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FINAL FEASIBILITY STUDY AT OPERABLE UNIT 4 (OU 4) WITH TRANSMITTAL LETTER
NTC ORLANDO FL
2/1/2001
HARDING LAWSON ASSOCIATES

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FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

UNIT IDENTIFICATION CODE: N65928
CONTRACT NO.: N62467-89-D-0317/135

FEBRUARY 2001

SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORTH CHARLESTON, SOUTH CAROLINA 29418

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February 8, 2001

Document No.: 2545.039

Commanding Officer
SOUTHNAVFACENGCOM
ATTN: Ms. Barbara Nwokike, Code 187300
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, SC 29406

SUBJECT: Final Feasibility Study
Operable Unit (OU) 4
Naval Training Center (NTC), Orlando, Florida
Contract No. N62467-89-D-0317/CTO 135

Dear Barbara:

Enclosed please find two copies of the Final NTC Orlando OU 4 Feasibility Study (FS). This document includes revisions in response to comments received on the Draft OU 4 FS, as well as updates to reflect the completion of the soil IRA by the Detachment, and the knowledge gained from the potassium permanganate pilot study.

The comment responses and revisions to the chemical oxidation alternative are identical to those included in our letter to you dated December 22, 2000. That letter and the proposed FS revisions were also sent to the OPT for comment. None were received. The contents of the December 22 submittal have therefore been incorporated into this Final FS.

If you have questions or comments regarding this document, please contact me at (781) 213-5652 or John Kaiser at (407) 522-7570.

Very truly yours,

HARDING LAWSON ASSOCIATES

Mark J. Salvetti

Mark J. Salvetti, P.E.
Task Order Manager

Enclosures

cc:

W. Hansel (SDIV)
D. Grabka (FDEP)
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FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

Unit Identification Code: N65928

Contract No. N62467-89-D-0317/135

Prepared by:

Harding Lawson Associates
2533 Greer Road, Suite 6
Tallahassee, Florida 32308

Prepared for:

Department of the Navy, Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, South Carolina 29418

Barbara Nwokike, Code 1873, Engineer-in-Charge

February 2001

CERTIFICATION OF TECHNICAL
DATA CONFORMITY (MAY 1987)

The Contractor, Harding Lawson Associates, hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0317/135 are complete and accurate and comply with all requirements of this contract.

DATE: February 8, 2001

NAME AND TITLE OF CERTIFYING OFFICIAL: John P. Kaiser
Installation Manager

NAME AND TITLE OF CERTIFYING OFFICIAL: Mark Salvetti, P.E.
Project Technical Lead

(DFAR 252.227-7036)

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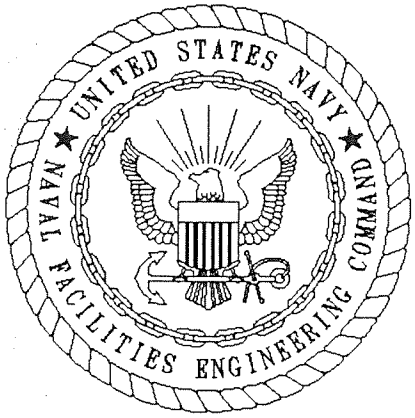
FGW.02.01



The engineering evaluations and professional opinions rendered in this planning document that describes the Feasibility Study for Operable Unit 4, Naval Training Center, Orlando, Florida, were conducted or developed in accordance with commonly accepted procedures consistent with applicable standards of practice. This document is not intended to be used for construction of the selected alternatives.

HARDING LAWSON ASSOCIATES
2533 Greer Road, Suite 6
Tallahassee, Florida 32308

Willard A. Murray, Ph.D.
Professional Engineer No. 39866
Expires February 28, 2001

Date: 2/2/01

FOREWORD

To meet its mission objectives, the U.S. Navy performs a variety of operations, some requiring the use, handling, storage, or disposal of hazardous materials. Through accidental spills and leaks and conventional methods of past disposal, hazardous materials may have entered the environment in ways unacceptable by today's standards. With growing knowledge of the long-term effects of hazardous materials on the environment, the Department of Defense (DOD) initiated various programs to investigate and remediate conditions related to suspected past releases of hazardous materials at their facilities.

One of these programs is the Base Realignment and Closure (BRAC) Cleanup Plan (BCP). This program complies with the Base Closure and Realignment Act of 1988 (Public Law 100-526, 102 Statute 2623) and the Defense Base Closure and Realignment Act of 1990 (Public Law 101-510, 104 Statute 1808), which require the DOD to observe pertinent environmental legal provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Executive Order 12580, and the statutory provisions of the Defense Environmental Restoration Program, the National Environmental Policy Act (NEPA), and any other applicable statutes that protect natural and cultural resources.

CERCLA requirements, in conjunction with corrective action requirements under Subtitle C of the Resource Conservation and Recovery Act (RCRA), govern most environmental restoration activities. Requirements under Subtitles C, D, and I of RCRA, as well as the Toxic Substances Control Act, the Clean Water Act, the Clean Air Act, the Safe Drinking Water Act, and other statutes, govern most environmental mission-related, operational-related, and closure-related compliance activities. These compliance laws may also be applicable or relevant and appropriate requirements (ARARs) for selecting and implementing remedial actions under CERCLA. NEPA requirements govern the Environmental Impact Analysis and Environmental Impact Statement preparation for the disposal and reuse of BRAC installations.

The BCP process centers on a single goal: expediting and improving environmental response actions to facilitate the disposal and reuse of a BRAC installation, while protecting human health and the environment.

The Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), the U.S. Environmental Protection Agency, and the Florida Department of Environmental Protection collectively coordinate the cleanup activities through the Orlando Partnering Team. This team approach is intended to foster partnering, accelerate the environmental cleanup process, and expedite timely, cost-effective, and environmentally responsible disposal and reuse decisions.

This report presents the Feasibility Study (FS) for Operable Unit 4, located at the Main Base, Naval Training Center (NTC), Orlando, Florida. The FS includes a discussion of remedial action objectives (RAOs), ARARs, the identification and screening of applicable technologies to address RAOs, the identification and description of remedial alternatives, and detailed analyses of the identified alternatives against nine criteria.

Questions regarding the BCP process at NTC, Orlando should be addressed to the SOUTHNAVFACENGCOM BRAC Environmental Coordinator for NTC, Orlando, Mr. Wayne Hansel at (407) 646-5294 or the Southern Division Engineer-in-Charge, Ms. Barbara Nwokike at (843) 820-5566.

EXECUTIVE SUMMARY

Harding Lawson Associates has been contracted by the Department of the Navy, Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM) to complete a Remedial Investigation and Feasibility Study (RI/FS) for Operable Unit (OU) 4, located at the Naval Training Center (NTC) in Orlando, Florida. OU 4 is located within Area C of the NTC, Orlando and includes Study Area (SA) 12 (Defense Reutilization and Marketing Office [DRMO] Warehouses and Salvage Yard), SA 13 (former base laundry and dry-cleaning facility), and SA 14 (DRMO Storage Area). This report documents the FS for OU 4.

The purpose of this FS is to identify remedial action objectives (RAOs), identify remedial action alternatives that will achieve those objectives, and evaluate the alternatives to provide the basis for selection of a preferred remedial alternative. This FS contains an overview of the RIs conducted at OU 4 and contains the identification and discussion of applicable or relevant and appropriate requirements (ARARs) to develop RAOs. Next, remedial technologies that address the RAOs are identified and screened. Technologies that pass the screening phase are developed into remedial alternatives. These remedial alternatives are then analyzed in detail for their ability to meet the RAOs and in comparison to each other.

The RI, identified contamination in OU 4 groundwater, surface soil, subsurface soil, surface water, and sediment. Surface soil contamination was addressed by an interim action (i.e., removal) conducted by the Navy in May 1999. Consideration of the fate and transport of the identified contaminants established that remediation of groundwater at OU 4 would also address contamination found in all other remaining media (surface soil, sediment, and surface water).

The primary chemicals of concern (COCs) include chlorinated volatile organic compounds (VOCs) (tetrachloroethene, trichloroethene, and cis-1,2-dichloroethene) and antimony. Two VOC plumes exist, a northern and a southern plume. These two plumes commingle and then discharge to Lake Druid. The antimony plume is located in the southeastern corner of OU 4 and appears to be relatively stationary.

The RAOs identified for OU 4 address contamination in groundwater and are meant to be protective of human health and ecological receptors under current and future use scenarios. The RAOs for OU 4 are as below.

RAO 1: Reduce the potential for human ingestion of groundwater containing COCs that exceed drinking water-based regulatory requirements or risk-based acceptable exposure levels.

RAO 2: Gain control over groundwater migration of VOC concentrations that contribute to exceedances of Florida surface water standards in Lake Druid.

Technologies and response actions that passed the technology screening process and these RAOs were developed into remedial alternatives. These alternatives are developed to achieve the treatment levels identified for OU 4. Alternatives addressing the VOC plumes are labeled "Alternative V-x." Alternatives addressing the antimony plume are labeled "Alternative A-x."

Seven remedial alternatives were developed to address the VOC plumes.

- Alternative V-1: No action;
- Alternative V-2: Limited action;
- Alternative V-3: *In situ* chemical oxidation, natural attenuation, and enhanced bioremediation;
- Alternative V-4: Air sparging, natural attenuation, and enhanced bioremediation;
- Alternative V-5: Source area recirculation wells, natural attenuation, and enhanced bioremediation;
- Alternative V-6: Groundwater extraction and treatment via air stripping; and
- Alternative V-7: Groundwater extraction and treatment via (UV)/oxidation.

It should be noted that all seven remedial alternatives include the continued operation of the Interim Remedial Action (two extraction wells and an air stripper) located between Port Hueneme Avenue and Lake Druid. Table ES-1 presents a summary of the comparative analysis for these alternatives.

Four remedial alternatives were developed to address groundwater contaminated with antimony.

- Alternative A-1: No action;
- Alternative A-2: Limited action;
- Alternative A-3: Groundwater extraction and discharge to Orlando STP; and
- Alternative A-4: Groundwater extraction, treatment, and discharge to Lake Druid.

Table ES-2 presents a summary of the comparative analysis for these alternatives.

The evaluation of alternatives was completed based on seven of the nine criteria established in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) as follows:

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, or volume of contaminants through treatment;
- short-term effectiveness;
- implementability; and
- cost.

Table ES-1
Summary of Comparative Analysis for VOC Plume Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Alternative:	V-1 No Action	V-2 Limited Action	V-3 Chemical Oxidation and Enhanced Biodegradation	V-4 Air Sparging and Enhanced Biodegradation	V-5 Recirculating Wells and Enhanced Biodegradation	V-6 Diffused Aeration	V-7 UV/Oxidation
Groundwater Remediation							
Groundwater extracted?	No	No	Yes	No	No	Yes	Yes
Organics reduced?	Yes (IRA)	Yes (IRA)	Yes	Yes	Yes	Yes	Yes
Estimated time until IRA is shut down (years):	Indefinite	Indefinite	10	10	27	10	10
Estimated time to achieve drinking water standards (years):	Indefinite	Indefinite	40+	40+	27/45+	[2]108/[3]89+	[2]108/[3]89+
Plume contained?	Yes (IRA)	Yes (IRA)	Yes (IRA)	Yes (IRA)	Yes (IRA)	Yes	Yes
Source area toxicity reduced?	No	No	Yes	Yes	Yes	Yes	Yes
Source area remedy permanent?	DNA	DNA	Yes	Yes	Yes	Yes	Yes
MCLs attained?	No	No	[4]Yes	[4]Yes	Yes	Yes	Yes
Source treatment residuals produced?	DNA	DNA	No	Yes	Yes	[1]No	No
Operation and Maintenance (Excluding IRA)							
North plume treatment O&M duration (yrs)	DNA	DNA	30+	30+	[2]27/[3]45+	[2]108/[3]89+	[2]108/[3]89+
South plume treatment O&M duration (yrs)	DNA	DNA	3	3	3	[5]DNA	[5]DNA

See notes at end of table.

Table ES-1 (Continued)
Summary of Comparative Analysis for VOC Plume Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Alternative:	V-1 No Action	V-2 Limited Action	V-3 Chemical Oxidation and Enhanced Biodegradation	V-4 Air Sparging and Enhanced Biodegradation	V-5 Recirculating Wells and Enhanced Biodegradation	V-6 Diffused Aeration	V-7 UV/Oxidation
Utilities maintenance	DNA	DNA	Yes	Yes	Yes	Yes	Yes
Groundwater monitoring	No	Yes	Yes	Yes	Yes	Yes	Yes
Costs							
Capital	DNA	$16,500	$494,702	$663,832	$938,027	$305,505	$386,732
Present worth	$861,140	$897,762	$1,474,387	$1,617,711	[2]$3,308,022/[3]2,986,580	[2]$1,848,589/[3]1,768,681	[2]$3,151,344/[3]3,034,993
Future worth	$3,034,793	$3,116,789	$3,130,492	$3,488,874	[2]$7,347,475/[3]6,277,945	[2]$53,216,854/[3]17,137,564	[2]$110,281,921/[3]28,578,131

[1] Air emissions meet FDEP air regulations without further treatment.
[2] MCL RGO.
[3] Site-specific RGO with natural attenuation to meet MCLs.
[4] MCLs eventually attained through monitored natural attenuation.
[6] Groundwater extraction and *ex situ* treatment addresses both the north and south plumes together.

Notes: VOC = volatile organic compound.
UV = ultraviolet.
IRA = Interim Remedial Action.
DNA = does not apply.
MCL = maximum contaminant level.
O&M = operation and maintenance.
FDEP = Florida Department of Environmental Protection.
RGO = remedial goal option.

Table ES-2
Summary of Comparative Analysis for Antimony Plume Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Alternative:	A-1 No Action	A-2 Limited Action	A-3[1,2] Extraction and Discharge to Orlando STP	A-4[1,2] Extraction and NP™ Microfiltration
Groundwater Remediation				
Groundwater extracted?	No	No	Yes	Yes
Antimony reduced?	No	No	Yes	Yes
Estimated time to achieve MCLs (yrs)[3]:	Indefinite	Indefinite	19	19
Uncertainty of attaining MCL?	Not attained	Not attained	Low	Low
Plume contained?	No	No	Yes	Yes
Toxicity reduced?	No	No	Yes	Yes
Remedy permanent?	DNA	DNA	Yes	Yes
Treatment residuals produced?	No	No	[4]Yes	Yes
Operation and Maintenance				
Treatment O&M duration (yrs)	DNA	DNA	9	9
Utilities maintenance	DNA	DNA	Yes	Yes
Groundwater monitoring	No	Yes	Yes	Yes

See notes at end of table.

Table ES-2 (Continued)
Summary of Comparative Analysis for Antimony Plume Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Alternative:	A-1 No Action	A-2 Limited Action	A-3[1,2] Extraction and Discharge to Orlando STP	A-4[1,2] Extraction and NP™ Microfiltration
Costs				
Capital (present worth)[2]	DNA	$16,500	$92,456	$251,041
Present worth	$81,174	$221,683	$553,276	$724,521
Delayed Capital (future worth)	DNA	$16,500	$208,446	$590,114
Future worth	$345,331	$760,669	$1,630,701	$1,912,811

[1] Groundwater-use restrictions, 5-year site reviews and associated groundwater monitoring would be implemented immediately following the signed Record of Decision.
[2] Construction and operation of the groundwater extraction, treatment and discharge systems would be delayed for 10 years so not to adversely impact the remediation of southern VOC plume.
[3] Includes 10-year delay in start-up of pump-and-treat.
[4] Treatment residuals generated at City of Orlando STP.

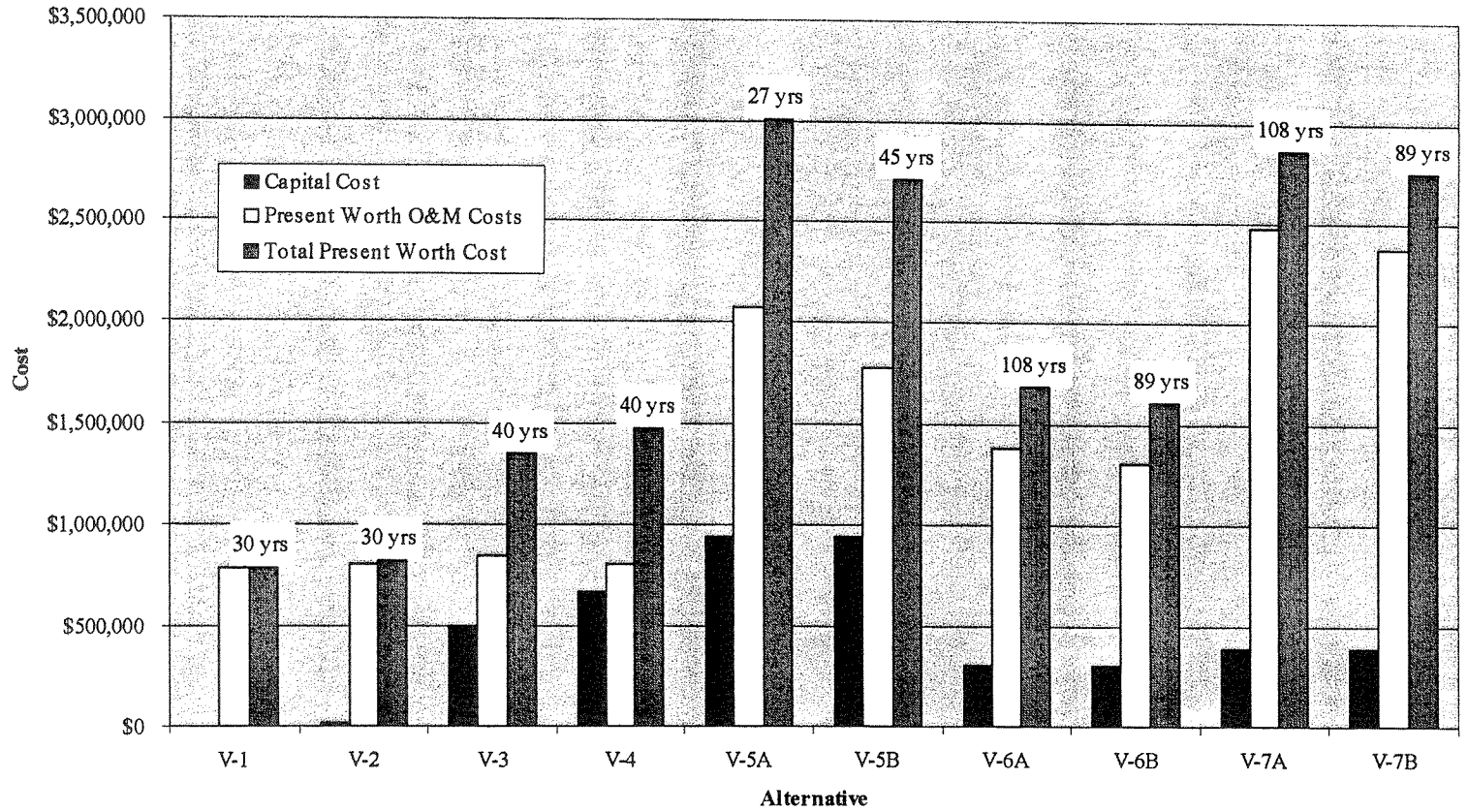
Notes: STP = sewage treatment plant.
NP™ = Neutral Process™.
MCL = maximum contaminant level.
yrs = years.
DNA = does not apply.
O&M = operation and maintenance.
VOC = volatile organic compound.

The eighth and ninth criteria, State and public acceptance, will be addressed for OU 4 once review comments on the FS are received from the State and once a public comment period for the Proposed Plan for OU 4 has occurred.

As part of the cost-effectiveness evaluation, both the present and future worth costs were calculated for each of the remedial alternatives. In accordance with U.S. Environmental Protection Agency (USEPA) guidance (USEPA, 1988), the costs for each of the remedial alternatives presented in Tables ES-1 and ES-2 are present worth values for capital and O&M costs. Side-by-side graphical presentation of these present worth costs are shown on Figures ES-1 and ES-2.

A present worth cost evaluation is valid, assuming the required present worth funds would be available now for the government to set aside for future use, while receiving compounding interest on the original principal deposited. In actuality, the U.S. government sets aside funds on an annual basis. This would support the evaluation of future worth costs as they more accurately reflect the costs that would be incurred by the U.S. Navy on a "pay-as-you-go" basis to construct and operate the remedial alternatives until RAOs were achieved at OU 4. These future worth costs are presented for each of the remedial alternatives on Figures ES-3 and ES-4.

Clearly, this more realistic consideration of remedial costs demonstrates the emphasis for remediation of OU 4 should be on shorter term *in situ* technologies for VOCs. Given the antimony plume appears to be stationary, concentrating on VOC plume remediation while only monitoring the antimony plume also appears to be prudent.



LEGEND

VOC	Volatile organic compound
MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE ES-1
PRESENT WORTH COSTS
VOC ALTERNATIVES V-1 THROUGH V-7

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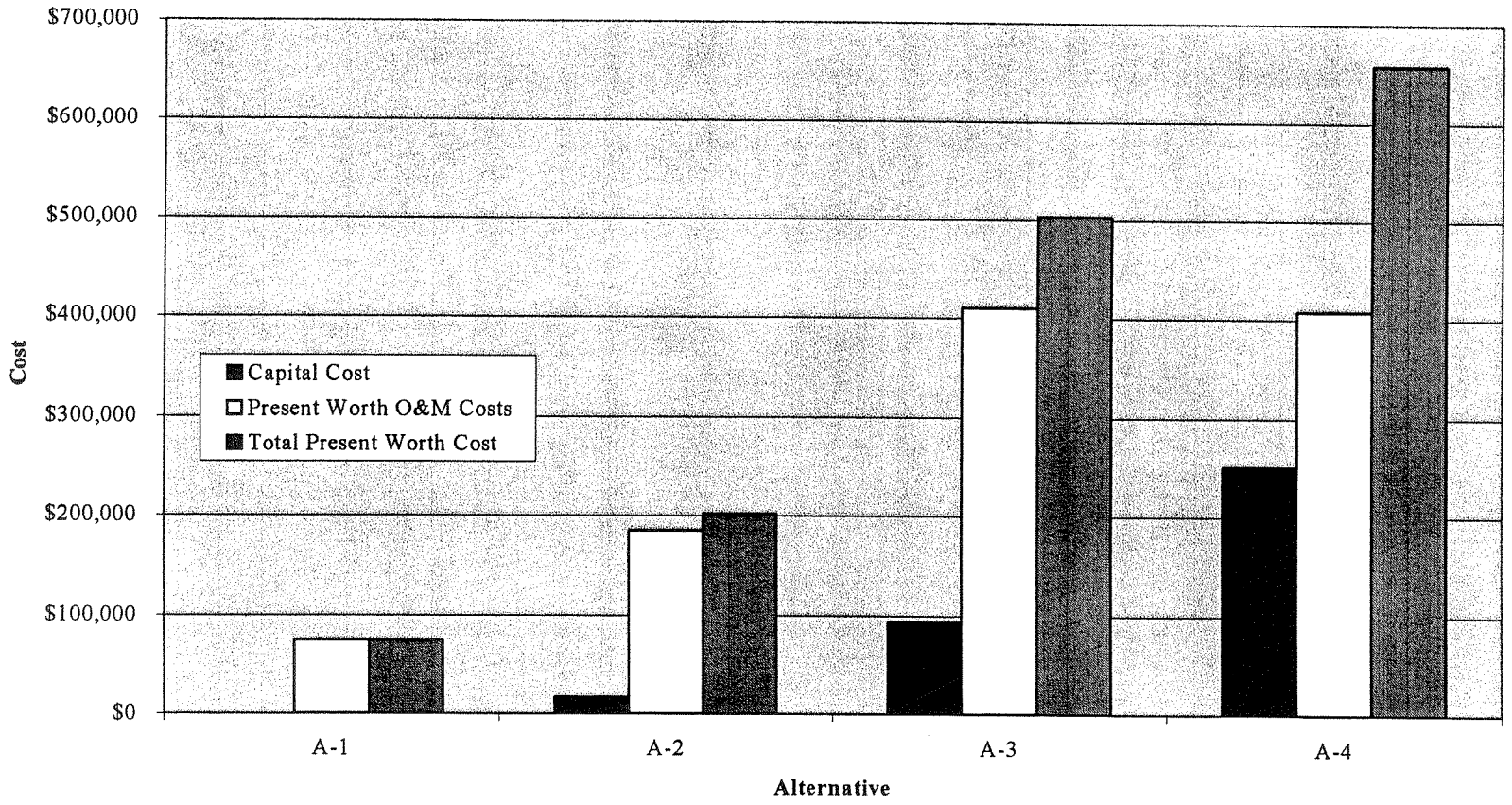
FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA



LEGEND

MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE ES-2
PRESENT WORTH COSTS
ANTIMONY ALTERNATIVES A-1 THROUGH A-4

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FEASIBILITY STUDY
OPERABLE UNIT 4

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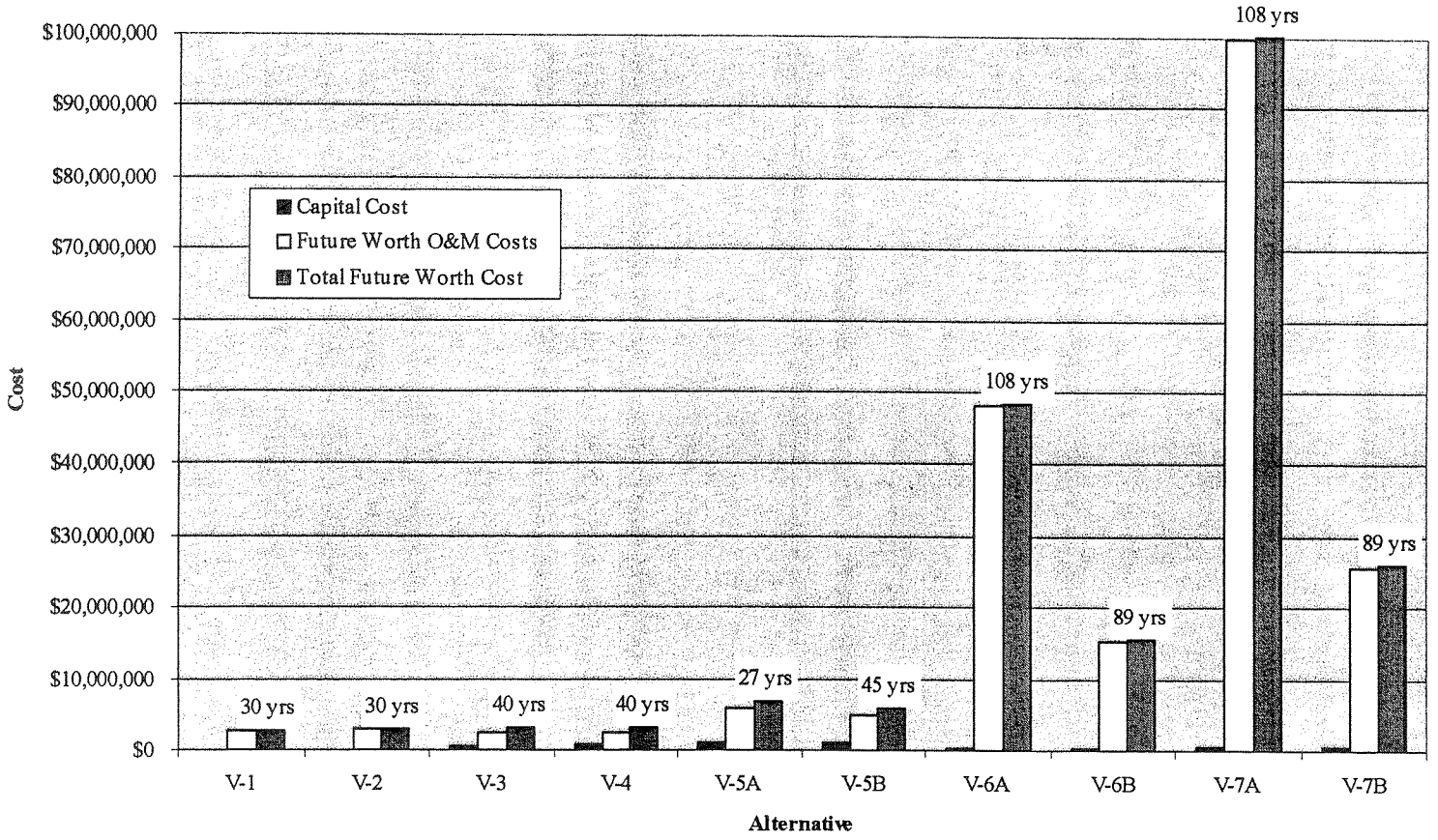
ORLANDO, FLORIDA



LEGEND

VOC	Volatile organic compound
MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE ES-3
FUTURE WORTH COSTS
VOC ALTERNATIVES V-1 THROUGH V-7

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OPERABLE UNIT 4

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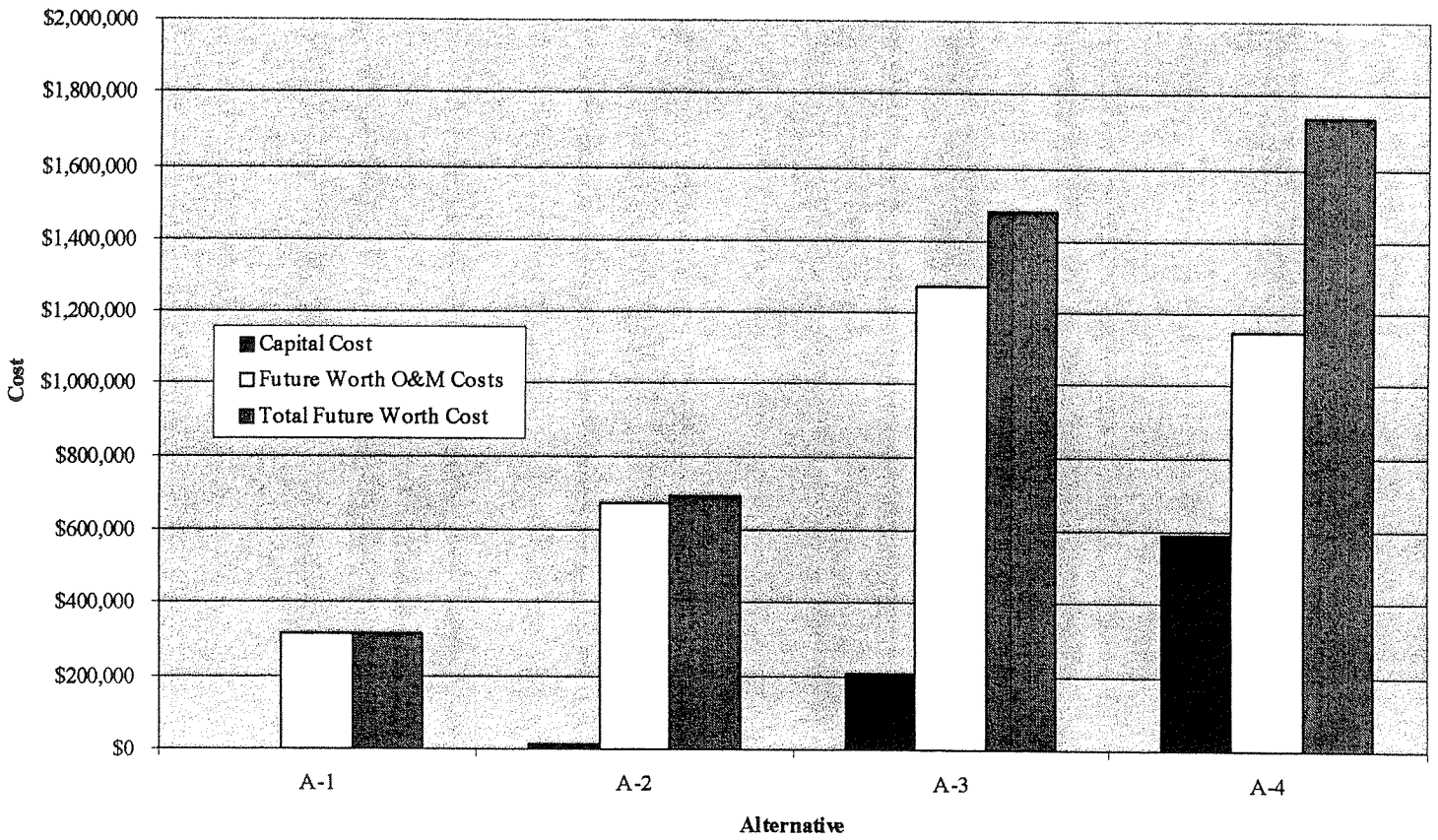

LEGEND

MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE ES-4
FUTURE WORTH COSTS
ANTIMONY ALTERNATIVES A-1 THROUGH A-4

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FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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Naval Training Center
Orlando, Florida

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GLOSSARY

ABB-ES	ABB Environmental Services, Inc.
ARAR	applicable or relevant and appropriate requirement
AWQC	ambient water quality criteria
BCP	BRAC Cleanup Plan
bls	below land surface
BRAC	Base Realignment and Closure (Act)
°C	degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-DCE	cis-1,2-dichloroethene
COC	chemical of concern
COPC	chemical of potential concern
DDT	dichlorodiphenyltrichloroethane
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
DPT	direct-push technology
DRMO	Defense Reutilization and Marketing Office
ECPC	ecological contaminant of potential concern
ERA	ecological risk assessment
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FS	feasibility study
FSWQS	Florida Surface Water Quality Standards
ft/day	feet per day
GAC	granular activated carbon
GCTL	groundwater cleanup target level
g/ℓ	grams per liter
gpm	gallons per minute
HHRA	human health risk assessment
HI	hazard index
HLA	Harding Lawson Associates
HOCl	Hypochlorous acid
HRC™	Hydrogen Release Compound™
H_2O_2	hydrogen peroxide
ID	inside diameter
IRA	Interim Remedial Action
$KMnO_4$	potassium permanganate
kW	kilowatt
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol-water partition coefficient

lbs/day	pounds per day
lbs/year	pounds per year
$logK_{oc}$	logarithmic form, organic carbon partition coefficient
$logK_{ow}$	logarithmic form, octanol-water partition coefficient
MCL	maximum contaminant level
mmHg	millimeters of mercury
MNA	monitored natural attenuation
MnO_4^-	permanganate ion
mg/kg	milligrams per kilogram
µg/kg	micrograms per kilogram
µg/ℓ	micrograms per liter
NAPL	nonaqueous-phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NPDES	National Pollutant Discharge Elimination System
NP™	Neutral Process™
NTC	Naval Training Center
O&M	operation and maintenance
OPT	Orlando Partnering Team
ORP	oxidation-reduction potential
OU	Operable Unit
OVA	organic vapor analyzer
PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PLC	programmable logic control
POTW	publicly owned treatment works
ppb	parts per billion
ppm	parts per million
PVC	polyvinyl chloride
RAO	remedial action objective
RBC	risk-based concentration
RGO	remedial goal objective
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SA	study area
SARA	Superfund Amendments and Reauthorization Act
scfm	standard cubic feet per minute
SCG	soil cleanup goal
SCM	site conceptual model
SCTL	soil cleanup target level
SM	service mark

SOUTHNAV-FACENGCOM	Southern Division, Naval Facilities Engineering Command
STP	sewage treatment plant
SVE	soil vapor extraction
SVOC	semivolatile organic compounds
SWQS	surface water quality standards
TBC	to be considered
TCE	trichloroethene
THM	trihalomethanes
™	trade mark
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UV	ultraviolet
VC	vinyl chloride
VOC	volatile organic compounds
WHPA	Wellhead Protection Area

CHAPTER 1.0

1.0 INTRODUCTION

Harding Lawson Associates (HLA) has been contracted by the Department of the Navy, Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM) to complete a Remedial Investigation (RI) and Feasibility Study (FS) for Operable Unit (OU) 4 at Naval Training Center (NTC), Orlando, Florida. OU 4 is located within Area C of the NTC, Orlando and includes Study Area (SA) 12 (Defense Reutilization and Marketing Office [DRMO] Warehouses and Salvage Yard), SA 13 (former base laundry and dry-cleaning facility), and SA 14 (DRMO Storage Area) (Figures 1-1 and 1-2). The OU 4 RI/FS is being conducted under contract number N62467-89-D-0317/135.

The approach for the OU 4 RI/FS was developed with guidance from the Orlando Partnering Team (OPT), which includes representatives from the Florida Department of Environmental Protection (FDEP), the U.S. Environmental Protection Agency (USEPA) Region IV, SOUTHNAVFACENGCOM and their consultants, and the NTC, Orlando Public Works Department.

1.1 REGULATORY BACKGROUND. As part of the base closure of NTC, Orlando, environmental investigation and cleanup activities have been conducted in accordance with the Federal Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA) of 1980, as amended by the 1986 Superfund Amendments and Reauthorization Act (SARA). References to CERCLA in this report should be interpreted as "CERCLA, as amended by SARA". Under CERCLA, the RI/FS process is the methodology used to characterize the nature and extent of contamination at confirmed hazardous waste sites and to evaluate potential remedial solutions (USEPA, 1988).

This report provides the Final FS for OU 4, including the identification of applicable or relevant and appropriate requirements (ARARs) in Section 3.1, remedial action objectives (RAOs) (Section 3.2), the development and evaluation of remedial alternatives (Chapters 4.0 and 5.0), and a comparative analysis of alternatives (Chapter 6.0). Chapter 2.0 outlines the CERCLA FS process and its application to OU 4, including a description of the existing remedial response (the OU 4 Interim Remedial Action [IRA]) and the role of the IRA in the FS and final remediation of OU 4.

1.2 SITE BACKGROUND AND CONDITIONS. Area C occupies 46 acres, and is located approximately 1 mile west of the Main Base (Figure 1-1). Area C served as a supply center for NTC, Orlando and included the base laundry and dry-cleaning facility and the DRMO. Currently, with the pending closure of NTC, Orlando, all Navy activities at Area C have ceased.

Area C is surrounded by urban development, including single- and multifamily residential developments to the north and south, an office park to the east, and Lake Druid to the west. Lake Druid is semicircular in shape, approximately 1,200 feet at maximum length, 800 feet wide, and a maximum 15 feet deep. Approximately one-third of the lake is surrounded by the undeveloped portion of Area C. This land is mostly forested, and the shoreline is thick with floating emergent plants. The remainder of the lake is surrounded by approximately 3/4 acre of private residential properties.

FIGURE 1-1
NAVAL TRAINING CENTER, ORLANDO
SITE LOCATION MAP

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FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

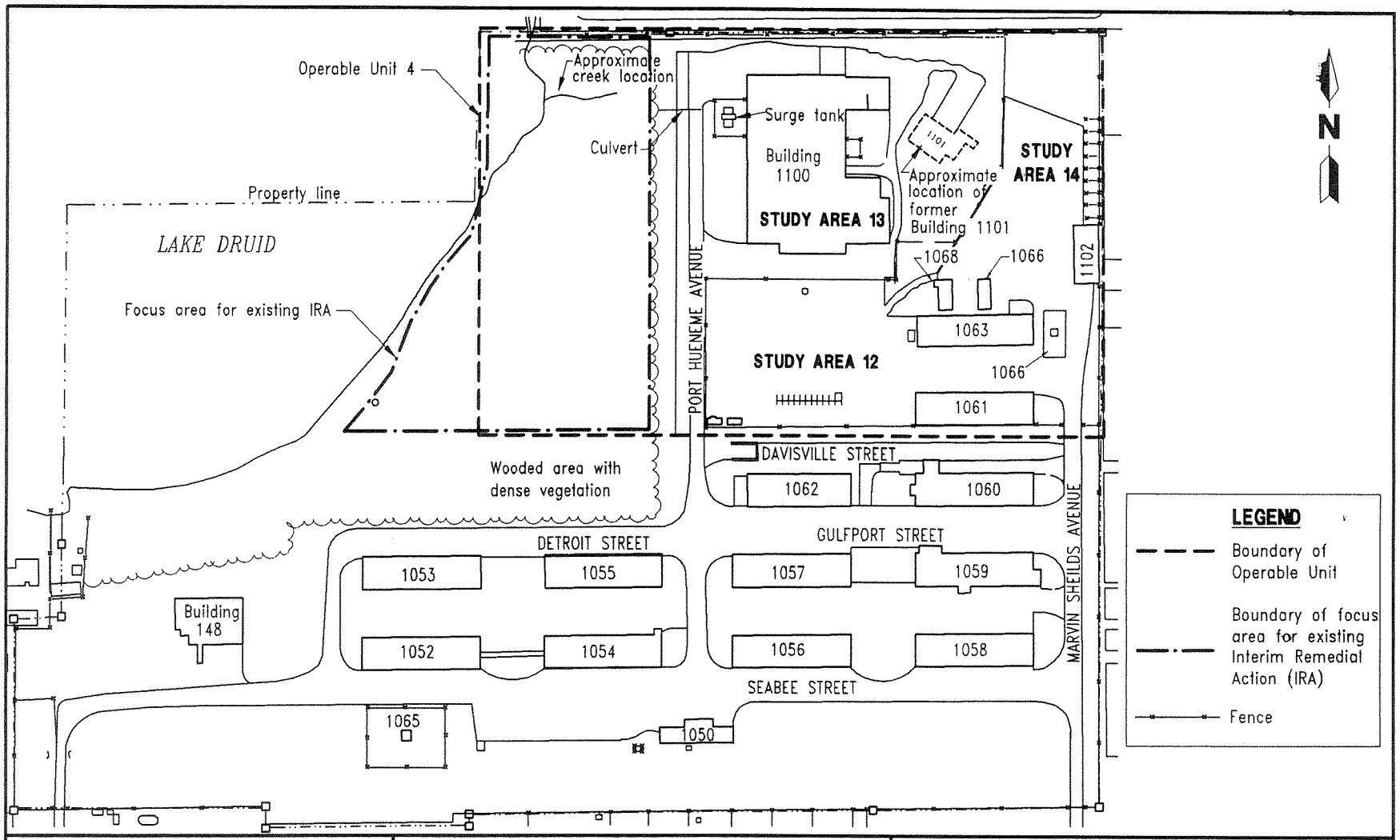

FIGURE 1-2
MAP OF AREA C

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

OU 4 includes SA 12 (DRMO Warehouses and Salvage Yard), SA 13 (former base laundry and dry-cleaning facility), and SA 14 (DRMO Storage Area). These facilities were all constructed during the 1940s. SAs 12 and 14 were used as a salvage, scrap, and disposal yard for their entire history.

The laundry facility (SA 13) is the primary focus for OU 4. The laundry building (Building 1100) was constructed in 1943. Dry-cleaning operations began in 1958, and possibly earlier. Laundry operations ceased in the fall of 1994, and the facility is currently inactive. All laundry equipment (both conventional water-based and dry-cleaning) was removed from the building.

A more detailed site background and history can be found in the Base Realignment and Closure (BRAC) Environmental Site Screening Report (ABB Environmental Services, Inc. [ABB-ES], 1996a), the OU 4 RI/FS Workplan (ABB-ES, 1997a), and the OU 4 RI Report (HLA, 2001).

1.3 INVESTIGATIVE RESULTS. A series of environmental investigations have been conducted at the SAs that make up OU 4, beginning with the initial site screening report (ABB-ES, 1996a) that first identified the presence of chlorinated solvent contamination. After assigning OU status to the three SAs in December 1995, a focused field investigation was performed to evaluate the source of Lake Druid contamination (ABB-ES, 1996b), a focused source investigation was conducted to evaluate the extent of the source area (ABB-ES, 1997b), and a natural attenuation assessment was performed to evaluate the potential for natural attenuation of the chlorinated volatile organic compounds (VOCs) in groundwater (HLA, 1998b).

These initial investigations identified a plume of chlorinated VOCs (tetrachloroethene [PCE], trichloroethene [TCE], and dichloroethene [cis-DCE]) migrating westerly from Building 1100 and into Lake Druid. Further, it was deduced that cis-DCE was biologically degraded into vinyl chloride (VC) within the lake sediment. VC is present in Lake Druid surface water and sediment, but has generally not been detected in groundwater collected from drive points installed through the lake bottom. Concentrations of PCE, TCE, and VC within and adjacent to Lake Druid exceeded Florida surface water standards.

A Focused Feasibility Study was performed (ABB-ES, 1997c) to evaluate technologies for an IRA to mitigate the chlorinated VOC contamination of the lake. Two recirculation wells were installed in December 1997 between Building 1100 and Lake Druid to intercept and treat the chlorinated solvent plume. Despite their initial success in effectively reducing VOC concentrations in the plume, the recirculation wells were shut down in mid-2000 due to poor re-injection rates, biofouling and equipment malfunction. The system was converted to a standard groundwater recovery and treatment system to continue interception and treatment of the chlorinated solvent plume. The amended IRA continues to operate. The IRA is discussed in more detail in Section 2.3.

1.3.1 RI Results The OU 4 RI was conducted between September 1997 and March 1998. The Final RI for OU 4 (HLA, 2001) contained an assessment of the nature and extent of contamination in soil and groundwater for all SAs at OU 4. The Final RI also contained an assessment of the risks posed to human health and the environment by site-related contamination.

The chemicals of concern (COCs) at OU 4 are primarily PCE and its degradation products (TCE, cis-DCE, and VC) in the groundwater, surface water, and sediment of Lake Druid. The extent of the VOC contamination in groundwater is shown on Figure 1-3. A primary (northern) chlorinated solvent plume originates in the suspected source area(s) (Figure 1-4) at the northern and northwestern end of Building 1100. Monitoring well and direct-push technology (DPT) data have shown that this plume is likely confined to Area C along the northern property line, and does not extend into the condominium property located north of OU 4. However, additional groundwater monitoring will be performed along the property line to confirm that the plume is confined to Area C. The southern extent of the northern plume is loosely defined as a line drawn through monitoring wells OLD-13-19B and OLD-13-24A (Figure 1-3).

A second, much lower concentration chlorinated solvent plume exists at the southern end of Building 1100. This southern plume appears to originate near the southeast corner of Building 1100 or the southern end of SA 14. Approximately 3 gallons of PCE were reportedly released from scrap dry-cleaning equipment in 1989, but the exact location was not recorded. It is likely that the release would have occurred in SA 14 while it was operated as a DRMO storage yard. A number of drums of contaminated soil were reportedly removed from the spill location (ABB-ES, 1994). This effort appears to have been successful in removing the source area. No source was discovered during the soil gas program conducted during site screening (ABB-ES, 1996a), and the relatively low VOC concentrations in groundwater concentrations suggest a source area is not present.

The highest PCE concentrations are in the shallow portion of the aquifer (less than 20 feet below land surface [bls]) near the source area(s) at the northern end of Building 1100. As the PCE plume migrates toward Lake Druid the PCE degrades to TCE. The downgradient extent of the PCE plume is generally limited by this degradation.

As the plume continues to migrate towards the lake, the TCE biologically degrades to cis-DCE. The highest cis-DCE concentrations are generally in the lower portion of the aquifer, downgradient or collocated with the highest TCE concentrations. The maximum depth of the plume is approximately 45 feet bls. The relatively high concentrations of TCE and cis-DCE are present in groundwater as the plume completes its migration westward and discharges upward into Lake Druid. Very little PCE is present in this portion of the plume. The presence of chlorinated VOCs in Lake Druid is presumed to be due solely to the discharge of contaminated groundwater to the lake (discussed further in Section 1.4).

Antimony was also detected in groundwater at SA 14. The affected area is limited (approximately 300 feet in diameter), and the antimony does not appear to have migrated substantially during the last three years (Figure 1-5 and Table 1-1). Antimony data are only available for the shallow (less than 20 feet bls) portion of the surficial aquifer. No known site-related source for the antimony contamination has been identified. Antimony was not detected in soils at SA 14. However, antimony is often used as a flame retardant for clothing. It is possible that antimony was used by the laundry facility for this purpose, and an undocumented release occurred at one time in the vicinity of SA 14.

Because OU 4 is currently inactive, there is little potential for exposure to contaminants under current site conditions. An exception would be to trespassers that could be exposed to contaminated surface water and sediment along the Navy

LAKE DRUID

Property line

Approximate ditch location

PORT HUENEME AVENUE

Building 1100

1102

1068

1066

1063

1069

1061

4062

1062

1060

DAVISVILLE STREET

GULFPORT STREET

DETROIT STREET

Property line

OLD-13-11C
OLD-13-09A
OLD-13-23B
OLD-13-22B
OLD-13-15A
OLD-13-21B
OLD-13-12A
OLD-13-43C
OLD-13-02C
OLD-13-01A
OLD-13-40B
OLD-13-07A
OLD-13-41B
OLD-13-20B
OLD-13-19B
OLD-13-04C
OLD-13-03A
OLD-14-01A
OLD-13-25B
OLD-13-24A
OLD-13-38C
OLD-13-37B
OLD-13-36A
OLD-13-27A
OLD-13-39B
OLD-14-04A
OLD-14-02A
OLD-14-05A
OLD-13-33A
OLD-13-34B
OLD-13-35C
OLD-12-01A
OLD-14-08A
OLD-14-03A
OLD-14-06A
OLD-12-02A
OLD-14-07A
OLD-12-03A
OLD-12-04A

100
10
1,000
5,000

N

LEGEND

OLD-13-11C	Monitoring well location and designation
OLD-13-19B	Microwell location and designation and designation
10	VOC contour (in micrograms per liter, dashed where inferred)
VOC	Volatile organic compound
×——×	Fence

0 50 100
SCALE: 1 INCH = 100 FEET

FIGURE 1-3
MAXIMUM TOTAL VOC CONCENTRATIONS

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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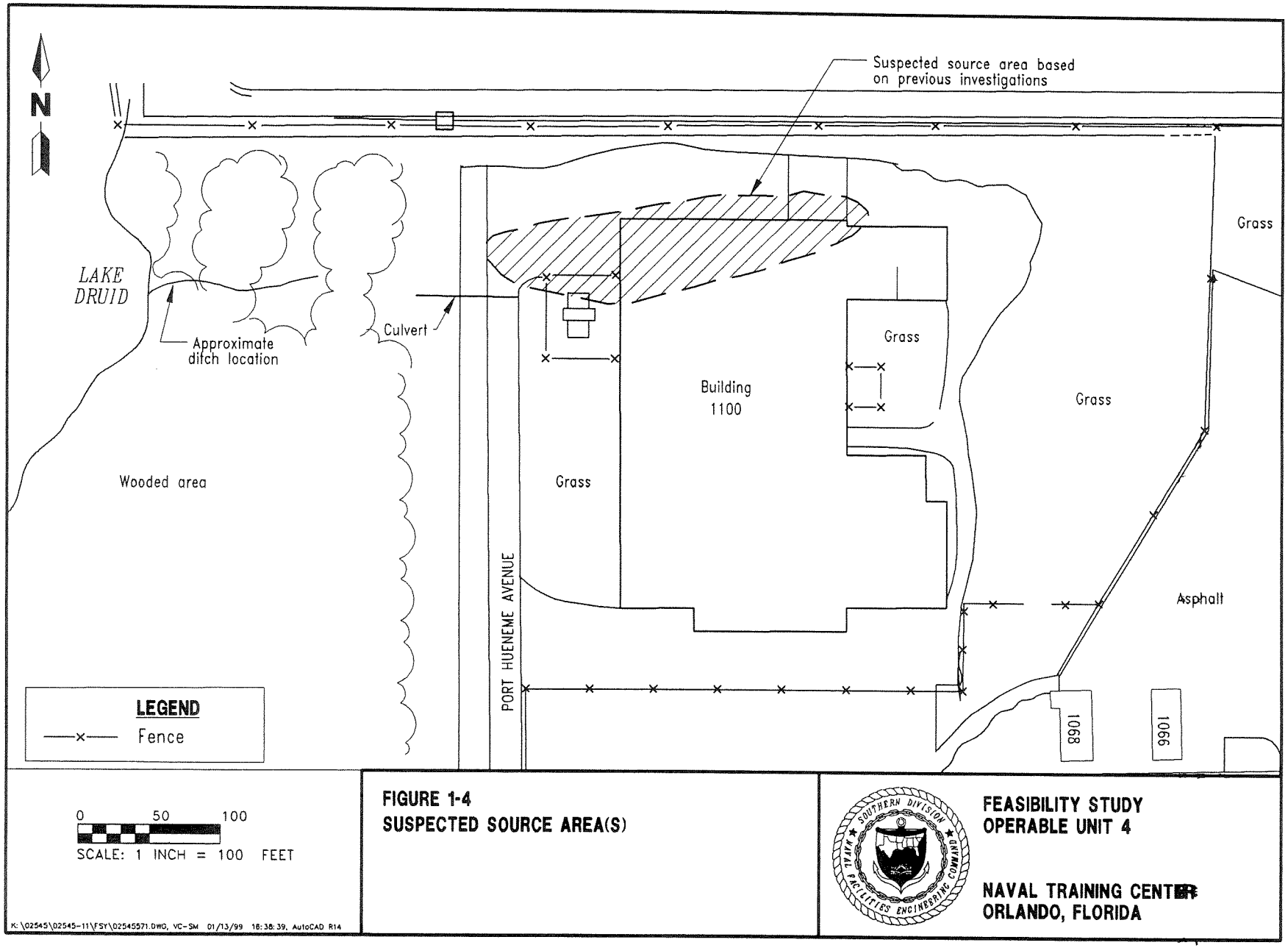
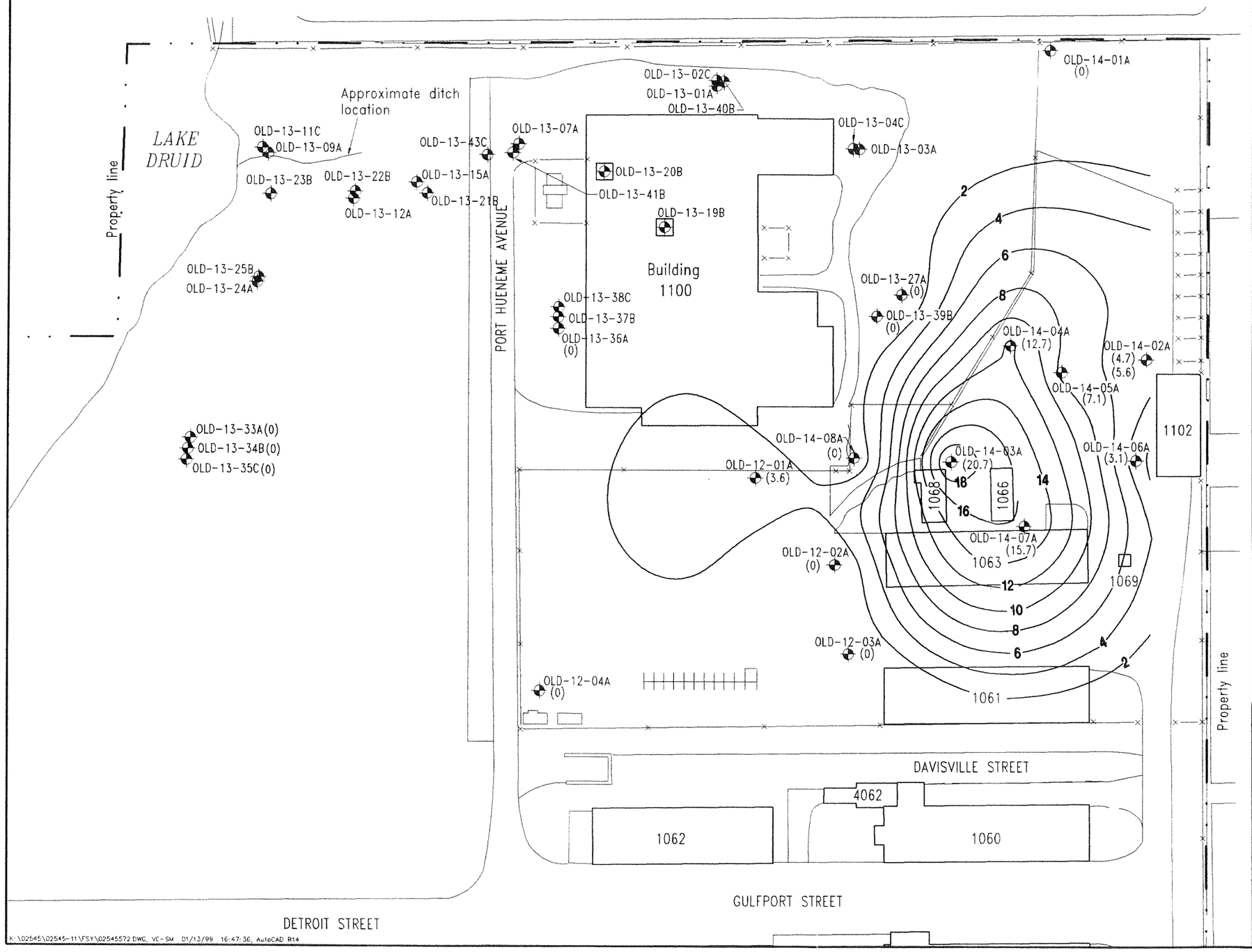


FIGURE 1-4
SUSPECTED SOURCE AREA(S)

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA



LEGEND

OLD-13-11C	Monitoring well location and designation
OLD-13-19B	Microwell location and designation
(12.7)	Antimony concentration (in micrograms per liter)
10	Antimony plume contour (in micrograms per liter)
×——×	Fence

0 50 100
SCALE: 1 INCH = 100 FEET

FIGURE 1-5
ANTIMONY PLUME

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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Table 1-1
Historic Antimony Data

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Well ID	Antimony Concentration (µg/ℓ)	
	April 1995	February 1998
OLD-14-01A	2.5 U	2.5 U
OLD-14-02A	10.1 B	4.7 J
OLD-14-03A	17.6	20.7 J
OLD-14-14A	10.6 B	12.7 J
OLD-12-01A[1]	2.5 U	3.6 J

[1] OLD-12-01A is located approximately 200 feet downgradient of OLD-14-03A.

Notes: µg/ℓ = micrograms per liter.
U = analyte not detected at the reporting limit.
B = reported concentration is between the instrument detection limit and the contract-required detection limit.
J = reported concentration is an estimated quantity.

owned shoreline of Lake Druid. However, because Area C is expected to be transferred to the City of Orlando under BRAC for reuse, the potential exists that residences could be constructed, including the potential for exposure to groundwater through drinking and showering. These scenarios were evaluated in the OU 4 risk assessment (HLA, 2001).

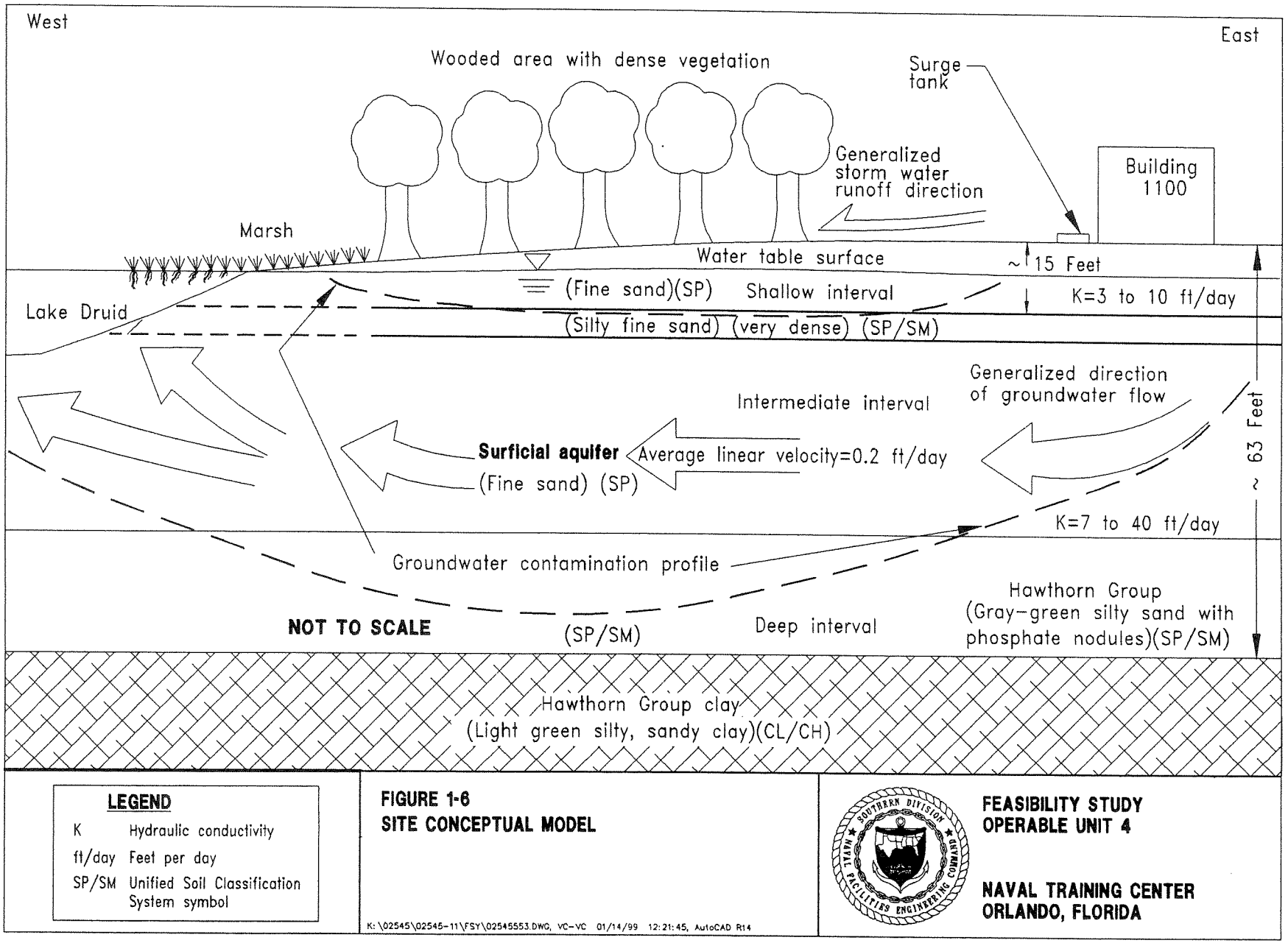
Results of the human health risk assessment (HHRA) indicate that the cumulative risk associated with potential future residential exposure to surface soil, groundwater, surface water, and sediment at OU 4 is above the USEPA acceptable cancer risk range and the FDEP target level of concern. This risk is primarily due to chlorinated VOCs in groundwater. The estimated lifetime excess cancer risk at OU 4 associated with potential exposures to soil ($5x10^{-6}$), groundwater ($2x10^{-3}$), and surface water ($4x10^{-5}$) did exceed Florida's target cancer risk level of concern of 1×10^{-6}.

Risks to terrestrial, aquatic, and semiaquatic receptors based on exposure to contaminants in surface soil, groundwater, surface water, and sediment at OU 4 were evaluated in the ecological risk assessment (ERA) (HLA, 2001). Potential sublethal risks were identified for terrestrial plants and wildlife exposed to surface soil at OU 4, primarily due to aluminum, lead, silver, vanadium, and zinc. Potential sublethal risks were also identified for certain aquatic and semiaquatic organisms exposed to surface water and sediment at OU 4. Pelagic aquatic organisms are not at risk from exposure to chlorinated VOCs in groundwater.

Risks related to surface soil were primarily due to the presence of polycyclic aromatic hydrocarbons (PAHs) and arsenic at three discrete locations (HLA, 2001). The soil from these locations was excavated and removed by the Navy in May 1999. The risks related to surface soil are primarily due to low concentrations of PAHs still remaining at one of the excavated locations. However, this portion of the site receives stormwater runoff from much of the paved area around OU 4. Florida's target cancer risk level of concern (1×10^{-6}) is exceeded only for a future residential scenario, which is expected to be prohibited by deed.

1.4 REFINED SITE CONCEPTUAL MODEL. The site conceptual model (SCM) provides a framework within which the source and release mechanism, transport of contaminants, and environmental pathways of concern are identified schematically (Figure 1-6). The SCM has been previously defined and refined throughout the execution of a comprehensive IRA and RI at OU 4. One of the objectives of the RI was to identify data needs left from the IRA SCM and evaluate those needs to complete the definition of the SCM.

The current version of the SCM is best represented by the Project Logic Diagram (Figure 1-7). This diagram identifies the critical or likely route for contaminant release and mitigation through exposure pathways to potential receptors. The contaminant sources for this SCM are the fluids associated with the dry-cleaning processes at Building 1100. Source areas and release mechanisms are identified as those areas where releases of chlorinated solvents are documented or believed to have occurred and have migrated into the environment. These contaminants may affect multiple receptors through one or more exposure pathways. The following discussions elaborate on the components of the SCM shown on Figure 1-7.


West
East
Wooded area with dense vegetation
Surge tank
Generalized storm water runoff direction
Building 1100
Marsh
Water table surface
~15 Feet
(Fine sand)(SP)
Shallow interval
K=3 to 10 ft/day
Lake Druid
(Silty fine sand) (very dense) (SP/SM)
Generalized direction of groundwater flow
Intermediate interval
Surficial aquifer
Average linear velocity=0.2 ft/day
(Fine sand) (SP)
~63 Feet
K=7 to 40 ft/day
Groundwater contamination profile
Hawthorn Group
(Gray-green silty sand with phosphate nodules)(SP/SM)
NOT TO SCALE
(SP/SM)
Deep interval
Hawthorn Group clay
(Light green silty, sandy clay)(CL/CH)
LEGEND
K Hydraulic conductivity
ft/day Feet per day
SP/SM Unified Soil Classification System symbol
FIGURE 1-6
SITE CONCEPTUAL MODEL
K:\02545\02545-11\FSY\02545553.DWG, VC-VC 01/14/99 12:21:45, AutoCAD R14
FEASIBILITY STUDY
OPERABLE UNIT 4
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

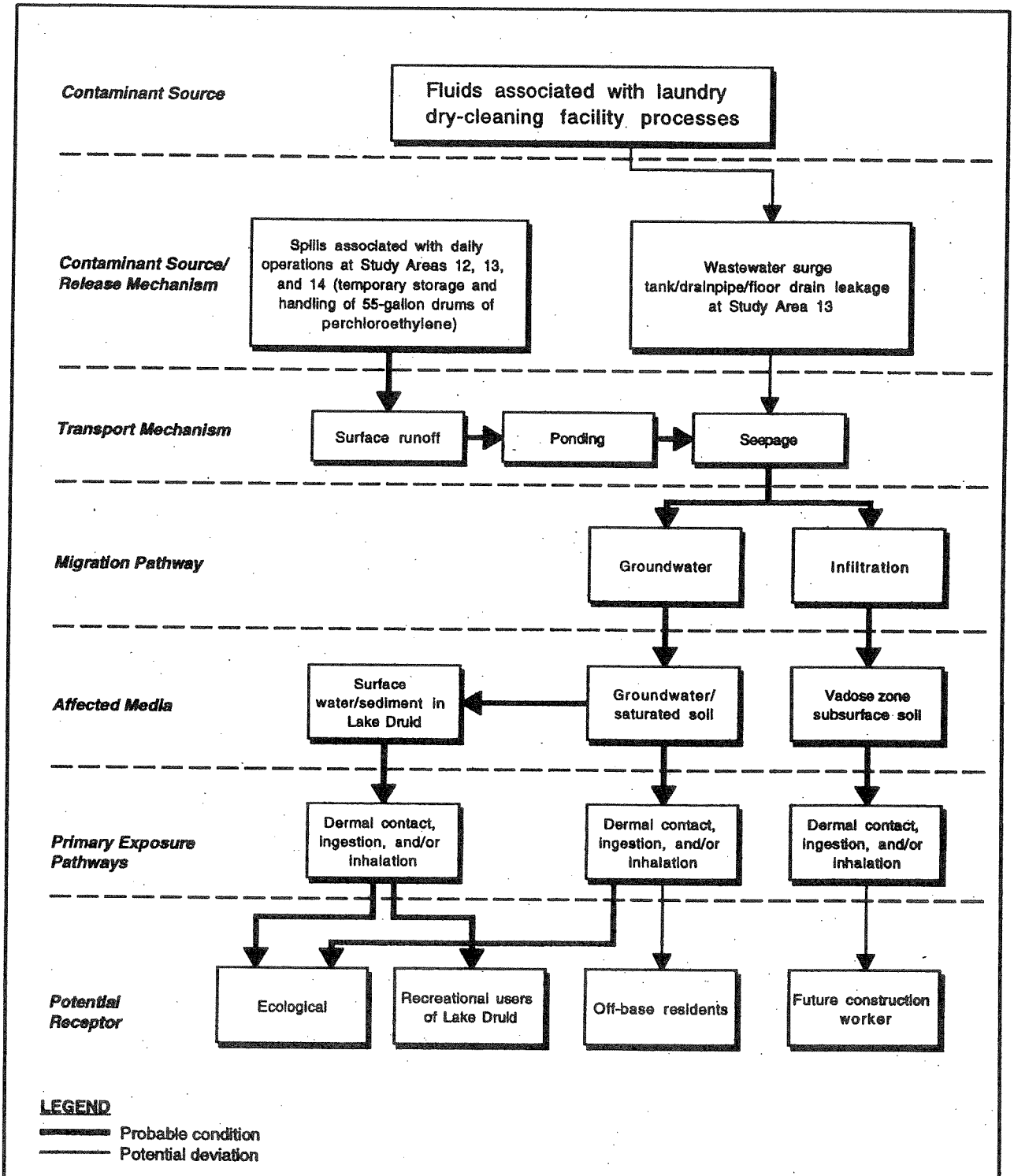


FIGURE 1-7
SITE CONCEPTUAL MODEL: PROJECT LOGIC DIAGRAM

P:\CAD\02545\02545-11\FSY\02545669.DWG, - VC 01/31/01 12:36:28, R2000

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

1.4.1 Contaminant Source and Release Mechanism The source of contamination has been identified during the IRA process and confirmed during the RI as PCE associated with the industrial laundry and dry-cleaning facility during its operation from 1943 to 1994.

The probable contaminant source and release mechanisms at OU 4 are

- operational spills on the ground surface outside the building during the loading and unloading of containers of PCE (ranging from 5- to 55-gallon containers);
- leaks associated with the collection and transport of wastewater from laundry and dry-cleaning machines; and
- spills inside the building transferring via leaks in floor drains, drainpipes, the surge tank, and/or sanitary sewer pipes and migrating to the subsurface.

The specific information below has been gained from investigations regarding the contaminant source/release mechanisms.

- During the source investigation (ABB-ES, 1997b), groundwater was collected via TerraProbe™, which resulted in concentrations of 8,600 micrograms per liter ($\mu g/\ell$) PCE and 15,000 $\mu g/\ell$ TCE. Considering 15,000 $\mu g/\ell$ of TCE to be the by-product of the degradation of 19,000 $\mu g/\ell$ of PCE, the equivalent PCE concentration in this sample is approaching 20 percent of the theoretical solubility for PCE. Similar PCE concentrations were also detected elsewhere at the northern end of Building 1100. These results suggest a strong possibility that a source area of residual nonaqueous-phase liquid (NAPL) is present beneath the former laundry building, possibly at more than one location (Figure 1-4).
- Contaminated groundwater appears to be the source of VOCs detected in Lake Druid. It has been estimated that approximately 25 pounds per year (lbs/year) of total VOC enters Lake Druid via groundwater. Approximately 1 to 5 pounds of VOCs are present in Lake Druid sediment (ABB-ES, 1997c).

1.4.2 Transport Mechanism The mechanism for transport of contaminants away from the source or release areas is through gravity drainage associated with rainfall runoff and infiltration, or independently as gravity drainage of NAPL.

1.4.3 Migration Pathway The migration pathways listed below show the route by which the chlorinated solvents migrate.

- Chlorinated solvents infiltrate through the vadose zone into the groundwater by separate phase gravity drainage as well as by dissolution into infiltrating rain water.
- Groundwater in the vicinity of Building 1100 flows in a westerly direction toward Lake Druid, thereby "carrying" dissolved-phase VOCs to the lake.

The specific information below has a direct effect on the migration pathway. Further details are provided in the OU 4 RI Report (HLA, 2001).

- Stratigraphic information obtained within the surficial aquifer indicates the subsurface is relatively homogeneous, composed of fine sand.

- The soil density of the surficial aquifer typically ranges from medium dense to dense, with the exception of a hard layer (very dense) approximately 15 to 20 feet bls, with varying thickness averaging about 5 feet. However, this hard layer does not act as a hydraulic or chemical confining layer or barrier.

- Results of the DPT groundwater investigation indicated that the width of the groundwater VOC plume extends approximately 500 feet from the north fence line down the shoreline of Lake Druid (Figure 1-3). VOCs detected in groundwater at depths ranging from 4 to 68 feet bls include chlorinated solvents, primarily cis-DCE, TCE, and PCE.

- Analysis of pumping test data indicated that the surficial aquifer can be separated into two zones. From the groundwater surface to approximately 20 to 25 feet bls, the horizontal hydraulic conductivity is about 10 feet per day (ft/day). Below that point to approximately 55 feet bls, the horizontal hydraulic conductivity is about 40 ft/day. In both zones the vertical hydraulic conductivity was determined to be about three times lower than the horizontal hydraulic conductivity.

1.4.4 Affected Media Contaminated media include:

- surface water and sediment in Lake Druid,

- groundwater, and

- surface soil and subsurface soil in the vicinity of Building 1100 (source area).

The specific information below has been gained from previous investigations regarding the affected media.

- Lake Druid is a Class III surface water, as described in Chapter 62-302, Florida Administrative Code (FAC) surface water quality standards (SWQSs). In comparing SWQSs for a Class III body, concentrations of PCE and TCE were above the numeric standards. VC concentrations also exceeded minimum criteria (the detection limit), as specified in Chapter 62-302.500, FAC (FDEP, 1996a). There are no specific published standards for cis-DCE. However, Chapter 62-777, FAC (Contaminant Cleanup Target Levels [FDEP, 1999]) provides a freshwater surface water criteria of 7,000 $\mu g/\ell$ for total cis-DCE. Although cis-DCE concentrations in Lake Druid surface water and in groundwater discharging to the lake have been below this value, the discharge of cis-DCE to Lake Druid must be controlled to help prevent the formation of VC in the lake. The highest surface water and sediment VOC concentrations were detected where the "creek" (actually a surface expression of groundwater) enters the lake (Figure 1-3).

- The highest VOC concentrations in groundwater (up to 34,000 $\mu g/\ell$ of PCE) were detected in the vicinity of the surge tank and beneath the laundry building. These concentrations (over 20 percent of the theoretical PCE solubility) are consistent with the presumed presence of pure residual PCE in the source area.

- Antimony was detected above the FDEP maximum contaminant level (MCL) only in monitoring wells at SA 14. There has been no documented release to account for this plume, nor was antimony detected in SA 14 soils. Evaluation of historic antimony concentrations in groundwater (Table 1-1) suggests the antimony plume is essentially stable.

- PCE has been detected in OU 4 surface soil samples above the groundwater leachability soil cleanup target level (SCTL) of 50 micrograms per kilogram ($\mu g/kg$) for PCE, primarily from the suspected source area. Although gross concentrations (in the percent range) of PCE have never been detected in soil, the groundwater concentrations in the source area suggest pure residual PCE is likely present.

  Three PAHs (benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)-anthracene) exceeded SCTLs in samples collected in surface drainage swales at SA 13 and under the asphalt in one location in SA 12. Arsenic was also detected in a surface soil sample above the SCTL. The PAHs and arsenic were removed in May 1999, with the exception of very low concentrations of PAHs remaining in a drainage swale that continues to receive stormwater runoff from large paved areas of the site. As discussed in Chapter 4, soil contamination at OU 4 will be addressed through VOC source area remediation.

1.5 TREATABILITY STUDIES. Three treatability studies were conducted to evaluate potential remedial technologies were for OU 4: a natural attenuation assessment, an air sparging pilot study and a pilot study of *in situ* oxidation using injection of potassium permanganate ($KMnO_4$).

1.5.1 Natural Attenuation Assessment Details of the data collection plan for assessing natural attenuation at OU 4 can be found in Treatability Study Work Plan No. 1 (ABB-ES, 1997d). Data collection occurred in December 1997 and focused on the portion of the chlorinated VOC plume between the northern end of Building 1100 and Lake Druid. This effort occurred before the IRA system began operation to eliminate the possibility that the recirculation wells could alter the biological conditions in the aquifer. It was expected that natural attenuation could be used as a remedial alternative after VOC concentrations in groundwater were reduced to levels that would allow shutdown of the IRA.

Evaluation of analytical results confirmed that anaerobic dechlorination of source contaminants was occurring *in situ*. Subsurface conditions associated with anaerobic biodegradation of chlorinated solvents (methanogenesis, sulfate reduction, and iron reduction) were observed to exist at a few locations. However, these conditions were not widespread across the plume, suggesting that biodegradation may be limited. Most biodegradation was evident near the source and in the deeper zones.

Most PCE and TCE was transformed to cis-DCE by the time the plume discharged to the lake; however, within the plume, further biodegradation was limited. Therefore, nonbiological attenuation mechanisms (such as dispersion) were shown to influence the overall reduction in VOCs more than biodegradation. Conditions in the plume were not sufficient to facilitate complete degradation of VOCs. A 3 to 10 times reduction in VOC concentrations associated with natural attenuation in the plume occurs between Building 1100 and Lake Druid (HLA, 1998b).

Alternatives in this FS with a natural attenuation component will assume a 10 times reduction in VOC concentrations between the source area at the north end of Building 1100 and the lake.

1.5.2 Air Sparging Details of the data collection plan for assessing air sparging at OU 4 can be found in Treatability Study Work Plan No. 2 (ABB-ES, 1998a). Air sparge testing was conducted in May 1998. The original intent was to test the feasibility of implementing an *in situ* air sparging system to remediate source area contaminant concentrations. Of particular concern was a hard, cemented sand layer located approximately 20 feet bls. Because the source area was suspected to extend beneath the hard layer, successful application of air sparging at OU 4 would require air injection beneath this zone. Although the hard layer of hydraulic conductivity is similar to the hydraulic conductivity of the aquifer above and below, it was not clear if the hard layer would be permeable to air injected beneath it.

The initial phase of the pilot test was to inject air into the aquifer at increasing pressures and various flow rates to determine optimum operational parameters prior to conducting a 72-hour steady state test (the second phase of the test). As air was injected through a deep sparge point (screened from 45 to 50 feet bls), monitoring of shallow observation points indicated the injected air was not migrating to the shallow zone of the aquifer (i.e., the zone above the hard layer). However, air bubbles were observed entering a well (OLD-13-41B) screened from 23 to 28 feet bls (below the hard layer), approximately 25 feet east of sparge well OLD-13-43C. A VOC concentration of over 200 parts per million (ppm) was measured with an organic vapor analyzer (OVA) in air leaving OLD-13-41B. These results implied a 25-foot radius of influence could be achieved sparging beneath the hard layer, and it was apparently possible to strip VOCs from this zone.

When the air injection was stopped, the pressure was released from the compressor and the well-head assembly was removed. It was discovered at that time that the sparge well was still under pressure and air and water were vented from the well for approximately 15 minutes, with the discharge reaching 6 to 10 feet above the well. This behavior further confirmed the accumulation of sparge air beneath the hard layer.

At this point in the test it was determined that implementation of a sparge system as originally conceived was not practical and that subsequent testing should be modified to aid in assessing possible design alternatives. Two design options were considered the most feasible for applying air sparging technology to this site. The first was to design a sparge system to operate only in the shallow zone. However, substantial groundwater contamination is present below the hard layer. The second was to engineer a pathway through the hard layer by which sparge air could migrate into the shallow zone for subsequent capture and treatment (if necessary).

The sparging pilot was then modified to also sparge the shallow aquifer above the hard layer, using shallow microwells originally installed to monitor VOC concentrations in groundwater. The intent of this modification was to verify if the shallow aquifer could be successfully sparged. Measurement of groundwater mounding, off-gas VOC concentrations (up to 260 ppm via OVA), and sparge air emissions confirmed the ability to inject and recover air sparged into the shallow aquifer, achieving a radius of influence in the aquifer above the hard layer of approximately 15 feet.

These events were interpreted as indicating that air could be injected into the aquifer as predicted in the test design, the hard layer was sufficiently impermeable in the test area to prevent the rapid migration of air from the lower zone to the upper zone, injected air could successfully move horizontally through the shallow and deep zones, and sparging appeared to be capable of stripping VOCs from groundwater both above and below the hard layer.

In general, the pilot indicated that air sparging could be technically feasible at OU 4, assuming a means of penetrating the hard layer to allow upward migration of the deeply injected air. The air sparging alternative for this FS (described in detail in Chapter 5.0) assumes that holes will be augered through the hard layer to provide pathways for the upward migration of deep sparge air.

1.5.3 *In Situ* Chemical Oxidation A pilot study was conducted in February, 2000 to evaluate *in situ* chemical oxidation using potassium permanganate as a VOC source area remedial alternative. Research conducted by the University of Waterloo, Canada (Schnarr, et al, 1996), and by Oak Ridge National Laboratory (West, et al, 1997) has shown that *in situ* chemical oxidation using $KMnO_4$ can be an effective remediation technology at chlorinated VOC sites. Chemical oxidation using $KMnO_4$ oxidizes contaminants via the permanganate ion (MnO_4^-). Objectives of the pilot study were to: 1) create and maintain a groundwater circulation cell; 2) determine the optimum aqueous concentration of $KMnO_4$ required to oxidize the OU 4 source area VOCs; 3) treat source area VOCs both above and below the hard layer of dense sand; and 4) determine the maximum reduction of groundwater VOC concentrations that is achievable with this technology.

Treatment involves the flushing of the contaminant zone using an aqueous permanganate solution. Groundwater is extracted, dosed with $KMnO_4$, and then reinjected at an upgradient location. This creates a treatment cell, allowing flushing of several pore volumes of solution through the contaminated zone until the contaminants have been oxidized.

Three injection wells were installed approximately 10 feet apart and adjacent to the northeast corner of Building 1100. The injection wells were screened from 5 to 30 feet bgs. Three extraction wells were installed 65 feet to the west of the injection wells approximately 10 feet apart. Both shallow and deep monitoring wells were installed within the treatment cell area for monitoring and sampling above and below the dense sand layer. Details of the data collection plan for assessing *in situ* chemical oxidation at OU 4 can be found in Treatability Study Work Plan No. 3 (HLA, 1999).

Prior to full system start-up, ex-situ oxidation of VOCs was assessed. Groundwater was extracted from all three recovery wells at a rate of 3.5 to 4.0 gpm and pumped into two tanks in series. $KMnO_4$ was added to the extracted groundwater to correspond to a 4 g/ℓ dosage. Sampling indicated that PCE was reduced from approximately 3000 μg/ℓ to 85 μg/ℓ in Tank 1 and below the MCL of

3 $\mu g/\ell$ after 1.5 hours in Tank 2. TCE and DCE (at concentrations of 780 and 320 $\mu g/\ell$, respectively) were reduced below detection limits in Tank 1.

After demonstrating that VOCs were effectively oxidized *ex situ*, continuous operation of the full system commenced. Various operational difficulties arose, such as power failures, pump maintenance, failure of system automation, and fouling in injection wells, which reduced the number of days the system was operational. In particular, fouling of the injection well screens due to MnO_2 solids became a problem after one month of operation and system flow rates had to be decreased from 4 to 3 gpm. Elevated water levels were observed in the injection wells, but receded after treatment with sulfamic acid. In mid-April, sulfamic acid treatments became less effective. The injection wells were redeveloped with a surge block, resulting in the removal of a significant amount of solids with a peristaltic pump. Upon restart of the system at 4 gpm, injection well water levels increased only slightly, indicating that solids had not clogged the filter pack or aquifer. It was quite apparent that the filter system designed to remove the MnO_2 solids was not effective, as solids had likely bypassed the filters. Flow rates were subsequently decreased to 3 gpm and filters replaced more frequently.

Over the course of 14 weeks, VOC concentrations in the shallow zone above the dense sand layer decreased from levels as high as 24,000 $\mu g/\ell$ to below MCLs in monitoring wells approximately 15 feet downgradient from the injection wells. VOC concentrations decreased to less than 100 $\mu g/\ell$ in wells further downgradient after 4 months. In some instances, VOC concentrations briefly leveled off then decreased further, indicating that $KMnO_4$ took longer to penetrate low permeability zones where residual PCE may have been trapped. Decreased VOC concentrations were accompanied by increases in conductivity due the increase in dissolved solids in the presence of $KMnO_4$.

Decreases in VOC concentrations in the zone beneath the dense sand layer (deep zone) were more modest. Reduced VOC concentrations were not observed until after the sixth week. Corresponding increases in conductivity were also delayed and small. It is likely that the $KMnO_4$ solution was not adequately delivered to the deep zone due to precipitate fouling of the well screen. Modeling of travel times within the upper and lower zones indicate that travel times in the upper zone were faster than predicted and travel times within the lower zone were two to five times slower than predicted. Therefore, the chemical front in the deep zone was delayed since the actual flow rate and thus, mass of $KMnO_4$ injected, into the deep zone was less then predicted.

The pilot study of *in situ* chemical oxidation with $KMnO_4$ indicated that PCE concentrations could be reduced by 99.995% with this technology. However, these reductions in VOC concentrations were observed within the shallow zone. Reductions within the deeper zone occurred more slowly due to ineffective delivery of the $KMnO_4$ solution, which delayed the potassium permanganate front. System operations can be improved by using both shallow and deep injection wells to allowing targeting of the $KMnO_4$ solution and replacing the cartridge filters with a more efficient and maintenance-intensive alternative, such as a sand filter or rotary drum filter. Costs associated with this treatment alternative can be further refined based upon the results of this pilot study. This study has indicated that *in situ* oxidation with potassium permanganate is a viable, effective alternative for reducing VOC source area concentrations and can be readily implemented at OU 4.

CHAPTER 2.0

2.0 DESCRIPTION OF THE FEASIBILITY STUDY

The RI for OU 4 assessed the nature and extent of contamination at the OU. The risk assessment qualitatively and quantitatively assessed the impact of contamination at OU 4 and the risks posed to human health and the environment by site-related contamination. This report provides the FS for OU 4, including the identification of RAOs, the development and evaluation of remedial alternatives, and a comparative analysis of alternatives to provide a permanent remedy.

NTC, Orlando is not listed on the National Priorities List; therefore, remedial action at NTC, Orlando is not directed by the CERCLA. Instead, remedial action at NTC, Orlando is directed by the Navy's Installation Restoration (IR) program. In this manner, the CERCLA process is not directly appropriate for use at NTC, Orlando. However, remedial activities at NTC, Orlando that are conducted in accordance with the IR program are being conducted in a manner similar to CERCLA guidance. The program structure and terminology of the standard IR program (i.e., preliminary assessment, site inspection, remedial investigation and feasibility study, etc.) are discussed in detail in Chapter 1.0 of the RI Report (HLA, 2001). This chapter of the FS Report discusses the CERCLA FS process and its application to OU 4 (Section 2.1), considerations for identifying RAOs (Section 2.2), and other remedial actions that will be considered in this FS (Section 2.3).

2.1 THE FS PROCESS. The development of remedial alternatives for CERCLA sites consists of developing RAOs and then identifying applicable technologies and developing those technologies into remedial alternatives to meet the RAOs. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) requires that a range of alternatives be presented in the FS to the maximum practicable extent.

The first step in the FS process is to develop RAOs, which are media-specific goals established to protect human health and the environment. RAOs specify the COCs, media of interest, and exposure pathways, and are established such that a range of alternatives could be developed to achieve the objectives. RAOs for OU 4 are developed considering the site investigation information presented in the RI report.

Once RAOs are identified, general response actions for each medium of interest are developed. General response actions typically fall into the following categories: no action, containment, excavation, extraction, treatment, disposal, or other actions that, singularly or in combination, may be taken to satisfy the RAOs established for the site.

The next step in the FS process is to identify and screen applicable technologies for each general response action. This step eliminates those technologies that cannot be implemented technically. Those technologies that pass the screening phase are then assembled into remedial alternatives. It should be noted that the purpose of the FS report for OU 4 is not to present all the possible variations and combinations of remedial actions that could be taken at the OU, but to present distinctly different alternatives representing a range of opportunities for meeting the RAOs. It is expected that these different alternatives could be adjusted during the proposed plan and decision process, and to a lesser extent during detailed design to accomplish RAOs in a manner similar to the initially

proposed alternative. This FS report also does not present information on alternatives that fail to meet the RAOs, except for a no action alternative, which provides a baseline for comparison of all alternatives.

Once remedial alternatives are identified, they are then described and analyzed in detail using seven criteria described in the NCP, which are listed below.

Threshold criteria
- overall protection of human health and the environment
- compliance with ARARs

Primary balancing criteria
- long-term effectiveness and permanence
- reduction of toxicity, mobility, or volume of contaminants through treatment
- short-term effectiveness
- implementability
- economics (i.e., cost)

The detailed analyses of remedial alternatives for these seven criteria are summarized and compared to each other within this FS. Remedial alternatives are also evaluated against two modifying criteria after the review and comment on the draft FS. These criteria include

- State acceptance, and
- community acceptance.

The two threshold and five primary balancing criteria are used because SARA requires them to be considered during remedy selection. However, State acceptance is evaluated when the State reviews and comments on the draft FS report. A proposed remedial action plan (i.e., Proposed Plan) is then prepared in consideration of the State's comments. Community acceptance is evaluated based on comments received on the Final FS and Proposed Plan during a public comment period. Comments from the community are addressed in a responsiveness summary in the Record of Decision (ROD), which documents the identification and selection of the remedy. The entire FS process provides the technical information and analyses that form the basis for a proposed remedial action plan (Proposed Plan) and subsequent ROD.

2.2 REMEDIAL CONSIDERATIONS. Prior to establishing RAOs for OU 4, several issues concerning OU 4 should be considered including facility operations, adjacent land use and future land use.

2.2.1 Facility Operations The stated mission of NTC, Orlando was to exercise command over and coordinate the efforts of the assigned subordinate activities in recruit training of enlisted personnel; provide initial skill, advanced, and/or specialized training for officer and enlisted personnel of the regular Navy and Naval Reserve; and to support other activities as directed by a higher authority (ABB-ES, 1996c).

Area C (shown on Figure 1-3) served as a supply center for NTC, Orlando and includes a former laundry and dry-cleaning facility, and the DRMO. The laundry and dry-cleaning facility closed in the fall of 1994.

