinyl chloride	1
1,1,1-Trichloroethane	200
1,1-Dichloroethane	70
Chloroethane	12
Benzene	1

[a]µg/L = micrograms per liter

2.2.3 Cleanup Goals

As discussed previously, COCs are identified only for groundwater. Per EPA and FDEP direction, the cleanup goals for groundwater are FDEP drinking water MCLs. These MCLs are listed for the individual COCs in Table 3. For the purposes of this report, these cleanup goals apply only to the plume control and dissolved phase treatment tasks.

During the screening, the plume control technologies will be required to either (1) contain onsite the groundwater that contains concentrations of contaminants above their cleanup goals, or (2) treat the groundwater so that it does not contain COCs at concentrations above the cleanup goals prior to the groundwater moving off the property. The source treatment task will have cleanup goals specific to source removal. The dissolved phase treatment will be the final remedy for the Building 100 Area and therefore must reduce the concentrations of all groundwater contaminants to below their cleanup goals.

2.3 Nature and Extent of Contamination at the Building 100 Area

This section discusses contamination at the Building 100 Area, including the potential presence of contaminant sources. Building 100 Area geochemistry and data gaps also are discussed.

2.3.1 Soil Contamination

As mentioned in Section 2.2.1, no COCs have been identified for Building 100 Area soils. Therefore, soil contamination is not considered here.

2.3.2 Groundwater Contamination

During the RFI, groundwater samples were collected from 12 wells installed around the perimeter of the building (DOE 1991). These wells were screened from 3 to 13 ft bls, and samples from these wells indicated that contaminant concentrations were relatively low or non-detect.

Subsequent to the RFI, a number of additional groundwater investigations were conducted by installing additional temporary and permanent wells around the perimeter of the building, through the floor of the building, and in the areas near the property boundary to the south and east of the building (DOE 1994, 1996a, 1996b, 1996c, 1998a). These investigations resulted in revisions to the previous conceptual model of groundwater contamination at the Building 100 Area by determining that contaminant concentrations were considerably higher than previously thought, and that contamination was present in middle and deep areas of the surficial aquifer, under the building, and to the south and east of Building 100 near the property boundary. A summary of Building 100 Area historic data is shown in Table 4.

Table 4. Summary of Historic Groundwater Data for the Building 100 Area
(This table includes data from PIN06, PIN09, PIN10, PIN12, and PIN21 wells)

COC	Maximum Concentration (μg/L)	Average of Detected Values (μg/L)	Number of Detections	Total Number of Analyses	Percentage of Detections
Tetrachloroethene	140	39	12	1,524	1
TCE	80,000	7,013	306	1,528	20
cis-1,2-DCE	88,000	3,807	654	1,328	49
trans-1,2-DCE	19,000	917	227	1,315	17
1,1-DCE	3,700	477	112	1,253	9
Vinyl chloride	16,000	569	735	1,560	47
1,1,1-Trichloroethane	12	5.0	3	1,522	0.2
1,1-Dichloroethane	2,100	55	236	1,556	15
Chloroethane	880	57	81	1,530	5
Benzene	77	5.7	48	1,533	3

The current status of groundwater contamination in the Building 100 Area is based on data collected during the April 2001 quarterly sampling event. This was an annual event wherein all 75 existing wells at the Building 100 Area were sampled.

Ten COCs were identified for the Building 100 Area groundwater, as summarized in Section 2.2.2, and their concentrations in April 2001 are discussed here (Table 5). Tetrachloroethene, 1,1,1-trichloroethane, and benzene were not detected in any wells. Chloroethane was detected at three locations, but the concentrations were not above the cleanup goal. The remaining COCs were detected at several locations above their respective cleanup goals.

Table 5. Summary of April 2001 Water Quality Data Collected at the Building 100 Area (This table includes data from PIN06, PIN09, PIN10, PIN12, and PIN21 wells for a total of 75 wells)

COCs[a]	Maximum Concentration (μg/L)	Average of Detected Values (μg/L)	Number of Detections (out of 75 analyses)	Number of Detections > Cleanup Goal	Cleanup Goal (μg/L)
TCE	35,000	5,974	14	8	3
cis-1,2-DCE	71,000	5,036	31	13	70
trans-1,2-DCE	10,000	1,169	15	2	100
1,1-DCE	1,300	335	4	3	7
Vinyl chloride	16,000	1,298	30	30	1
1,1-Dichloroethane	120	26	9	1	70
Chloroethane	6.5	4.6	3	0	12

[a]Tetrachloroethene, 1,1,1-trichloroethane, and benzene are COCs, but were not detected in any wells in April 2001

The total VOCs plume map shown in Figure 9 demonstrates that a plume of dissolved phase VOCs extends from the vicinity of the Old Drum Storage Site at the northwest corner of Building 100, beneath a good portion of the building, and into areas south and east of the building to near the property boundary. This VOCs plume includes all measured COCs concentrations, above or below the cleanup goal levels, and also includes the concentrations of a few other VOCs that are not COCs.

Trichloroethene (TCE) above the three micrograms per liter (μg/L) cleanup goal was found (1) as a plume that extends from the Old Drum Storage Site to near the center of the western half of the building, and (2) in well S57 near the center of the building (Figure 10). Cis-1,2-DCE above the 70 μg/L cleanup goal was found in the same areas as the TCE plume and also extended to areas beyond the TCE plume (Figure 11). Trans-1,2-DCE and 1,1-DCE were found in the highest concentrations in the same areas as cis-1,2-DCE near the northwest corner of the building and in well S57.

A large plume of vinyl chloride above the one μg/L cleanup goal was found extending from the Old Drum Storage Site, under much of Building 100, and to near the eastern and southern property boundaries (Figure 12). Vinyl chloride has been detected in wells PIN12–S66C and PIN21–0512, the wells nearest the property boundary, since these wells were first sampled in 1997 and 1998, respectively. Vinyl chloride concentrations have never exceeded 15 μg/L in these wells, which are both screened at 20–30 ft bls. PIN12–S66B and PIN12–S66D are co-located with PIN12–S66C, are screened at 10–20 ft bls and 30–40 ft bls, and have never exhibited vinyl chloride detections, indicating that vinyl chloride contamination in these areas appears to be limited to medium depths in the surficial aquifer.

Concerning the plume near the property boundary, cis- and trans-1,2-DCE and TCE have all been detected hydraulically downgradient from Building 100 during past sampling events, at concentrations that occasionally have exceeded the cleanup goals. For example, cis-1,2-DCE currently is present near the property boundary but below the cleanup goal, as can be seen on Figure 11. Therefore, any plume control technology needs to have the capability to treat these compounds as well as vinyl chloride.

From the observed distribution of contamination, it would appear that the Old Drum Storage Site is probably a source of some of the contamination. Additionally, high concentrations of contamination are found in isolated areas under Building 100, indicating that documented drain leaks (DOE 1987a & b) may be the source of some of the contamination. Therefore, based on the current extent of characterization, it would appear that Building 100 Area contamination has multiple sources unevenly distributed over a large area under Building 100.

In general, most contamination at the Building 100 Area is located at medium to deep depths in the surficial aquifer. Wells screened at shallow depths (down to approximately 15 ft bls) have relatively lower contaminant concentrations, while wells screened to depths of 25, 30, and 40 ft show relatively higher contaminant concentrations.

It is unknown if contamination exists in the Hawthorn because no direct investigation of this unit has been conducted. The surficial deposits/Hawthorn contact occurs at between 35 and 46 ft bls in the Building 100 Area (Section 2.1.2). Therefore, the potential exists that some of the deep wells (screened at 30 to 40 ft bls) are screened a few feet into the Hawthorn. However, it is probable that little water is drawn from the Hawthorn when these wells are sampled, due to the much lower permeability of the Hawthorn relative to the surficial deposits. Therefore, direct evidence of contamination in the Hawthorn does not exist.

2.3.3 Non-Aqueous Phase Liquids

TCE and cis-1,2-DCE were measured in April 2001 at concentrations that potentially indicate that these compounds could be present as NAPLs (Table 6). The EPA has suggested that when the dissolved concentration of a compound exceeds one percent of its aqueous solubility, it may be assumed that this compound could be present as a NAPL in a location hydraulically upgradient from the well (EPA 1992). The aqueous solubilities of TCE and cis-1,2-DCE are 1,100,000 μg/L and 5,000,000 μg/L, so one percent of the aqueous solubilities are 11,000 μg/L and 50,000 μg/L, respectively.

Table 6. Measured Concentrations of TCE and cis-1,2-DCE in April 2001 Indicating Potential NAPL Presence

Compound	Location	Measured Concentration in April 2001 (μg/L)	April 2001 Concentration as Percent of Aqueous Solubility
TCE	S35B	35,000	3.2
TCE	S30B	20,000	1.8
TCE	S57C	16,000	1.5
Cis-1,2-DCE	S35B	71,000	1.4

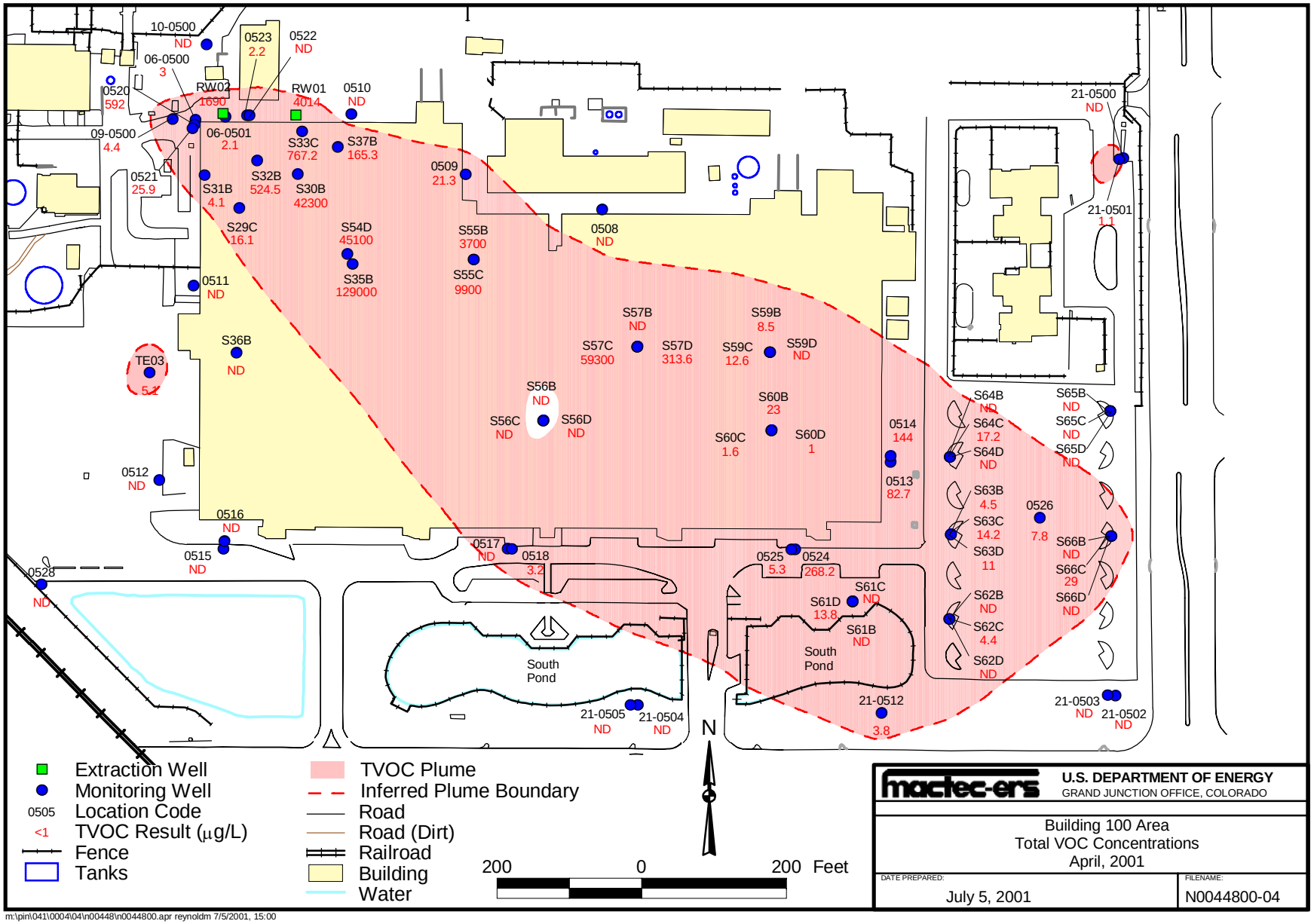

Figure 9. Total VOCs Plume at the Building 100 Area, April 2001 Data

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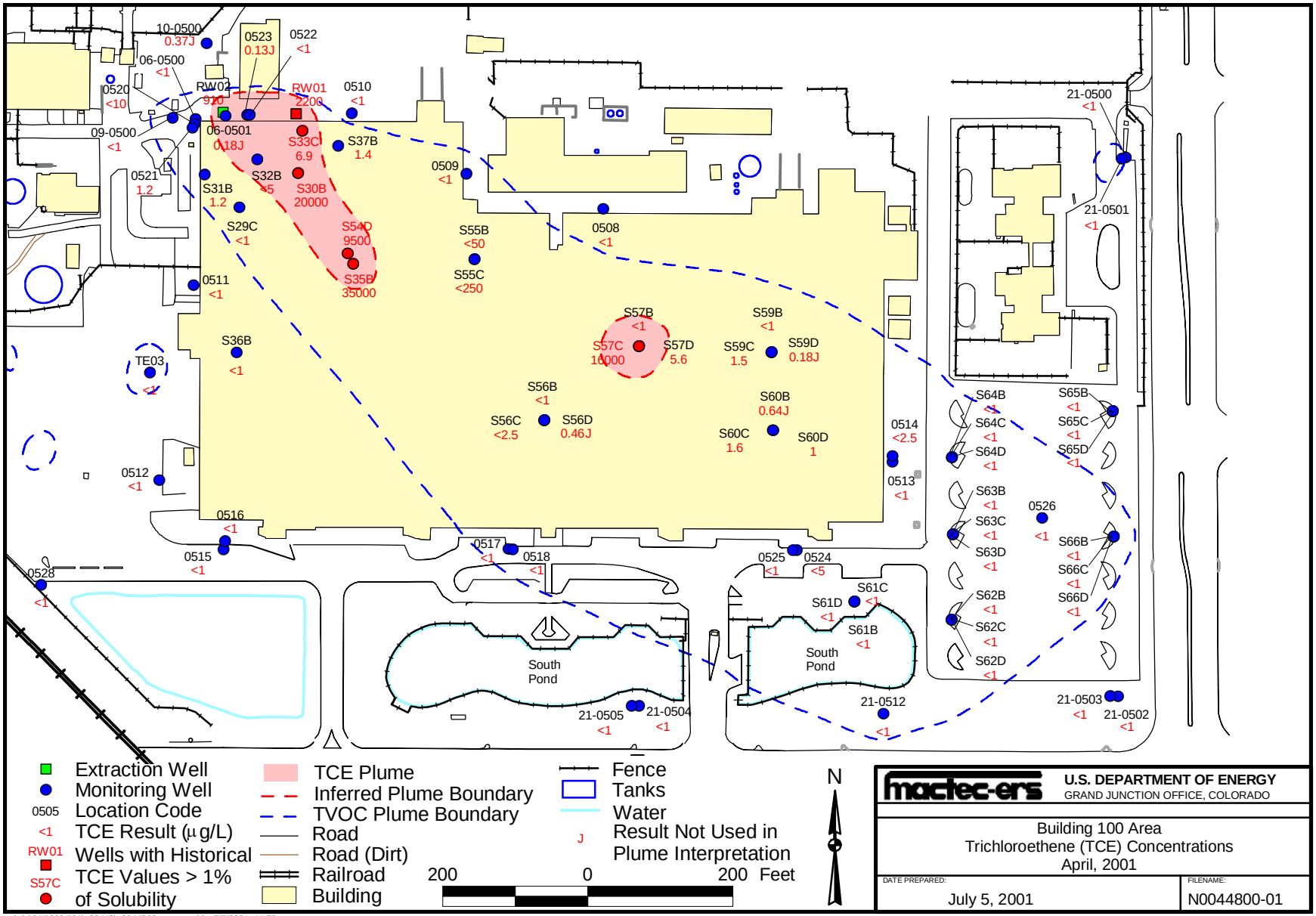

Figure 10. TCE Plume at the Building 100 Area, April 2001 Data

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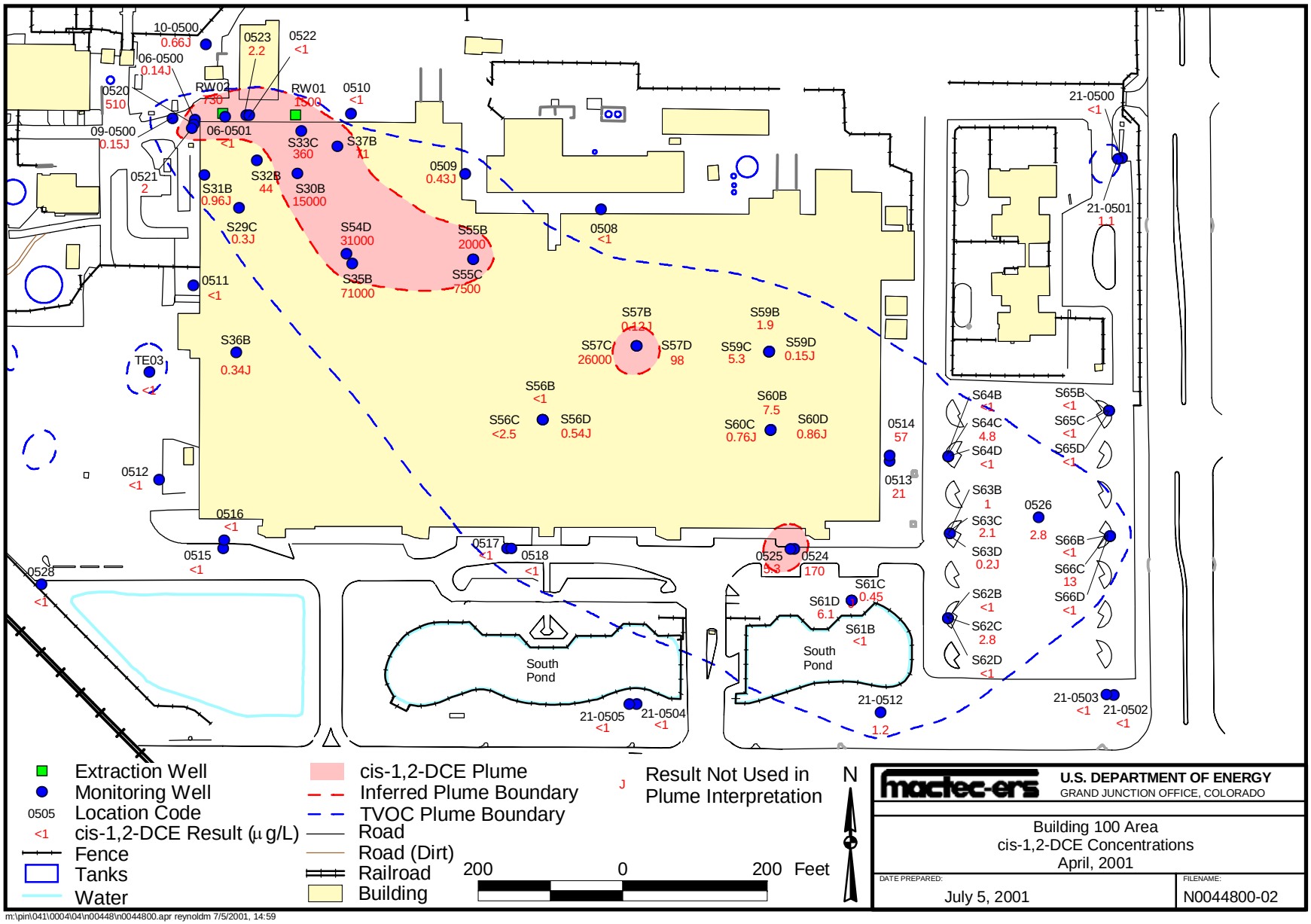