2.2.2 Adjacent Land Use Area C is surrounded by urban development, including single- and multifamily residential developments to the north and south, Lake Druid to the west, and an office park to the east. Lake Druid is approximately 300 feet west of Port Hueneme Avenue. It is circular in shape, with a maximum length of approximately 1,200 feet and a width of 800 feet. Approximately one-third of the lake is surrounded by undeveloped land to the east, owned by NTC, Orlando, which is mostly forested, and the shoreline is thick with floating emergent plants. The remainder of the lake is surrounded by approximately 3/4 acre of residential properties.

2.2.3 OU 4 Land Use A number of factors were taken into account in the preparation of the risk assessment for OU 4 and the evaluation of potential remedial alternatives to address the identified risks to human health and the environment. These include potential exposure of humans to the contamination under existing and future land-use scenarios, current and future groundwater use, long-term access to OU 4, and treatment durations required to achieve the RAOs.

In accordance with USEPA guidance, the risk assessment evaluated the contaminated media for both existing and future land-use scenarios. The contaminated media included surface water, sediment, surface and subsurface soil and groundwater. Existing land-use scenarios assumed that the public could access the Lake Druid surface water and sediment for recreational use (trespassers). Future exposure scenarios included recreational users, construction and maintenance workers, and future residential use. However, actual future conditions at OU 4 and NTC, Orlando as a whole will be dictated by the proposed redevelopment of the land following the closure of the installation. NTC, Orlando is currently undergoing closure under the BRAC program. A BRAC Cleanup Plan (BCP) was developed for NTC, Orlando that includes the proposed land reuse plan (ABB-ES, 1996c). The current proposed reuse for land comprising OU 4 is continued industrial use. Therefore, the associated risk estimates, as summarized in the Final RI (HLA, 2001), and the proposed remedial alternatives developed and evaluated within this FS are likely overly conservative for the actual proposed reuse of OU 4.

Groundwater from the surficial aquifer at OU 4 is not currently used as a potable water source because municipal water hookups are available. All past and current drinking water at NTC, Orlando and surrounding areas has been derived from an aquifer at great depth (primarily the Floridan aquifer) and provided by the Orlando Utility Commission. In addition, there is no evidence of a direct connection between the shallow aquifer and the primary potable water supplies at NTC, Orlando; therefore, the water supply aquifer is not likely to be affected by the contamination detected at OU 4.

Because the closure, transfer, and redevelopment of NTC, Orlando is a high priority for the Navy and the local community, it is unclear what an acceptable time frame for remedial actions may be. There are also legal implications related to the transfer, including potential lease or transfer of land prior to cleanup; the need for land-use controls; and future access by the Navy or its contractors to conduct operation and maintenance (O&M) activities on treatment systems, or to perform monitoring.

2.3 INCORPORATION OF THE IRA INTO THE FEASIBILITY STUDY. The IRA implemented at OU 4 in December 1997 consisted of two recirculation wells with in-well stripping. The recirculation well system was designed to intercept, both horizontally and vertically, the portion of the VOC plume defined by the 100

parts per billion (ppb) or greater total VOC contaminant contour, as defined in the OU 4 Focused Field Investigation report (ABB-ES, 1997e). The recirculation wells are located in the wooded portion of OU 4, approximately 200 feet west of the northwest corner of Building 1100 (Figure 2-1). Detailed performance requirements and system design criteria were provided in the IRA Conceptual Design and Performance Specification, OU 4 (ABB-ES, 1997f), and are summarized below.

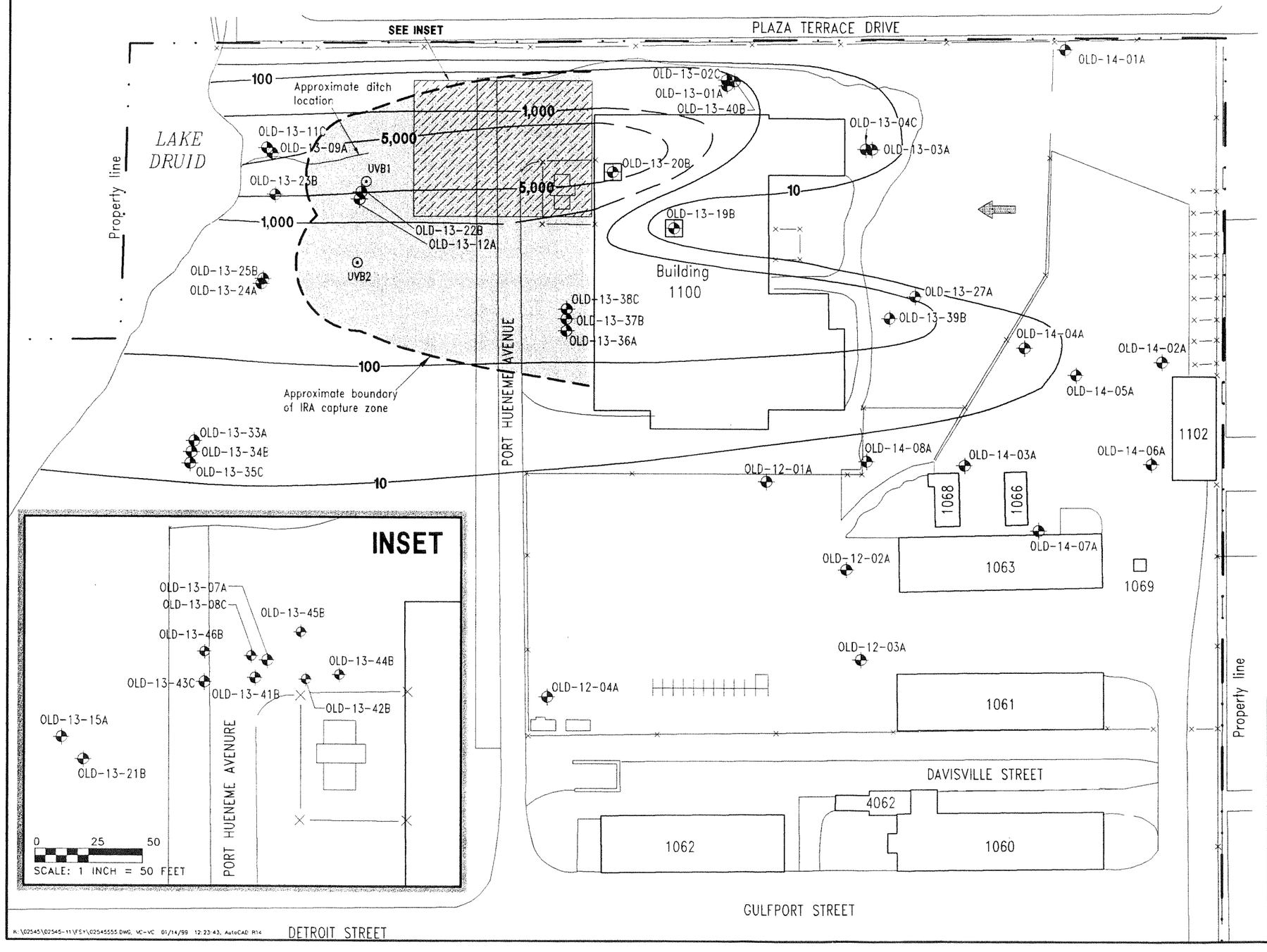
Recirculation well technology creates a spherical treatment zone within a certain radius of each well. Groundwater is extracted from the aquifer through the upper screen of each recirculating well, and is passed through an air stripper unit to volatilize the VOCs in the water before it travels down the well. The treated groundwater is injected back into the surficial aquifer through a second screen near the bottom of the well.

The volatilized VOCs are transported out of the well by means of negative pressure created by a vacuum blower. An exclusion from off-gas treatment was granted by the FDEP, which allows the off-gases to be vented from the well casing to the atmosphere without treatment. Because the contaminated groundwater is treated and discharged without leaving the wells, no consumptive use permit or underground injection permit is required.

The OU 4 recirculation wells were installed in December 1997. Startup occurred in January 1998, and the system operated approximately 3 months before shutdown for repair of failed packers and other improvements. The system again operated from May 1998 through September 1998, during which time some difficulties were encountered maintaining the design pumping rate. The system was initially successful in capturing and treating the chlorinated solvent plume. However, continual problems such as poor re-injection rates, biofouling of the well screens, intermittent system operation and high operation and maintenance costs prompted a re-evaluation of the effectiveness of the recirculation well system.

In mid-2000, the recirculation well system was shut down and converted to a standard groundwater recovery and treatment system. The existing recirculation wells are capable of extracting groundwater at a maximum rate of 30 gpm, which is more than sufficient to capture and treat the solvent plume. The extracted groundwater is pumped to a low-profile tray air stripper and discharged to the City of Orlando sanitary sewer. Monitoring of system influent/effluent and groundwater VOC concentrations have confirmed that the amended system is effectively removing VOCs, thus reducing VOC concentrations entering Lake Druid. System operations and groundwater monitoring data will continue to be reported to the OPT.

The groundwater recovery and treatment system for the OU 4 IRA is achieving the objective of treating groundwater with high concentrations of VOCs before reaching Lake Druid. Continued operation of the IRA will be included in the remedial alternatives developed in this FS, where appropriate. The IRA's primary focus is on contaminated groundwater between Port Hueneme Avenue and Lake Druid (Figures 1-3 and 2-1). For convenience, this contaminated portion of OU 4 will be referred to as the downgradient plume. The IRA will be shut down only if a remedial technology is sufficiently effective in reducing upgradient VOC concentrations so that treatment of the plume by the IRA system will no longer be required.



LEGEND

OLD-13-11C	Monitoring well location and designation
OLD-13-19B	Microwell location and designation
UVB2	Extraction well location and designation
10	VOC contour as of March, 1998 (in micrograms per liter, dashed where inferred)
IRA	Interim Remedial Action
VOC	Volatile organic compound
×——×	Fence
	Groundwater flow direction
	IRA capture zone

FIGURE 2-1
INTERIM REMEDIAL ACTION
SITE PLAN

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

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CHAPTER 3.0

3.0 REMEDIAL ACTION OBJECTIVES

This chapter presents the goals and objectives for remedial action at OU 4 that provide the basis for selecting appropriate RAOs, and subsequently, identifying remedial technologies and developing alternatives to address contamination at the site. To establish these objectives, regulatory requirements are first identified (Section 3.1). Next, RAOs are defined based primarily on consideration of regulatory requirements and the RI Report conceptual model and Risk Assessment (RA) for the site (Section 3.2). Next, COCs and action/treatment levels are defined (Section 3.3) followed by a description of the characteristics of the COCs (Section 3.4). Finally, general response actions that may be employed to satisfy RAOs are discussed (Section 3.5). The general response actions used in conjunction with COC and site characteristics provide the basis for identifying appropriate remedial technologies for OU 4 (presented in Chapter 4.0).

3.1 REGULATORY REQUIREMENTS. Regulatory requirements, or ARARs, are Federal and State human health and environmental requirements used to define the appropriate extent of site cleanup, identify sensitive land areas or land uses, develop remedial alternatives, and direct site remediation.

As previously discussed in Chapter 2.0, remedial action at NTC, Orlando is not directed by CERCLA. In this manner, ARARs, under the CERCLA definition set forth in the NCP, are not directly appropriate for use at NTC, Orlando. However, remedial activities at NTC, Orlando that are conducted in accordance with the IR program are being conducted in a manner consistent with CERCLA guidance. Therefore, ARARs, in the form of regulatory requirements, are identified in this section.

CERCLA and the NCP require that remedial actions comply with State ARARs if they are more stringent than Federal ARARs, legally enforceable, and consistently enforced statewide. The following subsections define the components of ARARs, and provide the specific regulatory requirements appropriate to OU 4.

3.1.1 Definition of ARARs The NCP defines two ARAR components: (1) applicable requirements, and (2) relevant and appropriate requirements.

> Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under Federal or State environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, or other circumstance found at a CERCLA site. State standards that may be applicable are only those which (1) have been identified by the State in a timely manner, (2) are consistently enforced, and (3) are more stringent than Federal requirements.
>
> Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements under Federal and State environmental and facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, or remedial action, address situations sufficiently similar to those encountered at the CERCLA site so that their use is well suited to the

particular site. Only those State standards that are identified in a timely manner and are more stringent than Federal requirements may be relevant and appropriate.

"Applicability" is a legal determination of jurisdiction of existing statutes and regulations, whereas "relevant and appropriate" is a site-specific determination of the appropriateness of existing statutes and regulations. Therefore, relevant and appropriate requirements allow flexibility not provided by applicable requirements in the final determination of cleanup levels. Once a requirement is identified as an ARAR, the selected remedy must comply with ARARs, even if the ARAR is not required to ensure protectiveness. The general relevant and appropriate requirements apply only to actions at the site. Applicable requirements apply to both on- and off-site remedial actions.

Other requirements "to be considered" (TBC) are Federal and State nonpromulgated advisories or guidance that is not legally binding and does not have the status of potential ARARs (i.e., they have not been promulgated by statute or regulation). However, if there are no specific ARARs for a chemical or site condition, or if ARARs are not deemed sufficiently protective, then guidance or advisory criteria should be identified and used to ensure the protection of human health and the environment.

State and Federal regulatory requirements identified for OU 4 are categorized as

- chemical-specific (i.e., governing the extent of site remediation with regard to specific contaminants and pollutants),
- location-specific (i.e., governing site features such as wetland, floodplains, and sensitive ecosystems and pertaining to existing natural and man-made site features such as historical or archaeological sites), and
- action-specific (i.e., pertaining to the proposed site remedies and governing the implementation of the selected site remedy).

Compliance with regulatory requirements will be evaluated during the detailed analysis of remedial alternatives (Chapter 5.0). Chemical-, location-, and action-specific regulatory requirements are discussed in the following subsections, and presented in Table 3-1.

3.1.2 Chemical-Specific Regulatory Requirements Chemical-specific requirements are standards that limit the concentration of a chemical found in or discharged to the environment. They govern the extent of site remediation by providing either actual cleanup levels or the basis for calculating such levels. Chemical-specific requirements for a site may also be used to indicate acceptable levels of discharge in determining treatment and disposal requirements, and to assess the effectiveness of remedial alternatives.

Currently, there are no promulgated Federal or State chemical-specific regulatory requirements that are appropriate for OU 4 that would provide limits for the concentration of chemicals in soil or sediment. The State of Florida has provided Soil Cleanup Target Levels (SCTLs) for sites in Florida (Chapter 62-777, FAC Contaminant Cleanup Target Levels [FDEP, 1999]), and has indicated that these SCTLs should be applied to sites at NTC, Orlando.

Table 3-1
Synopsis of Federal and State Regulatory Requirements and Guidance Materials for OU 4

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Name and Regulatory Citation	Description	Consideration in the Remedial Action Process for OU 4	Type
Federal Regulatory Requirements			
Clean Water Act (CWA), General Pretreatment Regulations for Existing and New Sources of Pollution (40 Code of Federal Regulations [CFR] Part 403])	Regulations for the introduction of pollutants from nondomestic sources into POTWs, to control pollutants that pass through, cause interference, or are otherwise incompatible with treatment processes at the plant.	If groundwater is discharged to a POTW, the discharge must meet local limits imposed by the plant.	Action-specific
CWA, National Permit Discharge Elimination System (NPDES) [40 CFR Part 122 and 125)	Requires permits for discharge of any pollutant into the navigable waters of the United States. Permits specify allowable concentrations of contaminants that may be present in the effluent stream.	Remedial alternatives that involve discharging pollutants to navigable water will require a NPDES permit.	Action-specific
CWA, Water Quality Standards (40 CFR Part 131)	Ambient Water Quality Criteria (AWQC), which are nonenforceable, ecological- and human health-based criteria, have been developed to establish water quality standards under the CWA.	Remedial actions that involve the discharge of groundwater to a surface water body must consider the Federal AWQC in the absence of a State surface water standard.	Chemical-specific
Endangered Species Act Regulations (50 CFR Parts 81, 225, 402)	The Act requires Federal agencies to take action to avoid jeopardizing the continued existence of federally listed endangered or threatened species.	Endangered or threatened species may be present in the vicinity of OU 4. If a planned remedial action could potentially affect an endangered species, this regulation would apply.	Location-specific
National Environmental Policy Act (NEPA) Wetlands, Floodplains, Important Farmland, Coastal Zones, etc. (40 CFR Section 6.302(a))	Contains the procedures for carrying out the executive order on wetland protection (EO 11990). Requires Federal agencies to minimize the degradation, loss, or destruction of wetlands, and take steps to preserve and enhance the natural and beneficial value of wetlands.	When choosing a remedial action, any possible impact to wetlands should be considered and mitigated.	Location-specific

See notes at end of table.

Table 3-1 (Continued)
Synopsis of Federal and State Regulatory Requirements and Guidance Materials for OU 4

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Name and Regulatory Citation	Description	Consideration in the Remedial Action Process for OU 4	Type
Federal Regulatory Requirements (Continued)			
National Environmental Policy Act (NEPA) Wetlands, Floodplains Important Farmland, Coastal Zones, etc. (40 CFR Part 6)	Appendix A sets forth the policy for carrying out the Floodplains EO 11988. This appendix requires cleanup in a floodplain not be selected unless determination is made that no practicable alternative exists.	If a remedial action will be implemented in a designated floodplain, alternatives should be considered to reduce the risk of flood loss and preserve and restore floodplains.	Location-specific
NESHAP [40 CFR Part 61]	Regulates specific sources of pollution. Requires these sources to meet emission standards based on maximum available control technology. Section contains NESHAP for PCE dry--cleaning sources.	Although these requirements are not generally applicable to CERCLA activities because the sources regulated are not present, the emission limitations for certain pollutants (e.g., PCE) may be considered.	TBC (Chemical-specific)
Resource Conservation and Recovery Act (RCRA) Regulations, Identification and Listing of Hazardous Wastes (40 CFR Part 261)	Defines listed and characteristic hazardous wastes subject to RCRA. Appendix II contains the toxicity characteristic leaching procedure.	These regulations would apply when determining whether or not waste on site is hazardous either by being listed or exhibiting a hazardous characteristic as described in the regulations.	Chemical-specific Action-specific
RCRA Regulations, Standards Applicable to Transporters of Hazardous Waste (40 CFR Part 263)	These regulations establish procedures to be followed when transporting manifested hazardous waste within the United States.	If a remedial alternative for OU 4 were to include the offsite transportation of hazardous waste for treatment and/or disposal, transporters must meet these requirements.	Action-specific
Safe Drinking Water Act (SDWA) Regulations, Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs) (40 CFR Part 141, Subparts B and F)	Establishes enforceable standards (MCLs) for potable water for specific contaminants that have been determined to adversely affect human health. MCLGs are nonenforceable health goals established by USEPA.	MCLs can be used for groundwater or surface waters that are current or potential drinking water sources. Nonzero MCLGs can be considered potential relevant and appropriate requirements for groundwater used as a current or potential drinking water source.	Chemical-specific
SDWA Regulations, Underground Injection Control Program (40 CFR Parts 144, 146, 147, and 1000)	These regulations outline minimum program and performance standards for underground injection programs.	If a remedial alternative for OU 4 includes injection into the aquifer, then these regulations would apply.	Action-specific

See notes at end of table.

Table 3-1 (Continued)
Synopsis of Federal and State Regulatory Requirements and Guidance Materials for OU 4

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Name and Regulatory Citation	Description	Consideration in the Remedial Action Process for OU 4	Type
Federal Guidance Material			
USEPA Region III Risk-Based Concentration Tables	This table contains reference doses and carcinogenic potency slopes for nearly 600 chemicals. These toxicity constants have been combined with standard exposure scenarios to calculate chemical concentrations corresponding to fixed levels of risk.	The chemical-specific soil and groundwater values provided in this guidance are TBC values when evaluating these media in the risk assessment and the FS.	TBC
State Regulatory Requirements			
Florida Rules on Permits (Chapter 62-4, Florida Administrative Code [FAC])	Provides permitting requirements for water pollution sources and air emissions units.	The regulation would apply to off-site CERCLA activities or non-CERCLA remedial activities requiring air emissions or water discharge permits.	Action-specific
Florida Surface Water Quality Standards (Chapter 62-302, FAC)	Rule distinguishes surface water into five classes based on designated uses and establishes ambient water quality standards (called Florida water quality standards) for listed pollutants.	Because these standards are specifically tailored to Florida waters, they should be used to establish cleanup levels rather than the Federal AWQC for remedial actions that involve the discharge of groundwater to a surface water body.	Chemical-specific
Florida Groundwater Classes, Standards and Exemptions (Chapter 62-520, FAC)	Rule designates the groundwaters of the State into five classes and establishes minimum "free from" criteria. Rule also specifies that Class I & II waters must meet the primary and secondary drinking water standards listed in Chapter 62-550, FAC.	These regulations should be used when determining cleanup levels for groundwater.	Chemical-specific
Florida Underground Injection Control Regulations (Chapter 62-522, FAC)	This rule establishes a State underground injection control program consistent with the Federal requirements and appropriate to the hydrogeology of Florida. Five classes of injection wells are defined.	If a remedial alternative for OU 4 includes injection into the aquifer, then these regulations would apply.	Action-specific

See notes at end of table

Table 3-1 (Continued)
Synopsis of Federal and State Regulatory Requirements and Guidance Materials for OU 4

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Name and Regulatory Citation	Description	Consideration in the Remedial Action Process for OU 4	Type
State Regulatory Requirements (Continued)			
Florida Drinking Water Standards (Chapter 62-550, FAC)	Rule adopts Federal primary and secondary drinking water standards and also creates additional rules to fulfill State and Federal requirements for community water distribution systems.	The standards provided in this rule will be used when evaluating cleanup levels for groundwater at OU 4.	Chemical-specific
Florida Wastewater Facility Permits (Chapter 62-620, FAC)	Establishes requirements for wastewater permits. Because Florida is a designated state (i.e., has the authority to implement the NPDES permits), one permit will suffice to meet both Federal and State discharge requirements.	If a remedial alternative consists of the discharge of wastewater to navigable waters, the substantive requirements of this rule would need to be achieved.	Action-specific
Pretreatment Requirements for Existing and New Sources of Pollution (Chapter 62-625, FAC)	Rule establishes the authority of various bodies to implement pretreatment standards to control pollutants that pass through or interfere with treatment processes in domestic wastewater facilities.	The regulation would apply to remedial activities involving the discharge of remediation waters to a POTW.	Chemical-specific
Florida Water Quality Based Effluent Limitations (WQBELs) (Chapter 62-650, FAC)	Requires that all activities and discharges, except dredge and fill, must meet effluent limitations based on technology or water quality. WQBELs are determined by FDEP based on the characteristics of the receiving discharge, the receiving water, and the surface water criteria promulgated by FDEP.	The regulation would apply to remedial alternatives that discharge contaminated groundwater to surface water.	Chemical-specific
Hazardous Waste Rules (Chapter 62-730, FAC)	These rules adopt by reference appropriate sections of 40 CFR Parts 260 through 268 and established minor additions and exceptions to these regulations concerning the generation, storage, treatment, transportation, and disposal of hazardous waste.	Based on the history of operations at OU 4 and the solvents used during operations, the wastes encountered at the OU would be classified as hazardous wastes, and these regulations would therefore apply.	Action-specific

See notes at end of table.

Table 3-1 (Continued)
Synopsis of Federal and State Regulatory Requirements and Guidance Materials for OU 4

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Name and Regulatory Citation	Description	Consideration in the Remedial Action Process for OU 4	Type
State Guidance Materials			
Contaminant Cleanup Target Levels (Chapter 62-777, FAC)	Provides risk-based and/or toxicity-based cleanup target levels for contaminants in groundwater (GCTL), surface water (SWCTL), and soil (SCTL) based on direct human contact. Includes levels for residential, industrial, and leaching to groundwater exposure scenarios.	The values in this guidance should be considered when determining cleanup levels for groundwater, surface water, and soil.	TBC

Notes: OU = Operable Unit.
POTW = publicly owned treatment works.
EO = Executive Order.
NESHAP = National Emission Standard for Hazardous Air Pollutants.
PCE = tetrachloroethene.
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act.
TBC = to be considered.
USEPA = U.S. Environmental Protection Agency
FS = Feasibility Study.
FDEP = Florida Department of Environmental Protection.
GCTL = Groundwater Cleanup Target Level
SCTL = Soil Cleanup Target Level
SWCTL = Surface Water Cleanup Target Level

Therefore, the SCTLs, as well as the USEPA Region III Risk-Based Concentrations (RBCs) will be used as TBC requirements for soil. Furthermore, the USEPA has guidance for sediment quality criteria that are considered TBCs for this FS.

Federal and State chemical-specific regulatory requirements are available for groundwater, and include Federal MCLs and Florida drinking water standards (FDEP, 1994a). The State of Florida has classified groundwater at OU 4 as G-II, indicating that it is a potential future source of drinking water for the state. Chemical-specific TBCs include the State of Florida's groundwater cleanup target levels (GCTLs) for sites in Florida (the FDEP has indicated that these GCTLs should be applied to groundwater at NTC, Orlando) and USEPA Region III's RBCs.

Chemical-specific regulatory requirements for surface water include the Florida SWQS and the Federal ambient water quality criteria (AWQC). Lake Druid is a Class III surface water body, as described in Chapter 62-302, FAC, SWQSs. Class III water use is primarily for recreation and propagation/maintenance of a healthy, well-balanced population of fish and wildlife. Lake Druid is a potential discharge option for *ex situ* groundwater treatment options, and also receives recharge from groundwater from OU 4. The chemical-specific requirements and guidelines considered in this FS for OU 4 are included in Table 3-1.

3.1.3 Location-Specific Regulatory Requirements Location-specific requirements govern site features (e.g., wetland, floodplains, wilderness areas, and endangered species) and man-made features (e.g., places of historical or archaeological significance). These requirements place restrictions on concentrations of hazardous substances or the conduct of activities based solely on the site's particular characteristics or location.

There are no places of historical or archaeological significance at OU 4. No State or federally listed rare, threatened, or endangered species are known to exist at OU 4, although gopher tortoises have been observed on the golf course, and other species have been confirmed elsewhere at NTC, Orlando (refer to Table 3-3 in the RI Report [HLA, 2001]). OU 4 includes the eastern shore area of Lake Druid. Four acres are densely vegetated with large trees and heavy undergrowth.

Two acres are classified as Palustrine wetland by the U.S. Department of the Interior, Fish and Wildlife Service (ABB-ES, 1996a). Therefore, regulatory requirements addressing endangered species, wetlands, and floodplains are considered. These location-specific requirements are included in Table 3-1.

3.1.4 Action-Specific Regulatory Requirements Action-specific requirements are technology- or activity-based regulations that control activities for remedial actions. Action-specific regulatory requirements generally set performance or design standards, controls, or restrictions on particular types of activities. To develop technically feasible alternatives, applicable performance or design standards must be considered during the detailed analysis of remedial alternatives (Chapter 5.0). Each alternative will be analyzed to determine compliance with action-specific regulatory requirements during the detailed analysis of alternatives.

Certain action-specific regulations include permit requirements. Under CERCLA Section 121(e), permits are not required for remedial actions conducted entirely on site at Superfund sites. This permit exemption applies to all administrative requirements, including approval of or consultation with administrative bodies,

documentation, record keeping, and enforcement. However, the substantive requirements of these regulations must be attained.

3.2 IDENTIFICATION OF RAOs. RAOs are media-specific goals that are established to protect human health and the environment and are typically based on COCs, exposure routes, and receptors present or available at the site (USEPA, 1988). RAOs are identified for OU 4 by medium, and consider the results of the RI, specifically the refined SCM (Section 1.3), the regulatory requirements and TBCs (Section 3.1), and the results of the RAs as detailed in the following subsections for each media.

For this FS, RAOs will only be identified for a medium in which

- a potential risk exists, as estimated in the human health or the ecological risk assessments, as documented in the OU 4 RI (HLA, 2001), or,
- there are chemical exceedances of the defined regulatory requirements or TBC guidelines identified in Section 3.1.

3.2.1 RAOs for Sediment Sediment samples were collected from five locations (and one control location) at the shore of Lake Druid immediately adjacent to OU 4 during the RI. These data are summarized and discussed in Section 5.2 of the RI Report (HLA, 2001). As previously stated in Subsection 3.1.2, there are no promulgated Federal or State chemical-specific regulatory requirements that provide limits for the concentration of chemicals in sediment at OU 4. USEPA Region III Residential RBCs (USEPA, 1998) and Florida SCTLs (FDEP, 1999) that were used to identify chemicals of potential concern (COPCs) in the HHRA. The USEPA Region IV (USEPA, 1995) provides toxicity benchmark values that were used to identify COPCs in the ERA.

Human Health Risk Assessment. Potential exposures to sediment in Lake Druid were evaluated for wading activities by trespasser under current land use, a recreational user under future land use, and future residents. Evaluation of this exposure pathway is conservative because sediment is always covered by surface water; potential exposure to sediment via dermal exposure to the lower legs and feet was the only exposure route considered reasonable because the sediment is submerged. The HHRA revealed that no unacceptable risks (cancer or noncancer) exist to the current and future receptors evaluated based on USEPA and FDEP target risk ranges and target levels. The USEPA target cancer risk range is 1 in 10,000 ($1x10^{-4}$) to 1 in 1,000,000 ($1x10^{-6}$). FDEP's target cancer risk level of concern is $1x10^{-6}$. Both USEPA and FDEP have established a noncancer risk target hazard index (HI) of 1.

Ecological Risk Assessment. Potential risks associated with exposures to ecological contaminant of potential concern (ECPCs) in OU 4 sediment were evaluated for both semiaquatic wildlife and aquatic receptors. The ecological risk assessment revealed that exposure to ECPCs in sediment do not have an acute toxic effect (i.e., cause mortality) on the wildlife receptor populations at OU 4. Sublethal risks (i.e., potential reductions in the reproduction and growth of terrestrial wildlife) associated with ingestion of mercury (millimeters of mercury [mmHg]) in sediment and food items are predicted for piscivorous birds at OU 4. However, this result is based on data collected from one sample

location. The concentration detected (estimated 0.30 milligrams per kilogram [mg/kg]) was less than the control sample concentration that was collected (0.73 mg/kg). The control sample, believed to be unaffected by OU 4 activity, is likely typical of local conditions. There is no known source of mercury at OU 4.

Potential risks associated with exposures to ECPCs in OU 4 sediment were also evaluated for benthic aquatic organisms in the wetland area and for aquatic receptors in Lake Druid. Sediment ECPCs were compared to sediment criteria and guidelines. Although several exposure concentrations slightly exceed sediment toxicity benchmarks, the magnitude of exceedances was low (i.e., less than a factor of 3.5). Furthermore, the analytes that exceeded benchmarks are not related to the release of chlorinated VOCs from OU 4. Therefore, the ERA concluded that benthic aquatic organisms are not at risk.

RAOs. No RAOs are required for sediments in Lake Druid at OU 4 because the risk estimated for human receptors is within the USEPA and FDEP acceptable target risk range and target levels and ecological receptors are not at risk from contaminants originating from OU 4.

3.2.2 RAOs for Surface Water Surface water samples were collected along with the sediment samples from five locations (and one control location) in Lake Druid during the RI. These data are summarized and discussed in Section 5.2 of the RI Report (HLA, 2001). Chemical-specific regulatory requirements for surface water include the Florida surface water standards (refer to Subsection 3.1.2) for Class III freshwater. A comparison of site data to these standards was completed, and concentrations of PCE and two pesticides (dichlorodiphenyltrichloroethane [4,4'-DDT] and endrin ketone) exceeded these standards.

Human Health Risk Assessment. An HHRA was completed for human exposure to surface water. Potential exposures to Lake Druid surface water in the vicinity of OU 4 were evaluated for wading activities by a current trespasser, future resident living at OU 4, or a future recreational user. Potential exposures to surface water from wading, rather than from swimming in the lake, were evaluated because the area is too heavily vegetated to permit swimming. Potential exposure to surface water COPCs from consuming fish taken from the lake would be considered low, as VOCs do not substantially accumulate in fish tissue. Therefore, exposure to current trespassers, future recreational users (adult and adolescent), and future residents (adult and child) to surface water through ingestion and dermal contact were evaluated in the HHRA.

The risk characterization results for surface water exposure scenarios revealed that for the current land-use scenario, the cancer risks associated with exposure to surface water (ingestion and dermal contact) are $1x10^{-5}$ for an aggregate trespasser (combined adult and adolescent). These cancer risk values are within the USEPA acceptable cancer risk range of 1 in 10,000 to 1 in 1,000,000, but exceed the Florida level of concern of $1x10^{-6}$. The noncancer risks associated with surface water ingestion and dermal contact under the current land-use scenario (adolescent and adult trespasser user) are below USEPA's and FDEP's target HI of 1.

The risk characterization results for potential future land-use exposure scenarios reveal that the cancer risks associated with exposure to surface water (ingestion and dermal contact) are $1x10^{-5}$ for an aggregate recreational user (combined adult and adolescent) and $4x10^{-5}$ for a resident (combined adult and

child). Both of these receptors' cancer risks are within or below the USEPA acceptable cancer risk range of 1 in 10,000 to 1 in 1,000,000; however, they exceed the Florida level of concern of 1×10^{-6} (primarily due to PCE, TCE, VC, and 4,4'-DDT). The noncancer risks associated with surface water ingestion and dermal contact under the future land-use scenario for all potential future receptors are below USEPA's and FDEP's target HI of 1.

Ecological Risk Assessment. An ERA was conducted for both semiaquatic wildlife and aquatic receptor exposure to surface water at OU 4. This assessment indicated that risks are not associated with receptor exposure to ECPCs in surface water at the site.

RAOs. Based upon the SCM, contaminated groundwater appears to be the source of VOCs detected in Lake Druid. It has been estimated that approximately 25 lbs/year of total VOC enters Lake Druid via groundwater. Therefore, it is also affirmed that remedial action is necessary for groundwater as opposed to remedial action for surface water alone. If only surface water were addressed, the source of surface water contamination (groundwater) would continue to discharge VOCs to the lake. No RAOs will be established for surface water at OU 4. Rather, the focus of the RAO will be to gain control over the migration of contaminated groundwater discharging to Lake Druid. In this manner, the source of surface water contamination would be addressed.

3.2.3 RAOs for Surface Soil To assess the quality of the surface soil, 20 surface soil samples (plus 3 duplicates) were collected from 0 to 2 feet bls for laboratory analysis. Initially, 9 of these 20 surface soil samples were collected during the initial site screening of SAs 12, 13, and 14 (ABB-ES, 1996a). The additional 11 surface soil samples were collected during the RI where voids in the data set existed, primarily in SA 13. Twelve samples were collected under the asphalt, while eight were collected in grass or unpaved areas.

In May 1999, a surface soil IRA was initiated at OU 4. Surface soil was removed from three locations with analytes (arsenic, PAHs, and PCBs) above Florida residential SCTLs. Each excavation measured 10 feet by 10 feet, centered on the surface soil sample location, and extended to a depth of 2 feet bls. Confirmatory samples were collected from the four sidewalls of each excavation. The confirmatory sampling results indicated that the elevated concentrations had been significantly reduced or completely removed. Very low concentrations of PAHs remained in a drainage swale that continues to receive stormwater runoff from large paved areas of the site.

These data are summarized and discussed in Section 5.2 of the RI Report (HLA, 2001). Further details of the soil removal are included in Section 2.7 and Appendix M of the RI Report (HLA, 2001).

As previously stated in Subsection 3.1.2, there are no promulgated Federal or State chemical-specific regulatory requirements that provide limits for the concentration of chemicals in soil at OU 4. Florida SCTLs (FDEP, 1999) were used to identify COPCs in the HHRA. Benzo(a)pyrene, barium, and vanadium were detected at concentrations that exceeded the SCTLs.

Human Health Risk Assessment. Potential exposure of future residents (adult and child), future occupational workers, current and future site maintenance workers,

future excavation workers, current trespassers (adult and adolescent), and current and future recreational users (adult and adolescent) to surface soil contaminants through ingestion, dermal contact, and inhalation of particulates was evaluated in the HHRA.

The risk characterization results for current land-use exposure scenarios revealed that the cancer risks associated with exposure to surface soil (ingestion, dermal contact, and fugitive dust inhalation) are 3×10^{-7} for an aggregate trespasser (combined adult and adolescent) and 1×10^{-7} for a site maintenance worker. Both receptors' cancer risk values are below the USEPA acceptable cancer risk range of 1 in 10,000 to 1 in 1,000,000 and the Florida level of concern of 1×10^{-6}. The noncancer risks associated with surface soil ingestion, dermal contact and fugitive dust inhalation under the current land-use scenarios (adolescent and adult trespasser, and site maintenance worker) are below USEPA's and FDEP's target HI of 1.

For potential future land use, the cancer risks associated with exposure to surface soil (ingestion, dermal contact, and fugitive dust inhalation) are 3×10^{-7} for an aggregate recreational user (combined adult and adolescent), 1×10^{-7} for a site maintenance worker, 5×10^{-6} for an aggregate resident (combined adult and child), 8×10^{-7} for a occupational worker, and 1×10^{-8} for an excavation worker. All of these receptors' cancer risks are within or below the USEPA acceptable cancer risk range of 1 in 10,000 to 1 in 1,000,000; however, the aggregate resident exceeds the Florida level of concern of 1×10^{-6} (primarily due to PAHs).

Ecological Risk Assessment. Risks associated with exposures to ECPCs in OU 4 surface soil were evaluated for terrestrial wildlife based on a model that estimates the amount of contaminant exposure obtained via the diet and incidental ingestion of surface soil. Exposure to ECPCs in surface soil would not have an acute toxic effect (i.e., cause mortality) on the wildlife receptor populations at OU 4. Ingestion of aluminum and zinc in surface soil and food items could potentially affect omnivorous small mammals at OU 4 by impairing reproduction or inhibiting growth.

Reduction in terrestrial plant and soil invertebrate biomass used as forage material was evaluated by comparing exposure concentrations for surface soil with toxicity benchmarks. Based on this comparison, terrestrial plants could potentially experience adverse growth and reproduction effects from exposure to detected concentrations of aluminum, lead, silver, vanadium, and zinc in the surface soil at OU 4. Although phytotoxicity benchmarks were exceeded for these inorganic constituents, no evidence of reduction in vegetative biomass was observed in the field at OU 4. Therefore, impacts to small mammals and birds that rely on plant biomass as a forage base are unlikely. The results of the invertebrate benchmark comparison indicate that it is unlikely that invertebrate biomass and/or abundance would be reduced such that small mammal and bird populations would be affected at OU 4.

RAOs. No RAOs will be established for surface soil at OU 4. This is because the IRA removed most of the elevated PAH, PCB, and arsenic concentrations that pose an unacceptable risk to human health and the environment. The remaining PAHs lead to a future residential cancer risk estimate slightly above the Florida level of concern. However, these PAHs are located in a surface water drainage area, and are likely present due to anthropogenic sources. Further, by agreement with the OPT, future residential use of the site will be prohibited by deed.

PCE concentrations in surface soil do not exceed residential or industrial SCTLs (10,000 and 20,000 μg/kg, respectively) but do exceed the groundwater leachability SCTL (50 μg/kg). There is no unacceptable risk associated with PCE in surface soils. Because there is PCE groundwater contamination above Florida drinking water standards, the leachability-based cleanup goals are applicable. However, it should be noted that the Focused Investigation/Source Confirmation performed in the Building 1100 Surge Tank area (ABB-ES, 1997b) did not identify any grossly contaminated soils that would suggest the presence of residual NAPL in the vadose zone soil. The highest PCE concentrations in vadose zone soils included 260 μg/kg (sample U4P020), 158 μg/kg (sample U4P016) and 133 μg/kg (sample U4P014) generally located within the 4-foot interval below the northwest corner of the Building 1100 floor slab (ABB-ES, 1997b). The highest concentration detected in surface soil beneath paved areas at the exterior of the building was 110 μg/kg located at the north end of the building (HLA, 2001).

No horizontal pattern suggesting a specific release area is evident. Rather, these low concentrations detected in the vadose zone are likely attributed to the volatilized fraction from contaminated saturated soils that has collected and adsorbed to soil beneath the floor slab and pavement.

3.2.4 RAOs for Subsurface Soil To assess the quality of subsurface soil, 24 subsurface soil samples (plus 2 duplicates) were collected at depths ranging from 8 to 58 feet bls for laboratory analysis. Initially, 12 of these 24 subsurface soil samples were collected during the initial site screening of SAs 12, 13, and 14 (ABB-ES, 1996a). The additional 12 subsurface samples were collected during the RI when further delineation was required. These data are discussed in Section 5.2 of the RI Report (HLA, 2001). As previously stated in Subsection 3.1.2, there are no promulgated Federal or State chemical-specific regulatory requirements that provide limits for the concentration of chemicals in soil at OU 4. The USEPA Region III industrial RBCs (USEPA, 1998) and the Florida SCTLs (FDEP, 1999) were used to identify COPCs in the HHRA.

Human Health Risk Assessment. There are no current exposures to subsurface soil because no excavation or construction activities are ongoing at OU 4. However, a potential exposure of future excavation workers to subsurface soil contaminants through ingestion, dermal contact, and inhalation of particulates was evaluated in the HHRA.

The risk characterization results for the potential future land-use exposure scenario revealed that the cancer risks associated with exposure to subsurface soil (ingestion, dermal contact, and fugitive dust inhalation) are 9×10^{-8} for an excavation worker. This cancer risk is below the USEPA acceptable cancer risk range of 1 in 10,000 to 1 in 1,000,000 and below the Florida level of concern of 1×10^{-6}. The noncancer risks associated with subsurface soil ingestion, dermal contact, and fugitive dust inhalation under the future land-use scenario for the excavation worker was below USEPA's and FDEP's target HI of 1.

RAOs. No RAOs are required for subsurface soil at OU 4. This is because there are no unacceptable exposures to human health and the environment. The maximum detected PCE concentration in subsurface soil (31 μg/kg) does not exceed the Florida groundwater leachability SCTL (50 μg/kg).

3.2.5 RAOs for Groundwater Groundwater at OU 4 was sampled and analyzed during several investigations conducted in support of the RI/FS at OU 4. These

investigations and the analytical results are discussed in Section 5.2 of the RI Report (HLA, 2001).

The investigations identified that the majority of contamination at OU 4 is apparently the result of industrial laundry and dry-cleaning facility operations. The highest PCE contamination (34,000 $\mu g/\ell$) is found near and under the former laundry building. Passing groundwater flows to the west, from the former laundry building towards Lake Druid, where it discharges. As groundwater flows toward Lake Druid, PCE degrades to TCE and cis-DCE.

A small isolated plume of antimony was first detected in March 1993 at SA 14. Since then, antimony has not been detected above MCLs in any downgradient monitoring wells at SAs 12 or 13 and seems relatively immobile. This antimony plume does not appear to be moving towards Lake Druid. PCE and TCE are also present at concentrations up to 28 $\mu g/\ell$ in several wells within the antimony plume. These detections are believed to represent the eastern extent of the southern VOC plume.

Chemical-specific regulatory requirements and TBCs for groundwater are identified in Subsection 3.1.2. A comparison of groundwater data to these regulatory requirements and TBCs was completed. Cis-1,2-dichloroethene, PCE, TCE, and antimony exceeded their respective Federal and State drinking water standards. Mercury also was detected at a concentration above its Federal and State drinking water standard of 2 $\mu g/\ell$ in one unfiltered sample at a concentration of 3.7 $\mu g/\ell$. Examination of the sampling logs for this well indicated a highly turbid sample. The well was resampled and groundwater was analyzed for filtered and unfiltered inorganics. Mercury was not detected in the unfiltered sample, and was detected above the background screening concentration in the filtered analysis, but below the drinking water standard of 2 $\mu g/\ell$. Aluminum and iron exceeded secondary drinking water standards in several wells. Sodium was detected above the FDEP MCL in one well. None of these detections are believed to be site related.

Human Health Risk Assessment. An HHRA was completed for human exposure to groundwater. Currently, no humans reside at OU 4 and groundwater is not used for any potable or nonpotable purpose. However, if OU 4 were developed for residential use, exposure to future adult and child residents (ingestion of drinking water and inhalation of volatiles while showering) could occur; therefore, this residential exposure was evaluated in the HHRA as a conservative measure. Because of the shallow groundwater, the migration of VOCs to indoor air is possible even for buildings constructed on slabs. The migration of VOCs to indoor air was also identified as a potential exposure pathway for residential (adult and child) and occupational receptors. As described in the RI Report, three separate plume areas were evaluated: the northern VOC plume, southern VOC plume, and antimony plume (Figures 1-3 and 1-5).

Northern Plume. The risk characterization results for groundwater exposure scenarios revealed that for potential future land-use scenarios, the cancer risks associated with northern VOC plume groundwater ingestion, inhalation of VOCs while showering, and inhalation of VOCs that may migrate from groundwater to indoor air are 2×10^{-3} for an aggregate resident (combined adult and child) and 1×10^{-8} for an occupational worker (inhalation of VOCs that may migrate from groundwater to indoor air). The potential future residential receptor cancer risk for the northern VOC plume is above both the USEPA acceptable risk range of 1×10^{-4} to 1×10^{-6} and the FDEP level of concern of 1×10^{-6} (mainly due to PCE and

TCE). However, the risk was primarily due to potential ingestion of groundwater because risks for inhalation of VOCs that may migrate to indoor air were only 4×10^{-6}. The potential occupational receptor cancer risk was below the USEPA acceptable risk range and the FDEP level of concern.

The noncancer risks associated with the northern VOC plume for groundwater ingestion under the future land-use scenario for potential future adult (HI of 8) and child (HI of 20) residential receptors are above USEPA's and FDEP's target HI of 1 (mainly due to cis-DCE, PCE, and TCE).

Southern Plume. For potential future land-use scenarios, the cancer risks associated with southern VOC plume groundwater ingestion, inhalation of VOCs while showering, and inhalation of VOCs that may migrate from groundwater to indoor air are 9×10^{-5} for an aggregate resident (combined adult and child) and 6×10^{-10} for an occupational worker (inhalation of VOCs that may migrate from groundwater to indoor air). The potential future residential and occupational worker receptor cancer risks for the southern VOC plume are within the USEPA acceptable risk range of 1×10^{-4} to 1×10^{-6}. However, risk for the resident exceeds the FDEP level of concern of 1×10^{-6} (mainly due to PCE and TCE). However, the risk was primarily due to potential ingestion of groundwater because risks for inhalation of VOCs that may migrate to indoor air were only 2×10^{-7}.

The noncancer risks associated with the southern VOC plume for groundwater ingestion under the future land-use scenario are an HI of 1 for the adult and an HI of 2 for the child. The adult residential receptor was at USEPA's and FDEP's target HI of 1 but the child residential receptor HI exceeds both the USEPA's and FDEP's target HI (due to cis-DCE, PCE, and TCE).

Antimony Plume. For potential future land-use scenarios, the cancer risks associated with the antimony plume (including the chlorinated VOCs colocated with the antimony), groundwater ingestion, inhalation of VOCs while showering, and inhalation of VOCs that may migrate from groundwater to indoor air are 6×10^{-6} for an aggregate resident (combined adult and child) and 4×10^{-11} for an occupational worker (inhalation of VOCs that may migrate from groundwater to indoor air). The potential future residential and occupational worker receptor cancer risk for the antimony plume is within the USEPA acceptable risk range of 1×10^{-4} to 1×10^{-6}. However, risk for the resident exceeds the FDEP level of concern of 1×10^{-6} (mainly due to PCE and TCE). The risk was primarily due to potential ingestion of groundwater because risks for inhalation of VOCs that may migrate to indoor air were only 1×10^{-8}.

The noncancer risks associated with the antimony plume for groundwater ingestion under the future land-use scenario is an HI of 1 for an adult and an HI of 2 for a child. The adult residential receptor was at USEPA's and FDEP's target HI of 1 but the child residential receptor HI exceeds both the USEPA's and FDEP's target HI (due to antimony).

Ecological Risk Assessment. Potential risks associated with exposures to ECPCs in OU 4 groundwater were evaluated for benthic aquatic organisms in the wetland area and for aquatic receptors in Lake Druid. A comparison of groundwater ECPCs with surface water toxicity benchmarks indicates that pelagic aquatic organisms are not at risk from exposure to chlorinated VOCs or manganese.

RAOs. Based only on current risks to groundwater exposure, RAOs would not be required at OU 4 because groundwater is not currently being used as a potable water supply. However, groundwater at OU 4 has been classified as G-II by the State of Florida, indicating that it is a potential future source of drinking water for the state. Furthermore, as previously discussed in Subsection 3.2.2 for surface water, groundwater at OU 4 appears to be the source of VOCs detected in surface water near the shore of Lake Druid. Surface water along the shore of OU 4 creates a potential future unacceptable risk that exceeds the Florida level of concern of $1x10^{-6}$. Therefore, remedial action is necessary for groundwater to address potential future risks associated with its use as a potable water supply and to gain control over the migration of contaminated groundwater discharging to Lake Druid. The RAOs listed below are established for groundwater at OU 4.

RAO 1: Reduce the potential for human ingestion of groundwater containing COCs that exceed drinking water-based regulatory requirements or risk-based acceptable exposure levels.

RAO 2: Gain control over groundwater migration of VOC concentrations that contribute to exceedances of FDEP surface water standards in Lake Druid.

3.3 ACTION AND TREATMENT LEVELS. Action levels, or the concentrations of chemicals above which remedial action would be necessary, are defined for media of concern at OU 4 in Subsection 3.3.1. Treatment levels, or the concentrations of chemicals that a treatment technology would be required to achieve if implemented, are defined in Subsections 3.3.2 (for *in situ* treatment technologies) and 3.3.3 (for *ex situ* treatment technologies). The information presented in this section will be used to identify appropriate remedial technologies for OU 4 in Chapter 4.0, and an evaluation of those alternatives is in Chapter 5.0.

3.3.1 Action Levels Action levels are the concentrations of chemicals in contaminated media above which remedial action or control would be necessary to meet RAOs. Specifically, action levels are identified in this subsection for groundwater because the RAOs established for OU 4 relate to only this medium.

The first step in establishing action levels was to define the set of chemicals associated with the medium (groundwater) for which RAOs were developed. This was accomplished by listing all chemicals detected in groundwater samples at OU 4 that were identified as COPCs in the HHRA. Tables from the OU 4 RI Report (HLA, 2001) identifying the COPCs and risk-based remedial goal objectives (RGOs) for OU 4 groundwater have been included in Appendix A for reference.

The second step was to determine the selection criteria that may be appropriate for the anticipated site use (e.g., RBCs, regulatory requirements, and TBCs discussed in Subsection 3.1.2).

For groundwater, the selection criteria are presented in Appendix A, Table A-1, and were assigned as follows:

For organic chemicals, the selection criteria was established as

(1) the lower of the Florida drinking water standard (if available) or the Florida surface water standard,

(2) if no Florida standards were available, then the Federal MCL (if available) was used, or

(3) if (1) or (2) were not applicable, then the higher value of the Florida GCTL (higher of groundwater or freshwater values) or RBC developed from the RI report was used.

For inorganic chemicals, the selection criteria were established as the higher value of

- the criteria selected using the hierarchy as listed for organic chemicals in groundwater; and
- the site-specific background concentration.

It should be noted that groundwater from OU 4 ultimately discharges to surface water (Lake Druid) (Subsection 3.2.2, RAOs for Surface Water). This is the reason that comparison of groundwater concentrations is made to Florida surface water standards.

The third step in identifying action levels at OU 4 was to compare the concentration of the chemicals detected in groundwater to the corresponding selection criteria. If the maximum concentration of a chemical in groundwater was greater than the appropriate selection criterion, then the chemical was considered a COC for this FS. The COC was then assigned an action level equal to the appropriate selection criterion. Table 3-2 presents a summary of the COCs for groundwater and proposed action levels. The comparison shows that groundwater contains detections of chemicals at concentrations greater than the selected criteria.

Alternatives identified in Chapter 4.0 will be evaluated in Chapter 5.0 based on the practicability of achieving these action levels.

3.3.2 *In Situ* Treatment Levels This subsection presents the treatment levels, or the concentration of a chemical to which groundwater would be treated, using *in situ* treatment technologies. These levels apply to remedial alternatives where water would not be extracted during the treatment process.

For an *in situ* groundwater treatment alternative to achieve RAO 1, the treatment level would be the action level (described in Subsection 3.3.1). As per discussions with the State of Florida in the November and December 1997 OPT meetings, and consistent with the requirements of the State of Florida, the Florida SWQSs would be selected as the treatment levels for COCs discharging to Lake Druid to achieve RAO 2. Freshwater surface water criteria from Chapter 62-777, FAC, will be used for treatment levels of COCs without surface water standards. Table 3-3 presents a summary of the treatment levels that would be applicable to groundwater at OU 4 if an *in situ* treatment alternative were considered. This table also indicates the approximate percent removal required for each chemical.

Table 3-2
Groundwater Action Levels

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

COPC[1]	Maximum Detected Concentration	Florida MCL[2]	Florida Surface Water Quality Standard[3]	Federal MCL[4]	Florida Contaminant Cleanup Target Level Groundwater/ Surface Water[5]	Groundwater Background Screening Concentration[6]	Action Level
Volatile Organic Compounds (µg/l)							
cis-1,2-Dichloroethene	1,650	70	--	70	70/7,000	--	70[7]
trans-1,2-Dichloroethene	1.4	100	--	100	100/11,000	--	NA[13]
Tetrachloroethene	29,800	3	8.85 [9]	5	3/[9]8.85	--	3[7]
Trichloroethene	2,475	3	80.7 [9]	5	3/[9]80.7	--	3[7]
Inorganic Analytes (µg/l)							
Aluminum	35,500	--[8]	--	--[8]	200/13	4,067	NA[14]
Antimony	20.7	6	4,300	6	6/4,300	4.1	6[7]
Barium	289	2,000	--	2,000	2,000/[10]57	31.4	NA[14]
Chromium	59.4	100	--[11]	100	100/--[11]	7.8	NA[15]
Iron	4,920	--[8]	1,000	--[8]	300/1,000	1,227	NA[14]
Mercury	3.7	2	0.012	2	2/0.012	0.12	NA[16]
Sodium	1,120,000	160,000	--	--	160,000/[12]14,100	18,222	NA[17]

See notes at end of table.

Table 3-2 (Continued)
Groundwater Action Levels

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

[1] Chemical of potential concern identified in the RI Report (HLA, 2001).
[2] Florida MCLs from Primary Standards of the Florida Department of Environmental Protection (FDEP) Groundwater Guidance Concentrations (June 1994)
[3] Florida Surface Water Standard from Chapter 62-302 (Surface Water Quality Standards) of the Florida Administrative Code (FAC) Class III Freshwater, December 26, 1996.
[4] Federal MCLs from the U.S. Environmental Protection Agency (USEPA) Drinking Water Regulations and Health Advisories (October 1996)
[5] Florida Groundwater Cleanup Target Level and Florida Freshwater Surface Water Criteria taken from Chapter 62-777, Contaminant Cleanup Target Levels, FAC (August 1999). Value for cis-1,2-dichloroethene in surface water is for total-1,2-dichloroethene.
[6] Background Screening Concentration from the ***Background Sampling Report*** (ABB-ES, 1995).
[7] Action level based on Florida MCL. See text (Subsection 3.3.1) for selection criteria hierarchy.
[8] Only Secondary MCLs exist. (200 $\mu g/\ell$ for aluminum; 300 $\mu g/\ell$ for iron)
[9] Annual average
[10] Not greater than 10% above background = 57 $\mu g/\ell$ (barium = 52.2 $\mu g/\ell$ in Lake Druid control sample).
[11] Not available for total chromium.
[12] Not greater than 50% above background or 1,275 $\mu g/\ell$, whichever is greater = 14,100 $\mu g/\ell$ (sodium = 9,400 $\mu g/\ell$ in Lake Druid control sample).
[13] Maximum concentration does not exceed any of the selection criteria.
[14] COPC not associated with site activities; elevated concentrations correlate to elevated suspended solids in the sample; hazard index less than 1.
[15] Maximum concentration below selection criteria concentrations; hazard index less than 1.
[16] COPC not associated with site activities; elevated concentrations (only one sample exceeds MCLs) correlates to elevated suspended solids in the sample.
[17] COPC not associated with site activities; detected in only 2 of 33 samples; Florida MCL is exceeded in only one sample.

Notes: COPC = chemical of potential concern.
MCL = maximum contaminant level.
$\mu g/\ell$ = micrograms per liter.
NA = not applicable, no action level required.
-- = not available.
% = percent.

Table 3-3
In Situ Treatment and *Ex Situ* Treatment Discharged to Groundwater Requirements

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Frequency of Detection[1]	Range of Detected Concentrations	Mean of Detected Concentrations[2]	Maximum Detected Concentration	Selected Groundwater Criteria[3]	Percent Removal Required[4]
Northern Plume						
Organics (µg/ℓ)						
cis-1,2-Dichloroethene	10/16	1 to 1,650	350	1,650	70	95.8
Tetrachloroethene	10/16	2 to 29,800	1,900	29,800	3	99.99
Trichloroethene	11/16	0.7 to 2,475	410	2,475	3	99.9
Inorganics (µg/ℓ)						
Antimony	0/16	--	--	--	6	0
Southern Plume						
Organics (µg/ℓ)						
cis-1,2-Dichloroethene	5/8	1 to 43.6	12	43.6	70	0
Tetrachloroethene	6/8	2 to 390	110	390	3	99.2
Trichloroethene	7/8	2 to 105	23	105	3	97.1
Inorganics (µg/ℓ)						
Antimony	0/8	--	--	--	6	0
Antimony Plume						
Organics (µg/ℓ)						
cis-1,2-Dichloroethene	0/4	--	--	--	70	0
Tetrachloroethene	2/4	1 to 28	7.5	28	3	89.3
Trichloroethene	1/4	2 to 2	0.88	2	3	0
Inorganics (µg/ℓ)						
Antimony	4/4	7.1 to 20.7	14.1	20.7	6	71

[1] Frequency of detection is the number of groundwater samples in which the analyte was detected versus the total number of groundwater samples analyzed.
[2] The average of detected concentrations is the arithmetic mean of all samples in which the analyte was detected. It does not include those samples in which the analyte was not detected.
[3] Refer to selected groundwater criteria in Table 3-2.
[4] Percent removal from maximum detected concentrations to meet the selected groundwater criteria.

Notes: µg/ℓ = micrograms per liter.
-- = not detected.

3.3.3 *Ex Situ* Treatment Levels This subsection presents *ex situ* treatment levels for contaminated groundwater. If an *ex situ* treatment alternative is considered, the treatment level would depend on (1) the concentration of chemicals in extracted groundwater, and (2) acceptance criteria of the receiving water for treated groundwater (e.g., groundwater, surface water, or wastewater treatment plant). Any *ex situ* treatment alternative would be designed to treat chemicals in extracted groundwater to concentrations that meet these acceptance criteria.

For purposes of this FS, the concentrations of chemicals in extracted groundwater were generally assigned as the maximum detected concentrations shown in Table 3-3, as reported in the RI (HLA, 2001). It is expected, however, that the concentrations of these chemicals in extracted groundwater would be less than the maximum concentration from any one point. This assumption was made to provide a conservative estimate of the percent removal required if an *ex situ* treatment alternative is considered for groundwater remediation.

The following paragraphs present the treatment levels for extracted groundwater for each potential medium receiving water.

3.3.3.1 **Treated Groundwater Discharged to Groundwater** An *ex situ* treatment alternative for groundwater that includes a discharge to groundwater component would be designed to treat chemicals whose concentrations are greater than the MCLs (State and Federal). These treatment criteria for COCs are the same as the action levels for an *in situ* groundwater treatment alternative, and are summarized in Table 3-3. This table also indicates the percent removal that needs to be achieved by an *ex situ* treatment alternative prior to discharge to groundwater.

3.3.3.2 **Treated Groundwater Discharged to Surface Water** An *ex situ* treatment alternative for groundwater that includes a discharge to surface water component would likely discharge water to Lake Druid via direct pipeline. The selection criteria for organic contaminants for this discharge option are (1) the Florida surface water standards, (2) Florida GCTLs (for freshwater surface water), or the Federal AWQC (where Florida surface water standards are not available), whichever is lower. Florida surface water standards considered at this step were for Class III surface water because that is the classification of Lake Druid.

To identify which organic chemicals in the extracted groundwater would require treatment prior to discharge to surface water, the maximum concentrations of each organic COC detected in groundwater at each plume at OU 4 were compared to the selected surface water criteria. This comparison is shown in Table 3-4. Two VOCs (PCE and TCE) would require treatment if extracted groundwater were discharged to surface water. This table also presents the percent removal required for each of the organic chemicals if this discharge option is considered.

Similarly, the selection criteria for inorganic contaminants for this discharge option are (1) the Florida surface water standards (if available), or (2) Florida GCTLs (for freshwater surface water). A comparison of the selected surface water criteria to the maximum concentrations of each inorganic detected during an 18-hour pumping test for OU 4 was made to determine which inorganic chemicals would require treatment prior to discharge to surface water. Appendix B presents the

Table 3-4
Groundwater to Surface Water *Ex Situ* Treatment Requirements for Organics

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Frequency of Detection[1]	Range of Detected Concentrations	Mean of Detected Concentrations[2]	Maximum Detected Concentration	Florida Surface Water Quality Standard[3]	Contaminant Cleanup Target Level[4]	Federal AWQC[5]/ Florida MCLs[6]	Selected Surface Water Criteria[7]	Percent Removal Required[8]
Northern Plume (µg/ℓ)									
cis-1,2-Dichloroethene	10/16	1 to 1,650	350	1,650	--	7,000	[11]11,600/70	7,000	0
Tetrachloroethene	10/16	2 to 29,800	1,900	29,800	[9]8.85	[9]8.85	[10]840/3	[9]8.85	99.99
Trichloroethene	11/16	0.7 to 2,475	410	2,475	[9]80.7	[9]80.7	[10]21,900/3	[9]80.7	99.9
Southern Plume (µg/ℓ)									
cis-1,2-Dichloroethene	5/8	1 to 43.6	12	43.6	--	7,000	[11]11,600/70	7,000	0
trans-1,2-Dichloroethene	1/8	1.4	1.4	1.4	--	11,000	[11]11,600/100	100	0
Tetrachloroethene	6/8	2 to 390	110	390	[9]8.85	[9]8.85	[10]840/3	[9]8.85	99.2
Trichloroethene	7/8	2 to 105	23	105	[9]80.7	[9]80.7	[10]21,900/3	[9]80.7	97.1
Antimony Plume (µg/ℓ)									
Tetrachloroethene	2/4	1 to 28	7.5	28	[9]8.85	[9]8.85	[10]840/3	[9]8.85	89.3
Trichloroethene	1/4	2	0.88	2	[9]80.7	[9]80.7	[10]21,900/3	[9]80.7	0

See notes at end of table.

Table 3-4 (Continued)
Groundwater to Surface Water *Ex Situ* Treatment Requirements for Organics

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

[1] Frequency of detection is the number of groundwater samples in which the analyte was detected versus the total number of groundwater samples analyzed.
[2] The average of detected concentrations is the arithmetic mean of all samples in which the analyte was detected. It does not include those samples in which the analyte was not detected.
[3] Florida Surface Water Standard from Chapter 62-302 (Surface Water Quality Standards) of the Florida Administrative Code (FAC) Class III Freshwater, December 26, 1996.
[4] Florida Freshwater Surface Water Criteria from Chapter 62-777, Contaminant Cleanup Target Levels, FAC (August 1999).
[5] Federal AWQC, 1991, based on freshwater, chronic exposure unless otherwise specified.
[6] Florida Maximum Contaminant Levels (MCLs) from Primary Standards of the Florida Department of Environmental Protection (FDEP) Groundwater Guidance Concentrations (June 1994).
[7] Selected in this order (1) Florida Surface Water Standards, (2) Contaminant Cleanup Target Levels (freshwater surface water criteria), (3) the lower of the Federal AWQC or Florida MCLs.
[8] Percent removal from maximum detected concentrations to meet the selected surface water criteria.
[9] Annual average = the maximum concentration at average annual flow conditions.
[10] Insufficient data to develop criterion; value represents a lowest observed effects level.
[11] For dichloroethenes, acute lowest observed effects level.

Notes: AWQC = ambient water quality criteria.
$\mu g/\ell$ = micrograms per liter.
-- = not detected.

analytical results of the three water samples collected during various points during the 18-hour pumping test for OU 4. The pumping test was performed August 1996 to assess groundwater conditions in the downgradient part of the plume for the IRA and provides analytical results for both organic and inorganic chemicals. Although organic concentrations are not representative of source area conditions, inorganic sampling results likely approximate inorganic concentrations in the source areas (northern, southern,and antimony plumes) where groundwater extraction would be performed.

Comparison of selected surface water criteria with anticipated inorganic concentrations in OU 4 groundwater is shown in Table 3-5. Three inorganic chemicals (aluminum, lead, and zinc) may require treatment if extracted groundwater were discharged to surface water. This table also presents the percent removal required for each of the inorganic chemicals if this discharge option is considered, based on meeting the criteria listed above.

However, Lake Druid surface water and NTC, Orlando basewide background groundwater screening concentrations all ready exceed FDEP Class III surface water quality criteria for several inorganics unrelated to OU 4, as does OU 4 groundwater. Because OU 4 groundwater naturally discharges to Lake Druid, and Lake Druid surface water samples from the control location exceed inorganic surface water criteria (HLA, 2001), inorganic treatment of extracted groundwater should not be necessary. The inorganic concentrations detected in the antimony plume do not exceed the FDEP surface water quality criteria; however, it was assumed that inorganic treatment will be provided prior to the discharge of extracted antimony plume groundwater into the lake.

3.3.3.3 **Treated Groundwater Discharged to Publicly Owned Treatment Works (POTWs)** An *ex situ* treatment alternative that includes discharge to a wastewater treatment plant would discharge to the City of Orlando's Sewage Treatment Plant (STP). Currently, NTC, Orlando has an industrial user discharge permit (Permit No. CO62QA) with the City of Orlando for discharge of industrial waste from Area C (this permit is provided in Appendix C). Additionally, the City of Orlando has indicated that they would accept extracted groundwater from OU 4 as long as individual VOC concentrations comply with the proposed 414.111 limits.

These conditions are the treatment levels (or local limits) for a remedial alternative that includes discharge of groundwater to the Orlando STP and are summarized in Table 3-6 for organics and Table 3-7 for inorganics.

The Orlando STP indicated that the concentrations of inorganics present in samples from the extracted groundwater are acceptable for direct discharge to the treatment plant (i.e., pretreatment for inorganic chemicals is not necessary). Based on the local limits set by the STP, the percent removal, or the degree of pretreatment necessary, was calculated (see Tables 3-7 and 3-8).

3.4 CHARACTERISTICS OF COCs. Table 3-8 presents characteristics of the COCs (PCE, TCE, cis-DCE and antimony). A brief explanation of these characteristics follows.

Specific gravity, also known as relative density, is defined as ratio of the density of a substance to the density of distilled water. The density of water is 1.00 grams per milliliter at 4 degrees Celsius (°C). The density of a

Table 3-5
Groundwater to Surface Water *Ex Situ* Treatment Requirements for Inorganics

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte[1]	Inorganic Analytical Results from Extracted Groundwater[2]			Florida Surface Water Quality Standard[3]	Florida Contaminant Cleanup Target Level Criteria[4]	*Ex Situ* Treatment Level for Discharge to Surface Water[5]	Percent Removal Required[6]
	ETP-1	ETP-2	ETP-3				
All Plumes[7] (µg/l)							
Antimony	NA	NA	NA	4,300	4,300	4,300	[11]0
Beryllium	ND (<3)	ND (<3)	ND (<3)	[8]0.13	[8]0.13	[8]0.13	--
Cadmium	ND (<1)	ND (<1)	ND (<1)	[9]0.4	[9]0.4	[9]0.4	--
Copper	ND (<5)	ND (<5)	ND (<5)	[9]3.7	[9]3.7	[9]3.7	--
Mercury, total	ND (<0.2)	ND (<0.2)	ND (<0.2)	0.012	0.012	0.012	--
Silver, total	ND (<5)	ND (<5)	ND (<5)	0.07	0.07	0.07	--
Zinc	45	40	25	[9]34	[9]34	[9]34	24
Inorganic Analytes µg/l							
Aluminum	220	200	190	NA	13	13	94
Iron	490	370	350	1,000	1,000	1,000	0
Lead	14	ND (<3)	3	[8]0.57	[8]0.57	[8]0.57	95.9
Sodium	13,000	13,000	13,000	NA	[10]14,100	[10]14,100	0

See notes at end of table.

Table 3-5 (Continued)
Groundwater to Surface Water *Ex Situ* Treatment Requirements for Inorganics

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

[1] Detected nonfiltered (total) inorganic analytes in the OU 4 pumping test. Nondetected analytes with detection limit greater than the surface water criteria are also included. The presence or absence of these nondetected analytes cannot be verified at this time.
[2] Analytical results from an 18-hour pumping test conducted August 1996 at OU 4 within the downgradient plume.
[3] Florida Surface Water Standard from Chapter 62-302 (Surface Water Quality Standards) of the Florida Administrative Code (FAC) Class III Freshwater, December 26, 1996.
[4] Florida Freshwater Surface Water Criteria from Chapter 62-777, Contaminant Cleanup Target Levels, FAC (August 1999)
[5] Selected in this order (1) Florida Surface Water Quality Standard, if available, (2) Florida Contaminant Cleanup Target Level (freshwater surface water criteria).
[6] Percent removal calculated based on maximum detected value.
[7] All listed analytes are pertinent for the northern, southern, and antimony plumes except that the reported concentrations for antimony are for the antimony plume only.
[8] Annual average (maximum concentration at average annual flow conditions).
[9] Hardness based.
[10] Not greater than 50% above background or 1,275 µg/ℓ, whichever is greater = 14,100 µg/ℓ (sodium = 9,400 µg/ℓ in Lake Druid control sample).
[11] Based on the maximum detected antimony concentration of 20.7 µg/ℓ at monitoring well OLD-14-03A.

Notes: ETP = Engineering Treatability Parameter.
µg/ℓ = micrograms per liter.
NA = not applicable.
ND = not detected.
< = less than.
-- = percent removal is not calculated for these analytes, as detection limits were higher than their respective surface water standards, and until surface water samples are reanalyzed to obtain lower detection limits, the presence or absence of this compound cannot be verified.

Table 3-6
Groundwater *Ex Situ* Organic Treatment Requirements for Discharge to Orlando STP

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Frequency of Detection[1]	Range of Detected Concentrations	Mean of Detected Concentrations[2]	Maximum Detected Concentration	Orlando STP Discharge Criteria (max/day)	Orlando STP Discharge Criteria (max/month)	Percent Removal Required[3]
Northern Plume (µg/ℓ)							
cis-1,2-Dichloroethene	10/16	1 to 1,650	350	1,650	--	--	--
Tetrachloroethene	10/16	2 to 29,800	1,900	29,800	164	52	99.8
Trichloroethene	11/16	0.7 to 2,475	410	2,475	69	26	98.9
Southern Plume (µg/ℓ)							
cis-1,2-Dichloroethene	5/8	1 to 43.6	12	43.6	--	--	--
trans-1,2-Dichloroethene	1/8	1.4	1.4	1.4	66	25	--
Tetrachloroethene	6/8	2 to 390	110	390	164	52	86.7
Trichloroethene	7/8	2 to 105	23	105	69	26	75.2
Antimony Plume (µg/ℓ)							
Tetrachloroethene	2/4	1 to 28	7.5	28	164	52	--
Trichloroethene	1/4	2	0.88	2	69	26	--

[1] Frequency of detection is the number of groundwater samples in which the analyte was detected versus the total number of groundwater samples analyzed.
[2] The average of detected concentrations is the arithmetic mean of all samples in which the analyte was detected. It does not include those samples in which the analyte was not detected.
[3] Percent removal from maximum detected concentrations to meet the Orlando STP Discharge Criteria (maximum for any monthly average).

Notes: STP = sewage treatment plant.
max/day = maximum for any one day.
max/month = maximum for any monthly average.
µg/ℓ = micrograms per liter.
-- = not calculated; removal of chemical is not necessary prior to discharge to Orlando STP.

Table 3-7
Groundwater *Ex Situ* Inorganic Treatment Requirements for Discharge to Orlando STP

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte[1]	Analytical Results from Samples of Extracted Groundwater[2]			Mean of Detected Concentrations	Orlando STP Discharge Criteria	Overall Percent Removal Required[3]
	ETP-1	ETP-2	ETP-3			
All Plumes[4] (µg/ℓ)						
Aluminum	220	200	190	203	NA	--
Antimony	NA	NA	NA	NA	1,000	--[5]
Calcium	5,000	ND (<5,000)	ND (<5,000)	3,333	NA	--
Iron	490	370	350	403	NA	--
Lead	14	ND	ND	5	400	--
Magnesium	2,200	2,200	2,200	2,200	NA	--
Sodium	13,000	13,000	13,000	13,000	300,000	--
Zinc	45	40	25	37	1,000	--
Alkalinity	5.9	6.1	7.7	6.6	5.5< x <9.5[6]	--
Chloride	22	21	23	22	NA	--
Hardness	32	24	22	26	NA	--
TDS	16	21	6	14	NA	--
Sulfate	16	16	15	16	NA	--
Sulfide	0.2	0.2	0.2	0.2	NA	--

[1] Detected nonfiltered (total) inorganic analytes in the OU 4 pumping test. Nondetected analytes with detection limit greater than the surface water criteria are also included. The presence or absence of these nondetected analytes cannot be verified at this time.
[2] Analytical results from an 18-hour pumping test conducted August 1996 at OU 4 within the downgradient plume.
[3] Percent removal calculated based on maximum detected value.
[4] All listed analytes are pertinent for the northern, southern, and antimony plumes except that the reported concentrations for antimony are for the antimony plume only.
[5] Based on the maximum detected antimony concentration of 20.7 µg/ℓ at monitoring well OLD-14-03A.
[6] Value (x) is greater than 5.5 but less than 9.5.

Notes: ETP = Engineering Treatability Parameter.
STP = sewage treatment plant.
µg/ℓ = micrograms per liter.
NA = not applicable.
-- = not calculated, removal of chemical is not necessary prior to discharge to Orlando STP.
ND = not detected.
< = less than.
TDS = total dissolved solids.

Table 3-8
Characteristics of Chemicals of Concern

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

CAS Number	Contaminant	Molecular Weight (g/mole)[1]	Specific Gravity[1]	Solubility (mg/ℓ) at 25°C[1]	Vapor Pressure (mmHg) at 25°C[1]	Henry's Law Constant (atm-m³)/ mole 25°C[1]	Log K_{ow} 25°C[2]	Log K_{oc} 25°C[1]
7440-36-0	Antimony	121.75	6.618	NA	NA	NA	NA	NA
127-18-4	Tetrachloroethene	165.8	1.62	150	18.9	1.53 E-02	2.60	2.56
79-01-6	Trichloroethene	131.5	1.46	1,100	75	9.10 E-03	2.38	2.10
156-59-4	cis-1,2-dichloroethene	97	1.27	3,500	205	3.7 E-03	0.70	1.93

[1] Pankow and Cherry, 1996. *Dense Chlorinated Solvents*. Ontario, Canada: Waterloo Press.
[2] Nyer, E. et. al., 1996. *In Situ Treatment Technology*. Boca Raton, Florida: CRS Press.

Notes: CAS = Chemical Abstract System.
g/mole = grams per mole.
mg/ℓ - milligrams per liter.
°C = degrees Celsius.
mmHg = millimeters of mercury.
atm-m³/mole = atmosphere-cubic meter per mole.
K_{ow} = octanol-water partition coefficient.
K_{oc} = soil-sediment partition coefficient.
NA = not available.

substance is an indicator of whether or not it will tend to sink or float in water.

Solubility is defined as a compound's saturated concentration in water at a given temperature and pressure.

Vapor pressure is defined as the pressure exerted by the vapor of a substance when it is under equilibrium conditions. The vapor pressure of all liquids increases with temperature. Vapor pressure provides a rough estimation of how well a substance will volatilize from soil and/or water. The vapor pressure of water at 20 °C is 18 mmHg.

Henry's law constant (H), also known as the air-water partitioning coefficient, is defined as the ratio of a compound's partial pressure in air to the concentration of the compound in water at a given temperature and under equilibrium conditions. Henry's law constant provides an indication of the relative volatility of a substance. The following guidelines are for Henry's law constants in atmospheres times cubic meters per mole.

$H > 10^{-3}$	rapid volatilization
$10^{-5} < H < 10^{-3}$	midrange volatilization
$10^{-7} < H < 10^{-5}$	slow volatilization
$H < 10^{-7}$	extremely low volatilization

The octanol-water partition coefficient (K_{ow}) is defined as the ratio of the solute concentration in the water-saturated octanol phase to the solute concentration in the octanol-saturated water phase. It is used to estimate the hydrophobicity and sorptive tendencies of hydrocarbons. For convenience, K_{ow} is often reported in logarithmic form ($\log K_{ow}$) because values from the class of immiscible hydrocarbons that are of environmental concern span several orders of magnitude. Negative $\log K_{ow}$ values indicate a preference for the aqueous phase (hydrophilicity). Positive $\log K_{ow}$ values indicate a hydrocarbon's preference to form separate phases (hydrophobicity), sorb strongly to solids, or potentially volatilize.

The soil and/or sediment organic carbon partition coefficient (K_{oc}) is defined as the ratio of adsorbed chemical per unit weight of organic carbon to the aqueous solute concentration. K_{oc} is a measure of a chemical's relative adsorption potential, i.e., a chemical's tendency to sorb to particulate or organic matter. This is largely dependent on the organic content of soil. For convenience, K_{oc} is often reported in logarithmic form ($\log K_{oc}$) because values that are of environmental concern span several orders of magnitude. Sorption is generally considered to be high for $\log K_{oc}$ values of 5 to 6, moderate for $\log K_{oc}$ values of 3, and weak for values of 2.2 or less. Compounds that bind strongly to organic carbon have low solubilities, whereas compounds that do not tend to adsorb to organic materials have high solubilities.

3.5 GENERAL RESPONSE ACTIONS. General response actions describe potential medium-specific measures that may be employed to address RAOs. Potential response actions for OU 4 are developed for groundwater and are discussed in more detail in Chapter 4.0. These response actions include no action, limited action, containment, extraction, *in situ* treatment, *ex situ* treatment, and discharge.

CHAPTER 4.0

4.0 REMEDIAL ACTION ALTERNATIVES

The approach and rationale leading to the development of remedial alternatives are presented in this chapter. The development of remedial alternatives for CERCLA sites consists of identifying applicable technologies, screening those technologies, and using the selected technologies to develop remedial alternatives that accomplish the identified RAOs. For OU 4, remedial alternatives will be developed for groundwater because this is the medium identified in the previous chapter as having both potential risks to human health and exceedances of ARARs or TBCs.

The NCP requires that a range of remedial alternatives be considered. SARA emphasizes the use of treatment technologies that reduce the toxicity, mobility, or volume of contaminants rather than technologies that solely prevent exposure. Plume immobilization techniques, such as subsurface barriers, may reduce mobility, but do not provide reduction in toxicity or volume of contaminants in the aquifer. Alternatively, groundwater extraction and treatment or *in situ* treatment processes are a means to provide reduction of toxicity, mobility, and volume of contaminants. The primary goal of alternative development for OU 4 is to provide alternatives that will restore the aquifer to beneficial use by removing contaminants from the aquifer to the extent practicable.

The remaining sections of this chapter identify the types of technologies that contribute to achieving the RAOs, evaluate and select representative technologies for each technology type, and develop remedial alternatives using the selected technologies. A detailed evaluation of remedial alternatives is presented in Chapter 5.0.

4.1 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES. In this section, traditional and innovative technologies have been researched and categorized according to their basic operating principles. The remedial technologies described in this section are evaluated using the general criteria recommended by the NCP (effectiveness, implementability, and cost). This evaluation for OU 4 considers these criteria, but focuses on issues specific to the technologies selected. These issues include process residuals and air emissions, required O&M activities, and relative effectiveness. Based on the results of this screening, a recommendation is made to either eliminate or retain the technology for the development of remedial alternatives (Section 4.2). A summary of the screening process for OU 4 technologies is included in Table 4-1.

For the remedial alternatives retained for subsequent analysis in Chapters 5.0 and 6.0, one representative technology is then selected from each technology type for costing purposes. For example, a shallow-tray air stripper may be selected from a group of four aeration technologies as the representative air stripping technology to treat VOCs in extracted groundwater. Additionally, emerging technologies are continually introduced; if a new technology arises that uses the same operating principles and achieves the same objectives as the technology selected, it could be considered for implementation during the remedial design.

Supplemental technologies may be required for residuals and emissions generated during treatment of groundwater at OU 4. For example, the vapor collection portion of an air sparging system may require treatment of organic vapors prior

Table 4-1
Screening of Remedial Technologies for Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
No Action				
No action	Prevents contaminant migration to Lake Druid.	The components of the IRA are in place.	Low	Retain
Limited Action				
Deed restriction with monitoring	Reduces potential public exposure to contaminated groundwater.	Use restrictions could be enforced.	Low	Retain
Lake-use restrictions	Reduces potential public exposure to contaminated groundwater and sediments.	Lake-use restrictions would be difficult to enforce.	Low	Eliminated
Extraction				
Vertical Wells	Proven technology to extract areas of contaminated groundwater.		Low	Retain
Horizontal wells	Proven technology to extract areas of contaminated groundwater.		Medium	Retain
Collection Trench	Proven technology to intercept groundwater flow.	Depth of trench limited by excavation equipment.	Low	Eliminated
Surfactant Flushing	Florida field test results available late 1999.	Requires injection, extraction, and treatment systems.	High	Eliminated
***In Situ* Treatment**				
Air Sparging with Vapor Collection	Proven effective to remove VOCs. Site lithology may limit effectiveness. Capture of generated vapors.	May require off-gas treatment. Site lithology greatly complicates system installation.	Medium	Retain
Chemical Oxidation	Can achieve more than 90% VOC destruction efficiency.	Requires bench- and pilot-scale testing.	Medium	Retain
Natural Attenuation	Natural biodegradation of chlorinated solvents has been observed at the site.	Requires groundwater and system monitoring. Require long-term system monitoring.	Low	Retain

See notes at end of table.

Table 4-1 (Continued)
Screening of Remedial Technologies for Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
***In Situ* Treatment (Continued)**				
Enhanced Biodegradation	Site data suggest biodegradation occurring.	Bench- and pilot-scale studies would be required to demonstrate effectiveness.	Medium	Retain
Phytoremediation	Site-specific effectiveness. Would not eliminate contaminated groundwater flow into Lake Druid.	Requires a drainage ditch to be excavated; establishment of plant communities. May require additional testing prior to regulatory approval.	Medium	Eliminated
Steam stripping	Proven to remove SVOCs from soils at pilot scale.	Requires vapor extraction system, steam condenser, air emission control devices, wells, and underground injection permit.	High	Eliminated
Recirculation/In-Well Stripping	Proven technology to remove VOCs, in use as part of IRA plan.	May require vapor phase treatment system.	Medium	Retain
Permeable Reactive Wall	Patented technology. Long-term effectiveness proven in laboratory tests only.	Requires fate, transport, and hydraulic modeling. Requires bench-scale column tests for optimum design. Soil excavated to construct wall would require separate management. Precipitates may form on reactive materials, limiting hydraulic lifetime of wall and requiring flushing of wall. Integrity of permeable reactive wall and hydraulic barrier must be evaluated periodically to maintain optimum groundwater treatment. Requires vendors with chemical expertise.	High	Eliminated
In Situ Fixation (Inorganic Treatment)	Questionable effectiveness to remove antimony.	Requires bench- and pilot-scale testing.	Medium	Eliminated

See notes at end of table.

Table 4-1 (Continued)
Screening of Remedial Technologies for Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
***Ex Situ* Treatment**				
Air Stripping and Aeration	Proven technology to remove VOCs.	May require off-gas treatment and monitoring.	High	Retain
		May require carbon adsorption to achieve effluent discharge limits.		
Organic Adsorption	Proven technology to remove VOCs.	Spent carbon must be regenerated or disposed of.	High	Eliminated
Chemical Oxidation(UV/OX with Hydrogen Peroxide)	Typically achieves more then 99% destruction of organics.	Treatability studies required if inorganic treatment required.	High	Retain
		Pretreatment may be required.		
Biological	Proven technology to reduce organic concentrations.	Requires treatability studies.	High	Eliminated
		Effluent or residuals may require additional treatment.		
POTW (Inorganic Treatment)	VOCs would require separate treatment.	Current inorganic concentrations are below industrial user discharge limits.	Medium	Retain
Ion exchange (Inorganic Treatment)	Proven to reduce concentrations in concentrated waste streams.	Wastewater is generated and would require treatment.	High	Retain
		Specialized equipment required.		
Metals Precipitation (Inorganic Treatment)	Unproven technology at low concentrations.	Requires bench-scale testing.	High	Retain
		Sludge generated must pass TCLP prior to disposal.		
Electrochemical (Inorganic Treatment)	Unproven technology at low concentrations.	Requires bench scale testing.	Medium	Retain
		Sludge generated must pass TCLP prior to disposal.		
Microfiltration (Inorganic Treatment)		Patented process	Medium	Retain

See notes at end of table.

Table 4-1 (Continued)
Screening of Remedial Technologies for Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Representative Technology	Effectiveness	Implementability	Cost	Recommendation
Discharge				
POTW (Orlando STP)		Effluent or residuals may require additional treatment.	High	Eliminated
Surface Water (Lake Druid)	Mixing zone may be allowed at discharge point.	NPDES permit required; FDEP may determine treatment levels.	Low	Retain
Groundwater Reinjection	Mixing zone may be allowed within zone of recharge.	FDEP approval required; FDEP may determine treatment levels.	Low	Eliminated

Notes: IRA = Interim Remedial Action.
VOCs = volatile organic compounds.
SVOCs = semivolatile organic compounds.
UV/OX = ultraviolet oxidation.
% = percent.
POTW = publicly owned treatment works.
TCLP = toxicity characteristic leaching procedure.
STP = sewage treatment plant.
NPDES = National Pollutant Discharge Elimination System.
FDEP = Florida Department of Environmental Protection.

to exhaust. Also, chemical precipitation of inorganics requires treatment and disposal of separated solids. The effective treatment of residuals and emissions is dependent upon the technology used. The appropriate method of conditioning and dewatering sludge from chemical precipitation may be different than conditioning and dewatering sludge from a biological process. Thus, the identification of required supplemental technologies will be deferred to the detailed evaluation of remedial alternatives (Chapter 5.0).

A no action alternative is typically included in the FS process to provide a baseline comparison to other remedial alternatives evaluated in the detailed analysis. The no action alternative is defined as conducting no response and no long-term monitoring of the contaminated groundwater. However, this definition of no action alternative is not completely appropriate for OU 4 because an IRA is currently operating between Port Hueneme Avenue and the shore of Lake Druid, downgradient of the source area. As discussed in Section 2.3 of this report, the IRA consists of two recirculating or *in situ* air stripping wells treating VOC contaminated groundwater prior to discharging it into Lake Druid. It has been assumed that the IRA will continue to operate until the groundwater discharging into the lake meets FDEP surface water standards. Operation of the recirculating wells also includes groundwater monitoring for the COCs (VOCs). The continued operation of this IRA and groundwater monitoring of the VOC-contaminated northern and southern plumes will be retained as a component of the no action alternative for comparison as a baseline condition. Details of the O&M of the recirculation wells are discussed in the IRA Performance Monitoring and Sampling Plan (ABB-ES, 1997f).

The IRA does not address the antimony plume. The no action alternative consisting of no treatment, containment, or restricted access will be retained for the antimony plume. These no action alternatives will not be discussed under the identification and screening discussions below, but will be evaluated as part of the remedial alternatives in Chapter 5.0.

4.1.1 Identification of Limited Action Technologies Limited action technologies include zoning and/or groundwater-use restrictions, lake-use restrictions, and the continued operation of the IRA for the VOC groundwater plume along with the long-term monitoring of groundwater quality. A detailed description of these technologies is presented below.

4.1.1.1 Zoning and/or Groundwater-Use Restrictions This limited action involves the implementation of zoning and groundwater-use restrictions to reduce the potential exposure of the public to the VOC and antimony groundwater plumes. These restrictions would likely limit the depth of excavation at OU 4 due to a shallow water table, and limit the future installation of a water supply well. In addition to these restrictions, environmental monitoring of the groundwater plumes would be conducted. The IRA would also continue to operate downgradient of the source area prior to the contaminated groundwater discharging into Lake Druid. The groundwater-use restrictions will be included in any leases, deed, or other property transfer documents and will apply to future property owners and tenants. A site review would be conducted every five to seven years to determine if this response action is protective of the public or if the groundwater has achieved FDEP MCLs such that the IRA could be turned off and the groundwater-use restrictions eliminated.

4.1.1.2 **Lake-Use Restrictions** As in the case of the groundwater-use restrictions, use restrictions would be implemented for Lake Druid to eliminate potential exposure to contaminated groundwater discharging into the surface water body and contaminated sediment on the lake bottom. These restrictions would eliminate swimming and fishing in the lake along the general boundary of OU 4. Residents have already been notified of existing contamination; signs have been posted along the shore of the lake on Navy property. However, more formal and legally enforceable restrictions will be required for this alternative. The contaminated groundwater and sediment will be monitored to determine if the contaminant concentrations have been naturally reduced to support future recreational use of the lake shore and restricted portion of the lake water.

4.1.1.3 **Screening of Limited Action Technologies** Of the two limited actions available for implementation at OU 4, groundwater-use restrictions will be retained for use at the antimony plume and the VOC plumes (Table 4-1). Implementation of groundwater-use restrictions for the VOC plume will minimize potential human exposure to groundwater containing contaminants that exceed MCLs while continued operation of the IRA prevents contaminant migration to Lake Druid. Groundwater-use restrictions would also be effective for the antimony plume because the plume appears to be stable and does not have any ongoing treatment system in operation. Use restrictions for Lake Druid are not being retained because the lake is currently being used for recreational activities and restrictions would be very difficult to enforce, and the operation of the IRA is expected to greatly reduce contaminant concentrations in the lake. Continued operation of the IRA will support the regulatory compliance with the discharge of groundwater to the lake and, as previously stated, is considered as part of the no action alternative due to its current operation.

4.1.2 Identification of Groundwater Containment Technologies

4.1.2.1 **Hydraulic Barrier** Hydraulic barriers isolate contaminated groundwater by restricting groundwater flow from the contamination zone through the use of wells. Extraction wells are typically installed directly downgradient of the source area to collect contaminated groundwater. At OU 4, two wells advanced to approximately 60 feet would likely be required to fully contain both the northern and southern plumes. Following extraction of contaminated groundwater, *ex situ* groundwater treatment would be required using one of the technologies discussed in Subsection 4.1.6. Groundwater would then need to be discharged to Lake Druid, reinjected back into the ground, or discharged to the Orlando STP as is evaluated in Subsection 4.1.5.

4.1.2.2 **Slurry Wall** A slurry wall may be constructed immediately outside the source area to encompass and contain the highest concentrations of VOCs. This slurry wall would be constructed by excavating a 3-foot-wide trench approximately 60 feet deep and keyed into the Hawthorn layer. The trench would be filled with a slurry mixture consisting of excavated soil, bentonite, and water. The slurry hydraulically shores the trench to prevent collapse and forms a filter cake to reduce groundwater flow. It is assumed that approximately 70 percent of the excavated soil would be reused in the slurry mix. The remaining soil that is unusable would be screened for COCs and spread on site.

Construction of a low-permeability cap over the source area would also be necessary to effectively eliminate infiltration of precipitation. The cap could consist of an extension of the paved concrete surface or the installation of an

high density polyethylene liner covered with soil and seeded. In place of a surface cap, a groundwater extraction and treatment system could be installed to eliminate the "bath tub" effect.

4.1.2.3 **Sheet Pile** Containment of contaminated groundwater can be accomplished by the installation of sheet piles into the overburden and keyed into the Hawthorne layer to provide a cutoff wall. Sheeting joints may be grouted to reduce the flow of groundwater at the joints, depending on the degree of containment required. The sheet pile wall would be installed to completely surround the source area. To reduce the development of a "bath tub" effect, either an impermeable cover or a groundwater pump and treat system would need to be installed. Sheet pile walls are difficult to install in dense soil. The contaminants may also react with the joint grout material; therefore, predesign testing would be required.

4.1.2.4 **Screening of Groundwater Containment Technologies** All of the containment technologies were eliminated from further evaluation. There is a concern that the containment technology will not be completely impermeable, such that low concentrations of VOC contaminants may escape the containment and migrate into Lake Druid. The existing IRA may never be turned off due to this small release from the source area. Hydraulic containment may be effective based on the results of a pumping test conducted as part of the IRA at OU 4, but instead will be evaluated as part of an *ex situ* treatment technology.

Physical containment of the antimony plume does not appear to be necessary because the plume appears to be stable already. Therefore, no containment technologies were retained for further evaluation.

4.1.3 Identification of *In Situ* Groundwater Treatment Technologies *In situ* technologies are processes that are capable of removing compounds from groundwater without extracting the groundwater. In contrast to groundwater extraction and *ex situ* treatment, *in situ* treatment does not generate water requiring discharge. Additionally, only the target COCs are treated, as opposed to treating nontarget constituents to achieve discharge limitations for extracted groundwater. *In situ* treatment technologies identified for OU 4 are presented below.

4.1.3.1 **Air Sparging with Vapor Extraction** Air sparging is generally used to remove VOCs from groundwater without extracting the water. Air is injected into the saturated zone to create turbulence and volatilize organic compounds. As air moves up through the aquifer, contaminants partition into the gas phase and are then extracted as organic vapors from the vadose zone. Injected air can also stimulate microbial degradation of contaminants if the required microbes thrive in aerobic conditions (Johnson et. al., 1993).

Air sparging is typically used in combination with vapor extraction to control off-gas generated by organic compound volatilization. Vapor extraction uses negative pressure to collect the vapors generated from the air sparging of the saturated zone. Vapor extraction wells or trenches are installed above the water table in a configuration to capture vapors generated from air sparging. The spatial extent of effectiveness of an air sparging vapor extraction system can be enhanced by dewatering saturated soil.

Field performance testing was conducted at OU 4 for air sparging. Test results revealed that a hard layer of cemented sand located approximately 20 feet bls prevented the injected air from migrating to the surface. However, the test results suggested that OU 4 would be amenable to air sparging if some means of penetrating the cemented sand layer is provided to remove the generated vapors.

4.1.3.2 ***In situ* Chemical Oxidation** *In situ* chemical oxidation requires the injection of liquid chemical formulations into the contaminated portion of the aquifer. The two most common technologies require injection of $KMnO_4$ or a sequence of compounds that together create a Fenton's reaction.

In Fenton's reaction, hydrogen peroxide (H_2O_2) reacts with ferrous ion to produce the hydroxyl radical, a powerful oxidizer. The hydroxyl radical progressively reacts with organic compounds to produce carbon dioxide and water. Several vendors offer commercial versions of this technology. Typically, injection of ferrous sulfate is followed by injection of H_2O_2. The ensuing reaction is highly exothermic. Dosage is dependent on contaminant mass. Distribution of the injected chemical solution can be difficult to control.

Chemical oxidation using $KMnO_4$ oxidizes contaminants via MnO_4^-. Treatment involves the flushing of the contaminant zone using an aqueous permanganate solution. Groundwater is extracted, dosed with $KMnO_4$, and then reinjected at an upgradient location. This creates a treatment cell, allowing flushing of several pore volumes of solution through the contaminated zone until the contaminants have been oxidized. No heat is generated, and the physical flushing action aids in distribution of the oxidant through the treatment zone. Dosage is also not dependent on source mass; instead, the mass may affect the number of pore volumes treated.

In situ chemical oxidation using $KMnO_4$ has been selected for OU 4, due to its advantages over Fenton's reaction. A field-scale pilot study of this technology will occur at OU 4 in early 1999.

4.1.3.3 ***In situ* Bioremediation** For purposes of this FS report, bioremediation is intended to categorize a broad group of technologies where organic contaminants are biologically reduced to less hazardous byproducts (i.e., carbon dioxide and water). Three technology process options are considered. These include natural attenuation, enhanced biodegradation, and phytoremediation.

Natural Attenuation. Natural attenuation is defined by the USEPA as naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contamination through those media (USEPA, 1997). Natural attenuation works through nondestructive mechanisms such as dispersion, adsorption, dilution, volatilization, and/or chemical and biological stabilization of contaminants and destruction mechanisms such as biodegradation. Natural attenuation is recognized as a legitimate and responsible solution for contaminated aquifers and has been shown to be a viable and cost-effective remedial approach.

Natural attenuation is applicable to OU 4 based on the COCs at the OU and their ability to biodegrade. The RI revealed that natural biodegradation (reductive dechlorination) has been occurring at OU 4. As the VOC plume moves downward (due to the downward groundwater potential) and west towards the lake, PCE degrades to TCE. The downgradient extent of the PCE plume is generally limited by this

degradation. As the plume continues to migrate towards the lake, the TCE biologically degrades to cis-DCE. The highest cis-DCE concentrations are generally in the lower portion of the aquifer, downgradient or collocated with the highest TCE concentrations. Relatively little PCE is present as the plume completes its migration west and discharges upward into Lake Druid (HLA, 2001).

Enhanced Biodegradation. Enhanced biodegradation of groundwater is the process of enhancing natural bacterial degradation of organic contaminants. This is accomplished by introducing nutrients or other compounds to stimulate bacterial growth and the speed of biodegradation of organic compounds. Bioremediation can be applied using aerobic (oxygen-rich) conditions or anaerobic (oxygen-poor) conditions.

PCE, TCE, and cis-DCE have been shown to biodegrade under anaerobic conditions, but PCE is resistant to degradation under aerobic conditions. Less chlorinated compounds such as TCE and cis-DCE can be degraded under either anaerobic conditions or under aerobic conditions. Aerobic biodegradation of TCE and cis-DCE can be accomplished by a type of aerobic bacteria known as methanotrophs or methane-utilizing bacteria.

Generally, anaerobic degradation of highly chlorinated VOCs, such as PCE, produces TCE, cis-DCE, and VC over time through a process called reductive dechlorination. Complete anaerobic transformation of these compounds results in the production of ethene and ethane, which are nonchlorinated and nontoxic end-products. However, in anaerobic degradation of chlorinated VOCs, the rate-limiting factor is the final step where VC is transformed to ethene. If an anaerobic *in situ* treatment system can be implemented such that there is sufficient residence time within a biologically active zone to completely dechlorinate the VOCs, then an anaerobic process could be used for remediation. However, if the dechlorination process is incomplete and biodegradation intermediates such as cis-DCE and VC remain, a second (aerobic-methanotrophic) biological process can be used to rapidly oxidize the remaining intermediate products. Aerobic-methanotrophic biodegradation of these intermediates results in the production of carbon dioxide and water as the final end-products.

The presence of TCE and cis-DCE in groundwater at OU 4 implies that natural anaerobic biodegradation of PCE is already occurring *in situ*. However, concentrations of VOCs in Lake Druid indicate that this degradation is neither complete nor rapid enough to meet regulatory standards. The following approach could potentially be implemented to increase the rate of natural biodegradation of organic compounds at OU 4:

- Enhance the rate and extent of anaerobic biodegradation by injecting lactic acid. The lactic acid is metabolized by indigenous anaerobic bacteria (such as acetogens) to produce hydrogen. The resulting hydrogen can be used by reductive dehalogenators, which are capable of dechlorinating chlorinated hydrocarbons.

- If monitoring demonstrates that complete degradation is still not occurring, aerobic conditions in the downgradient portion of the plume could be established to complete biodegradation of chlorinated VOCs. This would be accomplished by injecting oxygen and methane, if required. This aerobic stage is not believed to be required, based upon pilot-scale testing at a Massachusetts facility using Hydrogen

Release Compound™ (HRC) (see Appendix E) and will not be costed for FS purposes. However, the technology is available, if required. HRC™ is a proprietary polylactate ester manufactured by Regenesis that is specially formulated for slow release of lactic acid upon hydration.

This *in situ* bioremediation technology would be considered innovative. Because of the variability of natural microbial processes, laboratory-scale biodegradation testing may be required to evaluate the microbial conditions present in site groundwater, establish suitable amendment (nutrients and carbon sources) concentrations, and identify any factors that may inhibit microbial growth. An additional pilot-scale phase would then be required to demonstrate the effectiveness of this technology under the actual field conditions at OU 4.

Phytoremediation. Phytoremediation is the use of naturally-occurring and genetically engineered vegetation to clean up or contain contaminated environmental media. It is considered an innovative technology at this time because, although the technology has shown to be very effective in specific situations, the processes are not well understood and they have been applied (in full-scale) to a relatively small, but growing, number of contaminated sites.

The are several mechanisms involving plants that accomplish removal, degradation, or stabilization of contaminated water. Phytoextraction involves the direct uptake and translocation of contaminants into plant tissues. Phytodegradation or phytotransformation involves the breakdown or transformation of contaminants by enzymes in plants (or exudates) into other harmless chemicals. Rhizofiltration involves the uptake of contaminants by plant root systems, where contaminants remain. Phytostimulation or assisted bioremediation involves selective stimulation of microbial action in the root zone of the soil strata to enhance biodegradation.

The applicability of phytoextraction at OU 4 has been investigated by the U.S. Geological Survey (USGS) (USGS, 1998). The USGS report concludes that under existing conditions, phytoremediation alone at OU 4 cannot stop the discharge of contaminants into Lake Druid because the overall estimated evapotranspirative losses would be small relative to the groundwater discharge to Lake Druid. However, the report suggests that the installation of a drainage ditch approximately 300 feet long, 10 feet wide, and 5 feet deep could redirect groundwater flow through the rooting zone of aquatic plants, which could remediate the groundwater discharge. The drainage ditch would intercept flow from 0 to approximately 40 feet below the water table but would still allow water in the lower 20 feet of the surficial aquifer system to continue to discharge to Lake Druid. The OPT discussed this alternative and eliminated the ditch from consideration because of the large amount of site disruption required, because the ditch would likely also be considered a surface water body, and because source remediation would still be necessary.

Phytoremediation may someday have a role as a final remediation step in Lake Druid itself. Researchers from the University of Georgia have detected the presence of the enzyme dehalogenase in the lake. Dehalogenase has been shown to breakdown chlorinated VOCs. The USEPA research lab in Athens, Georgia, and the University of Georgia continue to study phytoremediation at OU 4.

4.1.3.4 **Steam Stripping Technologies** The injected steam is used to strip VOCs and semivolatile organic compounds (SVOCs) from soil and saturated soil by

increasing the subsurface temperature. This increases the mass transfer and phase exchange rates from liquid to vapor phase, reduces liquid viscosities, and accelerates desorption of contaminants from the contaminated media. The heat also destroys contaminants via pyrolysis. Due to the transfer of contaminants from liquid to vapor phase, a soil vapor extraction (SVE) system is required to collect the contaminants from the subsurface. Other supporting equipment includes a steam condenser, a contaminant separation and collection system, and air emission control devices. Steam injection is typically performed through central vertical wells surrounded by vertical extraction wells. Prior to implementing this technology, an underground injection permit will be required.

4.1.3.5 **Recirculation/In-Well Stripping** The recirculation well technology creates a circulation sphere within the affected portion of the aquifer. Typically, groundwater enters through a screen in the lower part of the recirculation well, travels up through the well, and returns to the aquifer through a screen near the top, thus creating a spherical recirculation cell. Groundwater treatment occurs within the well prior to returning to the aquifer. Treatment levels for groundwater discharge to Lake Druid were identified in Chapter 3.0, Table 3-3. Several different proprietary designs of this technology are available.

The various versions of this technology can be separated into two general categories: negative pressure systems and positive pressure systems. In the negative pressure system, a blower is used to create a negative pressure within the recirculation well. A submersible pump is typically used to draw groundwater up through the bottom screen, into the well, and into a proprietary stripping reactor positioned within the well casing. The stripper is vented to the ambient air. The negative pressure within the well draws air into the stripper, where VOCs in groundwater are volatilized and drawn out of the well by the blower. If necessary, this off-gas stream can be treated. The treated groundwater exits the in-well stripper, and returns to the aquifer by gravity through the upper well screen.

In a positive pressure system, pressurized air is injected into the recirculation well through a diffuser. The air bubbles rise up the water column, inducing groundwater to enter the well through the lower screen (air lift pumping). As the air-water mixture rises through the well casing, VOCs transfer from the groundwater to the air bubbles. A deflector plate separates the air-water mixture, allowing the air and VOC vapors to be drawn out of the well by a vacuum blower. If necessary, this off-gas stream can be treated. The treated groundwater returns to the aquifer by gravity through the upper well screen.

Both types of recirculation wells return groundwater to the aquifer without extraction. This eliminates the need to consider water disposal options. No drawdown occurs, eliminating the possibility of wetland dewatering. Groundwater in the spherical treatment cell undergoes several stripping cycles, dependent on the recirculation flow rate within the well and the rate that groundwater enters the cell due to the existing natural gradient. This allows low treatment levels to be achieved within and downgradient of the recirculation cell. The vertical component of the recirculating water can also be very effective at flushing areas where contaminants may be concentrated, accelerating cleanups compared to conventional groundwater extraction, and reducing the likelihood of concentration rebound after system shut down.

As previously discussed in Section 2.3, the recirculation well technology was implemented at OU 4 as an initial IRA to control migration of VOCs that contribute to the exceedances of FDEP surface water standards in Lake Druid. The OU 4 IRA consisted of two negative pressure, reverse flow recirculation wells. Unlike a conventional recirculation well, the IRA system used a submersible pump set at the upper screen for groundwater intake, and then discharged treated water through the lower screen via sump pumps. This reverse flow allays concerns over groundwater mounding if treated water was returned to the shallow water table through the upper screen. It is anticipated that any additional recirculation wells installed at OU 4 would also be this configuration. Analytical data presented to the OPT indicated substantial decreases in VOC concentrations entering Lake Druid downgradient of the IRA prior to encountering operational difficulties.

4.1.3.6 **Permeable Reactive Wall** A permeable reactive wall is constructed of zero-valent iron (or other zero-valent metal) material. The wall is installed in a location to intercept contaminated groundwater. As contaminated groundwater passes through the wall under natural groundwater flow conditions, the contaminants are removed through chemical and physical processes. This technology relies on the thermodynamic instability of carbon atoms in halogenated organic compounds, such as PCE and TCE, in a reducing environment, thus causing iron in the permeable reactive wall to be oxidized while PCE and TCE are reduced. Once these chemicals have been reduced, degradation of the chemicals to ethenes and ethanes occurs. This technology is patented by the University of Waterloo of Ontario, Canada.

If this technology were implemented at OU 4, a bench-scale study would have to be performed. There is also a concern that groundwater inorganic concentrations (particularly iron) would increase after passing through the wall, potentially exceeding Florida SWQSs. In addition, fate and transport modeling would be required to predict the fate of organic and inorganic chemicals as groundwater discharges to Lake Druid. This modeling would attempt to predict if any adverse effects would occur. Installation of a permeable reactive wall at OU 4 would also likely require complex hydraulic modeling because the confining unit is approximately 60 feet bls.

Laboratory tests have been conducted at the University of Waterloo to simulate over 20 years of use, and the results indicate that the chemical activity of the iron material was maintained. However, the first full-scale implementation of this technology has only been in place for 4 years. The University of Waterloo continues to recommend that remediation budgets consider replacement of the reactive material every 10 years. Therefore, long-term effectiveness is still unproven.

4.1.3.7 **Screening of *In Situ* Treatment Technologies for Groundwater** The screening of selected technologies and recommendations for the development of remedial alternatives for *in situ* groundwater treatment is presented in Table 4-1. Air sparging with SVE, chemical oxidation (using $KMnO_4$), enhanced bioremediation, monitored natural attenuation (MNA), and recirculation wells are retained for further evaluation as *in situ* groundwater treatment alternatives. Steam stripping and permeable reactive walls were eliminated from further analysis.

Steam stripping was eliminated due to the potential for releasing dense nonaqueous-phase liquid (DNAPL) into the groundwater plume without having full hydraulic containment of the source area. In addition, the source area is very large (surface area of approximately 17,000 square feet) such that excessive energy costs will be incurred to treat the VOC-contaminated soil and groundwater to a depth of 40 feet bls. The existing building structure will also limit site access to the source area.

The reactive wall technology was eliminated from further consideration because the long-term effectiveness of the wall has not been field-verified. In addition, precipitates or films may form on the reactive materials, and although they do not appear to inhibit the rate of the degradation reaction in laboratory studies, they could limit the hydraulic lifetime of the wall and require intensive O&M (i.e., flushing).

The installation of a reactive wall also would not address the source area. Because of NTC, Orlando's status as a BRAC facility, the intent to transfer OU 4 to the City of Orlando for reuse favors technologies that can address the source. Finally, a reactive wall downgradient of the source area would duplicate the function of the currently operating IRA.

4.1.4 Identification of Groundwater Collection Technologies To implement *ex situ* treatment technologies, contaminated groundwater must be extracted from the aquifer. When groundwater is extracted, a cone of depression is created around the well as groundwater is pumped. This influences the local hydrogeology and causes groundwater to flow toward the well, thus flushing contaminants from the aquifer. Wells may be drilled either vertically or horizontally, and may be installed directly into the aquifer or installed in an excavated trench that has been backfilled with permeable soil material. The applicability of a particular extraction method depends primarily on soil conditions, and plume configuration and depth. Remedial alternatives discussed in Section 4.2 and Chapter 5.0 may include specific applications of the collection technologies described in this subsection.

4.1.4.1 **Vertical Wells** The advantages of using vertical wells for groundwater extraction at OU 4 include the ability to extract isolated areas of contamination when installed singularly, or larger areas when installed in groups, and the ability to extract groundwater from various depths. The number of wells and pumping rates for groundwater extraction were developed for the detailed evaluation of the remedial alternatives in Chapter 5.0 of this FS. During detailed design, the well locations would be selected and operating parameters refined to obtain an efficient configuration capable of capturing and extracting the contaminated groundwater. For a groundwater extraction system to be fully effective, it may have to be modified during the course of the remedial action. When multiple wells are pumped simultaneously, stagnation zones (areas where there is no groundwater flow) can develop. This can leave behind pockets of contaminants. To capture these remaining pockets, the pumping operational scheme may have to be changed by adjusting pumping rates, injecting clean water into some wells, or installing additional wells to replace wells no longer effective.

4.1.4.2 **Horizontal Wells** Horizontal wells may be used to span the entire length or width of an elongated groundwater plume; however, they are generally more expensive to install than vertical wells. Horizontal wells are therefore more cost effective in areas of contaminated soil and groundwater where surface access

is limited or nonexistent. They also are effective at extracting groundwater within low-permeability saturated soils.

4.1.4.3 **Surfactant Flushing** Surfactant flushing involves the injection of a solvent mixture in to either the vadose zone, the saturated zone or both to extract organic contaminants. This process can be used to solubilize either the source of contamination or the contaminant plume emanating from the source area. The enhanced contaminated groundwater is extracted downgradient and treated on the surface. Depending on the *ex situ* treatment process, the surfactant may be recirculated through the treatment cell, while the organic contaminants are collected for off-site disposal.

Surfactants can increase the contaminant removal by increasing the solubility of the organic contaminants in water, resulting in an improved mass removal. Greater concentrations of surfactants can also be used to reduce the interfacial tension between the groundwater and the NAPL resulting in direct mobilization of the NAPL and more efficient contaminant extraction. However, the increased mobility of the NAPL can lead to substantial source migration if hydraulic containment of the treatment cell is not complete.

Surfactant flushing is effective in areas where the organic content in saturated soil is low, the groundwater flow and subsurface layers are well defined, an injection/recirculation treatment cell can be created and controlled, and the COCs are not a mixture, but simple degradation products of the NAPL. Within the last few years, surfactant flushing has been used to expedite the removal of chlorinated organics from saturated soil for *ex situ* treatment.

Surfactant flushing using a mixture of ethanol and water was recently implemented to remove PCE from the saturated soil at a dry-cleaning site in Florida (Rao, 1998). This was the first time this technology has been applied in the field for the removal of PCE. The preliminary results indicate that approximately 80 percent of the PCE was removed from the treatment cell. Final field results will not be available until sometime in 1999. However, initial estimates indicate a very high cost, on the order of approximately $1,000 per cubic yard treated.

4.1.4.4 **Collection Trench** Interceptor trenches or series of trenches may be constructed downgradient to the direction of groundwater flow to intercept contaminated groundwater and prevent further migration. The contaminated groundwater currently recharges into the lake. This recharge can be made to occur closer to the source area for collection and *ex situ* treatment of the contaminated groundwater. Piping and drains may be installed in the trench to collect groundwater either by gravity flow or pumping. One concern with this collection process is that the lower portion of the groundwater plume may pass beneath the collection trench and continue on to the lake. This discharge to Lake Druid currently exceeds FDEP surface water standards.

4.1.4.5 **Screening of Groundwater Collection Technologies** The practicality of groundwater extraction depends on the hydrogeologic conditions at a site. To evaluate these conditions, a pumping test was conducted at OU 4 in August 1996 as described in Subsection 1.2.1. Analysis of the pumping test data indicated that the recovery well provided good horizontal and vertical connection through the surficial aquifer. Results of the test indicated a hydraulic conductivity of 32.7 ft/day and a transmissivity of 1,960 ft^2/day. Further detail of the

pumping test can be found in the OU 4 *IRA Treatability Study: Pumping Test Implementation and Results letter report* (ABB-ES, 1996d).

The pumping test demonstrated that, for the OU 4 IRA, hydraulic control can be provided via a vertical recovery well as opposed to a horizontal well or collection trenches. Horizontal wells are significantly more expensive than vertical wells. The use of collection trenches was also eliminated due to the potential for contaminated groundwater exceeding FDEP surface water standards to migrate beneath the collection trench and discharge into Lake Druid (Table 4-1).

Subsurface conditions at OU 4 appear to meet the general criteria for surfactant flushing, particularly the ability to contain the surfactant injection within the treatment cell. However, unsuccessful application of surfactant could lead to groundwater VOC concentrations too high to be treated by the IRA. Further, because field data of the ethanol-based surfactant application for PCE removal is still under evaluation, and because of the potential exorbitant cost, this technology is not being retained at this time. Following the release and complete evaluation of the FDEP dry-cleaning site data in 1999, this removal technology may be reevaluated for use at OU 4.

4.1.5 Discharge Options for Treated Groundwater If groundwater is treated by extraction and treatment, the process would produce an effluent that requires discharge. The method of discharge dictates the degree of treatment required. Specific discharge criteria for various discharge options are presented in Tables 3-3 through 3-7. The following three discharge options have been identified for OU 4 and are described below:

- discharge to surface water
- reinjection to groundwater
- discharge to Orlando STP

4.1.5.1 **Discharge to Surface Water** Groundwater extracted and treated may be discharged to Lake Druid (i.e., surface water) via direct pipeline. Anticipated treatment levels for organic and inorganic compounds for a discharge to surface water component are presented in Tables 3-4 and 3-5. These treatment levels will be used for developing an appropriate treatment process (for both organic constituents and inorganic constituents, as both treatment processes would be necessary) for extracted groundwater. However, actual treatment levels may be modified by the FDEP. Technology-based and water-quality-based treatment levels would be considered during remediation. According to Chapter 62-4.224, FAC, the applicability of a mixing zone at the discharge point could also be considered during remediation. A National Pollutant Discharge Elimination System (NPDES) permit will be needed for discharge to the surface water.

4.1.5.2 **Reinjection to Groundwater** Effluent from an *ex situ* treatment system may be reinjected into the aquifer through wells or infiltration galleries. For the purposes of this evaluation, it is assumed that the effluent would have to achieve the treatment levels presented in Table 3-3. (Treatment levels for an *ex situ* technology including reinjection to groundwater are the same as treatment levels for *in situ* groundwater treatment). However, similar to surface water discharge, FDEP may modify these treatment levels on a case-by-case basis. Specifically, a zone of recharge could be established for reinjection of the effluent, and the specified treatment levels may not need to be achieved within this zone. According to Standards for Class G-I and Class G-II Groundwater

(Chapter 62-520.420, FAC), a zone of discharge allows for some mixing of the treated water and the aquifer, provided that the quality of groundwater outside that zone is not adversely affected. A request to discharge to groundwater would require FDEP approval.

4.1.5.3 **Discharge to Orlando STP** The Orlando STP relies primarily on its Bardenpho (a suspended growth anoxic nitrification/denitrification system process) to degrade organic matter prior to discharge. The STP is capable of providing treatment for extracted groundwater provided that constituents in the groundwater do not exceed the influent requirements (Table 3-6).

The advantage of a discharge to the STP is that existing treatment capacity is utilized and only pretreatment would be required to reduce selected constituent concentrations to a level that can be accepted as influent. Anticipated pretreatment requirements for discharge to the STP were presented in Tables 3-6 and 3-7. TCE, PCE, and cis-DCE are the only groundwater constituents that exceed the treatment levels, and thus would require pretreatment.

4.1.5.4 **Screening of Discharge Options for Treated Groundwater** Of the three discharge options available, only the discharge of treated groundwater to Lake Druid has been retained (Table 4-1).

Analytical requirements for injecting treated groundwater are FDEP primary drinking water standards. Both the POTW discharge criteria and surface water discharge criteria are less stringent and can more readily be achieved using available *ex situ* treatment technologies. This would also eliminate the need to maintain injection wells due to potential biomass or iron buildup currently occurring in the IRA wells.

NTC, Orlando maintains an industrial user's permit for the discharge of investigation-derived waste generated at Area C to the Orlando STP (Appendix C). This permit could be modified to include the discharge of extracted groundwater from the VOC plume. Based on the existing contaminant concentrations detected in the groundwater, the organics would need to be treated prior to discharge. At approximately 4 dollars per 1,000 gallons of treated water discharged into the City of Orlando POTW, the cost for an 80 gallons per minute (gpm) system is $160,000 per year in sewer discharge fees, in addition to pretreatment costs. Discharge to the Orlando STP has been eliminated for the VOC technologies due to this high cost, coupled with the need for VOC pretreatment and the long duration of the VOC treatment technologies.

The elimination of Orlando STP discharge for <u>treated</u> groundwater should not be confused with the discharge of <u>untreated</u> groundwater from the antimony plume. Groundwater extracted for remediation of the antimony plume would require no pretreatment prior to STP discharge, and the expected duration of this discharge is much less than for the VOC plumes. Therefore, discharge to the Orlando STP will be retained as an alternative for antimony remediation, as discussed in Paragraph 4.1.6.5.

Surface water discharge from OU 4 has been retained for both the VOC plume and the antimony plume. Obtaining a permit for discharge to a surface water body will require an NPDES permit and FDEP surface water discharge permit. Prior to discharging the VOC plume, the extracted groundwater will be treated for organics; however, it has been assumed that inorganic treatment will not be

required. The Lake Druid surface water and NTC, Orlando basewide background groundwater screening concentrations all ready exceed FDEP Class III surface water quality criteria for several inorganics unrelated to OU 4, as does OU 4 groundwater. Because OU 4 groundwater naturally discharges to Lake Druid, and Lake Druid surface water samples from the control location exceed inorganic surface water criteria (HLA, 2001), inorganic treatment of extracted groundwater should not be necessary. The inorganic concentrations detected in the antimony plume do not exceed the FDEP surface water quality criteria, however, it was assumed that inorganic treatment will be provided prior to the discharge of extracted groundwater into the lake.

Based on this evaluation, alternatives including groundwater extraction and treatment will only include discharge of treated water to Lake Druid. Alternatives requiring groundwater extraction and no treatment (such as for antimony) will also include discharge to the Orlando STP.

4.1.6 Technologies for Treatment of Extracted Groundwater In the previous subsection, it was recommended that the groundwater be discharged into Lake Druid or the City of Orlando STP. Based on the existing contaminant concentrations detected in the groundwater, the organics in the VOC plumes would need to be treated prior to discharge; however, the nonsite-related inorganic concentrations in the VOC and antimony plumes are currently below the discharge criteria for surface water and the STP such that no metals treatment (with the exception of antimony) would be required. The following paragraphs present treatment technologies to remove organic and inorganic compounds from extracted groundwater to achieve treatment levels presented in Tables 3-4 to 3-7.

4.1.6.1 **Air Stripping and Aeration** Air stripping and aeration are used to remove VOCs from contaminated water. It is generally considered to be only partially effective for SVOCs. The VOCs are transferred from the liquid to the vapor phase by contacting the water with a continuous supply of clean air. Although many vendor-specific air stripping and aeration units exist, they can be grouped into the following four categories:

- packed towers
- diffused aeration
- cascade towers
- tray towers

Packed Towers. A typical packed tower system consists of a tower (or column) in which influent groundwater flows downward from the top, while a stream of air flows upward from the bottom. The tower is filled with an inert packing material. Plastic packing is usually used in water treatment operations and provides a large surface area for air-water interface. As clean air moves upward, the VOCs are transferred from the water to the airstream. The liquid effluent is discharged from the bottom, and the air containing VOCs is discharged from the top (American Water Works Association, 1990). The presence of inorganic compounds can potentially clog packing material. Frequent cleaning, adjustment, or replacement of packing may be required to maintain effective removal efficiencies (Dzombak et al., 1993).

Diffused Aeration. Diffused aeration is a process of bringing air bubbles into contact with contaminated water. This process is similar in principle to a packed tower, but it is typically accomplished by a "low profile" unit that

requires less operating space. Air is bubbled into a tank containing contaminated water. A variety of aeration rates and bubble diffusers are available to achieve different effects. Diffused aeration generally requires a higher power cost than packed towers and can be accomplished in tanks (American Water Works Association, 1990). Similar to shallow-tray air strippers, access to the diffusers is readily available via a latched and locking cover for periodic cleaning of bacterial growth and precipitated inorganics. These tanks can either be stacked or placed in series to increase the contact time between the contaminants and the diffused air.

Cascade Towers. Cascade towers are gravity-fed, stepped systems that aerate contaminated water by continually "splashing" the water onto subsequent steps. Small pools of water are exposed to air as thin sheets cascade down each step. The number and height of the required steps can be designed to achieve the desired contact time for air-water interface (Metcalf and Eddy, 1991).

Tray Towers. Tray towers, such as low profile tray units, are similar in principle to cascade towers. Rather than a series of steps, a series of stacked trays are used to maximize air-water interface. Water flows over a flat tray, discharges to a lower tray, and continues to pass over the required number of trays to achieve the desired removal efficiency. Trays consist of porous bottoms, allowing for air to be forced through the tray as the water passes over the trays, increasing turbulence and aeration. Tray tower aeration maximizes air-water contact by using multiple trays. If a greater air-water contact time is desired, additional trays may be added.

Recommendation. These air stripping and aeration technologies have similar effectiveness in volatilizing VOCs. Use of diffused aeration is a demonstrated technology that is easily obtained to achieve a variety of treatment levels. For comparative purposes, a diffused aeration tank will be used as a representative air-stripping and aeration technology for subsequent screening. Alternate innovative or vendor-specific processes that accomplish the same type of treatment as air stripping could be used in lieu of this technology.

4.1.6.2 **Organic Adsorption** Adsorption is a process in which a substance is transferred from water to a solid medium. This technology is effective for VOCs and SVOCs. When compared to air stripping, aeration, and oxidation, organic adsorption is more effective for the removal of SVOCs.

The molecule that accumulates or adsorbs at the water-solid interface is called the adsorbate, and the solid on which the adsorption occurs is the adsorbent. Common adsorbents in water treatment include activated carbon, ion exchange resins, adsorbent resins, metal oxides, and carbonates. While some of these technologies are used primarily for the treatment of inorganic compounds, this discussion will focus on the following technologies for the treatment of organic compounds:

- granular activated carbon (GAC)
- powdered activated carbon (PAC)

Granulated Activated Carbon. GAC is a physical treatment technology in which groundwater is passed through a packed-bed reaction vessel filled with activated carbon. GAC adsorbs organic compounds and inorganic constituents. The particle shape of crushed activated carbon is irregular, while extruded activated carbon

is smooth and cylindrical. The basic manufacturing process includes carbonization, or conversion, of the raw material to a char and activation (or oxidation) to develop the internal pore structure. Carbonization is usually performed in the absence of air at temperatures less than 700 °C (American Water Works Association, 1990).

GAC adsorption is applicable to different water flow rates and concentrations. Two GAC canisters are typically used in series to monitor breakthrough and to ensure treatment effectiveness. GAC can be used as either a polishing step or a pretreatment step, depending upon the other technologies used in the treatment system. The primary cost consideration is the regeneration or disposal of spent carbon.

Powdered Activated Carbon. PAC is used in a sequential process, by adding it to groundwater within a holding tank and then separating the water and PAC. After the PAC contacts the water, the carbon is allowed to settle, and the treated water is removed. PAC particles are typically smaller than GAC particles and are supplied in bulk rather than in canisters (Metcalf & Eddy, Inc., 1991).

PAC has advantages over GAC in that it has lower capital costs and allows greater flexibility in altering carbon doses as the water quality changes. The disadvantages are that the PAC can not be regenerated, it attains lower total organic carbon removal, the sludge in the bottom of the tank must be disposed of, and it is difficult to remove the spent carbon from the water.

Recommendation. These technologies have similar effectiveness in removing organic contaminants from groundwater. However, for comparative purposes, GAC will be used as the representative organic adsorption technology for screening. GAC is easy to implement and has demonstrated effectiveness for removing organic compounds, such as those present in groundwater at OU 4. If an alternate adsorption medium is identified that has advantages over GAC, it could also be used. An alternate adsorbent could be used in series with GAC or in place of GAC.

4.1.6.3 **Oxidation** Oxidation involves destroying VOCs in groundwater by changing the oxidation state of target contaminants. This process is also effective for precipitating selected inorganic compounds, such as iron and other multivalent cations. Oxidation is usually not effective for the removal of SVOCs. Oxidation is attractive for use at contaminated sites, as the systems have very low, if any, air emissions.

The following four general categories of oxidation are

- ultraviolet light,
- ozone,
- H_2O_2,
- peroxone, and
- other chemical oxidants.

Ultraviolet Light. Ultraviolet light oxidation (UV/oxidation) is a process that enhances chemical oxidation using the hydroxyl ion by exposing contaminated water to ultraviolet light. In this process, hydrocarbons are broken down into carbon dioxide and water. Oxidizers typically used with UV/oxidation include H_2O_2 and/or ozone. UV/oxidation occurs in a stainless-steel chamber containing

vertically or horizontally mounted ultraviolet lamps. The process is the same for either oxidant (i.e., H_2O_2 or ozone); however, the manner in which the oxidant is introduced into the waste stream may differ. H_2O_2 is blended into the waste stream prior to entering the reactor, and ozone is piped to a sparging tank or chamber and diffused as a gas into the reactor. UV/oxidation typically achieves more than 99 percent destruction efficiency of organic compounds. Pretreatment for removal of naturally occurring inorganics (e.g., iron, lead, or manganese) may be required to prevent fouling of the oxidation system. Treatability studies would be required to determine optimum operating parameters such as pH and chemical dosage if inorganic treatment is required.

Ozone. Ozone is a highly reactive gas that is typically generated on site. It can be used alone, in combination with UV/oxidation, or in combination with H_2O_2 (peroxone oxidation). Alone, it is bubbled as a gas through diffusers into the water. In contrast to other types of chemical oxidants, ozone does not typically create organic residuals that remain in the waste stream after treatment. Ozone is an extremely powerful oxidant because it nonselectively oxidizes compounds dissolved in groundwater. However, ozone does have its limitations. Ozone is very reactive, and it may dissipate rapidly in natural water either by reacting with natural constituents or by spontaneous decomposition. The primary difference between ozone and other chemical oxidants is that ozone does not produce residuals (American Water Works Association, 1990).

H_2O_2. H_2O_2 is a moderately powerful liquid oxidizing agent that is usually shipped to the treatment plant and not generated on site. H_2O_2 with ultraviolet light or with ozone is generally a more effective oxidation process than H_2O_2 or ozone used alone. This process generates hydroxyl radicals that effectively oxidize VOCs and SVOCs (American Water Works Association, 1990).

Peroxone. Peroxone is an oxidation process that uses ozone and H_2O_2 to form hydroxyl radicals, without the use of UV light, to destroy organic contaminants (VOCs and SVOCs). This technology is effective in destroying chlorinated compounds detected in the groundwater at OU 4. Because peroxone does not require the addition of high concentrations of chemical oxidizers and UV light, a significant reduction in cost may be achieved compared to traditional UV/-oxidation. A peroxone treatment system consists of several reaction vessels piped in series, through which the contaminated groundwater is pumped. The reaction vessels are designed to provided the necessary holding time to achieve the required destruction efficiency. H_2O_2 is introduced through metering pumps before each reactor. An inline static mixer is used in the feed line to mix the groundwater and H_2O_2 before entering the reactor. Ozone is sparged into each reaction vessel in a counter-current flow to the groundwater- H_2O_2 flow. Typical resident times for peroxone to treat groundwater contaminated with low concentrations of VOCs is 10 to 20 minutes.

Other Chemical Oxidants. Chlorine is an effective oxidant frequently used for the disinfection of water supplies. It can be added to water in liquid or gas form. Hypochlorous acid (HOCl) is the most effective form of chlorine for oxidation. However, if inappropriately applied, it can combine with organic matter to form trihalomethanes (THMs). THMs are potentially carcinogenic compounds, such as chloroform and bromoform (American Water Works Association, 1990). Other chlorinated compounds that can be used to oxidize organic matter include chloramines and chlorine dioxide. These compounds are generally less

powerful oxidants than HOCl and are not as effective in oxidizing high concentrations of organic compounds (American Water Works Association, 1990).

$KMnO_4$ is another chemical oxidant that has been used to treat organic compounds. $KMnO_4$ is typically fed into a waste stream as either a solid or a liquid solution, prepared on site. $KMnO_4$ can be used to oxidize the majority of organic compounds, as well as selected inorganic compounds. However, similar to other chemical additives, precipitation from the application of $KMnO_4$ requires subsequent treatment and disposal (American Water Works Association, 1990).

Recommendation. When comparing various methods of oxidation, chlorine is typically used for the disinfection of water supplies. The advantage of chlorine is the formation of a chlorine residual. This residual continues to disinfect water through distribution systems or receiving water bodies. Those same residuals can also react with organic matter and form THMs. However, destruction of organic compounds, not disinfection, is the objective of oxidizing groundwater extracted from OU 4. Thus, UV/oxidation with ozone and/or H_2O_2 is a more effective oxidation technique.

Peroxone is particularly effective if the extracted groundwater is high in sediment (UV light not required to destroy the organic contaminants), the technology does not have problems associated with lamp fouling and can potentially be fielded at costs much lower than UV-based processes. Peroxone is also a preferred oxidation process if VC is present in the groundwater. However, peroxone is less effective in treating groundwater with high concentrations of VOCs. Based on the site conditions at OU 4, the benefits of peroxone over traditional UV/oxidation will not be realized.

The remaining oxidation alternatives consist of UV/oxidation with either ozone or H_2O_2. Due to construction and operational costs and operational concerns with an ozone generator, UV/oxidation with H_2O_2 is selected as the representative oxidation technology for subsequent screening.

4.1.6.4 Biological Treatment Biological treatment is a common method of reducing the concentration of organic compounds in wastewater. The same techniques typically applied in wastewater treatment can be applied to groundwater treatment. PCE and TCE typically degrade faster under anaerobic conditions, while cis-DCE and lesser-chlorinated compounds degrade faster under aerobic conditions. Thus, both aerobic and anaerobic conditions (applied individually or sequentially) will be considered for biological treatment for the extracted groundwater. Biological treatment can be further categorized as either of the following processes:

- suspended growth
- attached growth

Suspended Growth. Suspended growth systems include digesters and activated sludge processes. In these systems, the active biomass that metabolizes organic matter is suspended in the liquid and requires subsequent separation. The most critical parameter in the operation of a suspended growth process is the "sludge age." The sludge age is the average cell residence time in the reaction tank, prior to removing and settling the accumulated biomass. A portion of the biomass is then returned to the reaction tank to stimulate continued microbial growth. This is a well demonstrated, effective technology to biodegrade organic matter.

The primary disadvantage is its susceptibility to toxic shocks, residuals created, and O&M required to maintain an effective biomass.

Attached Growth. Attached growth systems include trickling filters, rotating biological contractors, and packed-bed reactors. In these systems, the active biomass is attached to an inert medium and forms a "fixed film" to biologically filter organic matter. Attached growth can be effective in reducing the concentrations of organic matter that pass near the biomass. Frequent cleaning, stimulation, and distribution of the biomass along the surface of the medium are required to maintain effective treatment.

Recommendation. If biological treatment of extracted groundwater is desired, the most appropriate biological method that would achieve treatment levels established in Chapter 3.0 would be the City of Orlando's STP, which is considered a suspended growth biological process. However, as previously discussed, the Orlando STP has placed local limits on the influent water to its plant. These local limits (i.e., treatment levels) were discussed in Paragraph 3.3.3.3.

4.1.6.5 **POTW Treatment (Inorganics Only)** Based on the capability of the STP to treat certain contaminants, it was determined that pretreatment was required only for the VOCs prior to discharge to the STP. Inorganic analytes (antimony, iron, aluminum, zinc, etc.) in groundwater at OU 4 are below the STP industrial user's permit discharge criteria. As a result, extracted groundwater from the antimony plume could be discharged directly to the STP.

4.1.6.6 **Metals Precipitation (Inorganics Only)** Precipitation may be accomplished through a simple pH adjustment or additional reagents to enhance the separation of the dissolved metals. Recent technology developments have resulted in the combined use of reagents and pH buffers to precipitate and chemically convert heavy metals to a mineral form that is insoluble, unleachable, and non-hazardous when tested using the toxicity characteristic leaching procedure or other disposal analytical methods. In particular, a product called Metalock 300™ has been developed by Geo-Chem Technologies to treat waste streams with antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, selenium, silver, thallium, vanadium, and zinc. Only antimony is a COC in the groundwater at OU 4.

Based on the low concentrations of antimony detected in the OU 4 groundwater plume (2 to 20 $\mu g/\ell$) and a FDEP drinking water MCL of 6 $\mu g/\ell$, a bench-scale test would have to be conducted as Metalock 300™ has not been used to treat these low concentrations.

4.1.6.7 **Microfiltration (Inorganics Only)** This heavy metals removal process does not rely on pH adjustment to precipitate out the inorganics, but operates at a neutral pH and passes the metals-contaminated groundwater through a cross-flow microfiltration membrane system. A Neutral Process (NP™) system was developed by Geo-Chem using caustic soda, patented chemical additives, sulfuric acid and ceramic membranes to precipitate out the metals. This process also greatly reduces the quantity of chemicals required to treat the groundwater and produces less sludge, resulting in lower O&M costs and waste disposal costs.

4.1.6.8 **Screening of Technologies for Extracted Groundwater** The NCP recommends a screening of treatment technologies using the general criteria of effective-

ness, implementability, and cost. This evaluation for *ex situ* groundwater treatment technologies for OU 4 considers these criteria, but focuses on issues specific to the technologies selected. These issues include process residuals and air emissions, required O&M activities, and relative effectiveness compared to related technologies. The screening of selected technologies for development of remedial alternatives is presented in Table 4-1. Air stripping and chemical oxidation technologies are retained for further evaluation as *ex situ* groundwater treatment alternatives for organic treatment. Adsorption using GAC and biological treatment is eliminated from further analysis due to excessive cost and maintenance requirements. In addition, the concentration of organic contaminants within the OU 4 source area may be toxic to the biological organisms used to treat the contaminated groundwater.

Treatment technologies for the antimony plume are limited to discharge to the POTW and *ex situ* treatment using either precipitation or microfiltration. Water quality in the antimony plume currently meets the City of Orlando's STP industrial discharge standards such that no prior treatment is required. This technology is therefore retained for further evaluation. Microfiltration can achieve metals precipitation without pH adjustment, and generates a small volume of sludge for disposal and the treated effluent can be discharged into Lake Druid. The design of the system also eliminates the need for mixing tanks and clarifiers thereby reducing costs from traditional metals removal technologies. A bench-scale test will be required to optimize the concentration of chemical additives. *Ex situ* treatment using pH adjustment to precipitate inorganics was eliminated based on the generation of more inorganic sludge for disposal, larger capital and O&M costs and limited experience treating low concentrations of antimony to FDEP drinking water standards.

4.2 DEVELOPMENT OF REMEDIAL ALTERNATIVES. This section presents the development of remedial alternatives to address contaminated groundwater at OU 4. Technologies/process options retained following the screening described in Section 4.1 are combined to form remedial action alternatives. Alternatives are developed to attain the RAOs discussed in Section 3.2, using the following general response actions either singly or in combination: (1) no action; (2) limited action; (3) containment; (4) collection; (5) treatment; or (6) discharge. The NCP requires that a range of remedial alternatives be considered to address contaminated media at the site to satisfy the established RAOs. Development of the no action alternative is required by the NCP in order to provide a baseline for comparison against other remedial alternatives. For the no action alternative, no new remedial action would be executed at the source area; however, the existing IRA would continue to implemented.

One set of remedial alternatives has been developed for the VOC plumes (northern and southern plumes) (Table 4-2) and one set for the antimony plume (Table 4-3).

4.2.1 Remedial Alternatives for VOC Plumes VOC contaminated groundwater is located at and extends from the northern and northwestern end of Building 1100 (northern plume) (Figure 1-3). A second, much lower concentration plume exists at the southern end of Building 1100 originating near the southeast corner of Building 1100 or the southern end of SA 14 (Figure 1-3). Remedial alternatives developed for the VOC plumes will focus on the treatment of PCE, TCE, and cis-DCE, which are the COCs in groundwater.

Table 4-2
Development of Remedial Alternatives for VOC-Contaminated Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Remedial Action Component	Remedial Alternatives			
	V-1 No Action	V-2 Limited Action	V-3 *In Situ* Chemical Oxidation and Enhanced Biodegradation	V-4 Air Sparging/Soil Vapor Extraction and Enhanced Biodegradation
No Action				
Continue IRA operation	X	X	X	X
Five-Year Site Review	X	X	X	X
Limited Action				
Groundwater-Use Restrictions		X	X	X
Groundwater Collection				
Vertical Wells			X	
***In Situ* Treatment**				
Air Sparging/Soil Vapor Extraction with Off-Gas Treatment				X
Chemical Oxidation			X	
Natural Attenuation			X	X
Enhanced Biodegradation (HRC™)			X	X
Recirculation/In-Well Stripping				
***Ex Situ* Treatment**				
Diffused Aeration				
UV/Oxidation				
Discharge				
Surface Water Discharge (Lake Druid)				

See notes at end of table.

Table 4-2 (Continued)
Development of Remedial Alternatives for VOC-Contaminated Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Remedial Action Component	V-5 Recirculation Wells and Enhanced Bioremediation	V-6 *Ex Situ* Diffused Aeration and Discharge to Lake Druid	V-7 *Ex Situ* UV/Oxidation and Discharge to Lake Druid
No Action			
Continue IRA operation	X	X	X
5-Year Site Review	X	X	X
Limited Action			
Groundwater-Use Restrictions	X	X	X
Groundwater Collection			
Vertical Wells		X	X
***In Situ* Treatment**			
Air Sparging/Soil Vapor Extraction with Off-Gas Treatment			
Chemical Oxidation			
Natural Attenuation	X	X	X
Enhanced Biodegradation (HRC™)	X		
Recirculation/In-Well Stripping	X		
***Ex Situ* Treatment**			
Diffused Aeration		X	
UV/Oxidation			X
Discharge			
Surface Water Discharge (Lake Druid)		X	X

Notes: VOC = volatile organic compound.
IRA = Interim Remedial Action.
HRC = Hydrogen Release Compound™.
UV = ultraviolet.

Table 4-3
Development of Remedial Alternatives for Antimony-Contaminated Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Remedial Action Component	Remedial Alternatives			
	A-1 No Action	A-2 Limited Action	A-3 Groundwater Extraction and Discharge to Orlando STP	A-4 Groundwater Extraction, Microfiltration and Discharge to Lake Druid
No Action				
5-Year Site Review	X	X	X	X
Limited Action				
Groundwater-Use Restrictions		X	X	X
Groundwater Collection				
Vertical Wells			X	X
***Ex Situ* Treatment**				
Orlando STP			X	
Microfiltration				X
Discharge				
Surface Water Discharge (Lake Druid)				X

Note: STP = sewage treatment plant.

Except for the no action and limited action alternatives, the remedial alternatives for VOCs involve some form of the following components:

1) Continued operation of the IRA to intercept the downgradient VOC plume and treat groundwater to surface water criteria before discharging to Lake Druid;

2) source remediation for the northern VOC plume along with continued operation of the IRA, followed by MNA to reach MCLs; and

3) source remediation for the southern VOC plume and downgradient plume treatment by enhanced bioremediation and natural attenuation or plume flushing to reach MCLs.

Groundwater monitoring will be performed along the property line for all of the alternatives except no action, to confirm that the plume is confined to Area C.

Each alternative uses various combinations of the available technologies as follow:

Alternative V-1: No Action

- Calls for continued operation of the IRA, essentially the status quo. The IRA would continue to operate until groundwater concentrations in the source are low enough (due to dissolution) that operation of the IRA will no longer be necessary to achieve surface water standards in groundwater.

Alternative V-2: Limited Action

- Identical to Alternative V-1, with the addition of zoning/groundwater-use restrictions to prevent exposure. These restrictions would be maintained until VOC concentrations in groundwater are below the Florida MCL.

- Long-term groundwater monitoring

Alternative V-3: *In Situ* Treatment by Chemical Oxidation and Enhanced Biodegradation

- Inject $KMnO_4$ in the north plume source area. This should reduce VOC concentrations to levels that will naturally attenuate to surface water standards before the plume reaches Lake Druid. The IRA continues to operate to ensure that groundwater between the source area remediation and the IRA is treated. After this downgradient portion of the plume has been treated, the IRA can be shut down. The remaining contamination in the northern VOC source area and the downgradient plume will be allowed to naturally attenuate to MCLs.

- The southern VOC source area and plume will be treated by enhanced biodegradation to MCLs. The IRA will continue to operate until groundwater concentrations have been reduced to levels that will meet surface water standards at the lake without treatment by the IRA.

Alternative V-4: *In Situ* Treatment by Air Sparging and Enhanced Biodegradation

- Uses air sparging to attack the northern VOC plume source area. All other aspects of this alternative are identical to V-3.

Alternative V-5: Recirculation Wells/Enhanced Biodegradation

- Install recirculation wells in the northern VOC plume source area. These wells can be operated until the entire source area has been flushed out and groundwater VOC concentrations no longer exceed MCLs. This option will be designated Option A, or specifically, alternative V-5A. Another option, designated Option B or alternative V-5B, is to only operate the wells until groundwater VOC concentrations have been reduced to levels that will naturally attenuate to surface water standards (and eventually MCLs) before the plume reaches Lake Druid. Both of these scenarios will be evaluated in this FS as alternatives V-5A and V-5B.

  As with the preceding alternatives, the IRA continues to operate to ensure that groundwater between the source area remediation and the IRA is treated. However, because the recirculation wells in the source area discharge treated water that initially may still require treatment by the IRA, the IRA wells will be operated for a longer period of time than for Alternatives V-3 and V-4. These durations will be further discussed and developed in Chapter 5.0. The southern VOC plume will be treated using enhanced bioremediation, as discussed in Alternative V-3.

Alternative V-6: *Ex Situ* Treatment by Air Stripping

- Install vertical groundwater extraction wells in the northern VOC plume source area, and place to also intercept the southern plume. Extracted groundwater will be treated using a diffused aeration system; treated water will be discharged to Lake Druid. As with the source area recirculation wells in Alternative V-5, these wells can be operated to achieve MCLs in the source area (Option A), or only until groundwater VOC concentrations have been reduced to levels that will naturally attenuate to surface water standards (and eventually MCLs) before the plume reaches Lake Druid (Option B). Both of these scenarios will be evaluated in this FS as alternatives V-6A and V-6B. The IRA will continue to operate for a period, as described in Alternative V-3.

  Because the extraction wells will also intercept and treat the southern plume, no additional treatment (such as the enhanced bioremediation described in the previous alternatives) will be required.

Alternative V-7: *Ex Situ* Treatment by UV/oxidation

- Identical to Alternative V-6, except groundwater is treated using a UV/oxidation system. Alternative V-7 will also have two options corresponding to VOC concentration endpoints within the source area, as described for Alternatives V-5 and V-6. Both of these scenarios will be evaluated in this FS as alternatives V-7A and V-7B.

4.2.2 Remedial Alternatives for Antimony Plume The antimony plume is limited to the southeast corner of OU 4 (Figure 1-5). Concentrations above the Florida

drinking water standards of 6 $\mu g/\ell$ are limited to an area approximately 300 feet in diameter. Even though antimony has a tendency to be highly soluble, the small isolated plume at SA 14 seems relatively immobile and stable. Calculations (Appendix I) indicate the antimony plume would be expected to migrate only 0.5 foot per year. Remedial alternatives developed for the antimony plume will focus on the treatment of antimony.

Except for the no action and limited action alternatives, the remedial alternatives for remediation of the antimony plume require groundwater extraction. Because the eastern edge of the southern VOC plume is colocated with the antimony plume (see Subsection 3.2.5), extraction of groundwater would influence the southern plume and interfere with its remediation. Therefore, if active remediation of the antimony plume is required, it will be necessary to delay implementation until the southern VOC plume remediation is complete. For costing purposes, this FS assumes antimony remediation will begin 10 years after VOC plume remediation has begun.

The remedial alternatives developed for the antimony plume include

Alternative A-1: No Action

- No treatment, containment or restricted use of the groundwater.

Alternative A-2: Limited Action

- Zoning/groundwater-use restrictions to prevent exposure. These restrictions would be maintained until antimony concentrations in groundwater are below the Florida MCL.

- Long-term groundwater monitoring.

Alternative A-3: Discharge to the Orlando STP

- Install a vertical groundwater extraction well in the center of the antimony plume. Groundwater will be pumped directly to sanitary sewer without treatment because antimony concentrations in groundwater are less than the discharge limits to the Orlando STP.

Alternative A-4: On-Site *Ex Situ* Treatment

- Install a vertical groundwater extraction well in the center of the antimony plume and treat the extracted groundwater using a microfiltration system (described in Chapter 5.0) to remove antimony. The treated water will then be discharged to Lake Druid. This alternative is proposed because of the high cost of discharging water to the Orlando STP.

CHAPTER 5.0

5.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

This chapter presents a detailed description and analysis of the remedial alternatives that address contaminated groundwater at OU 4 at NTC, Orlando. Section 5.1 presents remedial alternatives for the VOC plume and Section 5.2 presents the remedial alternatives for the antimony plume. A detailed analysis is performed to provide decision makers with sufficient information to select the appropriate remedial alternatives for groundwater at OU 4. The detailed analysis has been conducted in accordance with CERCLA Section 121, the NCP, and USEPA RI/FS guidance (USEPA, 1988).

The detailed evaluation of each remedial alternative includes the following:

- a detailed description of the alternative, emphasizing the application of the technology or actions; and
- an analysis of the alternative against seven of the nine CERCLA criteria.

The remedial alternatives are examined with respect to the requirements stipulated by CERCLA and factors described in the USEPA RI/FS guidance document (USEPA, 1988). The nine criteria from the RI/FS guidance document are

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, and volume of contaminants through treatment;
- short-term effectiveness;
- implementability;
- cost;
- State acceptance; and
- community acceptance.

There may be some redundancies when considering costs for the entire site. For example, each VOC and antimony plume treatment alternative includes a cost for a 5-year site review. Combined treatment costs for a given VOC and antimony plume alternative do not necessarily represent remedial costs for the entire site since the total cost for each alternative is for comparative purposes only. The State (FDEP) and USEPA have participated in the review of this document through the NTC, Orlando Partnering Team, and have concurred with the issuance of this FS. Therefore, the only criterion not specifically addressed by this FS is community acceptance. Community acceptance will be addressed upon receipt of public comments on the FS and Proposed Plan (USEPA, 1988). The Record of Decision will address community acceptance in its responsiveness summary, which is a response to comments received during a public comment period for the Proposed Plan. The detailed analysis presented in this FS presents the evaluation of the first seven criteria in the alternative evaluation process. Table 5-1 outlines the specific elements considered for these seven criteria.

5.1 DETAILED ANALYSIS OF VOC PLUME REMEDIAL ALTERNATIVES. This section presents the detailed description and analysis of remedial alternatives that address the

Table 5-1
Criteria for Evaluation of Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Factors	Criteria to Consider
Overall protection of human health and the environment	How risks are eliminated, reduced, or controlled. Short-term or cross-media effects.
Compliance with ARARs	Compliance with chemical-specific ARARs. Compliance with location-specific ARARs. Compliance with action-specific ARARs.
Long-term effectiveness and permanence	Magnitude of residual risk. Adequacy of controls. Reliability of controls.
Reduction of mobility, toxicity, and volume	Treatment process and remedy. Amount of hazardous materials destroyed or treated. Reduction of mobility, toxicity, or volume through treatment. Irreversibility of treatment. Type and quantity of treatment residual.
Short-term effectiveness	Protection of community during remedial action. Protection of workers during remedial action. Environmental effects. Time until RAOs are achieved.
Implementability	Ability to construct technology. Reliability of technology. Ease of undertaking additional remedial action, if necessary. Coordination with other agencies.
Cost	Capital cost. Operation and maintenance cost. Total present worth of alternative.

Notes: ARARs = applicable or relevant and appropriate requirements.
RAO = remedial action objective.

contamination in the northern and southern plumes at OU 4. The remedial alternatives that were developed for these plumes requiring remedial action were discussed in Subsection 4.2.1. For all of the alternatives, except the no action alternative, groundwater monitoring along the property line will be conducted to confirm that the plume is confined to Area C. The costs associated with this component are not included since they are not significant relative to the existing costs in this feasibility study for each alternative. Issues specific or unique to each plume will be addressed with each alternative. The remainder of this subsection presents the detailed analysis of remedial Alternatives V-1 through V-7.

5.1.1 Alternative V-1: No Action Typically, the no action alternative is defined as doing no response and no long-term monitoring of the contaminated groundwater. However, as discussed in detail in Sections 2.3 and 4.1, an IRA is currently operating downgradient of the source area at OU 4. Because the IRA is an ongoing action, the continued operation will be retained as a component of the no action alternative for comparison as a baseline condition. A description of this alternative is presented in Paragraph 5.1.1.1 and analysis of this alternative against the seven USEPA criteria is presented in Paragraph 5.1.1.2.

5.1.1.1 **Detailed Description** In accordance with the NCP, the no action alternative is used as a baseline for comparison against alternatives that incorporate remedial actions. The no action alternative would include the following components:

- continue IRA operation
- downgradient groundwater/surface water monitoring
- 5-year site reviews

Continue IRA Operation. As discussed in detail in Section 2.3, an IRA is currently operating downgradient of the source area between Port Hueneme Avenue and the shore of Lake Druid. The IRA consists of two extraction wells and an air stripper. VOC contaminated groundwater recovered by the extraction wells is treated by the air stripper prior to the groundwater discharging into Lake Druid. It has been assumed in this FS that the IRA will continue to operate until the extracted groundwater is less than five times the FDEP surface water standards. Natural attenuation studies have shown that a natural reduction in VOC concentration of five times can be expected. Operation of the IRA system also includes groundwater monitoring for the COCs (VOCs) in the treatment area. Details of the groundwater monitoring plan are discussed in the IRA conceptual design (ABB-ES, 1997f).

Downgradient Groundwater/Surface Water Monitoring. Operation of the IRA system also includes groundwater and surface water monitoring between the IRA extraction wells and Lake Druid to assess the effectiveness of the treatment system and to verify that the VOC concentrations are reduced to surface water standards prior to the groundwater discharging into Lake Druid. Details of the groundwater sampling program in the extraction well area are also provided in the IRA conceptual design (ABB-ES, 1997f).

Five-Year Site Reviews. Because contaminated groundwater upgradient of the IRA would not be addressed if this alternative were implemented the Navy, USEPA, and FDEP must conduct a 5-year review of site conditions and determine that the operation of this alternative remains appropriate. Site reviews would occur

every five years until the action levels (i.e., Florida surface water and drinking water standards) are attained in the source areas of both the northern and southern VOC plumes and in downgradient areas where the two plumes merge before discharging to Lake Druid. Reviews would consist of assessing changes in site conditions (e.g., construction or demolition of buildings overlying the plumes, receptors, or qualitative risks) and assessing the field data collected from the ongoing IRA. The appropriateness of this alternative would be compared to other remedial alternatives to confirm that this alternative was still the most appropriate selection for OU 4.

5.1.1.2 **Technical Criteria Analysis** This paragraph provides the technical criteria analysis of the no action alternative compared against the seven criteria in Table 5-1.

Overall Protection of Human Health and the Environment. The risk assessment for OU 4 predicted unacceptable risks to human health associated with contaminants in the surface water and groundwater for the exposure scenarios evaluated (ingestion and dermal exposure to surface water for an existing aggregate trespasser, and groundwater ingestion and VOC inhalation for future residential receptors). Based on this assessment, a no action alternative, which includes the IRA component, would eventually provide protection from human exposure to surface water (by halting migration of contaminated groundwater to surface water), but would not protect potential future residential receptors from groundwater ingestion and VOC inhalation.

Compliance with ARARs. The chemical-specific ARARs identified for the groundwater at OU 4 are the Florida surface water and drinking water standards. Organic compound exceedances currently exist for PCE, TCE, and cis-DCE. The no action alternative would eventually comply only with the Florida surface water standards downgradient of the IRA. Although natural attenuation processes (including dilution) may eventually reduce contaminant concentrations upgradient of the IRA, this process will likely require decades before contaminant concentrations in the source area meet Florida MCLs.

Long-Term Effectiveness and Permanence. The IRA pump and treat technology will permanently remove contaminants from the groundwater at OU 4. However, residual risk in the source area and downgradient groundwater (outside the area treated by the IRA) will likely remain without source area treatment and the reduction of groundwater contaminants to meet FDEP drinking water standards.

Administrative actions proposed for this alternative (5-year site reviews) would not provide treatment of existing contamination, or prevent possible human exposure or consumption of groundwater. However, these reviews would assess the field data collected from the ongoing IRA to ensure that the recirculating wells continue to treat VOCs in groundwater that exceed Florida surface water standards from migrating Lake Druid.

Reduction of Toxicity, Mobility, and Volume Through Treatment. The no action alternative would reduce the toxicity, mobility, and volume of VOCs in OU 4 groundwater. This is accomplished downgradient in the plume by the IRA which would continue to act as a barrier by intercepting the groundwater. VOCs would be physically removed (stripped) from the groundwater by the air stripper prior to discharge of the groundwater to the City of Orlando POTW. Emission of the off-gas from the air stripper is in compliance with Florida air quality

requirements (less than 13.7 pounds per day [lbs/day]), but does not destroy the contaminants. Based on the continued operation of the IRA system, the small volume of vapor emissions would not require collection or treatment. However, vapor emissions would be monitored as part of the treatment system monitoring to ensure compliance with the FDEP air regulations.

Short-Term Effectiveness. This remedial alternative will achieve only one of the RAOs by treating a portion of the downgradient plume using the IRA system to reduce VOC concentrations to Florida surface water standards. Because there would be no treatment of the source area, remedial duration for Alternative V-1 to meet drinking water standards is expected to be indefinite and its cost estimate is based on 30 years of implementation. Although there would be minimal exposure to workers operating the IRA wells, groundwater-use restrictions would not be implemented to protect future residential receptors from ingesting the groundwater. The residuals produced by the air stripper (vapor emissions) are expected to be negligible, not exceeding 0.2 lbs/day (ABB-ES, 1998b), far below the FDEP limit of 13.7 lb/day. Air emissions would also continue to be monitored to ensure they do not exceed FDEP air quality standards.

Implementability. The IRA system is already constructed and is operating at the site. Building 1100 is currently vacant so treatment system operation does not interfere with any ongoing operations at NTC, Orlando. The other activities, including groundwater and surface water monitoring and 5-year site reviews, are easily implemented.

Cost. The present worth cost for Alternative V-1 is estimated to be $861,140. A breakdown of these costs is presented in Table 5-2. This estimate includes the cost of operating the IRA wells for 30 years, conducting groundwater monitoring between the IRA wells and Lake Druid, and performing 5-year site reviews over a 30-year period, as suggested by the USEPA guidance (USEPA, 1988). The detailed breakdown for the cost estimate for the no action alternative is presented in Appendix D. CERCLA guidance also suggests that the cost of all alternatives presented in the FS should be accurate within +50 percent to -30 percent of the estimated cost.

5.1.2 Alternative V-2: Limited Action Under this alternative, similar components of the no action alternative would be implemented to meet Florida surface water standards plus administrative actions would be enforced to reduce the risk to human receptors posed by consumption of VOC-contaminated groundwater at OU 4. A description and technical assessment of this alternative are presented in Paragraph 5.1.2.1 and Paragraph 5.1.2.2, respectively.

5.1.2.1 Detailed Description Under this alternative, institutional controls in the form of groundwater-use restrictions would be implemented to restrict the use of the groundwater in the Building 1100 area while the IRA would continue operating. The limited action alternative would include the following components:

- implement groundwater-use restrictions
- continue IRA operation
- downgradient groundwater/surface water monitoring
- 5-year site reviews

Table 5-2
Cost Summary for Alternative V-1: No Action

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item		Cost
DIRECT COSTS		
		$0
	Total Direct Cost	$0
INDIRECT COSTS		
		$0
	Total Indirect Cost	$0
	Total Capital Cost (Direct + Indirect)	$0
OPERATION AND MAINTENANCE (O&M) COSTS (30-year period)		
IRA Wells (30 years)		
	Present Worth - System Operation (6%, 30 years)	$586,411
	Present Worth - Groundwater Monitoring (6%, 30 years)	$129,804
5-Year Site Review		
	Present Worth - 5-Year Site Reviews (6%, 30 years)	$44,491
	Present Worth - Groundwater Monitoring (6%, 30 years)	$22,148
	Total O&M Cost (present worth)	$782,854
	Total Capital and O&M Cost	$782,854
	Contingency (10%)	$78,285
	Total Cost of Alternative V-1: No Action	$861,140

Notes: IRA = Interim Remedial Action.
% = percent.

Groundwater-Use Restrictions. Land-use plans and property deeds for land in the vicinity of Building 1100 and downgradient property to Lake Druid would be annotated to indicate that groundwater extraction for potable use in this area may pose an unacceptable health risk if consumed without treatment. The annotation would reference the RI, baseline RA, FS, Proposed Plan, and ROD. The agency currently responsible for administering the well installation permit program will be formally requested not to issue permits for installation of potable wells screened within the surficial aquifer. Planning agencies, permitting agencies, and owners of property affected by OU 4 would be reminded annually of the groundwater-use restrictions. These restrictions would be removed only when a 5-year site review indicates, based on the groundwater monitoring program results, that FDEP drinking water standards have been achieved.

Continue IRA Operation. The IRA would continue operation as discussed in Alternative V-1. For this alternative, it has been assumed that the IRA will continue to operate until the extracted groundwater is less than five times the FDEP surface water standards.

Downgradient Groundwater and Surface Water Monitoring. Groundwater and surface water monitoring between the IRA wells and Lake Druid would be performed as discussed in Alternative V-1 to assess the effectiveness of IRA treatment and to verify that the VOC concentrations in groundwater are reduced to surface water standards prior to discharge into Lake Druid. In addition to this monitoring, Alternative V-2 would include monitoring existing wells in the source areas of the northern and southern plumes. These data would be reviewed during the 5-year site reviews and used to assess plume stability and the need for continued groundwater-use restrictions.

Five-Year Site Reviews. Since contaminated groundwater upgradient of the IRA would not be addressed if this alternative were implemented, the Navy, USEPA, and FDEP would conduct 5-year reviews of site conditions and determine that the implementation of groundwater-use restrictions and continued operation of the IRA remains appropriate. Details of these site reviews are discussed in Alternative V-1.

5.1.2.2 **Technical Criteria Analysis** This paragraph provides the technical criteria analysis of Alternative V-2 compared against the seven criteria in Table 5-1.

Overall Protection of Human Health and the Environment. The risk assessment for OU 4 predicted unacceptable risks to human health associated with contaminants in the surface water and groundwater for the existing and future exposure scenarios evaluated (HLA, 2001). Based on this assessment, the limited action alternative, which includes groundwater-use restrictions and continued operation of the IRA, would eventually provide protection from human exposure to surface water (by halting migration of contaminated groundwater to surface water) and would protect future residential receptors from potential groundwater ingestion and VOC inhalation by implementing groundwater-use restrictions.

Compliance with ARARs. The chemical-specific ARARs identified for the groundwater at OU 4 are the Florida surface water and drinking water standards. Organic compound exceedances currently exist for PCE, TCE, and cis-DCE. The limited action alternative would comply only with the Florida surface water

standards downgradient of the IRA. Although natural attenuation processes (including dissolution) may eventually reduce contaminant concentrations upgradient of the IRA, this process will likely require decades before contaminant concentrations in the source area meet Florida MCLs.

Long-Term Effectiveness and Permanence. The IRA pump and treat technology permanently removes volatile organic contaminants from groundwater.

Administrative actions proposed for this alternative (groundwater-use restrictions) would prevent possible human exposure and consumption of contaminated groundwater. Five-year site reviews would assess the field data collected from the ongoing IRA to ensure that the system continues to treat VOCs in groundwater that exceed Florida surface water standards before discharging to Lake Druid.

Reduction of Toxicity, Mobility, and Volume Through Treatment. The limited action alternative would reduce the toxicity, mobility, and volume of VOCs in the OU 4 groundwater. This would be accomplished in the downgradient plume by the IRA system, which intercepts and treats VOC contaminated groundwater. The VOCs are physically removed (stripped) from the groundwater by the air stripper prior to discharge of the groundwater to the City of Orlando POTW. Emission of the off-gas from the air stripper is in compliance with Florida air quality requirements (less than 13.7 lbs/day), but the contaminants are not destroyed. Based on the continued operation of the IRA system, the small volume of vapor emissions would not require collection or treatment. However, vapor emissions would be monitored as part of the treatment system monitoring to ensure compliance with the FDEP air regulations.

Short-Term Effectiveness. This remedial alternative will protect human health over the short-term. The IRA system intercepts and treats the downgradient VOC plume. Groundwater-use restrictions would be implemented to protect future residential receptors from exposure to the contaminated groundwater. Because there would be no treatment of the source area, the remedial duration for Alternative V-2 is expected to be indefinite. However, the cost estimate for this alternative is based on 30 years of implementation. There would be minimal exposure to workers operating the IRA system over this 30-year period. The residuals produced by the air stripper (vapor emissions) are expected to be negligible, not exceeding 0.2 lb/day (ABB-ES, 1998b), far below the FDEP limit of 13.7 lb/day. Air emissions would also continue to be monitored to ensure they do not exceed FDEP air quality standards.

Implementability. The IRA system is already constructed and is operating at the site. Building 1100 is currently vacant; therefore, treatment system operation does not interfere with any ongoing operations at NTC, Orlando. The other activities, groundwater-use restrictions, groundwater and surface water monitoring, and 5-year site reviews, are easily implemented.

Cost. The present worth cost for Alternative V-2 is estimated to be $897,763. A breakdown of these costs is presented in Table 5-3. This estimate includes the cost of operating and maintaining the IRA system and associated groundwater monitoring between the wells and the lake, implementing groundwater-use restrictions for the entire VOC plume at OU 4 and performing 5-year site reviews over a 30-year period (USEPA, 1988). The detailed breakdown for the cost estimate for the limited action remedial alternative is presented in Appendix D.

Table 5-3
Cost Summary for Alternative V-2: Limited Action

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Total Direct Cost	$10,000
INDIRECT COSTS	
Health and Safety	500
Administration and Permitting	1,000
Engineering and Design	4,000
Construction Support Services	1,000
Total Indirect Cost	$6,500
Total Capital Cost (Direct + Indirect)	$16,500
OPERATION AND MAINTENANCE (O&M) COSTS (30-year period)	
IRA Wells (30 years)	
Present Worth - System Operation (6%, 30 years)	$586,411
Present Worth - Groundwater Monitoring of IRA Area (6%, 30 years)	$146,597
5-Year Site Reviews	
Present Worth - 5-Year Site Reviews (6%, 30 years)	$44,491
Present Worth - Groundwater Monitoring (6%, 30 years)	$22,148
Total O&M Cost (present worth)	$799,648
Total Capital and O&M Cost	$816,148
Contingency (10%)	$81,615
Total Cost of Alternative V-2: Limited Action	$897,763

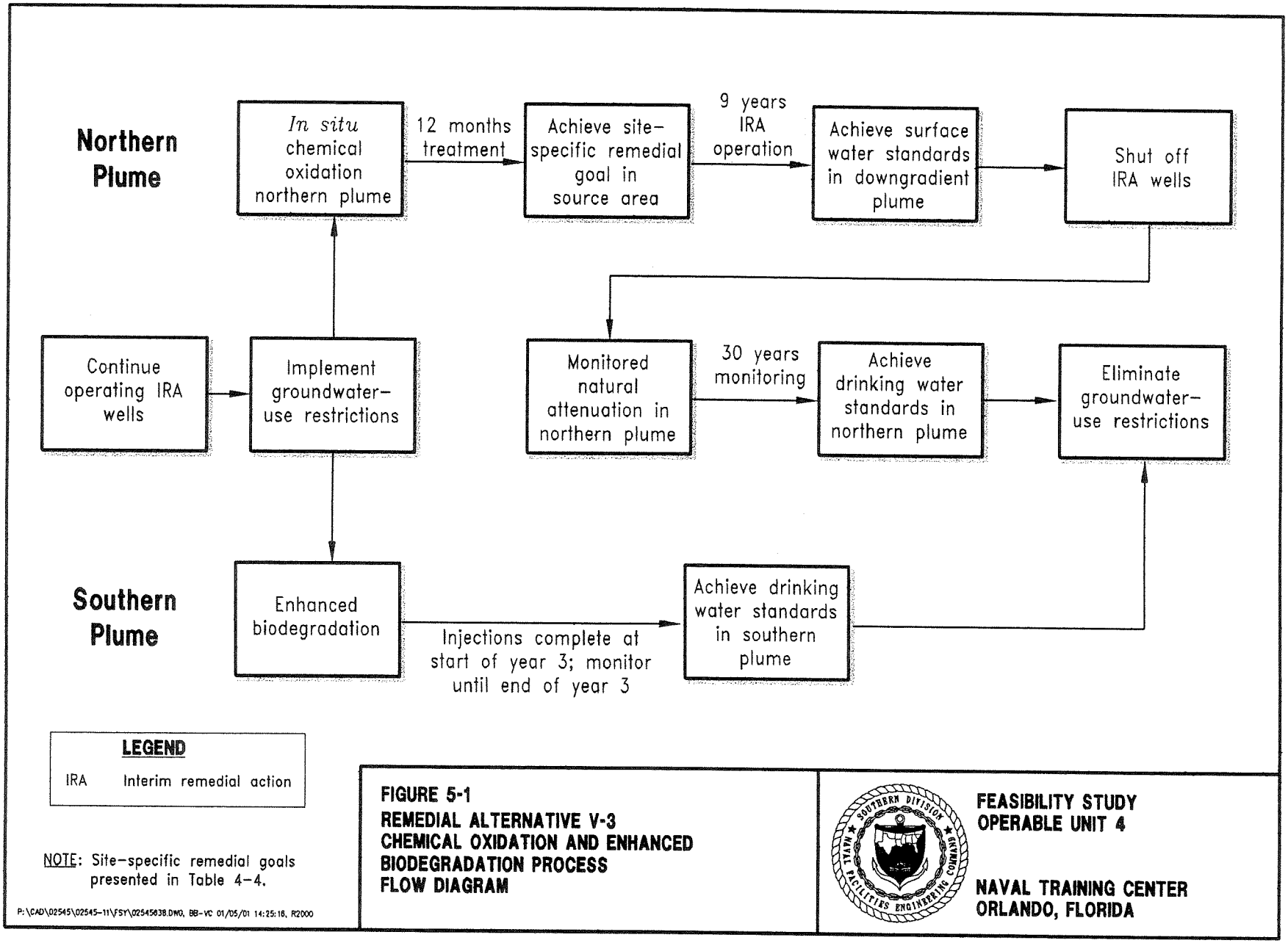
Notes: IRA = Interim Remedial Action.
% = percent.

5.1.3 Alternative V-3: Chemical Oxidation and Enhanced Biodegradation This alternative consists of injecting $KMnO_4$ into the groundwater at the source area of the northern plume at OU 4 to chemically destroy the chlorinated compounds in dissolved and nonaqueous phases. This alternative also entails injecting a lactic acid producing compound (HRC™) within the southern plume to enhance ongoing natural biodegradation of chlorinated compounds. The IRA continues operating to treat groundwater in the downgradient plume west of the source area remediation. After completion of the chemical oxidation in the source area, MNA will be used to achieve surface water standards at Lake Druid and eventually MCLs. A detailed description of this alternative is presented in Paragraph 5.1.3.1 and technical assessment is presented in Paragraph 5.1.3.2. Vendor information used to develop this alternative is included in Appendix E.

5.1.3.1 Detailed Description This alternative, chemical oxidation and enhanced biodegradation, is intended to address VOC contamination within the source areas of the northern and southern plumes at OU 4, reducing concentrations of PCE, TCE, and cis-DCE to Florida surface water standards for discharge into Lake Druid and eventually to Florida drinking water standards (see Table 3-3). As will be discussed in further detail in the following sections, it is anticipated that chemical oxidation within the northern plume source area will be able to reduce source area groundwater concentrations to site-specific standards, based on the results of a field pilot test conducted at OU4. When combined with MNA, it is sufficient to meet the Florida surface water standards at Lake Druid. The downgradient portion of the northern plume will continue to be treated by operating the existing IRA wells until the downgradient groundwater (between Port Hueneme Avenue and Lake Druid, see Figure 2-1) has met Florida surface water standards and then MNA will be used to reduce the contaminant levels down to drinking water standards. Enhanced biodegradation within the southern plume is anticipated to be able to reduce VOC contamination to meet Florida drinking water standards.

A process flow diagram depicting how this remedial alternative will meet the overall remedial objectives for the northern and southern plumes is shown on Figure 5-1. *In situ* chemical oxidation treatment will be used to remediate the source area of the northern plume. Contaminant concentrations will be reduced to a site-specific remedial goal, defined as the concentration at which MNA would be capable of meeting surface water standards (8 $\mu g/\ell$ for PCE) by the time groundwater naturally discharges into Lake Druid. Based on a previous natural attenuation study of OU 4, the contaminant concentration decreases by a factor of 3 to 10 within the groundwater plume between Building 1100 and Lake Druid (HLA, 1998b). With a Florida surface water standard of 8 $\mu g/\ell$ for PCE and an attenuation reduction factor of 3 to 10, PCE concentrations in groundwater leaving the source area must be in the range of 24 to 80 $\mu g/\ell$. It is estimated that chemical oxidation treatment in the source area will take 1 year (see Appendix G, relevant material is attached) to meet this site-specific RGO. Upon completion of the 1-year treatment period, the remaining low-level contaminants within the source area plume would be treated to surface water standards using MNA. For estimating purposes, the total duration for remediation of the VOC contamination (both the northern and southern plumes) using this alternative will be 40 years.

The downgradient VOC plume would be addressed by the existing IRA as discussed previously. It is anticipated that it will require approximately 10 years before the untreated zone of contaminated water (located between the downgradient


Northern Plume
In situ chemical oxidation northern plume
12 months treatment
Achieve site-specific remedial goal in source area
9 years IRA operation
Achieve surface water standards in downgradient plume
Shut off IRA wells
Continue operating IRA wells
Implement groundwater-use restrictions
Monitored natural attenuation in northern plume
30 years monitoring
Achieve drinking water standards in northern plume
Eliminate groundwater-use restrictions
Southern Plume
Enhanced biodegradation
Injections complete at start of year 3; monitor until end of year 3
Achieve drinking water standards in southern plume
LEGEND
IRA Interim remedial action
NOTE: Site-specific remedial goals presented in Table 4-4.
P:\CAD\02545\02545-11\FSY\02545038.DWG, BB-VC 01/05/01 14:25:16, R2000
FIGURE 5-1
REMEDIAL ALTERNATIVE V-3
CHEMICAL OXIDATION AND ENHANCED
BIODEGRADATION PROCESS
FLOW DIAGRAM
FEASIBILITY STUDY
OPERABLE UNIT 4
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

extraction well of the chemical oxidation system/HRC™ injection points and the IRA wells) is treated by the IRA wells (see Appendix I). The IRA wells will be shut down once this zone of water is treated to surface water standards. The IRA duration estimate also assumes that no significant VOC mass (greater than 24 to 80 $\mu g/\ell$) migrates beyond the source area once treatment of the source area with $KMnO_4$ begins. VOCs from the source area will be captured by extraction wells and treated using $KMnO_4$.

Chemical oxidation will likely affect subsurface conditions within the source area and may temporarily cause cessation of biological activity. Treatment byproducts of chemical oxidation at neutral pH are carboxylic acids, manganese dioxide (MnO_2), chloride, and water. The effects of chemical oxidation will likely decrease biological activity within the source area, but will not significantly affect natural attenuation downstream of the source area.

Although natural attenuation should achieve surface water standards prior to the plume discharging into the lake, MCLs will not be achieved until dissolution of any remaining unoxidized source has occurred. For estimation purposes, MNA will begin once the IRA wells have been shut down (estimated 10-year duration) and will require 30 years to achieve MCLs, although the duration could potentially be longer or shorter. Should MNA not readily achieve surface water standards, the individual IRA wells could be restarted to ensure continued compliance with Florida surface water standards for groundwater discharging into the lake, or an enhanced biodegradation program could be implemented for the northern plume. Neither of these two contingent actions have been evaluated for this alternative.

Figure 5-1 also depicts how enhanced biodegradation using HRC™ will be used to remediate the southern plume to drinking water standards. It is anticipated that contaminant concentrations will be reduced to Florida drinking water standards from the source area down to the IRA wells within a 3-year period (Appendix F). As with the northern plume, should enhanced biodegradation not readily achieve surface water standards in the southern plume, the individual IRA wells could be restarted to ensure continued compliance with Florida surface water standards for groundwater discharging into the lake.

Major components of this alternative include the following:

- treatability studies
- groundwater-use restrictions until RAOs are achieved
- Florida underground injection control variance for $KMnO_4$ injection
- $KMnO_4$ injection and extraction wells (northern plume)
- $KMnO_4$ storage and metering system
- chemical oxidation monitoring points
- HRC™ injection (southern plume)
- enhanced biodegradation monitoring network (southern plume)
- phase-out operation of IRA system
- natural attenuation monitoring
- source area soil sampling
- 5-year site reviews

The treatment process and conceptual layout for the chemical oxidation component of this alternative (northern plume) are depicted on Figures 5-2 and 5-3. The treatment process and conceptual layout for implementing enhanced biodegradation (southern plume) are depicted on Figures 5-4 and 5-5.