Figure 11. Cis-1,2-DCE Plume at the Building 100 Area, April 2001 Data

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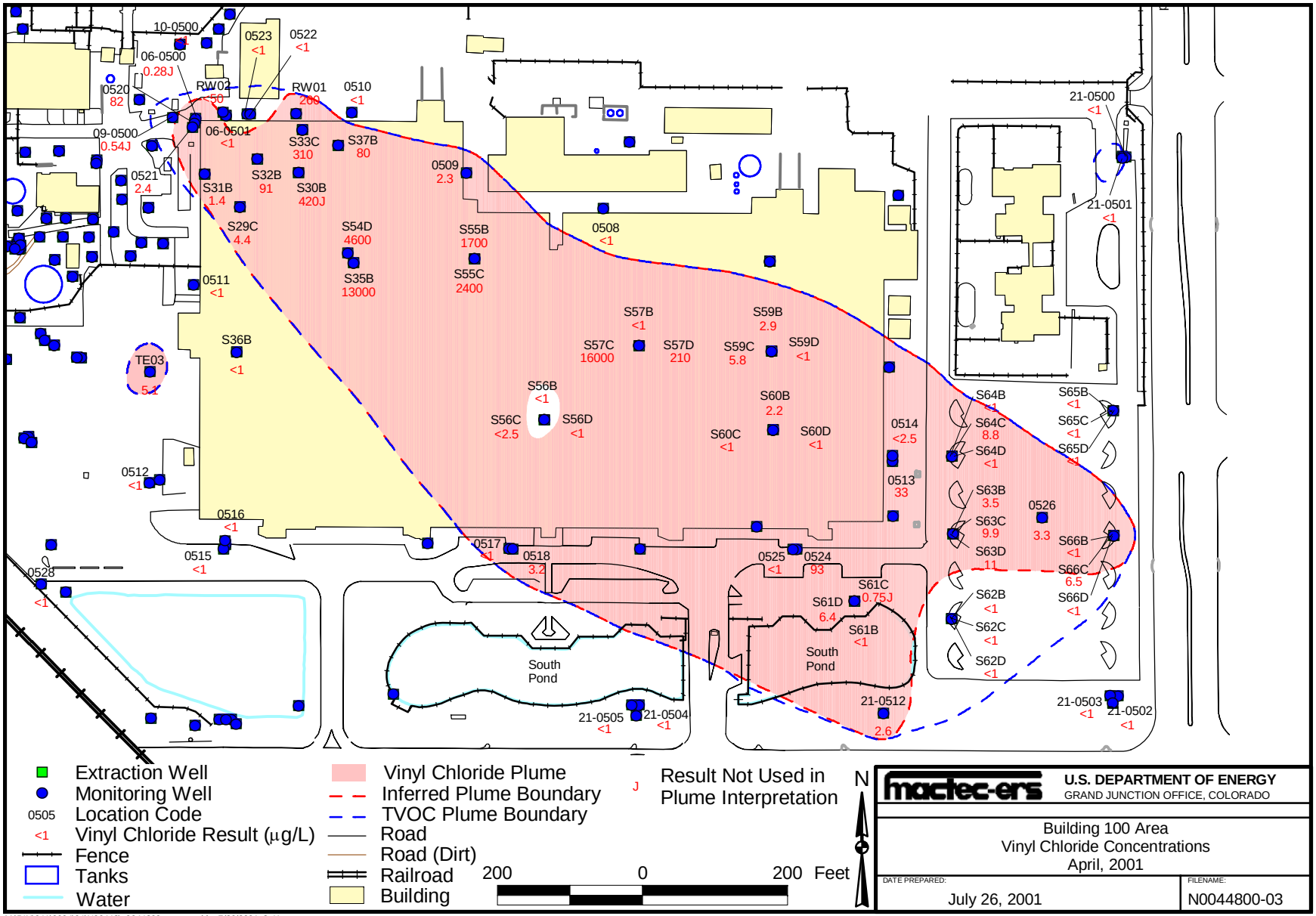

Figure 12. Vinyl Chloride Plume at the Building 100 Area, April 2001 Data

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The historic maximums for TCE and cis-1,2-DCE concentrations at the Building 100 Area are 80,000 μg/L and 88,000 μg/L (Table 4), equating to 7.3 percent and 1.8 percent of the compounds' aqueous solubilities, respectively.

The use of cis-1,2-DCE at the former Pinellas Plant has not been documented, although trans-1,2-DCE use has been confirmed (CH2MHill 1987). Cis-1,2-DCE is a common intermediate formed during TCE degradation, and it has been found in elevated concentrations in most contaminated areas of the Center. It is possible that cis-1,2-DCE concentrations above one percent of the solubility could result solely from TCE degradation. Based on the facts that it barely exceeds the one percent rule for all historic data and that it has not been documented to have been used at the site, the screening conducted in this document assumes that non-aqueous phase cis-1,2-DCE is not present at the Building 100 Area. TCE use has been documented at the former Pinellas Plant (DOE 1987a & b), and it is a common contaminant at the Center.

Historically, TCE concentrations greater than one percent of the solubility have been measured in six wells (Figure 10; Table 7). These wells are screened at shallow, medium, and deep depths, indicating that non-aqueous phase TCE may be dispersed throughout the surficial aquifer.

Table 7. List of Wells That Have Contained Historic TCE Concentrations Greater Than 1% of the Aqueous Solubility
(These wells are highlighted on Figure 10)

Well	Screened Interval (ft bls)	Highest TCE Concentration (μg/L)	Date
RW01	19–29	16,000	March 1999
S30B	5–15	21,000	April 2000
S33C	11–21	37,000	January 1996
S35B	5–15	80,000	January 1998
S54D	36–41	13,000	July 1999
S57C	20.5–30.3	68,000	January 1999

Large pools of non-aqueous phase TCE probably are not present at the Building 100 Area, based on the current extent of characterization and the comparison with contaminant concentrations at the Center's Northeast Site where free product has been observed in wells. It is probable that the drain leaks resulted in relatively small volumes of waste entering the subsurface on a sporadic basis. Because TCE is denser than water, it would move downward through the unsaturated zone until it dispersed into small globules remaining in the soil matrix.

If the volume of solvent was large enough, it could have moved through the saturated zone until it reached the Hawthorn confining layer, where its progress would have been impeded by the low permeability of this unit. Based on observations at the Center's Northeast Site, if a volume of NAPL reached the Hawthorn, some of this NAPL could potentially have infiltrated into the Hawthorn for a few feet. Non-aqueous phase TCE movement could also have been restricted by less permeable layers such as clay lenses dispersed in intermediate depths in the surficial aquifer, leading to potential TCE sources at medium depths.

2.3.4 Geochemical Conditions

Geochemical parameters measured within the last year at the Building 100 Area are summarized in Table 8. As indicated by the average values, most dissolved oxygen and oxidation-reduction potential measurements were low, indicating that reducing conditions are present throughout most of the surficial aquifer. Groundwater temperatures are relatively warm because of the subtropical climate, and pH is generally near neutral.

Table 8. Summary of Geochemical Data From July 2000 to April 2001 for all Wells at the Building 100 Area (Unit abbreviations are milligrams per liter [mg/L], millivolts [mV], degrees Celsius [°C], micromhos per centimeter [μmhos/cm], and nephelometric turbidity units [NTU])

Parameter	Minimum Value	Maximum Value	Average Value
Dissolved Oxygen (mg/L)	0.06	8.22	1.25
Oxidation-Reduction Potential (mV)	-279	737	-87
pH	6.35	9.36	6.82
Temperature (°C)	21.6	32.4	25.7
Specific Conductance (μmhos/cm)	13	2,910	1,238
Turbidity (NTU)	0	1,483	109

2.3.5 Data Gaps

Considering the size of Building 100 (approximately 11 acres), the amount of characterization that has been conducted under the building is minimal, particularly in light of the potential presence of NAPLs. Currently there are only 14 sampling locations (24 wells) under the building, and most of these are grouped at the northwest side of the building.

The locations of the drain leaks under the building are unknown, and because of the limited number of wells under the building, there is potential for unidentified NAPL to exist.

No investigation into the Hawthorn has been conducted, so it is unknown if contamination exists in this layer. Because of the very low permeability of this layer, different types of remediation could be required relative to those used in the surficial aquifer. For the purposes of this document, it is assumed that contamination does not exist in the Hawthorn. If contamination is identified in the Hawthorn, the recommendations made as a result of the screening in Sections 5.0, 6.0, and 7.0 could need to be reevaluated.

A baseline sampling of soil and groundwater under the building where feasible, in areas currently not sampled, should be conducted prior to selection of the final remediation technologies. Additionally, baseline sampling will be necessary along the south and east property boundaries to better define the extent of the contaminant plume in these areas. Without these additional data, broad assumptions would be necessary for remediation technology design. It is likely that these broad assumptions would result in significantly higher remediation costs relative to systems with designs based on more detailed data.

Additionally, a concerted effort will need to be made to locate, as much as possible, all utilities under Building 100 and around the Building 100 Area before the design of any remediation technology is undertaken. The presence of these utilities could seriously complicate technology implementation.

2.4 Affected Environmental Pathways

The environmental threat at the Building 100 Area is the presence of organic compounds in groundwater, as documented in the RFI Report (DOE 1991) and the CMS Report (DOE 1994). To date, the identified contaminant plume has not been detected beyond the Center property boundary, but the potential exists for the contaminant plume to migrate. Currently, the groundwater in the surficial aquifer is not used for drinking, but may be used for irrigation. If the surficial aquifer was to be used at a potable water source at some time in the future, pretreatment would be required because the groundwater is generally brackish and of poor quality. Currently, no direct ingestion pathway for contaminated groundwater exists.