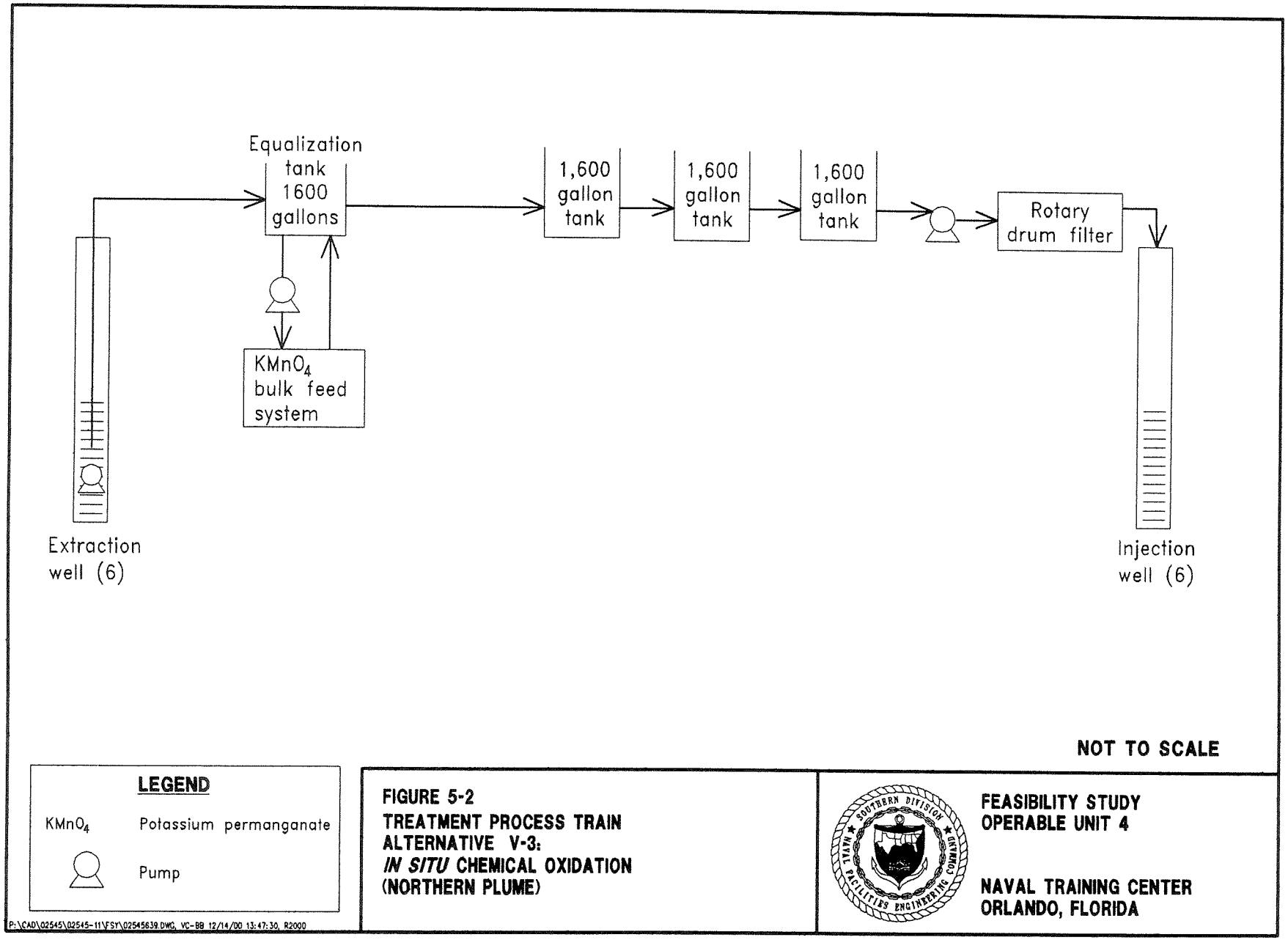


FIGURE 5-2
TREATMENT PROCESS TRAIN
ALTERNATIVE V-3:
***IN SITU* CHEMICAL OXIDATION**
(NORTHERN PLUME)

FEASIBILITY STUDY
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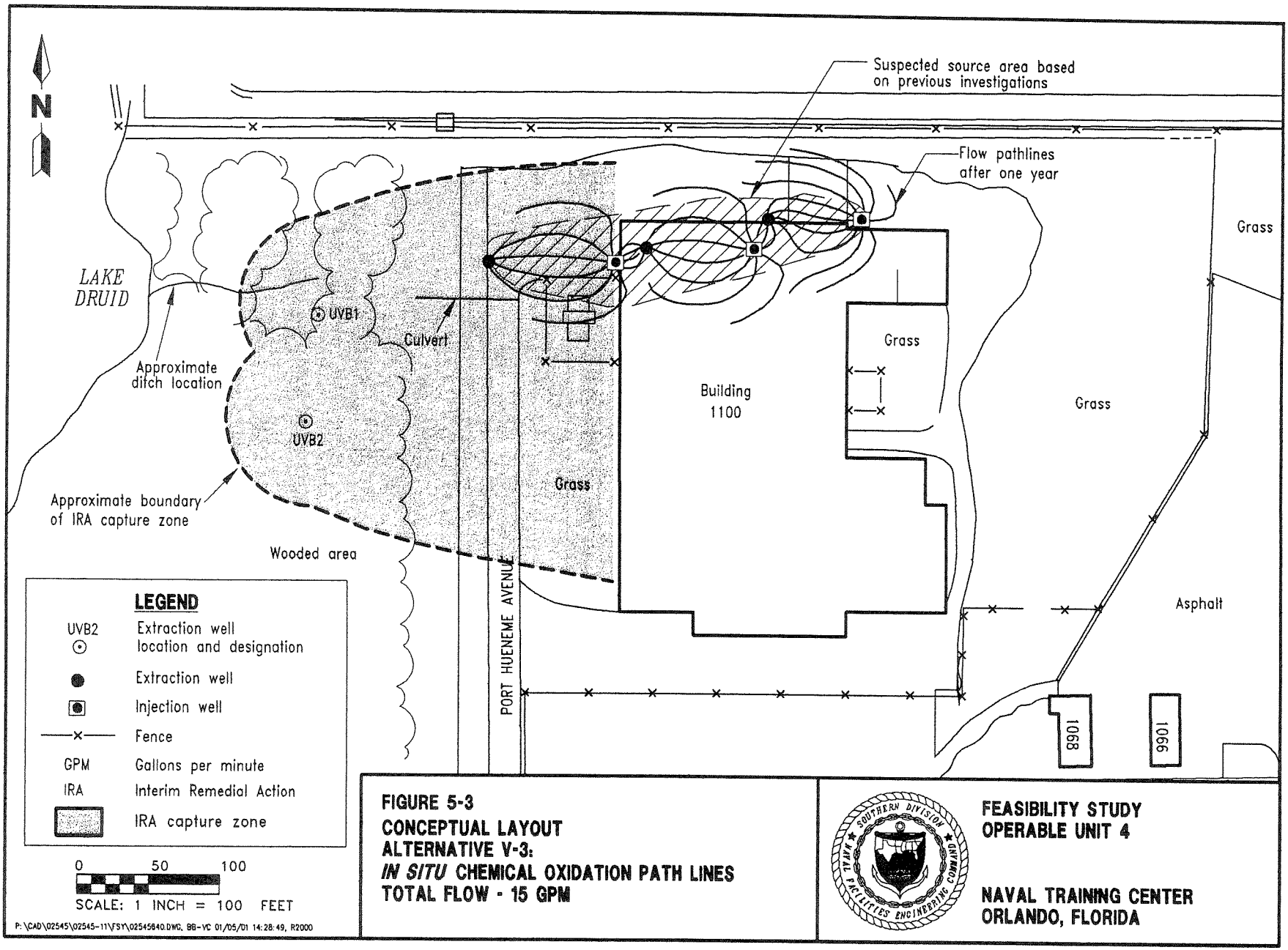
N
Suspected source area based on previous investigations
Flow pathlines after one year
LAKE DRUID
UVB1
Culvert
Approximate ditch location
UVB2
Approximate boundary of IRA capture zone
Wooded area
Grass
Building 1100
Grass
Grass
Grass
PORT HUENEME AVENUE
Asphalt
1068
1066
LEGEND
UVB2 Extraction well location and designation
Extraction well
Injection well
Fence
GPM Gallons per minute
IRA Interim Remedial Action
IRA capture zone
0 50 100
SCALE: 1 INCH = 100 FEET
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FIGURE 5-3
CONCEPTUAL LAYOUT
ALTERNATIVE V-3:
IN SITU CHEMICAL OXIDATION PATH LINES
TOTAL FLOW - 15 GPM
FEASIBILITY STUDY
OPERABLE UNIT 4
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

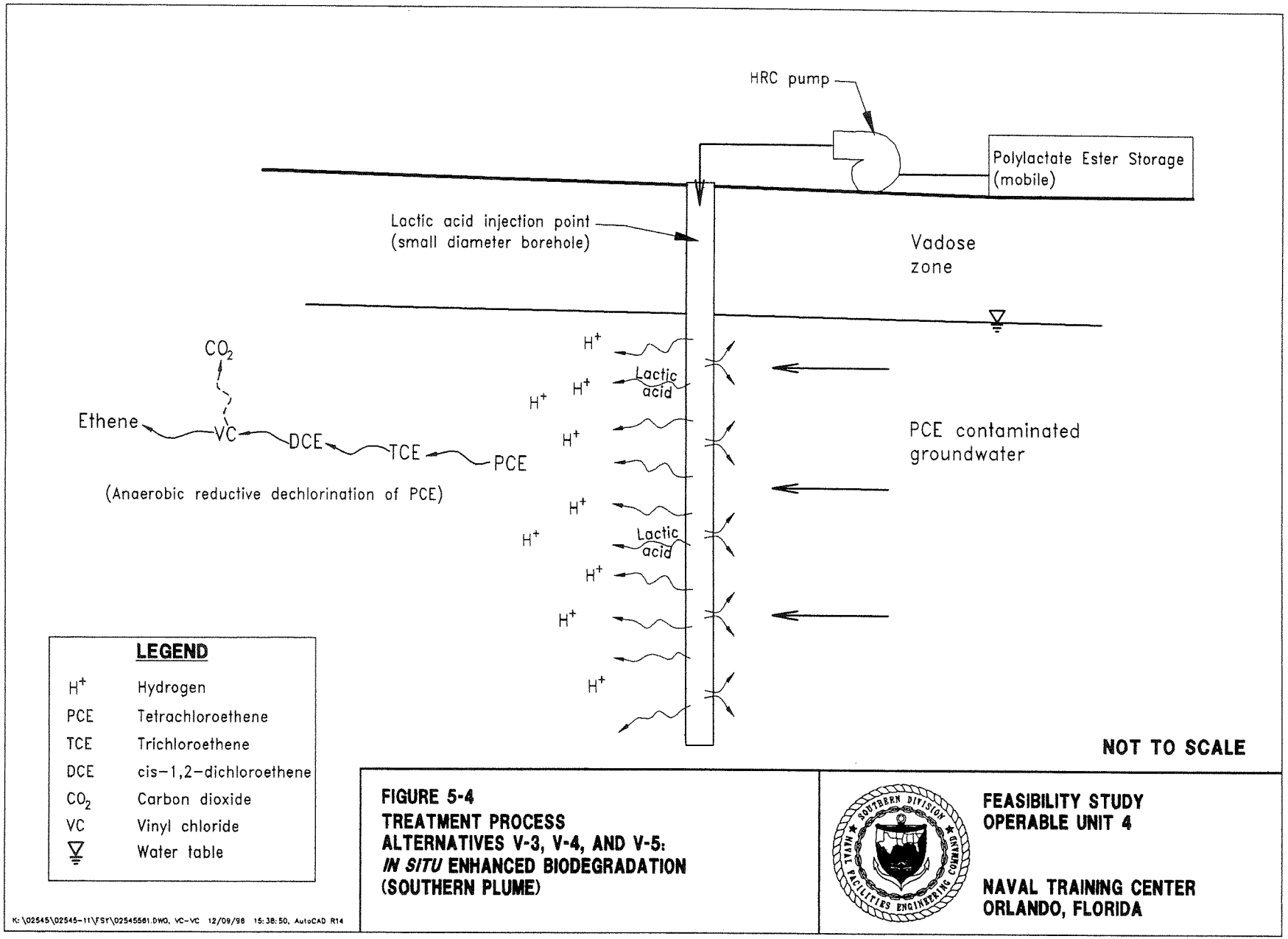

FIGURE 5-4
TREATMENT PROCESS
ALTERNATIVES V-3, V-4, AND V-5:
***IN SITU* ENHANCED BIODEGRADATION**
(SOUTHERN PLUME)

FEASIBILITY STUDY
OPERABLE UNIT 4

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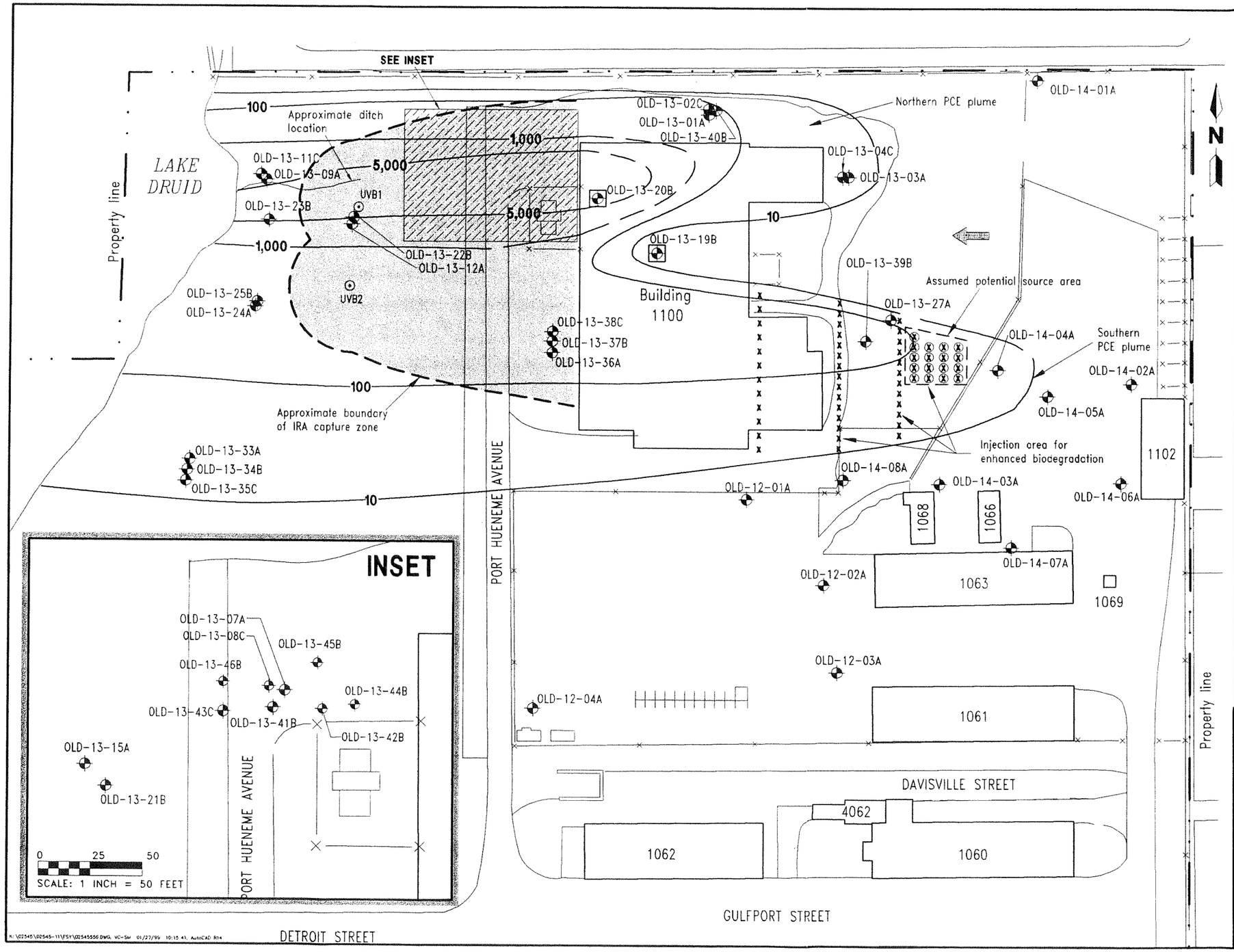

LEGEND

- OLD-14-05A — Monitoring well location and designation
- OLD-13-19B — Microwell location and designation
- UVB2 — Extraction well location and designation
- Hydrogen injection points (one-time application)
- Hydrogen injection points (multiple applications)
- 10 — VOC contour (in micrograms per liter, dashed where inferred)
- IRA — Interim Remedial Action
- PCE — Tetrachloroethene
- VOC — Volatile organic compound
- Fence
- Groundwater flow direction
- IRA capture zone

0 50 100
SCALE: 1 INCH = 100 FEET

FIGURE 5-5
CONCEPTUAL LAYOUT
ALTERNATIVES V-3, V-4, AND V-5:
***IN SITU* ENHANCED BIODEGRADATION**
(SOUTHERN PLUME)

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
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Treatability Studies. A pilot study was conducted from February to July 2000 to evaluate *in situ* chemical oxidation of the source area within the northern VOC plume using $KMnO_4$ and is described in detail in Subsection 1.5.3, the final $KMnO_4$ workplan (HLA, 1999), and an interim letter report issued in July 2000. A final pilot study report will be issued in late December 2000 or early January 2001. This study established that $KMnO_4$ effectively reduces VOC source area concentrations and allowed improved quantification of system design parameters and costs.

In order to fully implement this alternative at OU 4, a pilot-scale test would be necessary to evaluate the enhanced biodegradation component within the southern VOC plume. This would involve the injection of HRC™ in a series of points upgradient of the existing monitoring wells OLD-13-39B and OLD-13-27A (Figure 5-5), and monitoring for a period of approximately 6 months. The pilot study would help determine the feasibility and effectiveness of enhanced biodegradation and provide design and cost information for full-scale application (e.g., data collected from the test would assist in refining the estimated quantity of HRC™ needed for full-scale implementation and duration of treatment).

Groundwater-Use Restrictions. Paragraph 5.1.2.1 presents a detailed description of the groundwater-use restrictions proposed for OU 4. In addition to these details, the following discussion describes the duration of the groundwater-use restrictions as they support the remedial Alternative V-3.

As previously discussed, this FS assumes 40 years will be required for Alternative V-3 to achieve all RAOs. Because of this duration, institutional controls in the form of groundwater-use restrictions will be required to minimize potential risk to future residents from using groundwater as a drinking water source. Groundwater-use restrictions will be implemented prior to chemical oxidation and enhanced biodegradation remedial activities. These restrictions will be continued throughout the operation of the IRA and use of MNA until contaminant levels meet MCLs in both the northern and southern plumes. Once the entire groundwater plume has been treated to Florida drinking water standards, the groundwater-use restrictions will be eliminated.

$KMnO_4$ Injection and Extraction Wells (Northern Plume). A numerical, three dimensional groundwater flow model (Visual MODFLOW or VMODFLOW) was used to design the $KMnO_4$ injection system. Visual MODFLOW is widely used by consulting firms, educational institutions, and government agencies, such as the USGS and USEPA. Figure 5-3 illustrates the results of the VMODFLOW simulation.

Three groundwater circulation cells will be required to adequately treat the source area. Each circulation cell will consist of two injection/extraction well pairs, one pair screened to the base of the hard layer (shallow zone, approximately 0 to 20 ft bgs), and one pair screened below the hard layer (deep zone, approximately 20 to 35 ft bgs). This arrangement will allow separate treatment of the shallow and deep zones (i.e., above and below the hard layer). The injection/extraction wells for the central circulation cell (four wells total) will be installed at an angle beneath Building 1100 to avoid access problems inside the building. The western and central circulation cells will be operating at approximately 6 gpm total (2 gpm in the shallow zone and 4 gpm in the deep zone), while the eastern circulation cell will operate at approximately 3 gpm (1 gpm in the shallow zone and 2 gpm in the deep zone). These flow rates were

selected to ensure the source area is within the treatment zone. The VMODFLOW simulation results are presented in Appendix G (see attached material).

Each extraction and injection well will be constructed of 4-inch diameter, polyvinyl chloride (PVC) casing with slotted screens. The shallow wells will be installed to approximately 20 feet bls with 10 feet of screen. The deep wells will be installed to approximately 35 feet bls and screened below the hard layer from 20 to 35 feet bls. The injection and extraction wells installed beneath Building 1100 will be installed at an angle using sonic drilling. The low overhead in the building limits drill rig access and drilling capabilities. The point of entry for these angled wells will be approximately 12 feet from the edge of the building. The shallow wells will be drilled at a 27 degree angle from ground surface to a total length of 42 feet and screened over the last 20 feet. The angled, deep injection and extraction wells will be drilled to a total length of 50 feet at a 43.5 degree angle from ground surface and will be screened over the last 20 feet. Screen lengths of the angled wells will be sufficient to cover the appropriate vertical aquifer thickness (i.e., 10 feet shallow and 15 feet deep).

Groundwater from each extraction well will be pumped via a submersible pump to a single 1600-gallon equalization tank (Figure 5-2). A transfer pump will circulate water from the equalization tank to the $KMnO_4$ feed system and then back to the tank. Based upon pilot test results, this FS assumes that over the period of treatment, an average of 1 gram per liter (g/ℓ) of $KMnO_4$ will be added to the extracted groundwater stream. After dosage, the treated groundwater will be pumped to three unstirred 1,600-gallon tanks piped in series. Calculations regarding the number of tanks based on PCE oxidation kinetics are presented in Appendix E (see attached material). These tanks will provide the required residence time to allow the $KMnO_4$ to oxidize any VOCs present in the extracted groundwater to below Florida drinking water standards. The treated water is then pumped through a rotary drum filter to remove particulates, and distributed via appropriate valving and flow meters to the three injection well pairs. Reinjected water will comply with State of Florida regulatory limits and the terms of the Underground Injection Control (UIC) permit for the site.

The $KMnO_4$ pilot study conducted in February 2000 established that approximately 2 pore volumes are required to treat the source area. Based upon numerical modeling results, two pore volumes can be flushed through the shallow zone (0 to 20 ft bgs) within approximately 1 year of operation. The time required for 2 pore volumes to flush through the deep zone is likely to be much shorter (4 to 6 months) due to higher hydraulic conductivity. It was assumed for estimating purposes that the entire system will operate for one year.

$KMnO_4$ Storage and Metering System. The above-ground treatment system used during the pilot study consisted of extraction and injection pumps, two $KMnO_4$ drum feeders, two 1,600-gallon tanks, and cartridge filters. This above-ground system was rented from Carus Chemical for $8,500 per month. This FS assumes the full-scale feed system will also be supplied by Carus on a rental basis. Carus is currently developing a second generation family of $KMnO_4$ feed systems specifically for groundwater remediation.

At the anticipated average $KMnO_4$ dosage of 1 g/ℓ, this alternative will consume approximately 82 kilograms (180 pounds) of $KMnO_4$ per day. During the latter stages of treatment, $KMnO_4$ feed may only be makeup to reach 1 g/ℓ. However, the

cost of this alternative assumes 180 lbs/day of $KMnO_4$ will be required for the full duration of treatment. Currently, 42 drums of $KMnO_4$ remain on-site, left over from the field-scale pilot test. These drums will reduce the required amount of $KMnO_4$ that must be ordered from Carus and result in cost savings.

Chemical Oxidation Monitoring Points. Groundwater monitoring points will be installed in both the shallow and deep zones to monitor VOC concentrations and monitor the progress of the injected $KMnO_4$. Five shallow zone and two deep zone monitoring wells will be installed between each injection and extraction well pair (a total of 15 shallow and 6 deep wells). Shallow monitoring wells will be installed to 20 feet bgs (screened from 5 to 20 feet bgs) using direct-push technology, both outside and within the building. However, direct-push methods are not capable of penetrating the hard sand layer present at approximately 20 feet bgs. Therefore, monitoring wells screened in the deep zone below Building 1100 will be installed from outside the building using angled sonic drilling as discussed earlier for the extraction and injection wells.

Samples will be collected from each monitoring well every two months and analyzed for VOCs. Monthly samples of the treatment system influent will be analyzed for VOCs. Monthly samples of the treatment system effluent will be analyzed for VOCs and TAL metals to ensure the injected water complies with State of Florida drinking water standards and UIC permit requirements. Based on the $KMnO_4$ pilot study results, the presence of $KMnO_4$ in groundwater can be determined by visual observations and increasing groundwater specific conductance. Groundwater color will vary from pale yellow, to amber, to brown, and finally, to purple. Purple groundwater indicates the presence of unreacted $KMnO_4$ because all organics at that location have been oxidized.

HRC™ Injection (Southern Plume). Alternative V-3 also entails injecting a Hydrogen Release Compound (HRC™) into the southern plume to enhance the ongoing natural biodegradation of chlorinated compounds. HRC™ is a polyacetate ester specially formulated for slow release of lactic acid upon hydration. As previously discussed in Paragraph 4.1.3.3, the lactic acid is metabolized by indigenous anaerobic bacteria to produce hydrogen. The resulting hydrogen can be used by reductive dehalogenators to dechlorinate chlorinated hydrocarbons.

The HRC™ compound has the consistency of thick paste. The HRC™ would be injected into the groundwater via small diameter boreholes advanced by hollow-stem auger or direct-push methods, or injected through groundwater monitoring wells. A reciprocating pump would be used to inject the compound down the borehole or well. Figure 5-4 depicts this treatment process.

Prior to injection, a predesign investigation would be performed to better refine the vertical and horizontal confines of the southern plume source area. HRC™ would then be injected within the source area at points spaced between 8 and 12 feet apart arranged in a grid pattern. The compound is injected the full depth of the contaminated saturated zone (assumed to be approximately 40 feet). To treat the downgradient plume, lines of injection points that transect the plume (hereon referred to as injection barriers) would be positioned downgradient of the source area. Injection at these barriers would be performed only once to treat downgradient VOCs in solution and adhered to saturated soil. Injection at the source area is estimated to require multiple applications (once a year for 3 years). Figure 5-5 shows the approximate positioning of the gridded injection

points within the source area and the injection barriers within the downgradient portion of the plume.

Modeling (using a proprietary software provided by the HRC™ vendor) of HRC™ use indicates that approximately 5,900 pounds of HRC™ are required in the downgradient injection barriers (first year only) and approximately 680 pounds per year (for a 3 year period) is needed in the source area. HRC™ usage is based upon the following assumptions:

- maximum concentration of PCE and TCE in the southern plume source area is 800 $\mu g/\ell$ and 500 $\mu g/\ell$, respectively
- seepage velocity is approximately 224 ft/year (assuming a hydraulic conductivity of 40 ft/day; see Appendix F)
- competing electron acceptors are oxygen and sulfate at 1.0 mg/ℓ and 16.0 mg/ℓ, respectively

For FS purposes only, HRC™ usage computation sheets for the source area and for the downgradient injection barriers are provided in Appendix F. If this alternative is selected as the preferred remedial action, a detailed design to assess HRC™ application requirements would be performed upon completion of the treatability study.

Enhanced Biodegradation Groundwater Monitoring. Following the initial injection of HRC™, groundwater monitoring will commence to provide a means of monitoring the progress of the enhanced biodegradation in the southern plume. Wells located within the source area and between the source area and the downgradient IRA wells will be sampled every three months during the duration of the three years of treatment. Analytes would include PCE, TCE, cis-DCE, VC, ethene/ethane, volatile fatty acids (i.e., lactic, proprionic, acetic and pyruvic acids) and natural attenuation parameters such as oxygen, nitrate, iron (II), sulfate, sulfide, methane, oxidation-reduction potential (ORP), pH, temperature, carbon dioxide, alkalinity, and chloride. For FS cost estimating purposes, it is assumed that a total of 5 existing and 11 new groundwater monitoring wells will be used for the monitoring of the enhanced biodegradation process in the southern plume. If this alternative is selected, a groundwater monitoring plan would be prepared detailing well positions, sampling frequency, and analytical program. This plan would be submitted for regulatory review and approval prior to implementation.

Phase-Out Operation of IRA System. Upon start-up of the chemical oxidation treatment system in the northern plume, it is anticipated that it will require approximately 10 years before the residual downgradient plume (plume between the chemical oxidation treatment zone and the IRA wells) will be treated by the IRA system to meet surface water standards at the Lake Druid shoreline. This duration is based on groundwater seepage velocity and considers retardation for PCE (see Appendix I). Wells between Building 1100 and Lake Druid will be used to monitor the performance of the IRA system and indicate when the IRA wells may be turned off, and at which point monitored natural attenuation will commence. MNA is discussed in the paragraphs below.

Monitored Natural Attenuation (MNA). Upon the shutdown of IRA wells, natural attenuation processes will be monitored. Monitoring will serve two purposes: to confirm that natural attenuation processes will effectively reduce the remaining

VOC concentrations such that surface water standards will continue to be maintained at the shoreline of Lake Druid without IRA well operation; and to observe further reduction in VOC concentrations. These data will also be used for refinement of estimates for cleanup times to reach Florida drinking water standards. This monitoring period is expected to be 30 years.

Wells located within the source area, between the source area and the IRA wells, and downgradient to the Lake Druid shoreline, initially will be sampled every 3 months after the IRA wells have been shut down. Thereafter, the sampling frequency may be reduced depending upon natural attenuation assessment results. Analytes would include PCE, TCE, cis-DCE, VC, ethene/ethane, and natural attenuation parameters such as oxygen, nitrate, iron (II), sulfate, sulfide, methane, ORP, pH, temperature, carbon dioxide, alkalinity, and chloride. For FS cost estimating purposes, it is assumed that approximately 18 existing monitoring wells would be monitored on an annual basis. Following the selection of this remedial alternative, a natural attenuation monitoring plan would be prepared detailing well positions, sampling frequency, and analytical program. This plan would be submitted for regulatory review and approval prior to implementation.

Source Area Soil Sampling. As previously discussed in Subsection 3.2.3, the RI revealed that PCE concentrations in surface soil do not exceed residential or industrial SCTLs (8,900 and 17,000 μg/kg, respectively), but do exceed the groundwater leachability SCTL (30 μg/kg). Investigations performed in the Building 1100 Surge Tank area (ABB-ES, 1997b) did not identify any highly contaminated soils that would suggest the presence of residual NAPL in the vadose zone soil. Rather, the highest PCE concentrations in vadose zone soils ranged from 133 μg/kg to 260 μg/kg, generally located within the 4-foot interval below the northwest corner of the Building 1100 floor slab. The highest concentration detected in surface soil beneath paved areas at the exterior of the building was 110 μg/kg located at the north end of the building.

The low concentrations detected in the vadose zone are likely attributable to the volatilized fraction from contaminated saturated soils that has collected and adsorbed to vadose zone soil beneath the floor slab and pavement. The presence of the building slab and pavement likely minimize any PCE migration potential, if it exists. However, to confirm that vadose zone soil concentrations will decrease through groundwater remedial actions, soil sampling would be performed at the areas where PCE concentrations were previously found to exceed the groundwater leachability SCTL. This soil sampling would be performed upon achieving Florida drinking water standards at the site.

Five-Year Reviews. A detailed description of the 5-year site review process is presented in Paragraph 5.1.1.1. In addition to these activities, treatment performance and groundwater monitoring data will be summarized and evaluated. This evaluation will include an assessment of the reduction in contaminant concentrations in both VOC plumes, the effectiveness of the chemical oxidation and enhanced biodegradation treatment for the periods of operation, and an assessment for supporting the IRA system shutdown. Once these treatment processes are complete and IRA operation has ceased, reviews will include assessing the effectiveness of natural attenuation to maintain contaminant concentrations below SWQSs at the shoreline of Lake Druid and to reduce concentrations further to drinking water standards.

5.1.3.2 **Technical Criteria Analysis** This subsection presents the technical criteria analysis of the Alternative V-3 compared against the seven criteria in Table 5-1.

Overall Protection of Human Health and the Environment. The VOC-contaminated groundwater, if used for drinking water, and contaminant migration to Lake Druid pose unacceptable risks to future residents at OU 4. Alternative V-3 relies on chemical destruction (chemical oxidation), biological processes (enhanced biodegradation and natural attenuation), and physical removal (air stripping) of the VOCs in the groundwater to eliminate these human health risks. Groundwater-use restrictions will be implemented temporarily to minimize potential human exposure to the groundwater until contaminants can be reduced to Florida drinking water standards.

As depicted in the remedial alternative process flow diagram (Figure 5-1), chemical oxidation would be used to treat the northern plume source area groundwater to VOC concentrations sufficient to achieve Florida surface water standards by the time the plume reaches Lake Druid. The existing IRA would continue to treat the contaminated groundwater plume downgradient of the source area until Florida surface water standards are achieved. Natural attenuation would complete the reduction of contaminants in the source and downgradient areas to Florida MCLs. Biodegradation of VOCs would also be enhanced to meet Florida surface water and drinking water standards in the southern plume. Groundwater-use restrictions will be required to eliminate groundwater exposure pathways because the VOC contaminant plumes at OU 4 will continue to pose a potential risk to future residents during operation of the remedial actions. Once the entire OU 4 groundwater plume has been treated to MCLs, the groundwater-use restrictions will be eliminated. The combination of the chemical oxidation treatment, enhanced biodegradation, continued operation of the existing IRA, and implementation of groundwater-use restrictions will ensure that public health and the environment are properly protected.

Compliance with ARARs. In the short-term, this alternative would comply with the chemical-specific ARARs for VOCs in groundwater discharging into a surface water body. However, it will not comply with State drinking water standards until MNA of the downgradient plume is complete.

This alternative emphasizes treatment of the VOC source area reducing the overall operation of the IRA and expediting the time to achieve these ARARs. Monitoring of the groundwater quality at the point of compliance near the lake edge and at the source area would be used to ensure compliance with the ARARs.

$KMnO_4$ injection may cause an exceedance of certain Florida secondary drinking water standards and would therefore, require a petition to the Florida Department of Environmental Protection for a UIC variance to exceed these standards. The variance is company-specific and must be acquired by the firm responsible for the full-scale remedial action.

Long-Term Effectiveness and Permanence. This alternative is focused on the treatment of VOC contamination within the source area and the downgradient plume prior to it discharging into Lake Druid. Based on the field pilot-scale test results, chemical oxidation would chemically destroy the organic COCs permanently and reduce source area groundwater concentrations to site-specific standards, based on the results of the field pilot test. Furthermore, the potential

presence of residual DNAPL does not adversely affect the chemical process. The field pilot-scale test is described in detail in Subsection 1.5.3, the final $KMnO_4$ workplan (HLA, 1999), and an interim letter report issued in July 2000. The pilot study will be used to establish the detailed site-specific performance and design parameters prior to implementing this remedial technology.

Enhanced biodegradation is a proven technology that permanently destroys chlorinated solvents, especially when natural biological degradation is already being observed at OU 4. Pilot studies performed at other sites and available vendor information can provide assistance on assessing the ability of HRC™ to enhance the complete dechlorination of PCE, TCE, and cis-DCE (Dooley *et al.*, 1999; Koenigsburg and Norris, 1999; Murray *et al.*, 2000; Koenigsburg, 2000). However, as part of the design phase, field pilot tests at OU 4 would be required to optimize the injection distribution, quantity, and frequency of HRC™ injections.

The IRA pump and treat system permanently removes volatile organic contaminants from groundwater. Groundwater treatment and natural attenuation durations were also prepared based on site-specific hydraulic characteristics to determine the applicable short-term or long-term permanence of the groundwater-use restrictions. This permanence will vary based on the remedial goals of the active treatment systems within the source areas and the use of natural attenuation throughout the groundwater plume to achieve MCLs.

Reduction of Toxicity, Mobility, and Volume Through Treatment. This alternative would reduce the toxicity, mobility, and volume of VOCs in the OU 4 groundwater. This would be accomplished through the chemical destruction of the VOCs *in situ* in the northern plume by chemical oxidation. Enhanced biodegradation would be used to biologically destroy the VOCs *in situ* in the southern plume. The downgradient plume would continue to be treated by the existing IRA system, which intercepts and physically removes the VOCs from the groundwater. Estimated emissions of the off-gas from the IRA air stripper are approximately 2.4 lb/day (CH2M Hill, 2000), which is in compliance with Florida air quality requirements (less than 13.7 lbs/day), but the contaminants are not destroyed. Based on the continued operation of the IRA system, the small volume of vapor emissions would not require collection or treatment. However, vapor emissions will be monitored as part of the treatment system operation to ensure compliance with the FDEP air regulations. If treatment is found to be required, an emissions treatment system could be added. MNA, implemented once surface water criteria can be achieved without IRA operation, uses naturally occurring *in situ* biodegradation to reduce the toxicity and volume of VOCs.

Short-Term Effectiveness. This remedial alternative will achieve the remedial goals for groundwater quality by treatment of the VOCs using *in situ* chemical oxidation, enhanced *in situ* biodegradation, IRA wells and natural attenuation. Chemical oxidation and enhanced biodegradation would have operating durations of approximately 1 year and 3 years, respectively. However, contaminant reduction to drinking water standards is assumed to require a total of 40 years. Due to the long-term operation of the remedial actions, groundwater-use restrictions will provide the necessary short-term effectiveness in protecting the public from the existing contaminants. There would be only slight exposures to workers performing well installations, treatment process operations, and groundwater monitoring during these time frames. The residuals produced by the air stripper (vapor emissions) are expected to be negligible, not exceeding 2.4 lb/day (CH2M

Hill, 2000), far below the FDEP limit of 13.7 lb/day. Air emissions would also continue to be monitored to ensure they do not exceed FDEP air quality standards.

Implementability. Construction of a chemical oxidation treatment system would be relatively easy to implement using a mobile $KMnO_4$ storage and feed system, as would installation of the $KMnO_4$ injection and groundwater extraction wells. Figure 5-2 presents the $KMnO_4$ treatment process and Figure 5-3 presents a conceptual layout of the proposed injection and extraction wells.

Drilling beneath Building 1100 may prove challenging because the wells will be drilled at an angle. Angled drilling is not uncommon and various drillers have been contacted in regard to the feasibility and cost of angled well installation. Similarly, injection of the HRC™ would be readily implementable in that it requires only basic drilling techniques. The presence of the hard layer makes using conventional augering more attractive than direct push methods for injection of the HRC™. The IRA system is already constructed (converted recirculating wells to pump and treat) and will continue operation.

The required utilities are also readily available at the site. Building 1100 is currently vacant and construction of the treatment systems will not interfere with any ongoing operations at NTC, Orlando.

Cost. The present worth cost for Alternative V-3 is estimated to be $1,472,000. A breakdown of this cost is presented in Table 5-4. The present worth cost includes direct, indirect, and O&M costs for groundwater treatment using chemical oxidation (12 months) and enhanced biodegradation (3 years) for the northern and southern VOC plumes, respectively, and the IRA wells (10 years) for the downgradient plume (Figure 5-1). Groundwater monitoring of the downgradient plume would be conducted during the 10 years of IRA operation and natural attenuation monitoring would be conducted for 30 years upon the shut-down of the IRA wells to ensure that the VOC plume achieves drinking water standards. Air monitoring would also be conducted on the IRA air stripper. These system operation durations have been estimated based on actual site hydrogeologic characteristics and operational data. Administrative O&M costs for the 5-year reviews, and groundwater-use restrictions presented in the limited action remedial alternatives, have also been included in this cost estimate.

The direct cost was estimated to be $347,000, which includes site preparation, all remedial construction activities, and a short report summarizing the remedial action. The indirect cost was approximately $149,000 and includes health and safety costs, administrative fees, engineering and design and construction support services, and the pilot-test of the enhanced biodegradation treatment technology for the southern VOC plume. The present worth O&M cost for all of the treatment systems O&M and 5-year site reviews was estimated to be $843,000 over the 40-year duration. The contingency for this alternative is approximately $134,000. The detailed present worth cost calculations are included in Appendix D (see attached material).

5.1.4 Alternative V-4: Air Sparging and Enhanced Biodegradation This alternative consists of sparging air into the groundwater at the source area of the northern plume of OU 4 to enhance volatilization of the VOCs and reduce the concentration of PCE and its chlorinated degradation products. All other components of this alternative are identical to Alternative V-3, including enhanced bioremediation of the southern plume, continued operation of the IRA to

Table 5-4
Cost Summary for Alternative V-3: *In Situ* Chemical Oxidation and Enhanced Biodegradation to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$15,052
In Situ Chemical Oxidation System (Northern Plume)	$239,175
HRC™ Injection System (Southern Plume)	$84,375
Total Direct Cost	$348,602
INDIRECT COSTS	
Health and Safety	$11,000
Administration and Permitting	$22,500
Engineering and Design	$40,000
Pilot-Test of HRC™ System	$25,000
Construction Support Services	$50,000
Total Indirect Cost	$148,500
Total Capital Cost (Direct + Indirect)	$497,102
OPERATION AND MAINTENANCE (O&M) COSTS	
In Situ Chemical Oxidation Operation (12 months)	$182,444
HRC™ O&M (for 3 years of operation)	
Present Worth - System Operation Years 2 and 3 (6%, 1 and 2 years)	$33,060
Present Worth - HRC™ Monitoring (6%, 3 years)	$46,911
IRA Wells (10 years)	
Present Worth - System Operation (6%, 10 years)	$313,548
Present Worth - GW Monitoring in Capture Area (6%, 10 years)	$78,384
Monitored Natural Attenuation (10 to 40 years, a 30-year period)	
Present Worth - Entire VOC Plume (6%, 10-40 years)	$140,270
5-Year Site Reviews (every 5 years for 42 years)	
Present Worth - 5-Year Site Reviews (6%, 40 years)	$48,633
Total O&M Cost (present worth)	$843,250

See notes at end of table.

Table 5-4 (Continued)
Cost Summary for Alternative V-3: *In Situ* Chemical Oxidation and Enhanced Biodegradation to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
O&M COSTS (Continued)	
Total Capital and O&M Cost	$1,340,352
Contingency (10%)	$134,035
Total Cost of Alternative V-3: *In Situ* Chemical Oxidation and Enhanced Biodegradation to Drinking Water Standards	$1,474,387

Notes: HRC™ = Hydrogen Release Compound™.
IRA = Interim Remedial Action.
VOC = volatile organic compound.
% = percent.

complete treatment of the downgradient plume, and the use of MNA to achieve surface water standards at Lake Druid and eventually MCLs.

A description of the air sparging component of this alternative is presented in Paragraph 5.1.4.1 and a technical assessment of this alternative is presented in Paragraph 5.1.4.2. The portions of the discussion that are unchanged from Alternative V-3 will be mentioned only briefly.

5.1.4.1 **Detailed Description of Alternative V-4** This alternative is intended to address the saturated zone source areas of the northern and southern plumes, reducing concentrations of PCE, TCE, and cis-DCE to Florida surface water standards for natural discharge into Lake Druid and eventually reducing concentrations to Florida drinking water standards (Table 3-3).

Air sparging would consist of installing air sparge wells and an aeration system to inject air into the wells and induce the mass transfer of the VOCs from dissolved and nonaqueous phases into the vapor phase. Generated vapors would be collected via an SVE system and treated with activated carbon. These air emissions would be monitored to ensure that they do not exceed Florida air emission guidelines.

A process flow diagram depicting how this remedial alternative would meet the overall remedial objectives for the northern and southern plumes is shown on Figure 5-6. It is anticipated that air sparging within the northern plume source area would remove sufficient contaminant mass to achieve a site-specific remedial goal. It is estimated that air sparging in the source area will require approximately 2 years (based on typical sparge system performance) to reduce groundwater concentrations within the source area such that natural attenuation is capable of reducing the remaining groundwater contaminants to Florida surface water standards prior to discharging into Lake Druid.

Upon completion of source area remediation by air sparging (2 years), the IRA will continue to operate for approximately 10 years to complete treatment of the downgradient plume (located between the farthest downgradient air sparge well and the IRA well). After shut-down of the IRA wells, MNA of the northern plume and source area would commence. As for Alternative V-3, a duration of 30 years was assumed for cost purposes to achieve Florida drinking water standards via MNA. Should MNA not readily achieve surface water standards in either the northern or southern plumes, the individual IRA wells may be restarted to ensure continued compliance with Florida surface water standards for groundwater discharging into the lake.the remaining low-level contaminants within the source area would then be treated to surface water standards (and eventually MCLs) via natural attenuation. The total time required for this alternative to reduce VOC concentrations to drinking water standards is 42 years.

Air sparging will cause aerobic conditions within the source area for the duration of treatment (2 years). During this period, natural attenuation of the VOCs by anaerobic reductive dechlorination will temporarily cease within the source area. However, the reduction-oxidation potential will quickly decrease once air sparging has been completed and will return to background levels well within the 10 year period before MNA commences. Also, the change in redox levels due to aeration will be localized and will not be significant downstream of the source area, where natural attenuation of the VOCs will continue to occur.

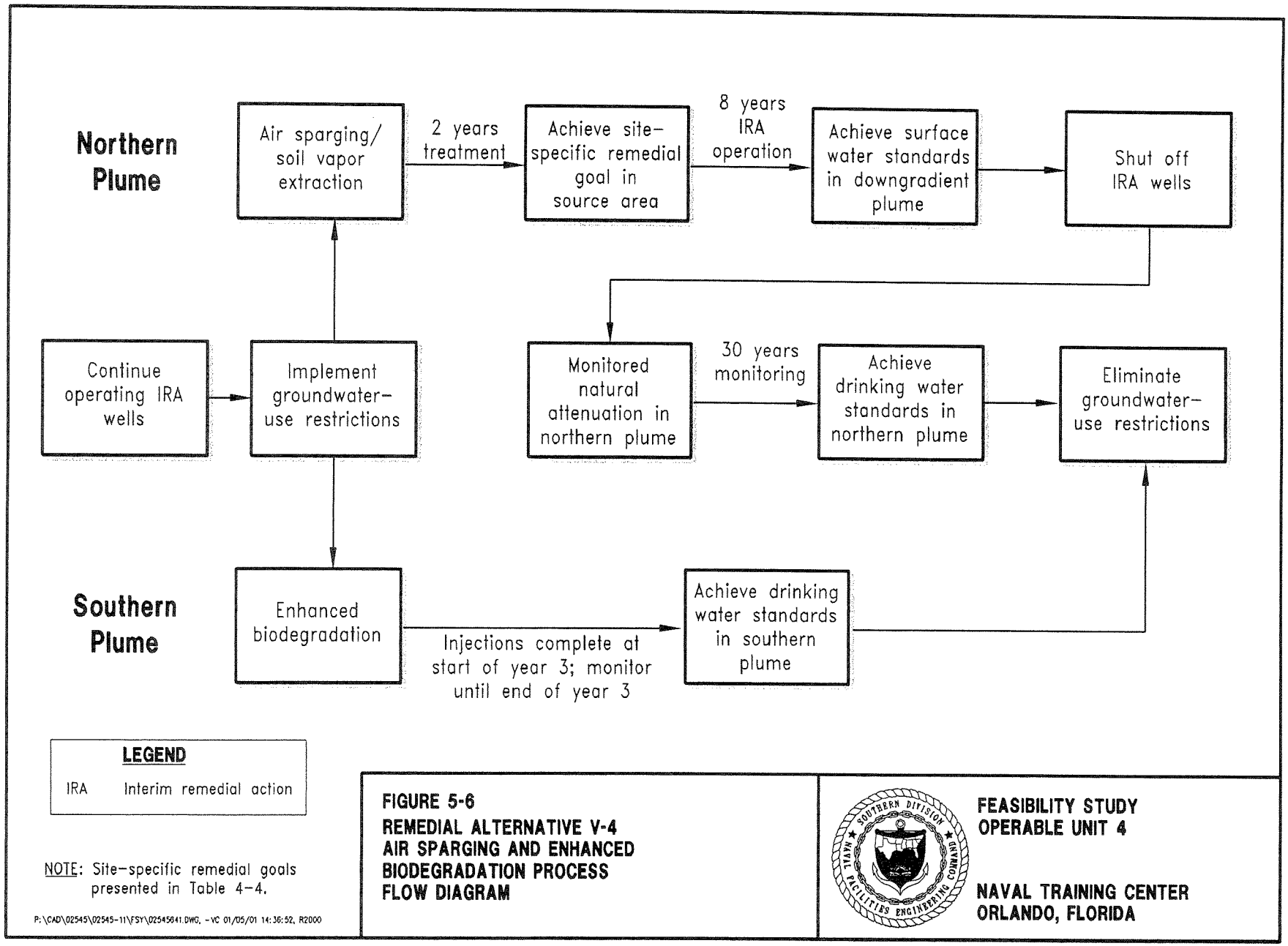

FIGURE 5-6
REMEDIAL ALTERNATIVE V-4
AIR SPARGING AND ENHANCED BIODEGRADATION PROCESS FLOW DIAGRAM

FEASIBILITY STUDY
OPERABLE UNIT 4

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Figure 5-6 also depicts how enhanced biodegradation would be used to remediate the southern plume. The details of this treatment component for Alternative V-4 are identical to Alternative V-3 (see Paragraph 5.1.3.1).

Major components of Alterative V-4 include the following:

- groundwater-use restrictions until RAOs are achieved
- air sparging system construction
- drill/drive holes through the hard layer
- SVE with temporary GAC treatment
- air sparging system monitoring points
- air monitoring of the SVE system
- O&M of air sparge and SVE systems
- HRC™ injection
- enhanced biodegradation monitoring
- phase-out operation of IRA system
- natural attenuation monitoring
- source area soil sampling
- 5-year site reviews

A schematic and conceptual layout for the air sparging component (northern plume) is depicted on Figures 5-7 and 5-8. The treatment process and conceptual layout for enhanced biodegradation component (southern plume) are depicted on Figures 5-4 and 5-5.

Groundwater-Use Restrictions. Refer to Paragraph 5.1.2.1 for a detailed description of groundwater-use restrictions to be implemented at OU 4.

Air Sparging System Construction. It is estimated that 36 deep sparge wells and 89 shallow sparge wells would be sufficient to treat the contaminated water in the source area of the VOC plume. The deep sparge wells would be constructed with 2-inch inside diameter (ID), schedule 40 PVC, and a 5-foot screen at the bottom of each well. The deep sparge wells would extend to the bottom of the plume in their respective locations (approximately 45 feet bls) and would be connected to an air compressor that induces a flow of approximately 10 standard cubic feet per minute (scfm) per well. The blowers for the air sparging system would be housed within the existing building at the site.

The shallow sparge points would consist of 0.5-inch-diameter steel microwells with 3-foot screens installed via a GeoProbe. These wells would extend down to the top of the hard layer, which is approximately 20 feet bls. These sparge points would be connected to a second compressor designed to inject approximately 10 scfm per well. Separate compressors are used for the shallow and deep sparge wells because the shallow wells require significantly less air pressure than the deep wells.

Hard Layer Holes. In addition to drilling the air sparge wells, approximately 35 holes would be drilled through the hard layer, distributed equally between the deep sparge points. These additional holes are required to allow upward migration of the air injected below the hard layer by the deep sparge wells. A hollow-stem auger is the preferred drilling method for the installation of the holes. The auger would be advanced to penetrate the hard layer, and then the hole would be backfilled with the drill cuttings and sealed at the pavement.

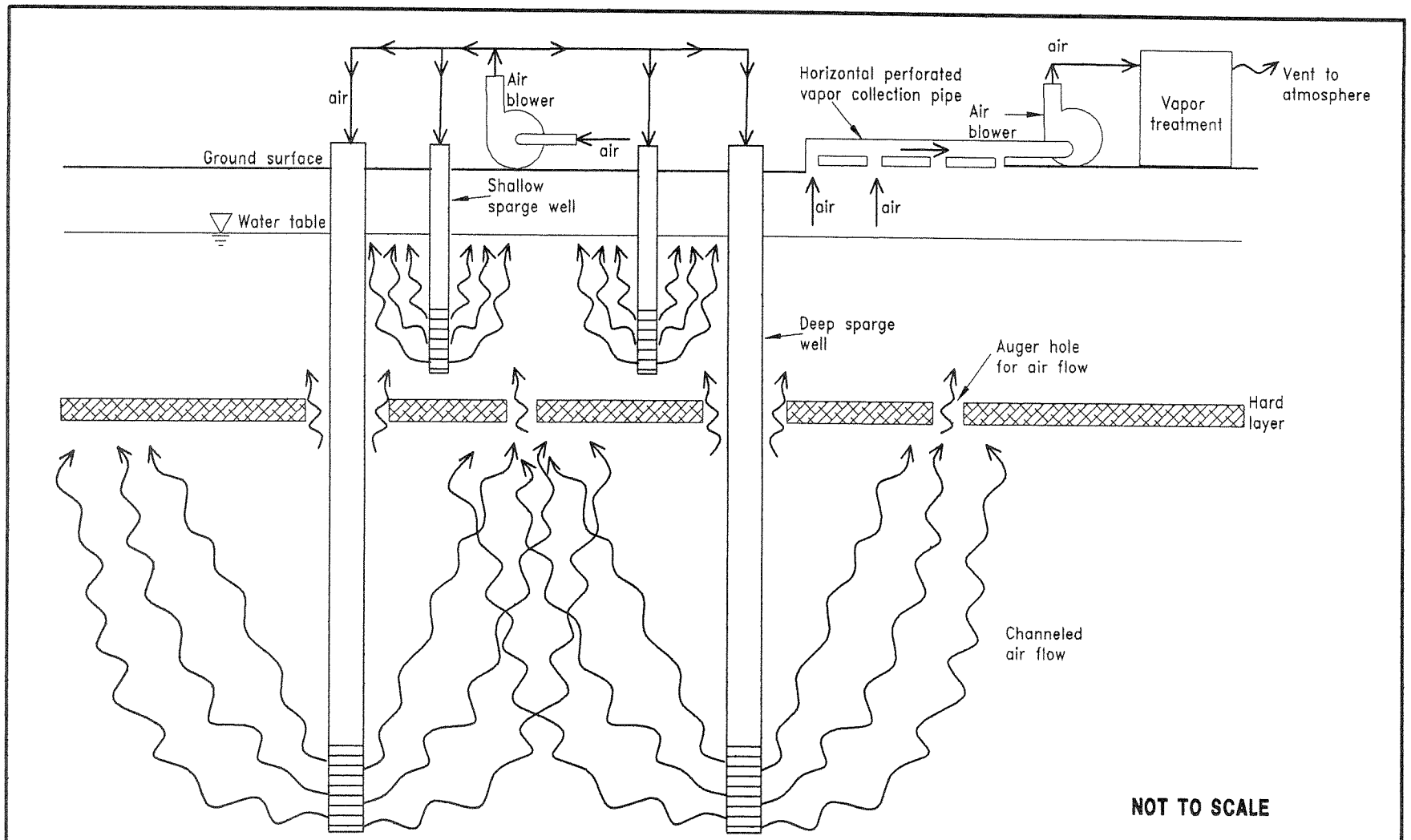

FIGURE 5-7
AIR SPARGING SCHEMATIC

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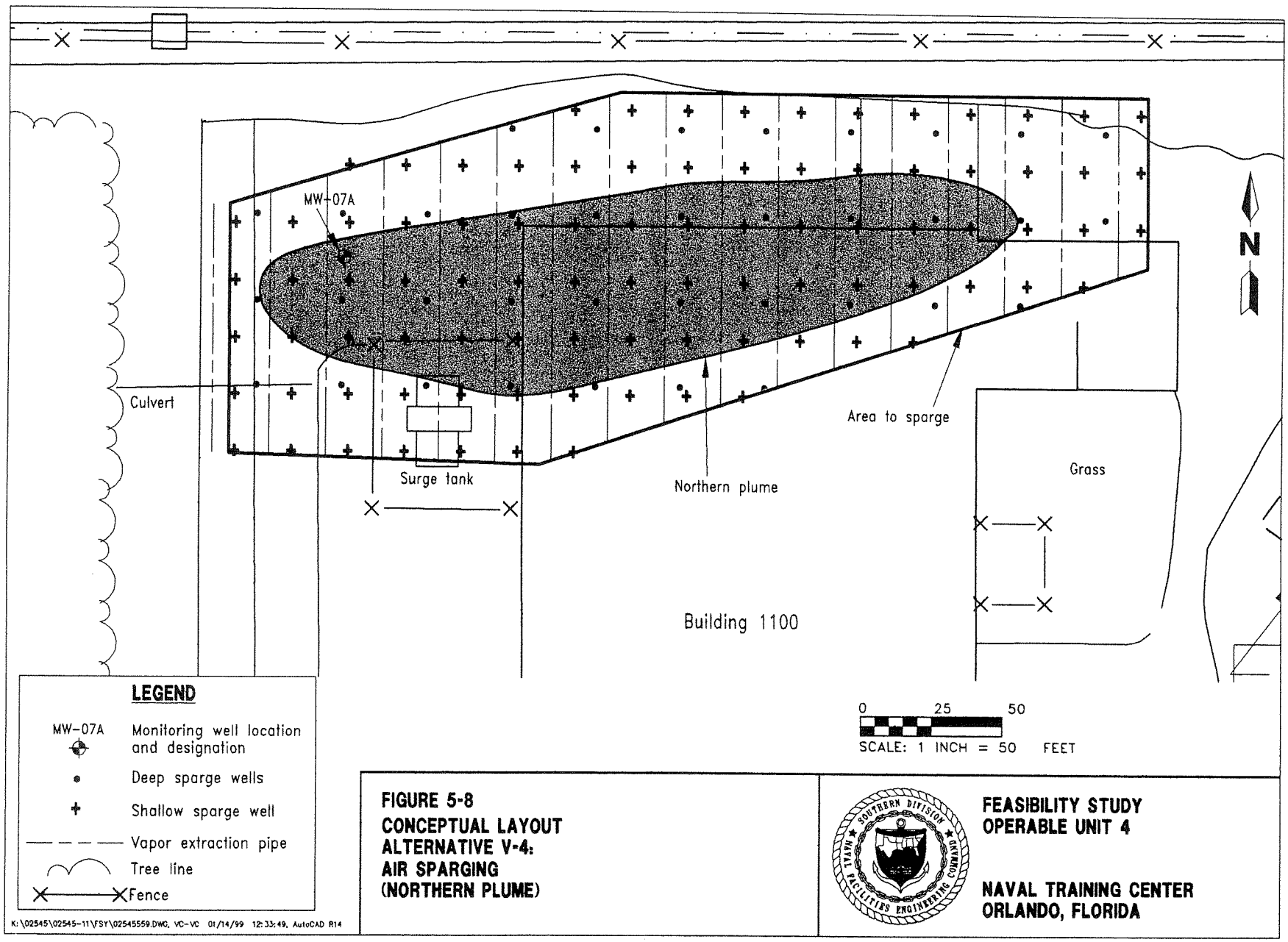

FIGURE 5-8
CONCEPTUAL LAYOUT
ALTERNATIVE V-4:
AIR SPARGING
(NORTHERN PLUME)

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SVE with Temporary GAC Treatment. The VOC emissions resulting from air sparging would be collected via an SVE system. Because of the shallow water table and the pavement (or building) that covers the majority of the source area, vapors would be collected using horizontal pipes set beneath the pavement between the rows of sparge wells (Figure 5-8). Rather than continuing these lines beneath the building, the SVE system will be used to induce a negative pressure within the sand-filled building foundation under the floor slab. The SVE piping would be constructed with 4-inch ID, Schedule 40 PVC. Vapor-phase treatment of the off-gas may be necessary to remove organic vapors prior to discharge. It is anticipated that the generated vapors from air sparging would initially exceed Florida air emission standards (maximum of 13.7 pounds of VOCs per day). These emissions would likely fall below the 13.7 lbs/day limit after one year of operation such that off-gas treatment would be discontinued. Monitoring of organic vapors in the extraction system would be required to assess the rate of gas transfer, the effectiveness of treatment, and compliance with discharge limitations. Two 10,000-pound GAC canisters, connected in series, would be installed at the discharge end of the regenerative vacuum blower. A vertical stack would then be installed to adequately disperse the treated exhaust. These canisters would be monitored for break through of VOC vapors. However, the cost for this alternative assumes that replacement of these GAC canister will not be necessary.

Air Sparging System Monitoring Points. Groundwater would be sampled for analysis of VOCs, dissolved oxygen (DO), pH, ORP, conductivity, and temperature within the source area and at downgradient locations toward the IRA wells during treatment. The monitoring results would be used to evaluate the effectiveness of this remedial alternative. Scheduled monitoring would be performed until VOC concentrations in the groundwater comply with established treatment levels. The presumed sampling schedule and rationale are included in the cost estimate for this alternative (Appendix D). It has been assumed that existing groundwater monitoring wells and air sparge points could be used for groundwater monitoring points.

Air Monitoring of the SVE System. Samples of exhaust gases prior to, between, and following the GAC canisters would be routinely collected during the first year of operation to ensure proper compliance with air discharge limits. Analysis of these gases would include, but not be limited to, total organic vapors.

Operation and Maintenance of the Air Sparging and SVE Systems. In addition to monitoring of the groundwater at OU 4, the operations of the air sparging and SVE systems would be monitored on a regularly scheduled basis. System monitoring activities would include measurement and adjustments of sparged air flow rate and system pressure, air emissions monitoring, vacuum and soil gas temperature measurements, as well as the mechanical integrity of the system components.

HRC™ Injection (Southern Plume). Alternative V-4 also entails injecting a lactic acid producing compound (HRC™) within the southern plume to enhance natural biodegradation of chlorinated compounds. The details of this component are identical to those for Alternative V-3 (Paragraph 5.1.3.1).

Phase-Out Operation of IRA System. It is anticipated that the IRA would operate for 10 years after the source area has been treated using air sparging. Details are identical to Alternative V-3 (Paragraph 5.1.3.1).

Natural Attenuation Monitoring. Following the shut-down of the downgradient IRA wells, natural attenuation monitoring would be implemented. Details are identical to Alternative V-3 (Paragraph 5.1.3.1).

Source Area Soil Sampling. Source area soil sampling to demonstrate compliance with leachability SCTLs will be required upon achieving Florida MCLs. Details can be found in Alternative V-3 (Paragraph 5.1.3.1).

Five-Year Reviews. Remedial Alternative V-4 will require 5-year site reviews, as described for Alternative V-3 (Paragraph 5.1.3.1).

5.1.4.2 **Technical Criteria Analysis** This paragraph presents the technical criteria analysis of remedial Alternative V-4 compared against the seven USEPA criteria in Table 5-1.

Overall Protection of Human Health and the Environment. The VOC-contaminated groundwater poses an unacceptable risk to human health under future land-use scenarios at OU 4. Alternative V-4 relies on physical removal (air sparging and SVE and air stripping via the IRA) and biological processes (enhanced biodegradation and natural attenuation) to reduce VOC concentrations and eventually eliminate human health risks. Institutional controls would be temporarily implemented to minimize potential human consumption of the groundwater until contaminants can be reduced to Florida drinking water standards.

As depicted in the remedial alternative process flow diagram (Figure 5-6), air sparging would be used to treat the northern plume source area groundwater to meet Florida surface water standards prior to discharge into Lake Druid. The existing IRA system would continue to treat the contaminated downgradient groundwater plume to Florida surface water standards. Existing natural attenuation would complete the reduction of contaminants in the source and downgradient areas to Florida drinking water standards. Biodegradation of VOCs would also be enhanced to meet Florida surface water and drinking water standards in the southern plume. Groundwater-use restrictions would be required because the contaminant plume at OU 4 will continue to pose a potential risk to future residents during operation of the remedial actions (air stripping, enhanced biodegradation, IRA wells) and, upon shut-down of the IRA wells, to further reduce contaminants to meet Florida drinking water standards in the northern plume. Once the entire groundwater plume has been treated to Florida drinking water standards, the groundwater-use restrictions will be eliminated. The combination of the air sparging, enhanced biodegradation, operation of the existing IRA wells and implementation of groundwater-use restrictions would ensure that human health and the environment were properly protected.

Compliance with ARARs. In the short-term, this alternative would comply with the chemical-specific ARAR for VOCs in groundwater discharging into a surface water body. However, it would not comply with the State drinking water standards until MNA of the entire VOC plume at OU 4 has been completed.

This alternative emphasizes treatment of the VOC source area reducing the overall operation of the IRA wells and expediting the time to achieve these ARARs. Monitoring of the groundwater quality at the point of compliance near the lake edge and at the source area would be used to ensure compliance with the ARARs.

Long-Term Effectiveness and Permanence. This remedial alternative is focused on the treatment of VOC contamination within the source area and the downgradient plume prior to it discharging into Lake Druid. Air sparging would physically and permanently remove the organic COCs. It is also a well proven and readily available technology. The OU 4 air sparging pilot test revealed that it is an appropriate technology for OU 4 providing that a means of transferring the stripped VOCs through the hard layer is provided.

Enhanced biodegradation is still an emerging technology, but shows great promise at biologically destroying chlorinated solvents permanently, especially when natural biological degradation is already being observed at OU 4. Pilot studies performed at other sites and available vendor information can provide assistance on assessing the ability of HRC™ to enhance degradation of PCE, TCE, and cis-DCE. However, as part of the design phase, field pilot tests at OU 4 would be required to optimize injection distribution, quantity, and frequency.

The IRA pump and treat system permanently removes volatile organic contaminants from groundwater.

Groundwater treatment and natural attenuation durations were prepared based on site-specific hydraulic characteristics to determine the applicable short-term or long-term permanence of the groundwater-use restrictions.

Reduction of Toxicity, Mobility, and Volume Through Treatment. This alternative would reduce the toxicity, mobility, and volume of VOCs in the OU 4 groundwater. This would be accomplished in the northern plume by injecting air into the saturated zone to volatilize the VOCs and extracting the organic vapors from the vadose zone with SVE. Vapor-phase treatment of the off-gas will be provided to remove organic vapors prior to discharge. It is anticipated that the generated vapors from air sparging may initially exceed Florida air emission standards (maximum of 13.7 lbs/day of VOCs). Based on the monitoring of the SVE air emissions, off-gas treatment would be removed after one year of operation because they would likely be below Florida guidance. Contaminants would be destroyed off site when the carbon is regenerated. Enhanced biodegradation biologically destroys the VOCs *in situ* in the southern plume. Initially, the downgradient plume would continue to be treated by the existing IRA system that intercepts and physically removes the VOCs from the groundwater. Emission of the off-gas from the air stripper is in compliance with Florida air quality requirements (less than 13.7 lbs/day). Based on the continued operation of the IRA system, the small volume of vapor emissions to ambient air would not require collection or treatment. However, vapor emissions will be monitored as part of the treatment system monitoring to ensure compliance with the Florida air regulations. If treatment is found to be required, an emissions treatment system could be added. Monitored natural attenuation, implemented once surface water criteria was achieved without IRA operation, would use biodegradation as a treatment process to reduce the toxicity and volume of VOCs.

Short-Term Effectiveness. This remedial alternative will achieve the remedial goals for groundwater quality by treatment of the VOCs using *in situ* air sparging, enhanced biodegradation, IRA wells, and natural attenuation. Air sparging and enhanced biodegradation would be operated approximately two years and three years, respectively. However, contaminant reduction to State surface water and drinking water standards is expected to require 10 years (IRA wells) and over 30 years (monitored natural attenuation), respectively. Due to the

long-term operation of the remedial action, groundwater-use restrictions would be implemented to provide the required short-term effectiveness in protecting the public from the existing contaminants. There would be only slight exposures to workers performing well installations, treatment process operations, and groundwater monitoring during these time frames. The residuals produced by the alternative (e.g., vapor emissions) would be collected and treated, and would be monitored to ensure they do not exceed Florida air quality standards. The residuals produced by the IRA air stripper (vapor emissions) are expected to be negligible, not exceeding 0.2 lbs/day (ABB-ES, 1998b), far below the FDEP limit of 13.7 lbs/day. Air emissions would also continue to be monitored to ensure they do not exceed FDEP air quality standards.

Implementability. Construction of an air sparging system is relatively easy to implement requiring only basic construction practices and readily available equipment. However, the presence of the hard layer and Building 1100 covering a large portion of the source area add complexity for OU 4. Figure 5-7 presents the air sparging treatment process and Figure 5-8 presents a conceptual layout of the proposed air injection wells relative to the position of the northern plume source area. The need to drill approximately 10 deep sparge points and an even greater number of penetrations through the hard layer with low overhead clearance will require a low-profile or tripod mounted drilling system. Of greater concern is the hard layer. It is unknown if the holes drilled through the hard layer will properly function to allow deep sparge air to migrate upward. Also, VOC contamination present beneath the hard layer and between the drilled holes is not likely to be in direct contact with any established air channels. Therefore, these VOCs will not be immediately removed from the subsurface by volatilization but must first migrate toward the air channels by diffusion, which is a very slow transport process. Further, any contamination present within the hard layer (both dissolved and non-aqueous) would be inaccessible to the sparge air.

Injection of the HRC™ would be easily implementable in that it requires only basic drilling techniques. The presence of the hard layer makes using conventional augering more attractive than push methods for injection of the HRC™. The IRA system is already constructed and operating at the site.

The required utilities are also readily available at the site. Building 1100 is currently vacant such that construction of the treatment system will not interfere with any ongoing operations at NTC, Orlando.

Cost. The present worth cost for Alternative V-4 was estimated to be $1,617,711 over a 32-year period. A breakdown of this cost is presented in Table 5-5. This cost would include the direct, indirect, and O&M costs for the treatment system, HRC™ injection, and air and groundwater monitoring, in addition to the administrative O&M cost for the 5-year reviews presented in the limited action alternative.

The direct cost is approximately $458,832, which includes site preparation, remedial construction activities of the air sparging and/or SVE system, one year of vapor phase carbon treatment for the SVE off-gas and the HRC™ injection (one year), and a short report summarizing the remedial construction activities. The indirect cost is approximately $205,000. The detailed cost calculations are included in Appendix D.

Table 5-5
Cost Summary for Alternative V-4: Air Sparging/Soil Vapor Extraction and Enhanced Biodegradation to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$58,061
Air Sparging/SVE System (Northern Plume)	$269,496
Vapor-Phase Off-Gas System (1 year only)	$36,900
HRC™ Injection System (Southern Plume)	$84,375
Total Direct Cost	$458,832
INDIRECT COSTS	
Health and Safety	$20,000
Administration and Permitting	$30,000
Engineering and Design	$60,000
Pilot-Test of HRC™ System	$25,000
Construction Support Services	$70,000
Total Indirect Cost	$205,000
Total Capital Cost (Direct + Indirect)	$663,832
OPERATION AND MAINTENANCE (O&M) COSTS	
Air Sparging/SVE System (2 years)	
Present Worth - System Operation	$106,901
HRC™ O&M (3 years)	
Present Worth - System Operation Years 2 and 3 (6%, 2 and 3 years)	$33,060
Present Worth - HRC™ Monitoring (6%, 3 years)	$46,911
IRA Wells (10 years)	
Present Worth - System Operation (6%, 12 years)	$357,172
Present Worth - Groundwater Monitoring (6%, 12 years)	$89,290
Natural Attenuation Monitoring (30 years)	
Present Worth - Entire VOC Plume (6%, year 13 to 42)	$124,848
5-Year Site Reviews (every 5 years for 30 years)	
Present Worth - 5-Year Site Reviews (6%, 42 years)	$48,633
Total O&M Cost (present worth)	$806,815

See notes at end of table.

Table 5-5 (Continued)
Cost Summary for Alternative V-4: Air Sparging/Soil Vapor Extraction and Enhanced Biodegradation to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
O&M COSTS (Continued)	
Total Capital and O&M Cost	$1,470,646
Contingency (10%)	$147,065
Total Cost of Alternative V-4: Air Sparging/Soil Vapor Extraction and Enhanced Biodegradation to Drinking Water Standards	$1,617,711

Notes: SVE = soil vapor extraction.
HRC™ = Hydrogen Release Compound™.
% = percent.
IRA = Interim Remedial Action.
VOC = volatile organic compound.

The present worth O&M cost would be approximately $806,815. These costs assume that the air sparging and/or SVE system would be operated and maintained for 2 years, the HRC™ injection for 3 years, and the IRA wells for 10 years (Figure 5-6). Groundwater monitoring would also be conducted throughout the entire VOC plume for a period for 30 years, along with the site reviews every 5 years.

5.1.5 Alternative V-5: Recirculation Wells and Enhanced Biodegradation This alternative consists of four new recirculation wells at the source area of the northern plume at OU 4 to physically remove (strip) the chlorinated compounds from the groundwater. All other components of this alternative are identical to Alternative V-3, including enhanced bioremediation of the southern plume, continued operation of the IRA to complete treatment of the downgradient plume, and the use of MNA to achieve surface water standards at Lake Druid and eventually MCLs.

5.1.5.1 Detailed Description This alternative, which includes recirculation wells, and enhanced biodegradation, is intended to address contamination within the source areas of the northern and southern plumes at OU 4, reducing concentrations of PCE, TCE, and cis-DCE to Florida surface water standards for groundwater discharge into Lake Druid and eventually to Florida drinking water standards (Table 3-3).

Calculations have been performed to estimate the duration of a conventional groundwater extraction and treatment system (Appendix G). These calculations required an estimate of the total source area mass (6,000 pounds), the horizontal and vertical distribution of this mass, and the initial concentration of VOCs in extracted groundwater. Two durations can be calculated; one to reduce VOC concentrations in the source area to levels that will naturally attenuate to Florida surface water standards before reaching Lake Druid, and a considerably longer duration for achieving MCLs in the source area.

Recirculation wells operate by creating vertical groundwater flow patterns that are expected to more efficiently contact and remove source area residual than conventional extraction wells using radial flow. For this reason, recirculation wells should be capable of remediating the source area more rapidly than conventional extraction wells. For the purposes of this FS, it has been assumed that recirculation well treatment durations will be 4 times less than conventional wells, i.e., 27 years to achieve MCLs and 15 years to achieve surface water standards via natural attenuation.

As with the previous alternatives, the IRA system would continue to operate to ensure VOCs in the downgradient plume have been treated to ensure compliance with Florida surface water standards at Lake Druid. However, unlike the preceding alternatives, the source area technology (recirculation wells) is expected to require a significant number of years (15) before source area VOC concentrations will be reduced sufficiently to naturally attenuate to surface water standards before reaching Lake Druid. This means the duration for IRA operation for Alternative V-5 would be 15 years longer (i.e. 25 years) than Alternatives V-3 and V-4. If the source area recirculation wells are operated to achieve MCLs, the IRA and the source area recirculation wells essentially operate for the same period of time.

Two process flow diagrams for this remedial alternative are presented to achieve the overall RGOs (Figures 5-9 and 5-10). The process flow diagram presented on

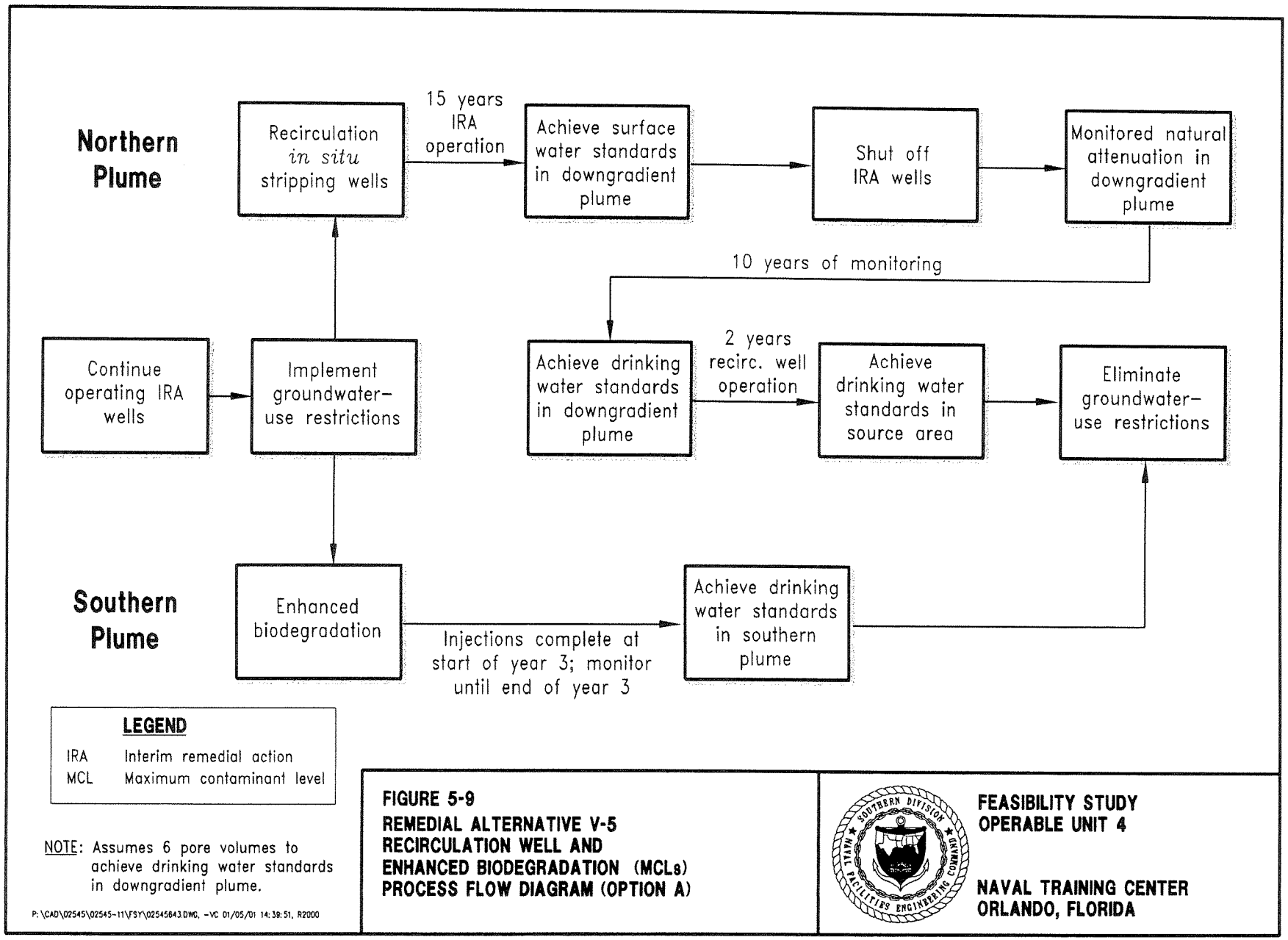

FIGURE 5-9
REMEDIAL ALTERNATIVE V-5
RECIRCULATION WELL AND
ENHANCED BIODEGRADATION (MCLs)
PROCESS FLOW DIAGRAM (OPTION A)

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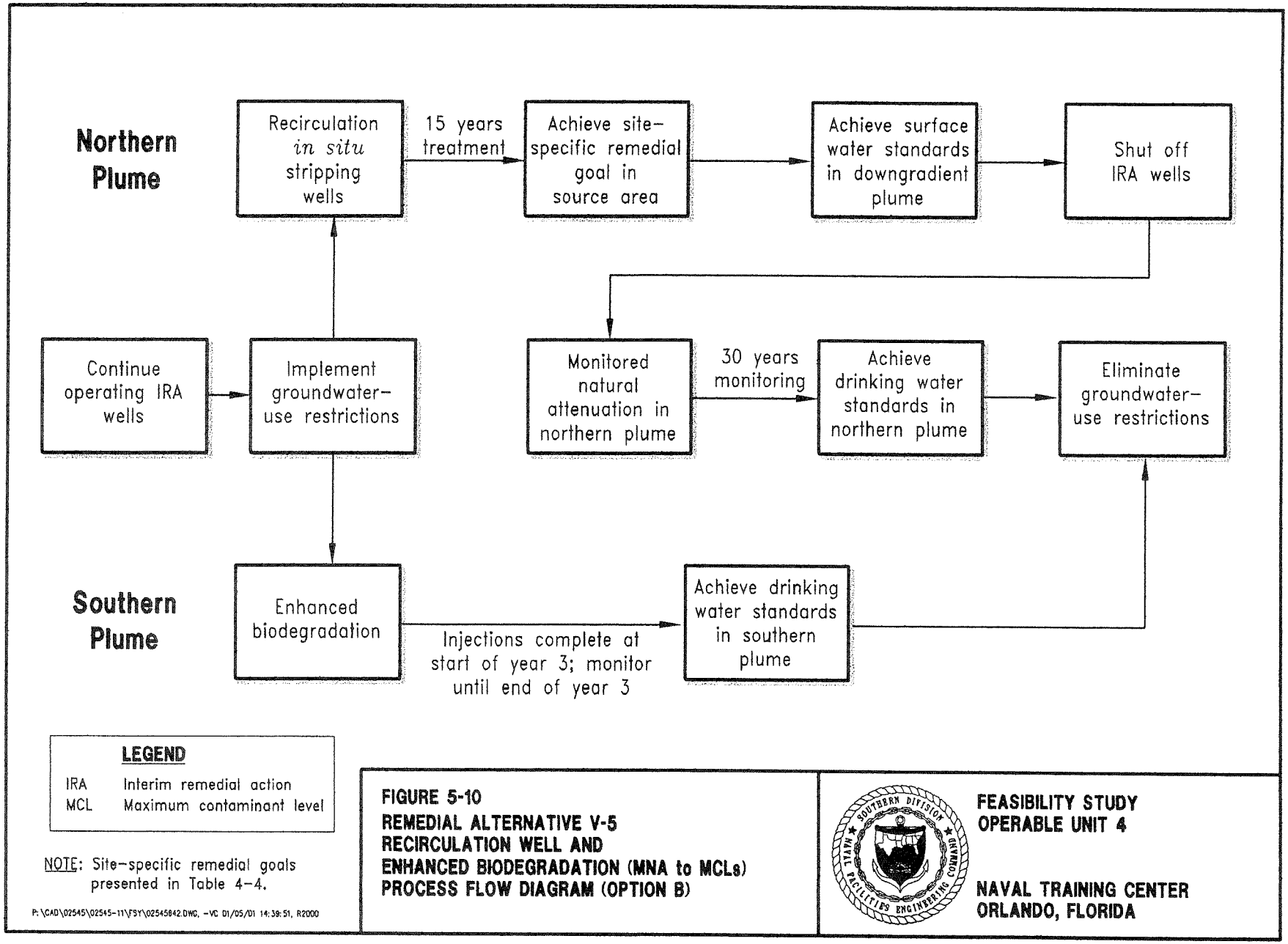

FIGURE 5-10
REMEDIAL ALTERNATIVE V-5
RECIRCULATION WELL AND
ENHANCED BIODEGRADATION (MNA to MCLs)
PROCESS FLOW DIAGRAM (OPTION B)

FEASIBILITY STUDY
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Figure 5-9 depicts alternative V-5A, where the source area is treated *in situ* by recirculation wells for an estimated 27 years until the source area groundwater has met Florida drinking water standards. The groundwater plume located downgradient of the source area would also be addressed by the existing IRA wells for 27 years, at which time the wells would be shut down.

Natural attenuation monitoring would then be conducted in the downgradient plume until Florida drinking water standards are achieved. Based on groundwater flow velocity and PCE retardation, MCLs would be achieved 10 years following IRA shut-down. Following the remediation of the contaminated groundwater in the source area and the downgradient plume to drinking water standards, the original groundwater-use restrictions implemented to protect human health would be eliminated.

The second process flow diagram presented on Figure 5-10 depicts alternative V-5B. For this option, the source area is treated by the recirculating well system for an estimated 15 years. Natural attenuation would reduce the remaining concentrations to Florida surface water standards prior to discharging into Lake Druid. The downgradient VOC plume would be addressed by the existing IRA wells for 25 years as discussed above for the first process flow diagram.

The remaining low-level contaminants within the source area and downgradient plumes would be treated to surface water standards and then to drinking water standards using MNA. The rate limiting factor to achieve drinking water standards would be the dissolution of any remaining source into the groundwater. For estimating purposes, a duration of 30 years was assumed. Should MNA not readily achieve these goals, the downgradient IRA wells may be restarted to ensure compliance prior to the groundwater discharging into the lake.

Recirculation wells will cause aerobic conditions within the source area for the duration of treatment (15 years). During this period, natural attenuation of the VOCs by anaerobic reductive dechlorination will temporarily cease within the source area. However, the reduction-oxidation potential will quickly decrease once treatment has been completed and will return to background levels well within the 10 year period before MNA commences. Also, the change in redox levels due to aeration will be localized and will not be significant downstream of the source area, where natural attenuation of the VOCs will continue to occur.

Figures 5-9 and 5-10 also depict how enhanced biodegradation would be used to remediate the southern plume. The details of this treatment component of Alternative V-5 are identical to Alternative V-3 (see Paragraph 5.1.3.1).

Major components of this alternative include the following:

- groundwater-use restrictions until RAOs are achieved
- recirculating well construction (northern plume)
- recirculating system monitoring points
- vapor phase treatment and air monitoring
- recirculating system O&M
- HRC™ injection (southern plume)
- enhanced biodegradation monitoring network (southern plume)
- phase-out operation of IRA system
- natural attenuation monitoring
- source area soil sampling

- 5-year site reviews

The schematic and conceptual layout for the recirculating well component of this alternative (northern plume) are depicted on Figures 5-11 and 5-12. The treatment process and conceptual layout for implementing enhanced biodegradation (southern plume) are depicted on Figures 5-4 and 5-5.

Groundwater-Use Restrictions. Refer to Paragraph 5.1.2.1 for a detailed description of groundwater-use restrictions to be implemented at OU 4.

Recirculating Well Construction (Northern Plume). Based on the performance of the existing IRA wells, it is anticipated that four recirculating wells would be required to remediate the source area at OU 4. Figure 5-12 depicts the approximate proposed positions of these wells in relation to the source area and existing IRA wells. Because the low overhead clearance of Building 1100 would make drilling these wells very difficult, the wells have all been placed outside the structure. The proposed wells would be 10 inches in diameter, constructed of PVC and installed to a depth of approximately 45 feet bls, just below the suspected depth of the source area. Well details would be similar to the existing IRA wells except that the stripping unit within the well would be positioned below grade in a waterproof vault to meet current FDEP requirements that no portion of the wells be above grade.

Recirculating System Monitoring Points. Following start-up of the recirculating well system in the source area, groundwater monitoring would commence to provide a means of monitoring the effectiveness of the recirculating wells at treating the northern plume. Two piezometer pairs would be installed radially away from each of the recirculation wells. Each piezometer would be equipped with an *in situ* TROLL to constantly monitor water levels. Comparison of the changes in water levels in each piezometer pair would allow monitoring of the hydraulic performance of each recirculation well. This method has proven to be very reliable for monitoring the IRA wells. Monitoring wells located within the source area would be used to monitor the groundwater quality for VOCs to determine when the RGOs have been met. The VOC and hydraulic data would be used to evaluate the effectiveness of the recirculating well system on the source area groundwater plume and the existing downgradient IRA wells. For estimating purposes, it was assumed that a total of 10 existing monitoring wells would be sampled annually for monitoring the source area and downgradient plume.

Vapor Phase Treatment and Air Monitoring. The VOC emissions resulting from air stripping within each of the recirculating wells would be collected and treated through vapor phase GAC. It is anticipated that the generated vapors from source area recirculation wells could initially exceed Florida air emission standards (see Appendix H) (maximum of 13.7 lbs/day of VOCs). Samples of organic vapors in the treatment system would be required to assess the rate of gas transfer, the effectiveness of treatment, and compliance with discharge limitations. It has been assumed that one 1,000 pound vessel of GAC would be connected to each recirculating well. Furthermore, it was assumed that the vapor phase treatment would be required only for the first year of operation, after which time the organic vapor concentrations would diminish such that Florida air emissions are no longer exceeded without treatment.

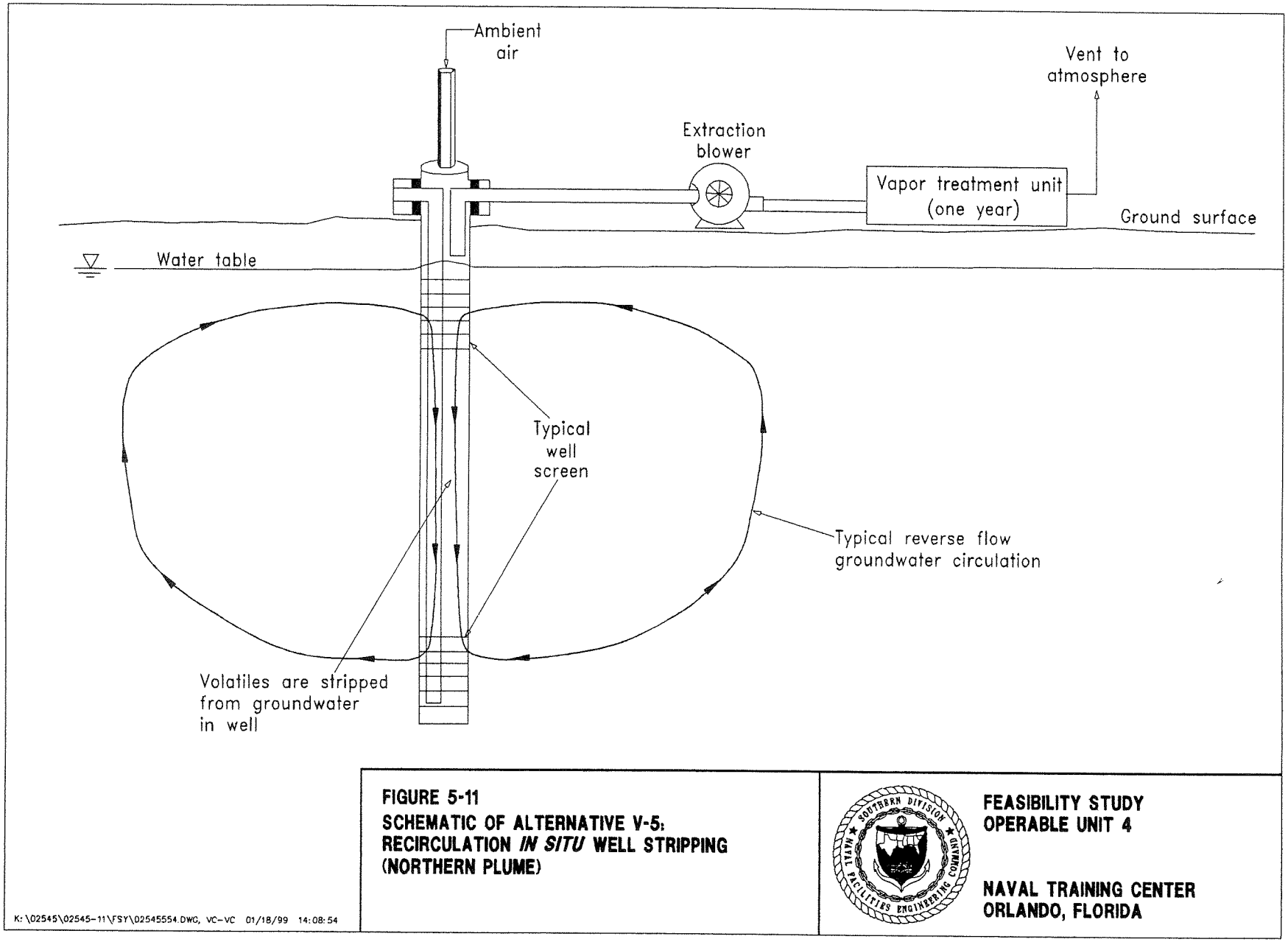

FIGURE 5-11
SCHEMATIC OF ALTERNATIVE V-5: RECIRCULATION *IN SITU* WELL STRIPPING (NORTHERN PLUME)

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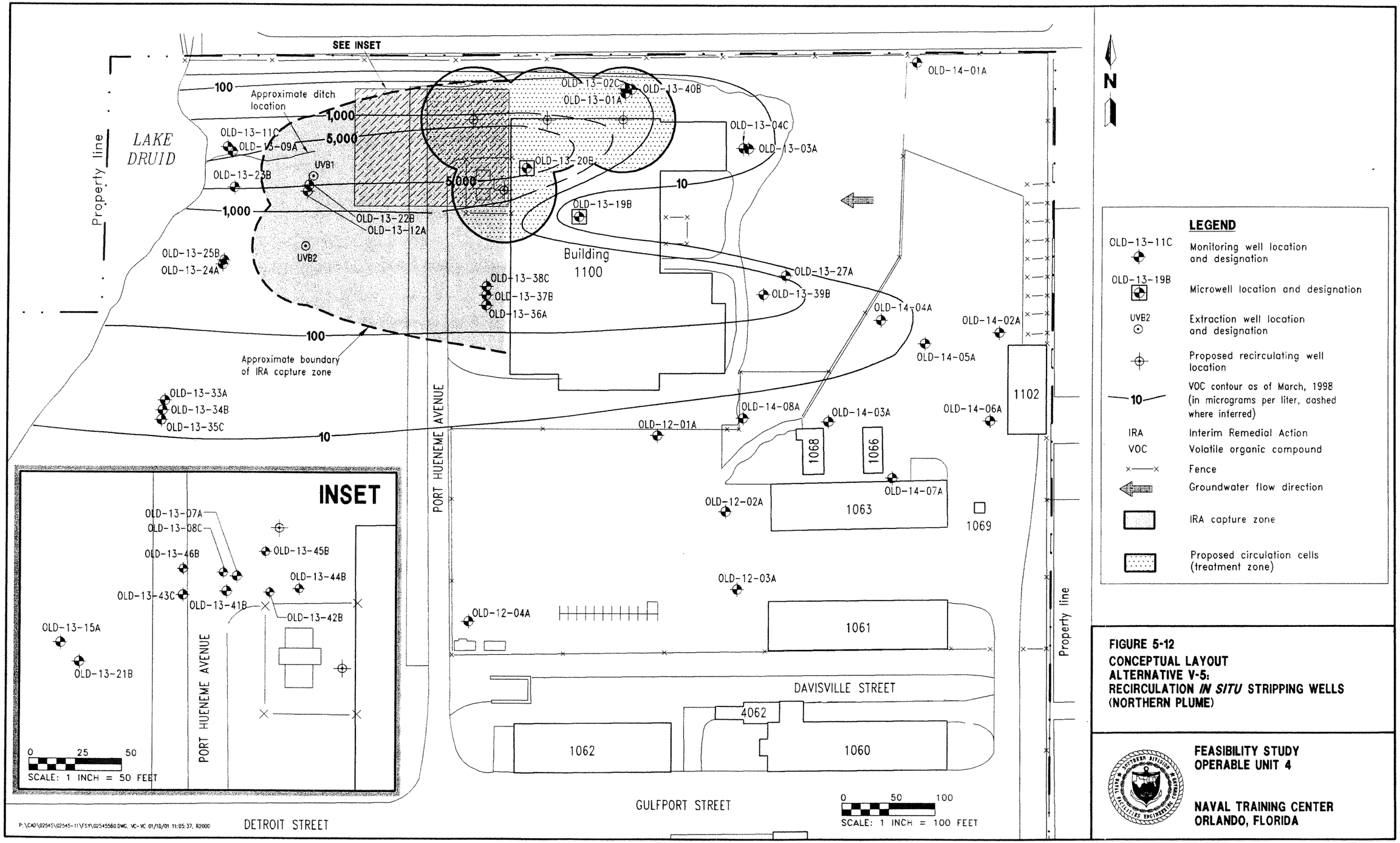

LEGEND

OLD-13-11C	Monitoring well location and designation
OLD-13-19B	Microwell location and designation
UVB2	Extraction well location and designation
	Proposed recirculating well location
10	VOC contour as of March, 1998 (in micrograms per liter, dashed where inferred)
IRA	Interim Remedial Action
VOC	Volatile organic compound
	Fence
	Groundwater flow direction
	IRA capture zone
	Proposed circulation cells (treatment zone)

FIGURE 5-12
CONCEPTUAL LAYOUT
ALTERNATIVE V-5:
RECIRCULATION *IN SITU* STRIPPING WELLS
(NORTHERN PLUME)

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Samples of treated exhaust gases would be routinely collected to ensure proper compliance with air discharge limits. Analysis of these gases would include, but not be limited to, total organic vapors.

Recirculating System O&M. In addition to monitoring of air emissions and groundwater, the recirculating well operations would be monitored on a continual basis throughout their operation. System monitoring activities would include measuring water levels in each of the piezometers, recording and adjusting pumping and air flow rates as needed, quarterly influent and effluent grab samples from each of the recirculating wells, and checking the mechanical integrity of the system components (i.e., blowers and pumps), and checking for system fouling.

HRC™ Injection (Southern Plume). Alternative V-5 also entails injecting a lactic acid producing compound (HRC™) within the southern plume to enhance natural biodegradation of chlorinated compounds. The details of this component are identical to those for Alternative V-3 (see Paragraph 5.1.3.1).

Phase-Out Of IRA Operations. As discussed above, the IRA is expected to operate 25 to 27 years before the residual downgradient plume (the plume between the most downgradient source area recirculation well and the IRA wells) would be treated.

Natural Attenuation Monitoring. Following shut-down of the downgradient IRA wells, natural attenuation monitoring would be implemented. This monitoring would ensure that the groundwater naturally discharging into Lake Druid continued to meet surface water standards and that the VOC concentrations were being reduced to ultimately meet Florida drinking water standards. For estimating purposes, a duration of 30 years was assumed. Natural attenuation monitoring is discussed in greater detail in Alternative V-3 (Paragraph 5.1.3.1).

Source Area Soil Sampling. Source area soil sampling to demonstrate compliance with leachability SCTLs will be required upon achieving Florida MCLs. Details can be found in Alternative V-3 (Paragraph 5.1.3.1).

Five-Year Reviews. Remedial Alternative V-5 will require 5-year site reviews, as described for Alternative V-3 (Paragraph 5.1.3.1).

5.1.5.2 **Technical Criteria Analysis** This paragraph presents the technical criteria analysis of the remedial Alternative V-5 compared against the seven criteria in Table 5-1.

Overall Protection of Human Health and the Environment. The VOC-contaminated groundwater poses an unacceptable risk to human health and the environment under future land-use scenarios. Alternative V-5 relies on physical removal (*in situ* recirculation wells and IRA air stripper) and biological degradation (enhanced biodegradation and natural attenuation) of the VOCs in the groundwater to eventually eliminate human health risks. Institutional controls would be temporarily implemented to minimize potential human consumption of the groundwater until contaminant concentrations were reduced to Florida drinking water standards.

Two options are available as to the specific treatment levels achieved within the source area. For Option A, recirculating wells would be used to treat the northern plume source area to meet Florida drinking water standards while the

existing IRA wells would treat the downgradient contaminated groundwater *in situ* to State surface water standards. The process flow diagram for this option is shown on Figure 5-9. Groundwater-use restrictions would be required because the contaminant plume at OU 4 would pose a potential risk to future residents during operation of the treatment systems (source area recirculating system and existing IRA wells) and following the shut-down of the IRA wells. Once the entire groundwater plume was treated to State drinking water standards, the groundwater-use restrictions would be eliminated. The combination of the recirculating system, operation of the existing IRA wells, and implementation of groundwater-use restrictions would ensure that the public health and the environment were properly protected.

Option B for this alternative involves the treatment of the source area groundwater to site-specific standards and existing natural attenuation to complete the reduction of contaminants to State drinking water standards. The process flow diagram for this option is depicted on Figure 5-10. As stated above, groundwater-use restrictions would be implemented during the operation of the source area recirculating system and existing IRA well system and MNA until the groundwater met drinking water standards. This remedial alternative would protect human health and the environment through the use of temporary groundwater-use restrictions and the treatment of the VOCs detected in the OU 4 groundwater prior to the discharge into Lake Druid.

Compliance with ARARs. In the short-term, this alternative would comply with the chemical-specific ARAR for VOCs in groundwater discharging into a surface water body. However, it would not comply with the drinking water standards until MNA reduced the residual VOCs in the entire VOC plume to these State standards.

This alternative emphasizes treatment of the VOC source area, reducing the overall operation of the IRA and expediting the time to achieve these ARARs. Monitoring of the groundwater quality at the point of compliance near the lake edge and at the source area would be used to ensure compliance with the ARARs.

Long-Term Effectiveness and Permanence. This alternative is focused on the treatment of VOC contamination within the source area and the downgradient plume prior to it discharging into Lake Druid. The recirculating well technology has all ready been proven successful at permanently removing contaminants from the groundwater at OU 4. Operation of the existing IRA wells at OU 4 has provided significant information on system optimization and its ability to treat the groundwater to Florida surface water standards.

Enhanced biodegradation is still an emerging technology, but shows great promise at biologically destroying chlorinated solvents permanently, especially when natural biological degradation is already being observed at OU 4. As part of the design phase, field pilot tests at OU 4 would be required to optimize injection distribution, quantity, and frequency.

Groundwater treatment and natural attenuation durations were prepared based on site-specific hydraulic characteristics of OU 4 to determine the applicable short term or long-term permanence of the groundwater-use restrictions.

Reduction of Toxicity, Mobility, and Volume Through Treatment. This alternative would reduce the toxicity, mobility, and volume of VOCs in the OU 4 groundwater. This would be accomplished through the physical removal of the VOCs *in situ* in

the northern plume source area by recirculating wells, while enhanced biodegradation would destroy the VOCs *in situ* in the southern plume. The downgradient plume would initially continue to be treated by the existing IRA wells that physically remove the VOCs from the groundwater. Emission of the off-gas from the proposed recirculating wells in the source area of the northern plume would be treated by GAC for compliance with Florida air quality requirements (less than 13.7 lbs/day). Contaminants adsorbed by the GAC would be destroyed during carbon regeneration. Emission of the off-gas from the existing IRA wells is in compliance with Florida air quality requirements, but does not destroy the contaminants. Based on the continued operation of the existing IRA wells, the small volume of vapor emissions would not require collection or treatment. However, vapor emissions will be monitored as part of the treatment system monitoring to ensure compliance with the FDEP air regulations. If treatment is found to be required, an emissions treatment system could be added. Monitored natural attenuation, implemented once surface water criteria was achieved without IRA operation, would biologically reduce the toxicity and volume of VOCs.

Short-Term Effectiveness. This remedial alternative would achieve the remedial goals for groundwater quality by treatment of the VOCs using recirculating wells, enhanced biodegradation, and natural attenuation. For either process option alternative A or B (Figure 5-9 or Figure 5-10), contaminant reduction to Florida drinking water standards is expected to require longer than 25 years. Due to the long-term operation of the remedial action, groundwater-use restrictions would provide the necessary short-term effectiveness in protecting the public from the existing contaminants. There would be only slight exposures to workers performing well installations, treatment process operations, and groundwater monitoring during these time frames. The residuals produced by the IRA air stripper (vapor emissions) are expected to be negligible, not exceeding 0.2 lb/day (ABB-ES, 1998b), far below the FDEP limit of 13.7 lb/day. Air emissions would also continue to be monitored to ensure they do not exceed FDEP air quality standards.

Implementability. Installation of the recirculating well system will require use of specially designed equipment and contractors that are technically trained for construction of the system. However, design and construction will be somewhat simplified because of the site-specific experience gained through installation of the former IRA recirculation wells.

As indicated in Section 2.3, operational difficulties did occur with the former IRA system and three primary problems were identified: intermittent operation, biofouling and poor re-injection rates. Intermittent operation was due to limited recharge capacity in the lower screen interval. Biofouling did affect the recharge capacity although it was not the major cause, as indicated by similarities in pumping rates before and after acid treatment and redevelopment of the well screens. The design re-injection rates were not achieved after redevelopment. All of these factors contributed to the failure to develop and maintain a recirculation cell. Based on experience with the former IRA system, it is anticipated that recirculation wells installed to remediate the VOC source area could only be operated successfully with potentially excessive system maintenance. Therefore, the use of recirculation wells at OU 4 may be technically infeasible.

Injection of the HRC™ would be easily implementable in that it requires only basic drilling techniques. The presence of the hard layer makes using

conventional augering more attractive than direct-push methods for injection of the HRC™.

The required utilities are also readily available at the site. Building 1100 is currently vacant such that construction of the treatment system will not interfere with any ongoing operations at NTC, Orlando.

Cost. Present worth costs have been prepared for process options A and B (Figures 5-9 and 5-10). System operation durations have been estimated based on actual site hydrogeologic characteristics. They are also based on the assumption that recirculation wells would be approximately 4 times faster at removing residual contamination within the source area than conventional extraction wells. These present worth costs include direct, indirect, and O&M costs for the recirculating well system; HRC™ injection; and groundwater, natural attenuation and air monitoring. Administrative O&M costs for the 5-year site reviews presented in the limited action alternative were also included. A complete cost summary for remedial alternative process options A and B is presented in Tables 5-6 and 5-7, respectively. The detailed cost calculations are included in Appendix D.

- Alternative V-5A: Drinking Water Standards RGO (Figure 5-9).

  The total estimated cost for the active treatment of VOC-contaminated groundwater to drinking water standards was $3,308,022 (Table 5-6). The direct cost for this remedial alternative process option is approximately $733,027, which includes site preparation, remedial construction of the four recirculation wells in the northern plume source area, vapor phase carbon for off-gas treatment (first year operation only) and the HRC™ injections, and a short report summarizing these remedial actions. The indirect cost is approximately $205,000. Indirect costs would include health and safety costs, administrative fees, engineering and design and construction support services, and a pilot-test for the HRC™ treatment system in the southern plume.

  The present worth O&M cost would be approximately $2,069,265 for the 5-year site reviews and groundwater monitoring, treatment system O&M and associated utilities over a 27-year treatment duration, and a total 27-year period of monitoring the OU 4 VOC groundwater plume.

- Alternative V-5B: Site-specific RGO (Figure 5-10).

  The total estimated cost for the active treatment of VOC-contaminated groundwater to site-specific remedial goals and the use of natural attenuation to achieve drinking water standards is $2,986,578 (Table 5-7). The direct cost for this remedial alternative process is estimated to be $733,027, which includes site preparation, remedial construction of the source area recirculation wells, and the first HRC™ injection in the southern plume. A short report summarizing the remedial construction actions would also be prepared. The indirect cost is approximately $205,000.

  The present worth O&M cost would be approximately $1,777,044 for the 5-year site reviews and groundwater monitoring, treatment system O&M and

Table 5-6
Cost Summary for Alternative V-5A: Recirculation Wells and Enhanced Bioremediation, Groundwater Treated to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$50,112
Recirculation Wells (Northern Plume)	$568,000
Vapor-Phase Off-Gas System (1 year only)	$20,540
HRC™ Injection System (Southern Plume)	$84,375
Total Direct Cost	$733,027
INDIRECT COSTS	
Health and Safety	$20,000
Administration and Permitting	$30,000
Engineering and Design	$60,000
Pilot-Test of HRC™ System	$25,000
Construction Support Services	$70,000
Total Indirect Cost	$205,000
Total Capital Cost (Direct + Indirect)	$938,027
OPERATION AND MAINTENANCE (O&M) COSTS	
Recirculation Wells (27 years)	
Present Worth - System Operation (6%, 27 years)	$1,241,834
Present Worth - Groundwater Monitoring (6%, 27 years)	$152,587
HRC™ System (3 years)	
Present Worth - System Operation Years 2 and 3 (6%, 2 and 3 years)	$33,060
Present Worth - HRC™ Monitoring (6%, 3 years)	$46,911
IRA Wells (15 years)	
Present Worth - System Operation (6%, 15 years)	$413,755
Present Worth - Groundwater Monitoring (6%, 15 years)	$103,435
Natural Attenuation Monitoring (10 years)	
Present Worth - Downgradient VOC Plume (6%, 16 to 25 years)	$36,363
5-Year Site Reviews (every 5 years for 27 years)	
Present Worth - 5-Year Site Reviews (6%, 27 years)	$41,319
Total O&M Cost (present worth)	$2,069,264

See notes at end of table.

Table 5-6 (Continued)
Cost Summary for Alternative V-5A: Recirculation Wells and Enhanced Bioremediation, Groundwater Treated to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
O&M COSTS (Continued)	
Total Capital and O&M Cost	$3,007,291
Contingency (10%)	$300,729
Total Cost of Alternative V-5A: Recirculation Wells and Enhanced Bioremediation to Drinking Water Standards	$3,308,020

Notes: HRC™ = Hydrogen Release Compound™.
% = percent.
IRA = Interim Remedial Action.
VOC = volatile organic compound.

Table 5-7
Cost Summary for Alternative V-5B: Recirculation Wells and Enhanced Bioremediation, Groundwater Treated to Site-Specific Remedial Goals

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$50,112
Recirculation Wells (Northern Plume)	$568,000
Vapor-Phase Off-Gas System (1 year only)	$20,540
HRC™ Injection System (Southern Plume)	$84,375
Total Direct Cost	$733,027
INDIRECT COSTS	
Health and Safety	$20,000
Administration and Permitting	$30,000
Engineering and Design	$60,000
Pilot-Test of HRC™ System	$25,000
Construction Support Services	$70,000
Total Indirect Cost	$205,000
Total Capital Cost (Direct + Indirect)	$938,027
OPERATION AND MAINTENANCE (O&M) COSTS	
Recirculation Wells (15 years)	
Present Worth - System Operation (6%, 15 years)	$912,928
Present Worth - Groundwater Monitoring (6%, 15 years)	$112,174
HRC™ System (3 years)	
Present Worth - System Operation Years 2 and 3 (6%, 2 and 3 years)	$33,060
Present Worth - HRC™ Monitoring (6%, 3 years)	$46,911
IRA Wells (15 years)	
Present Worth - System Operation (6%, 15 years)	$413,755
Present Worth - Groundwater Monitoring (6%, 15 years)	$103,435
Natural Attenuation Monitoring (15-45 years)	
Present Worth - Entire VOC Plume (6%, 16 to 45 years)	$104,824
5-Year Site Reviews (every 5 years for 45 years)	
Present Worth - 5-Year Site Reviews (6%, 45 years)	$49,957
Total O&M Cost (present worth)	$1,777,044

See notes at end of table.

Table 5-7 (Continued)
Cost Summary for Alternative V-5B: Recirculation Wells and Enhanced Bioremediation, Groundwater Treated to Site-Specific Remedial Goals

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
O&M COSTS (Continued)	
Total Capital and O&M Cost	$2,715,071
Contingency (10%)	$271,507
Total Cost of Alternative V-5B: Recirculation Wells and Enhanced Bioremediation, Groundwater Treated to Site-Specific Remedial Goals	$2,986,578

Notes: HRC = Hydrogen Release Compound™.
% = percent.
IRA = Interim Remedial Action.
VOC = volatile organic compound.

associated utilities over a 15-year treatment duration, and a total 45-year period of monitoring the OU 4 VOC groundwater plume.

5.1.6 Alternative V-6: Groundwater Extraction, Air Stripping, and Discharge into Lake Druid This alternative consists of hydraulic control of the source area through the extraction of contaminated groundwater, treatment via a diffused aeration stripper and discharge of the treated effluent to Lake Druid. Based on the modeling of the contaminated aquifer, two groundwater extraction wells will be installed within the source area of the VOC plume. The zone of influence would eventually cover the groundwater plumes (northern and southern) located beneath and east of Building 1100. The groundwater extracted from the source area would be treated by passing the groundwater through a diffused aeration tank and forcing air up through the water to transfer the VOCs into the air stream. The extracted groundwater would be treated to Florida surface water standards and then discharged into Lake Druid. Based on existing data, the air emissions would not require treatment prior to their release into the atmosphere (Appendix H). As discussed in Chapters 3.0 and 4.0, posttreatment for inorganics will not be required prior to discharge to Lake Druid. This alternative also makes use of MNA in the downgradient plume to achieve surface water standards at Lake Druid and eventually MCLs.

A description of this alternative is presented in Paragraph 5.1.6.1, and a technical criteria assessment of this alternative is presented in Paragraph 5.1.6.2.

5.1.6.1 **Detailed Description** This alternative would address contamination within the source areas of the northern and southern VOC plumes at OU 4, reducing concentrations of PCE, TCE, and cis-DCE to Florida surface water standards for discharge into Lake Druid and eventually to Florida drinking water standards (Table 3-3). The downgradient portion of the plumes would continue to be treated by operating the existing IRA wells until the groundwater met Florida surface water standards and then natural attenuation would be used to reduce the residual contaminants down to drinking water standards.

As discussed for Alternative V-5 (Paragraph 5.1.5.1), calculations have been performed to estimate the duration of a conventional groundwater extraction and treatment system (Appendix G). These calculations required an estimate of the total source area mass (6,000 pounds), the horizontal and vertical distribution of this mass, and the initial concentration of VOCs in extracted groundwater. Two durations can be calculated, one to reduce VOC concentrations in the source area to levels that will naturally attenuate to Florida surface water standards before reaching Lake Druid (59 years), and a considerably longer duration for achieving MCLs in the source area (108 years).

As with the previous alternatives, the IRA system would continue to operate for 10 years to ensure VOCs in the downgradient plume have been treated to ensure compliance with Florida surface water standards at Lake Druid.

Two process flow diagrams for this remedial alternative are presented on Figure 5-13 to achieve the overall RGOs. The first process flow diagram presented on Figure 5-13 depicts Option A, where the source area is treated *ex situ* by diffused air stripping for an estimated 108 years until the source area groundwater meets Florida drinking water standards. The groundwater plume located downgradient of the source area would be addressed by the two existing

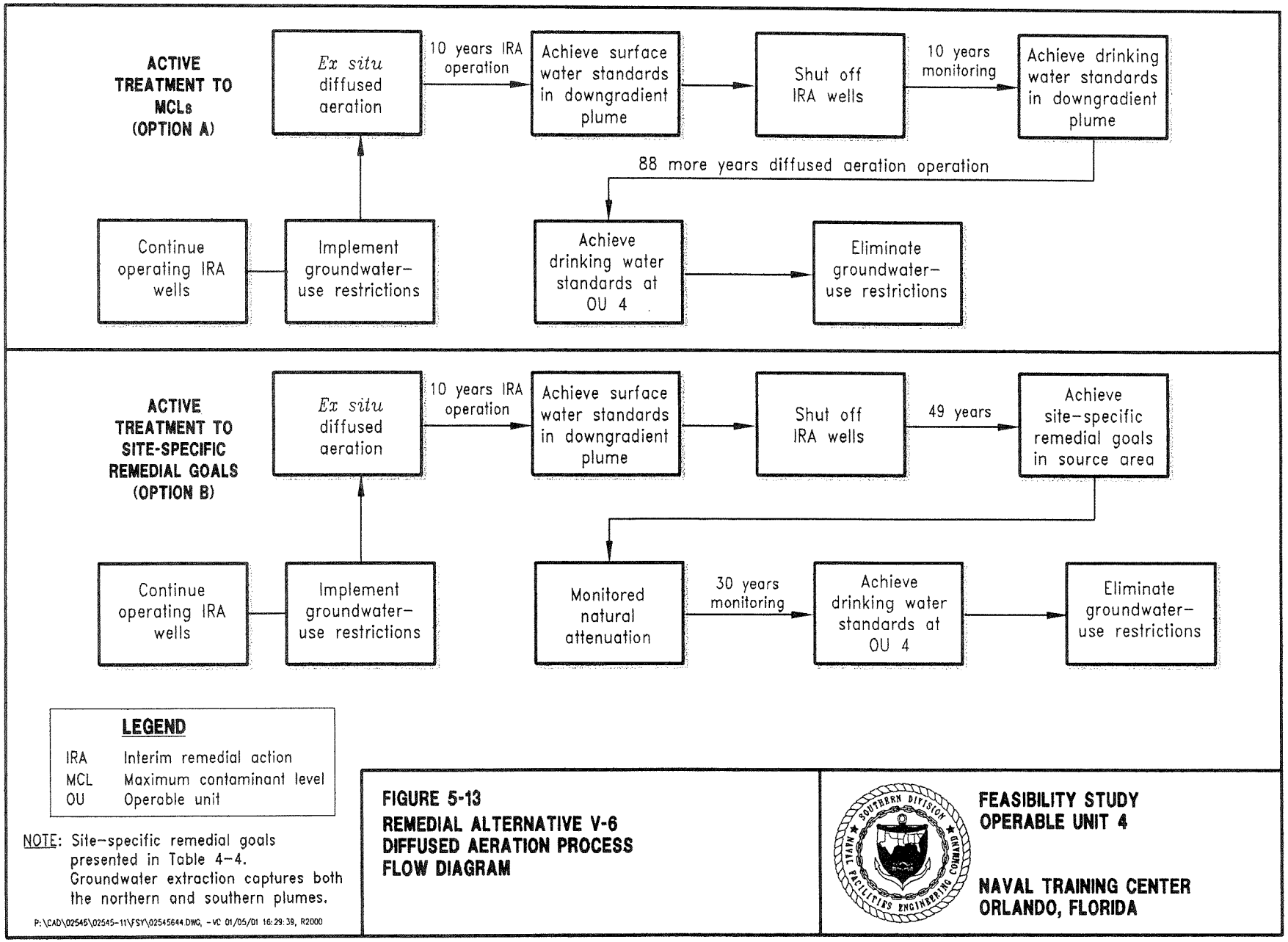

FIGURE 5-13
REMEDIAL ALTERNATIVE V-6
DIFFUSED AERATION PROCESS
FLOW DIAGRAM

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IRA wells for a duration of 10 years, based on the estimated travel time for the contaminants to flow from just outside the capture zone of the groundwater extraction wells to the IRA wells. Groundwater monitoring would then be conducted in the downgradient plume for the degradation of the contaminants to Florida drinking water standards over a period of 10 additional years. Following the remediation of the contaminated groundwater in the source area and the downgradient plume to Florida drinking water standards, the original groundwater-use restrictions implemented to protect the public health would be eliminated.

The second process flow diagram presented on Figure 5-13 depicts Option B, where the diffused air stripper treatment system remediates the source area for 59 years to contaminant concentrations that will naturally attenuate to achieve surface water standards prior to reaching the lake, and eventually MCLs. The downgradient VOC plume would be addressed by the existing IRA wells for 10 years, as discussed above.

After 59 years of operation, the groundwater extraction system in the source area would be shut down. The associated termination of hydraulic containment would release low levels of contaminants from the source area to migrate downgradient towards the lake.

These remaining low-level contaminants within the source area and downgradient plume would be treated to drinking water standards using MNA. The rate limiting factor to achieve Florida drinking water standards would be the dissolution of any remaining source into the groundwater. For estimating purposes, a duration of 30 years was assumed to achieve this final cleanup goal. Should MNA not readily achieve the goals of surface water standards, the individual IRA wells could be restarted to ensure compliance prior to the groundwater discharging into the lake.

Major components of this alternative include the following:

- groundwater-use restrictions until RAOs are achieved
- two groundwater extraction wells
- diffused air stripper
- discharge of treated groundwater to Lake Druid
- monitoring of treatment system
- O&M of the diffused air stripper system
- phase-out IRA operations
- groundwater monitoring points
- natural attenuation monitoring (only for non-MCL RGO)
- source area soil sampling
- 5-year site reviews

A schematic layout of this alternative is presented on Figure 5-14 and a detailed discussion of the individual components of this *ex situ* treatment alternative are provided below.

Groundwater-Use Restrictions. Refer to Paragraph 5.1.2.1 for a detailed description of groundwater-use restrictions required to be implemented at OU 4.

Groundwater Extraction Wells. Based on site-specific characteristics of the OU 4 groundwater plume and source area, two extraction wells were proposed. Operating at a flow rate of 40 gpm per well, the zone of influence is anticipated to

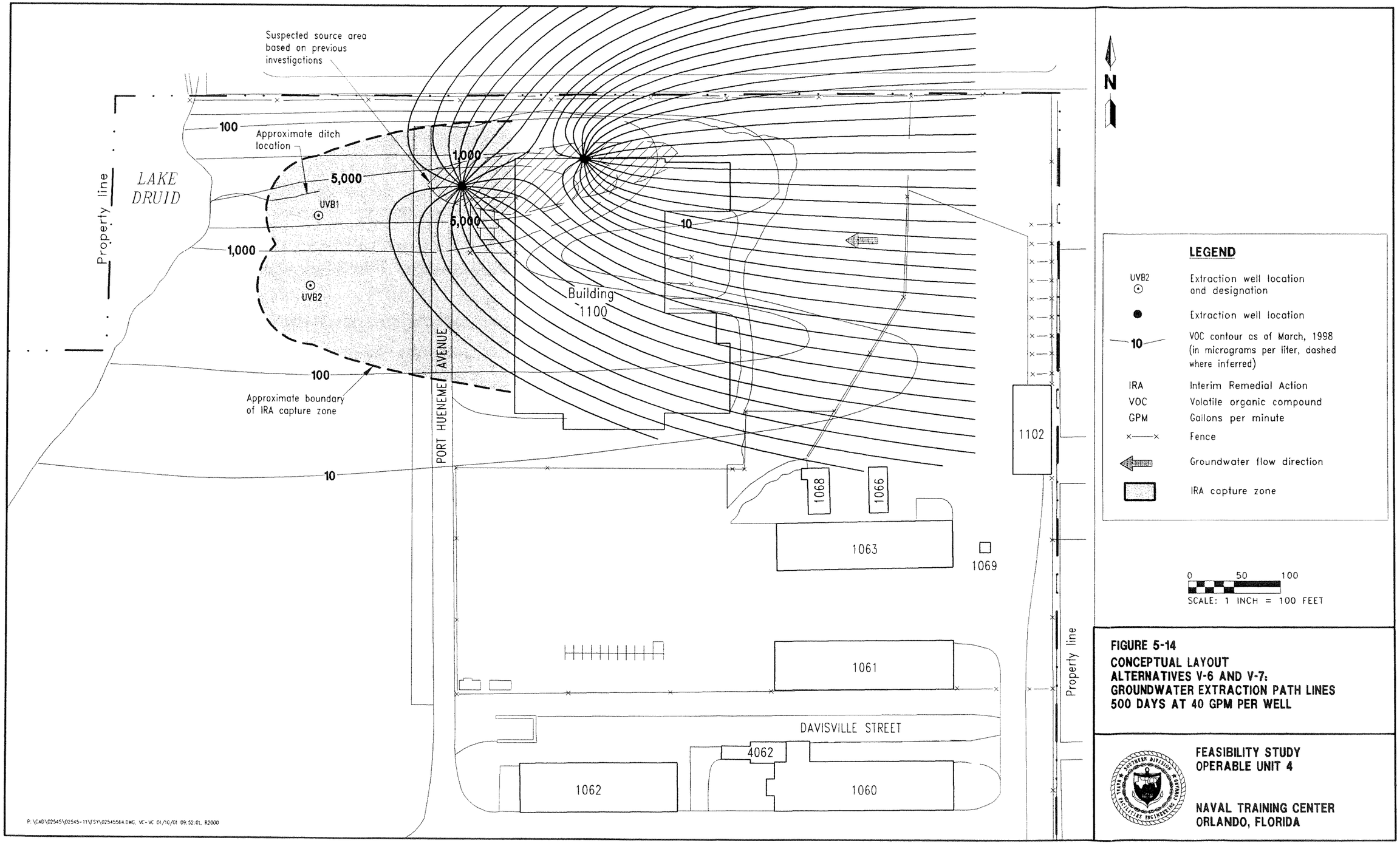

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FIGURE 5-14
CONCEPTUAL LAYOUT
ALTERNATIVES V-6 AND V-7:
GROUNDWATER EXTRACTION PATH LINES
500 DAYS AT 40 GPM PER WELL

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encompass the entire groundwater plume extending east of Port Hueneme Avenue, including the VOC contaminant source area. The wells would be installed to a depth of approximately 45 feet bls and located as shown on Figure 5-14. The extraction wells would be constructed of 4-inch Schedule 80 PVC casing and would have a screen length of 30 feet. A locking vault would be installed over the surface of the extraction wells and would contain the controls for the float switches and pump. A sampling port would also be included in the piping from the well to the treatment system for overall performance monitoring, as discussed below. The extraction wells would be connected via a manifold and conveyance piping to the groundwater treatment system.

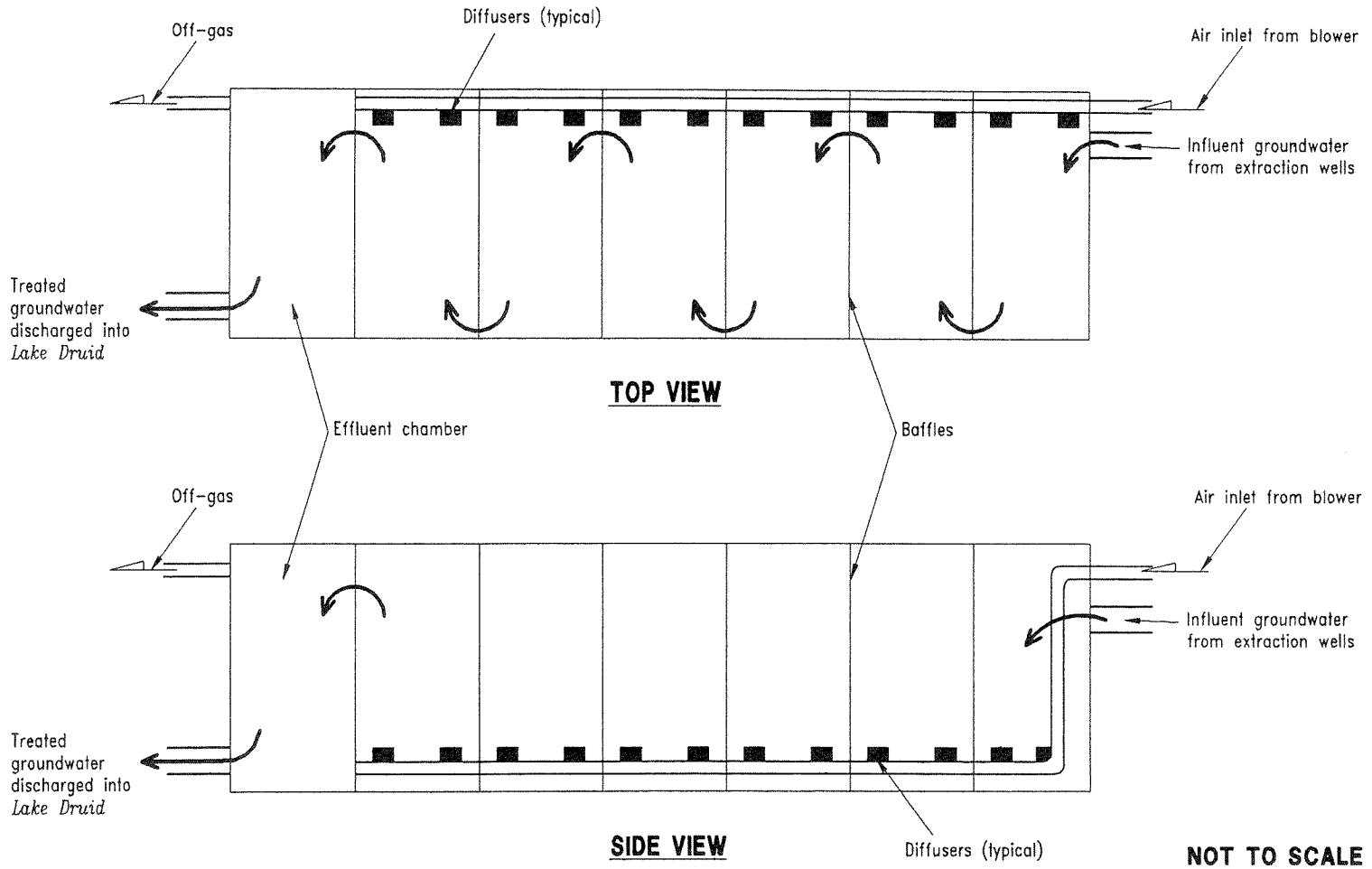
Diffused Aeration Stripping. Treatment levels for the surface water discharge into Lake Druid are presented in Table 3-3. Based on the removal rates required for the extracted groundwater to meet these discharge criteria, a diffused aeration system with a 6-baffle tank would be used to treat the extracted groundwater. This treatment system includes a polypropylene tank, an air blower, and stainless steel air diffusers. The diffused aeration tank has a flow capacity of 1 to 170 gpm, and an anticipated flow rate of 80 gpm. The serpentine flow path through the aeration tank would maximize the detention time within the tank and increase the air to water contact to strip the VOCs from the groundwater. The blower delivers the air to the diffusers, which then contact the dissolved contaminants and transfer them into the air within the tank. The contaminated air is drawn out of the tank for monitoring and discharge into the atmosphere. No off-gas treatment is expected to be necessary (Appendix H). The air flow rate is estimated to be approximately 360 cubic feet per minute. A schematic of the diffused aeration stripper is presented on Figure 5-15.

Discharge of Treated Groundwater to Lake Druid. The treated groundwater would be discharged into Lake Druid along the northern perimeter fence of NTC, Orlando. Effluent groundwater from the IRA system would also be combined with this flow and would no longer discharge to the City of Orlando POTW. The 2-inch discharge pipe would be buried approximately 2 to 3 feet bls and discharge out a newly constructed head wall immediately above the waters edge. Estimated flow is 90 gpm or approximately 0.2 cubic feet per second. A pump would be used to convey treated water from the stripper to the lake.

An NPDES permit and a FDEP surface water discharge permit will be required prior to constructing the discharge pipe and the new headwall at the edge of the lake.

System Monitoring. The groundwater quality at each extraction well and the treatment system influent and effluent would be monitored on a frequent basis to evaluate the mass removal of organic contaminants from the source area and to ensure that SWQSs were being met prior to discharging into Lake Druid. This sampling would be limited to VOCs and any other surface water discharge criteria (e.g., total suspended solids [TSS], pH, temperature, etc.) required under the NPDES permit and FDEP surface water discharge permit. Sampling ports would be included in the individual extraction well vaults and at the equalization tank following the air stripper, prior to surface water discharge. The presumed sampling schedule and rationale are included in the cost estimate for this alternative (Appendix D).

Off-gas monitoring of the air stripper emissions would be conducted to confirm that the emissions do not exceed the 13.7 lbs/day limit. Preliminary emission calculations from the air stripper (Appendix H) indicated that off-gas treatment



NOTE:
Contaminated water flows in a serpentine pattern via alternating holes in baffles separating the chambers. Treated water cascades into effluent chamber and is discharged into *Lake Druid*.

FIGURE 5-15
SCHEMATIC OF ALTERNATIVE V-6: DIFFUSED AERATION (NORTHERN AND SOUTHERN PLUMES)

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was not required. However, samples of organic vapors from the air stripper would be collected and analyzed for VOCs on a regular basis. If treatment of the off-gas were to become necessary, vapor-phase GAC could be used to treat VOCs in accordance with action-specific ARARs for air treatment prior to discharge. Based on the air emission calculations, costs for off-gas control were not included for this remedial alternative.

Operation and Maintenance. O&M of the diffused air stripper system would be limited by the simplicity of the system, proposed telemetry system to monitor ongoing operations from a distance, and the programmable logic controls (PLCs) used to operate the groundwater pumps and blower. On-site system monitoring would include a site visit once every two weeks to check groundwater pumping rates, VOC concentration in the air emissions, and buildup of inorganics and bacteria within the diffused aeration tank. The equipment within the tank is readily accessible via the removable locking cover. System maintenance would also involve preventative maintenance of the groundwater extraction pumps, discharge pump and blower, cyclone diffusers, and maintenance of spare parts and supplies, as necessary.

Phase-Out Operation of IRA System. As with Alternative V-3, it is anticipated that the IRA will operate for 10 years before the residual downgradient plume (plume between the downgradient edge of the source area extraction well capture zone and the IRA wells) would be treated.

Groundwater Monitoring. Groundwater monitoring would be conducted within both the source area and downgradient VOC plumes using both existing and proposed monitoring wells. The source area wells would be used to monitor the groundwater for VOCs to determine when the RGOs were met. This VOC data would be used to evaluate the effectiveness of the pump-and-treat system on the source area. As part of this evaluation, the pumping rates may be adjusted or an extraction well temporarily shut down to improve the overall capture of the contaminant plume.

The downgradient monitoring wells would be used to monitor the performance of the IRA wells and indicate when the IRA wells could be turned off, relying on natural degradation to complete the remediation of the residual concentrations of organics in the groundwater. This monitoring is discussed below.

Source Area Soil Sampling. Source area sampling to demonstrate compliance with leachability SCTLs will be required upon achieving Florida MCLs. Details can be found in Alternative V-3 (Paragraph 5.1.3.1).

Natural Attenuation Monitoring. Natural attenuation monitoring would be required after the 59 years required to achieve source area concentrations that will naturally attenuate to surface water standards. This monitoring would ensure that the groundwater naturally discharging into Lake Druid continued to meet surface water standards and that the VOC concentrations were being reduced to ultimately meet Florida drinking water standards. For estimating purposes, a duration of 30 years was assumed. Natural attenuation monitoring is discussed in greater detail in Alternative V-3 (Paragraph 5.1.3.1).

No natural attenuation monitoring would be required if the source area treatment system was operated to achieve MCLs in the source area (108 years).

Five-Year Site Reviews. Remedial Alternative V-6 will require 5-year site reviews, as described for Alternative V-3 (Paragraph 5.1.3.1).

5.1.6.2 **Technical Criteria Analysis** This paragraph presents the technical criteria analysis of the diffused air stripping remedial alternative compared to the seven USEPA criteria identified in Table 5-1. As part of this analysis, two options are evaluated based upon the treatment goals of the groundwater plume, which may either be Florida drinking water standards (Option A) or a site-specific remedial goal that then relies on natural attenuation to achieve the drinking water standards (Option B). Figure 5-13 clearly illustrates the remedial process flow diagrams for each of these remedial goals. Both options provide a range of treatment durations, overall compliance with ARARs, and capital and O&M costs.

Overall Protection of Human Health and the Environment. The VOC-contaminated groundwater at OU 4 poses an unacceptable risk to future residents and the environment that is associated with the drinking water supply and discharge into Lake Druid. Remedial Alternative V-6 relies on the extraction of contaminated groundwater from the source area of the VOC plume for treatment prior to discharge into Lake Druid, while the downgradient plume is treated by the existing IRA system. The two groundwater extraction wells would develop a radius of influence that encompassed both the northern and southern groundwater plumes, thereby cutting off the source of contamination and subsequently the downgradient migration towards Lake Druid (Figure 5-14).

For treatment goal Option A, the source area plume would be treated to Florida drinking water standards by the air stripper, while the existing IRA would treat the contaminated groundwater *in situ* to Florida surface water standards. The process flow diagram for this remedial alternative is depicted in Figure 5-13 under Option A. Groundwater-use restrictions would be required because the contaminant plume at OU 4 poses a potential risk to future residents during operation of the treatment systems (air stripping and IRA) and following the shut-down of the IRA wells. Once the entire groundwater plume was treated to drinking water standards, the groundwater-use restrictions would be eliminated. The combination of the *ex situ* air stripping system, operation of the existing IRA wells, and implementation of groundwater-use restrictions would ensure that human health and the environment are properly protected in both the short- and long-term.

Treatment goal Option B involves the treatment of the source area groundwater to site-specific standards followed by the use of ongoing natural attenuation to complete the reduction of contaminants to drinking water standards. The process flow diagram for this remedial alternative is shown in Figure 5-13 under Option B. As stated above, groundwater-use restrictions would be implemented during the operation of the air stripper and IRA systems, and MNA until the groundwater achieved drinking water standards. This remedial alternative would protect human health and the environment through the use of groundwater-use restrictions and the treatment of the VOCs detected in the OU 4 groundwater prior to discharging into Lake Druid.

Compliance with ARARs. In the short-term, this alternative would comply with the chemical-specific ARAR for VOCs in groundwater discharging into a surface water body due to the ongoing operation of the IRA wells. Under Option A (Figure 5-13), the source area would be treated to reduce the VOC contaminant concentra-

tions down to State drinking water standards. However, it would not comply with the State drinking water standards until natural attenuation of the downgradient plume has been completed.

Under Option B, presented on Figure 5-13, compliance with the chemical-specific ARARs for Florida drinking water standards would not be met until MNA was completed for the entire groundwater plume. The process to achieve compliance with the ARARS would involve the treatment of the source area plume to a site-specific standard and then the use of ongoing natural attenuation. The downgradient plume would be addressed in a similar fashion as in the first process option, where the IRA wells would treat the groundwater to surface water standards and then natural attenuation to complete the remediation to drinking water standards.

Both of these process options would emphasize treatment of the VOC source area reducing the overall operation of the IRA system and expediting the time to achieve these ARARs. Monitoring of the groundwater quality at the point of compliance near the lake edge would be used to ensure compliance with the ARARs.

Long-Term Effectiveness and Permanence. This alternative is focused on the treatment of VOC contamination within the source area and the downgradient plume prior to it discharging into Lake Druid. Both the air stripping and the IRA well technologies are well proven and the technologies readily available. Diffused aeration has been effectively used to remediate organics and inorganics in groundwater at hazardous waste sites and at wastewater treatment facilities. Operation of the existing IRA wells at OU 4 has provided significant information on system optimization and its ability to treat the groundwater to Florida surface water standards. Groundwater treatment and natural attenuation durations were prepared based on site-specific hydraulic characteristics to determine the applicable short-term or long-term permanence of the groundwater-use restrictions.

Groundwater and surface water monitoring would provide a means of evaluating the overall long-term effectiveness of the remedial alternative and the permanence of achieving the RGOs.

Reduction of Toxicity, Mobility, and Volume of Contaminants through Treatment. This alternative would permanently reduce the toxicity, mobility, and volume of VOCs in extracted groundwater. VOCs would be removed from the extracted groundwater via air stripping to reduce the mobility of the contaminants, and the off-gas from the air stripper would be monitored to determine whether or not collection and treatment via GAC is necessary. The treated groundwater would be discharged into Lake Druid. This treated effluent would readily meet the Florida surface water discharge standards for VOCs. The IRA system has already proven its ability to remove the contaminants from the groundwater. This system would also transfer the contaminants to the air stream without any treatment prior to discharge. However, only the natural attenuation component of this alternative would readily reduce the toxicity, mobility, and volume of contamination in the groundwater.

Short-Term Effectiveness. By implementing this alternative, the migration of groundwater contamination into Lake Druid would be affected immediately and overall operation of the IRA wells would be reduced by providing hydraulic containment of the source area. Contaminated groundwater would be extracted via

two recovery wells located north of Building 1100 (Figure 5-14), thereby mitigating further migration from the source area. The IRA wells would also continue to support the treatment of the downgradient plume to surface water standards prior to the groundwater discharging into the lake.

Implementability. Construction of the extraction and treatment system is relatively easy to implement and would not pose a threat to workers or the community. Components of the proposed diffused aeration system are readily available (i.e., "off-the-shelf" products). The IRA wells are already in place and the diffused aeration system is available from multiple vendors. The treatment system would be located at the northern end of Port Hueneme Road along the base perimeter fence (Figure 5-16). The required utilities are also readily available at the site. Figure 5-16 presents the schematic layout of the proposed air stripper system, groundwater extraction wells, and effluent discharge into Lake Druid and the existing IRA wells. Building 1100 is currently vacant such that construction of the treatment system would not interfere with any ongoing operations at NTC, Orlando.

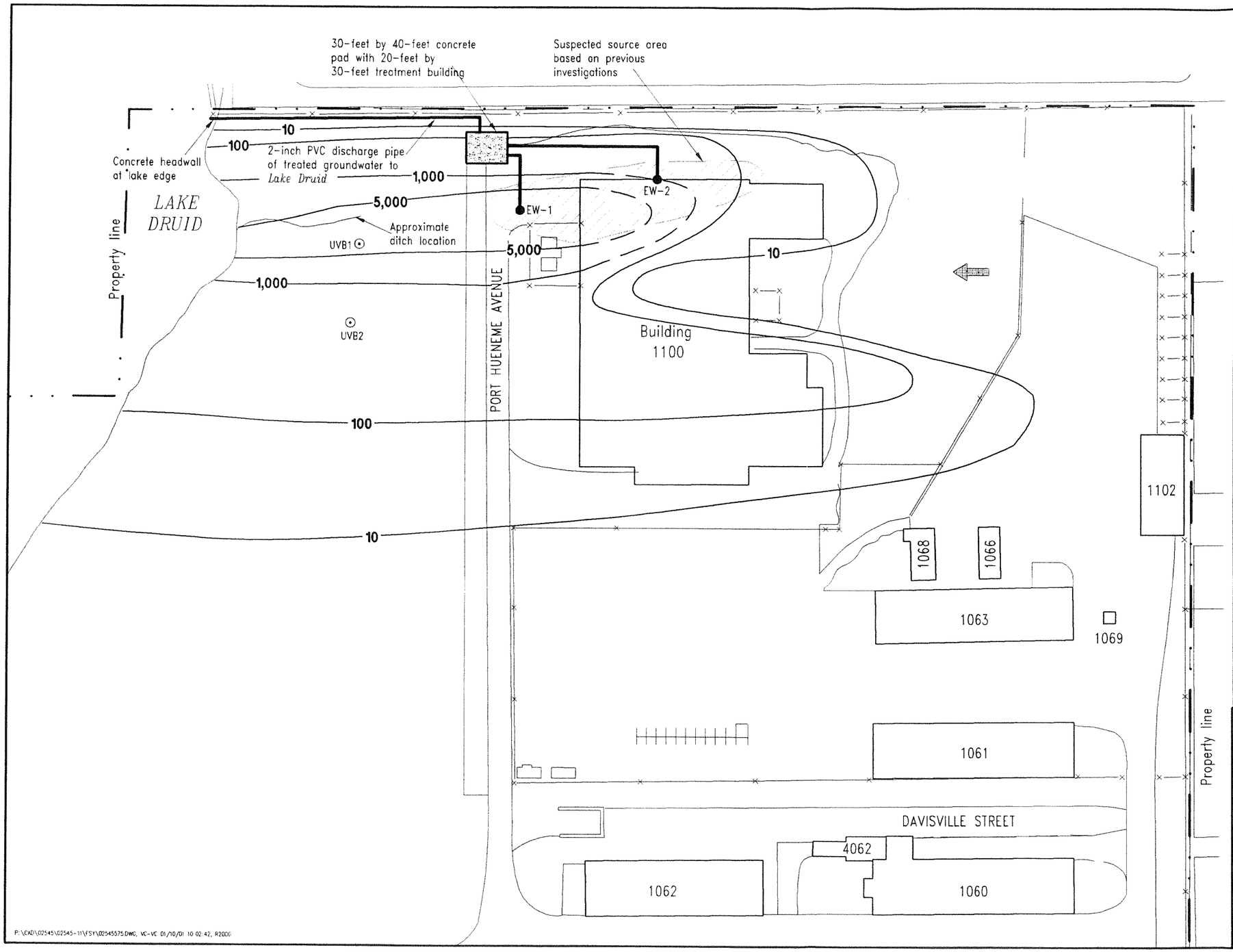
Cost. The present worth costs of Alternatives V-6A and V-6B are presented in Tables 5-8 and 5-9, respectively. The process flow diagrams for each of these options are presented on Figure 5-13. The cost estimates include site preparation; installation of the groundwater extraction system; construction of the diffused aeration system and the effluent discharge into Lake Druid; system O&M, groundwater and air monitoring; natural attenuation, where applicable; and utilities for the system operation.

The duration of the diffused aeration system operation would vary from 108 years to achieve drinking water standards to 59 years to achieve the site-specific standards and then over 30 years (30 years assumed for costing) of natural attenuation monitoring of the entire VOC plume to ensure that the groundwater is remediated to drinking water standards. The operating duration of the IRA wells would be 10 years for both remedial process options.

- Alternative V-6A: Drinking Water Standards RGO (Figure 5-13).

  The total estimated cost for the active treatment of VOC-contaminated groundwater to drinking water standards is $1,848,590 (Table 5-8). The direct cost for this remedial alternative process option is approximately $200,505, which includes site preparation, remedial construction of the groundwater extraction, and diffused aeration system for the entire VOC plume and effluent discharge piping to Lake Druid. A short report would also be prepared that summarized the remedial construction activities. The indirect cost is approximately $105,000. Indirect costs would include health and safety costs, administrative fees, engineering and design, and construction support services.

  The present worth O&M cost would be approximately $1,375,030 for the 5-year site reviews and groundwater monitoring, IRA system operation for 10 years, diffused aeration system O&M, and associated utilities over a 108-year treatment duration.



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LEGEND

UVB2 ⊙	Extraction well location and designation
EW-1 ●	Extraction well location
—10—	VOC contour as of March, 1998 (in micrograms per liter, dashed where inferred)
IRA	Interim Remedial Action
VOC	Volatile organic compound
GPM	Gallons per minute
PVC	Polyvinyl chloride
×——×	Fence
⇦	Groundwater flow direction

0 50 100
SCALE: 1 INCH = 100 FEET

FIGURE 5-16
CONCEPTUAL LAYOUT
ALTERNATIVES V-6 AND V-7:
DISCHARGE TO LAKE DRUID

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Table 5-8
Cost Summary for Alternative V-6A: *Ex Situ* Diffused Aeration and Discharge to Lake Druid Groundwater Treated to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$62,112
Groundwater Extraction System	$109,893
Diffused Aeration System	$18,500
Total Direct Cost	$200,505
INDIRECT COSTS	
Health and Safety	$10,000
Administration and Permitting	$15,000
Engineering and Design	$40,000
Construction Support Services	$40,000
Total Indirect Cost	$105,000
Total Capital Cost (Direct + Indirect)	$305,505
OPERATION AND MAINTENANCE (O&M) COSTS	
IRA Wells (10 years)	
Present Worth - System Operation (6%, 10 years)	$240,048
Present Worth - Groundwater Monitoring (6%, 10 years)	$78,384
Diffused Aeration (108 years)	
Present Worth - System Operation (6%, 108 years)	$760,598
Present Worth - Source Area Groundwater Monitoring (6%, 108 years)	$192,146
Natural Attenuation Monitoring (10 years)	
Present Worth - Downgradient Plume (6%, 11 to 20 years)	$50,142
5-Year Site Reviews (every 5 years for 108 years)	
Present Worth - 5-Year Site Reviews (6%, 108 years)	$53,713
Total O&M Cost (present worth)	$1,375,031
Total Capital and O&M Cost	$1,680,536
Contingency (10%)	$168,054
Total Cost of Alternative V-6A: *Ex Situ* Diffused Aeration and Discharge to Lake Druid Groundwater Treated to Drinking Water Standards	$1,848,590

Notes: % = percent.
IRA = Interim Remedial Action.

Table 5-9
Cost Summary for Alternative V-6B: *Ex Situ* Diffused Aeration and Discharge to Lake Druid Groundwater Treated to Site-Specific Remedial Goals

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$62,112
Groundwater Extraction System	$109,893
Diffused Aeration System	$18,500
Total Direct Cost	$205,505
INDIRECT COSTS	
Health and Safety	$10,000
Administration and Permitting	$15,000
Engineering and Design	$40,000
Construction Support Services	$40,000
Total Indirect Cost	$105,000
Total Capital Cost (Direct + Indirect)	$305,505
OPERATION AND MAINTENANCE (O&M) COSTS	
IRA Wells (10 years)	
Present Worth - System Operation (6%, 10 years)	$240,048
Present Worth - Downgradient Groundwater Monitoring (6%, 10 years)	$78,384
Diffused Aeration (59 years)	
Present Worth - System Operation (6%, 59 years)	$737,326
Present Worth - Source Area Groundwater Monitoring (6%, 59 years)	$186,267
Natural Attenuation Monitoring (30 years)	
Present Worth - Entire VOC Plume (6%, year 60 to 89)	$6,802
5-Year Site Reviews (every 5 years for 89 years)	
Present Worth - 5-Year Site Reviews (6%, 89 years)	$53,560
Total O&M Cost (present worth)	$1,302,387
Total Capital and O&M Cost	$1,607,892
Contingency (10%)	$160,789
Total Cost of Alternative V-6B: *Ex Situ* Diffused Aeration and Discharge to Lake Druid Groundwater Treated to Site-Specific Remedial Goals	$1,768,681

Notes: % = percent.
IRA = Interim Remedial Action.
VOC = volatile organic compound.

- Alternative V-6B: Site-specific RGO Alternative (Figure 5-13).

  The total estimated cost for the active treatment of VOC-contaminated groundwater to site-specific remedial goals and the use of natural attenuation to achieve drinking water standards is $1,768,681 (Table 5-9). The direct cost for this remedial alternative process is estimated to be $200,505, which includes site preparation, remedial construction of the groundwater extraction system and diffused aeration treatment system, and the effluent discharge to Lake Druid. A short report summarizing the remedial construction actions would also be prepared. The indirect cost was approximately $105,000.

  The present worth O&M cost would be approximately $1,302,387 for the 5-year site reviews and groundwater monitoring, IRA system operation for 10 years, diffused aeration system O&M and associated utilities over a 59-year treatment duration, and a total 89-year period of monitoring the OU 4 VOC groundwater plume.

5.1.7 Alternative V-7: UV/Oxidation and Discharge to Lake Druid This alternative involves the extraction of VOC-contaminated groundwater and *ex situ* treatment using UV light and H_2O_2 to destroy the organic contaminants. As discussed in Alternative V-6, two groundwater extraction wells will be installed within the source area of the VOC plume. The zone of influence would eventually cover the groundwater plume located beneath and east of Building 1100. The remainder of the plume downgradient of Port Hueneme Avenue will continue to be treated by the existing IRA wells. The extracted groundwater would be treated through the addition of H_2O_2 and the enhanced groundwater passing along a UV lamp or a series of lamps. The UV light splits the H_2O_2 molecules creating hydroxyl radicals capable of breaking down the VOCs into nontoxic compounds. These non-toxic compounds include water, carbon dioxide, and residual chloride. The UV/oxidation process would reduce the VOC concentrations down to either Florida drinking water standards or to levels such that natural attenuation would reduce VOC concentrations to Florida drinking water standards prior to being discharged into Lake Druid. As discussed in Chapters 3.0 and 4.0, posttreatment for inorganics will not be required prior to discharge to Lake Druid. This alternative also makes use of MNA in the downgradient plume to achieve surface water standards at Lake Druid and eventually MCLs.

A description of this alternative is presented in Paragraph 5.1.7.1 and technical assessment of this alternative is presented in Paragraph 5.1.7.2.

5.1.7.1 Detailed Description This alternative, UV/oxidation, is intended to address contamination within the source area of the VOC plume at OU 4, eventually reducing the concentration of PCE, TCE and cis-DCE to meet both the Florida surface water standards for natural discharge into Lake Druid and Florida drinking water standards (Table 3-3). The downgradient portion of the plumes would continue to be treated by operating the existing IRA wells until the groundwater met surface water standards. Then natural attenuation would be used to reduce the contaminant levels down to drinking water standards.

As with Alternatives V-5 and V-6, there are two options available (designated A and B) depending on the specified treatment goals. The process flow diagrams for these remedial options are shown in Figure 5-17. For Option A, the source area would be treated *ex situ* by UV/oxidation for an estimated 108 years until the

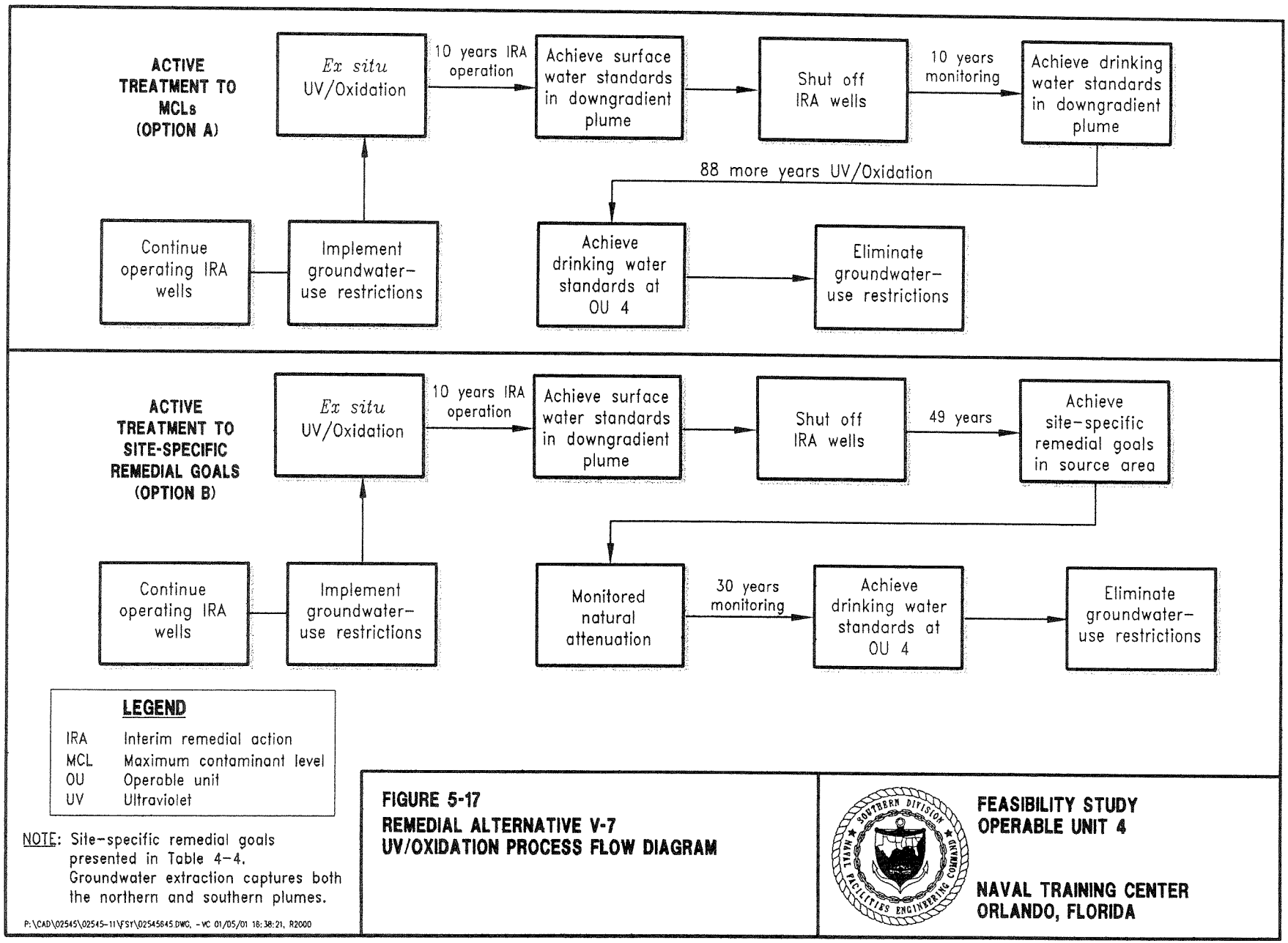


FIGURE 5-17
REMEDIAL ALTERNATIVE V-7
UV/OXIDATION PROCESS FLOW DIAGRAM

FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

source area groundwater has met drinking water standards. The groundwater plume located downgradient of the source area would be addressed by the existing IRA wells operating for 10 years. Groundwater monitoring would then be conducted in the downgradient plume for the natural attenuation of the contaminants to drinking water standards over a period of 12 years. Following the remediation of the contaminated groundwater in the source area and the downgradient plume to drinking water standards, the groundwater-use restrictions implemented to protect human health would be eliminated.

For Option B of this alternative, the UV/oxidation treatment system would remediate the source area to contaminant concentrations exceeding surface water standards. These remedial goals are based on the prior confirmation of natural attenuation (HLA, 1998b) to reduce the remaining groundwater contaminants to surface water standards and ultimately drinking water standards prior to it discharging into Lake Druid. Based on the results of this natural attenuation study, the contaminant concentration is decreased by a factor of 10 during the travel from Building 1100 to Lake Druid. Based on the site-specific RGO, the UV/oxidation system would need to operate for approximately 59 years, at which time the *ex situ* treatment system and hydraulic containment of the source area would be turned off.

The downgradient VOC plume would be addressed by the existing IRA as discussed above, such that the IRA wells would be operated for 10 years. Groundwater monitoring of the downgradient plume (Port Hueneme Avenue to Lake Druid) would then continue for 12 years while the remaining plume naturally attenuates to Florida drinking water standards. Groundwater monitoring would be started up again following the source area treatment system achieving the site-specific RGOs. The shut-down of the source area treatment system and associated hydraulic containment would release low levels of contaminants from the source area to migrate downgradient towards the lake into the area that previously met drinking water standards. These remaining low-level contaminants within the source area and downgradient plumes would be treated to surface water standards, and ultimately drinking water standards, using MNA. The rate limiting factor to achieve drinking water standards would be the complete dissolution of any remaining source into the groundwater. For estimating purposes, a duration of 30 years was assumed to achieve drinking water standards. Should MNA not readily achieve surface water standards, the individual IRA wells could be restarted to ensure compliance prior to the groundwater discharging into the lake.

Major components of this alternative include the following:

- groundwater-use restrictions until RAOs are achieved
- two groundwater extraction wells
- UV/oxidation with H_2O_2
- chemical storage and metering system
- discharge of treated groundwater to Lake Druid
- monitoring of treatment system influent and effluent
- O&M of the UV/oxidation system and chemical metering system
- phase-out operation of IRA system
- groundwater monitoring points
- natural attenuation monitoring
- source area soil sampling
- 5-year site reviews

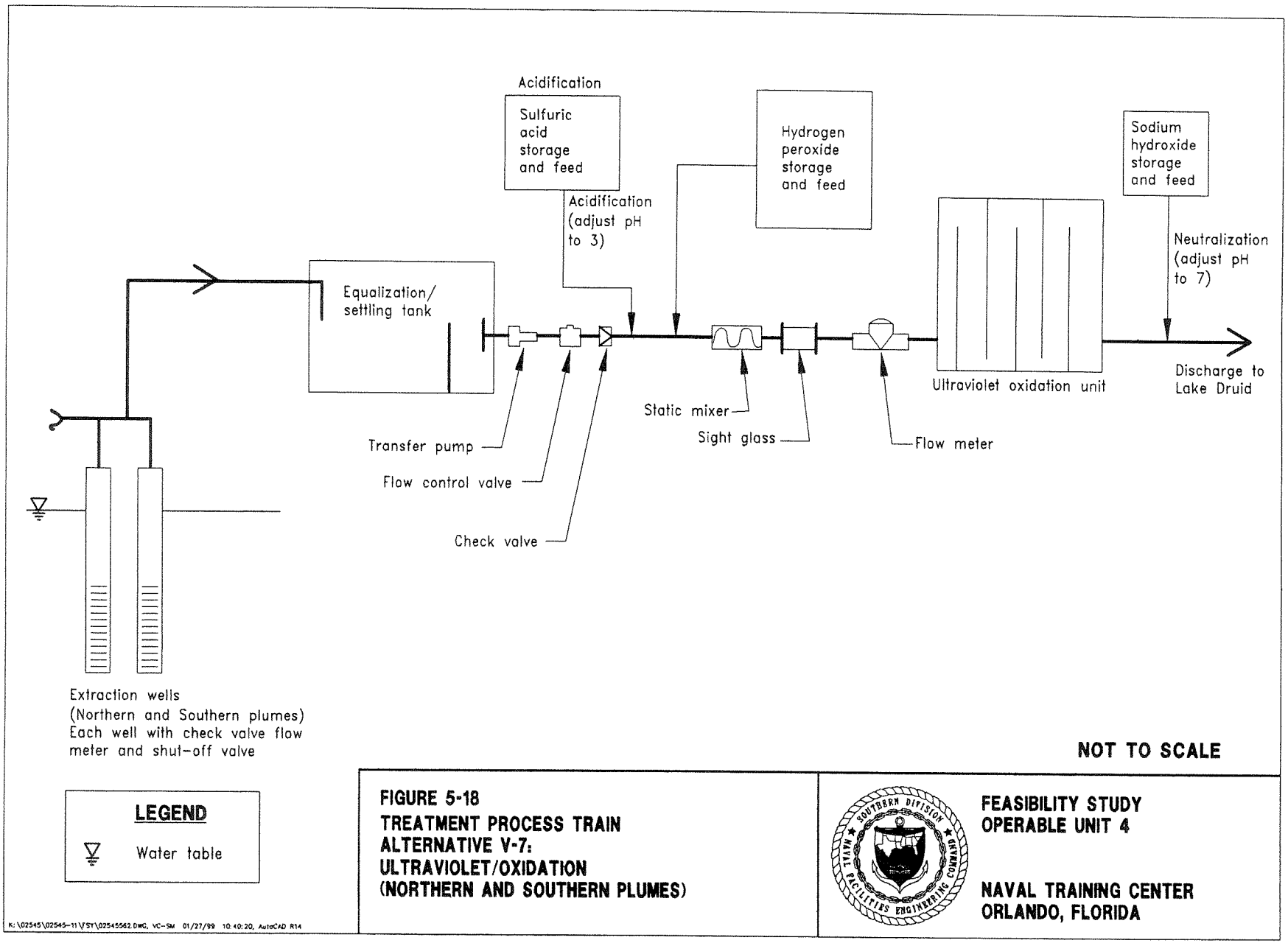
A schematic layout of this alternative is presented on Figures 5-17 and 5-18, and a detailed discussion of the individual components of this *ex situ* treatment alternative are provided below.

Groundwater-Use Restrictions. Paragraph 5.1.2.1 presents a detailed description of groundwater-use restrictions required to protect human health and the environment under the existing and future land-use scenarios evaluated for OU 4. As discussed above, the time required for remedial Alternative V-7 to achieve all of the RAOs is greater than 30 years. Because of this lengthy duration, groundwater-use restrictions would be required to minimize potential risks to future residents from using the groundwater as a drinking water source. Groundwater-use restrictions would be implemented prior to *ex situ* UV/oxidation treatment system construction and operation. These restrictions would continue to be implemented throughout the operation of the UV/oxidation system and the IRA wells until natural attenuation achieved State drinking water standards in the entire VOC plume. Only after achieving this RAO could the groundwater-use restrictions be removed.

Groundwater Extraction Wells. Based on site-specific characteristics of the OU 4 groundwater plume and source area, two extraction wells are proposed. Operating at a flow rate of 40 gpm per well, the zone of influence is anticipated to encompass the entire groundwater plume extending east of Port Hueneme Avenue, including the VOC contaminant source area (Figure 5-14). The design information for these extraction wells was presented in Paragraph 5.1.6.1 under remedial Alternative V-6.

UV/Oxidation and Hydrogen Peroxide Metering System. Based on an estimated average influent concentration of PCE at 5,000 $\mu g/\ell$, and TCE and cis-DCE at 1,000 $\mu g/\ell$ each, a 30 kilowatt (kW) UV and H_2O_2 system was recommended. The H_2O_2 would be injected at the entrance to the oxidation chamber using metering pumps and an in-line static mixer. The H_2O_2 could also be injected at two or more points within the oxidation chamber, if necessary. The enhanced contaminated groundwater would then flow through one or more UV reactors where the destruction of the organics occurs. Within each reactor is one medium-pressure mercury lamp with 30 kW of power. The contaminated groundwater would be separated from the lamp by a quartz sleeve, which is cleaned by a pneumatically driven wiper. This wiper would eliminate the buildup of sediment on the heated lamp fixture and potential reduction in treatment performance. A PLC is included on this skid-mounted unit that operates the chemical metering system and ancillary equipment such as sensors, switches, and valves. The PLC could also control remote diagnostics via a telephone modem and customized program to address changes in the system operations. UV and H_2O_2 systems do not generate vapor emissions or by-products requiring further treatment and would be relatively simple to operate once programmed.

Discharge of Treated Groundwater to Lake Druid. The treated groundwater would be discharged into Lake Druid along the northern perimeter fence of NTC, Orlando. As discussed in Paragraph 5.1.6.1, the 2-inch buried pipe would discharge out a newly constructed head wall immediately above the lake waters edge. Estimated flow would be 90 gpm or approximately 0.2 cubic feet per second. The treated groundwater would be pumped into the lake due to the flat terrain of the site. Should the treated groundwater be discolored due to the oxidation of the inorganics naturally present, a bag filter system could be installed prior to


Acidification
Sulfuric acid storage and feed
Acidification (adjust pH to 3)
Hydrogen peroxide storage and feed
Sodium hydroxide storage and feed
Neutralization (adjust pH to 7)
Equalization/ settling tank
Transfer pump
Flow control valve
Check valve
Static mixer
Sight glass
Flow meter
Ultraviolet oxidation unit
Discharge to Lake Druid
Extraction wells
(Northern and Southern plumes)
Each well with check valve flow meter and shut-off valve
NOT TO SCALE
LEGEND
Water table
FIGURE 5-18
TREATMENT PROCESS TRAIN
ALTERNATIVE V-7:
ULTRAVIOLET/OXIDATION
(NORTHERN AND SOUTHERN PLUMES)
FEASIBILITY STUDY
OPERABLE UNIT 4
NAVAL TRAINING CENTER
ORLANDO, FLORIDA
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discharge into the lake. However, this polishing step was not considered within the cost estimate for this alternative.

An NPDES permit and a Florida surface water discharge permit would be required prior to constructing the discharge pipe and the new headwall at the edge of the lake.

System Monitoring. The groundwater quality at each extraction well and the treatment system influent and effluent would be monitored on a frequent basis to evaluate the mass removal of organic contaminants from the source area and to ensure that SWQSs were being met prior to discharging into Lake Druid. This analyses would be limited to VOCs and any other surface water discharge criteria (e.g., TSS, pH, temperature, etc.) required under the NPDES permit and Florida surface water discharge permit.

Sampling ports would be included in the individual extraction well vaults and following UV treatment prior to surface water discharge. The presumed sampling schedule and rationale are included in the cost estimate for this alternative (Appendix D).

Operation and Maintenance. O&M of the UV/oxidation system and chemical metering system would be limited by the PLC and telemetry to track and adjust the chemical feed, lamp cleaning and groundwater flow metering. System monitoring would involve a site visit once a week to check groundwater pumping rates, H_2O_2 chemical storage volume and concentration within the extracted groundwater (via test kits), and lamp current (indicator of lamp sedimentation and/or failure).

Phase-Out of Operation of IRA System. The objective of the IRA was to treat the contaminated groundwater in the downgradient plumes to Florida surface water standards prior to the groundwater naturally discharging into Lake Druid. The estimated travel time for the contaminants to flow from just outside the capture zone of the groundwater extraction wells to the IRA wells and be treated to these standards is approximately 10 years, at which time the IRA wells would be shut down. Groundwater monitoring would then be conducted in the downgradient plume for the natural degradation of contaminants to Florida drinking water standards over a period of 12 years.

Groundwater Monitoring. Groundwater monitoring would be conducted both within the source area and downgradient using existing and proposed monitoring wells. The source area wells would be used to monitor the groundwater for VOCs to determine when the RGOs have been met. This VOC data would be used to evaluate the effectiveness of the pump-and-treat system on the source area groundwater plume and the IRA wells. As part of this evaluation, the pumping rates could be adjusted or an extraction well temporarily shut down to improve the overall capture of the contaminant plume. These data would also further support the ongoing estimation of product released into the aquifer for monitoring of mass removal and the overall effectiveness of the treatment system.

The downgradient monitoring wells would be used to monitor the performance of the IRA wells and indicate when the IRA wells should be turned off, relying on natural attenuation to complete the remediation of the residual concentrations of organics in the groundwater. This monitoring is discussed below.

Source Area Soil Sampling. Source area sampling to demonstrate compliance with leachability SCTLs will be required upon achieving Florida MCLs. Details can be found in Alternative V-3 (Paragraph 5.1.3.1).

Natural Attenuation Monitoring. Following the shut-down of the downgradient IRA wells, natural attenuation monitoring would be implemented. This monitoring would ensure that the groundwater naturally discharging into Lake Druid continued to meet surface water standards and that the VOC concentrations were being reduced to ultimately meet Florida drinking water standards. If the source area is treated to State drinking water standards, the duration of MNA in the downgradient plume will be 12 years. If the source area is treated to site-specific remedial goals (after 41 years), the duration of MNA will be 30 years. Details of MNA can be found in Alternative V-3 (Paragraph 5.1.3.1).

Five-Year Site Reviews. Paragraph 5.1.1.1 presents a detailed description of the 5-year site review process. The 5-year review process would also include the summary and evaluation of the treatment system performance, and surface water discharge and groundwater monitoring data. This evaluation would include the mass removal rate of the contaminants from the groundwater, cost-effectiveness of the treatment system O&M, reduction in contaminant concentrations downgradient of the source area and the effectiveness of natural attenuation to remediate this groundwater prior to discharging into Lake Druid.

5.1.7.2 **Technical Criteria Analysis** This paragraph presents the technical criteria analysis of the UV/oxidation remedial alternative compared to the seven USEPA criteria identified in Table 5-1. As part of this analysis, two options are evaluated based upon the treatment goals of the groundwater plume, which may either be Florida drinking water standards (Option A) or a site-specific remedial goal that then relies on natural attenuation to achieve the drinking water standards (Option B). These optional goals provide a range of treatment durations, overall compliance with ARARs, and capital and O&M costs.

Overall Protection of Human Health and the Environment. The VOC-contaminated groundwater at OU 4 poses an unacceptable risk under future land-use scenarios and therefore must be addressed. This remedial Alternative V-7 relies on the extraction of contaminated groundwater from the source area of the VOC plume for treatment prior to discharge into Lake Druid while the downgradient plume would be treated by the existing IRA system. The two groundwater extraction wells would develop a radius of influence that encompasses both the northern and southern groundwater plumes, thereby cutting off the source of contamination and subsequently the downgradient migration towards Lake Druid (Figure 5-14).

Two treatment level options (designated A and B) are available depending on the specified remediation goals. The process flow diagrams for Options A and B under this alternative are shown in Figure 5-17. Under Option A, the source area plume would be treated to Florida drinking water standards, while the existing IRA wells would treat the contaminated groundwater *in situ* to State surface water standards. Groundwater-use restrictions would be required because the contaminant plume at OU 4 will pose a potential risk to future residents during operation of the treatment systems (UV/oxidation and IRA wells) and following the shut-down of the IRA wells (surface water standards versus drinking water standards). Once the entire groundwater plume achieved drinking water standards, the groundwater-use restrictions would be eliminated. The combination of the UV/oxidation system, operation of the existing IRA wells, and implementation of

groundwater-use restrictions would ensure that the human health and the environment were properly protected.

For Option B, the source area groundwater would be treated to site-specific standards and natural attenuation would reduce contaminants to drinking water standards. As stated above, groundwater-use restrictions would be implemented during the operation of the UV/oxidation and IRA systems, and MNA until the groundwater met State drinking water standards. This remedial alternative would protect human health and the environment through the use of temporary groundwater-use restrictions and the treatment of the VOCs detected in the OU 4 groundwater prior to the discharge into Lake Druid.

Compliance with ARARs. In the short-term, this alternative would comply with the chemical-specific ARAR for VOCs in groundwater discharging into a surface water body. The source area would be hydraulically contained and the groundwater plume treated to drinking water standards. The IRA wells would treat the downgradient plume to Florida surface water standards. However, it would not comply with the State drinking water standards until natural attenuation of the downgradient plume was completed.

Under Option B, presented on Figure 5-17, compliance with the chemical-specific ARARs for Florida drinking water standards would not be met until MNA was completed for the entire groundwater plume.

Both options for this alternative will emphasize treatment of the VOC source area reducing the overall operation of the IRA wells and expediting the time to achieve these ARARs. Monitoring of the groundwater quality at the point of compliance near the lake edge would be used to ensure compliance with the ARARs.

Long-Term Effectiveness and Permanence. This alternative is focused on the treatment of existing VOC contamination within the source area and the downgradient plume prior to it discharging into Lake Druid. Both UV/oxidation and the IRA well technologies are well proven and the technologies readily available. UV/oxidation has been effectively used at hundreds of sites and has historically been used for treatment of drinking water supplies. Operation of the existing IRA wells at OU 4 has provided significant information on system optimization and its ability to treat the groundwater to Florida surface water standards. Groundwater treatment and natural attenuation durations were prepared based on site-specific hydraulic characteristics to determine the applicable short-term or long-term permanence of the groundwater-use restrictions.

Reduction of Toxicity, Mobility, and Volume Through Treatment. This alternative would reduce the toxicity, mobility, and volume of VOCs in the OU 4 groundwater. This would be accomplished through extraction of contaminated groundwater and *ex situ* destruction of the VOCs by UV/oxidation. The downgradient plume would be treated by the existing IRA wells that strip the VOCs from the groundwater. Emission of the off-gas from the IRA air stripper would be in compliance with Florida air quality requirements (less than 13.7 lbs/day), but would not destroy the contaminants. Based on the continued operation of the IRA system, the small volume of vapor emissions would not require collection or treatment. However, vapor emissions would be monitored as part of the treatment system monitoring to ensure compliance with the State air regulations. If treatment was found to be required, an emissions treatment system could be added. Monitored natural attenuation would also biologically reduce the toxicity and volume of the VOCs.

Short-Term Effectiveness. This remedial alternative would achieve the remedial goals for groundwater quality by treatment of the VOCs using UV/oxidation, IRA wells, and natural attenuation. Due to the long-term operation of the treatment systems, groundwater-use restrictions would provide the necessary short-term effectiveness in protecting the public from the existing contaminants. In addition, both the UV/oxidation and IRA well technologies are well proven and reliable in the short-term for meeting their specific remedial goals. The residuals produced by the IRA air stripper (vapor emissions) are expected to be negligible, not exceeding 0.2 lb/day (ABB-ES, 1998b), far below the FDEP limit of 13.7 lbs/day. Air emissions would also continue to be monitored to ensure they do not exceed FDEP air quality standards.

Implementability. Construction of a UV/oxidation treatment system would be relatively easy to implement using a skid-mounted unit within a treatment building. Figure 5-16 presents the schematic layout of the proposed UV/oxidation system, groundwater extraction wells, effluent discharge into Lake Druid, and the existing IRA wells. The required utilities are also readily available at the site. Building 1100 is currently vacant such that construction of the treatment system would not interfere with any ongoing operations at NTC, Orlando.

Cost. Present worth costs have been prepared for Alternatives V-7A and V-7B and are presented in Tables 5-10 and 5-11, respectively. System operation durations have been estimated based on actual site characteristics. These present worth costs include direct, indirect, and O&M costs for the treatment system and groundwater, natural attenuation, and air monitoring (IRA system only). Administrative O&M costs for the 5-year reviews presented in the limited action alternative have also been included.

The duration of the UV/oxidation system operation would vary from 108 years to achieve drinking water standards to 59 years to achieve the site-specific standards and then over 30 years (30 years assumed for costing) of natural attenuation monitoring of the entire VOC plume (total of 89 years) to ensure that the groundwater is remediated to drinking water standards (Figure 5-17). The operating duration of the IRA wells would be the same for both remedial process options (10 years).

- Alternative V-7A: Drinking Water Standards RGO (Figure 5-17).

  The total estimated cost for the active treatment of VOC-contaminated groundwater to drinking water standards is $3,151,344 (Table 5-10). The direct cost for this remedial alternative process option is approximately $281,732, which includes site preparation, remedial construction of the groundwater extraction and UV/oxidation system for the entire VOC plume, and effluent discharge piping to Lake Druid. A short report would also be prepared that summarizes the remedial construction activities. The indirect cost is approximately $105,000.

  Indirect costs would include health and safety costs, administrative fees, engineering and design, and construction support services.

  The present worth O&M cost would be approximately $929,115 for the 5-year site reviews and groundwater monitoring, IRA system operation for 10 years, UV/oxidation system O&M, and associated utilities over a 108-year treatment duration.

Table 5-10
Cost Summary for Alternative V-7A: *Ex Situ* UV/Oxidation and Discharge to Lake Druid Groundwater Treated to Drinking Water Standards

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$62,169
Groundwater Extraction System	$93,063
UV/Oxidation System	$116,500
Total Direct Cost	$281,732
INDIRECT COSTS	
Health and Safety	$10,000
Administration and Permitting	$15,000
Engineering and Design	$40,000
Construction Support Services	$40,000
Total Indirect Cost	$105,000
Total Capital Cost (Direct + Indirect)	$386,732
OPERATION AND MAINTENANCE (O&M) COSTS	
IRA Wells (10 years)	
Present Worth - System Operation (6%, 10 years)	$240,048
Present Worth - Downgradient Groundwater Monitoring (6%, 10 years)	$78,384
UV/Oxidation (108 years)	
Present Worth - System Operation (6%, 108 years)	$1,863,843
Present Worth - Source Area Groundwater Monitoring (6%, 108 years)	$191,996
Natural Attenuation Monitoring (10 years)	
Present Worth - Downgradient Plume (6%, 11 to 20 years)	$50,142
5-Year Site Reviews (every 5 years for 108 years)	
Present Worth - 5-Year Site Reviews (6%, 108 years)	$53,713
Total O&M Cost (present worth)	$2,478,126
Total Capital and O&M Cost	$2,864,858
Contingency (10%)	$286,486
Total Cost of Alternative V-7A: *Ex Situ* UV/Oxidation and Discharge to Lake Druid Groundwater Treated to Drinking Water Standards	$3,151,344

Notes: UV = ultraviolet.
% = percent.
IRA = Interim Remedial Action.

Table 5-11
Cost Summary for Alternative V-7B: *Ex Situ* UV/Oxidation and Discharge to Lake Druid Groundwater Treated to Site-Specific Remedial Goals

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions	$10,000
Site Preparation and Mobilization	$62,169
Groundwater Extraction System	$93,063
UV/Oxidation System	$116,500
Total Direct Cost	$281,732
INDIRECT COSTS	
Health and Safety	$10,000
Administration and Permitting	$15,000
Engineering and Design	$40,000
Construction Support Services	$40,000
Total Indirect Cost	$105,000
Total Capital Cost (Direct + Indirect)	$386,732
OPERATION AND MAINTENANCE (O&M) COSTS	
IRA Wells (10 years)	
Present Worth - System Operation (6%, 10 years)	$240,048
Present Worth - Downgradient Groundwater Monitoring (6%, 10 years)	$78,384
UV/Oxidation (59 years)	
Present Worth - System Operation (6%, 59 years)	$1,807,292
Present Worth - Source Area Groundwater Monitoring (6%, 59 years)	$186,267
Natural Attenuation Monitoring (89 years)	
Present Worth - Entire VOC Plume (6%, 60 to 89 years)	$6,802
5-Year Site Reviews (every 5 years for 89 years)	
Present Worth - 5-Year Site Reviews (6%, 89 years)	$53,560
Total O&M Cost (present worth)	$2,372,353
Total Capital and O&M Cost	$2,759,085
Contingency (10%)	$275,909
Total Cost of Alternative V-7B: *Ex Situ* UV/Oxidation and Discharge to Lake Druid Groundwater Treated to Site-Specific Remedial Goals	$3,034,994

Notes: UV = ultraviolet.
IRA = Interim Remedial Action.
% = percent.

- Alternative V-7B: Site-Specific RGO (Figure 5-17).

The total estimated cost for the active treatment of VOC-contaminated groundwater to site-specific remedial goals and the use of natural attenuation to achieve drinking water standards is $3,034,993 (Table 5-11). The direct cost for this remedial alternative process is estimated to be $281,732, which includes site preparation, remedial construction of the groundwater extraction system and UV/oxidation treatment system, and the effluent discharge to Lake Druid. A short report summarizing the remedial construction actions would also be prepared. The indirect cost is approximately $105,000.

The present worth O&M cost would be approximately $2,478,126 for the 5-year site reviews and groundwater monitoring, IRA system operation for 10 years, UV/oxidation system O&M and associated utilities over a 59-year treatment duration, and a total 89-year period of monitoring the OU 4 VOC groundwater plume.

5.2 DETAILED ANALYSIS OF ANTIMONY PLUME REMEDIAL ALTERNATIVES. This section presents the detailed description and analysis of remedial alternatives that address the antimony contamination in the groundwater southeast of Building 1100 (Figure 1-5). These remedial alternatives were developed following the same procedures as used for the VOC plumes. The antimony plume alternatives include: 1) no action; 2) limited action; 3) extraction and discharge to the Orlando STP, and 4) extraction, *ex situ* microfiltration, and discharge into Lake Druid. Unlike the VOC plumes evaluated in Section 5.1 of this FS, the no action and limited action alternatives do not include the continued operation of the IRA wells near Lake Druid because the IRA has no impact on the antimony plume. The following subsections present the detailed description of the four remedial alternatives and their comparison to the seven USEPA evaluation criteria.

5.2.1 Alternative A-1 (No Action) Under this alternative, only administrative actions would be taken to periodically review the site conditions and exposure scenarios. A description of remedial Alternative A-1 is presented in Paragraph 5.2.1.1 and a technical analysis of this alternative is presented in Paragraph 5.2.1.2.

5.2.1.1 Detailed Description In accordance with the NCP, the no action alternative is used as a baseline for comparison against alternatives that incorporate remedial actions. Because there would be no treatment of the antimony plume, the assumed duration for remedial Alternative A-1 is expected to be indefinite. Because hazardous substances would be left in place at OU 4 as part of this alternative, it would include a 5-year site review for unlimited duration. Based on USEPA guidance (USEPA, 1988), the assumed duration to determine costs for this alternative is 30 years.

Five-Year Site Reviews. Because contaminated groundwater would be left on the site if this alternative were implemented, the Navy, USEPA, and FDEP must conduct a 5-year review of site conditions and determine that implementation of this alternative remains appropriate. Site reviews would occur every 5 years unless action levels (i.e., Florida drinking water standards) were attained in the antimony plume. Reviews would consist of assessing changes in site conditions (e.g., construction or demolitions of buildings overlying the plumes, receptors,

or qualitative risks) and assessing field data (if any) that might be collected. The appropriateness of this alternative would be compared to other possible remedial alternatives to confirm that this alternative was still the most appropriate selection for OU 4.

5.2.1.2 **Technical Criteria Analysis** This paragraph provides the technical criteria analysis of the no action alternative compared against the seven criteria in Table 5-1.

Overall Protection of Human Health and the Environment. The risk assessment for OU 4 identified potentially unacceptable risks to human health associated with the antimony-contaminated groundwater for a future residential land-use exposure scenario (groundwater ingestion and VOC inhalation). Based on this assessment, a no action alternative would not protect future residential receptors from potential groundwater ingestion.

Compliance with ARARs. The chemical-specific ARARs identified for the groundwater at OU 4 are the Florida surface water and drinking water standards. The no action alternative would comply with the Florida surface water standards, excluding one PCE exceedance in a monitoring well where both the southern VOC plume and the antimony plume overlap, which is addressed in the VOC remedial alternatives. However, the no action alternative is not considered compliant with the Florida drinking water standards because of the exceedances in antimony concentrations.

Long-Term Effectiveness and Permanence. Human health risk within the antimony plume would likely remain without remedial action within the source area to meet drinking water standards or to prohibit residential ingestion of the groundwater. Administrative actions proposed for this alternative (5-year site reviews) would not provide treatment of existing contamination or prevent possible human exposure to the contaminated groundwater.

Reduction of Toxicity, Mobility, and Volume Through Treatment. The no action alternative would not reduce the toxicity, mobility, or volume of antimony in OU 4 groundwater. No treatment would be implemented.

Short-Term Effectiveness. Drinking water standards would likely not be achieved in the foreseeable future. Groundwater-use restrictions would not be implemented to protect future residential receptors from exposure to the contaminated groundwater.

Implementability. 5-year site reviews are easily implemented.

Cost. The present worth cost for Remedial Alternative A-1 was estimated to be $81,174. A breakdown of these costs is presented in Table 5-12. This estimate includes the cost of performing site reviews and associated groundwater monitoring every 5 years over the assumed 30-year period.

A more detailed breakdown of the cost estimate for the no action alternative is presented in Appendix D.

5.2.2 Alternative A-2 (Limited Action). Under this alternative, only administrative actions and groundwater monitoring would be implemented to meet RAOs. A description of Alternative A-2 is presented in Paragraph 5.2.2.1 and a

Table 5-12
Cost Summary for Alternative A-1: No Action

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
	$0
Total Direct Cost	$0
INDIRECT COSTS	
	$0
Total Indirect Cost	$0
Total Capital Cost (Direct + Indirect)	$0
OPERATION AND MAINTENANCE (O&M) COSTS (30-year period)	
5-Year Site Reviews (30 years)	
Present Worth - 5-Year Site Reviews (6%, 30 years)	$44,491
Present Worth - Groundwater Monitoring (6%, 30 years)	$29,303
Total O&M Cost (present worth)	$73,794
Total Capital and O&M Cost	$73,794
Contingency (10%)	$7,379
Total Cost of Alternative A-1: No Action	$81,174

Note: % = percent.

technical criteria analysis of this alternative is presented in Paragraph 5.2.2.2.

5.2.2.1 **Detailed Description** Under this alternative, institutional controls in the form of groundwater-use restrictions would be implemented to restrict the use of the groundwater in the Building 1100 area. However, because there would be no treatment of the antimony plume, the assumed duration for remedial Alternative A-2 is expected to be indefinite. Because hazardous substances would be left in place at OU 4 as part of this alternative, it would include a 5-year site review for unlimited duration. Based on USEPA guidance (USEPA, 1988), the assumed duration to determine costs for this alternative is 30 years.

The limited action alternative would include the following components:

- implement groundwater-use restrictions
- groundwater monitoring
- 5-year site reviews

Groundwater-Use Restrictions. Land-use plans and property deeds for land in the vicinity of Building 1100 and downgradient property to Lake Druid would be annotated to indicate that groundwater extraction for potable use in this area may pose a significant health risk if consumed without treatment. These restrictions would be implemented as detailed in the description of Remedial Alternative V-2 (Paragraph 5.1.2.1).

Groundwater Monitoring. Upon implementing groundwater-use restrictions, groundwater within the antimony plume would be monitored. The monitoring would be used to observe the stability of the plume and to ensure that it remains within the groundwater-use restriction boundaries.

Wells located within the antimony plume would likely be sampled and analyzed for antimony every year initially for the first 3 years. Thereafter, sampling frequency would be reduced depending upon assessment results. For FS cost estimating purposes, it was assumed that approximately 12 existing monitoring wells would be monitored, and that this monitoring would occur annually for the assumed 30 years (Appendix D). A groundwater monitoring plan would be prepared detailing well positions, sampling frequency, and analytical program. This plan would be submitted for regulatory review and approval prior to implementation.