Remediation technologies proposed for the Building 100 Area must provide measures which ensure that contaminant vapors cannot escape to the surface and cause a potential inhalation pathway to Center employees.

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3.0 Remediation Tasks and Objectives

3.1 Remediation Tasks

Remediation at the Building 100 Area has been divided into three tasks, arranged in order of decreasing priority.

Task 1. Plume control near the property boundary at the southeast corner of the Center.

Task 2. Treatment of potential contaminant source(s) under Building 100.

Task 3. Treatment of dissolved phase contamination in the Building 100 Area.

Plume control needs to be accomplished first because vinyl chloride has been measured above the cleanup goal in wells PIN12–S66C and PIN21–0512, both of which are approximately 50 ft from the property boundary (Figure 12). Vinyl chloride was already present in well S66C when this well was first sampled in April 1997, so the location of the leading edge of the vinyl chloride plume in this area is not known. Vinyl chloride appeared in well 0512 above the cleanup goal in January 1999, and has continued to be present above the goal in subsequent sampling events. Therefore, DOE's initial objective for Building 100 Area remediation is to control the plume by either (1) containing onsite the groundwater that contains concentrations of contaminants above their cleanup goals, or (2) treating the groundwater so that it does not contain COCs at concentrations above the cleanup goals prior to the groundwater moving off the Center property. Plume control (Task 1) will need to continue until the dissolved phase plume that reaches from under the building to near the property boundary is treated (Task 3).

Source treatment is the next priority following plume control. As discussed in Section 2.3.3, TCE is present in the groundwater at concentrations that are high enough to indicate that this compound may be present in its non-aqueous phase. Because NAPLs present a continuing source of dissolved phase contamination that may last for many years, the NAPLs need to be treated before dissolved phase treatment can be completed.

To reach the desired objective of meeting cleanup goals by 2010, treatment of the dissolved phase contamination is required. This task consists of treatment of the entire dissolved phase plume, from the Old Drum Storage Site near the northwest corner of Building 100, under much of the building, to near the property boundary at the southeast corner of the Center.

The current plan is for source treatment to start approximately six months prior to the beginning of dissolved phase treatment in 2006, and for these two tasks to be conducted simultaneously until the end of scheduled remediation in 2010, as discussed in Section 3.2. The reasons for this are as follows.

- Access to the area under Building 100 is the main obstruction to remediation. If both source and dissolved phase treatment can be accomplished at the same time, the need to access the subsurface under the building potentially is changed from two events to one event, depending on the technology or technologies that are implemented. This would also minimize the impact to Center activities.

- NAPLs are probably limited to TCE, and therefore NAPL treatment is a much simpler issue than at the Northeast Site, where the NAPLs are composed of a complex mixture of several chlorinated and non-chlorinated solvents as well as oils.

- NAPL pools probably do not exist in the Building 100 Area, based on current site data and lack of visual identification of free product in wells. Therefore, it is probable that the mass of NAPL is small relative to a site with NAPL pools.

- It may be more cost effective to treat both NAPL and dissolved phase at the same time.

3.2 Remediation Objectives

The general objectives for remediation at the Building 100 Area are as follows:

- Protect human health and the environment.

- Control the source of releases to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment.

- Comply with applicable standards for management of wastes.

The focused objectives for remediation at the Building 100 Area are as follows:

- Treat contamination to levels below the applicable FDEP drinking water standards.

- Accomplish the remediation within the timeframe listed in the Pinellas Lifecycle Baseline. Currently, plume control is scheduled to be in place by October 2003. Source treatment startup is scheduled for March 2006 and dissolved phase treatment startup is scheduled for October 2006. Remediation under all three tasks is scheduled to be completed by September 2010, with closure and decommissioning completed by September 2014.

- Conduct remediation in a manner such that activities do not impact Building 100 occupants.

- Conduct remediation in a manner such that activities cause minimal impact to public perception.

The focus of this document is to screen the available remediation technologies to eliminate technologies that are infeasible because they do not accomplish the remediation objectives presented here. If, in the future, the objectives change, the screening and subsequent technology recommendations made in the following sections may not apply. Potential circumstances that could change the objectives for Building 100 Area remediation include significant extension of the timeframe for remediation, gaining full access to the interior of Building 100, and modification of cleanup goals to less rigorous standards.

4.0 Identification and Categorization of Remediation Technologies

The following sections identify the available remediation technologies (Section 4.1) and categorize the technologies into those that are applicable to the three remediation tasks (Section 4.2).

4.1 Identification of Technologies

Identification of remediation technologies consisted of a number of information-gathering activities. A considerable amount of information was gained through the Internet. This information ranged from general descriptions of technologies and their applications to detailed evaluations and case studies supplied by various Federal organizations and regulatory agencies, as well as information obtained from technology vendors. The scientific literature also was reviewed to identify technologies and obtain peer-reviewed information and data about the performance of the technologies.

In particular, the Federal Remediation Technologies Roundtable (FRTR) provided a wealth of information (FRTR 2001a). The FRTR member agencies are the U.S. Department of Defense, the EPA, DOE, the U.S. Department of the Interior, the U.S. Department of Commerce, the U.S. Department of Agriculture, and the National Aeronautics and Space Administration (NASA).

The FRTR provided a treatment technology matrix that identified most treatment technologies. This matrix was adapted to produce Table 9, which lists and provides a brief description of the treatment technologies. A few additional treatment technologies were identified through other sources, including the remediation specialists under contract to MACTEC–ERS. Other sources of technology information included EPA's CLU-IN and REACH-IT websites, Interstate Technology and Regulatory Cooperation (ITRC), Remediation Technologies Development Forum (RTDF), Ground-Water Remediation Technologies Analysis Center, Environmental Security Technology Certification Program, and Strategic Environmental Research and Development Program websites.

Technologies that were considered to be unproven were not included in this list. These are technologies that are theoretical or that have only been tested on a laboratory scale. To be included in Table 9, a technology must have, at least, been proven effective on demonstration scale in field applications.

A number of technologies were listed by the FRTR as ex situ treatments. These ex situ treatments assume that either 1) contaminated groundwater will be pumped out of the subsurface and treated at the surface, or 2) contaminated soil will be excavated and treated at the surface. The ex situ groundwater treatments were combined into one listing in the table, and the ex situ soil treatments were considered under the soil removal option.

Table 9. List and Description of Remediation Technologies

Technology Type	Description
In Situ Biological Treatment	
Natural Attenuation	Natural attenuation is not a technology, but is a set of naturally occurring subsurface processes such as dilution, volatilization, biodegradation, adsorption, and chemical reactions resulting in reduction of contaminant concentrations.
Enhanced Biodegradation Includes bioaugmentation, (addition of microbes), nutrient addition, electron donor addition, electron acceptor addition, and addition of heat.	Increasing the concentration of electron acceptors, electron donors, nutrients, or microorganisms in groundwater to enhance the rate of direct or cometabolic, aerobic or anaerobic, biodegradation of organic contaminants by microorganisms.
Phytoremediation	Process that uses plants to remove, transfer, stabilize, and destroy contamination in groundwater.
In Situ Physical /Chemical Treatment	
Air Sparging	Air is injected into saturated matrices to remove contaminants through volatilization. Typically coupled with soil vapor extraction.
In-Well Air Stripping	Involves pumping of water from a contaminated zone into a well from an upper (or lower) screen zone, sparging the water with air to volatilize contaminants, then pumping the cleaned water back into the subsurface through an upper (or lower) screen zone, thus creating a circulating flow cell.
Biosparging	Injection of air into the subsurface to attain aerobic conditions which facilitates direct or cometabolic aerobic biodegradation of contaminants. Sparging is a minor component of this process because air flow rates are much lower than with air sparging.
Bioslurping	Combines bioventing and vacuum-enhanced free-product recovery to remove light non-aqueous phase liquids (LNAPLs) from the surface of the water table. Stimulates aerobic bioremediation.
Dual Phase Extraction (DPE)	Uses a high vacuum system to remove various combinations of contaminated groundwater, non-aqueous phase liquid, and contaminant vapors from the subsurface.
Electrokinetics	Involves applying an electric potential across the contaminated zone using electrodes placed in the ground. Contaminants are mobilized and then removed via a separate process.
Permeable Reactive Barrier (PRB) Walls Funnel and gate, continuous trench, or hydraulic fracture configurations.	An opening filled with reactive material is placed to intercept a contaminant plume. Degradation or removal of contaminants occurs as contaminated water passes through the wall. Reactive materials include iron metal, limestone, organic carbon, bone char phosphate, and microorganisms.
Lasagna™	Couples electrically-driven transport (electro-osmosis) with layered treatment zones containing a reactive medium such as zero-valent iron.
In Situ Redox Manipulation	Creates a treatment zone by injection of chemical reagents or microbial nutrients downgradient of the contaminant source. Changes the redox conditions so that contaminants are degraded or immobilized by biotic or abiotic means.
Chemical Oxidation Oxidants include permanganate, Fenton's reagent, and ozone	Injection of strong oxidizing agents degrades contaminants in place.
Soil Flushing/Solubilization 1. Surfactant flushing 2. Cosolvent flushing	Surfactants or cosolvents are applied to the soil or injected into the groundwater to enhance contaminant solubility. The groundwater containing the solubilized contaminant is then extracted and treated.
Dewatering with hot air flushing/vapor extraction	Barrier wall is installed around treatment area, area is dewatered and then flushed with hot air to volatilize and remove contaminants. Vapors require surface treatment.