Five-Year Site Reviews. Remedial Alternative A-2 will require 5-year site reviews, as described for Alternative A-1 (Paragraph 5.2.1.1).

5.2.2.2 **Technical Criteria Analysis** This paragraph provides the technical criteria analysis of the limited action alternative compared against the seven criteria in Table 5-1.

Overall Protection of Human Health and the Environment. The risk assessment for OU 4 identified potentially unacceptable risks to human health associated with the antimony-contaminated groundwater for a future residential land-use exposure scenario. Based on this assessment, the limited action alternative would be protective of future residential receptors by implementing groundwater-use restrictions at OU 4. Groundwater monitoring would be performed to monitor the antimony concentrations exceeding Florida drinking water standards and determine if the plume migrates from within the groundwater-use restriction boundary.

Compliance with ARARs. The chemical-specific ARARs identified for the groundwater at OU 4 are the Florida surface water and drinking water standards. The limited action alternative would comply with the Florida surface water standards. The limited action alternative is not considered compliant with the Florida drinking water standards because of the exceedances in antimony concentrations. Groundwater-use restrictions and monitoring would not help achieve this ARAR.

Long-Term Effectiveness and Permanence. Human health risks from the antimony plume would likely remain without a remedial action to reduce the antimony concentrations down to Florida drinking water standards. However, an administrative action (groundwater-use restrictions) coupled with groundwater monitoring as proposed for this alternative would effectively prevent human exposure from groundwater ingestion.

Reduction of Toxicity, Mobility, and Volume Through Treatment. The limited action alternative would not reduce the toxicity, mobility, or volume of antimony in OU 4 groundwater. No treatment would be implemented.

Short-Term Effectiveness. Drinking water standards would not be achieved in the foreseen future because there would be no treatment of the antimony source area. For cost estimating purposes, the remedial duration for Alternative A-2 is based on 30 years of implementation. Groundwater-use restrictions and groundwater monitoring would be implemented to protect future residential receptors from ingesting the groundwater.

Implementability. Groundwater-use restrictions, groundwater monitoring, and 5-year site reviews are easily implemented.

Cost. The present worth cost for remedial Alternative A-2 was estimated to be $221,683. A breakdown of these costs is presented in Table 5-13. This estimate included the cost of implementing groundwater-use restrictions for the antimony plume at OU 4, and performing site reviews and associated groundwater monitoring every 5 years over the assumed 30-year period. The detailed cost breakdown for the limited action alternative is presented in Appendix D.

5.2.3 Alternative A-3: Extraction and Discharge to Orlando STP This alternative involves the extraction of antimony-contaminated groundwater and direct discharge into the City of Orlando STP without prior treatment. Based on the modeling of the site hydraulic characteristics, one groundwater extraction well could be used to capture the contaminated groundwater exceeding Florida drinking water standards for antimony. The maximum concentration detected in the OU 4 antimony plume is well below the City of Orlando STP discharge standards.

Because the southern VOC plume is colocated with the antimony plume, an active remedial alternative such as groundwater extraction would influence the VOC plume. Therefore, this antimony alternative will not be implemented until the southern VOC plume has been remediated. For cost purposes, this FS assumes Alternative A-3 will be implemented 10 years after remediation of the VOC plumes has begun. Only groundwater monitoring and 5-year site reviews will occur during the first 10 years of this alternative.

A description of this alternative is presented in Paragraph 5.2.3.1 and technical assessment of this alternative is presented in Paragraph 5.2.3.2.

Table 5-13
Cost Summary for Alternative A-2: Limited Action

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item		Cost
DIRECT COSTS		
Groundwater-Use Restrictions		$10,000
	Total Direct Cost	$10,000
INDIRECT COSTS		
Health and Safety		$500
Administration and Permitting		$1,000
Engineering and Design		$4,000
Construction Support Services		$1,000
	Total Indirect Cost	$6,500
	Total Capital Cost (Direct + Indirect)	$16,500
OPERATION AND MAINTENANCE (O&M) COSTS		
Groundwater Monitoring (30 years)		
	Present Worth - Groundwater Monitoring (6%, 30 years)	$140,539
5-Year Site Reviews (30 years)		
	Present Worth - 5-Year Site Reviews (6%, 30 years)	$44,491
	Total O&M Cost (present worth)	$185,030
	Total Capital and O&M Cost	$201,530
	Contingency (10%)	$20,153
	Total Cost of Alternative A-2: Limited Action	$221,683

Note: % = percent.

5.2.3.1 **Detailed Description** This alternative is intended to address the antimony contamination east of Building 1100. The maximum antimony concentrations detected within this plume was 20.7 $\mu g/\ell$, while the Florida standards for drinking water and discharge to the Orlando STP are 6 $\mu g/\ell$ and 1,000 $\mu g/\ell$, respectively. This groundwater extraction system would be operated at approximately 40 gpm to influence the portion of the plume exceeding the drinking water standard. The extracted groundwater would then be discharged directly into the sanitary sewer line located within Area C and flow into the City of Orlando STP (Figure 5-19). The duration of the groundwater extraction system operation was estimated to be 9 years (Appendix G).

The Orlando STP relies primarily on its Bardenpho process to degrade organic matter and address low concentrations of inorganics prior to discharge. The STP is capable of providing treatment for extracted groundwater provided that constituents in the groundwater do not exceed the influent requirements (Table 3-6).

The advantage of the discharge to the STP is that the treatment facility all ready exists, and requires no additional capital investment for an on-site treatment system. Anticipated pretreatment requirements for discharge to the STP were presented in Table 3-6.

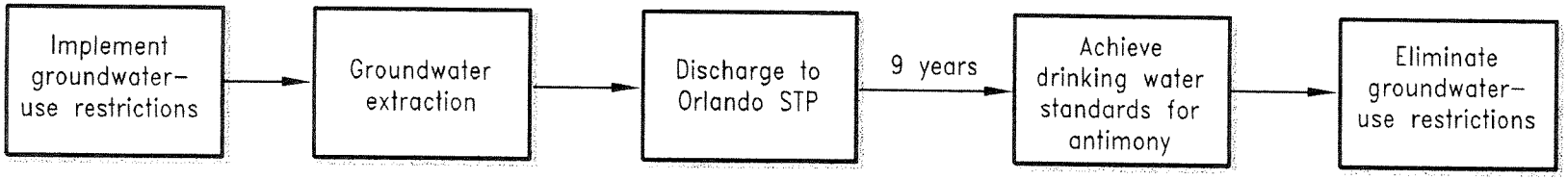
The major components of this remedial alternative include the following:

- groundwater-use restrictions until RAOs are achieved
- one groundwater extraction well
- discharge of untreated groundwater into the sanitary sewer
- monitoring of groundwater quality going into the sewer
- O&M of the groundwater extraction well and pump
- groundwater monitoring points
- 5-year site reviews

Groundwater-Use Restrictions. Refer to Paragraph 5.1.2.1 for a detailed description of groundwater-use restrictions to be implemented at OU 4.

Groundwater Extraction Well. Contaminated groundwater would be captured and removed from the aquifer by one extraction well, which is located at the center of the plume (Figure 5-20). The extraction well pump would remove the contaminated water at a rate of approximately 40 gpm, resulting in the remediation of the antimony plume to drinking water standards in approximately 9 years. The well would be installed to a depth of approximately 45 feet bls and located as shown on Figure 5-20. The extraction well would be constructed of 4-inch Schedule 80 PVC casing and would have a screen length of 30 feet. A locking vault would be installed over the surface of the extraction wells and would contain the controls for the float switches and pump. A sampling port would also be included in the piping from the well to the sanitary sewer manhole for discharge monitoring purposes.

Discharge to Orlando STP. Groundwater would be extracted and discharged into a sanitary sewer line located within Area C. This sanitary sewer line ultimately discharges into the City of Orlando STP for final treatment. The discharge pipe into the sanitary sewer line would be a buried 2-inch PVC pipe. The discharge pipe would connect into an existing sanitary sewer manhole approximately 60 feet west of Building 1068 (Figure 5-21). The untreated groundwater will readily meet



LEGEND

STP	Sewage Treatment Plant
VOC	Volatile organic compound

NOTE: Active remediation of antimony plume not started until 10 years after southern VOC plume remediation started; antimony groundwater extraction would adversely impact VOC plume treatment.

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FIGURE 5-19
REMEDIAL ALTERNATIVE A-3
STP DISCHARGE PROCESS FLOW DIAGRAM

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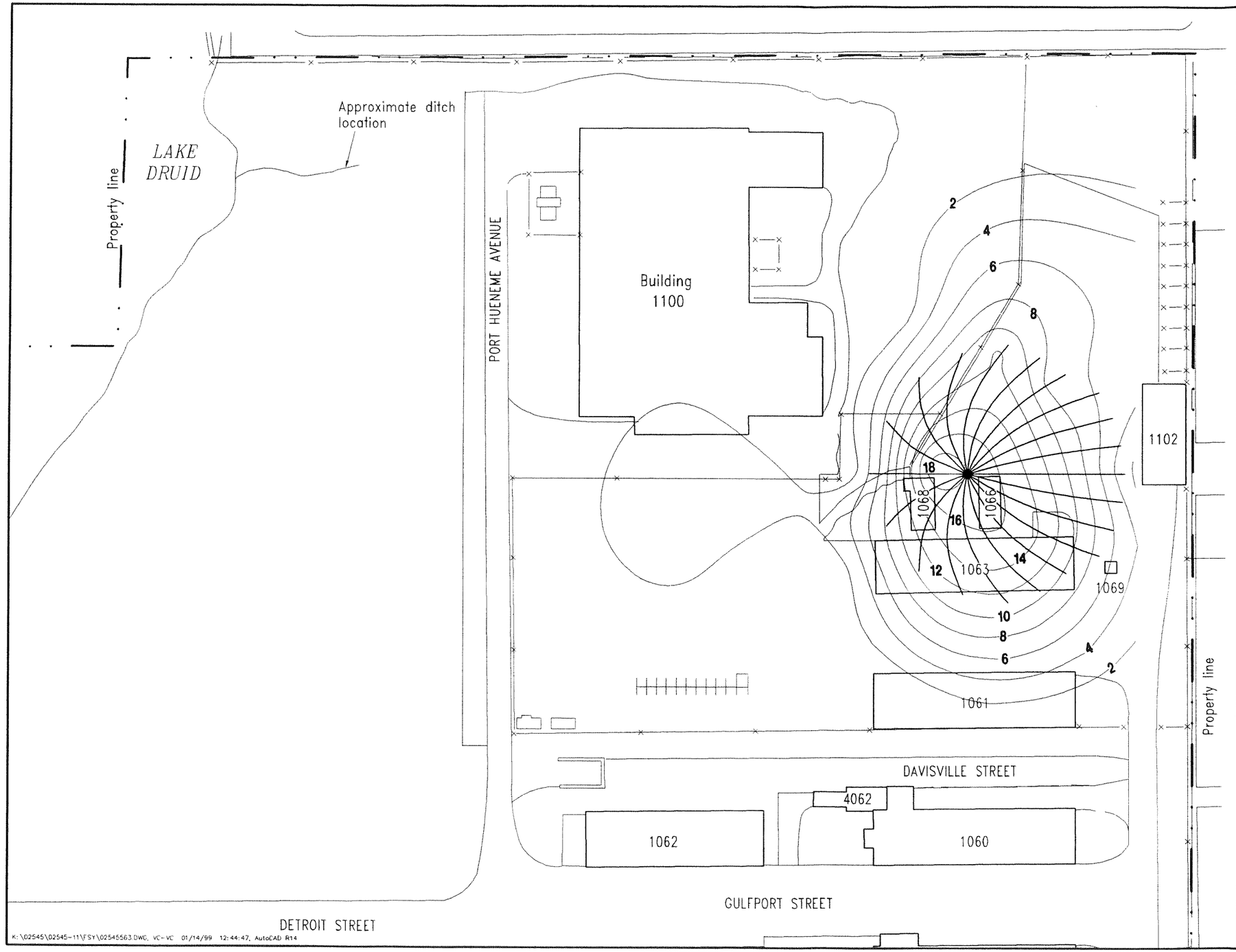

FIGURE 5-20
CONCEPTUAL LAYOUT
ALTERNATIVES A-3 AND A-4:
ANTIMONY GROUNDWATER EXTRACTION
PATH LINES - 100 DAYS AT 40 GPM

FEASIBILITY STUDY
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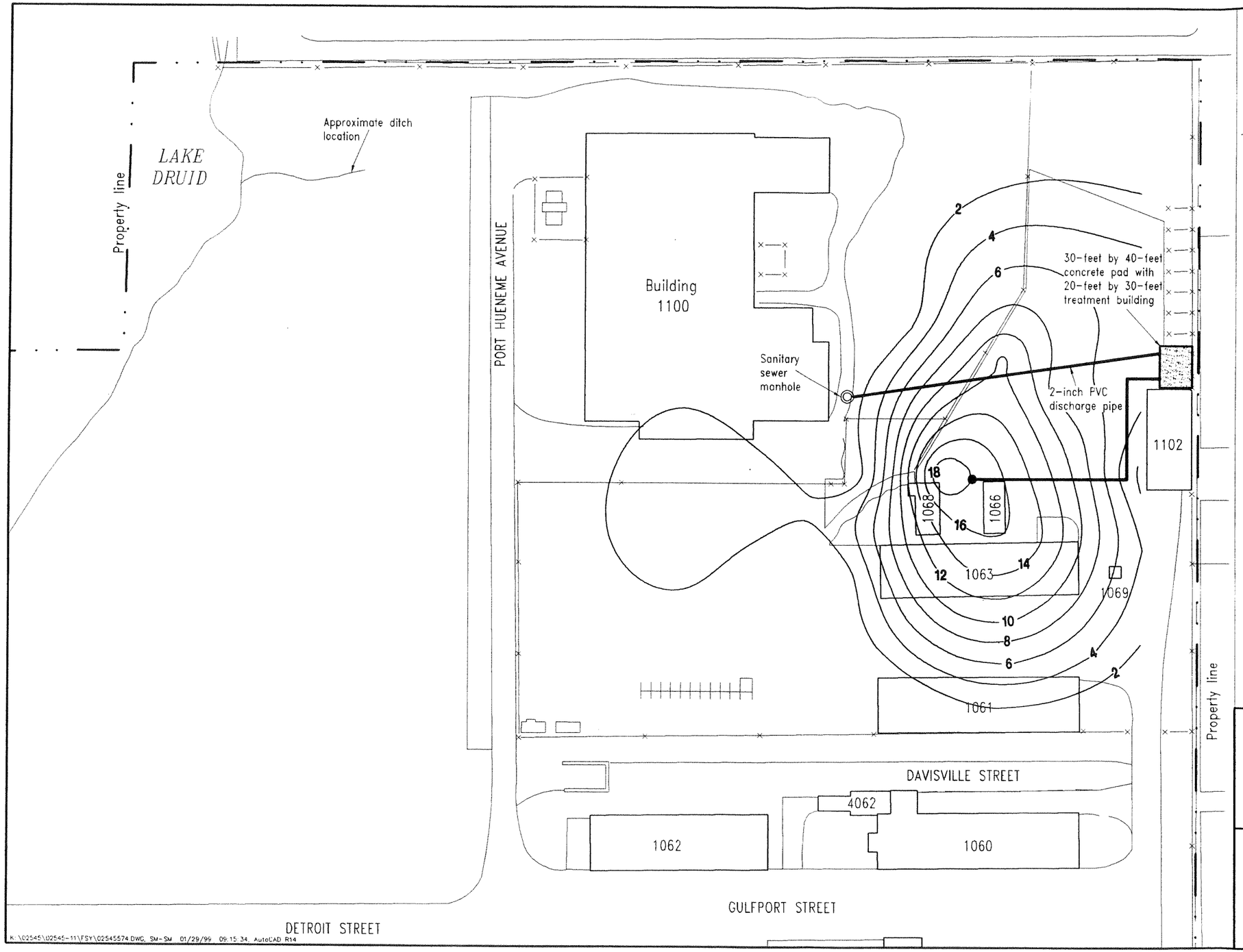

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FIGURE 5-21
CONCEPTUAL LAYOUT
ALTERNATIVE A-3:
DISCHARGE TO SEWAGE TREATMENT PLANT

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the Orlando STP industrial discharge standard of 1,000 $\mu g/\ell$ for antimony because the maximum contaminant concentration detected at OU 4 is 20.7 $\mu g/\ell$. NTC, Orlando currently maintains an industrial user's permit for the discharge of investigation-derived waste generated at Area C (Appendix C). This permit could be modified to include the discharge of extracted groundwater from the antimony plume.

System Monitoring. The groundwater quality discharging to sewer would be monitored on a frequent basis to evaluate the mass removal of inorganics from the OU 4 plume and to ensure that the Orlando STP industrial standards were being met prior to the sanitary sewer. This sampling would be limited to inorganics and any other industrial discharge criteria (e.g., TSS, pH, temperature, etc.) required under the industrial user's permit. The presumed sampling schedule and rationale were included in the cost estimate for this alternative (Appendix D).

Operation and Maintenance of the Extraction Well and Discharge Pump. System O&M would include servicing the groundwater extraction well and the discharge pump. The system could operate at 40 gpm 24 hours per day and would be monitored 2 to 4 hours per week for groundwater extraction rates, concentration of inorganics, and general maintenance of the pumps and water meters.

Groundwater Monitoring Points. Groundwater monitoring would be conducted throughout the OU 4 antimony plume using existing monitoring wells. The wells would be used to monitor the overall groundwater quality for antimony, determine when the RGOs have been met, and evaluate the effectiveness of groundwater extraction to reduce the antimony concentrations in the groundwater plume. As part of this evaluation, the pumping rate might be adjusted to improve the overall capture of the contaminant plume. These data would also further support the ongoing estimation of mass removal and the overall effectiveness of the remedial alternative.

For estimating purposes, this FS assumes that a total of 10 existing monitoring wells would be used for the monitoring of the antimony plume over a 9-year period.

Five-Year Site Reviews. Remedial Alternative A-3 will require 5-year site reviews, as described for Alternative A-1 (Paragraph 5.2.1.1). For this alternative, these reviews would occur every 5 years for 10 years for a total of two reviews.

5.2.3.2 **Technical Criteria Analysis** This paragraph presents the technical criteria analysis of the extraction and direct discharge of groundwater into the Orlando STP compared to the seven USEPA criteria identified in Table 5-1. As part of this analysis, the treatment goals of the groundwater plume and the treated effluent would be State drinking water standards and industrial sewer discharge criteria.

Overall Protection of Human Health and the Environment. The antimony-contaminated groundwater at OU 4 poses an unacceptable risk to future residents and the environment associated with the drinking water supply and therefore must be addressed. Remedial Alternative A-3 relies on the extraction of contaminated groundwater for discharge into the City of Orlando STP. The one groundwater extraction well would develop a radius of influence to fully encompass the

antimony plume exceeding the Florida drinking water standard of 6 $\mu g/\ell$ (Figure 5-20).

Based on the remedial alternative process flow diagram (Figure 5-19), the groundwater plume would be treated to State drinking water standards. Groundwater-use restrictions would be required because the antimony plume at OU 4 may pose a potential risk to future residents during operation of the remedial alternative. Once the antimony concentrations within the groundwater plume were reduced to drinking water standards, the groundwater-use restrictions would be eliminated. The combination of groundwater extraction and discharge into the sanitary sewer and the implementation of groundwater-use restrictions would ensure that the human health and the environment were properly protected.

Compliance with ARARs. This alternative would comply with ARARs associated with the discharge of industrial waters into the sanitary sewer. This remedial alternative would also ultimately meet the chemical-specific ARARs for drinking water by the removal of the antimony from the OU 4 groundwater plume. The maximum antimony concentration detected in the groundwater (20.7 $\mu g/\ell$) is well below the industrial discharge standard of 1,000 $\mu g/\ell$. This remedial alternative emphasizes treatment of the antimony plume within 9 years expediting the time to achieve these ARARs. Monitoring of the groundwater quality within the plume would also be performed to ensure compliance with the ARARs.

Long-Term Effectiveness and Permanence. This alternative is focused on the removal of antimony from the groundwater plume at OU 4. Assuming that there is sufficient capacity for the discharge of untreated groundwater into the sanitary sewer, there is both long-term effectiveness and permanence in this remedial alternative. A groundwater treatment duration estimate was prepared based on site-specific hydraulic characteristics to determine the applicable short-term or long-term permanence of the groundwater-use restrictions. Based on the operation of an extraction well at 40 gpm, the antimony plume would be reduced to Florida drinking water standards for antimony in approximately 9 years. This would require the temporary implementation of groundwater-use restrictions until the groundwater plume was remediated.

Reduction of Toxicity, Mobility, and Volume Through Treatment. This alternative would reduce the toxicity, mobility, and volume of antimony in the OU 4 groundwater, but would transfer the contaminants to the Orlando STP for treatment. This would be accomplished through the extraction of contaminated groundwater and direct discharge of untreated groundwater into the sanitary sewer.

Short-Term Effectiveness. This remedial alternative would achieve the remedial goals for groundwater quality by the extraction of the antimony-contaminated groundwater. During the operation of the extraction well groundwater-use restrictions would be implemented to provide the necessary short-term effectiveness in protecting the future residents.

Implementability. The groundwater extraction and discharge system could readily be constructed because the surrounding area is an inactive paved parking lot and/or storage area. In addition, an existing sewer manhole is located approximately 60 feet west of Building 1068 for the discharge of the extracted groundwater (Figure 5-21). The required utilities are also readily available at the site. Buildings 1063, 1066, and 1068 are currently vacant such that the

installation of an extraction well and discharge system would not interfere with any ongoing operations at NTC, Orlando.

Cost. Present worth costs have been prepared for the capital and O&M of the groundwater extraction and discharge into the City of Orlando STP system. These costs assume that the implementation of groundwater-use restrictions, 5-year site reviews, and associated groundwater monitoring would be implemented immediately following the signed ROD for OU 4. The construction and operation of the groundwater extraction and discharge into the City of Orlando STP would be delayed 10 years so that the groundwater extraction would not adversely impact the remediation of the southern VOC plume. The groundwater extraction of antimony-contaminated groundwater would then be operated for 9 years based on actual hydrogeologic characteristics at OU 4. This would result in a total duration of 19 years.

The total present worth cost estimate for this remedial alternative is $713,115. These present worth costs include direct, indirect, and O&M costs for the groundwater extraction system and discharge to the sanitary sewer on base, ultimately discharging into the Orlando STP. Effluent monitoring for organics and metals would also be conducted to comply with the industrial users permit. Administrative O&M costs for the 5-year reviews presented in the no action remedial alternative were also included. A complete cost summary for the remedial alternative is presented in Table 5-14, while the detailed cost calculations are presented in Appendix D.

The direct cost is approximately $109,063, which includes site preparation, construction of the groundwater extraction well and discharge pipe into the sanitary sewer, and a short report summarizing the remedial construction activities. The indirect cost is approximately $50,000. The present worth for the delayed capital costs (direct and indirect) would be $93,237.

The present worth O&M cost would be approximately $555,049 for the system O&M, groundwater plume and effluent monitoring, and four 5-year site reviews over a 10-year monitoring period followed by a 9-year operating and monitoring period (total 19 years).

5.2.4 Alternative A-4: Extraction, Treatment via NPO Microfiltration System, and Discharge to Lake Druid This alternative involves the extraction of antimony contaminated groundwater and *ex situ* treatment using an NP™ microfiltration process to remove the metals. The treated groundwater would be discharged into Lake Druid (Figure 5-22). As discussed in Alternative A-3, one groundwater extraction well would be installed in the antimony plume to extract the groundwater for treatment. This treatment does not require a lowered pH to precipitate the out the metals and limits the generation of metals sludge requiring disposal. The treated effluent would then meet Florida surface water criteria for discharge into Lake Druid. A description of this alternative is presented in Paragraph 5.2.4.1 and technical assessment of this alternative is presented in Paragraph 5.2.4.2.

5.2.4.1 Detailed Description This alternative, NP™ microfiltration, is intended to address the antimony contamination east of Building 1100. The antimony concentrations within this plume range from nondetect to 20.7 $\mu g/\ell$, while the Florida drinking water standard for antimony is 6 $\mu g/\ell$. This pump-and-treat system would be operated and the treated groundwater discharged into Lake Druid

Table 5-14
Cost Summary for Alternative A-3: Groundwater Extraction and Discharge to Orlando Sewage Treatment Plant

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions[1]	$10,000
Site Preparation and Mobilization[2]	$34,601
Groundwater Extraction/Discharge System[2]	$63,063
Total Direct Cost	$107,664
INDIRECT COSTS[2]	
Health and Safety	$5,000
Administration and Permitting	$10,000
Engineering and Design	$15,000
Construction Support Services	$20,000
Total Indirect Cost	$50,000
Total Capital Cost (Direct + Indirect)	$157,664
Present Worth - Delayed Capital Costs (6%, 10 years)	$92,456
OPERATION AND MAINTENANCE (O&M) COSTS	
Groundwater Extraction/Discharge System (9 years)	
Present Worth - Groundwater Discharge (6%, 10 to 19 years)	$244,233
Present Worth - Groundwater Monitoring (6%, 19 years)	$128,875
5-Year Site Reviews (10 years)	
Present Worth - 5-Year Site Reviews (6%, 5, 10, 15 and 19 years)	$37,415
Total O&M Cost (present worth)	$410,522
Total Capital and O&M Cost	$502,978
Contingency (10%)	$50,298
Total Cost of Alternative A-3: Groundwater Extraction and Discharge to Orlando STP	$553,276

[1] Groundwater-use restrictions, 5-year site reviews and associated groundwater monitoring would be implemented immediately following the signed Record of Decision.
[2] Construction and operation of groundwater extraction and discharge to Orlando STP delayed for 10 years so not to adversely impact remediation of southern volatile organic compound plume.

Notes: STP = sewage treatment plant.
% = percent.
VOC = volatile organic compound.

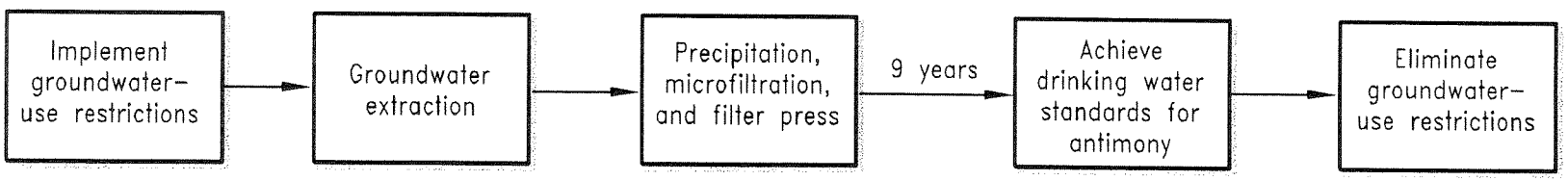

FIGURE 5-22
REMEDIAL ALTERNATIVE A-3
EX SITU MICROFILTRATION PROCESS
FLOW DIAGRAM

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until the groundwater quality met this standard. While the maximum concentration of antimony detected in the OU 4 plume is well below the surface water standard of 4,300 $\mu g/\ell$, the alternative of groundwater extraction and immediate discharge of untreated groundwater into the lake was not considered practical.

The major components of this remedial alternative include the following:

- groundwater-use restrictions until RAOs are achieved
- one groundwater extraction well
- NP™ microfiltration
- chemical storage and metering system
- discharge of treated groundwater to Lake Druid
- monitoring of treatment system influent and effluent
- O&M of the microfiltration system and chemical metering system
- groundwater monitoring points
- 5-year site reviews

Groundwater-Use Restrictions. Refer to Paragraph 5.1.2.1 for a detailed description of groundwater-use restrictions to be implemented at OU 4.

Groundwater Extraction Well. The extraction well required for this alternative is identical to that described for Alternative A-3 (Paragraph 5.2.3.1).

Neutral Process™ Microfiltration System. The NP™-7000 series metals removal system is a compact, skid-mounted unit that removes heavy metals from wastewater using neutral pH precipitation and cross-flow microfiltration (Figure 5-23). The system operates at a flow rate of 10 to 50 gpm. The system is designed so that the filtered effluent meets State drinking water standards. The dewatered chemical sludge could be disposed of as hazardous waste (or preferably non-hazardous waste) or sent to a reclamation facility for recycling the heavy metals.

The system operates by neutralizing the waste stream, as necessary, using an acid or hydroxide. Reagents are then added that reduce and complex the metal ions and precipitate them from the wastewater. The precipitated metals are separated from the effluent using crossflow microfiltration technology. The resulting effluent water would be readily suitable for surface water discharge. The metal precipitate would be concentrated in a sludge holding chamber and then dewatered through a filter press. The filter cake, which is typically approximately 50 percent solids, would be disposed of or processed to reclaim valuable metals.

Chemical Storage and Metering System. Chemicals are contained in and automatically fed from their original containers, greatly reducing the risk of any spill. Small amounts of chemicals would be stored at the site. All regulatory guidelines for the handling of these chemicals would be met.

Discharge to Lake Druid. Groundwater that is extracted and treated by the NP™ microfiltration system would be discharged to Lake Druid via a buried 2-inch pipe and headwall at the edge of the lake. The discharge pipe would extend from a treatment building located near Building 1102, north of the NTC, Orlando property line, then and west along the perimeter fence into Lake Druid (Figure 5-24). The total distance is approximately 1,350 feet. The treated effluent would readily achieve the FDEP surface water standard of 4,300 $\mu g/\ell$ for antimony because the maximum contaminant concentration detected at OU 4 is 20.7 $\mu g/\ell$. A Federal NPDES

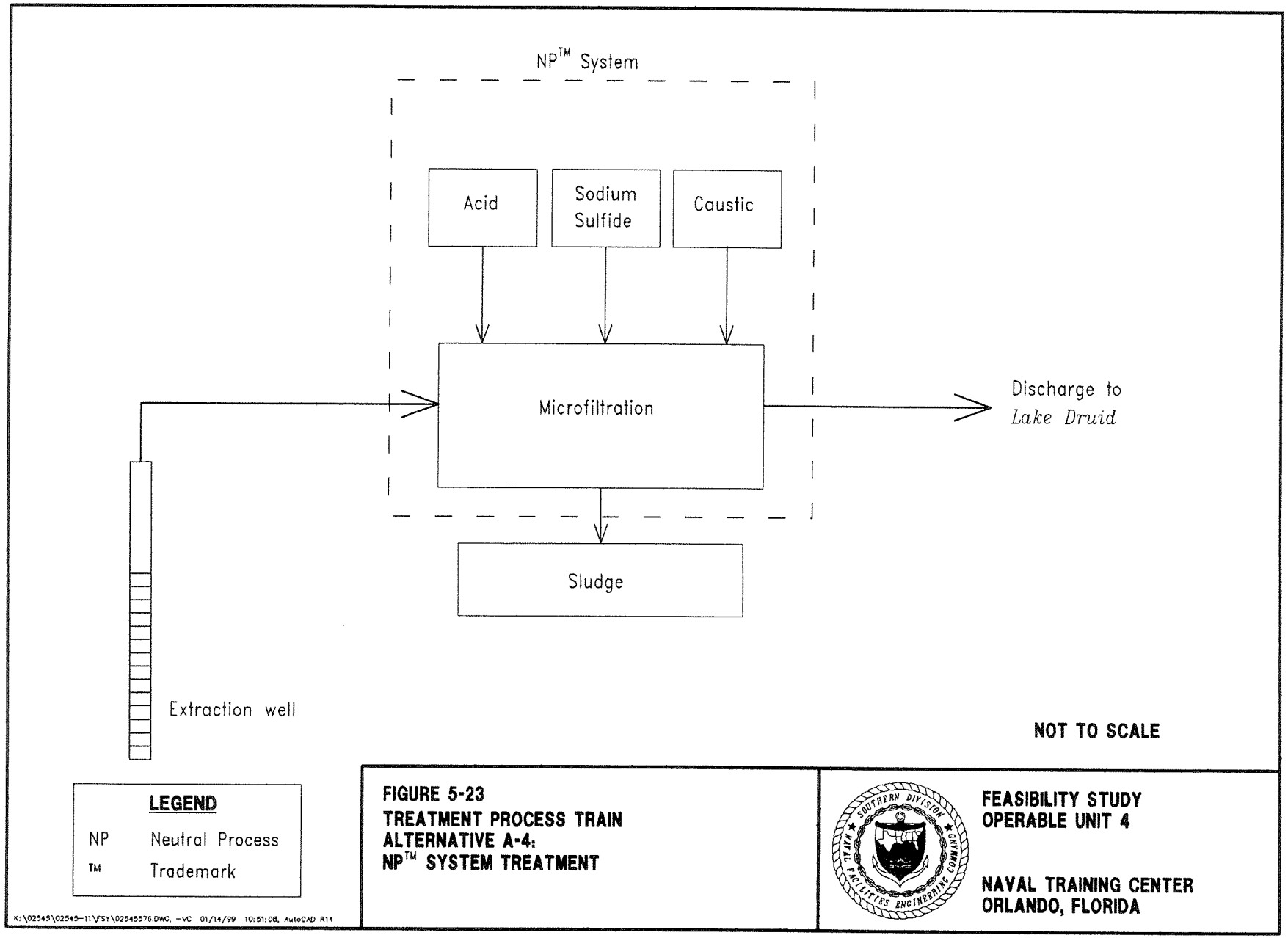

FIGURE 5-23
TREATMENT PROCESS TRAIN
ALTERNATIVE A-4:
NP™ SYSTEM TREATMENT

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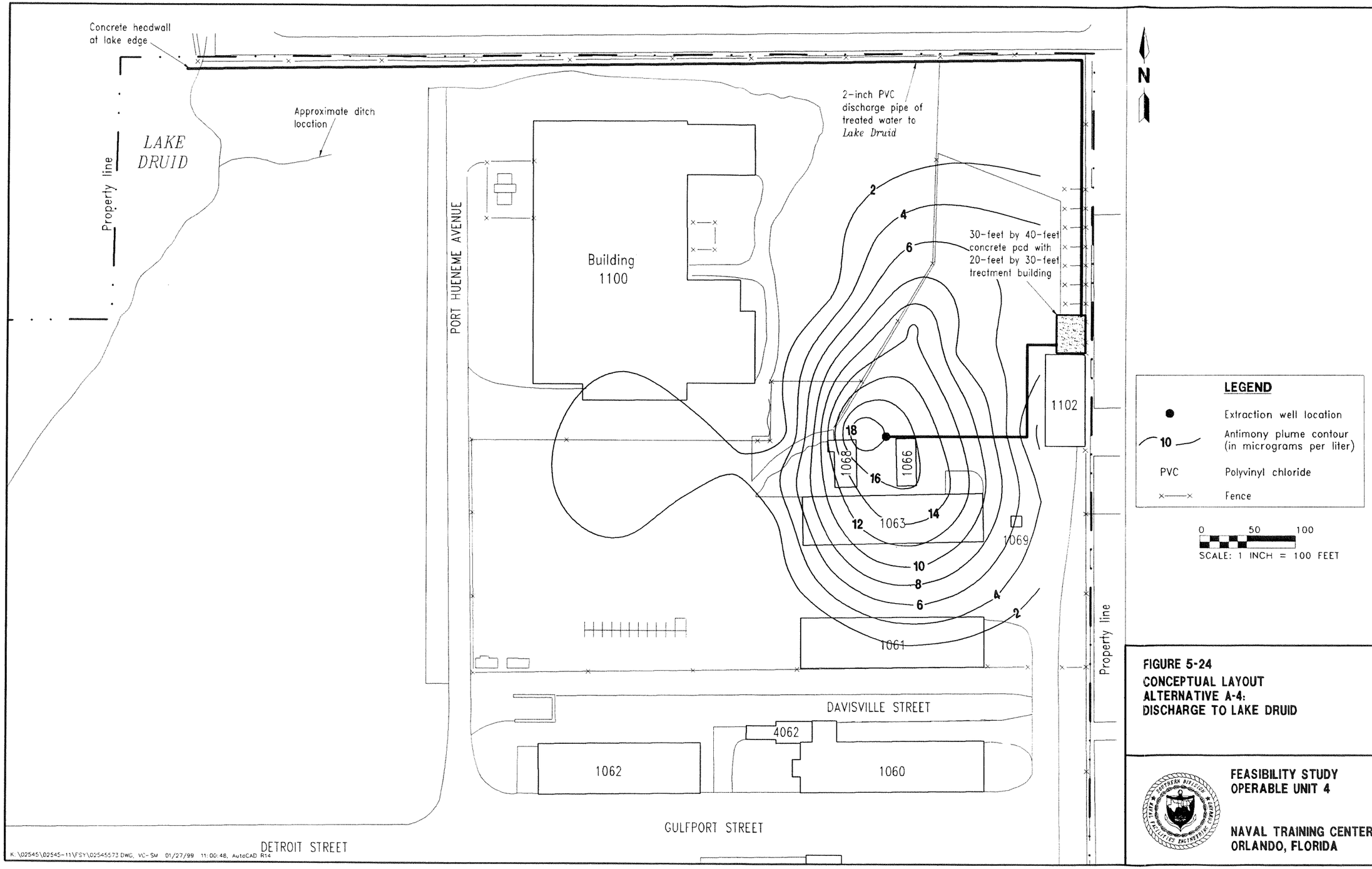

FIGURE 5-24
CONCEPTUAL LAYOUT
ALTERNATIVE A-4:
DISCHARGE TO LAKE DRUID

FEASIBILITY STUDY
OPERABLE UNIT 4

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permit and FDEP surface water discharge permit would be required for discharge to Lake Druid.

System Monitoring. The groundwater quality at the extraction well and the treatment system effluent would be monitored on a frequent basis to evaluate the mass removal of inorganics from the OU 4 plume and to ensure that SWQSs were being met prior to discharging into Lake Druid. This sampling would be limited to inorganics and any other surface water discharge criteria (e.g., TSS, pH, temperature, etc.) required under the NPDES permit and FDEP surface water discharge permit. Sampling ports would be included prior to the chemical addition and following microfiltration, prior to surface water discharge. The presumed sampling schedule and rationale are included in the cost estimate for this alternative (Appendix D).

Operation and Maintenance of NP™ System. This system requires very little maintenance. Chemicals used to precipitate the inorganics would incur an annual cost of less than $500 per year. Sludge disposal (assuming nonhazardous material) is estimated to cost approximately $1000 per year. The system can operate at 40 gpm 24 hours per day and would be monitored 2 to 4 hours per week for groundwater extraction rates, use and concentration of chemical additives, sludge generation, chemical additive levels, and general maintenance of the microfilter and filter press.

Groundwater Monitoring Points. Groundwater monitoring requirements would be identical to those described for Alternative A-3 (Paragraph 5.2.3.1).

Five-Year Site Reviews. The 5-year site review requirements for this alternative would be identical to those described for Alternative A-3 (Paragraph 5.2.3.1).

5.2.4.2 Technical Criteria Analysis This paragraph presents the technical criteria analysis of the *ex situ* microfiltration remedial alternative compared to the seven USEPA criteria identified in Table 5-1. As part of this analysis, the treatment goals of the groundwater plume and the treated effluent would be State drinking water standards for antimony.

Overall Protection of Human Health and the Environment. The antimony-contaminated groundwater at OU 4 poses an unacceptable risk to future residents and the environment associated with the drinking water supply and therefore must be addressed. Remedial Alternative A-4 relies on the extraction of contaminated groundwater for treatment prior to discharge into Lake Druid. The one groundwater extraction well would develop a radius of influence to fully encompass the antimony plume exceeding the drinking water standard of 6 $\mu g/\ell$ (Figure 5-20).

Based on the remedial alternative process flow diagram (Figure 5-22), the groundwater plume would be treated to State drinking water standards. Groundwater-use restrictions would be required because the antimony plume at OU 4 may pose a potential risk to future residents during operation of the treatment system. Once the antimony concentrations within the groundwater plume were reduced to drinking water standards, the groundwater-use restrictions would be eliminated. The combination of the *ex situ* microfiltration system and implementation of groundwater-use restrictions would ensure that the human health and the environment is properly protected.

Compliance with ARARs. In the short-term, this alternative would comply with chemical-specific ARARs for discharging groundwater into a surface water body without any prior treatment as the maximum antimony concentration detected (20.7 $\mu g/\ell$) is well below the Florida surface water standard of 4,300 $\mu g/\ell$. However, this alternative of groundwater extraction and immediate discharge of untreated groundwater into the lake was not considered as it would equate to the no action alternative (groundwater continuing to discharge into Lake Druid untreated). Instead, *ex situ* treatment for antimony was provided to result in an effluent to the lake that meets drinking water standards further ensuring compliance with ARARs.

This remedial alternative emphasizes treatment of the antimony plume within 9 years expediting the time to achieve these ARARs. Monitoring of the groundwater quality within the antimony plume would also be performed to ensure compliance with the ARARs.

Long-Term Effectiveness and Permanence. This alternative is focused on the treatment of existing antimony contamination within the groundwater plume prior to it discharging into Lake Druid. Both the *ex situ* microfiltration and filter press technologies are well proven in the wastewater industry and are readily available. Groundwater treatment duration estimates were prepared based on site-specific hydraulic characteristics to determine the applicable short-term or long-term permanence of the groundwater-use restrictions. Based on the operation of an extraction well at 40 gpm, the antimony plume would be reduced to drinking water standards for antimony in approximately 9 years. This would require the temporary implementation of groundwater-use restrictions until the groundwater plume was remediated.

Reduction of Toxicity, Mobility, and Volume Through Treatment. This alternative would reduce the toxicity, mobility, and volume of antimony in the OU 4 groundwater. This would be accomplished through the extraction of contaminated groundwater and *ex situ* precipitation and/or microfiltration prior to discharge into the lake. The metals residual would be passed through filter press to increase the solids content in the waste to approximately 50 percent, which is sufficient for off-site disposal. Disposal of the metals has been assumed to be as a nonhazardous waste. Depending on the quality and volume of metals residual, it may be transferred for reuse.

Short-Term Effectiveness. This remedial alternative would achieve the remedial goals for groundwater quality by the extraction of the antimony-contaminated groundwater and treatment using microfiltration. Due to an estimated duration of 9 years to achieve drinking water standards, groundwater-use restrictions would be implemented to provide the necessary short-term effectiveness in protecting the future residents from the existing contaminants. In addition, both the microfiltration and filter press technologies are well proven and reliable in the short-term for meeting their specific remedial goals. The residuals produced by this remedial alternative would be evaluated for off-site reuse or off-site disposal as a nonhazardous waste.

Implementability. Construction of the NP™ microfiltration system would be relatively easy to implement using a skid-mounted unit within a treatment building. Figure 5-24 presents the schematic layout of the proposed extraction well, treatment system, and effluent discharge into Lake Druid. The required utilities are also readily available at the site. Buildings 1063, 1066, and 1068

are currently vacant such that the installation of an extraction well and construction of the treatment system would not interfere with any ongoing operations at NTC, Orlando.

Cost. Present worth costs have been prepared for the capital and O&M of the groundwater extraction and treatment system. These costs assume that the implementation of groundwater-use restrictions, 5-year site reviews, and associated groundwater monitoring would be implemented immediately following the signed ROD for OU 4. The construction and operation of the groundwater extraction and treatment system would be delayed for approximately 10 years so that the groundwater extraction would not adversely impact the remediation of the southern VOC plume. The groundwater extraction of antimony-contaminated groundwater would then be operated for 9 years based on actual hydrogeologic characteristics at OU 4 to achieve drinking water standards for inorganics. This would result in a total duration of 19 years.

The present worth cost of $583,001 included direct, indirect, and O&M costs for the *ex situ* treatment system, inorganics treatment system, discharge to Lake Druid, and the analysis and disposal of metals residual. Administrative O&M costs for the 5-year site reviews presented in the no action alternative were also included. A complete cost summary for this remedial alternative is presented in Table 5-15. The detailed cost calculations are presented in Appendix D.

The direct cost is approximately $388,063, which includes site preparation, construction of the groundwater extraction and *ex situ* treatment system, and a short report summarizing the remedial construction activities. The indirect cost is approximately $55,000. The present worth for the delayed capital costs (direct and indirect) would be $251,822.

The present worth O&M cost is estimated to be $278,179 for the system O&M, groundwater plume and surface water discharge monitoring, and four 5-year site reviews over a 10-year monitoring period followed by a 9-year operating and monitoring period (total 19 years).

Table 5-15
Cost Summary for Alternative A-4: Groundwater Extraction, Microfiltration and Discharge to Lake Druid

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Cost Item	Cost
DIRECT COSTS	
Groundwater-Use Restrictions[1]	$10,000
Site Preparation and Mobilization[2]	$49,601
Groundwater Extraction System[2]	$102,063
Microfiltration System[2]	$225,000
Total Direct Cost	$386,664
INDIRECT COSTS[2]	
Health and Safety	$5,000
Administration and Permitting	$10,000
Engineering and Design	$20,000
Construction Support Services	$20,000
Total Indirect Cost	$55,000
Total Capital Cost (Direct + Indirect)	$441,664
Present Worth - Delayed Capital Costs (6%, 10 years)	$251,041
OPERATION AND MAINTENANCE (O&M) COSTS	
Microfiltration System (9 years)	
Present Worth - System Operation (6%, 10 to 19 years)	$147,438
Present Worth - Groundwater Monitoring (6%, 19 years)	$128,875
5-Year Site Reviews (9 years)	
Present Worth - 5-Year Site Reviews (6%, 5, 10, 15 and 19 years)	$37,415
NP Treatment System replacement (after 5 years)	$93,886
Total O&M Cost (present worth)	$407,614
Total Capital and O&M Cost	$658,655
Contingency (10%)	$65,866
Total Cost of Alternative A-4: Groundwater Extraction, Microfiltration, and Discharge to Lake Druid	$724,521

[1] Groundwater-use restrictions, 5-year site reviews, and associated groundwater monitoring would be implemented immediately following the signed Record of Decision.
[2] Construction and operation of groundwater extraction and treatment system would be delayed 10 years so not to adversely impact remediation of the southern volatile organic compound plume.

Note: % = percent.
VOC = volatile organic compound.

CHAPTER 6.0

6.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

Remedial alternatives for OU4 groundwater were developed and individually evaluated in Chapters 4.0 and 5.0, respectively, using the seven technical criteria recommended in the NCP. For comparative purposes, these criteria are grouped into the following categories:

- threshold criteria
- primary balancing criteria
- modifying criteria

As presented in Chapter 5.0, the first two sets of criteria were used to evaluate each alternative individually. This chapter presents a comparison of remedial alternatives with respect to these threshold and primary balancing criteria. This comparison is intended to provide technical information to support selection of a preferred alternative. While the FDEP, USEPA, and OPT have reviewed this FS, the modifying criteria, consisting of State and community acceptance, are more appropriately evaluated after the public comment period on the Proposed Plan. It is anticipated these modifying criteria will be used in conjunction with the remedial alternative comparison presented herein to select the appropriate remedial alternatives for the VOC and antimony plumes at OU 4.

6.1 OVERALL APPROACH TO COMPARATIVE ANALYSIS. As presented in Chapter 4.0, remedial alternatives were developed to accomplish the RAOs identified for groundwater at OU 4. The RAOs are based on protecting human health by eliminating or minimizing exposure to COCs in groundwater. In addition, SARA emphasizes the use of treatment technologies that reduce the toxicity, mobility, or volume of contaminants rather than technologies that solely prevent exposure. The threshold and primary balancing criteria identified above are used to streamline the comparison between alternatives, while ensuring compliance with the RAOs. Components of these criteria are described below.

6.1.1 Threshold Criteria Because the selected remedy must be protective of human health and the environment, as well as comply with ARARs, the following threshold criteria are essential:

- overall protection of human health and the environment
- compliance with ARARs.

An individual assessment of each alternative with respect to these criteria was presented in Sections 5.1 and 5.2 for the VOC and antimony groundwater plumes, respectively. An overall comparative analysis of alternatives using threshold criteria for each of the plumes is presented in Section 6.2.

6.1.2 Primary Balancing Criteria Primary balancing criteria consist of the following five components:

- long-term effectiveness and permanence
- reduction of toxicity, mobility, and volume
- short-term effectiveness
- implementability
- cost

These criteria are used to provide an assessment of the permanence of each remedial alternative, while ensuring their implementability and cost-effectiveness. These criteria ensure the use of treatment technologies that reduce the toxicity, mobility, or volume of contaminants rather than technologies that solely prevent exposure. An individual assessment of each alternative with respect to these criteria is presented in Chapter 5.0. A comparative analysis of each of the alternatives using primary balancing criteria is presented in Section 6.2.

As part of the cost-effectiveness evaluation, both the present and future worth costs were calculated for each of the remedial alternatives. In accordance with USEPA guidance (USEPA, 1988), the costs for each of the remedial alternatives presented in Chapter 5.0 were present worth values for capital and O&M costs. However, this presentation assumes that the required present worth funds would be available now for the government to set aside for future use, while receiving compounding interest on the original principle deposited. In actuality, the U.S. government sets aside funds on an annual basis. This would support the evaluation of future worth costs as they more accurately reflect the costs that would be incurred by the U.S. Navy on a "pay-as-you-go" basis to construct and operate the remedial alternatives until RGOs were achieved at OU 4. These future worth costs are also presented for each of the remedial alternatives in Section 6.2, along with a comparison evaluation among these alternatives.

6.2 COMPARATIVE ANALYSIS. The following subsections present a comparison between alternatives for the VOC and antimony groundwater plumes using the seven NCP threshold and primary balancing criteria. Remedial alternatives for the VOC plumes are compared to each other in Subsection 6.2.1.

6.2.1 Comparative Analysis for VOC Plume Alternatives A comparative analysis was conducted for the seven remedial alternatives capable of addressing the VOC plumes at OU 4. In addition, three of these remedial alternatives were evaluated using a combination of active groundwater treatment to a site-specific remedial goal and MNA to achieve drinking water standards. As previously defined, the site-specific remedial goal is a calculated concentration (approximately 24 to 80 $\mu g/\ell$ for PCE) at which MNA would be capable of meeting surface water standards (8 $\mu g/\ell$ for PCE) by the time groundwater naturally discharges into Lake Druid. Alternatives discussed within this FS are identified as follows:

- V-1: No action
- V-2: Limited action
- V-3: Chemical oxidation and enhanced biodegradation
- V-4: Air sparging and enhanced biodegradation
- V-5: Recirculating wells and enhanced biodegradation
- V-6: Groundwater extraction and diffused aeration
- V-7: Groundwater extraction and UV/oxidation

6.2.1.1 Comparison of Threshold Criteria The following comparison is made between remedial alternatives that could be implemented to remediate the VOC plume at OU 4 with respect to two criteria: (1) overall protection of human health and the environment and (2) compliance with ARARs.

Overall Protection of Human Health and the Environment. According to the RI (HLA, 2000), contaminants in OU 4 groundwater present risks to human health if

groundwater is used as a drinking water source, or from ingestion and dermal exposure to surface water at the shore of Lake Druid. All alternatives, including Alternative V-1, would prevent potential surface water exposure by continuing IRA operation, thereby minimizing migration of VOCs to Lake Druid. Unlike Alternative V-1, Alternatives V-2 through V-7 also protect future residential receptors from ingestion of contaminated groundwater. This is achieved through the implementation of groundwater-use restrictions. These groundwater-use restrictions would last for an indefinite time under Alternative V-2. Alternatives V-3 through V-7 would implement temporary groundwater-use restrictions until FDEP drinking water standards are attained.

Alternatives V-3 and V-4 utilize *in situ* chemical oxidation and air sparging, respectively, to treat the northern VOC plume. Remedial Alternatives V-3, V-4 and V-5 all use enhanced *in situ* biodegradation to remediate the southern VOC plume. Chemical oxidation and air sparging have been assumed to be incapable of achieving drinking water standards within the source area. This is due to the difficulty of injecting the $KMnO_4$ or air homogeneously within the saturated zone and possible presence of DNAPL stringers. As a result, these two alternatives would rely on MNA to biodegrade the residual VOC concentrations to FDEP drinking water standards. A field pilot-scale test was conducted in February 2000 to evaluate the effectiveness of VOC oxidation using potassium permanganate. Test results indicate that VOC destruction efficiencies up to 99.99% can be achieved. An air sparging pilot-scale test performed at OU 4 in May 1998 revealed that Alternative V-4 is likely to be protective of human health, providing an effective means to extract the stripped contaminants (vapor phase) from beneath the hard layer is implemented. Based on the ongoing natural degradation of VOCs at OU 4 and published experience by Harding ESE (Dooley *et al.*, 1999; Murray *et al.*, 2000) and others (Koenigsburg and Norris, 1999; Koenigsburg, 2000) with the use of HRC™ to remediate chlorinated VOCs, it was assumed for this evaluation that enhanced biodegradation would be effective on the southern VOC plume. However, a pilot-test of the HRC™ would be required to support the design of the remedial alternative.

The remaining *in situ* alternative, V-5, utilizes recirculating wells to remediate the northern plume source area. Recirculating wells were used as the OU 4 IRA until mid-2000, when the IRA was converted to a pump and treat system due to operational and maintenance difficulties associated with the recirculating wells. This remedial alternative would be protective of human health and the environment when combined with the temporary groundwater-use restrictions. Alternative V-5 may not be technically feasible, however, based on previous experiences with the former IRA system (see Section 2.3).

Alternatives V-6 and V-7 (diffused aeration and UV/oxidation, respectively) would provide an aggressive groundwater extraction and treatment system to directly remove contaminants from the shallow aquifer. Alternatives V-6 and V-7 are proven techniques (i.e., pump-and-treat) for removing the bulk of contamination, but experience has shown that attainment of drinking water standards may be technically impractical.

Compliance with ARARs. Alternatives V-3 through V-7 are anticipated to eventually achieve all chemical-specific ARARs. Alternatives V-1 and V-2 do not use source treatment and therefore achieve only surface water standards at Lake Druid through the continued operation of the IRA for an indefinite period of time. Alternatives V-3 and V-4 rely on MNA to ultimately achieve FDEP drinking

water standards. Alternatives V-5, V-6, and V-7 are capable of achieving drinking water standards through mechanical treatment processes, but have long operating durations of 27 to 108 years. Secondary evaluations of Alternatives V-5, V-6, and V-7 were prepared for treatment to the site-specific remedial goal and the use of MNA to complete the degradation to drinking water standards. In some cases, this would reduce the overall duration to achieve drinking water standards within the OU 4 plume.

6.2.1.2 **Comparison of Primary Balancing Criteria** A comparison was made between the remedial alternatives with respect to the following NCP criteria: (1) long-term effectiveness and permanence; (2) reduction in toxicity, mobility, and volume; (3) short-term effectiveness; (4) implementability; and (5) cost. These criteria are discussed for each alternative detail within Section 5.1.

Long-Term Effectiveness and Permanence. Risk from potential consumption of source area and downgradient groundwater for Alternative V-1 will likely remain without remedial action within the source area and reduction of contaminants to meet drinking water standards. The IRA, which would continue to operate within all seven alternatives, including Alternative V-1, provides a permanent reduction in contaminant concentration and risk prior to groundwater naturally discharging to Lake Druid but only in the portion of the aquifer between the IRA and the lake. Alternative V-2 implements permanent administrative actions (groundwater-use restrictions) in addition to the IRA to manage residual risk and prevent possible human exposure from consumption of groundwater.

Alternatives V-3 through V-7 are all essentially equal in regard to long-term effectiveness and permanence. They all ultimately provide permanent reduction in contaminant concentrations such that no controls (administrative or physical) of residual risk would be required. However, temporary groundwater-use restrictions and associated groundwater monitoring would be implemented until drinking water standards were achieved within the OU 4 plume. Alternatives V-3 and V-7 produce the least treatment residuals in that contaminants from both the northern and southern plumes are chemically and/or biologically destroyed. Alternatives V-4, V-5, and V-6 utilize physical (stripping) processes that transfer the northern plume contaminants from the groundwater to off-gas, which is discharged to the atmosphere, assuming Florida air regulations are not exceeded. Vapor-phase GAC was assumed for the first year of operation on both Alternatives V-4 and V-5 (Appendix H), after which the emissions were estimated to meet the Florida air emission standards.

Reduction of Toxicity, Mobility, and Volume. Other than that accomplished through unmonitored natural transformation processes, Alternatives V-1 and V-2 would not reduce the toxicity, mobility, or volume of contaminants within the source areas. (The IRA, implemented in all alternatives, reduces the toxicity and volume of contaminants in the downgradient plume. Because of its position, it also intercepts and treats the plume prior to discharge into Lake Druid). Alternatives V-3, V-4, and V-5 provide a reduction in toxicity and volume of contaminants in the northern VOC source area groundwater by physically removing (stripping) contaminants from the groundwater. Alternatives V-6, V-7, and to some degree V-3, reduce the toxicity, mobility, and volume of the contaminants in the northern VOC source area due to the hydraulic control afforded by groundwater extraction and chemical or physical treatment of the VOCs. By extracting groundwater from strategic locations, the hydraulic flow paths would

be controlled, preventing contaminant migration plus providing extraction and treatment.

Short-Term Effectiveness. Because there would be no treatment of the source area, remedial duration to meet drinking water standards was expected to be indefinite for Alternative V-1. This was true for Alternative V-2 as well, except that groundwater-use restrictions would be implemented indefinitely to protect future residential receptors from ingesting groundwater.

Remedial Alternatives V-3 through V-7 would institute temporary groundwater-use restrictions to protect residential receptors for the short-term until drinking water standards were achieved through treatment. Alternative V-5 was expected to provide the quickest reduction in groundwater contaminant concentrations, potentially meeting RAOs within 27 years. In contrast, RAOs would likely be achieved by Alternatives V-6 and V-7 within a time period exceeding 80 years. After active source reduction, Alternatives V-3 and V-4 both rely on MNA to achieve RAOs, for which a standard duration of 30 years was used in accordance with USEPA guidance (USEPA, 1988). A longer period may be required for natural attenuation to reach Florida drinking water standards.

The remedial duration for Alternative V-5 is based on the assumption that contaminant removal for a recirculating well would be approximately 4 times faster (27 years) than a conventional extraction well. This is due to the vertical flow component associated with recirculation wells, which is more efficient at flushing contamination from stratified aquifers. The remedial duration for Alternative V-5 is primarily dictated by the time required to naturally flush residual downgradient contaminants (concentrations that meet surface water standards at Lake Druid) to concentrations below drinking water standards (27 years). Duration calculations are based on site-specific hydrogeologic characteristics, as discussed in Paragraph 5.1.5.1 and detailed calculations presented in Appendix I.

A WHPA simulation for Alternatives V-6 and V-7 (which both use conventional extraction wells) predicted that two extraction wells each pumping at 40 gpm would be capable of capturing both the northern source area plume and the southern area plume. Calculations also indicated that these two extraction wells would be capable of reducing PCE concentrations to drinking water standards within approximately 108 years and to the site-specific remedial goal within 59 years. WHPA simulation results and associated calculations are presented in Appendix G.

Alternatives V-3 and V-4 would use chemical and physical treatment processes, respectively, within the source area of the northern plume to achieve the site-specific remedial goal, but rely on long-term MNA to reduce contaminants to drinking water standards.

No alternatives present any major exposures to remedial workers or the community. However, alternatives that have long treatment system O&M durations could generally be expected to present the greatest exposure to workers. The estimated treatment durations for Alternatives V-6 and V-7 are 108 years for drinking water standards or 59 years for site-specific remedial goals. The source area treatment duration for Alternative V-5 was estimated to be 27 years (drinking water standards) or 15 years (site-specific remedial goals). The source area treatment duration for Alternatives V-3 and V-4 were estimated to be 1 year and

2 years, respectively. However, these durations would not achieve drinking water standards, but would rely on an indefinite period of time for MNA to achieve drinking water standards (NCP uses maximum of 30 years). All of the remedial alternatives would have a treatment component that would discharge organic vapors to ambient air at concentrations that meet Florida air emission standards (the IRA for all alternatives plus source area treatment for Alternatives V-4, V-5, and V-6).

Implementability. Alternatives V-1 and V-2 would be the easiest to implement because they only include the continued operation of the IRA system, groundwater monitoring, groundwater-use restrictions (V-2 only), and 5-year site reviews.

Alternative V-3 requires installation of several injection and extraction wells, of which 4 will be installed at an angle. Treatment system equipment is readily available from Carus Chemical Company and can be rented. Source area treatment by chemical oxidation is expected to require no more than one year. For Alternative V-4, an air sparging system, which is relatively straightforward to implement, would be constructed using basic practices and readily available equipment. The presence of the hard layer would require the advancement of additional borings to enable collection of stripped vapors from the groundwater.

Alternative V-5 would entail the construction of four recirculating wells in the northern VOC source area. Installation would also require hydraulic modeling, use of specially designed equipment, and contractors that are technically trained for construction of this innovative system. However, design and construction would be simplified based on the site-specific experience gained through installation of the former IRA wells at the site.

Alternatives V-6 and V-7 are the most labor intensive due to the *ex situ* treatment duration, associated utilities, and system maintenance. Although these alternatives would both require the same groundwater extraction system, Alternative V-6 (diffused aeration) would be easier to operate and maintain than V-7 (UV/oxidation) because the treatment process involves a simpler operation (physical stripping using diffused aerators versus chemical addition and UV chamber operation).

Cost. Table 6-1 summarizes the present worth costs estimated for remedial alternatives that could be used to treat the VOC-contaminated groundwater at OU 4. Figure 6-1 presents these costs in a graphical presentation for comparison purposes. Costs for treatment goal options A and B are included in Table 6-1 and Figure 6-1 for Alternatives V-5, V-6. and V-7. These present worth costs, presented in Appendix D (see attached material), include direct and indirect capital costs, system O&M, system and groundwater monitoring to ensure performance, monitoring of the groundwater plume, and 5-year site reviews. Present worth cost calculations used an assumed interest rate of 6 percent.

The cost estimates also incorporated treatment durations based on site-specific hydrogeologic characteristics at OU 4 (e.g., 108 years for Alternative V-6 and V-7). A fixed duration of 30 years (USEPA, 1988) was used only when an indefinite time was required to achieve the drinking water standard RGOs. These instances included the no action and limited action alternatives (continued operation of the IRA system), and the use of MNA as a polishing step to achieve the RGOs (e.g., Alternatives V-3 and V-4).

Table 6-1
Summary of Comparative Analysis for Volatile Organic Compound Plume Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Alternative:	V-1 No Action	V-2 Limited Action	V-3 Chemical Oxidation and Enhanced Biodegradation	V-4 Air Sparging and Enhanced Biodegradation	V-5 Recirculating Wells and Enhanced Biodegradation	V-6 Diffused Aeration	V-7 UV/Oxidation
Groundwater Remediation							
Groundwater extracted?	No	No	Yes	No	No	Yes	Yes
Organics reduced?	Yes (IRA)	Yes (IRA)	Yes	Yes	Yes	Yes	Yes
Estimated time until IRA is shut down (years):	Indefinite	Indefinite	10	10	15	10	10
Estimated time to achieve drinking water standards (years):	Indefinite	Indefinite	40+	40+	[2]27/[3]45+	[2]108/[3]89+	[2]108/[3]89+
Plume contained?	Yes (IRA)	Yes (IRA)	Yes (IRA)	Yes (IRA)	Yes (IRA)	Yes	Yes
Source area toxicity reduced?	No	No	Yes	Yes	Yes	Yes	Yes
Source area remedy permanent?	DNA	DNA	Yes	Yes	Yes	Yes	Yes
MCLs attained?	No	No	[4]Yes	[4]Yes	Yes	Yes	Yes
Source treatment residuals produced?	DNA	DNA	No	Yes	Yes	[1]No	No
Operation and Maintenance (Excluding IRA)							
North plume treatment O&M duration (yrs)	DNA	DNA	30+	30+	[2]27/[3]45+	[2]108/[3]89+	[2]108/[3]89+
South plume treatment O&M duration (yrs)	DNA	DNA	3	3	3	[5]DNA	[5]DNA

See notes at end of table.

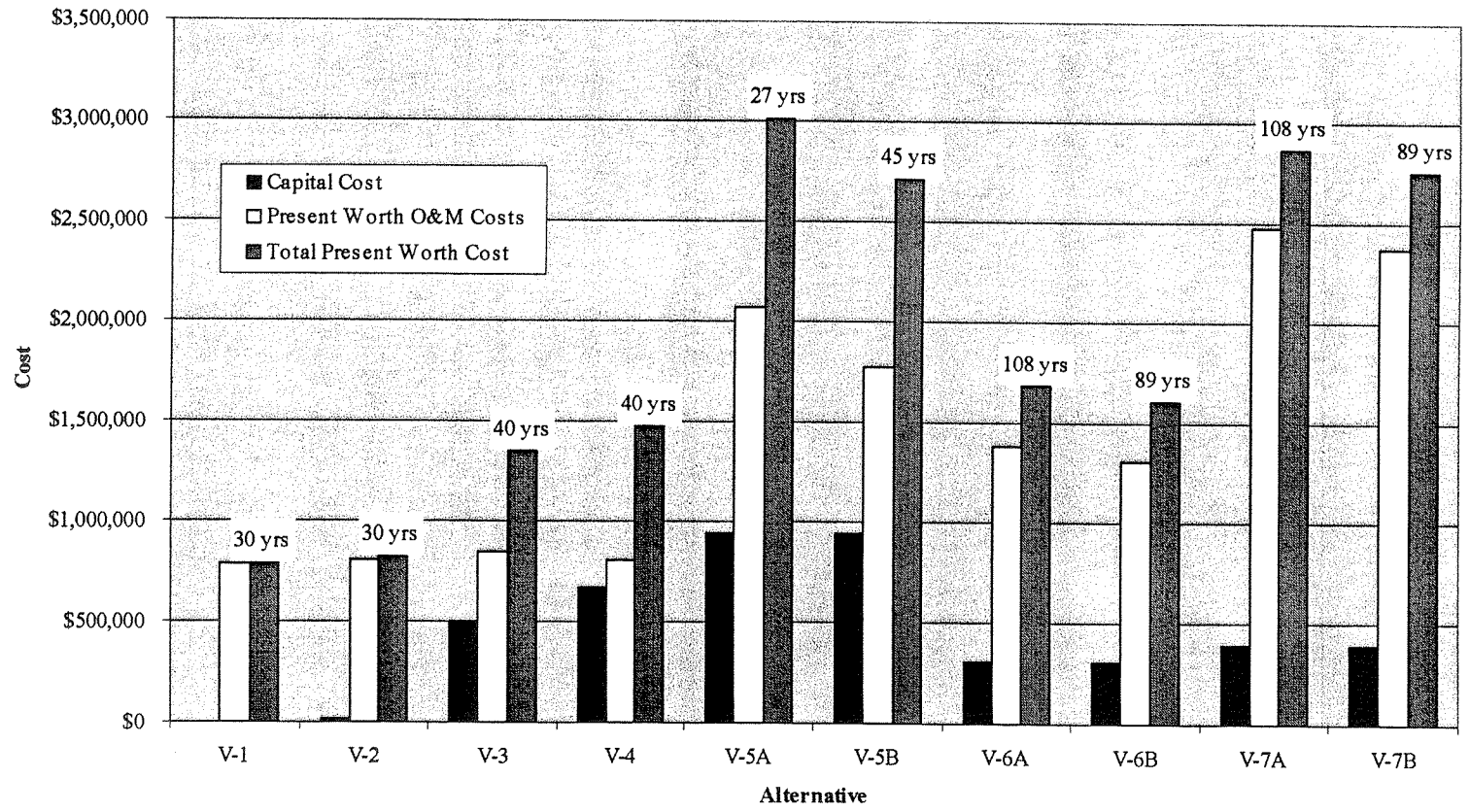
Table 6-1 (Continued)
Summary of Comparative Analysis for VOC Plume Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Alternative:	V-1 No Action	V-2 Limited Action	V-3 Chemical Oxidation and Enhanced Biodegradation	V-4 Air Sparging and Enhanced Biodegradation	V-5 Recirculating Wells and Enhanced Biodegradation	V-6 Diffused Aeration	V-7 UV/Oxidation
Operation and Maintenance (Excludes IRA) (Continued)							
Utilities maintenance	DNA	DNA	Yes	Yes	Yes	Yes	Yes
Groundwater monitoring	No	Yes	Yes	Yes	Yes	Yes	Yes
Costs							
Capital	DNA	$16,500	$497,102	$663,832	$938,027	$305,505	$386,732
Present worth	$861,140	$897,762	$1,474,387	$1,617,711	[2]$3,308,022/[3]2,986,580	[2]$1,848,589/[3]1,768,681	[2]$3,151,344/[3]3,115,843
Future worth	$3,034,793	$3,116,789	$3,130,492	$3,488,874	[2]$7,347,475/[3]6,277,945	[2]$53,216,854/[3]17,137,564	[2]$110,281,921/[3]28,704,064

[1] Air emissions meet FDEP air regulations without further treatment.
[2] Option A - MCL RGO.
[3] Option B - Site-specific RGO with natural attenuation to meet MCLs.
[4] MCLs eventually attained through monitored natural attenuation.
[5] Groundwater extraction and *ex situ* treatment addresses both the north and south plumes together.

Notes: VOC = volatile organic compound.
UV = ultraviolet.
IRA = Interim Remedial Action.
DNA = does not apply.
MCL = maximum contaminant level.
O&M = operation and maintenance.
FDEP = Florida Department of Environmental Protection.
RGO = remedial goal option.



LEGEND

VOC	Volatile organic compound
MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE 6-1
PRESENT WORTH COSTS
VOC ALTERNATIVES V-1 THROUGH V-7

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FEASIBILITY STUDY
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

As would be expected, Alternative V-1, no action, had the lowest present worth cost, relying on the continued operation of the IRA wells to ultimately achieve drinking water standards in the VOC plume. Limited action, Alternative V-2, had only slightly higher present worth costs, but would provide limited protection by eliminating the potential exposure to the contaminated groundwater.

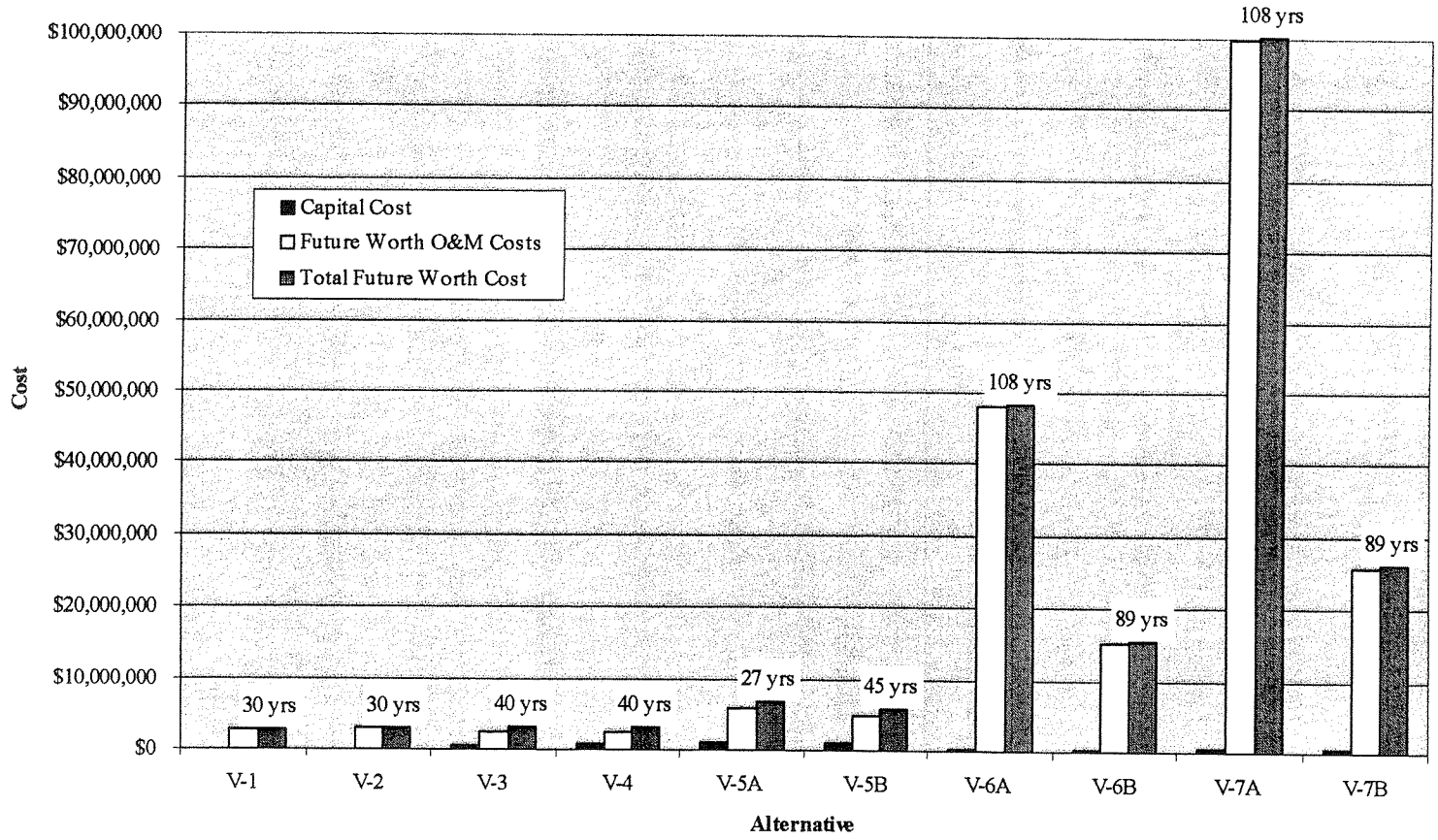
Of the three *in situ* treatment alternatives, chemical oxidation of the source area using potassium permanganate and enhanced biodegradation (V-3) had the lowest total present worth cost. Air sparging and SVE (Remedial Alternative V-4) was only $135,000 more than V-3, and recirculation well treatment (V-5) was approximately $1,400,000 to $1,650,000 more expensive than V-3. All three of these *in situ* remedial alternatives (V-3, V-4 and V-5) relied on enhanced biodegradation of the southern VOC plume and natural attenuation to achieve FDEP drinking water standards.

Based on historical USEPA remediation data, *ex situ* treatment technologies are typically more expensive than *in situ* treatment technologies when operated to achieve drinking water standards. However, the present worth cost of diffused aeration (V-6) was only $272,000 and $137,000 higher in cost than *in situ* remedial alternatives V-3 and V-4, respectively, and thus comparable to the present worth costs of the *in situ* alternatives. The present worth costs of UV/oxidation (V-7) was approximately two times that of Alternatives V-3 and V-4.

The present worth costs were also evaluated to identify the potential cost savings through the use of MNA to reduce residual VOC concentrations down to drinking water standards, rather than continued operation of the mechanical treatment system. The reductions in present worth cost ranged from approximately $300,000 for the recirculation well and enhanced biodegradation alternative, V-5, to $30,000 for UV/oxidation (V-7).

As discussed earlier in Subsection 2.1.2, present worth cost estimates assume that the funds are available today to be set aside compounding interest until they are needed to pay for the remedial alternative construction and annual O&M. In reality, the U.S. Navy funds the construction and operation of the remedial alternatives on an annual basis, as needed. Therefore, the use of future worth more accurately reflects the costs that would be incurred to achieve drinking water standards in the VOC plume of OU 4. These future worth costs are summarized on Figure 6-2 and a detailed cost estimate is provided in Appendix J (see attached material). Future worth costs were based on a 3 percent inflation rate.

Based on a review of Figure 6-2, the previous conclusions made using the present worth costs are not significantly altered. The least expensive remedial alternative using estimated future worth costs is V-1, the no-action alternative, at approximately $2,760,000. This remedial alternative is approximately $75,000 less costly than Alternative V-2, the limited action alternative. This cost difference is related to incurred capital costs, five-year site reviews and associated sampling/monitoring. Alternative V-3 is comparable to Alternatives V-1 and V-2, despite higher capital costs, due to shorter IRA system operation (10 years compared with 30 years, respectively).



LEGEND

VOC	Volatile organic compound
MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE 6-2
FUTURE WORTH COSTS
VOC ALTERNATIVES V-1 THROUGH V-7

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The remaining remedial alternatives are ranked as follows based on future worth costs:

(3) V-3, Chemical oxidation/enhanced biodegradation ($2,846,000),
(4) V-4, Air sparging/SVE/enhanced biodegradation ($3,172,000),
(5) V-5, Recirculation wells/enhanced biodegradation ($5,707,000 to $6,680,000),
(6) V-6, Diffused aeration ($15,580,000 to $48,379,000), and
(7) V-7, UV/oxidation ($26,095,000 to $100,256,000).

Ranges in future worth costs are provided for Alternatives V-5, V-6, and V-7 based on continuous flushing to reach the RGOs versus a reduced operating duration of the active groundwater treatment technologies (flushing) and the use of MNA to achieve the RGOs. MNA would be used to reduce the residual VOC concentrations remaining in the groundwater plume after the active treatment systems achieved the site-specific remedial goals (e.g., 89 years total duration versus 108 years). Treatment to site-specific RGOs then using MNA results in dramatic cost savings for Alternatives V-5, V-6 and V-7 when assessing the future worth costs of these alternatives. The future worth costs of Alternatives V-6 and V-7 are typical of groundwater extraction and *ex situ* treatment systems for VOC-contaminated groundwater because of their long treatment durations and resultant excessive operation and maintenance costs.

6.2.1.3 **Summary of Comparative Analysis for VOC Plume Alternatives** Table 6-1 presents a summary of the comparative analysis of the VOC plume remedial alternatives for OU 4. The evaluation criteria presented within this table provide a detailed evaluation of the individual remedial alternatives in their ability to achieve the seven NCP screening criteria. This summary table also supports the overall comparison of remedial alternatives to support the State and community acceptance process. Table 6-1 also presents capital, total present worth and total future worth costs for each remedial alternative to further support this evaluation and selection of the preferred remedial alternative.

Even though this detailed evaluation has been conducted to compare the abilities of the seven remedial alternatives to achieve the RAOs, uncertainties still exist. Uncertainties for Remedial Alternative V-3 include the $KMnO_4$ demand of the source area and the ability to effectively deliver the potassium permanganate to the entire source area. Even small changes in chemical demand and/or duration would significantly affect both the present and future worth costs of V-3. A pilot-test is also recommended for HRC™ treatment of the southern VOC plume to refine the design and costs of the treatment system for this remedial component of Alternatives V-3, V-4, and V-5.

Remedial Alternative V-4 was developed on the assumption that the VOC vapors stripped from the contaminated groundwater would readily pass through the holes in the impervious layer, and that the bulk of contamination was contained within the higher zone of conductivity. If the deep sparge air can not readily pass through the hard layer, air sparging would be less effective for remediating the lower portion of the source area. The majority of VOC contamination within the hard layer would also be inaccessible to the sparge air, further reducing the effectiveness of this alternative.

Remedial Alternative V-5 has the shortest duration of all the VOC treatment alternatives that were evaluated. However, this conclusion is based solely on

an assumed treatment duration of 27 years (four times faster than pump-and-treat) to reduce the VOC concentrations to drinking water standards. Longer durations could significantly increase the already high O&M costs associated with this alternative. In addition, based on experience gained with the former IRA system, the use of recirculation wells may be technically infeasible due to excessive system maintenance requirements.

Remedial Alternatives V-6 and V-7 have the least uncertainties based on their proven effectiveness, but also have the highest future worth costs.

6.2.2 Comparative Analysis for Antimony Plume Alternatives A comparative analysis was conducted for the four remedial alternatives capable of addressing the antimony plume at OU 4. Alternatives developed and evaluated within this FS are identified as follows:

- A-1, No action
- A-2, Limited action
- A-3, Extraction and discharge to Orlando STP
- A-4, Extraction and NP™ microfiltration

Except for the no action and limited action alternatives, the alternatives for remediation of the antimony plume require groundwater extraction. Because the eastern edge of the southern VOC plume is colocated with the antimony plume (Subsection 3.2.5), extraction of antimony-contaminated groundwater would influence the southern VOC plume, and interfere with its remediation. Therefore, if active remediation of the antimony plume is required (Alternatives A-3 and A-4), it will be necessary to delay implementation until the southern VOC plume remediation is complete. For costing purposes, this FS assumes antimony remediation will begin 10 years after VOC plume remediation has begun.

6.2.2.1 Comparison of Threshold Criteria A comparison was made between the antimony plume alternatives with respect to: (1) overall protection of human health and the environment and (2) compliance with ARARs.

Overall Protection of Human Health and the Environment. According to the RI (HLA, 2001), antimony in OU 4 groundwater poses potential risks to human health if groundwater is used as a drinking water source. Unlike Alternative A-1 (no action), Alternatives A-2 through A-4 protect future residential receptors from ingestion of contaminated groundwater. Alternative A-2 would achieve this through the implementation of permanent groundwater-use restrictions. Remedial Alternatives A-3 and A-4 would achieve this by implementing temporary groundwater-use restrictions until drinking water standards were attained through groundwater extraction and discharge (Alternative A-3) and groundwater treatment (Alternative A-4).

Alternative A-3 and A-4 protect human health by aggressively removing the contaminated groundwater. Alternative A-3 relies on off-site treatment (Orlando STP) while Alternative A-4 uses on-site treatment to consolidate the contaminant into a residual waste for off-site disposal. Although both alternatives utilize proven technologies (i.e., pump-and-discharge and pump-and-treat, respectively) for removing the bulk of antimony contamination, experience has shown that attainment of drinking water standards could be technically impractical.

Compliance with ARARs. Alternatives A-3 and A-4 were anticipated to achieve chemical-specific ARARs after a duration of 9 years. Alternatives A-1 and A-2 would not treat the antimony source area and therefore would not achieve these ARARs. Alternatives A-3 and A-4 rely on extraction to meet drinking water standards in the aquifer. Alternative A-3 would meet Orlando STP pretreatment requirements for off-site disposal of contaminated groundwater. Alternative A-4 would discharge treated effluent to Lake Druid and readily comply with Florida surface water standards because untreated extracted groundwater would already meet Florida surface water standards. *Ex situ* treatment would be performed as part of this alternative because it would otherwise equate to the no action alternative.

6.2.2.2 **Comparison of Primary Balancing Criteria** A comparison was made between the antimony plume alternatives with respect to following criteria: (1) long-term effectiveness and permanence; (2) reduction in toxicity, mobility, and volume; (3) short-term effectiveness; (4) implementability; and (5) cost. These criteria are discussed for each alternative in Section 5.2 of this FS.

Long-Term Effectiveness and Permanence. Potential risk from the consumption of OU 4 groundwater under Alternative A-1 would likely remain without remedial action within the source area and reduction in antimony concentrations to meet drinking water standards. Alternative A-2 would include the implementation of permanent administrative actions (groundwater-use restrictions) to manage residual risk and prevent possible human exposure from consumption of groundwater.

Alternative A-3 and A-4 would be equal in regard to long-term effectiveness and permanence. They both ultimately provide permanent reduction (removal) in antimony such that no permanent controls (administrative or physical) of residual risk would be required. Alternatives A-3 and A-4 would produce similar treatment residuals in that the antimony would be concentrated (more so in Alternative A-4 than A-3) for further treatment and/or disposal.

Reduction of Toxicity, Mobility, and Volume. Other than that accomplished through unmonitored natural transformation processes, Alternative A-1 and A-2 would not reduce the toxicity, mobility, or volume of antimony within the OU 4 plume. Alternatives A-3 and A-4 would reduce the toxicity and volume of antimony in the source area by physically removing it from the groundwater. Both Alternatives A-3 and A-4 would also reduce the mobility of the plume due to the hydraulic control afforded by groundwater extraction. By extracting groundwater from a strategic location, the hydraulic flow paths would be controlled, preventing contaminant migration plus providing extraction and discharge (A-3) and/or treatment (A-4).

Short-Term Effectiveness. Because there would be no treatment of the source area, remedial duration to meet drinking water standards was estimated to be indefinite for Alternative A-1. This was true for Alternative A-2 as well, except that groundwater-use restriction would be implemented indefinitely to protect future residential receptors from ingesting groundwater.

Alternatives A-3 and A-4 would institute temporary groundwater-use restrictions to protect residential receptors during the short-term until drinking water standards were achieved through treatment of the source area. The implementation of the *ex situ* treatment alternatives (A-3 and A-4) would be delayed approximate-

ly 10 years, adversely affecting short-term effectiveness. This delay is necessary because the eastern edge of the southern VOC plume is co-located with the antimony plume. Extraction of antimony-contaminated groundwater would influence the southern VOC plume and interfere with the remediation of the organic contaminants.

A WHPA simulation for Alternatives A-3 and A-4 predicted that one extraction well pumping at 40 gpm would be capable of capturing the plume. Calculations further show that the extraction well will be capable of reducing antimony concentrations to drinking water standards within approximately 9 years of pumping. WHPA simulation results and associated calculations are presented in Appendix G.

No alternatives would pose any major exposures to remedial workers or the community. However, Alternative A-4 would require on-site system maintenance and would produce a concentrated inorganic residual posing the greatest exposure to workers.

Implementability. Alternative A-1 implements no remedial action. Of the alternatives that would implement remedial actions, Alternative A-2 would be the easiest to execute because it would include only groundwater monitoring, groundwater-use restrictions, and 5-year site reviews. Alternative A-3 would also be easy to implement in that it would require only basic construction practices to install a groundwater extraction well and connection to the sanitary sewer. Alternative A-4 would be the most labor intensive due to the *ex situ* treatment process, associated utilities, and system maintenance.

Cost. Table 6-2 summarizes the present worth costs estimated for remedial alternatives that would be used to treat the antimony-contaminated groundwater at OU 4. Figure 6-3 presents these costs in a graphical presentation for comparison purposes. These present worth costs included direct and indirect capital costs, system O&M, system and groundwater monitoring to ensure performance, monitoring of the groundwater plume, and 5-year site reviews.

As with the VOC plumes, present worth costs were computed using the full remedial duration time frame of 19 years (i.e., 10-year delay, then 9 years operation for Alternatives A-3 and A-4). For alternatives where there were indefinite periods to achieve drinking water standards because no active remediation was proposed (i.e., Alternatives A-1 and A-2), the present worth cost was computed for a 30-year duration in accordance with USEPA guidance (USEPA, 1988).

As expected, Alternative A-1, the no action alternative, had the lowest estimated present worth cost at approximately $74,000. Alternative A-2, limited action, had the lowest present worth cost ($202,000) of the alternatives that perform a remedial action (groundwater-use restrictions and associated monitoring). Most of the cost for this alternative was for O&M activities (i.e., 5-year reviews and groundwater monitoring) over a 30-year duration (USEPA, 1988).

The two remedial alternatives that involved active treatment of the antimony plume were approximately $300,000 to $460,000 more than the limited action alternative. Discharge of extracted groundwater into the Orlando STP (A-3) had an estimated present worth cost of $503,000, while *ex situ* microfiltration and discharge of the treated groundwater into Lake Druid (A-4) had an estimated present worth cost of $659,000. Although both of these remedial alternatives would be operated for the same 9-year duration with associated groundwater

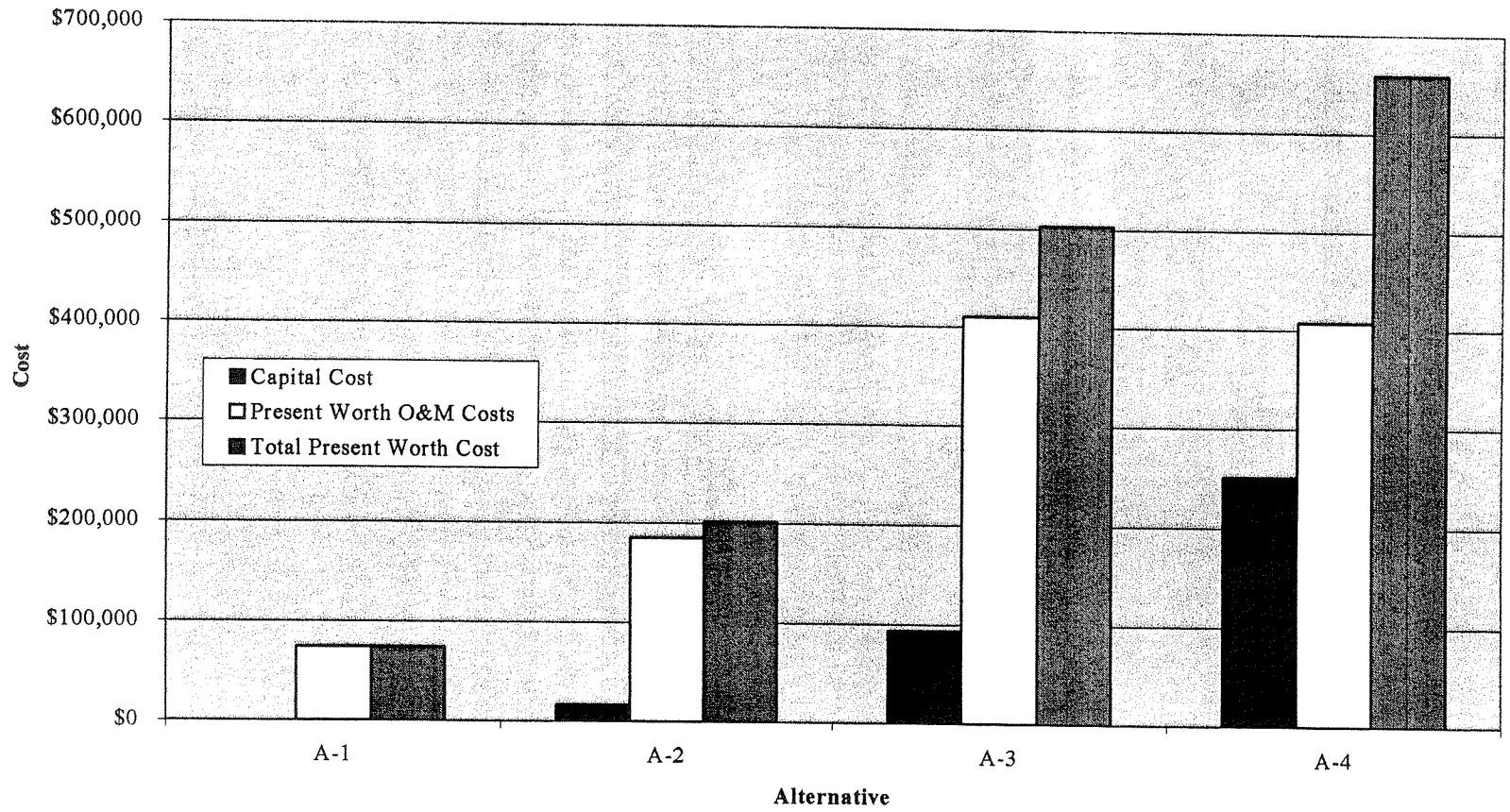
Table 6-2
Summary of Comparative Analysis for Antimony Plume Remedial Alternatives

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Alternative:	A-1 No Action	A-2 Limited Action	A-3[1,2] Extraction & Discharge to Orlando STP	A-4[1,2] Extraction & NP™ Microfiltration
Groundwater Remediation				
Groundwater extracted?	No	No	Yes	Yes
Antimony reduced?	No	No	Yes	Yes
Estimated time to achieve MCLs (yrs)[3]:	Indefinite	Indefinite	19	19
Uncertainty of attaining MCL?	not attained	not attained	Low	Low
Plume contained?	No	No	Yes	Yes
Toxicity reduced?	No	No	Yes	Yes
Remedy permanent?	DNA	DNA	Yes	Yes
Treatment residuals produced?	No	No	[4]Yes	Yes
Operation and Maintenance				
Treatment O&M duration (yrs)	DNA	DNA	9	9
Utilities maintenance	DNA	DNA	Yes	Yes
Groundwater monitoring	No	Yes	Yes	Yes
Total Cost				
Capital (present worth)[2]	DNA	$16,500	$92,456	$251,041
Present worth	$81,174	$221,683	$553,276	$724,521
Capital (future worth)[2]	DNA	$16,500	$208,446	$590,114
Future worth	$345,331	$760,669	$1,630,701	$1,912,811

[1] Groundwater-use restrictions, 5-year site reviews, and associated groundwater monitoring would be implemented immediately following the signed Record of Decision.
[2] Construction and operation of the groundwater extraction, treatment and discharge systems would be delayed for 10 years so not to adversely impact the remediation of southern volatile organic compound plume.
[3] Includes 10-year delay in start-up of pump-and-treat.
[4] Treatment residuals generated at City of Orlando STP.