Table 9 (continued). List and Description of Remediation Technologies

Technology Type	Description
Electrical Heating 1) Six Phase Heating 2) Three Phase Heating 3) In Situ Thermal Desorption 4) Radio Frequency Heating	Electricity is used to resistively or conductively heat the subsurface, volatilizing or destroying contaminants. Vapors removed via vapor extraction system and treated at the surface.
Contained Recovery of Oily Wastes (CROW)	Steam and hot water are used to mobilize non-aqueous phase oils for removal via pumping. Typically leaves residual oil in soil matrix.
Steam Injection May include electrical heating of cold spots or use of hydrous pyrolysis to degrade contaminants in situ.	Steam is forced into aquifer through injection wells to vaporize volatile contaminants. Vapors removed through vapor extraction system.
Ex Situ Groundwater Treatment	
Ex Situ Groundwater Technologies, Including bioreactors, constructed wetlands, adsorption, air stripping, granular activated carbon (GAC), ion exchange, precipitation, separation, sprinkler irrigation, and UV oxidation.	This category includes a number of different types of technologies that all require contaminated groundwater to be pumped from the subsurface for subsequent surface treatment. Water potentially may be reused after treatment.
Containment	
Groundwater Pumping	Extraction of groundwater for ex situ treatment, or to prevent contact with contaminated soil.
Vertical Barriers Includes slurry wall, geosynthetic wall, grout, deep soil mixing, surface caps, frozen soil barriers, calcite barriers, biobarriers, and sheet pile.	Vertical barriers are defined as subsurface barriers made of an impermeable material designed to contain or divert groundwater flow, thereby preventing contaminant movement.
Dual Drainline Techniques	Recovery lines are placed horizontally on top of an impermeable stratigraphic unit and DNAPL flows into the collection trenches and seeps into the recovery lines.
Removal	
Soil Removal Includes ex situ treatment options.	Excavate contaminated soil and treat on site or send to approved disposal facility.

4.2 Categorization Of Technologies

The remediation technologies identified in Table 9 are reviewed and categorized into plume control, source treatment, and dissolved phase treatment technologies in Table 10. If technologies are eliminated as not applicable for a particular remediation task, the reason for elimination is provided in the comments column. The technologies that are retained within each remediation task are screened in Sections 5.0, 6.0, and 7.0.

Table 10. Categorization of Remediation Technologies

Technology Type	Remediation Task			Comments
	Plume Control	Source Treatment	Dissolved Phase Treatment	
In Situ Biological Treatment				
Natural Attenuation	Eliminated	Retained	Retained	Not effective for plume control.
Enhanced Bioremediation	Retained	Retained	Retained	
Phytoremediation	Retained	Eliminated	Retained	Not applicable for source treatment.
In Situ Physical /Chemical Treatment				
Air Sparging	Retained	Retained	Retained	
In-Well Air Stripping	Retained	Retained	Retained	
Biosparging	Retained	Eliminated	Retained	Not applicable for source treatment.
Bioslurping	Eliminated	Retained	Eliminated	Mainly used when LNAPL is present.
Dual Phase Extraction (DPE)	Retained	Retained	Retained	
Electrokinetics	Retained	Eliminated	Retained	Not applicable for source treatment.
Permeable Reactive Barrier Walls	Retained	Eliminated	Retained	Not applicable for source treatment.
Lasagna™	Retained	Retained	Retained	
In Situ Redox Manipulation	Retained	Eliminated	Retained	Not applicable for source treatment.
Chemical Oxidation	Retained	Retained	Retained	
Soil Flushing/Solubilization	Eliminated	Retained	Eliminated	Not applicable for treatment of dissolved contaminants.
Dewatering with hot air flushing/vapor extraction	Eliminated	Retained	Retained	Not applicable for plume control.
Electrical Heating	Eliminated	Retained	Eliminated	Used mainly for NAPL remediation.
CROW: Contained Recovery of Oily Wastes	Eliminated	Retained	Eliminated	Used mainly for NAPL remediation.
Steam Injection with Vapor Extraction.	Eliminated	Retained	Eliminated	Used mainly for NAPL remediation.
Ex Situ Groundwater Treatment				
Ex Situ Groundwater Technologies	Retained	Retained	Retained	
Containment				
Groundwater Pumping	Retained	Retained	Retained	
Vertical Barriers	Retained	Retained	Retained	
Dual Drainline Techniques	Eliminated	Retained	Eliminated	Used mainly for NAPL remediation.
Removal				
Soil Removal	Eliminated	Retained	Eliminated	Used mainly for NAPL remediation.

5.0 Plume Control Technology Screening

Vinyl chloride is the only COC that currently is present above the cleanup goal near the property boundary in the Building 100 Area (Section 2.3.2). However, cis- and trans-1,2-DCE are present near the property boundary but below their cleanup goals, and TCE has been detected above its cleanup goal in wells hydraulically downgradient from Building 100 in the past. For the purposes of this report, the criteria developed in Section 5.1 concern mainly control of the vinyl chloride plume, but also consider control of a potential plume containing other COCs such as TCE and cis- and trans-1,2-DCE that could migrate to near the property boundary in the future.

5.1 Screening Criteria

Various types of screening criteria were reviewed including those used in RCRA CMS. After review of these criteria, consultation with remediation specialists, and review of the remediation objectives listed in Section 3.2, the following screening criteria were developed (Table 11).

Criterion 1 evaluates the potential effectiveness of the technology at the Building 100 Area, Criterion 2 evaluates the implementability of the technology within the current limitations, and Criterion 3 was developed to provide qualitative information about cost.

Table 11. Plume Control Technology Screening Criteria

Criterion 1: Effectiveness	The technology will contain the dissolved phase plume on the Center property until the main dissolved phase remediation is complete.
Criterion 2: Implementability	2a: The technology will be acceptable to the regulators, the Center, and the general public. 2b: The technology is technically feasible to implement given conditions such as numerous utilities, ponds, parking lots, and road expansion.
Criterion 3: Cost	The cost of the technology is low, medium, or high relative to the other technologies that are evaluated.

5.2 Technology Screening

Remediation technologies categorized as plume control technologies in Table 10 are screened in Table 12 according to the criteria developed in Section 5.1.

Technologies were eliminated from further consideration if they failed to satisfy either Criterion 1 or Criterion 2. If the technology was eliminated by Criterion 1, it was not evaluated under Criterion 2. If a technology failed to meet Criterion 2, the particular part of Criterion 2 that caused the technology to fail is listed in the Criterion 2 category. For example, air sparging failed Criterion 2a, so the air sparging cell under Criterion 2 reads “No (2a)”. Screening under Criterion 3 did not result in retention or elimination of the technology, but simply provided qualitative information on the cost of the technology relative to other technologies that were screened.

If a technology type failed the screening, the reasons for the failure are detailed in the text following the table. If the technology type was retained after screening, it is discussed in detail in Section 5.3, which lists the results of the plume control technology screening.

Table 12. Screening of Plume Control Technologies

Technology Type	Meets Criterion 1	Meets Criterion 2	Criterion 3	Status
In Situ Biological Treatment				
Enhanced Bioremediation	Yes	Yes	Low to medium	Retained
Phytoremediation	No	–	–	Eliminated
In Situ Physical /Chemical Treatment				
Air Sparging	Yes	No (2a)	–	Eliminated
In-Well Air Stripping	No	–	–	Eliminated
Biosparging	Yes	No (2a)		Eliminated
Dual Phase Extraction (DPE)	Yes	Yes	Medium to high	Retained
Electrokinetics	Yes	No (2b)	–	Eliminated
Permeable Reactive Barrier Walls	Yes	Yes	Medium	Retained
Lasagna™	Yes	No (2b)	–	Eliminated
In Situ Redox Manipulation	No	–	–	Eliminated
Chemical Oxidation	Yes	No (2a)	–	Eliminated
Ex Situ Groundwater Treatment				
Ex Situ Groundwater Technologies	Yes	Yes	Medium	Retained
Containment				
Groundwater Pumping	Yes	Yes	Medium	Retained
Vertical Barriers	Yes	Yes	Medium to high	Retained

As mentioned in Section 2.3.2, vinyl chloride contamination is present at 20–30 ft bls near the property boundary. Although phytoremediation using poplar trees has been applied for VOCs remediation to this depth (MSE 2001), it is questionable as to whether this approach would guarantee plume control (i.e., it is possible that the trees would not capture all the contaminated water). Therefore, phytoremediation was eliminated under Criterion 1.

Air sparging is not applicable for plume control at the Building 100 Area because:

- the thin vadose zone may limit effectiveness of soil vapor extraction,
- soil heterogeneities may result in untreated zones, and
- contaminant vapors could escape the vapor extraction system and appear at the surface (FRTR 2001a).

Because of the potential migration of vapors to the surface during air sparging, it is unlikely that this technology would be acceptable to the regulators or the public (Criterion 2a). Additionally, it is likely that groundwater would be forced to the surface, based on the observance of this phenomenon at the 4.5 Acre Site under biosparging operations and the fact that air flow rates during air sparging are much higher than with biosparging. Potentially untreated groundwater flowing to the surface would also be unacceptable to the regulators or the public.

Biosparging may be more applicable for plume control than air sparging because no vapor collection or treatment system is necessary. However, biosparging has been in operation at the 4.5 Acre Site for approximately 20 months, and the operation of the system has resulted in groundwater being brought to the surface on several occasions. Biosparging is eliminated

because the occurrence of this phenomenon at the southeast corner of the Center would not be acceptable to the regulators, the Center, or the public.

In-well air stripping was eliminated for plume control because:

- the thin vadose zone may limit effectiveness,
- soil heterogeneities may result in untreated zones, and
- the technology could potentially result in spreading the plume (FRTR 2001a).

In-well air stripping works by using a well screened at two intervals to draw contaminated water into the lower screened interval followed by reinjection of the water into the vadose zone through the upper screened interval. Volatile contaminants are stripped from the water by volatilization into air bubbles in the well, with the vapors captured by a vapor extraction system. However, because of the limited efficiency of the stripping in the well, the reinjected water may still contain some contaminants (FRTR 2001a). This potentially could result in spreading of the plume. Therefore, this technology was eliminated under Criterion 1 because it potentially is not effective for plume control.

Electrokinetics for plume control has potential implementability problems because of the presence of buried utilities (Van Cauwenberghe 1997), and therefore this technology was eliminated under Criterion 2b. Several other limitations such as reduced contaminant removal efficiency due to presence of shells, precipitation reactions of naturally occurring dissolved species such as iron, and incomplete remediation due to stagnant zones have been identified.

The basis of the Lasagna™ technology is electrokinetics. Therefore, this technology is eliminated under Criterion 2b for the same reasons given in the electrokinetics discussion above.

In situ redox manipulation has been shown to degrade TCE only on a bench scale, and has not seen field scale application for VOCs treatment (DOE 2000a). Although it is probable that the technology could also be effective at treating vinyl chloride, this has not been documented. Based on the relatively immature stage of its development, in situ redox manipulation was eliminated under Criterion 1.

Chemical oxidation was eliminated under Criterion 2a because of potential regulatory concerns with injection of materials near the property boundary. The current literature indicates that regulators generally are willing to accept the risks associated with injection of chemical oxidation materials into the subsurface to treat plumes that are contained within contaminated sites (Yin and Allen 1999, ITRC 2001). However, this literature indicates that regulators are unlikely to accept injection of these materials for treatment of plumes near property boundaries. The reasons for this are:

- injection of the oxidizing material may potentially cause spreading of the plume to areas off the property boundary, and
- some of the oxidizing materials are regulated or contain regulated materials, and injection of these materials near property boundaries could potentially result in migration of a plume of the regulated material off the property in concentrations that exceed cleanup goals.

5.3 Identification of Remediation Alternatives

The plume control technologies recommended for detailed evaluation are:

- enhanced bioremediation,
- dual phase extraction (DPE),
- PRB walls,
- groundwater pumping with ex situ treatment, and
- vertical barriers.

Enhanced bioremediation is applicable for plume control because currently only vinyl chloride is present near the property boundary, and concentrations are relatively low. Therefore, enhanced bioremediation needs only to accelerate the rate of vinyl chloride degradation. Additionally, enhanced bioremediation would be able to treat TCE and the DCE compounds if they reach areas near the property boundary within the specified remediation time frame. Depending on the type of enhanced bioremediation technology, costs are low to medium relative to other technologies retained for plume control.

The EPA has summarized current research into enhanced bioremediation of chlorinated solvents (EPA 2000a). This research has indicated that vinyl chloride, the DCE compounds, and TCE are susceptible to enhanced biodegradation. Natural biodegradation appears to be occurring in the Building 100 Area based on the presence of potential degradation intermediate compounds such as DCE, vinyl chloride, and chloroethane.

Operation and maintenance (O&M) costs associated with enhanced bioremediation would be significant if it were necessary to deliver a continuous source of material (such as methane) to the contaminated ground water (EPA 2000a). However, not all enhancements require continuous injection. Products such as the Regenesis company's hydrogen release compound and oxygen release compound require infrequent injection because these materials react slowly in the subsurface, thereby providing enhancement of biodegradation over long periods of time.

DPE was retained as a potential plume control technology, although it offers limited advantages over pump and treat and likely is more expensive. This technology was used at the 4.5 Acre Site from 1997 to 1999 and was effective at treating high concentrations of contaminants, but its use was discontinued once it was determined that the technology was not cost efficient for treating low concentrations (Rice 2000). This technology also requires surface treatment of water and vapor.

PRB walls are applicable for plume control. A treatability study using groundwater from the Building 100 Area was conducted (DOE 2000b) and the results indicated that a two-inch thick PRB wall containing iron filings would treat TCE, DCE, and vinyl chloride to below the cleanup goals and that the wall should remain effective for 20 to 30 years. A PRB wall would have an initial high cost for installation, but subsequent O&M costs would be minimal, probably consisting only of sampling of monitoring wells downgradient from the wall. EPA conducted a cost analysis comparison for PRBs and pump and treat systems and concluded that PRBs generally are cheaper than pump and treat systems in terms of total life-cycle costs (EPA 2001a).

Groundwater pumping with ex situ treatment is retained as a plume control technology. Groundwater pumping has been shown to be effective for plume control at other areas of the Center, and should function as effectively at the Building 100 Area. Groundwater pumping would require an ex situ treatment system for the recovered groundwater.

An ex situ treatment system exists at the Center (the Northeast Site air stripper), and this system currently receives groundwater recovered from the two recovery wells located at the northwest corner of Building 100. However, this system is limited by the rate of influent water that can be treated, and is currently running at approximately 50 to 57% of capacity. Groundwater modeling of current conditions should be conducted to estimate the rate of groundwater extraction that would be necessary for plume control, and this rate should be compared to the available capacity at the air stripper. Based on currently available estimates, it would appear that the rate of groundwater extraction for plume control would exceed the limit at the air stripper, necessitating either expansion of the existing treatment system or construction of an additional ex situ treatment system if this option was implemented.

Vertical barrier technology was retained for consideration for plume control. Types of vertical barriers include slurry wall, geosynthetic wall, grout, deep soil mixing, surface caps, frozen soil barriers, calcite barriers, biobarriers, and sheet pile (EPA 2001b, MSE 2001). These barriers would physically stop the flow of groundwater in the contaminated areas. Implementation of this technology would require a supplemental technology such as groundwater pumping to prevent groundwater mounding. Mounded groundwater would potentially flow over the barrier wall or escape to the surface where it would present a potential health hazard. Additionally, the extracted groundwater would probably require ex situ treatment.

The cost of installing a vertical barrier is comparable with other technologies retained for plume control. However, the additional costs associated with the necessary groundwater extraction and treatment result in the total cost of this technology being high relative to the other retained technologies.

End of current text

6.0 Source Treatment Technology Screening

NAPLs have not been observed at the Building 100 Area. However, as discussed in Section 2.3.3, non-aqueous phase TCE may be present based on past disposal practices and current and historic groundwater quality data. It is assumed for the purposes of this screening that only non-aqueous phase TCE could be present, that it could be present only in a relatively small amount as globules dispersed within the soil matrix (no NAPL pools present), and that it is not present in the Hawthorn.

6.1 Screening Criteria

Various types of screening criteria were reviewed including those used in RCRA CMS. After review of these criteria, consultation with remediation specialists, and review of the remediation objectives listed in Section 3.2, the following screening criteria for source treatment were developed (Table 13).

Table 13. Source Treatment Technology Screening Criteria

Criterion 1: Effectiveness	The technology will treat/remove contaminant sources (NAPL) under the building within a time frame that will allow dissolved phase remediation to be completed within the prescribed time frame.
Criterion 2: Implementability	2a: The technology will be acceptable to the regulators, the Center, and the general public. 2b: The technology does not adversely affect the health of the building occupants. 2c: The technology is technically feasible to implement given that: 1) all work must be conducted from outside the building, 2) the structural integrity of the building and under-building utilities must be protected, and 3) the technology must not interfere with business operations inside the building. 2d: The technology is technically feasible to implement given that source characterization is limited.
Criterion 3: Cost	The cost of the technology is low, medium, or high relative to the other technologies that are evaluated.

Criterion 1 evaluates the potential effectiveness of the technology at the Building 100 Area. Source treatment is scheduled to begin in March 2006 and be completed by September 2010. For the purposes of this screening, it was assumed that this schedule must be followed, and therefore, a technology must be capable of completing source treatment within this time frame to meet Criterion 1.

Criterion 2 encompasses a number of different limitations to technology implementability. Criterion 2a accounts for general acceptability. Criterion 2b directly addresses the protection of the health of the building occupants and was chosen mainly because of the possibility of contaminant vapors passing from the subsurface through the floor of the building into the interior. Criterion 2c concerns the technical feasibility of technology implementation given that no remediation may be conducted from inside the building. Aspect three of Criterion 2c was chosen to identify technologies that may cause electric fields or vibrations that could interfere with normal business operations inside the building. Criterion 2d addresses the fact that NAPL appears to be present at some locations under the building, but that the exact location or amount of NAPL is unknown.

Criterion 3 was developed to provide qualitative information about cost.

6.2 Technology Screening

Remediation technologies categorized as source treatment technologies in Table 10 are screened in Table 14 according to the criteria developed in Section 6.1.

Technologies were eliminated from further consideration if they failed to satisfy Criterion 1 or Criterion 2. If the technology was eliminated by Criterion 1, it was not evaluated under Criterion 2. If a technology failed to meet Criterion 2, the particular part of Criterion 2 that caused the technology to fail is listed in the Criterion 2 category. Screening under Criterion 3 did not result in retention or elimination of the technology, but simply provided qualitative information on the cost of the technology relative to other technologies that were screened.

If a technology type failed the screening, the reasons for the failure are detailed in the text following the table. If the technology type was retained after screening, it is discussed in detail in Section 6.3, which lists the results of the source treatment technology screening.

Table 14. Screening of Source Treatment Technologies

Technology Type	Meets Criterion 1	Meets Criterion 2	Criterion 3	Status
In Situ Biological Treatment				
Natural Attenuation	No	–	–	Eliminated
Enhanced Bioremediation	Yes	Yes	Low	Retained
In Situ Physical /Chemical Treatment				
Air Sparging	Yes	No (2b, 2c, 2d)	–	Eliminated
In-Well Air Stripping	Yes	No (2b, 2c, 2d)	–	Eliminated
Bioslurping	No	–	–	Eliminated
Dual Phase Extraction (DPE)	Yes	No (2c, 2d)	–	Eliminated
Lasagna™	No	–	–	Eliminated
Chemical Oxidation	Yes	Yes	Moderate	Retained
Soil Flushing/Solubilization	Yes	Yes	High	Retained
Dewatering with hot air flushing/vapor extraction	Yes	No (2b)	–	Eliminated
Electrical Heating	Yes	No (2c, 2d)	–	Eliminated
CROW	Yes	No (2c, 2d)	–	Eliminated
Steam Injection with Vapor Extraction	Yes	No (2b, 2c, 2d)	–	Eliminated
Ex Situ Groundwater Treatment				
Ex Situ Groundwater Technologies	No	–	–	Eliminated
Containment				
Groundwater Pumping	No	–	–	Eliminated
Vertical Barriers	No	–	–	Eliminated
Dual Drainline Techniques	No	–	–	Eliminated
Removal				
Soil Removal Includes ex situ treatment options	Yes	No (2c, 2d)	–	Eliminated

Natural attenuation was eliminated under Criterion 1 because it will not treat the source within the prescribed timeframe. The contaminant source has probably been under the building since at least the mid-1970s when the first drain leaks were identified, and current groundwater data indicate that the source may still be present. Therefore, if natural attenuation processes have not treated the source within the last 25 years, it is unlikely that these processes will complete source treatment by 2010.