Notes: STP = sewage treatment plant.
NP™ = Neutral Process™.
MCL = maximum contaminant level.
yrs = years.
DNA = does not apply.
O&M = operation and maintenance.



LEGEND

MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE 6-3
PRESENT WORTH COSTS
ANTIMONY ALTERNATIVES A-1 THROUGH A-4

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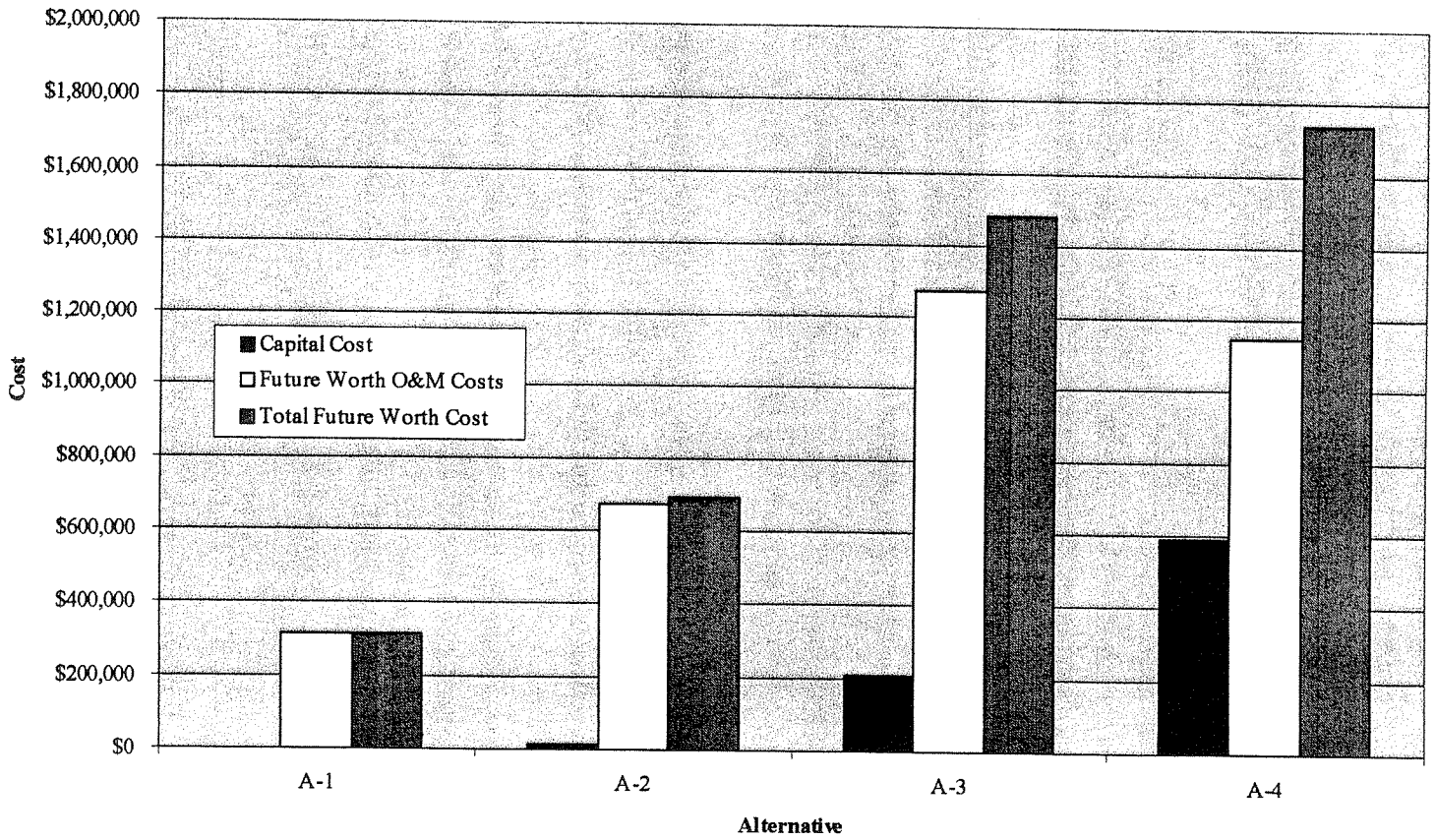
monitoring, discharge of the treated groundwater into Lake Druid (Alternative A-4) was more expensive due to higher capital costs.

As was the case for the cost comparison of the VOC plume remedial alternatives, future worth costs were calculated for the antimony plume remedial alternatives. These future worth costs are summarized on Figure 6-4 and the detailed costing information is presented in Appendix J, Tables J-11 through J-14. These costs accurately reflect the total costs of annually funding the remedial construction and O&M by the U.S. Navy. These future worth costs resulted in a similar ranking of remedial alternatives, starting with no action ($314,000) as the least expensive, limited action ($692,000), extraction and discharge to the Orlando POTW ($1,483,000) and, finally, *ex situ* treatment using microfiltration ($1,739,000). In both evaluations using present and future worth cost estimates, the limited action alternative is less than half of the active treatment alternatives, while protecting the public from exposure to the contaminated groundwater.

6.2.2.3 **Summary of Comparative Analysis for Antimony Plume Alternatives** Table 6-2 presents a summary of the comparative analysis for the proposed antimony plume remedial alternatives for OU 4. The evaluation criteria presented within this table provide a detailed evaluation of whether the individual remedial alternatives achieve the seven NCP screening criteria. This summary table also presents an overall comparison of remedial alternatives to support the State and community acceptance process. It should be noted that Table 6-2 does not include future worth costs for the remedial alternatives and Figure 6-4 should be used to further support this evaluation and selection of the preferred remedial alternative.

Even though this detailed evaluation has been conducted to compare the abilities of the four remedial alternatives to achieve the RAOs, one major uncertainty exists. This involves the actual delay in implementing groundwater extraction and discharge into the Orlando STP or *ex situ* treatment. For estimating purposes, a period of 10 years was proposed to delay groundwater extraction from the antimony plume so not to adversely affect the remediation of the southern VOC plume. If this 10-year delay period is not sufficient to complete the southern VOC plume remediation, then a further delay may be required, and the actual costs to the U.S. Navy would likely increase. However, this uncertainty should not affect the selection of the preferred remedial alternative for the OU 4 antimony plume.



LEGEND

MCL	Maximum contaminant level
RGO	Remedial goal option
O&M	Operation and maintenance
A	MCL RGO
B	Site-specific RGO (see Section 6.2.1.2)

FIGURE 6-4
FUTURE WORTH COSTS
ANTIMONY ALTERNATIVES A-1 THROUGH A-4

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APPENDIX A

APPENDIX A

GROUNDWATER CHEMICALS OF POTENTIAL CONCERN AND REMEDIAL GOAL OPTIONS

Table A-1
Selection of Human Health Chemicals of Potential Concern
Unfiltered Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Frequency of Detection[1]	Range of Reporting Limits	Range of Detected Concentrations[2]	Mean of Detected Concentrations[3]	Background Screening Concentration[4]	USEPA Region III Tap Water RBC[5]	Florida Groundwater Cleanup Target Level[6]	Analyte HHCOPC? (Yes/No)	Reason[7]
Semivolatile Organic Compounds (µg/ℓ)									
cis-1,2-Dichloroethene	15/39	1 to 1,100	1 to 1,650	362	NA	6.1	70	Yes	
trans-1,2-Dichloroethene	1/39	1 to 1,100	1.4	1.4	NA	12	100	Yes	C
Chloroform	1/39	1 to 1,100	4	4	NA	0.15	5.7	No	F
Tetrachloroethene	20/39	1 to 1,600	1 to 29,800	1,582	NA	1.1	3	Yes	
Trichloroethene	19/39	1 to 1,100	0.7 to 2,475	325	NA	1.6	3	Yes	
Inorganic Analytes (µg/ℓ)									
Aluminum	27/33	16.8 to 109	117 to 35,500	3,330	4,067	3,700	200	Yes	
Antimony	7/33	2.5 to 7.2	3.1 to 20.7	9.7	4.1	1.5	6	Yes	
Barium	33/33	NA	1.4 to 289	25.8	31.4	260	2,000	Yes	
Calcium	1/33	65 to 64,700	3,350	3,350	36,830	[8]1,055,398	NSC	No	B, E
Chromium	27/33	0.9	0.73* to 59.4	6	7.8	[9]11	100	Yes	
Copper	2/33	0.7 to 20.3	5.1 to 94.8	49.9	5.4	150	1,000	No	S, G
Iron	32/39	15.7 to 110	16.8 to 4,920	764	1,227	1,100	300	Yes	
Magnesium	1/33	6.7 to 8,450	1,340	1,340	4,560	[8]118,807	NSC	No	B, E
Mercury	4/33	0.1	0.13 to 3.7	1.1	0.12	[10]1.1	2	Yes	
Nickel	12/33	1.2	1.3* to 7.6	3.3	ND	73	100	No	S, G
Potassium	2/33	41.1 to 3,490	1,900 to 10,700	6,300	5,400	297,016	NSC	No	E
Selenium	3/33	3.6	3.0 * to 15.5	10.5	9.7	18	50	No	S, G
Sodium	2/33	307 to 115,500	13,000 to 1,120,000	566,500	ND	[8]396,022	160,000	Yes	
Vanadium	16/17	0.6	1.5 to 23	6.8	20.6	26	49	No	S, G

See notes at end of table.

Table A-1 (Continued)
Selection of Human Health Chemicals of Potential Concern
Unfiltered Groundwater

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Frequency of Detection[1]	Range of Reporting Limits	Range of Detected Concentrations[2]	Mean of Detected Concentrations[3]	Background Screening Concentration[4]	USEPA Region III Tap Water RBC[5]	Florida Groundwater Cleanup Target Level[6]	Analyte HHCOPC? (Yes/No)	Reason[7]

[1] Frequency of detection is the number of samples in which the analyte is detected over the total number of samples analyzed (excluding rejected values).
[2] A value indicated by an asterisk is the average of a sample and its duplicate. For duplicate samples having one nondetect, one-half of the reporting limit is used as a surrogate concentration for the nondetect.
[3] The mean of detected concentrations is the arithmetic mean of all samples in which the analyte was detected. It does not include those samples with "R," "U," or "UJ" validation qualifiers.
[4] The background screening concentration is twice the mean of detected concentrations for inorganic analytes. The background concentrations were obtained from the Naval Training Center Orlando *Background Sampling Report* (ABB Environmental Services, Inc., 1995).
[5] For all chemicals except the essential nutrients (calcium, magnesium, potassium, and sodium), USEPA Region III RBCs tap water values were used (USEPA, 1999). The RBC values are based on a carcinogenic risk of 1×10^{-6} and an adjusted hazard index of 0.1. For the essential nutrients, screening values were derived based on recommended daily allowances (See Appendix E-3).
[6] Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Levels from Chapter 62-777 (FDEP, 1999).
[7] Analyte was included or excluded from the risk assessment for the following reasons:
B = the maximum detected concentration did not exceed twice the arithmetic mean of detected concentrations at background locations and will not be considered further;
C = Included because one member of chemical class was selected as a COPC. Classes included carcinogenic PAHs, and PCBs;
S = the maximum detected concentration did not exceed the risk-based screening concentration and will not be considered further;
G = the maximum detected concentration did not exceed the Florida guidance concentration and will not be considered further;
E = the maximum detected concentration did not exceed the essential nutrient screening concentration derived in Appendix E-3; and
F = the analyte was detected in less than 5 percent of the samples and will not be considered further.
[8] Essential nutrient value (see Appendix E-3).
[9] Value is based on hexavalent chromium.
[10] Value is for mercuric chloride.

Notes: USEPA = U.S. Environmental Protection Agency.
HHCOPC = human health chemical of potential concern.
µg/ℓ = micrograms per liter.
NA = not available/not applicable.
NSC = No screening concentration available.
* = Value is the average of a sample and its duplicate.
ND = not detected.
PAH = polynuclear aromatic hydrocarbons.
COPC = chemical of potential concern.

Table A-2
Summary of Remedial Goal Options for Groundwater, Northern VOC Plume

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Range of Detected Concentrations	Exposure Point Concentration	Total Excess Lifetime Cancer Risk (Based on Risk to Resident [adult and child])			Total Hazard Index (Based on Risk to Child Resident)			Florida Groundwater Cleanup Target Level[1]	Federal MCL[2]	Background Screening Concentration
			10^{-4}	10^{-5}	10^{-6}	3	1	0.1			
Volatile Organic Compounds (µg/ℓ)											
cis-1,2-Dichloroethene	1 to 1,650	350	NA	NA	NA	NR	160	16	70	70	NA
Tetrachloroethene	2 to 29,800	1,900	130	13	1.3	480	160	16	3	5	NA
Trichloroethene	0.7 to 2,475	410	NR	61	6.1	280	93	9.3	3	5	NA
Inorganic Analytes (µg/ℓ)											
Aluminum	117 to 35,500	4,630	NA	NA	NA	NR	NR	1,540	200	200	4,067
Chromium	0.95 to 59.4	8.4	NA	NA	NA	NR	NR	7.6	100	100	7.8
Iron	35.3 to 4,920	751	NA	NA	NA	NR	NR	470	300	300	1,227

[1] Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Levels (Chapter 62-777; FDEP, 1999).
[2] Federal MCLs are taken from U.S. Environmental Protection Agency (USEPA) *Drinking Water Regulations and Health Advisories* from October 1996 (USEPA, 1996d).

Notes: MCL = maximum contaminant level.
µg/ℓ = micrograms per liter.
NA = not applicable.
NR = not reported because the calculated remedial goal option exceeds the exposure point concentration.
VOC = volatile organic compound.

Table A-3
Summary of Remedial Goal Options for Groundwater, Southern VOC Plume

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Range of Detected Concentrations	Exposure Point Concentration	Total Excess Lifetime Cancer Risk (Based on Risk to Resident [adult and child])			Total Hazard Index (Based on Risk to Child Resident)			Florida Groundwater Cleanup Target Level[1]	Federal MCL[2]	Background Screening Concentration
			10^{-4}	10^{-5}	10^{-6}	3	1	0.1			
Volatile Organic Compounds (µg/ℓ)											
Tetrachloroethene	2 to 390	110	NR	13	1.3	NR	NR	16	3	5	NA
Trichloroethene	2 to 105	23	NR	NR	6	NR	NR	9.2	3	5	NA
Inorganic Analytes (µg/ℓ)											
Aluminum	1,390 to 12,700	3,780	NA	NA	NA	NR	NR	1,580	200	200	4,067
Iron	16.8 to 3,350	738	NA	NA	NA	NR	NR	460	300	300	1,227

[1] Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Levels (Chapter 62-777; FDEP, 1999).
[2] Federal MCLs are taken from U.S. Environmental Protection Agency (USEPA) *Drinking Water Regulations and Health Advisories* from October 1996 (USEPA, 1996d).

Notes: MCL = maximum contaminant level.
µg/ℓ = micrograms per liter.
NR = not reported because the calculated RGO exceeds the EPC.
NA = not applicable.
VOC = volatile organic compound.

Table A-4
Summary of Remedial Goal Options for Groundwater, Antimony Plume

Feasibility Study
Operable Unit 4
Naval Training Center
Orlando, Florida

Analyte	Range of Detected Concentrations	Exposure Point Concentration	Total Excess Lifetime Cancer Risk (Based on Risk to Resident [adult and child])			Total Hazard Index (Based on Risk to Child Resident)			Florida Groundwater Cleanup Target Level[1]	Federal MCL[2]	Background Screening Concentration
			10^{-4}	10^{-5}	10^{-6}	3	1	0.1			
Volatile Organic Compounds (µg/l)											
Tetrachloroethene	1 to 28	7.5	NR	NR	1.3	NA	NA	NA	3	5	NA
Inorganic Analytes (µg/l)											
Antimony	7.1 to 20.7	14.1	NA	NA	NA	NR	6.1	0.6	6	6	4.1

[1] Florida Department of Environmental Protection (FDEP) Groundwater Cleanup Target Levels (Chapter 62-777; FDEP, 1999).
[2] Federal MCLs are taken from U.S. Environmental Protection Agency (USEPA) *Drinking Water Regulations and Health Advisories* from October 1996 (USEPA, 1996d).

Notes: MCL = maximum contaminant level.
µg/l = micrograms per liter.
NR = not reported because the calculated RGO exceeds the EPC.
NA = not applicable.

APPENDIX B

APPENDIX B

OU 4 PUMPING TEST GROUNDWATER ANALYTICAL RESULTS

Summary of Pumping Test
Analytical Results

Operable Unit 4

Naval Training Center, Orlando

Orlando, FL

Identifier	ETP-1		ETP-2		ETP-3		
SampleID	96080206-1		96080206-2		96080206-3		
Sampling Date	8/29/96		8/29/96		8/30/96		Florida Surface Water Discharge Criteria
Organics, ug/L							
1,1,1,2-Tetrachloroethane	20	U	20	U	20	U	
1,1,1-Trichloroethane	20	U	20	U	20	U	
1,1,2,2-Tetrachloroethane	20	U	20	U	20	U	<=10.8 ug/L annual average
1,1,2-Trichloroethane	20	U	20	U	20	U	
1,1-Dichloroethane	20	U	20	U	20	U	
1,1-Dichloroethene	20	U	20	U	20	U	<= 3.2 ug/L annual average
1,2,3-Trichloropropane	20	U	20	U	20	U	
1,2-Dibromomethane	20	U	20	U	20	U	
1,2-Dichlorobenzene	20	U	20	U	20	U	
1,2-Dichloroethane	20	U	20	U	20	U	
1,2-Dichloropropane	20	U	20	U	20	U	
1,3-Dichlorobenzene	20	U	20	U	20	U	
1,4-Dichlorobenzene	20	U	20	U	20	U	
2-Butanone	500	U	500	U	500	U	
2-Chloroethyl vinyl ether	20	U	20	U	20	U	
2-Hexanone	500	U	500	U	500	U	
4-Methyl-2-pentanone	500	U	500	U	500	U	
Acetone	500	U	500	U	500	U	
Acetonitrile	500	U	500	U	500	U	
Acrolein	500	U	500	U	500	U	
Acrylonitrile	500	U	500	U	500	U	
Benzene	20	U	20	U	20	U	<=71.28 ug\L annual average
Bromodichloromethane	20	U	20	U	20	U	
Bromoform	20	U	20	U	20	U	<= 360 ug/L annual average
Bromomethane	20	U	20	U	20	U	
Carbon disulfide	500	U	500	U	500	U	
Carbon tetrachloride	20	U	20	U	20	U	<=4.42 ug/L annual average
Chlorobenzene	20	U	20	U	20	U	
Chlorodibromomethane	20	U	20	U	20	U	<= 34 ug/L annual average
Chloroethane	20	U	20	U	20	U	
Chloroform	20	U	20	U	20	U	<= 470.8 ug/L annual average
Chloromethane	20	U	20	U	20	U	<=470.8 ug/L annual average
cis-1,2-Dichloroethene	570		572		606		
cis-1,3-Dichloropropene	20	U	20	U	20	U	
Dibromomethane	20	U	20	U	20	U	
Dichlorodifluoromethane	20	U	20	U	20	U	
Ethylbenzene	20	U	20	U	20	U	
Methylene chloride	20	U	20	U	20	U	<= 1,580 ug/L annual average
MTBE	100	U	100	U	100	U	
Styrene	20	U	20	U	20	U	
Tetrachloroethene	172		124		90		<=8.85 ug/L annual average
Toluene	20	U	20	U	20	U	
trans-1,2-Dichloroethene	20	U	20	U	20	U	
trans-1,3-Dichloropropene	20	U	20	U	20	U	
Trichloroethene	2660		2380		2220		
Trichlorofluoromethane	20	U	20	U	20	U	
Vinyl acetate	500	U	500	U	500	U	
Vinyl chloride	20	U	20	U	20	U	
Xylenes (total)	20	U	20	U	20	U	
Inorganics, ug/L							
Aluminum, Filtered	160		100		110		
Aluminum, Total	220		200		190		
Antimony, Filtered	5	U	5	U	5	U	
Antimony, Total	5	U	5	U	5	U	<=4,300 ug/L

Summary of Pumping Test
Analytical Results

Operable Unit 4

Naval Training Center, Orlando

Orlando, FL

Identifier	ETP-1		ETP-2		ETP-3		
SampleID	96080206-1		96080206-2		96080206-3		
Sampling Date	8/29/96		8/29/96		8/30/96		Florida Surface Water Discharge Criteria
Arsenic, Filtered	5	U	5	U	5	U	
Arsenic, Total	5	U	5	U	5	U	<=50 ug/L
Barium, Filtered	20	U	20	U	20	U	
Barium, Total	20	U	20	U	20	U	
Beryllium, Filtered	5	U	5	U	5	U	
Beryllium, Total	3	U	3	U	3	U	<=0.13 ug/L annual avg.
Cadmium, Filtered	1	U	1	U	1	U	
Cadmium, Total	1	U	1	U	1	U	$<=e^{(0.7852[\ln H]-3.49)}$ ug/L
Calcium, Filtered	5000	U	5000	U	5000	U	
Calcium, Total	5000		5000	U	5000	U	
Chromium, Filtered	5	U	5	U	5	U	
Chromium, Total	5	U	5	U	5	U	see below
Cobalt, Filtered	10	U	10	U	10	U	
Cobalt, Total	10	U	10	U	10	U	
Copper, Filtered	5	U	5	U	5	U	
Copper, Total	5	U	5	U	5	U	$<= e^{(0.8545[\ln H]-1.465)}$ ug/L
Iron, Filtered	270		120		150		
Iron, Total	490		370		350		<=1.0 mg/L
Lead, Filtered	6		3	U	3	U	
Lead, Total	14		3	U	3	U	$<= e^{(1.273[\ln H]-4.705)}$ ug/L
Magnesium, Filtered	2100		2100		2100		
Magnesium, Total	2200		2200		2200		
Manganese, Filtered	5	U	5	U	5	U	
Manganese, Total	5	U	5	U	5	U	
Mercury, Filtered	0.2	U	0.2	U	0.2	U	
Mercury, Total	0.2	U	0.2	U	0.2	U	<=0.012 ug/L
Nickel, Filtered	5	U	5	U	5	U	
Nickel, Total	5	U	5	U	5	U	$<=e^{0.846[\ln H]+1.1645)}$ ug/L
Potassium, Filtered	5000	U	5000	U	5000	U	
Potassium, Total	5000	U	5000	U	5000	U	
Selenium, Filtered	5	U	5	U	5	U	
Selenium, Total	5	U	5	U	5	U	<= 5.0 ug/L
Silver, Filtered	5	U	5	U	5	U	
Silver, Total	5	U	5	U	5	U	<= 0.07 ug/L
Sodium, Filtered	12000		12000		12000		
Sodium, Total	13000		13000		13000		
Thallium, Filtered	5	U	5	U	5	U	
Thallium, Total	5	U	5	U	5	U	<= 6.3 ug/L
Vanadium, Filtered	5	U	5	U	5	U	
Vanadium, Total	4	U	4	U	4	U	
Zinc, Filtered	41		42		19		
Zinc, Total	45		40		25		$<= e^{(0.8473[\ln H]+0.7614)}$ ug/L
General chemistry, mg/L							
Alkalinity	5.9		6.1		7.7		Shall not be depressed below 20 mg/L as $CaCO_3$
Chloride	22		21		23		
Hardness	32		24		22		
Residue, Filterable (TDS)	16		21		6		
Residue, non-Filterable (TSS)	1	U	1	U	1	U	
Sulfate	16		16		15		
Sulfide	0.2		0.2		0.2		
Total Organic Carbon	36.7		145		148		
Total Solids	1	U	1	U	1	U	
Unevaluated Surface Water Parameters							
Ammonia							<=0.02 mg/L

Summary of Pumping Test
Analytical Results

Operable Unit 4

Naval Training Center, Orlando

Identifier	ETP-1	ETP-2	ETP-3	Florida Surface Water Discharge Criteria
		Orlando, FL		
SampleID	96080206-1	96080206-2	96080206-3	
Sampling Date	8/29/96	8/29/96	8/30/96	
Bacteriological Quality (total coliform bacteria)				<=1,000 as a monthly average; nor exceed 1,000 in more than 20% of the samples examined during any month; <=2,400 at any time. Monthly averages shall be expressed as geometric means based on a minimum of 10 samples taken over a 30 day period using either the MPN or MF counts
Bacteriological Quality (fecal coliform bacteria)				MPN or MF counts shall not exceed a monthly average of 200 nor exceed 400 in 100% of the samples, nor exceed 800 on any one day. Monthly averages shall be expressed as geometric means based on a minimum of 10 samples taken over a 30 day period.
Biological Integrity				The index for benthic macroinvertebrates shall not be reduced to less than 75% of established background levels as measured using organisms retained by a U.S. Standard No. 30 sieve and collected and composited from a minimum of three Hester-Dendy type artificial substrate samplers of 0.10 to 0.15 m^2 area each, incubated for a period of four weeks.
BOD				Shall not be increased to exceed values which would cause dissolved oxygen to be depressed below the limit established for each class and, in no case, shall it be great enough to produce nuisance conditions.
Chromium (trivalent)				$<=e^{[0.819(lnH)+1.561]}$ ug/L
Chromium (hexavalent)				<=11 ug/L
Chronic Toxicity				see Section 62-302.200(3), F.A.C.
Chlorine (total residual)				<=0.01 mg/L
Conductance, specific				Shall not be increased more than 50% above background or to 1275 micromhos/cm, whichever is greater
Cyanide				<=5.2 ug/L
Detergents				<=0.5 mg/L
2,4-Dinitrotoluene				<= 9.1 ug/L annual average
Dissolved Oxygen				Shall not be less than 5.0 mg/L. Normal Daily and seasonal fluctuations above these levels shall be maintained
Fluorides				<= 10.0 mg/L
Dichlorobromomethane				<= 22 ug/L annual average
Hexachlorobutadiene				<= 49.7 ug/L annual average
Nuisance Species				substances which result in the dominance of nuisance species: none shall be present.
Nutrients (a)				The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter. Man-induced nutrient enrichment (total nitrogen or total phosphorus) shall be considered degredation in relation to the provisions of Sections 62-302.300, 62-302.700, and 62-4.242, F.A.C.
Nutrients (b)				In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora and fauna.
Oils and greases (a)				Dissolved or emulsified oils and greases shall not exceed 5.0 mg/L
Oils and greases (b)				No undissolved oil, or visible oil defined as iridescence, shall be present so as to cause taste or odor, or otherwise interfere with the beneficial use of waters.

Summary of Pumping Test
Analytical Results

Operable Unit 4

Naval Training Center, Orlando

Orlando, FL

Identifier	ETP-1	ETP-2	ETP-3	
SampleID	96080206-1	96080206-2	96080206-3	
Sampling Date	8/29/96	8/29/96	8/30/96	**Florida Surface Water Discharge Criteria**
pH				Shall not vary more than one unit above or below natrual background of predominantly fresh waters and coastal waters as defined in Section 62-302.520(3)(b), F.A.C. or more than two-tenths unit above or below natural background of open waters as defined in
				Section 62-302.520(3)(b), F.A.C. or more than two-tenths unit above or below natural background of open waters as defined in Section 62-302.520(3)(f), F.A.C., provided that the pH is not lowered to less than 6 units in predominantly fresh waters, or
				raised above 8.5 units. If natural background is less than 6 units, in predominantly fresh waters, the pH shall not vary below natural background or vary more than one unit above natural background of predominantly fresh waters, or more than two-tenths
				unit above natural background of open waters. If natural background is higher than 8.5 units, the pH shall not vary above natural background or vary more than one unit below natural background of predominantly fresh waters, or more than two-tenths unit
				below natural background of open waters.
Phenolic Compounds: total (a)				Phenolic compounds other than those produced by the natural decay of plant material, listed or unlisted, shall not taint the flesh of edile fish or shellfish or produce objectionable taste or odor in a drinking water supply.
Phenolic Compounds: total (b)				The total of all chlorinated phenols, and chlorinated cresols, shall not exceed 1.0 ug/L unless higher values are shown not to be chronically toxic. Such higher values shall be approved in writing by the Secretary.
Phthalate Esters				<= 3.0 ug/L
Substances in concentrations which injure, are chronically toxic to, or produce adverse physiological or behavioral response in humans, plants, or animals				None shall be present
Notes:				

(1) "annual average" means the maximum concentration at average annual flow conditions (see Section 62-4.020 (1), F.A.C.);

(2) "Maximum" means the maximum not to be exceeded at any time;

(3) "ln H" means the natural logarithm of total hardness expressed as milligrams/L of $CaCO_3$. For metals criteria involving equations with hardness, the hardness shall be set at 25 mg/L if actual hardness is < 25 mg/L and set at 400 mg/L if actual hardness is < 25 mg/L and set at 400 mg/L if actual hardness is > 400 mg/L;

(4) Criteria are protective of human health not of aquatic life.

APPENDIX C

APPENDIX C

NTC, ORLANDO INDUSTRIAL USER DISCHARGE PERMIT - AREA C

City of Orlando

VIRONMENTAL CONTROL SECTION
IRONMENTAL SERVICES DEPARTMENT

5100 L.B. McLEOD ROAD
ORLANDO, FLORIDA 32811

TELEPHONE (407) 246-2664
FAX (407) 246-2886

July 25, 1995

Lt. Commander Catherine A. Ballinger
United States Navy
1350 Grace Hopper Avenue, Suite 010
Orlando, FL 32813

RE: INDUSTRIAL USER DISCHARGE PERMIT

Dear Lt. Commander Ballinger:

Attached is your Industrial User Discharge Permit for your records. Please read over the contents carefully. Any comments previously submitted have been reviewed and considered by the City's Environmental Control Section and Legal Affairs Office. Please submit any further comments or questions you may have within ten (10) working days of the delivery of this Permit.

Very truly yours,

Colan S. Benner

Colan S. Benner
Environmental Supervisor

SB/llr

Attachment

c: Mark Zill
Greg Mudd
File

City of Orlando

ENVIRONMENTAL CONTROL SECTION
ENVIRONMENTAL SERVICES DEPARTMENT

5100 L.B. McLEOD ROAD
ORLANDO, FLORIDA 32811

TELEPHONE (407) 246-2664
FAX (407) 246-2886

July 25, 1995

Lt. Commander Catherine A. Ballinger
United States Navy
1350 Grace Hopper Avenue, Suite 010
Orlando, FL 32813

RE: INDUSTRIAL USER DISCHARGE PERMIT NO. CO62QA

Dear Lt. Commander Ballinger:

This Industrial User Discharge Permit has been prepared on the basis of all available information obtained from correspondence and from the investigation of your industry by the City of Orlando Environmental Services Department personnel.

IT IS IMPORTANT THAT YOU READ THE ENTIRE CONTENTS OF THIS DOCUMENT

The Permit is valid for five (5) years as long as there is compliance with all Permit conditions. The Permit is also subject to renewal and change as stated in Chapter 30 of the City Code.

The Industrial User Permittee shall comply with the City Code of the City of Orlando, Chapter 30, or with the applicable and related state or federal regulations, which ever may be the most stringent. Specific industrial pretreatment conditions are listed under Sections B, C and D.

If you have any questions pertaining to the Permit conditions or the information set forth in this letter, please contact the City's Environmental Control Section at (407) 246-2664 or (407) 246-2213.

Very truly yours,

Thomas L. Lothrop

Thomas L. Lothrop, P.E.
Director, Environmental Services

Colan S. Benner

Colan S. Benner
Environmental Supervisor
Environmental Control Section

TLL/CSB/llr

Save - Conserve water and reduce wastewater

INDUSTRIAL USER DISCHARGE PERMIT

SIGNATURE PAGE

Company Name: UNITED STATES NAVY

Company Address: 1350 Grace Hopper Avenue, Suite 010
Orlando, FL 32813

Consultant Name: Greg Mudd
ABB Environmental Services, Inc.

Consultant Address: 1080 Woodcock Road, Suite 100
Orlando, FL 32803

Permit No.: CO62QA

Facility Name: United States Navy (Area C)

Lt. Commander Catherine A. Ballinger
Name of Representative (typed)

has read and understands this document.

Effective Date: 08/01/95

Expiration Date: 08/01/00

Signature of Representative

INDUSTRIAL USER DISCHARGE PERMIT

Company Name:	UNITED STATES NAVY
Mailing Address:	1350 Grace Hopper Avenue Suite 010 Orlando, FL 32813
Permit No.:	CO62QA
Facility Name:	United States Navy (Area C)
Discharge Point:	Sand trap located on west side of Building 1053

The above Industrial User is authorized to discharge industrial wastewater to the City of Orlando's sewerage system in compliance with the City Code, Chapter 30, any applicable provision of federal or state law or regulation, and in accordance with discharge point(s), effluent limitations, monitoring requirements, and other conditions set forth herein.

This Permit is granted in accordance with the application filed in the office of the Environmental Control Section, and in conformity with plans, specifications, and other data submitted to the City in support of the above application.

Effective Date: 08/01/95

Expiration Date: 08/01/00

Thomas L. Lothrop

Thomas L. Lothrop, P.E.
Environmental Services Director

CERTIFICATE OF SERVICE

This is to certify that this NOTICE OF PERMIT was hand delivered/~~mailed by certified mail~~ to the above business on 8/19/95 by [signature].
Date Signature of Server

Permittee:

United States Navy
(Area C)

INDUSTRIAL USER DISCHARGE PERMIT
Number: CO62QA
Category:Groundwater Discharge
Expiration Date: 08/01/00

Pursuant to federal, state, and local regulations, the United States Navy (Area C) (Industrial User) is hereby authorized to discharge industrial sewage into the City of Orlando sewerage system, subject to the conditions set forth in the Permit.

This Permit may be modified by the City of Orlando, or the state, or federal government, or the agencies thereof.

Failure on the part of the Industrial User to fulfill any of the Permit conditions shall be sufficient cause for immediate revocation of this Permit and/or other enforcement action, such as fines, administrative orders and/or suspension of sewer service. This Permit is further subject to termination in accordance with the terms and provisions of the City Code.

ANY ASSIGNMENT OR TRANSFER OF THIS PERMIT SHALL AUTOMATICALLY MAKE IT NULL, VOID, AND OF NO FURTHER EFFECT.

A. PERMIT CONDITIONS

1. The Industrial User shall, except as otherwise provided herein, comply with the City Code of the City of Orlando, Chapter 30, or with the applicable and related state or federal regulations, whichever may be the most stringent.

2. The Industrial User shall allow City of Orlando personnel exhibiting proper credentials access to its premises for the purpose of inspection, sampling verification and/or copying of records which are maintained as a result of this Permit or any requirements by state or federal regulations or all of these things. Also, all necessary records required by this Permit shall be retained by the User for a minimum of three (3) years.

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3. The Industrial User shall notify the City of Orlando personnel of changes or modifications to the information provided in their industrial pretreatment permit application such as location, industrial processes, discharges (quantity or quality), or chemical storage procedures.

4. The Industrial User shall notify the City immediately in the event of any occurrence whatsoever that results in discharge to the City's sanitary sewerage system of any wastes or process wastewaters not allowable under this Permit or the City Code. Telephone notification shall be made immediately to the City at (407) 246-2213 (7:00 AM to 12:00 AM) or to the Conserv II Plant at (407) 246-2151 (12:00 AM to 7:00 AM) 7 days a week and, within 5 days, by delivery of a written report to the Director of Environmental Services in care of Environmental Control Section, City of Orlando, 5100 L. B. McLeod Road, Orlando, Florida 32811.

5. The Industrial User shall discharge wastewater only in conformance with the information contained in the permit application on file with the City's Environmental Control Section.

6. The Industrial User's discharge shall conform to the wastewater flows and characteristics listed in Sections B and C below.

7. The Industrial User shall submit a signed report and a signed Statement of Certification (see attached) to the City as further described in Section D below.

8. The Industrial User shall comply with all pretreatment requirements and compliance schedules listed in Section F below (if applicable).

9. The Industrial User shall comply with all federal and state requirements for disposal of hazardous wastes such as sludge from pretreatment. For further information contact the Florida Department of Environmental Protection (FDEP), Solid and Hazardous Waste Section, 2600 Blair Stone Road, Tallahassee, FL 32301. Telephone: (904) 488-0300.

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B. GENERAL LIMITATIONS ON WASTEWATER FLOWS AND CHARACTERISTICS

1. The following limitations and conditions apply to the Industrial User's discharge, until such time as this Section may be modified or revoked.

2. Discharge to the City's sanitary sewerage system shall be limited as follows:
General: Water or wastes that the municipality has identified as likely, either singly or by interaction with other substances, to:

a) harm either the sewerage system or the wastewater treatment process; or
b) be otherwise incompatible with the treatment process; or
c) cause a violation of local, federal, or state discharge permits issued to the City; or
d) adversely affect receiving waters; or
e) endanger life, limb, or public property; or
f) constitute a nuisance; or
g) create a fire or explosion hazard in the Publicly Owned Treatment Works (POTW) or its collection system; or
h) cause corrosive structural damage to the POTW or its collection system; or
i) cause obstruction to the flow in the POTW resulting in interference; or
j) cause any abnormal oxygen demand (BOD, etc.) that will result in interference at the POTW; or
k) create interference with the POTW biological processes or any other process due to excessive heat in such quantities that the temperature at the POTW exceeds 40 degrees Celsius (104 degrees Fahrenheit)

shall not be discharged or caused to be discharged into the City's sanitary sewerage system.

Slug (as defined by the City Code) shall not be discharged into the City's sanitary sewerage system.

Solids or Viscous Substances including but not limited to sand, mud, glass, wood, plastic, rubber, latex, and lime slurries, in quantities or of such size capable of causing obstruction to sewerage flows, or to otherwise interfere with the operation or maintenance of the system, shall not be discharged into the City's sanitary sewerage system.

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Fats, Wax, Grease, or Oil, whether emulsified or not, are limited to one hundred (100) mg/l. This also includes substances which may solidify or become viscous at temperatures between thirty-two (32) and one hundred fifty (150) degrees Fahrenheit (zero [0] and sixty-five [65] degrees Celsius).

Concentrated Chemical Solutions shall not be discharged to the City's sanitary sewerage system unless pretreated to acceptable levels.

Dilution to attain specific levels of discharge to municipal sewers, in the absence of industrial or any other type of treatment or pretreatment, is strictly prohibited.

pH shall be not less than 5.5, nor greater than 9.5.

Sludge or deposited solids resulting from an industrial or pretreatment process shall not be discharged into the City's sanitary sewerage system.

Daily Volume of permitted discharge may not be increased beyond fifteen percent (15%) without the Industrial User first securing a formal amendment to this Permit.

Uncontaminated Water, ground, storm, and surface waters; roof runoff; tidewater and subsurface drainage; any water not being metered by Orlando Utilities Commission; or any one of these conditions or any of these conditions in combination shall not be discharged into the City's sanitary sewerage system.

Flammable Substances including but not limited to gasoline, benzene, naphtha, solvent-type material of any sort, alcohol, fuel oil, crude oil, lubricating oils, flammable or explosive liquids, solids or gases, or any oils or greases of hydrocarbon or petroleum origin, shall not be discharged into the City's sanitary sewerage system.

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3. The wastewater constituents listed below shall at no time be discharged in concentrations which exceed the limitations given:

Constituent (to be limited)	Maximum Concentrations, mg/l
Antimony	1.0
Arsenic	0.25
Barium	10.0
Beryllium	0.25
Biological Oxygen Demand (BOD)	300.0
Boron	1.0
Cadmium	0.26
Chromium (Total)	1.0
Cobalt	0.3
Copper	2.0
Cyanide	0.5
Grease	100.0
Lead	0.4
Lower Explosion Limit (LEL)	less than 5% (of LEL on the meter)
Lithium	0.03
Manganese	1.5
Mercury	0.005
Nickel	0.7
pH*	not less than 5.5 or greater than 9.5
Selenium	0.5
Silver	0.24
Sodium	300.0
Tin	5.0
Zinc	1.0
Total Metals	10.0
Total Phenols	0.5
Total Suspended Solids (TSS)	300.0
Total Toxic Organics (TTO)	2.13

* (pH excursions of 15 minutes or longer are considered pH violations)

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C. SPECIFIC LIMITATIONS ON WASTEWATER FLOW CHARACTERISTICS

(The parameters and limits that apply to your industry are specified below.)

EFFLUENT LIMITS

PARAMETER	DAILY MAXIMUM	4-DAY AVERAGE	MONTHLY AVERAGE	LIMIT	UNITS
LEL	<5%				
LEAD	0.4				mg/l
pH	Not less than 5.5, not more than 9.5				
Reference	"Additional Provisions", Page 13				

Allowable water flow: 5000 gallons/day.

D. SELF-MONITORING AND REPORTING REQUIREMENTS

Monitoring parameters will include flow plus those specified in the list on the following page, and shall be sampled as indicated by either "Comp" or Grab".

- Composite Sample: A combination of individual samples of water or wastewater taken at selected intervals, generally hourly for some specified period, to minimize the effect of the variability of the individual sample. Individual samples may have equal volume or may be roughly proportioned to the flow at time of sampling.

- Grab Sample: A single sample of wastewater taken at neither set time nor flow.

If sampling performed by a user indicates a violation, the user must notify the Environmental Control Section within twenty-four (24) hours of becoming aware of the violation. The user shall also repeat the sampling and analysis and submit the results of the repeat analysis to the Environmental Control Section within thirty (30) days after becoming aware of the violation. The user is not required to resample if the Environmental Control Section monitors at the user's facility at least once a month, or if the Environmental Control Section samples between the user's initial sampling and when the user receives the results of this sampling.

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Parameter	Sample Type	Monitoring Frequency	Reporting Frequency
Antimony			
Arsenic			
Barium			
Beryllium			
BOD			
Boron			
Cadmium			
Chromium (Total)			
Cobalt			
Copper			
Cyanide			
Grease			
Lead			
LEL			
Lithium			
Manganese			
Mercury			
Nickel			
pH			
Selenium			
Silver			
Sodium			
Tin			
Zinc			
Total Metals			
Total Phenols			
TSS			
TTO			

To comply with Rule 62-625.600 (1) (e), F.A.C., and Chapter 62-160, F.A.C., industrial users must operate in accordance with the sampling and analysis procedures specified in the State of Florida's "Department of Environmental Protection Standard Operating Procedures for Laboratory Operation and Sample Collection Activities," (DEP-QA-001/92), (SOP) dated September 1992.

Reports on wastewater analysis and the amount of hazardous waste produced shall be submitted to the City of Orlando's Environmental Control Section as follows:

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REPORTING FREQUENCY	DUE DATE
Monthly	No later than the 10th of the following month.
Quarterly	No later than April 10, July 10, October 10, or January 10, as applicable.
Semiannually	No later than January 10 or July 10, as applicable.
Annually	No later than January 10.

To validate the report, a Statement of Certification (see attached) must be signed by an authorized company representative and submitted along with a signed copy of the report. Report copies and all monitoring data shall be retained by your company for a minimum of three (3) years or as otherwise specified by the City. All reports shall contain the following:

1. report date, sample date, sample type, sampling point location, time sample taken, sampler's name;
2. date the analysis was performed;
3. who performed the analysis;
4. the analytical method used; and
5. the results of the analysis.

Please see attached sample format or use a format of similar composition.

E. PENALTY

Violations of this Permit and/or violations of the City of Orlando's Ordinance are subject to such actions as administrative fines, Administrative Orders and civil/criminal penalties. Penalties may be invoked singularly or plurally or in any combination of these actions as authorized by the City's Ordinance. Any or all enforcement actions may be appealed to the Director of Environmental Services or his designee.

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F. COMPLIANCE SCHEDULE (for Groundwater Monitoring only)

All Compliance Schedule milestones must be reported in detail and in writing by the milestone date. Failure to comply with this Permit, the City's Ordinance, compliance meeting procedures, or the date certain, shall be deemed a violation of the provisions of this document, and may be grounds for revocation of the Industrial User's Discharge Permit and for such other actions, penalties, or enforcement, or all or any combination of these things, as may be authorized for violation of the City's Ordinance.

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G. UNCONTAMINATED COOLING WATER

Uncontaminated cooling water utilized by the Industrial User shall be permitted to be discharged into the City's sanitary sewerage system provided that:

1. Only metered City water shall be utilized by the Industrial User in its cooling processes (NOTE: Water from any other source may not be discharged into the City's system.);

2. Cooling water shall be directed through and treated by the Industrial User's wastewater treatment unit prior to discharge into the City's sanitary sewerage system; and

3. The total volume of cooling water discharged into the City's sanitary sewerage system shall not exceed three hundred (300) gallons per month.

H. UNCONTAMINATED INDUSTRIAL PROCESS WATER

Uncontaminated industrial process water utilized by the Industrial User shall be permitted to be discharged into the City's sanitary sewerage system provided that:

1. The source of the uncontaminated industrial process water is the City's metered water supply system; and

2. The uncontaminated industrial process water shall be discharged either in the Industrial User's sanitary-only sewer or at a point where it would not interfere with the determination of pretreatment compliance.

I. FEDERAL REGULATIONS

For applicable federal regulations, see the Code of Federal Regulations, Title 40, Part 403. Should you require a copy, please contact City of Orlando, Environmental Control Section, 5100 L. B. McLeod Road, Orlando, Florida 32811, (407) 246-2664.

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J. ADDITIONAL PROVISIONS

1. THIS PERMIT IS SUBJECT TO REVOCATION SHOULD THE FOLLOWING SEWER BILLING REQUIREMENTS NOT BE ADHERED TO:

   a. Your company hereby agrees that the monthly user fees for disposal of the effluent shall be charged to your company based upon the City's present commercial rate, and at the commercial rate as it may be from time to time amended.

   b. In calculating these fees, the City shall use the actual flows, as submitted to the Environmental Control Section by your company by the fifth (5) of each successive month following the date of start up of the recovery operation. In any month that the reports are not submitted in a timely fashion, the user fee will be based upon twice the maximum allowed flow 5000 (gpd) usage.

2. All discharges shall be batch and require prior written approval from the City of Orlando's Environmental Control Section.

3. All stored groundwater must be properly contained in DOT approved drums.

4. Drums will be approved for discharge on an individual basis. The most recent analytical data available will be used in making each determination.

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5. A signed monthly report must be submitted to the City of Orlando's Environmental Control Section semi-annually (see attached sample format).

6. A signed Statement of Certification (see attached) must accompany all semi-annual reports.

APPENDIX D

APPENDIX D

ALTERNATIVE DETAILED COST BREAKDOWNS

TABLE D-1

ALTERNATIVE V-1: NO ACTION
OPERATION AND MAINTENANCE (O&M) COSTS (annual)

	Quantity	Unit	Unit Cost	Total Cost
IRA System (annual for 30 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Present Worth IRA System O&M Costs @ i = 6%, n = 30 yrs				**$586,411**
GW Monitoring of IRA Plume (annual costs)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	24	hours	$45.00	$1,080
ODCs (PPE, sampling equip, expendibles)	1	LS	$500.00	$500
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal GW Monitoring Annual Costs				**$9,430**
Present Worth Costs GW Monitoring IRA Area @ i = 6%, n = 30 yrs				**$129,804**
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500

TABLE D-1

ALTERNATIVE V-1: NO ACTION
OPERATION AND MAINTENANCE (O&M) COSTS (annual)

	Quantity	Unit	Unit Cost	Total Cost
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five-Year Site Review Cost				**$18,220**
Present Worth 5-Yr Site Review (i = 6%, n = 5, 10..30 yrs)				**$44,491**
GW Monitoring for Five-Year Site Review (every 5 years for 30 years)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	24	hours	$60.00	$1,440
Technician	24	hours	$45.00	$1,080
ODCs (PPE, sampling equip, expendibles)	1	LS	$500.00	$500
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual GW Monitoring Costs				**$9,070**
Present Worth GW Mon. for 5-Yr Site Reviews @ i = 6%, n=5, 10..30 yrs				**$22,148**
TOTAL O&M COSTS				**$782,854**
CONTINGENCY @10 PERCENT				**$78,285**
TOTAL COST OF ALTERNATIVE V-1				**$861,140**

TABLE D-2

ALTERNATIVE V-2: LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	$10,000
TOTAL DIRECT COSTS				**$10,000**
INDIRECT COSTS				
Health and Safety				$500
Administrative Fees				$1,000
Engineering and Design				$4,000
Construction Support Services				$1,000
TOTAL INDIRECT COSTS				**$6,500**
TOTAL CAPITAL COSTS				**$16,500**
IRA System (annual for 30 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Present Worth IRA System O&M Costs @ i = 6%, n = 30 yrs				**$586,411**
GW Monitoring for IRA Downgradient Plume (annual costs)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual GW Monitoring Costs				**$10,650**
Present Worth Costs GW Monitoring IRA Area @ i = 6%, n = 30 yrs				**$146,597**

TABLE D-2

ALTERNATIVE V-2: LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Costs				**$18,220**
Present Worth 5 Year Site Review @ i = 6%, n =5, 10..30 yrs				**$44,491**
GW Monitoring for Five-Year Site Review (every 5 years for 30 years)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	24	hours	$60.00	$1,440
Technician	24	hours	$45.00	$1,080
ODCs (PPE, sampling equip, expendibles)	1	LS	$500.00	$500
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal GW Monitoring Annual Costs				**$9,070**
Present Worth GW Mon. for 5-Yr Site Review @ i = 6%, n = 5, 10..30 yrs				**$22,148**
TOTAL O&M COSTS				**$799,648**
TOTAL CAPITAL COSTS AND O&M COSTS				**$816,148**
CONTINGENCY @10 PERCENT				**$81,615**
TOTAL COST OF ALTERNATIVE V-2				**$897,762**

TABLE D-3

ALTERNATIVE V-3: IN-SITU CHEMICAL OXIDATION AND ENHANCED BIOREMEDIATION
TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization [Northern Plume]				
Storage Trailer	0	month	$150.00	$0
Office Trailer	12	month	$250.00	$3,000
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 30')	0	LS	$4,000.00	$0
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	0	month	$2,000.00	$0
Utility Connections for trailer, sys equip, controls	1	LS	$4,000.00	$4,000
Toilet/water cooler service	52	wks	$50.00	$2,600
Miscellaneous Equipment	1	LS	$1,000.00	$1,000
Decon Equipment and Pad:				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Labor (Site Preparation)				
Laborers (2 men @ 10 hrs/day)	2	days	$320.00	$640
Foreman/Superintendent (1 man @ 10 hrs/day)	1	days	$600.00	$600
Subtotal Site Preparation/Mobilization [Northern Plume]				**$15,052**
In-Situ Chemical Oxidation System [Northern Plume]				
(3 extraction well clusters pumping @ 6, 6, and 3 gpm each; 3 injection well clusters at same flows)				
Injection, Extraction and Monitoring Well Installation				
Sonic Mob/Demob (drillers and equip)	1	each	$2,000.00	$2,000
DPT Mob/Demob (drillers and equip)	1	each	$150.00	$150
Vert. Well Sonic Install. (8 wells @ 4" ID, PVC, 20'/35' bls)	220	ft	$65.00	$14,300
Angled Well Sonic Install. (4 wells @ 4" ID, PVC, 42'/50' lf)	184	lf	$100.00	$18,400
Vert. Well Sonic Install. (1 well @ 2" ID, PVC, 35' bls)	35	ft	$55.00	$1,925
Angled Well Sonic Install. (3 wells @ 2" ID, PVC, 40' lf)	120	lf	$90.00	$10,800
MicroWell DPT Installation (15 wells, 20' bls)	4	days	$400.00	$1,600
Extraction Well Vault	6	each	$2,500.00	$15,000
Extraction Pumps	6	pumps	$1,000.00	$6,000
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	0	poles	$550.00	$0
Power Cable	25	ft	$10.00	$250
Telephone line for Telemetry	100	ft	$10.00	$1,000
Water Service Connection	0	each	$1,000.00	$0
Gauge, curb box, appurtenances	0	each	$1,000.00	$0

TABLE D-3

ALTERNATIVE V-3: IN-SITU CHEMICAL OXIDATION AND ENHANCED BIOREMEDIATION
TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	400	ft	$20.00	$8,000
Equalization Tank Rental (Incl. Mob/demob; 12 months)	12	mo	$300.00	$3,600
Treatment System Rental (includes the following):	12	mo	$10,000.00	$120,000
KMnO4 Mix Tank Rental (Incl. Mob/demob; 3 tanks)	0	mo	$300.00	$0
Centrifugal Feed Pumps (25 GPM each)	0	each	$5,000.00	$0
KMnO4 Feed System (12 mo. rental + $4K mob/demob)	0	mo	$1,800.00	$0
Rotary Drum Filter	0	each	$3,000.00	$0
Flow Meters	0	each	$300.00	$0
Valves, piping, controls, gauges, etc.	0	LS	$5,000.00	$0
Instrumentation Controls	0	LS	$20,000	$0
Labor				
1 Carus Technician	5	days	$1,200.00	$6,000
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Chemical Oxidation [Northern Plume]				**$239,175**
TOTAL DIRECT COSTS [Northern Plume]				**$264,227**
INDIRECT COSTS [Northern Plume]				
Health and Safety				$1,000
Administrative Fees				$7,500
Engineering and Design				$20,000
Construction Support Services				$20,000
TOTAL INDIRECT COSTS [Northern Plume]				**$48,500**
TOTAL CAPITAL COSTS [Northern Plume]				**$312,727**
ENHANCED BIODEGRADATION				
Site Prep and Mobilization [Southern Plume]				
Decon Equipment and Pad:				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Subtotal Site Prep/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000

TABLE D-3

ALTERNATIVE V-3: IN-SITU CHEMICAL OXIDATION AND ENHANCED BIOREMEDIATION
TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test of HRC				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
OPERATION & MAINTENANCE COSTS				
In-Situ Chemical Oxidation System O&M (12 months operation)				
Chemicals				
KMnO4 Cost* (Dosage @ 1 g/L)	51,970	lb	$1.19	$61,844
KMnO4 Freight Cost	3	deliveries	$4,500.00	$13,500
Utilities				
Groundwater Extraction Pumps	12	month	$300.00	$3,600
Treatment System	12	month	$400.00	$4,800
System Maintenance				
Labor (1 operator @ 4 hrs/day, 7 days/wk, 52 weeks)	365	days	$180.00	$65,700
KMnO4 Feed System	12	month	$500.00	$6,000
Subtotal Chemical Oxidation System O&M				**$155,444**
Sampling and Monitoring				
(Includes 2 QA/QC Samples for each sampling event)				
Treatment System Influent Grab Samples (1 per month):				
TCL VOCs	14	samples	$150.00	$2,100
Treatment System Effluent Grab Samples (1 per month):				
TCL VOCs and TAL Inorganics	14	samples	$300.00	$4,200
Monitoring Well Samples (1 every two months, 21 wells)				
TCL VOCs	138	samples	$150.00	$20,700
Subtotal GW Sampling and Monitoring				**$27,000**
Total Chemical Oxidation System O&M Cost (12 mos.)				**$182,444**

TABLE D-3

ALTERNATIVE V-3: IN-SITU CHEMICAL OXIDATION AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal HRC Treatment O&M (yrs 2 and 3)				**$19,110**
Present Worth HRC (O&M) Costs @ i = 6%, n = 2-3 yrs				**$33,060**
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Staff Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal HRC Annual Monitoring Costs (yrs 1-3)				**$17,550**
Present Worth HRC Monitoring @ i = 6%, n = 3 yrs				**$46,911**
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Present Worth IRA System O&M @ i = 6%, n = 10 yrs				**$313,548**
GW Monitoring within Downgradient Plume (annual costs - 10 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (years 1-10)				
6 Wells + 1 QA/QC = 7 Samples				
Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800

TABLE D-3

ALTERNATIVE V-3: IN-SITU CHEMICAL OXIDATION AND ENHANCED BIOREMEDIATION
TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Staff Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 10 yrs				**$78,384**
Monitored Natural Attenuation O&M (annual costs - 30 yrs)				
GW Sampling & Monitoring Program for MNA within the entire VOC plume (yrs 11-40)				
18 Wells + 2QA/QC = 20 Samples				
Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Analysis-TCL Organics (VOCs only)	20	samples	$150.00	$3,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Staff Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA O&M				**$18,250**
Present Worth MNA O&M @ i = 6%, n = 11 to 40 yrs				**$140,270**
Five-year Site Reviews (every 5 years for 40 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Staff Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five-Year Site Review Costs				**$18,220**
Present Worth 5-Yr Site Review @ i = 6%, n = 5,10,..40 yrs				**$48,633**

TABLE D-3

ALTERNATIVE V-3: IN-SITU CHEMICAL OXIDATION AND ENHANCED BIOREMEDIATION
TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
TOTAL PRESENT WORTH O&M COSTS				**$843,250**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$1,340,352**
CONTINGENCY @10 PERCENT				**$134,035**
TOTAL PRESENT WORTH COST OF ALTERNATIVE V-3				**$1,474,387**

*The total amount of $KMnO_4$ required is 65,650 lbs. There are already 42 drums of $KMnO_4$ (330 lbs ea.) at the site left over from the pilot test. Thus, the amount of $KMnO_4$ required to make up this difference is costed here.

TABLE D-4

ALTERNATIVE V-4: AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for Equipment/Controls (30' x 30')	630	ft	$2.84	$1,789
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$58,061**
Air Sparging/SVE system costs				
Piping and Equipment				
SVE piping(4"ID, PVC)	1800	ft	$25.00	$45,000
Shallow sparge wells(SCH 40,2" ID, PVC)	1800	ft	$20.00	$36,000
Deep sparge wells(SCH 40,2" ID,PVC)	1500	ft	$20.00	$30,000
Deep sparge holes	500	ft	$10.00	$5,000
Miscellaneous Steel Piping for Connections	500	ft	$20.00	$10,000
Air Flow Meters	130	each	$78.70	$10,231
Pressure Gauges	130	each	$13.50	$1,755
Pressure Relief Valves	130	each	$16.50	$2,145
Vacuum Gauges for SVE	90	each	$18.50	$1,665
Compressors	1	each	$24,000	$24,000
Positive Displacement Blower	1	each	$12,000	$12,000
Regenerative Blower	1	each	$14,000	$14,000
Groundwater Monitoring Well Installation	2	each	$1,500.00	$3,000
Investigation Derived Wastes (soil and dev. Water)	2	rolloffs	$15,000.00	$30,000
Telemetry System	1	LS	$10,000.00	$10,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE D-4

ALTERNATIVE V-4: AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Air Sparging/SVE Collection System				**$269,496**
Vapor Phase Off-gas Carbon Adsorption				
Vapor Phase Carbon Unit (10,000 lb. unit)	2	each	$16,000	$32,000
Carbon Disposal (no refill - use for 1 year only)	2	each	$850.00	$1,700
Analytical for Carbon Disposal	2	units	$500.00	$1,000
Profile Fee	1	LS	$1,200.00	$1,200
Transportation Fee	1	LS	$1,000.00	$1,000
Subtotal Vapor Phase Off-gas Treatment				**$36,900**
TOTAL DIRECT COSTS (NORTHERN PLUME)				**$374,457**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS (NORTHERN PLUME)				**$105,000**
TOTAL CAPITAL COSTS (NORTHERN PLUME)				**$479,457**
ENHANCED BIODEGRADATION				
Site Preparation and Mobilization [Southern Plume]				
Decon Equipment and Pad: (Initial cost included in Northern Plume)				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Sub-total Site Preparation/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**

TABLE D-4

ALTERNATIVE V-4: AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
TOTAL CAPITAL COSTS ALTERNATIVE V-4 [Northern and Southern Plumes]				**$663,832**
OPERATION AND MAINTENANCE (O&M) COSTS (annual) Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (annual for 2 years)				
Utilities				
Treatment System	12	month	$500.00	$6,000
System Maintenance				
Labor (1 operators @ 8 hrs/day, 52 weeks/year)	416	hrs	$45.00	$18,720
Aeration System Components	12	month	$500.00	$6,000
Off-gas Treatment System Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$36,720**
Sampling and Monitoring				
Monitoring Well Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
GAC Influent/Effluent Analyses (2 sample, 1 per month)	24	samples	$150.00	$3,600
Subtotal GW Sampling and Monitoring				**$21,600**
Total Annual Treatment System O&M Cost				**$58,320**
Present Worth Treatment System (O&M) Costs @ i = 6%, n = 2 yrs				**$106,901**
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal Annual HRC O&M				**$19,110**
Present Worth HRC (O&M) Costs @ i = 6%, n = 2-3 yrs				**$33,060**

TABLE D-4

ALTERNATIVE V-4: AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual HRC Monitoring Costs				**$17,550**
Present Worth HRC Mon. Costs @ i = 6%, n = 3 yrs				**$46,911**
IRA System (annual for 12 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Present Worth IRA System (O&M) Costs @ i = 6%, n = 12 yrs				**$357,172**
GW Monitoring within Downgradient Plume (annual costs - 12 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (12 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 12 yrs				**$89,290**

TABLE D-4

ALTERNATIVE V-4: AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
Monitored Natural Attenuation O&M (annual costs - 30 yrs)				
GW Sampling & Monitoring Program for Natural Attenuation within the entire VOC plume (yrs 13-42)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-TCL Organics (VOCs only)	20	samples	$150.00	$3,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Natural Attenuation Annual Costs				**$18,250**
Present Worth NA Monitoring Costs @ i = 6%, n = 13-42 yrs				**$124,848**
Five-year Site Reviews (every 5 years for 42 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Annual Costs				**$18,220**
Present Worth 5-Yr Site Review @ i = 6%, n = 5,10,..40 yrs				**$48,633**
TOTAL PRESENT WORTH O&M COSTS				**$806,814**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$1,470,646**
CONTINGENCY @10 PERCENT				**$147,065**
TOTAL COST OF ALTERNATIVE V-4				**$1,617,711**

TABLE D-5

ALTERNATIVE V-5A: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$50,112**
Recirculation Well System (4 wells pumping @ 10 gpm each)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (4 wells @10" ID, PVC, 40' bls, cable tool)	4	each	$25,000.00	$100,000
Piezometers (4 per well, 60 feet total depth per pair, 2" PVC	480	ft	$50.00	$24,000
Per Diem/Lodging (3 men @ 24 days)	72	days	$100.00	$7,200
Well Development (Recirc)	4	each	$3,150.00	$12,600
IDW Disposal (Drill Cuttings & Development Water)	1	LS	$30,000.00	$30,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500
Piping and Equipment				
Recirc Well Internals	4	each	$52,000.00	$208,000
Recirc Well Vault	4	each	$14,650.00	$58,600
In-Situ TROLLS	16	each	$1,500.00	$24,000
Instrumentation Controls	4	LS	$10,000.00	$40,000
Telemetry System	1	LS	$10,000.00	$10,000

TABLE D-5

ALTERNATIVE V-5A: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Vapor Phase Off-gas Carbon Adsorption (One year only)				
Vapor Phase Carbon Unit (One 1000-lb Vessel Per Well)	4	each	$4,000.00	$16,000
Analytical for Carbon Disposal	4	units	$500.00	$2,000
Spent Carbon Disposal (4000 lb total)	2	tons	$170.00	$340
Profile Fee	1	LS	$1,200.00	$1,200
Transportation Fee	1	LS	$1,000.00	$1,000
Labor				
3 men @ 6 weeks @ 50 hrs/week	900	hr	$32.00	$28,800
1 Engineer/Foreman @ 6 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Recirculation Well System				**$588,540**
TOTAL DIRECT COSTS (NORTHERN PLUME)				**$648,652**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS (NORTHERN PLUME)				**$105,000**
TOTAL CAPITAL COSTS (NORTHERN PLUME)				**$753,652**
ENHANCED BIODEGRADATION				
Site Preparation and Mobilization [Southern Plume]				
Decon Equipment and Pad: (Initial cost included in Northern Plume)				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Sub-total Site Preparation/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**

TABLE D-5

ALTERNATIVE V-5A: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
TOTAL CAPITAL COSTS [Northern and Southern Plume]				**$938,027**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (annual for 27 years)				
Utilities				
Treatment System ($400/mo per recirc well)	12	month	$1,600.00	$19,200
System Maintenance				
Inspections/Service/Consumables ($25K one well, and $15K each additional well)	1	LS	$70,000.00	$70,000
Subtotal Treatment System O&M				**$89,200**
Sampling and Monitoring				
Recirc Well Influent Grab Samples (4 wells, 1 per quarter):				
TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Effluent Grab Samples (4 wells, 1 per quarter):				
TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Subtotal GW Sampling and Monitoring				**$4,800**
Total Annual O&M Cost (Treatment System 27 Yrs)				**$94,000**
Present Worth Treatment System (O&M) Costs @ i = 6%, n = 27 yrs				**$1,241,834**
Recirc Well Source Area GW Monitoring O&M (annual for 27 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples	= 12	samples		
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual Source Area GW Monitoring Costs				**$11,550**
Present Worth GW Monitoring Costs @ i = 6%, n = 27 yrs				**$152,587**

TABLE D-5

ALTERNATIVE V-5A: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal HRC Treatment O&M (years 2 and 3)				**$19,110**
Present Worth HRC O&M Costs @ i = 6%, n = 2, 3 yrs				**$33,060**
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual HRC Monitoring Costs (years 1-3)				**$17,550**
Present Worth HRC Monitoring Costs @ i = 6%, n = 3 yrs				**$46,911**
IRA System (annual for 15 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Present Worth IRA System (O&M) Costs @ i = 6%, n = 15 yrs				**$413,755**
GW Monitoring within Downgradient Plume (annual costs - 15 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (15 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950

TABLE D-5

ALTERNATIVE V-5A: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 15 yrs				**$103,435**
Monitored Natural Attenuation O&M (annual costs - 10 years)				
GW Sampling & Monitoring Program for Natural Attenuation within the Downgradient Plume (years 16-25)				
6 Wells + 1QA/QC = 7 Samples				
Associate Scientist	24	hrs	$60.00	$1,440
Technician	30	hrs	$45.00	$1,350
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Natural Attenuation Parameters	10	samples	$200.00	$2,000
TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA O&M				**$11,840**
Present Worth MNA O&M @ i = 6%, n = 16 to 25 yrs				**$36,363**
Five-year Site Reviews (every 5 years for 27 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five-Year Site Reviews				**$18,220**
Present Worth 5-Yr Site Reviews @ i = 6%, n = 5,10..27 yrs				**$41,319**
TOTAL PRESENT WORTH O&M COSTS				**$2,069,265**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$3,007,292**
CONTINGENCY @10 PERCENT				**$300,729**
TOTAL COST OF ALTERNATIVE V-5A				**$3,308,022**

TABLE D-6

ALTERNATIVE V-5B: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION
TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$50,112**
Recirculation Well System (4 wells pumping @ 10 gpm each)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (4 wells @10" ID, PVC, 40' bls, cable tool)	4	each	$25,000.00	$100,000
Piezometers (4 per well, 60 feet total depth per pair, 2" PVC)	480	ft	$50.00	$24,000
Per Diem/Lodging (3 men @ 24 days)	72	days	$100.00	$7,200
Well Development (Recirc)	4	each	$3,150.00	$12,600
IDW Disposal (Drill Cuttings & Development Water)	1	LS	$30,000.00	$30,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE D-6

ALTERNATIVE V-5B: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION
TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
Recirc Well Internals	4	each	$52,000.00	$208,000
Recirc Well Vault	4	each	$14,650.00	$58,600
In-Situ TROLLS	16	each	$1,500.00	$24,000
Instrumentation Controls	4	LS	$10,000.00	$40,000
Telemetry System	1	LS	$10,000.00	$10,000
Vapor Phase Off-gas Carbon Adsorption (One year only)				
Vapor Phase Carbon Unit (One 1000-lb Vessel Per Well)	4	each	$4,000.00	$16,000
Analytical for Carbon Disposal	4	units	$500.00	$2,000
Spent Carbon Disposal (4000 lb total)	2	tons	$170.00	$340
Profile Fee	1	LS	$1,200.00	$1,200
Transportation Fee	1	LS	$1,000.00	$1,000
Labor				
3 men @ 6 weeks @ 50 hrs/week	900	hr	$32.00	$28,800
1 Engineer/Foreman @ 6 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Recirculation Well System				**$588,540**
TOTAL DIRECT COSTS (NORTHERN PLUME)				**$648,652**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS (NORTHERN PLUME)				**$105,000**
TOTAL CAPITAL COSTS (NORTHERN PLUME)				**$753,652**
ENHANCED BIODEGRADATION				
Site Preparation and Mobilization [Southern Plume]				
Decon Equipment and Pad: (Initial cost included in Northern Plume)				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Subtotal Site Preparation/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000

TABLE D-6

ALTERNATIVE V-5B: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION
TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
TOTAL CAPITAL COSTS [Northern and Southern Plumes]				**$938,027**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (annual for 15 years)				
Utilities				
Treatment System ($400/mo per recirc well)	12	month	$1,600.00	$19,200
System Maintenance				
Inspections/Service/Consumables ($25K one well, $15K each additional)	1	LS	$70,000.00	$70,000
Subtotal Treatment System O&M				**$89,200**
Sampling and Monitoring				
Recirc Well Influent Grab Samples (4 wells, 1 per quarter): TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Effluent Grab Samples (4 wells, 1 per quarter): TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Subtotal GW Sampling and Monitoring				**$4,800**
Total Annual Treatment System O&M Cost				**$94,000**
Present Worth Treatment System (O&M) Costs @ i = 6%, n = 15 yrs				**$912,928**

TABLE D-6

ALTERNATIVE V-5B: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION
TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
Recirc Well Source Area GW Monitoring O&M (annual for 15 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples	= 12 samples			
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual GW Monitoring O&M				**$11,550**
Present Worth Source Area GW Monitoring @ i = 6%, n = 15 yrs				**$112,174**
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal Annual HRC Treatment O&M				**$19,110**
Present Worth HRC System (O&M) Costs @ i = 6%, n = 2,3 yrs				**$33,060**
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual HRC Monitoring Costs (years 1-3)				**$17,550**
Present Worth HRC Monitoring Costs @ i = 6%, n = 3 yrs				**$46,911**
IRA System (annual for 15 years)				

TABLE D-6

ALTERNATIVE V-5B: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION
TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Present Worth IRA System (O&M) Costs @ i = 6%, n = 15 yrs				**$413,755**
GW Monitoring within Downgradient Plume (annual costs - 15 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (15 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 15 yrs				**$103,435**
GW Sampling & Monitoring Program for Natural Attenuation within the entire VOC Plume (years 16-45)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Analysis-TCL VOCs	20	samples	$150.00	$3,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual NA Monitoring Costs				**$18,250**
Present Worth NA Monitoring @ i = 6%, n = 16 to 45 yrs				**$104,824**
Five-year Site Reviews (every 5 years for 45 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				

TABLE D-6

ALTERNATIVE V-5B: RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION
TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Annual Cost				**$18,220**
Present Worth 5-Yr Site Reviews @ i = 6%, n = 5,10..45 yrs				**$49,957**
TOTAL PRESENT WORTH O&M COSTS				**$1,777,045**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$2,715,072**
CONTINGENCY @10 PERCENT				**$271,507**
TOTAL COST OF ALTERNATIVE V-5B				**$2,986,580**

TABLE D-7

ALTERNATIVE V-6A: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	LS	$5,000.00	$5,000
Treatment Building (20' x 30')	1	LS	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$62,112**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vaults	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Wastes (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	100	ft	$10.00	$1,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE D-7

ALTERNATIVE V-6A: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	300	ft	$20.00	$6,000
Discharge to Lake Druid (2" ID, PVC)	500	ft	$20.00	$10,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Temperature Gauges	2	each	$80.00	$160
Instrumentation Controls	1	LS	$10,000	$10,000
Discharge Pump	1	each	$3,000	$3,000
Telemetry	1	LS	$10,000	$10,000
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Extraction System				**$109,893**
Ex-situ Diffused Aeration System				
Equalization Tank (1,000 gal)	1	each	$500	$500
Adjustable Flow Feed/Transfer Pump	2	each	$2,000	$4,000
Diffused Aeration System w/ Blower	1	LS	$14,000	$14,000
Subtotal Diffused Aeration System				**$18,500**
TOTAL DIRECT COSTS				**$200,505**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$305,505**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (1-108 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200
Treatment System	12	month	$150.00	$1,800
System Maintenance				
Labor (1 operators @ 8 hrs/wk, 52 weeks/year)	416	hrs	$45.00	$18,720
Aeration System Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$27,720**

TABLE D-7

ALTERNATIVE V-6A: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$18,000**
Total Annual Treatment System O&M Cost				**$45,720**
Present Worth System O&M Costs @ i = 6%, n = 108 yrs				**$760,598**
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	0	1,000 gals	$1.90	$0
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$32,615**
Present Worth IRA System (O&M) Costs @ i = 6%, n = 10 yrs				**$240,048**
GW Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program for VOCs within the source area during pump and treat (years 1-108) :				
10 wells + 2 QA/QC samples = 12 samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual Source Area GW Monitoring				**$11,550**
Present Worth Source Area GW Monitoring @ i = 6%, n = 108 yrs				**$192,146**
GW Sampling & Monitoring Program within IRA Capture Area (years 1-10)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500

TABLE D-7

ALTERNATIVE V-6A: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 10 yrs				**$78,384**
GW Sampling & Monitoring Program for Natural Attenuation within the IRA Capture Area (years 11-20)				
6 Wells + 1QA/QC = 7 Samples				
Associate Scientist	30	hrs	$60.00	$1,800
Technician	30	hrs	$45.00	$1,350
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Natural Attenuation Parameters	10	samples	$200.00	$2,000
Analysis - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual Monitored Natural Attenuation				**$12,200**
Present Worth MNA O&M @ i = 6%, n = 11 to 20 yrs				**$50,142**
Five-year Site Reviews (every 5 years for 108 yrs)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review				**$18,220**
Present Worth 5-Yr Site Reviews @ i = 6%, n = 5,10..108 yrs				**$53,713**

TABLE D-7

ALTERNATIVE V-6A: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
TOTAL PRESENT WORTH O&M COSTS				$1,375,030
TOTAL CAPITAL COSTS AND O&M COSTS				$1,680,536
CONTINGENCY @10 PERCENT				$168,054
TOTAL COST OF ALTERNATIVE V-6A				$1,848,589

TABLE D-8

ALTERNATIVE V-6B: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	LS	$5,000.00	$5,000
Treatment Building (20' x 30')	1	LS	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 40')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$62,112**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vault	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Waste (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone line for Telemetry	100	ft	$10.00	$1,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE D-8

ALTERNATIVE V-6B: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	300	ft	$20.00	$6,000
Discharge to Lake Druid (2" ID, PVC)	500	ft	$20.00	$10,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Telemetry	1	LS	$10,000.00	$10,000
Temperature Gauges	2	each	$80.00	$160
Instrumentation Controls	1	LS	$10,000.00	$10,000
Discharge pump	1	each	$3,000.00	$3,000
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Extraction System				**$109,893**
Ex-situ Diffused Aeration System				
Equalization Tank (1,000 gal)	1	each	$500.00	$500
Adjustable Flow Feed/Transfer pump	2	each	$2,000.00	$4,000
Diffused Aeration System w/ Blower	1	LS	$14,000.00	$14,000
Subtotal Diffused Aeration System				**$18,500**
TOTAL DIRECT COSTS				**$200,505**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$305,505**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Site-Specific Remedial Goals				
Treatment System O&M (annual for 59 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200
Treatment System	12	month	$150.00	$1,800
System Maintenance				
Labor (1 operators @ 8 hrs/week, 52 weeks/year)	416	hrs	$45.00	$18,720
Aeration System Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$27,720**

TABLE D-8

ALTERNATIVE V-6B: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$18,000**
Present Worth Treatment System O&M @ i = 6%, n = 59 yrs				**$737,326**
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	0	1,000 gals	$1.90	$0
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$32,615**
Present Worth IRA System (O&M) Costs @ i = 6%, n = 10 yrs				**$240,048**
Groundwater Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program within source area during pump and treat (years 1-59):				
10 wells + 2 QA/QC samples = 12 samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Source Area GW Monitoring Costs				**$11,550**
Present Worth Source Area GW Monitoring @ i = 6%, n = 59 yrs				**$186,267**
GW Sampling & Monitoring Program within IRA Capture Area (1-10 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500

TABLE D-8

ALTERNATIVE V-6B: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 10 yrs				**$78,384**
GW Sampling & Monitoring Program for Natural Attenuation within the entire Area (years 60-89)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal MNA O&M				**$15,250**
Present Worth MNA O&M @ i = 6%, n = 60-89 yrs				**$6,802**
Five-Year Site Reviews (every 5 years for 89 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five-Year Site Reviews				**$18,220**
Present Worth 5-Yr Site Reviews @ i = 6%, n = 5, 10..89 yrs				**$53,560**

TABLE D-8

ALTERNATIVE V-6B: GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
TOTAL O&M COSTS				$1,302,387
TOTAL CAPITAL COSTS AND O&M COSTS				$1,607,892
CONTINGENCY @10 PERCENT				$160,789
TOTAL COST OF ALTERNATIVE V-6B				$1,768,681

TABLE D-9

ALTERNATIVE V-7A: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	lump sum	$5,000.00	$5,000
Treatment Building (20' x 30')	1	lump sum	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 40')	140	feet	$2.84	$398
Trailer Area (40' x 80')	240	feet	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	lump sum	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	lump sum	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	lump sum	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Sub-total Site Preparation/Mobilization				**$62,169**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vault	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Wastes (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	lump sum	$2,000.00	$2,000
Utility Connections (Electrical and Potable Water)				
Utility Pole	1	poles	$550.00	$550
Power Cable	25	ft	$10.00	$250
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	100	ft	$10.00	$1,000
Water Service Connection	1	lump sum	$1,000.00	$1,000
Gauge, curb box, appurtenances	1	lump sum	$1,000.00	$1,000

TABLE D-9

ALTERNATIVE V-7A: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	350	ft	$20.00	$7,000
Discharge to Lake Druid (2" ID, PVC)	250	ft	$20.00	$5,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Temperature Gauge	1	each	$80.00	$80
Instrumentation Controls	1	lump sum	$10,000.00	$10,000
Discharge Pump	1	each	$3,000.00	$3,000
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Collection System				**$93,063**
Ex-situ UV/Oxidation with Hydrogen Peroxide				
Equalization Tank (1,000 gal)	1	each	$500.00	$500
Adjustable Flow Feed pump	1	each	$2,000.00	$2,000
Skid-mounted 30 KW Rayox UV/Oxidation Unit	1	lump sum	$100,000.00	$100,000
Telemetry for Off-site Monitoring	1	each	$10,000.00	$10,000
Compressor for Lamp Cleaner	1	each	$3,000.00	$3,000
Emergency Eye Wash Shower	1	each	$1,000.00	$1,000
Sub-total UV/Oxidation System				**$116,500**
TOTAL DIRECT COSTS				**$281,732**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$386,732**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (years1-108)				
UV Lamp Replacement and Hydrogen Peroxide				
Lamp Replacement ($0.40/1000 gal)	42048	1000 gal	$0.40	$16,819
(115,200 gpd x 365 d/1000 gal) = 42,048				
Hydrogen Peroxide (100 ppm, $/1000 gal)	42048	1000 gal	$0.60	$25,229
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200

TABLE D-9

ALTERNATIVE V-7A: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Treatment System ($0.10/kWhr,$/1000 gal)	42048	1000 gal	$0.62	$26,070
System Maintenance				
Labor (1 operators @ 8 hrs/day, 52 weeks/year)	416	hrs	$45.00	$18,720
Misc. UV/Oxidation and Chemical Feed Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$94,038**
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal Sampling and Monitoring O&M				**$18,000**
Total Annual System O&M				**$112,038**
Present Worth System O&M @ i = 6%, n = 108 yrs				**$1,863,843**
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	0	1,000 gals	$1.90	$0
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$32,615**
Present Worth IRA System (O&M) Costs @ i = 6%, n = 10 yrs				**$240,048**
GW Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program for VOCs within the Source area during pump and treat (year 1-108):				
10 Wells +2 QA/QC = 12 Samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Treatment System Annual Costs				**$11,550**
Present Worth GW Monitoring @ i = 6%, n = 108 yrs				**$191,996**

TABLE D-9

ALTERNATIVE V-7A: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
GW Sampling & Monitoring Program within IRA Capture Area (years 1-10)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 10 yrs				**$78,384**
GW Sampling & Monitoring Program for Natural Attenuation within the IRA Capture Area (yrs 11-20)				
6 Wells + 1QA/QC = 7 Samples				
Associate Scientist	30	hrs	$60.00	$1,800
Technician	30	hrs	$45.00	$1,350
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Natural Attenuation Parameters	10	samples	$200.00	$2,000
Analysis - TCL Organics (VOCs Only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal MNA O&M				**$12,200**
Present Worth MNA O&M @ i = 6%, n = 11-20 yrs				**$50,142**
Five-year Site Reviews (every 5 years for 108 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Annual Cost				**$18,220**
Present Worth 5-Yr Site Review @ i = 6%, n =5, 10...108 years				**$53,713**

TABLE D-9

ALTERNATIVE V-7A: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
TOTAL O&M COSTS				$2,478,126
TOTAL CAPITAL COSTS AND O&M COSTS				$2,864,858
CONTINGENCY @10 PERCENT				$286,486
TOTAL COST OF ALTERNATIVE V-7A				$3,151,344

TABLE D-10

ALTERNATIVE V-7B: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC-REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	lump sum	$5,000.00	$5,000
Treatment Building (20' x 30')	1	lump sum	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 40')	140	feet	$2.84	$398
Trailer Area (40' x 80')	240	feet	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	lump sum	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	lump sum	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	lump sum	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$62,169**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vault	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Waste (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	lump sum	$2,000.00	$2,000
Utility Connections (Electrical and Potable Water)				
Utility Pole	1	poles	$550.00	$550
Power Cable	25	ft	$10.00	$250
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	100	ft	$10.00	$1,000
Water Service Connection	1	lump sum	$1,000.00	$1,000
Gauge, curb box, appurtenances	1	lump sum	$1,000.00	$1,000

TABLE D-10

ALTERNATIVE V-7B: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC-REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	350	ft	$20.00	$7,000
Discharge to Lake Druid (2" ID, PVC)	250	ft	$20.00	$5,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Temperature Gauge	1	each	$80.00	$80
Instrumentation Controls	1	lump sum	$10,000.00	$10,000
Discharge Pump	1	each	$3,000.00	$3,000
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Extraction System				**$93,063**
Ex-situ UV/Oxidation with Hydrogen Peroxide				
Equalization Tank (1,000 gal)	1	each	$500.00	$500
Adjustable Flow Feed pump	1	each	$2,000.00	$2,000
Skid-mounted 30 KW Rayox UV/Oxidation Unit	1	lump sum	$100,000.00	$100,000
Telemetry for Off-site Monitoring	1	each	$10,000.00	$10,000
Compressor for Lamp Cleaner	1	each	$3,000.00	$3,000
Emergency Eye Wash Shower	1	each	$1,000.00	$1,000
Subtotal UV/Oxidation System				**$116,500**
TOTAL DIRECT COSTS				**$281,732**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$386,732**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Site-Specific Remedial Goals				
Treatment System O&M (annual for 59 years)				
UV Lamp Replacement and Hydrogen Peroxide				
Lamp Replacement ($0.40/1000 gal)	42048	1000 gal	$0.40	$16,819
(115,200 gpd x 365 d/1000 gal) = 42,048				
Hydrogen Peroxide (100 ppm, $/1000 gal)	42048	1000 gal	$0.60	$25,229
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200
Treatment System ($0.10/kWhr,$/1000 gal)	42048	1000 gal	$0.62	$26,070

TABLE D-10

ALTERNATIVE V-7B: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC-REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
System Maintenance				
Labor (1 operators @ 8 hrs/day, 52 weeks/year)	416	hrs	$45.00	$18,720
Misc. UV/Oxidation and Chemical Feed Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$94,038**
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$18,000**
Total Annual System O&M				**$112,038**
Present Worth System O&M Costs @ i = 6%, n = 59 yrs				**$1,807,292**
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	0	1,000 gals	$1.90	$0
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$32,615**
Present Worth IRA System (O&M) Costs @ i = 6%, n = 10 yrs				**$240,048**
GW Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program within IRA Capture Area (1-10 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Present Worth IRA GW Monitoring @ i = 6%, n = 10 yrs				**$78,384**

TABLE D-10

ALTERNATIVE V-7B: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC-REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
GW Sampling & Monitoring Program for VOCs within the Source area during pump and treat (year 1-59):				
10 Wells +2 QA/QC = 12 Samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual Source Area GW Monitoring				**$11,550**
Present Worth Monitoring Source Area @ i = 6%, n = 59 yrs				**$186,267**
GW Sampling & Monitoring Program for Natural Attenuation within the entire Area (years 59-89)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal MNA O&M				**$15,250**
Present Worth MNA O&M @ i = 6%, n = 60-89 yrs				**$6,802**
Five-year Site Reviews (every 5 years for 89 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Annual Five Year Site Review Costs				**$18,220**
Present Worth 5-Yr Site Review @ i=6%, n=5, 10..89 yrs				**$53,560**

TABLE D-10

ALTERNATIVE V-7B: GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC-REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
TOTAL O&M COSTS				$2,372,353
TOTAL CAPITAL COSTS AND O&M COSTS				$2,759,085
CONTINGENCY @10 PERCENT				$275,908
TOTAL COST OF ALTERNATIVE V-7B				$3,034,993

TABLE D-11

ALTERNATIVE A-1: NO ACTION

	Quantity	Unit	Unit Cost	Total Cost
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Five Year Site Review Annual Costs				**$18,220**
Present Worth 5 Year Site Review @ i = 6%, n = 5,10..30 years				**$44,491**
GW Monitoring for Five-Year Site Review (annual for 30 years)				
GW Sampling & Monitoring Program: 12 wells + 2 QA/QC samples	= 14 samples			
Associate Scientist	40	hrs	$60.00	$2,400
Technician	50	hrs	$45.00	$2,250
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$12,000**
Present Worth O&M @ i = 6%, n = 5, 10..30 years				**$29,303**
TOTAL O&M COSTS				**$73,794**
TOTAL CAPITAL COSTS AND O&M COSTS				**$73,794**
CONTINGENCY @10 PERCENT				**$7,379**
TOTAL COST OF ALTERNATIVE A-1				**$81,174**

TABLE D-12

ALTERNATIVE A-2: LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	$10,000
TOTAL DIRECT COSTS				**$10,000**
INDIRECT COSTS				
Health and Safety				$500
Administrative Fees				$1,000
Engineering and Design				$4,000
Construction Support Services				$1,000
TOTAL INDIRECT COSTS				**$6,500**
TOTAL CAPITAL COSTS				**$16,500**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
GW Monitoring O&M (annual for 30 years)				
GW Sampling & Monitoring Program: 12 wells + 2 QA/QC samples	= 14	samples		
Associate Scientist	32	hrs	$60.00	$1,920
Technician	32	hrs	$45.00	$1,440
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$500.00	$500
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$10,210**
Present Worth O&M @ i = 6%, n = 30 years				**$140,539**
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Five Year Site Review Annual Costs				**$18,220**
Present Worth 5 Year Site Review @ i = 6%, n = 5,10..30 years				**$44,491**

TABLE D-12

ALTERNATIVE A-2: LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
TOTAL O&M COSTS				$185,030
TOTAL CAPITAL COSTS AND O&M COSTS				$201,530
CONTINGENCY @10 PERCENT				$20,153
TOTAL COST OF ALTERNATIVE A-2				$221,683

TABLE D-13

ALTERNATIVE A-3: GROUNDWATER EXTRACTION AND DISCHARGE TO ORLANDO STP, TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	60	ft	$2.84	$170
Trailer Area (40' x 80')	120	ft	$2.84	$341
Gates	2	each	$95.00	$190
Treatment System Concrete Pad	1	LS	$4,000.00	$4,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$34,601**
Groundwater Extraction System (1 well pumping @ 40 gpm)				
Groundwater Extraction Well				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (1 wells @4" ID, PVC, 40' bls)	40	ft	$75.00	$3,000
Extraction Well Vault	1	each	$2,500.00	$2,500
Extraction Pump (40 gpm)	1	pumps	$5,000.00	$5,000
Per Diem/Lodging (3 men @ 3 days)	3	days	$100.00	$300
Decontamination	2	hrs	$100.00	$200
Investigation Derived Waste (soil and dev. Water)	1	LS	$5,000.00	$5,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,000.00	$1,000
Gauge, curb box, appurtenances	1	each	$1,000.00	$1,000

TABLE D-13

ALTERNATIVE A-3: GROUNDWATER EXTRACTION AND DISCHARGE TO ORLANDO STP, TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
Discharge to Sanitary Sewer (2" ID, PVC)	400	ft	$20.00	$8,000
Flow Meters	1	each	$300.00	$300
Pressure Gauges	2	each	$16.50	$33
Temperature Gauges	1	each	$80.00	$80
Instrumentation Controls	1	LS	$5,000.00	$5,000
Telemetry	1	LS	$5,000.00	$5,000
Labor				
3 men @ 2 weeks @ 50 hrs/week	300	hr	$32.00	$9,600
1 Engineer/Foreman @ 2 weeks @ 50 hrs/week	100	hr	$75.00	$7,500
Subtotal Groundwater Extraction System				**$63,063**
TOTAL DIRECT COSTS				**$107,664**
INDIRECT COSTS				
Health and Safety				$5,000.00
Administrative Fees				$10,000.00
Engineering and Design				$15,000.00
Construction Support Services				$20,000.00
TOTAL INDIRECT COSTS				**$50,000**
TOTAL CAPITAL COSTS				**$157,664**
Present Worth for Delayed Capital Costs @ i = 6%, n = 10 yrs				**$92,456**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (delayed start for 10 years then annual for the next 9 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$50.00	$600
POTW Discharge Fee @ $1.90/1000 Gallons	21,024	1000 gal	$1.90	$39,946
System Maintenance				
Labor (1 operators @ 4 hrs/week, 52 weeks/year)	208	hrs	$45.00	$9,360
Subtotal Treatment System O&M				**$49,906**
Sampling and Monitoring				
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$14,400**
Total Annual O&M Cost (Treatment System Yr 11-19)				**$64,306**
Present Worth O&M Costs @ i = 6%, n = 11 to 19 yrs				**$244,233**

TABLE D-13

ALTERNATIVE A-3: GROUNDWATER EXTRACTION AND DISCHARGE TO ORLANDO STP, TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
GW Monitoring O&M (annual for 19 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples	= 12 samples			
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$11,550**
Present Worth GW Monitoring Costs @ i = 6%, n = 19 yrs				**$128,875**
Five-year Site Reviews (every 5 years for 19 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Annual Five Year Site Review Costs				**$18,220**
Present Worth 5 Year Site Review @ i = 6%, n = 5,10..19 yrs				**$37,415**
TOTAL O&M COSTS				**$410,522**
TOTAL CAPITAL COSTS AND O&M COSTS				**$502,978**
CONTINGENCY @10 PERCENT				**$50,298**
TOTAL COST OF ALTERNATIVE A-3				**$553,276**

TABLE D-14

ALTERNATIVE A-4: GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	60	ft	$2.84	$170
Trailer Area (40' x 80')	120	ft	$2.84	$341
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Sub-total Site Preparation/Mobilization				**$49,601**
Groundwater Extraction System (1 well pumping @ 40 gpm)				
Groundwater Extraction Well				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (1 well @4" ID, PVC, 40' bls)	40	ft	$75.00	$3,000
Extraction Well Vault	1	each	$2,500.00	$2,500
Extraction Pumps (40 gpm per well)	1	pumps	$5,000.00	$5,000
Per Diem/Lodging (3 men @ 3 days)	3	days	$100.00	$300
Decontamination	2	hrs	$100.00	$200
Investigation Derived Waste (soil and dev. Water)	1	LS	$5,000.00	$5,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE D-14

ALTERNATIVE A-4: GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	300	ft	$20.00	$6,000
Discharge to Lake Druid (2" ID, PVC)	1,350	ft	$20.00	$27,000
Flow Meters	1	each	$300.00	$300
Pressure Gauges	2	each	$16.50	$33
Temperature Gauges	1	each	$80.00	$80
Instrumentation Controls	1	LS	$10,000.00	$10,000
Discharge Pump	1	each	$3,000.00	$3,000
Telemetry	1	LS	$10,000.00	$10,000
Labor				
3 men @ 2 weeks @ 50 hrs/week	300	hr	$32.00	$9,600
1 Engineer/Foreman @ 2 weeks @ 50 hrs/week	100	hr	$75.00	$7,500
Subtotal Groundwater Collection System				**$102,063**
NP Treatment System				
NP 7050 System	1	LS	$225,000	$225,000
Subtotal Treatment System				**$225,000**
TOTAL DIRECT COSTS				**$386,664**
INDIRECT COSTS				
Health and Safety				$5,000.00
Administrative Fees				$10,000.00
Engineering and Design				$20,000.00
Construction Support Services				$20,000.00
TOTAL INDIRECT COSTS				**$55,000**
TOTAL CAPITAL COSTS				**$441,664**
Present Worth of Delayed Capital Costs @ i = 6% and n = 10 yrs				**$251,041**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (delayed start for 10 years then annual for the next 9 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$50.00	$600
Treatment System	12	month	$150.00	$1,800
System Maintenance				
Labor (1 operators @ 8 hrs/week, 52 weeks/year)	416	hrs	$45.00	$18,720
Chemicals	1	LS	$500.00	$500
Sludge Disposal	1	LS	$1,000.00	$1,000
Subtotal Treatment System O&M				**$22,620**

TABLE D-14

ALTERNATIVE A-4: GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TAL Inorganics	12	samples	$150.00	$1,800
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$16,200**
Total Annual O&M Cost (Treatment System Yr 10-19)				**$38,820**
Present Worth System O&M Costs @ i = 6%, n = 11 to 19 yrs				**$147,438**
GW Monitoring O&M (annual for 19 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples	= 12	samples		
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$11,550**
Present Worth GW Monitoring O&M Costs @ i = 6%, n = 19 yrs				**$128,875**
Five-year Site Reviews (every 5 years for 19 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Annual Five Year Site Review Cost				**$18,220**
Present Worth 5 Year Review @ i = 6%, n=5,10..19 yrs				**$37,415**

TABLE D-14

ALTERNATIVE A-4: GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Equipment Replacement				
Replacement NP Treatment System after 5 yrs (n = 15)	1	LS	$225,000	$225,000
Present Worth Equipment Replacement @ i = 6%, n = 15 yrs				**$93,886**
TOTAL O&M COSTS				**$407,614**
TOTAL CAPITAL COSTS AND O&M COSTS				**$658,655**
CONTINGENCY @10 PERCENT				**$65,866**
TOTAL COST OF ALTERNATIVE A-4				**$724,521**

APPENDIX E

APPENDIX E

COST BACKUP AND VENDOR INFORMATION

In-Situ Biodegradation of Chlorinated Solvents
HRC Pilot-Scale Test Results
Status: September 12, 1998

Harding Lawson Associates (HLA) is conducting a pilot-scale test to evaluate in situ biodegradation of chlorinated solvents using Hydrogen Release Compound (HRC). HRC, developed and manufactured by Regenesis, is a polymer that slowly dissolves into groundwater and can be used to passively enhance anaerobic biodegradation of chlorinated solvents. The pilot test uses a recirculating system was created using three extraction and injection wells. HRC containing canisters have been placed into the injection wells and biodegradation is being measured by collecting samples from several monitoring wells placed between the injection and extraction wells and one of the injections wells. Figures 1 and 2 show schematics of the treatment cell.