Air sparging, in-well air stripping, and DPE all were eliminated under Criterion 2 for similar reasons. Air sparging and in-well air stripping produce vapors that potentially could escape the vapor extraction system and adversely affect the health of the building occupants. In-well air stripping and DPE have seen little or no application in horizontal configurations under buildings, thereby limiting their implementability under Building 100. Vertical wells could be installed around the perimeter of the building, and potentially could extract contaminated water from under most of the building, but it is unlikely that this scenario could complete source treatment within the time frame. These three technologies would need to be implemented near the source to be most effective, and the limited source characterization could preclude this scenario.

Bioslurping was eliminated under Criterion 1 because its main use for source treatment is the removal of light non-aqueous phase liquids (LNAPLs) from the top of the water table. TCE is a DNAPL that probably is dispersed in the soil matrix below the water table, and therefore bioslurping probably would not treat this source.

Although the Lasagna™ technology has been shown to potentially treat non-aqueous phase TCE (Ho et al. 1999), this technology has not been implemented on a full scale in a horizontal configuration. Therefore, it is unlikely that this technology can be implemented under Building 100, and it was eliminated under Criterion 1.

Dewatering with hot air flushing was eliminated under Criterion 2b because the technology would cause potential health risks to the building occupants. Injecting hot air could potentially cause contaminant vapors to move through the floor of the building into the interior.

Electrical heating and contained recovery of oily wastes (CROW) were both eliminated under Criteria 2c and 2d. Electrical heating has been implemented under buildings, but only by installing the hardware through the floor of the building, an action that is not possible at Building 100. CROW requires easy access for heavy equipment, and this access is limited by the presence of the building and its surroundings (EPA 2000b). Additionally, both of these technologies could potentially adversely affect the utilities under the building. Electrical heating causes electrical fields that potentially could effect business operations inside the building. The exact location of the source must be known for these technologies to be effective, therefore both fail to meet Criterion 2d.

Steam injection fails to meet Criteria 2b, 2c, and 2d. Injection of steam results in both vaporization of contaminants and pressurization of the subsurface, which together result in the potential for vapors to enter the building and adversely affect the health of the occupants. Steam injection potentially could adversely affect utilities under the building. The exact location of the source must be known for this technology to be effective, therefore it fails to meet Criterion 2d.

Groundwater pumping with ex situ treatment will not treat the source within the time frame and therefore fails to meet Criterion 1 (FRTR 2001a).

Although the vertical barriers technology type can be used to contain a source area, it is not a source treatment or removal technology type and therefore was eliminated under Criterion 1.

Dual drainline technology can be effective at removing NAPL pools, but the NAPL under Building 100 probably is dispersed within the soil matrix and therefore would not drain into the system. This technology was eliminated under Criterion 1.

Soil removal failed to meet Criteria 2c and 2d. Soil removal would not protect the structural integrity of the building and potentially could adversely affect business operations inside the building by causing vibrations. The exact location of the source must be known for soil removal to be effective, so the technology fails under Criterion 2d.

6.3 Identification of Remediation Alternatives

The source treatment technologies recommended for detailed evaluation are:

- enhanced bioremediation,
- chemical oxidation, and
- soil flushing/solubilization.

Enhanced bioremediation has been used for source treatment at several Superfund sites since 1982 (EPA 2001b). Enhanced bioremediation generally offers several advantages over other technologies:

- usually does not generate any residuals requiring additional treatment or disposal,
- does not require large inputs of energy,
- usually requires only relatively inexpensive inputs such as nutrients,
- can be considerably less expensive than other technologies, and
- has minimal impact at the surface.

Specifically, bioremediation is potentially applicable for source treatment at the Building 100 Area because it can potentially be effective within the prescribed time frame for cleanup at the Center, and has been shown to degrade non-aqueous phase TCE. Recent research by scientists at the Idaho National Engineering and Environmental Laboratory has shown that injection of a lactate solution enhanced bioremediation of non-aqueous phase TCE (Sorenson and Ely 2001).

The main obstruction to implementability at the Building 100 Area is difficulty of access to the subsurface beneath the building. Because bioremediation would probably require only injection of nutrients or other amendments, and not extraction of liquids or vapors, implementation under the building could be less problematic relative to other technologies. Horizontal wells placed at strategic locations and depths could be used for amendment injection. Enhanced bioremediation has the additional capability of treating both the source and the dissolved phase simultaneously.

Chemical oxidation is potentially applicable for treating non-aqueous phase TCE at the Building 100 Area. The oxidants that have been used most frequently are hydrogen peroxide (alone or as Fenton’s reagent), permanganate, and ozone (Yin and Allen 1999). A chemical oxidation treatability study using soil and water samples collected from the Center’s Northeast

Site, located a few hundred feet north of the Building 100 Area (Figure 1), was completed in January 2000 (DOE 2000c). This study used sodium and potassium permanganate to treat the suite of contaminants present as NAPLs at the Northeast Site. The results indicated that TCE was effectively treated by both forms of permanganate. The study also indicated that soil heterogeneities may limit the effectiveness of chemical oxidation.

Delivery of the oxidant to low permeability zones is problematic, potentially leading to untreated or partially treated areas. For this technology to be effective at the Building 100 Area, low permeability zones would need to be identified and targeted during oxidant injection. A supplemental technology that could be used to aid chemical oxidation is hydrofracturing of low permeability layers. This would allow the oxidant to be injected into the low permeability layers. Other potential limitations of chemical oxidation include regulator concern with injection of the oxidant and oxidant impurities (ITRC 2001).

Soil flushing/solubilization using surfactants or cosolvents is potentially applicable for source treatment at the Building 100 Area. This technology has been shown to be effective at treating non-aqueous phase TCE at several sites (FRTR 2001a).

Potential limitations of soil flushing/solubilization are similar to the limitations for chemical oxidation, and stem from soil heterogeneities (FRTR 2001b). Injected fluids, whether oxidants, surfactants, or cosolvents tend to follow the path of least resistance to flow (high permeability layers), and therefore tend not to effectively treat low permeability zones. As with chemical oxidation, hydrofracturing could aid the effectiveness of this technology. The cost of this technology is high relative to the other recommended technologies.

End of current text

7.0 Dissolved Phase Treatment Technology Screening

The dissolved phase treatment technology must treat the large area of the surficial aquifer in the Building 100 Area that contains dissolved phase COCs present above their respective cleanup goals. Currently, only TCE, cis-, trans-, and 1,1-DCE, vinyl chloride, and 1,1-dichloroethane are present in Building 100 Area groundwater samples at concentrations that exceed the cleanup goals (Table 5). However, it must be considered that the other COCs, particularly chloroethane and benzene, could be present above the cleanup goals in some areas, based on historic data (Table 4).

7.1 Screening Criteria

Various types of screening criteria were reviewed including those used in RCRA CMS. After review of these criteria, consultation with remediation specialists, and review of the remediation objectives listed in Section 3.2, the following screening criteria were developed (Table 15).

Table 15. Dissolved Phase Treatment Technology Screening Criteria

Criterion 1: Effectiveness	The technology will treat dissolved phase contamination over the entire Building 100 Area plume to below MCLs within the prescribed time frame.
Criterion 2: Implementability	2a: The technology will be acceptable to the regulators, the Center, and the general public. 2b: The technology does not adversely affect the health of the building occupants. 2c: The technology is technically feasible to implement given that: 1) all work must be conducted from outside the building, 2) the structural integrity of the building and under-building utilities must be protected, and 3) the technology must not interfere with business operations inside the building.
Criterion 3: Cost	The cost of the technology is low, medium, or high relative to the other technologies that are evaluated.

Criterion 1 evaluates the potential effectiveness of the technology at the Building 100 Area. Dissolved phase treatment is scheduled to begin in October 2006 and be completed by September 2010. For the purposes of this screening, it was assumed that this schedule must be followed, therefore, a technology must be capable of completing dissolved phase treatment within four years to meet Criterion 1. Aggressive treatment may be necessary to complete this task in this relatively short time frame.

Criterion 2 encompasses a number of different limitations to technology implementability. Criterion 2a accounts for general acceptability. Criterion 2b directly addresses the protection of the health of the building occupants and was chosen mainly because of the possibility of contaminant vapors passing from the subsurface through the floor of the building into the interior. Criterion 2c concerns the technical feasibility of technology implementation given that no remediation may be conducted from inside the building. Aspect three of Criterion 2c was chosen to identify technologies that may cause electric fields or vibrations that could interfere with normal business operations inside the building.

Criterion 3 was developed to provide qualitative information about cost.

7.2 Technology Screening

Remediation technologies categorized as dissolved phase treatment technologies in Table 10 are screened in Table 16 according to the criteria developed in Section 7.1.

Technologies were eliminated from further consideration if they failed to satisfy Criterion 1 or Criterion 2. If the technology was eliminated by Criterion 1, it was not evaluated under Criterion 2. If a technology failed to meet Criterion 2, the particular part of Criterion 2 that caused the technology to fail is listed in the Criterion 2 category. Screening under Criterion 3 did not result in retention or elimination of the technology, but simply provided qualitative information on the cost of the technology relative to other technologies that were screened.

If a technology type failed the screening, the reasons for the failure are detailed in the text following the table. If the technology type was retained after screening, it is discussed in detail in Section 7.3, which lists the results of the dissolved phase technology screening.

Table 16. Screening of Dissolved Phase Treatment Technologies

Technology Type	Meets Criterion 1	Meets Criterion 2	Criterion 3	Status
In Situ Biological Treatment				
Natural Attenuation	No	–	–	Eliminated
Enhanced Bioremediation	Yes	Yes	Low to medium	Retained
Phytoremediation	No	–	–	Eliminated
In Situ Physical /Chemical Treatment				
Air Sparging	Yes	No (2b)	–	Eliminated
In-Well Air Stripping	Yes	No (2b)	–	Eliminated
Biosparging	Yes	No (2a)	–	Eliminated
Dual Phase Extraction (DPE)	Yes	No (2c)	–	Eliminated
Electrokinetics	Yes	No (2c)	–	Eliminated
Permeable Reactive Barrier Walls	Yes	Yes	Medium	Retained[a]
Lasagna™	Yes	No (2c)	–	Eliminated
In Situ Redox Manipulation	No	–	–	Eliminated
Chemical Oxidation	Yes	Yes	High	Retained
Dewatering with hot air flushing/vapor extraction	Yes	No (2b)	–	Eliminated
Ex Situ Groundwater Treatment				
Ex Situ Groundwater Technologies	Yes	Yes	Medium	Retained
Containment				
Groundwater Pumping	Yes	Yes	Medium	Retained
Vertical Barriers	No	–	–	Eliminated

[a]PRB walls would require groundwater pumping enhancement to be effective.

Natural attenuation will not treat the dissolved phase plume within four years and was eliminated under Criterion 1. Phytoremediation will not treat the dissolved phase plume within four years and will not work under the building, and was eliminated under Criterion 1.

Air sparging and in-well air stripping were eliminated under Criterion 2b because these technologies produce vapors that potentially could escape the vapor extraction system and adversely affect the health of the building occupants.

Biosparging was eliminated under Criterion 2a. As mentioned in Section 5.2, operation of the biosparging system at the 4.5 Acre Site has resulted in groundwater being brought to the surface on several occasions. Biosparging is eliminated because the occurrence of this phenomenon in areas south and east of Building 100 would not be acceptable to the regulators, the Center, or the public.

DPE was eliminated under Criterion 2c. DPE has seen little or no application in horizontal configurations under buildings, thereby limiting its implementability under Building 100. An option other than horizontal DPE wells would be the installation of vertical DPE wells around the perimeter of the building. This scenario potentially could extract contaminated water from under most of the building, but it is not known if dissolved phase treatment could be completed within the time frame because of the large size of the building.

Electrokinetics and Lasagna™ were eliminated under Criterion 2c. It is unlikely that these technologies could be implemented under the building to treat the large dissolved phase plume. Additionally, these technologies could adversely affect under-building utilities and potentially could interfere with business operations inside the building by producing electric fields.

In situ redox manipulation has not been applied on a field scale for VOCs treatment (DOE 2000a). Based on the relatively immature stage of its development, in situ redox manipulation was eliminated under Criterion 1.

Dewatering with hot air flushing was eliminated under Criterion 2b because the technology would cause potential health risks to the building occupants. Injecting hot air could potentially cause contaminant vapors to move through the floor of the building into the interior.

Although the vertical barriers technology type can be used to contain a dissolved phase plume, it is not a dissolved phase treatment or removal technology type and therefore was eliminated under Criterion 1.

7.3 Identification of Remediation Alternatives

The dissolved phase treatment technologies recommended for detailed evaluation are:

- Enhanced bioremediation,
- PRB walls,
- Chemical oxidation, and
- Groundwater pumping with ex situ treatment.

Enhanced bioremediation is the second most common groundwater remediation technology for Superfund sites since 1982 (EPA 2001b). Enhanced bioremediation is potentially applicable for dissolved phase treatment at the Building 100 Area because it can potentially be effective within the prescribed time frame for cleanup at the Center, and has been shown to be effective at treating the COCs that currently are present above the cleanup goals.

The main obstruction to implementability at the Building 100 Area is difficulty of access to the subsurface beneath the building. Because bioremediation would probably require only injection of nutrients or other amendments, and not extraction of liquids or vapors, implementation under the building could be less problematic relative to some other technologies. Horizontal wells placed at strategic locations and depths could be used for amendment injection.

A pilot study of in situ anaerobic bioremediation was conducted at the Center's Northeast Site (Figure 1) under the Innovative Treatment Remediation Demonstration (ITRD) Program in 1997 (DOE 1998b). This study used horizontal wells and infiltration trenches to recirculate aqueous solutions of benzoate, lactate, and methanol in a 2,250 cubic yard area. During the approximately five month treatment period, VOCs concentrations were reduced by 70% to 99% in most areas, while areas of lower permeability that received little nutrient injection showed much lower reductions in VOCs concentrations. At the time this study was conducted, the extent of NAPLs at the Northeast Site was not known, and this study was designed to treat only dissolved VOCs. The subsequent NAPL characterization indicated the presence of non-aqueous phase TCE and toluene in the ITRD study area, indicating that this enhanced bioremediation project potentially may have treated some portion of the NAPLs as well as dissolved phase VOCs.

One problem with the ITRD study was that aggressive nutrient injection rates forced groundwater to the surface. As mentioned previously, air injection during biosparging at the 4.5 Acre Site has also caused groundwater to flow to the surface on a few occasions. Clearly, any potential remediation activity involving injection of liquids or gases into the subsurface at the Center must use low injection rates to avoid this problem.

In a separate study, scientists associated with the RTDF used microorganisms isolated from soil and water samples collected from the Center in enhanced bioremediation studies at Dover Air Force Base in Delaware (Harkness et al. 1999; Ellis et al. 2000). Column studies and field pilot tests indicated that TCE in the Dover soil and water was only partially degraded during nutrient injection, but that when the Pinellas microorganisms were added TCE was degraded completely to ethene. These studies indicate that the naturally occurring microorganisms at the Center have the capability to treat TCE, the DCE compounds, and vinyl chloride to concentrations below the cleanup goals, given the correct type and amount of enhancements.

PRB walls was retained as a technology type potentially applicable for dissolved phase treatment. This technology type alone would not be effective for dissolved phase treatment because of the very slow groundwater velocity in the Building 100 Area, and therefore would require hydraulic enhancement via groundwater pumping. Groundwater pumping would increase local hydraulic gradients, causing groundwater to flow through the PRB wall at a much faster rate. A pump and treat/PRB wall system was used to treat TCE, cis- and trans-1,2-DCE, and vinyl chloride at a site in Pennsylvania (FRTR 2000). This system used groundwater recovery wells located inside treatment cells containing iron metal. The contaminated groundwater was treated as it was drawn through the treatment cell by the recovery well, and the treated water was discharged to the POTW.

Chemical oxidation technologies could treat the dissolved phase plume at the Building 100 Area. The oxidants that have been used most frequently are hydrogen peroxide (alone or as Fenton's reagent), permanganate, and ozone (Yin and Allen 1999). As discussed in Section 6.3, a treatability study demonstrated that permanganate could degrade contaminants such as TCE, the

DCE compounds, and vinyl chloride. The effect of permanganate on the other Building 100 area COCs (1,1-dichloroethane, chloroethane, or benzene) was not evaluated in this study.

Groundwater pumping with ex situ treatment was the remediation alternative recommended in the Building 100 CMS Report (DOE 1994), and this technology was implemented by the installation of two recovery wells at the northwest corner of Building 100. The CMIP Addendum (DOE 1998a) suggested that two additional recovery wells be installed at the southeast corner of Building 100, but this has yet to be implemented, as discussed in Section 1.2.3. Because of the short time frame for dissolved phase remediation, additional groundwater modeling should be conducted to determine if the scenario recommended in the CMIP Addendum is still applicable.

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8.0 Summary and Conclusions

The purpose of this document was to identify new remediation technologies, analyze and screen all available remediation technologies for their applicability to the three remediation tasks at the Building 100 Area, and to recommend technologies or groups of technologies that should be retained for detailed consideration at a later time. The results of the screening are summarized in Table 17, and the recommended technology types are discussed in detail in Sections 5.3, 6.3, and 7.3.

Table 17. Summary of Recommended Technology Types

Plume Control	Source Treatment	Dissolved Phase Treatment
1) Enhanced bioremediation	1) Enhanced bioremediation	1) Enhanced bioremediation
2) DPE	2) Chemical oxidation	2) PRB walls
3) PRB walls	3) Soil flushing/solubilization	3) Chemical oxidation
4) Groundwater pumping with ex situ treatment		4) Groundwater pumping with ex situ treatment
5) Vertical barriers		

Enhanced bioremediation was retained for all three remediation tasks, and should be evaluated in detail in the near future. One potential aspect of this detailed evaluation could be a series of bench scale treatability studies to evaluate the various enhancements available, including the enhancements used in the Northeast Site ITRD study and the RTDF study at Dover Air Force Base, as well as other enhancements such as the Regenesis products. Treatability studies are recommended by EPA for evaluating applicability of enhanced bioremediation (EPA 2000a).

As discussed in Section 3.0, both the source and dissolved phase treatment tasks need to be completed in less than five years, with both tasks scheduled to be conducted at approximately the same time. Enhanced bioremediation and chemical oxidation are recommended technology types common to both these tasks. The available information indicates that each of these technology types should be able to accomplish both tasks simultaneously. Therefore, each of these technology types should be evaluated in detail in this regard.

Because of the data gaps identified in Section 2.3.5, a baseline sampling of soil and groundwater under the building, where feasible, should be conducted prior to selection of the final remediation technologies. Additionally, baseline sampling will be necessary along the south and east property boundaries to better define the extent of the plume in these areas. The relatively small cost associated with this baseline sampling will result in significant cost savings during remediation technology implementation.

Because of the relatively large area requiring remediation, including the complication of remediation under the 11-acre Building 100, the multiple remediation tasks, and the potential presence of NAPL, it may not be possible to complete Building 100 Area remediation within the prescribed time frame. Therefore, consideration needs to be given to other options, such as extending the time frame for remediation, acquiring access to implement remediation technologies through the floor of the building, or trying to work with stakeholders to consider use of different remediation activities. Changing these factors would change the remediation objectives listed in Section 3.2, which in turn would change the screening criteria in Sections 5.0,

6.0, and 7.0. Therefore, some technology types that were eliminated during this screening could be retained with revised criteria.

Implementation of a plume control technology is the next task for Building 100 remediation, and is scheduled to be in place by October 2003. Therefore, the five recommended plume control technologies should undergo detailed evaluation in the near future.

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