A significant reduction in the concentration of chlorinated volatile organic compounds (cVOCs) has been observed in a relatively short time period. The concentration of VOCs in wells within the treatment cell on Days 0 (February 13, 1998), 80 (May 5, 1998) and 180 (August 21, 1998) are presented in Figure 3. The concentration of all VOCs have been drastically reduced in all wells within the treatment cell. Currently cis-DCE and VC (anaerobic transformation products) are the predominant VOCs detected in groundwater. Ethene levels (data not shown) have increased indicating that PCE and TCE undergo complete reductive dechlorination under HRC enhanced conditions. Results to date show a greater than 99% reduction in concentration of TCE and PCE and a 90% reduction in total mass of cVOCs. The concentration of the individual cVOCs in well EPA -2 (which is in the middle of the treatment cell) are presented in Figure 4.

The cVOC reductions correspond with lower redox conditions and the detection of sulfide, however there has not been an increase in methane levels. This suggests cVOC biodegradation is occurring under sulfate reducing conditions rather than methanogenic. The redox levels, which started at or near 150mv, have been reduced to between -50mv and -200mv.

The total organic carbon levels near IN-2 range from 800-1200mg/L TOC levels are significantly lower in downgradient well EPA-3 (20mg/L). It appears that most of the carbon delivered from the HRC is used up before reaching EPA 3, which under pumping conditions is equivalent to a travel time of one week.

Overall, the pilot test results indicate that HRC can be used to lower redox conditions in the subsurface and enhance anaerobic cVOC biodegradation rates. Data continues to be collected and will focus on establishing DCE and VC biodegradation rates and to correlate results with HRC utilization.

Contact: Maureen Dooley (mdooley@harding.com)
Jay Johnson (jaretjohnson@harding.com)
Willard Murray (wmurray@harding.com)

Figure 1.

Biotreatment Cell

(a) Plan View showing groundwater flow pattern and wells

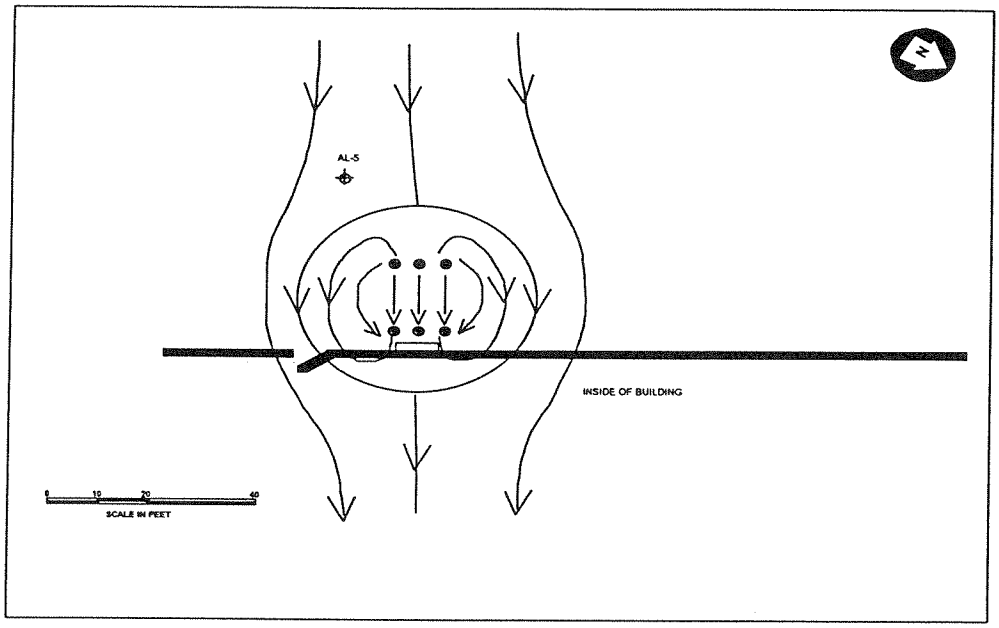

Figure 2
Vertical Section through biotreatment cell

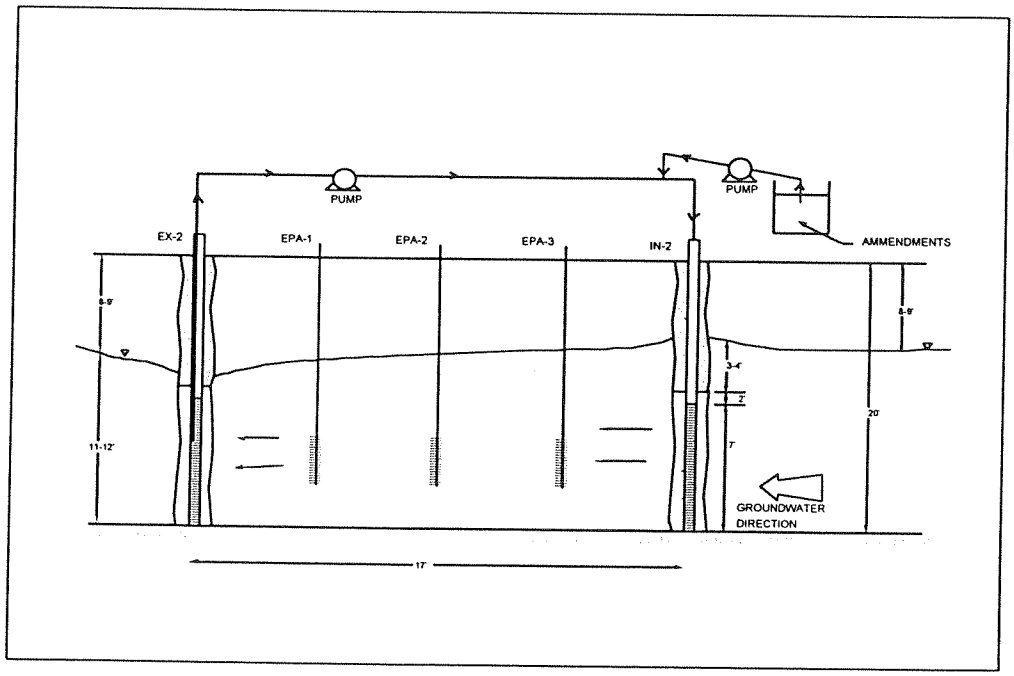

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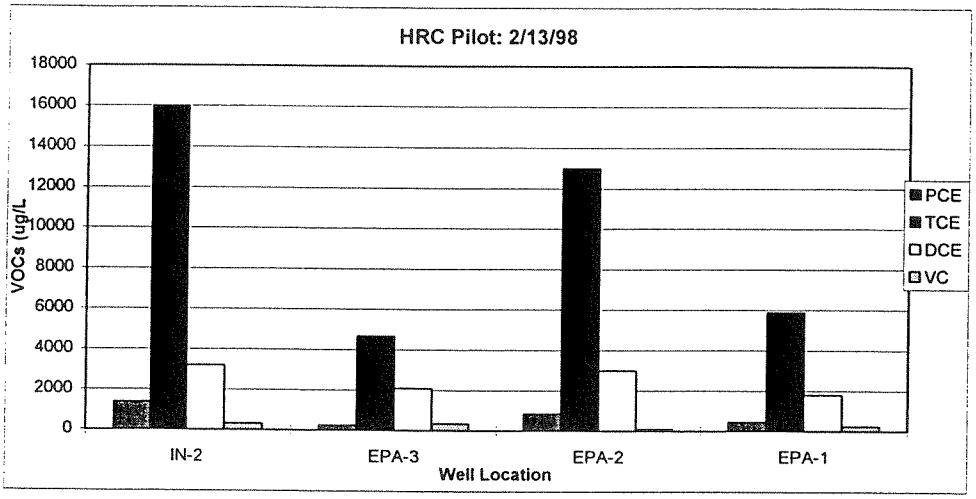
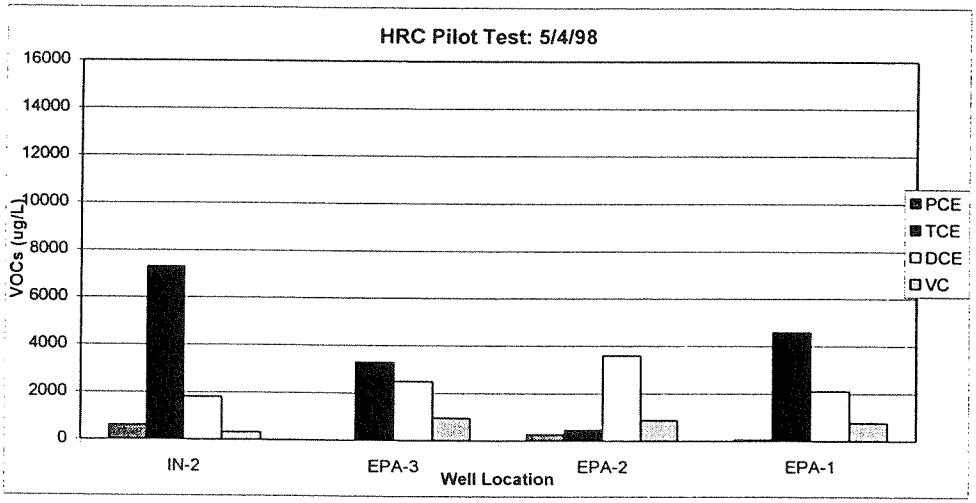
Figure 3. VOC Results From February 13, May 5 and August 21, 1998





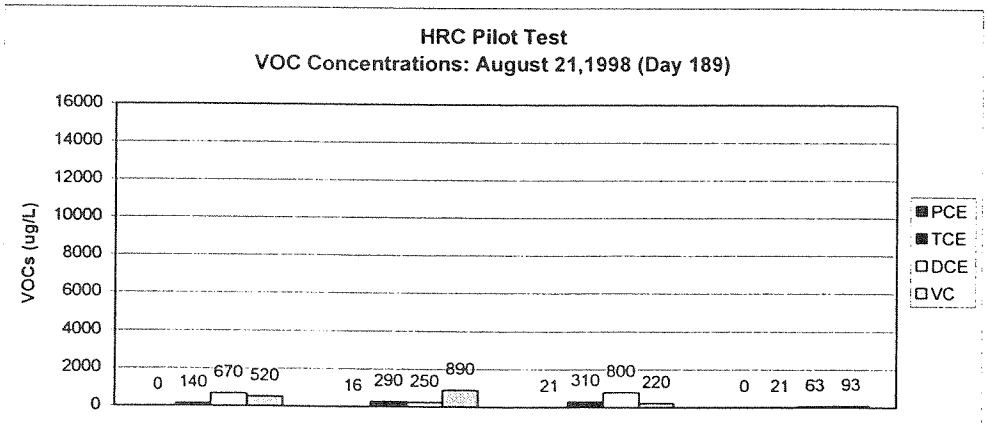
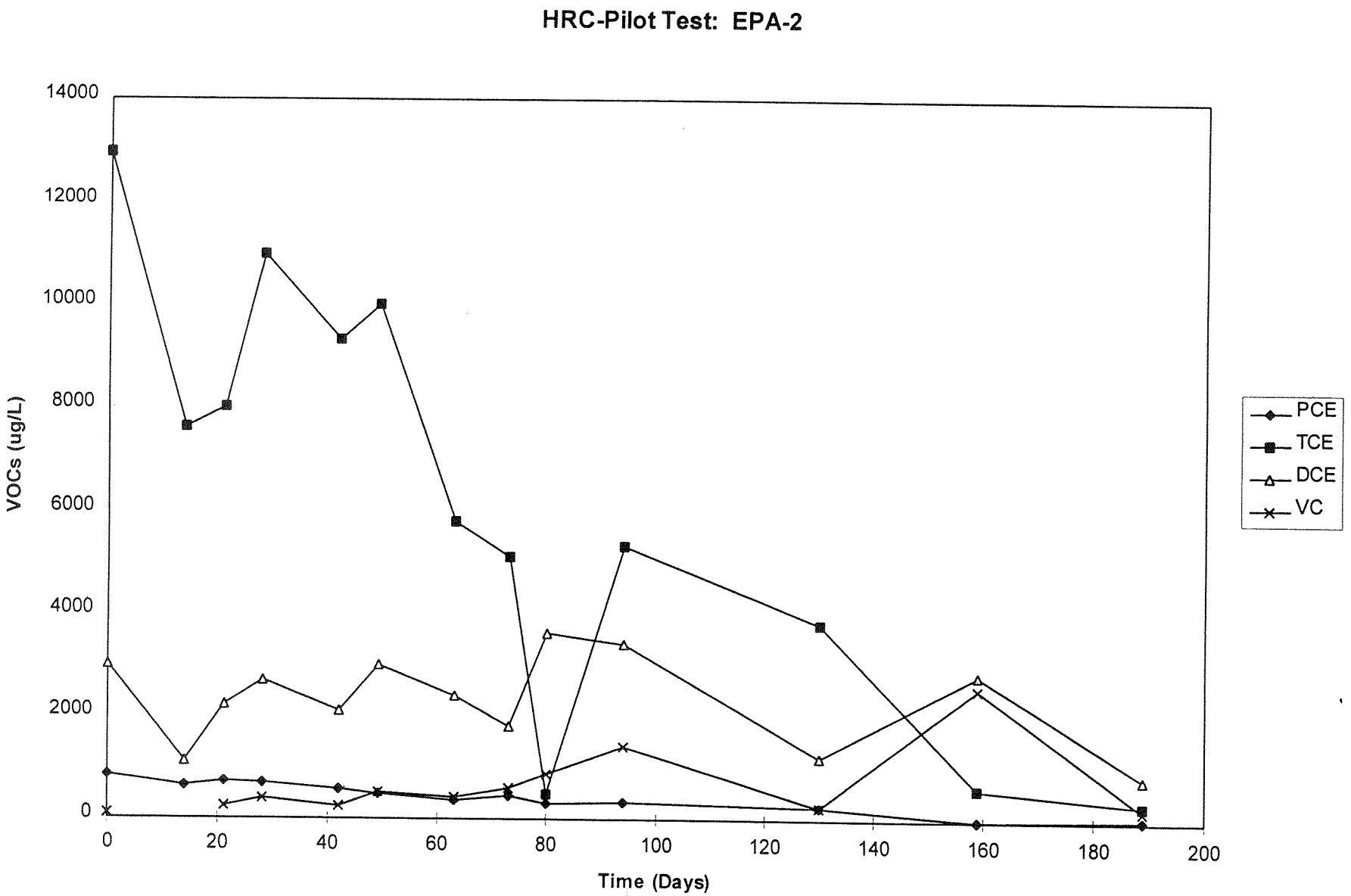


Figure 4. Data from Well EPA-2



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REGENESIS

Hydrogen Release Compound, HRC®

Price Sheet: Effective September 1, 2000

Cost Effective Treatment of Chlorinated Solvents

Hydrogen Release Compound (HRC) offers a passive, low-cost approach to rapid remediation of chlorinated solvent impacted sites. HRC is a proprietary, environmentally safe polylactate ester specially formulated for slow release of lactic acid upon hydration. When placed within a contaminated aquifer, HRC stimulates a multi-step process resulting in the degradation of chlorinated solvent compounds such as PCE, TCE and their derivatives as well as other groundwater contaminants. ***The use of HRC results in the cost-effective and rapid restoration of property values.***

HRC* Pricing

Regenesis offers a volume discount structure for the purchase of HRC as follows:

Quantity (lbs.)	HRC Price/lb. (US $)	Quantity (lbs.)	HRC Price/lb. (US $)
150	$8.00	6,000	$5.75
500	$7.50	10,000	$5.50
1,500	$7.00	20,000	$5.25
3,000	$6.00	40,000	$5.00

* HRC is shipped in four-and-a-quarter gallon containers weighing approximately 30 pounds. Material Safety Data Sheet is included with each shipment.

Freight – All freight is FOB San Clemente, CA unless otherwise specified when order is placed.

Minimum Order – 150 lbs. ($1,200.00) — ? see above

Bench-Scale Laboratory Testing

Laboratory testing of soil and groundwater is available to confirm the ability of HRC to stimulate dechlorination. However, such testing is generally not required. Testing cost is $2,500 per groundwater/soil slurry sample.

Payment Terms – Net 30 days. Accounts outstanding after 30 days will be assessed 1.5% interest per month. Accounts outstanding over 90 days will be re-invoiced at the undiscounted price of $8.00 per pound.

Return Policy – A 15% restocking fee will be charged for all returned product. Return freight must be prepaid. All requests to return product must be pre-approved by Regenesis. Returned product must be in original condition and no product will be accepted for return after a period of 90 days from time of delivery.

Terms & Conditions – Other terms and conditions are on reverse side.

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Peru, IL 61354-0599
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Fax (815) 224-6663

TO:	**Mr. Mark Salvetti, Harding Lawson Associates**
FAX #:	781/246-5060 – Ph: 245-6606
FROM:	Reggie T. George – Senior Applications Engineer
DATE:	08 December 1998
NUMBER OF PAGES (including cover sheet):	2

RE: TCE/PCE Remediation
Cairox® Potassium Permanganate Feed System for Orlando, FL

Dear Mr. Salvetti:

As per our conversation previously, the cost of leasing (3 month minimum) our Portable Bulk system is $1800.00 per month. Shipping is extra. This is also subject to availability based on prior rental/lease agreement with other clients. Also please find attached, a diagram of the Storage Unit of the Portable Bulk system. The Feed Unit is not shown here. The bulk system has a storage capacity of approximately 40,000 lbs. The feed unit is completely self contained with its on insulated housing unit.

Hopefully, this information will be helpful to you. Please feel free to contact me at (800) 435-6856 ext. 520, to further discuss your application. We look forward to working with you on this project.

Sincerely,

Reggie T. George, M.Sc
Sr. Applications Engineer

RTG/bim

Enclosures

CC: Robert L. Myers
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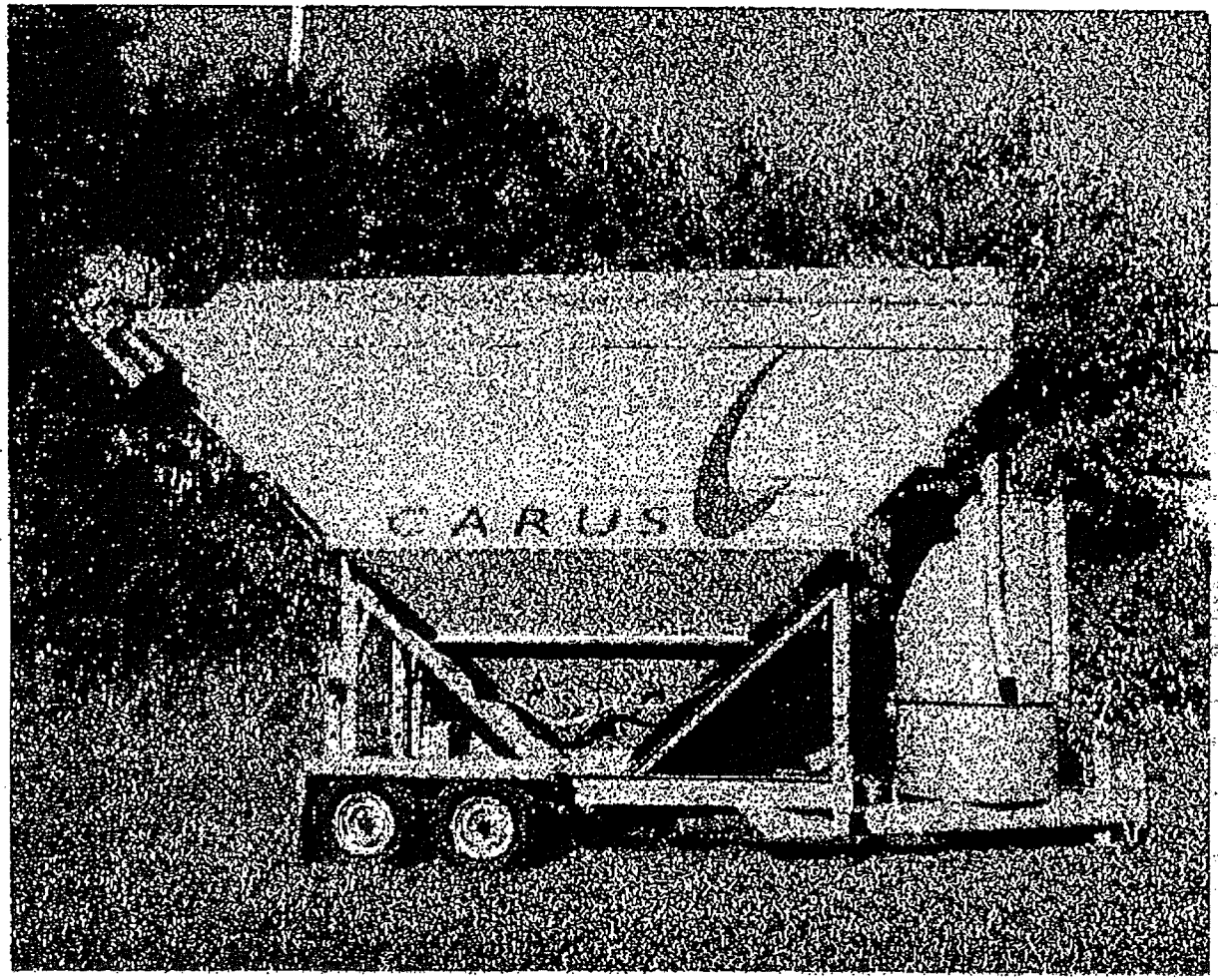

Laboratory and Controlled Field Experiments Using Potassium Permanganate To Remediate Trichloroethylene and Perchloroethylene DNAPLs In Porous Media

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ABSTRACT

Few proven technologies exist that may be used to treat DNAPL contaminants. *In situ* chemical flushing is a proposed technology which consists of flush DNAPL source zones with a reactive solution to degrade the contaminant mass below ground.

A laboratory and controlled field experimental program was conducted to assess the potential of potassium permanganate ($KMnO_4$) as a reagent for *in situ* DNAPL remediation. The results of laboratory experiments indicated that two common DNAPL contaminants, perchloroethylene (PCE) and trichloroethylene (TCE), were rapidly degraded to chloride and carbon dioxide. Column experiments, using residual PCE flushed with oxidant concentrations as high as 10 g/L, indicated that chloride could be used as a reaction tracer. From the chloride data, it appeared that the rate of PCE removal from the columns was a complex process dependent upon the kinetics of both dissolution and oxidation.

Two experimental applications of *in situ* oxidation were conducted in the Borden aquifer isolated within a 7.5 m^3 double sheet-pile cell. The cell was fitted with injection and recovery wells through which aqueous solutions of $KMnO_4$ were flushed to oxidize solvent source zones *in situ*. In the initial experiment, flushing of a 1 L PCE residual source with 10 g/L $KMnO_4$ at total flow rates of up to 100 L/day, completely remove the source within 120 days. A second experiment, using an 8 L mixture of PCE and TCE slowly allowed to infiltrate into the cell, was conducted using a system to recycle the oxidant. The oxidant was added at 10 g/L with a flow of approximately 50 L/day. After 290 days of flushing, it was concluded from the monitoring data that 62 % of the initial source (as equivalent chloride mass) had been oxidized and it was evident that oxidation was continuing in the upper third of the cell.

These experiments have suggested that the effectiveness of *in situ* chemical oxidation will depend primarily upon the distribution of the DNAPL in the subsurface and its effects upon dissolution. In both experiments, spatial variability of chloride measurements appeared to reflect both the DNAPL location and distribution.

INTRODUCTION

Trichloroethylene (TCE) and perchloroethylene (PCE) are two chlorinated organic solvents frequently identified as ground water aquifer contaminants (Westrick *et al.*, 1984; Smith *et al.*, 1990; Plumb, 1991). The US Environmental Protection Agency drinking water standards for each of these compounds is 5 µg/L compared to their solubility's of approximately 1,500 mg/L and 240 mg/L, respectively (Pankow and Cherry, 1996). With five to six orders of magnitude difference between solubility and regulated concentration, the presence of dense non-aqueous phase liquids (DNAPLs), especially in the form of pools in the subsurface, will remain as a very long-term source of contamination until either source containment, isolation or removal has occurred (Mackay and Cherry, 1989; Johnson and Pankow, 1992).

Frequently at sites where DNAPLs are present, pump and treat remediation is selected as a remedial alternative; however, pump and treat approaches to aquifer restoration have demonstrated a distinct lack of success even at sites without DNAPLs (National Research Council, 1993). At sites where DNAPL is present, this approach is primarily limited by low contaminant solubility, contaminant mass storage in low permeability zones, and the relatively large masses of the DNAPL present in the aquifer (Doty and Travis, 1991). The lack of success of pump and treat at these sites has added emphasis to remedial efforts designed to isolate, remove or treat DNAPL sources with the potential benefits of reducing the duration of a subsequent pump and treat containment process and reducing downgradient aqueous phase concentrations.

One example of a mass treatment technology is *in situ* oxidation, an approach which consists of flushing a zone of DNAPL contamination with a reactive solution. This technology is conceptually appealing since it combines hydraulic containment of a source zone with contaminant treatment below ground. Various reactive compounds have been suggested including hydrogen peroxide, Fenton's reagent, ozone and potassium permanganate (Cho and Bowers, 1991). To date, documented use of this technology is limited to a single industrial application in which hydrogen peroxide was used to remove an LNAPL release containing 50% formaldehyde with some success (Cowie and Weider, 1986). To our knowledge, the results

presented in this paper are the first evaluation of potassium permanganate ($KMnO_4$) as an *in situ* reagent and the first evaluation of *in situ* chemical flushing of DNAPL contaminants.

PERMANGANATE ION AS AN OXIDANT

The use of the permanganate ion (MnO_4^-) to indiscriminately scavenge and oxidize organic contaminants has a long history in both drinking water and wastewater treatment (Steel *et al.*, 1979; Eilbeck and Mattock, 1987), including removal of iron and manganese (Benefield *et al.*, 1982), phenols (Vella *et al.*, 1990), trihalomethane precursors (Colthurst and Singer, 1982) and more recently, TCE (Vella and Veronda, 1992). The reactive properties of MnO_4^- with both organic and inorganic compounds have been described in detail by Stewart (1965) and Lee (1980). Permanganate oxidation of organic compounds is used in the commercial production of various compounds with its most serious limitation being its lack of solubility in most hydrocarbons (Lee, 1980) including PCE and TCE. For example, MnO_4^- oxidation of alkenes is used in the synthesis of the corresponding glycols. In addition to its characteristics as an oxidant, potassium permanganate has a high aqueous solubility (64 g/L at 20 °C (Perry *et al.*, 1984)), a property which would allow for a significant loading rate of oxidant into a contaminated zone. As a solid, $KMnO_4$ is easily handled and currently costs approximately CDN$4/kg.

OXIDATION MECHANISM

There are few references dealing directly with the oxidation of specific chlorinated organic compounds by $KMnO_4$. In general, the existing research has focused on synthesis, rather than destruction, of commercially useful oxidation products from alkenes. Lee (1980) has identified two potential reaction mechanisms for alkene oxidation. Both mechanisms begin with the formation of a hypomanganate diester with subsequent steps generally dependent upon pH and the MnO_4^- concentration. Oxidation of alkenes is generally performed in an aqueous

solution due to the fact that $KMnO_4$ is insoluble in most hydrocarbons without the use of a phase transfer catalyst (Lee, 1980)

OXIDATION STOICHIOMETRY

Based on laboratory observations and the redox reactions for each compound, overall reactions between $KMnO_4$ and TCE and PCE were determined. Laboratory observations leading to these equations include the formation of a brown precipitate, determined to be $MnO_2(s)$, and the evolution of a gas, later confirmed as being CO_2.

Recognizing that MnO_4^- was reduced to $MnO_2(s)$ and assuming that the carbon in TCE and PCE was completely oxidized to CO_2, the following half cell reactions apply:

$$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2(s) + 2H_2O$$

$$\frac{1}{2}C_2Cl_4 + 2H_2O \rightarrow CO_2 + 4H^+ + \frac{1}{2}Cl_2 + Cl^- + 3e^-$$

which produce,

$$C_2Cl_4 + 2MnO_4^- \rightarrow 2CO_2 + 2MnO_2(s) + Cl_2 + 2Cl^- \qquad (1)$$

In a similar fashion, the reaction for TCE is:

$$C_2Cl_3H + 2MnO_4^- \rightarrow 2CO_2 + 2MnO_2(s) + 3Cl^- + H^+ \qquad (2)$$

Stoichiometrically, 0.81 kg of Cl^- are produced per kg of TCE oxidized (2). A similar situation exists for PCE except that (1) suggests the formation of Cl_2. Based on thermodynamic considerations, it was assumed that the Cl_2 is an intermediate and that Cl^- would be the sole chlorine species present. Therefore, oxidation of 1 kg of PCE should produce 0.86 g Cl^-.

COLUMN EXPERIMENTATION: QUANTIFYING OXIDATION WITH CHLORIDE ION

Experimental Outline

Equations (1) and (2) suggest several possibilities for monitoring the progression of *in situ* oxidation applications. Some preliminary column experiments indicated that CO_2 in the gas and aqueous phases could be used as a reaction tracer during TCE oxidation but that this would be impractical in natural porous media containing carbonate minerals and natural organic matter. During these experiments significant gas production was observed; in one experiment, the extremely vigourous gas production actually disrupted the soil with the column. It was anticipated that measuring the variation in Cl^- in the effluent during oxidation would provide both a measure of the mass of TCE or PCE oxidized as well an indication of the relative rates of mass removal.

Chloride analyses were performed using an ORION ion selective electrode with a portable meter (ORION Model 720A). Measurements of $KMnO_4$ concentrations were performed either by titration with thiosulphate or spectrophotometrically (Spectronic 20D). Analysis of TCE and PCE was performed with a Shimadzu GC-9A gas chromatograph with a flame ionization detector and purge and trap unit operated according to EPA Method 601. During these experiments, the detection limits for PCE and TCE analyses were 10 µg/L.

To investigate the effects of oxidant concentration and flushing rates upon mass removal, five column experiments were performed using glass columns packed with fine grained sand samples (foc=0.02%) from the Canadian Forces Base (CFB) Borden aquifer. In each of the column experiments, the sand was initially saturated with water and 1.0 mL of PCE added as a residual source (volumetric saturation ~1%) in the sand. Figure 1 is a schematic diagram of the experimental apparatus. The columns were subsequently flushed with $KMnO_4$ solutions at the concentrations and average Darcy fluxes specified in Table 1. Actual flow rates into the columns were variable and were assumed to have produced the principal source of error. One column (COL 5) was flushed only with deionized water to evaluate mass removal by dissolution alone. After the oxidant flush, the columns were flushed with deionized water at the same flow rates. Control experiments confirmed that oxidation of the PCE was the only source of Cl^- from the columns.

(insert Figure 1 here)

(insert Table 1 here)

Figure 2 provides combined Cl^-, $KMnO_4$ and PCE effluent data for the experiment (COL 3) flushed at the highest oxidant loading and is qualitatively similar to results observed in the other columns. This column was flushed with an aqueous solution of 10 g/L $KMnO_4$ for a period of 214 hours and then deionized water for the remainder of the experiment.

(insert Figure 2 here)

In COL 3, PCE in the effluent was initially high (~50 mg/L). As the oxidant reached the source zone, Cl- increased rapidly from non-detectable levels to a peak of 380 mg/L. When oxidant appeared in the effluent, the PCE concentrations dropped below 1 mg/L. The concentration of chloride began to decrease after 70 hours of flushing and was less than 1 mg/L after 180 hours of flushing. This decline in Cl^- was accompanied by a gradual increase of $KMnO_4$ in the effluent to above 9 g/L after 200 hours (influent concentration of 10 g/L). The rate of PCE removal had reduced significantly after approximately 170 hours.

In COL 5, the PCE concentration in the effluent from the column reached an initial peak of approximately 100 mg/L, and then declined slowly to a concentration of approximately 6 mg/L after 650 hours. The dissolution profile from COL 5 is representative of rate limited dissolution for this particular experimental setting.

Effluent Cl^- and PCE effluent concentrations for each of the columns are shown in Figure 3a) and b). All of the columns flushed with oxidant initially produced no effluent Cl^-. Chloride concentrations then rapidly rose to a peak and then slowly declined to non-detectable levels. The two columns flushed at 10 g/L $KMnO_4$ producing larger chloride peaks. The initial delay in the appearance of Cl^- and $KMnO_4$ in the column effluents was attributed to displacement of the initial pore volume of deionized water and consumption of the $KMnO_4$ through oxidation of organic matter in the sand. In contrast, PCE concentrations in the columns flushed with oxidant were initially high (~100 mg/L) and then dropped below 1 mg/L. In each of these columns, the PCE concentrations tended to increase once the deionized water flush began suggesting that

some PCE remained; however relative to the column flushed only with deionized water, effluent PCE concentrations were 1 to 2 orders of magnitude lower.

(insert Figure 3 here)

The accumulated equivalent PCE mass produced from each column is presented in Figure 4; the mass of the initial PCE source was 1640 mg. The equivalent mass includes both effluent PCE and PCE oxidized calculated from Cl^- in the effluent. The mass balance over-estimates the initial mass of PCE from 103-122%. This error in the mass balance was attributed mainly to variability in the flow rates.

(insert Figure 4 here)

During the deionized water flush following $KMnO_4$ addition, the PCE concentration in the effluents from COL 1, 2 and 4 increased from about 0.3 mg/L to as high as 6 mg/L then decreased below the detection limit. COL 3, which had the highest oxidant loading, did not experience this rebound. While most of the PCE had been oxidized *in situ* , a small amount of PCE remained within each column; however, for COL 3 and COL 4 (both flushed at close to the same flow rate as the dissolution control) the final effluent PCE concentrations were about 1% of those in COL 5.

FIELD EXPERIMENTATION

Experimental Cell Details

Two pilot scale experiments were performed at the CFB Borden research site in an unconfined, shallow aquifer consisting of a glaciolacustrine sand (Bolha, 1986). The sand is predominantly a medium to fine grained and, while relatively homogeneous, contains numerous horizontal bedding features varying in thickness from millimeters to a few centimeters (Ball *et al.*,1990; Poulsen and Kueper, 1992). The mean hydraulic conductivity of the sand is 7.2×10^{-3} cm/s (Sudicky, 1986). The experimental cell, consisting of double-walled, sealed joint sheet piling (Starr *et al.*,1992) extended from the surface down to a clay aquitard at a depth of

approximately 2.5 m (Figure 5). The pore volume of the cell, estimated from the sand porosity of 0.33 (Ball *et al.*, 1992), was approximately 2.48 m^3.

(Insert Figure 5 here)

Six injection and six extraction wells (2 in ID PVC) were located at opposite ends of the cell as shown; these were screened at upper, intermediate, and lower depths with each pair of well screens extending over one third of the depth. Also shown in Figure 5 are the multilevel samplers which allowed collection of small volume samples from various points with the cell. The multilevel piezometers consisted of 0.06 in ID Teflon® tubes attached at 1 foot intervals to a central 0.5 in OD PVC pipe. The instrumentation was installed by simultaneously driving and jetting a 3 in ID steel casing to the required depth with a handheld vibrating hammer, inserting the well casing or multilevel stem, withdrawing the larger steel casing and allowing the formation to collapse around the instrument.

Sampling Methods

Sample collection from the multilevels was performed by connecting individual sample points to a 250 mL Erlenmeyer flask through a stopper. A vacuum was applied to the flask using a 50 mL syringe. Typically, 75-100 mL of sample was collected. Part of this volume was decanted into an 8 mL vial with Teflon® lined septa for TCE and PCE analysis. A small quantity of granular sodium thiosulphate was added to reduce any $KMnO_4$ and prevent further solvent oxidation. The remaining volume was stored in a 40 mL EPA vial for Cl^- analysis. Sample analyses were conducted using the previously mentioned analytical methods.

EXPERIMENT I: HOMOGENEOUS RESIDUAL SOURCE

The DNAPL source for Experiment I consisted of 1 L (1.64 kg) PCE which was mixed with soil taken from a 0.3 m x 0.3 m x 0.35 m block below the water table. The soil:DNAPL

mixture was replaced in the excavated block (Figure 5). The residual DNAPL saturation was estimated to be 8% (v/v). The cell was subsequently flushed with a 10 g/L aqueous solution of $KMnO_4$ through the injection wells; effluent was withdrawn from the extraction wells. Constant head was maintained in the injection wells by siphoning from a constant head reservoir into each well. Flow rates were controlled by a peristaltic pump at the extraction wells. Initially, both the upper and intermediate extraction wells were pumped at a total flow rate of approximately 100 L/day. After monitoring confirmed that oxidation was occurring only in the upper third of the cell, pumping from the intermediate extraction wells was stopped at 1200 hours with the new flow rate of 50 L/day from the upper wells. The cell was flushed with oxidant solution for 120 days and then with water for a further 60 days to displace the remaining oxidant and reaction products. Effluent from the cell was continuously treated to remove residual oxidant and aqueous phase PCE.

Chloride monitoring from the multilevel piezometers indicated that Cl^- was produced only in the upper third of the cell. After approximately 300 hours of flushing, a rapid increase in Cl^- was observed in MLC-1 (Figure 6). Over the remainder of the experiment, Cl^- concentrations at this point gradually declined to non-detectable levels. Using the Cl^- data from the extraction wells, the cumulative mass of effluent Cl^- was determined to be 1486 g or 91% of the chloride content of the initial source mass (Figure 7).

(insert Figure 6)

(insert Figure 7)

Several other quantitative measures were used to evaluate the effectiveness of this experiment. PCE was not detected during the post-oxidation water flush. As well, a core was removed from the source zone after the water flush from which subsamples were taken and analyzed for their PCE content. Solvent concentrations in these subsamples were below the method detection limit (<0.0003% w/w).

EXPERIMENT II: HETEROGENOUS NAPL SOURCE

Experiment II used a mixture of PCE and TCE as a source; source emplacement was designed to simulate a slow leak release. Six 2.5 cm ID stainless steel pipes, 1.0 m long and equipped with drive points, were driven to a depth of 0.25 m in the centre of the cell in the same location as the Experiment I source. Equal masses of TCE and PCE (6.19 kg each, 8.0 L in total) were mixed with Sudan IV and distributed equally into the six source points over a period of 9 days. Volatilization of the TCE/PCE mixture was minimized by adding it below the water table; however, some minor loss from the separatory funnels containing the mixture was likely. The DNAPL mixture was allowed to migrate within the cell for an additional 10 days before beginning *in situ* $KMnO_4$ oxidation.

No effort was made to determine the distribution of the DNAPL within the cell; however, DNAPL was withdrawn from several of the multilevel sampling points throughout the course of the experiment. Initially, pure phase was evident in all the MLW and MLC sampling points but as treatment proceeded, free product persisted at only the lowest point of the centre multilevel (MLC-5).

Treatment System

The treatment system was designed to supply $KMnO_4$ at a concentration of 10 g/L through all six injection wells at a total flow rate of 48 L/d using the system of peristaltic pumps and a constant head reservoir as in Experiment I.

In Experiment I, the effluent eventually contained unused oxidant at concentrations close to 10 g/L. An oxidant recycle system was used in Experiment II to reduce the amount of oxidant used and to eliminate the need for continuous effluent treatment. In this system (Figure 8), effluent was pumped through a coarse cartridge filter and discharged to a equalization and settling tank for removal of suspended $MnO_2(s)$ and other solids. The main effluent line was drained by gravity to the constant head injection reservoir. A sample loop from the main effluent line ran through a spectrophotometer and was used to monitor $KMnO_4$ concentrations. The spectrophotometer provided an input to a PID controller. In turn, the controller ran a peristaltic

pump which diverted a fraction of the main effluent flow to a column packed with crystalline $KMnO_4$. The discharge from the column produced an oxidant solution near solubility (64 g/L at 20°C (Perry *et al.*,1984)). This stream was mixed back into the main effluent line before the spectrophotometer sample loop.

(insert Figure 8 here)

Cl^- Concentration Profiles in Multilevels

Figure 9 presents data from MLC. Low background Cl^- concentrations (generally less than 20 mg/L) were observed prior to $KMnO_4$ addition. After $KMnO_4$ addition, substantial increases in Cl^- concentration were observed. At three levels (MLC-2, MLC-3 and MLC-5), concentrations exceeded 3000 mg/L, indicating that significant oxidation was occurring adjacent to these points.

(insert Figure 9 here)

MLC-1 and MLC-4 exhibited little evidence of oxidation. Each experienced a gradual increase in Cl^- but this was due principally to Cl^- in the recycled $KMnO_4$ solution. Cl^- concentrations at each of these two points were generally similar to the profile of injection feed concentrations indicating relatively little DNAPL oxidization at these depths.

Cl^- and Solvent Concentration Profiles in Extraction Wells

PCE concentration data from the extraction wells are presented in Figures 10; the data points are averages for the pair of wells at each depth. TCE concentrations (not shown) were generally similar but slightly higher. Some trends are evident in spite of high variability in the data. The highest concentrations of both solvents were observed in the upper wells. From 2000 to 2500 hr, the concentrations of PCE were in the 10 to 50 mg/L range. During this time, the effluent from the extraction wells was nearly colourless indicating that most of the $KMnO_4$ had

been consumed. Beyond this time, $KMnO_4$ concentrations began to increase in the effluent with a corresponding reduction in the PCE concentrations.

(insert Figure 10 here)

The PCE and TCE concentrations declined with time and after approximately 6000 hr, remained at concentrations less than 0.01 mg/L. At this point, the effluent had high $KMnO_4$ concentrations approaching the injected concentration.

Chloride concentrations (Figure 11) in all of the extraction wells increase over time due to the recycling of the Cl^- in addition to the oxidant. The changes in concentration relative the concentration of Cl^- injected in the cell provide some clue to the location of DNAPL mass. The intermediate and lower extraction well profile are similar to the injection feed profile suggesting the little mass removal is occurring in the lower two thirds of the cell; however, up to the end of the oxidant flush, the Cl^- concentration in the upper extraction well is higher than the injection feed indicating that some solvent mass is still being oxidized.

(insert Figure 11 here)

Chloride Mass Balance

Mass balance calculations based on Cl^- production were used to estimate the extent of DNAPL oxidation. With a single pass system, such as that used in Experiment I, the concentration of Cl^- in the effluent from the extraction wells was readily converted to an equivalent mass of TCE/PCE oxidized. However, the recycle system used in Experiment II complicated the mass balance calculations because of the recycling of Cl^- back into the cell.

In addition, problems with the reinjection equipment during the initial stages of treatment resulted in periodic effluent losses from the system. It was estimated that 1.1 kg of Cl^- or 11 % of the initial Cl^- mass were lost in this way.

An approximate method was used to estimate the mass of DNAPL oxidized based on Cl^- release. The averages of the last five effluent and the feed concentrations shown in Figure 12 were assumed to represent the average Cl^- concentration in the entire cell. The total pore

volume of the cell plus the liquid volume in the above ground treatment system, was estimated to be 2800 L. Based on this average, it was determined that approximately 51% of the Cl^- content of the original solvent source was present in this volume. Including the 11% Cl^- loss, approximately 62% of the initial mass of chlorine had been released by the oxidant flush.

(insert Figure 12 here)

DISCUSSION

While *in situ* oxidation removed substantial DNAPL mass in both field experiments, it is likely that the subsurface distribution of DNAPL had a significant effect on the rates of mass removal. In Experiment I, the residual PCE source was rapidly and completely oxidized, a reflection of the homogeneous distribution of the DNAPL as a residual with a relatively large surface area:volume (A:V) ratio which would allow rapid dissolution. As well, the aqueous phase permeability in the source area would be high relative to the permeability of source zones with high NAPL saturations. In more typical DNAPL sources, such has that used in Experiment II, non-wetting phase saturations would be highly variable and could possibly include pooled DNAPL above slight permeability contrasts. For example, in an experimental PCE release at a nearby location, PCE flow was found to be controlled by millimeter scale sand bedding structures with non-wetting phase saturations ranging from 1% to 38.1% (Kueper *et al.*, 1993). Experiment II, containing a variable DNAPL distribution, would likely have some fraction of the solvent source present in both high and low saturations. The low saturations would be readily oxidized (as in Experiment I) but mass removal of high saturation zones would be slow due both the lower aqueous phase permeability and lower A:V ratios. In the extreme case, where all the DNAPL is present as pools above low permeability zones and is occupying almost the entire pore space, mass removal would be limited by weak dispersive processes, resulting in lower mass removal from the source zone than achievable by advectively dominated flushing.

Successful prediction of overall rates of mass removal would require rate expressions for both non-equilibrium dissolution and oxidation. In the conceptual model (Figure 13) proposed in

this work to describe mass removal rates, dissolution mass transfer, driven primarily by aqueous phase PCE/TCE concentration gradients, is enhanced by the oxidation reaction which increases these gradients. As the aqueous solvent gradient is increased, the dissolution mass flux is increased. Simultaneously, the concentration gradient of the oxidant would be increased, causing an increase in oxidant mass flux towards the DNAPL:water interface.

(insert Figure 13 here)

The ability of *in situ* oxidation to remove PCE was clearly demonstrated in Experiment I. Based on the Cl^- mass balance, greater than 90% of the 1.64 kg emplaced mass was oxidized in 120 days; however, it was inferred from source sampling that 100% of the mass had actually been removed. The peak PCE concentration observed in the extraction wells at the beginning of this experiment prior to oxidation was 18 mg/L. Assuming that this effluent concentration remained constant, removal of the entire source by water flushing alone would require, at a minimum, 900 days. In agreement with the conceptual model of dissolution and oxidation as parallel kinetic processes, the oxidant flush was able to accelerate dissolution of this source by increasing the concentration gradients of both the dissolved phase solvent and the oxidant. It was evident from the Cl^- profiles that that mass removal tailed off after the peak, an indication that mass transfer rates during the oxidant flush were decreasing as DNAPL mass was removed. This would suggest that the mass transfer rate expressions currently in the published literature (e.g., Powers *et al.*, 1994; Geller and Hunt, 1993; Guiguer and Frind, 1994) might be applied to estimate dissolution mass transfer during an oxidant flush.

The release of Cl^- provided a measure of the spatial extent of source. During Experiment I, Cl^- production occurred only in the upper third of the cell zone and the treatment process was adjusted to limit flow to this area alone. In Experiment II, most of the oxidation again appeared to occur in the upper third of the cell based on the extraction well Cl^- profiles. The Cl^- concentrations in the multilevel samplers generally supported this; however, the highest Cl^- concentrations were observed in MLC-5. The same multilevel contained pure phase during the entire experiment. These data suggest that during the DNAPL release at the beginning of the experiment, a portion of the solvent mixture moved laterally from the injection points,

migrated down the multilevel stem and became immobilized at or below MLC-5. This is supported by other observations. During the experiment, Cl^- concentrations in the lower extraction wells, covering the vertical position of MLC-5, were only slightly different from the feed concentrations implying that little oxidation was occurring in the bottom third of the cell. This is consistent with the possibility of a small amount of DNAPL located right at the multilevel MLC 5 being oxidized to produce high localized Cl^- concentrations but only a small amount of Cl^- mass in the extraction wells. Short-circuiting down multilevel stems was also observed by Kueper *et al.* (1993).

Recycling of the oxidant was an effective method of reducing the amount of oxidant required and the degree of effluent treatment. Experiment I used approximately 80 kg of oxidant while Experiment II, with a substantially larger source mass, used almost 50 kg.

During Experimental I, it was expected that organic material and reduced mineral species in the Borden sand (foc=0.027% w/w, Ball *et al.*, 1990) would consume oxidant. The oxidant demand of the Borden sand in the cell was estimated, based on effluent $KMnO_4$ data (not shown) from Experiment I, to be, at most, 7 kg $KMnO_4/m^3$ Borden sand.

APPLICATION OF *IN SITU* OXIDATION AT INDUSTRIAL SITES

Experimentation with $KMnO_4$ has been limited to oxidation of TCE and PCE. While some other NAPL contaminants may be oxidizable (for example, other chlorinated alkenes), it is probable that many compounds will either be largely resistant to permanganate oxidation or oxidized to secondary organic compounds which may also be hazardous. This factor may make permanganate an unsuitable oxidant at field sites contaminated with solvent mixtures other than PCE and TCE. At field sites with complicated hydrogeology, the DNAPL source is likely to be spatially large with a complex distribution; a comprehensive site characterization program will be required to design of an injection system capable of supplying oxidant to the entire source while minimizing the volume of the treatment zone. At many sites, some DNAPL will be isolated from advective flow causing mass removal to be limited by diffusion of oxidant into that zone. In

these zones, it is possible that mass removal by oxidation will be faster than technologies such as cosolvent/surfactant flushing, due to the increased concentration gradients proposed in the conceptual model. In many cases, it may be that the application of *in situ* oxidation will rapidly remove the fraction of the DNAPL mass which has the largest driving potential for dissolution (large area to volume ratios in high permeability zones). Removal of this fraction could result in significant lowering of aqueous concentrations with only a modest reduction in DNAPL mass, which would be advantageous from both economic and risk based perspectives.

SUMMARY AND CONCLUSIONS

Laboratory and pilot scale field experiments were performed to evaluate the effectiveness of $KMnO_4$ flushing as a means of DNAPL source removal through *in situ* oxidation.

Column experimentation indicated that using the reaction product Cl^- was an effective means of following the progress of the oxidation reaction. Calculated mass balances based on Cl^- tended to overpredict mass removal; however, it was inferred from post-oxidation aqueous phase PCE concentrations that nearly complete removal of the PCE source was achieved. As well, mass removal was significant faster and aqueous phase PCE concentrations were one to two orders of magnitude lower than with aqueous flushing alone.

Two field experiments were completed within a section of the CFB Borden aquifer isolated by double walled sheet piling. In each experiment, monitoring of the process was accomplished by measurements of Cl^- concentrations in multilevel piezometers and extraction wells. In Experiment I with a emplaced residual PCE source, the oxidant flush removed 100% of the DNAPL mass, as determined by aqueous phase concentrations, a chloride mass balance, and source zone core samples. In Experiment II, using a heterogeneous source produced by slowly leaking PCE and TCE into the field cell, about 60% of the DNAPL mass was removed from the source. Several factors appeared to control the effectiveness of *in situ* oxidation at the field scale. The process of dissolution is the principal determinant of DNAPL mass removal rates. It was clear that the rate of dissolution during an oxidant flush is much more rapid than

during a water flush. Linked to the dissolution process is the distribution of the DNAPL and geologic heterogeneity. Complex distributions will require careful site characterization to design an effective oxidant injection system that is capable of delivering oxidant to the entire source zone.

Oxidant recycling was determined to be an effective and practical method of reducing both the total amount of oxidant required as well as the need for effluent treatment.

Chloride monitoring during each experiment was used to estimate the amount of mass destruction and also provided some indication of the location of the DNAPL.

The *in situ* oxidation technology has potential to be an effective means of removing DNAPL mass at rates much more rapid than conventional pump and treat strategies. It is unlikely that *in situ* oxidation could ever remove 100% of the contaminant mass at an actual field site within a realistic time frame; however, it is feasible that rapid removal of the more accessible DNAPL will result in lower plume concentrations subsequent to the chemical flush and reduce the time required for a subsequent pump and treat system. Further work characterizing the dissolution process from various DNAPL distributions during an oxidant flush is presently ongoing to adequately address both these possibilities.

ACKNOWLEDGEMENTS

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Table 1: Darcy flux and oxidant concentration for experimental columns

	COL 1	COL 2	COL 3	COL 4	COL 5
Darcy flux (cm/day)	42	42	63	68	61
$KMnO_4$ (g/L)	10	7.5	10	7.5	0
Oxidant loading ($g/cm^2 \cdot day$)	0.42	0.32	0.63	0.51	0
Total mass removed @650 hrs(%)	121	103	122	119	92
%Mass removed as chloride	92	91	96	93	0

(Note: The cross sectional area of each column was 20.3 cm^2; porosity 0.41)

Figure Captions

Figure 1 Column apparatus; source consists of homogeneous PCE residual (1640 mg).

Figure 2 Column effluent profiles for Cl^-, PCE, input $KMnO_4$ and effluent $KMnO_4$. Also shown are effluent PCE concentrations for COL 5, which was flushed only with deionized water to compare mass removal by dissolution alone.

Figure 3 a) Effluent chloride concentrations (COL 1-4) and b) effluent PCE concentrations (COL1-5).

Figure 4 Accumulated effluent Cl^- mass as a fraction of initial Cl^- mass in column. The accumulated mass remove includes both aqueous PCE and equivalent PCE mass oxidized as calculated from Cl^- data. The initial PCE mass was 1640 mg.

Figure 5 Schematic of experiment cell at CFB Borden field site, including a) plan view and b) cross section, illustrating location of instrumentation and NAPL sources.

Figure 6 Chloride concentrations observed at MLC-1, directly downgradient of the residual PCE source.

Figure 7 Accumulated PCE mass destruction calculated based on observed chloride concentrations.

Figure 8 Treatment schematic for Experiment II oxidant recycle system.

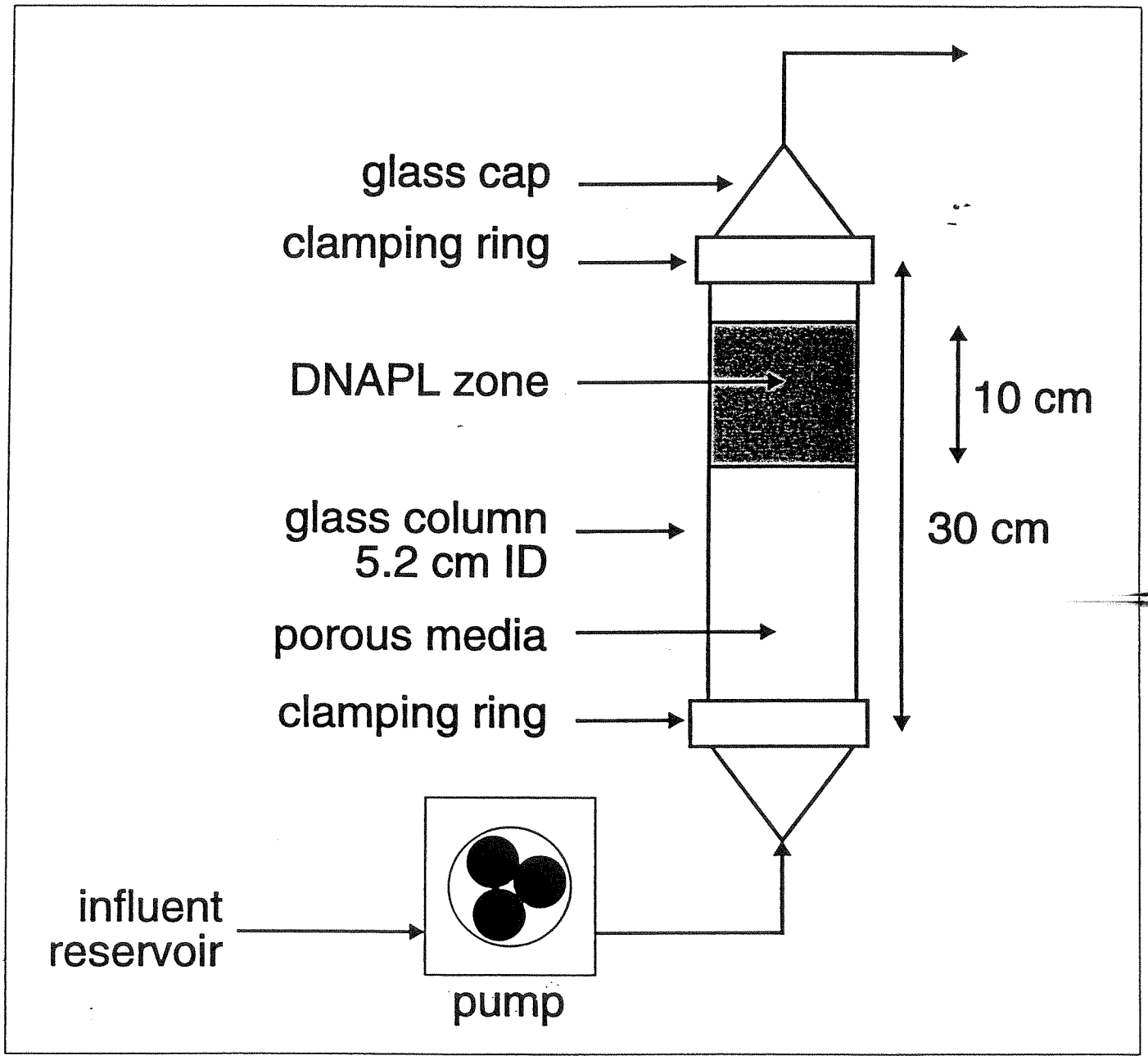
Figure 9 Chloride concentrations observed in MLC (MLC 1 is the shallowest; MLC 5 is the deepest). The heavy line represents the variation of Cl^- in the injected oxidant solution.

Figure 10 Effluent PCE in the three pairs of extraction wells (highest relative concentrations in the upper pair).

Figure 11 Chloride concentrations observed in the extraction wells.

Figure 12 Average effluent and injection feed chloride concentrations used to estimate total chloride mass in system.

Figure 13 Conceptual model describing mass removal by in situ chemical oxidation.


glass cap
clamping ring
DNAPL zone
glass column
5.2 cm ID
porous media
clamping ring
10 cm
30 cm
influent
reservoir
pump

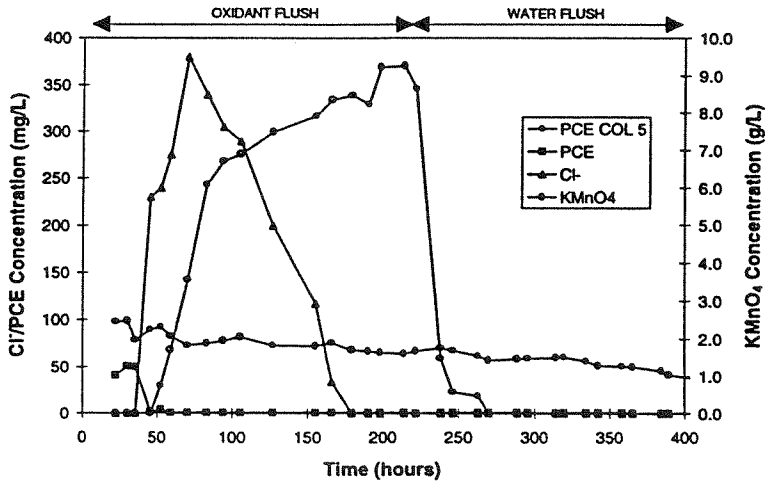

OXIDANT FLUSH
WATER FLUSH
Cl-/PCE Concentration (mg/L)
KMnO4 Concentration (g/L)
Time (hours)
PCE COL 5
PCE
Cl-
KMnO4
0
50
100
150
200
250
300
350
400
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

Fig 2

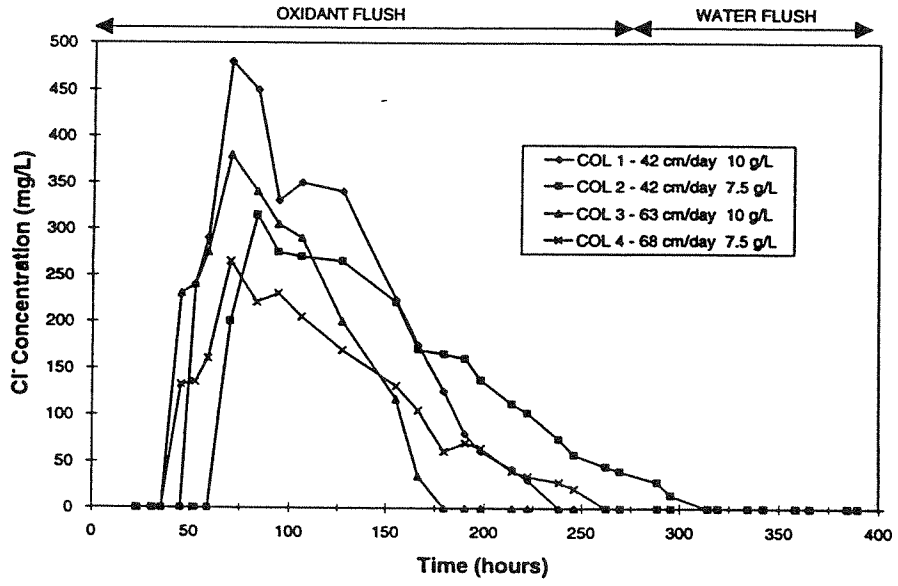

OXIDANT FLUSH
WATER FLUSH
Cl⁻ Concentration (mg/L)
Time (hours)
COL 1 - 42 cm/day 10 g/L
COL 2 - 42 cm/day 7.5 g/L
COL 3 - 63 cm/day 10 g/L
COL 4 - 68 cm/day 7.5 g/L
0
50
100
150
200
250
300
350
400
450
500

Fig 3a)

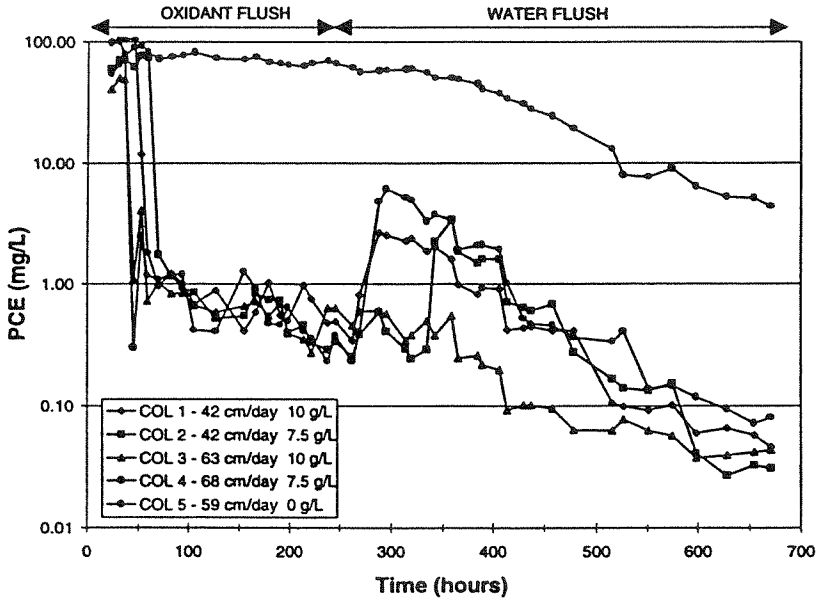

OXIDANT FLUSH
WATER FLUSH
100.00
10.00
1.00
0.10
0.01
PCE (mg/L)
0
100
200
300
400
500
600
700
Time (hours)
COL 1 - 42 cm/day 10 g/L
COL 2 - 42 cm/day 7.5 g/L
COL 3 - 63 cm/day 10 g/L
COL 4 - 68 cm/day 7.5 g/L
COL 5 - 59 cm/day 0 g/L

Fig 3b)

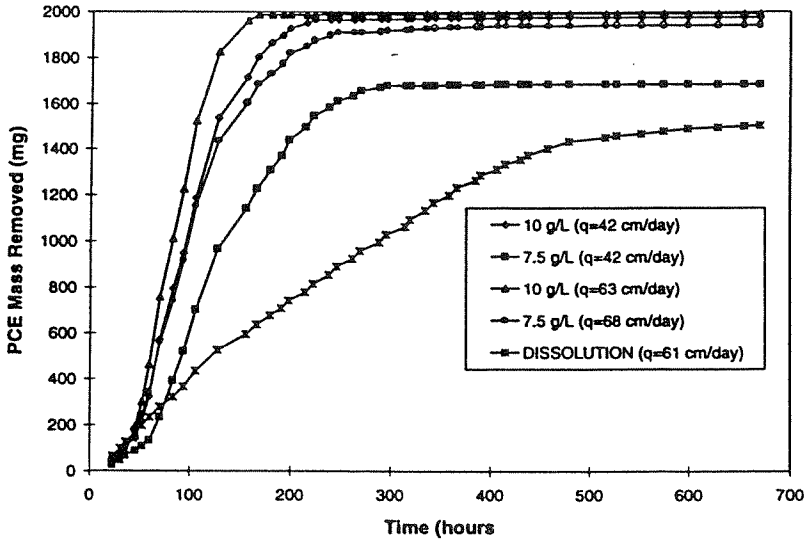
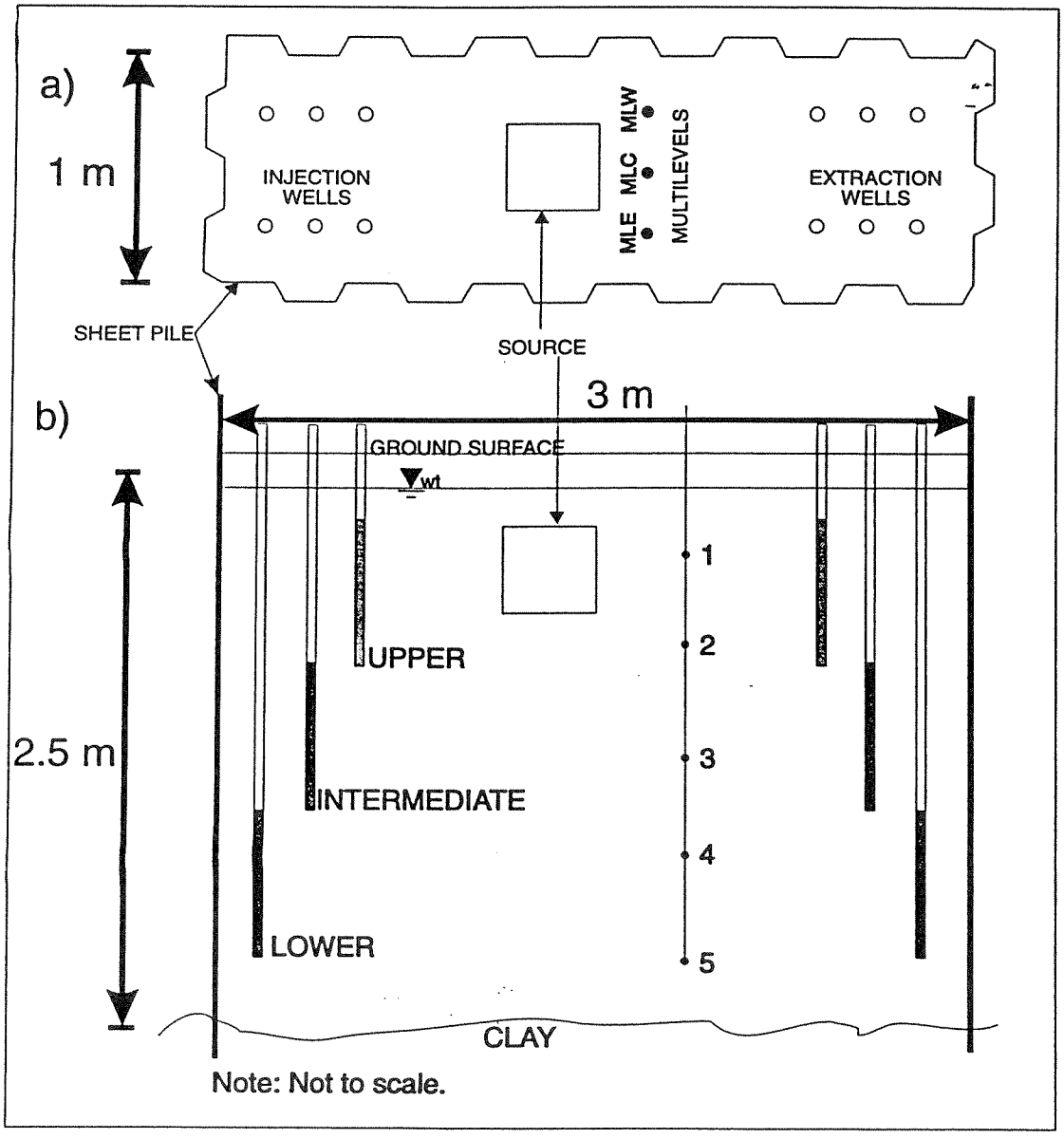

PCE Mass Removed (mg)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
100
200
300
400
500
600
700
Time (hours
10 g/L (q=42 cm/day)
7.5 g/L (q=42 cm/day)
10 g/L (q=63 cm/day)
7.5 g/L (q=68 cm/day)
DISSOLUTION (q=61 cm/day)

Fig 4


a)
1 m
INJECTION WELLS
MLE MLC MLW
MULTILEVELS
EXTRACTION WELLS
SHEET PILE
SOURCE
b)
3 m
GROUND SURFACE
wt
1
2
UPPER
2.5 m
3
INTERMEDIATE
4
LOWER
5
CLAY
Note: Not to scale.

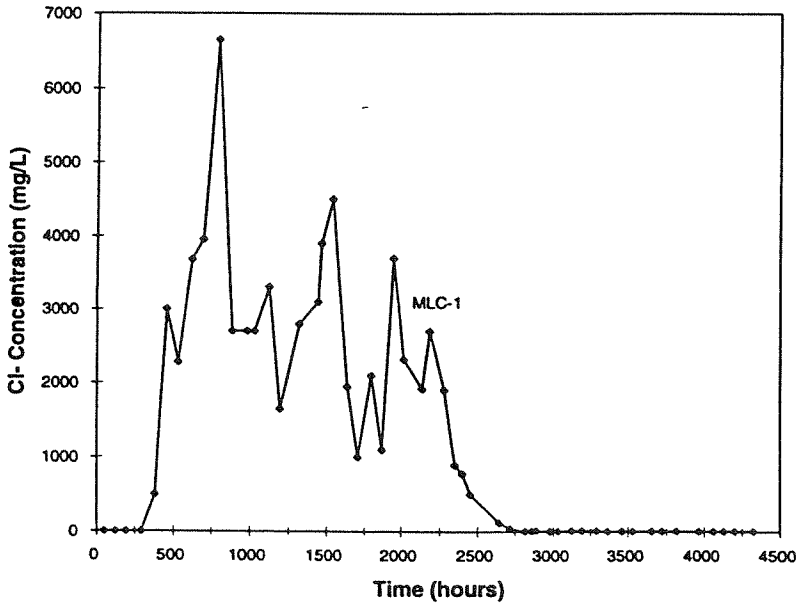

Cl- Concentration (mg/L)
7000
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (hours)
MLC-1

Fig 6

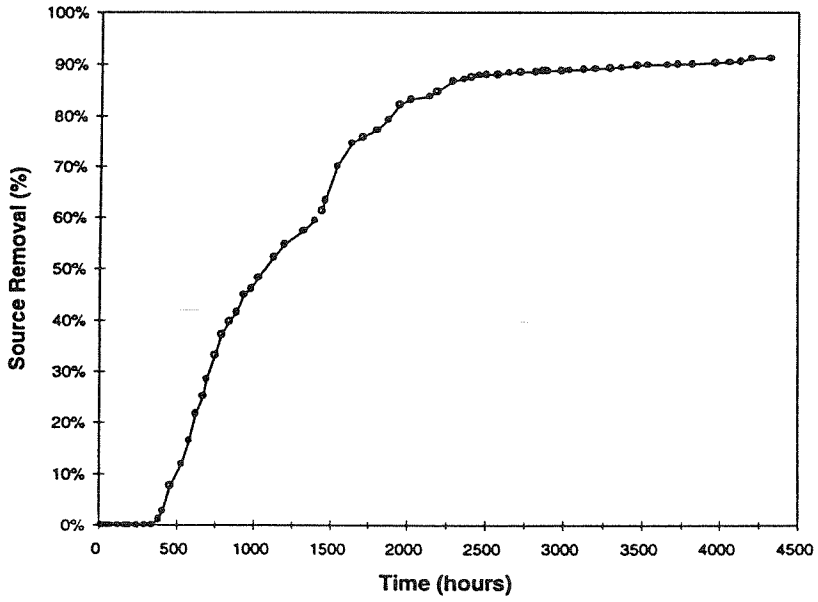
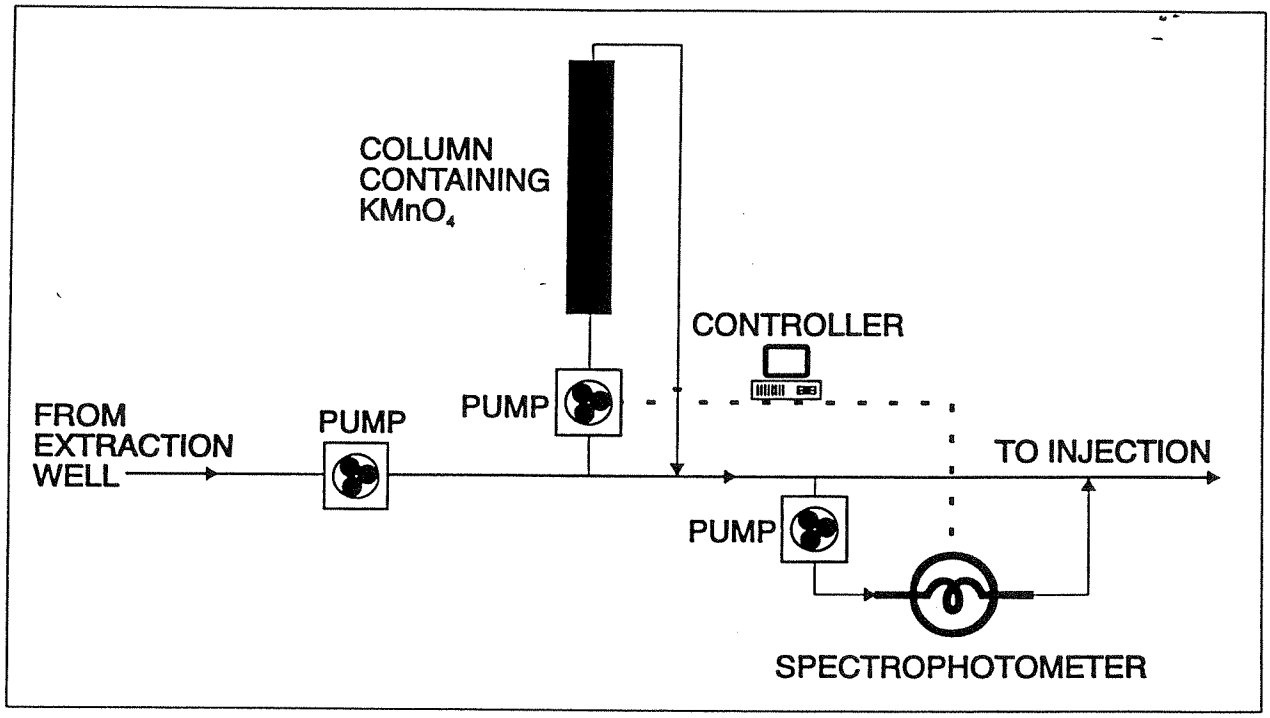

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Source Removal (%)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Time (hours)

Fig 7


COLUMN
CONTAINING
$KMnO_4$
CONTROLLER
FROM
EXTRACTION
WELL
PUMP
PUMP
PUMP
TO INJECTION
SPECTROPHOTOMETER

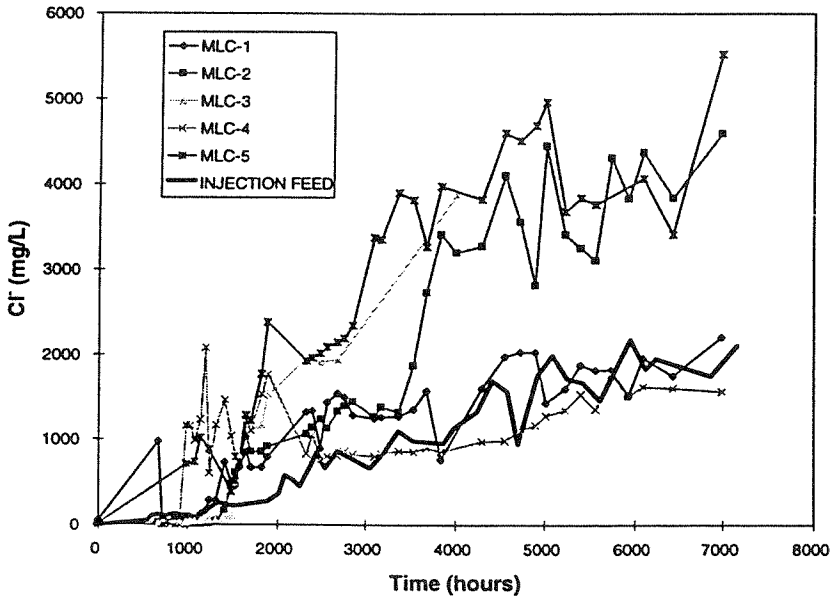
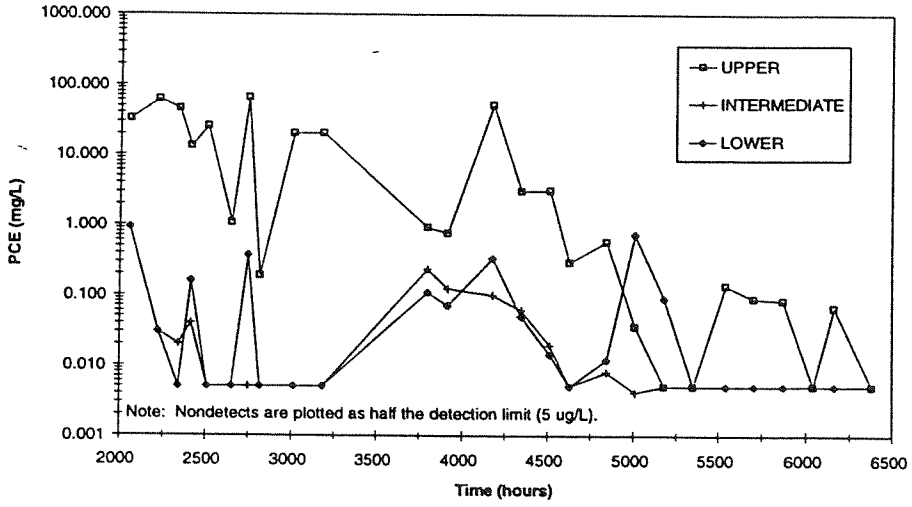
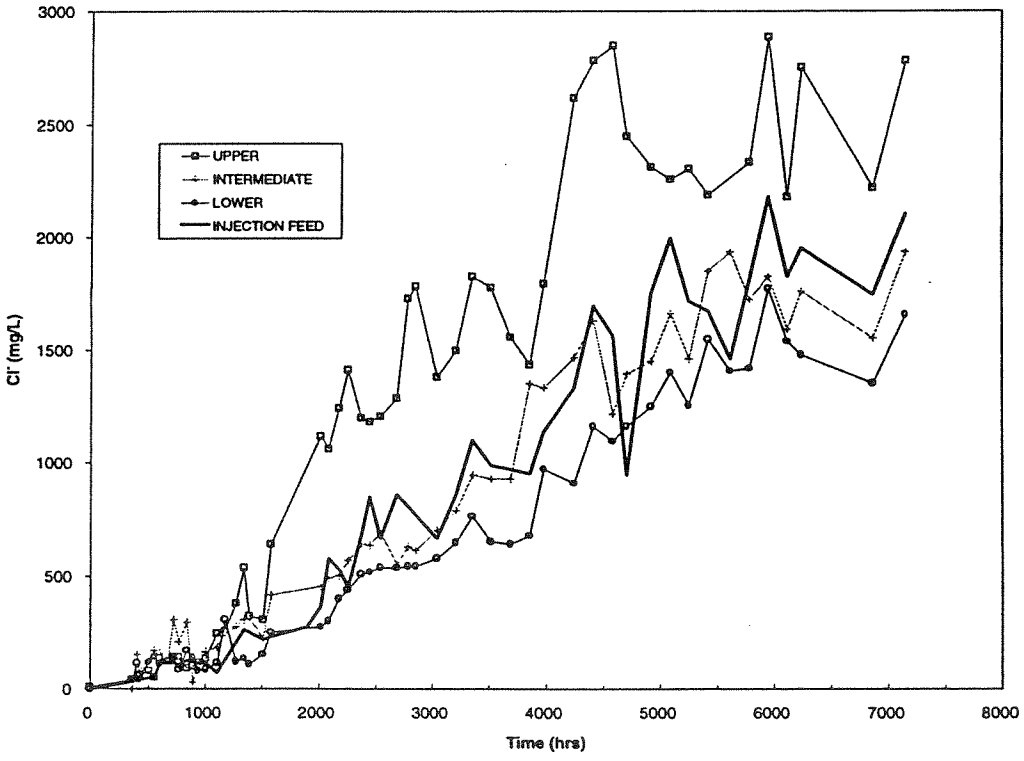
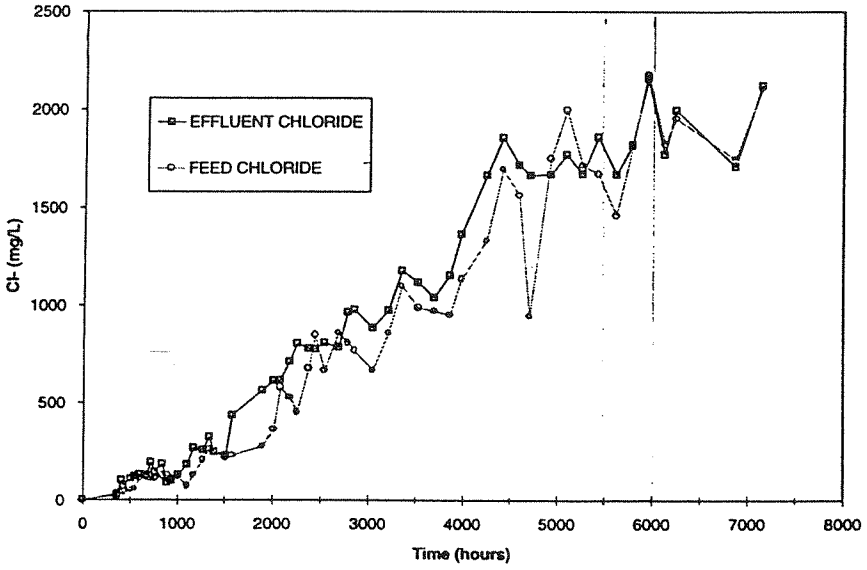

MLC-1
MLC-2
MLC-3
MLC-4
MLC-5
INJECTION FEED
Cl⁻ (mg/L)
Time (hours)
0
1000
2000
3000
4000
5000
6000
7000
8000

Fig 9.


1000.000
100.000
10.000
1.000
0.100
0.010
0.001
PCE (mg/L)
UPPER
INTERMEDIATE
LOWER
Note: Nondetects are plotted as half the detection limit (5 ug/L).
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
Time (hours)


UPPER
INTERMEDIATE
LOWER
INJECTION FEED
Cl⁻ (mg/L)
Time (hrs)
0
500
1000
1500
2000
2500
3000
0
1000
2000
3000
4000
5000
6000
7000
8000


2500
2000
1500
1000
500
0
Cl- (mg/L)
EFFLUENT CHLORIDE
FEED CHLORIDE
0
1000
2000
3000
4000
5000
6000
7000
8000
Time (hours)

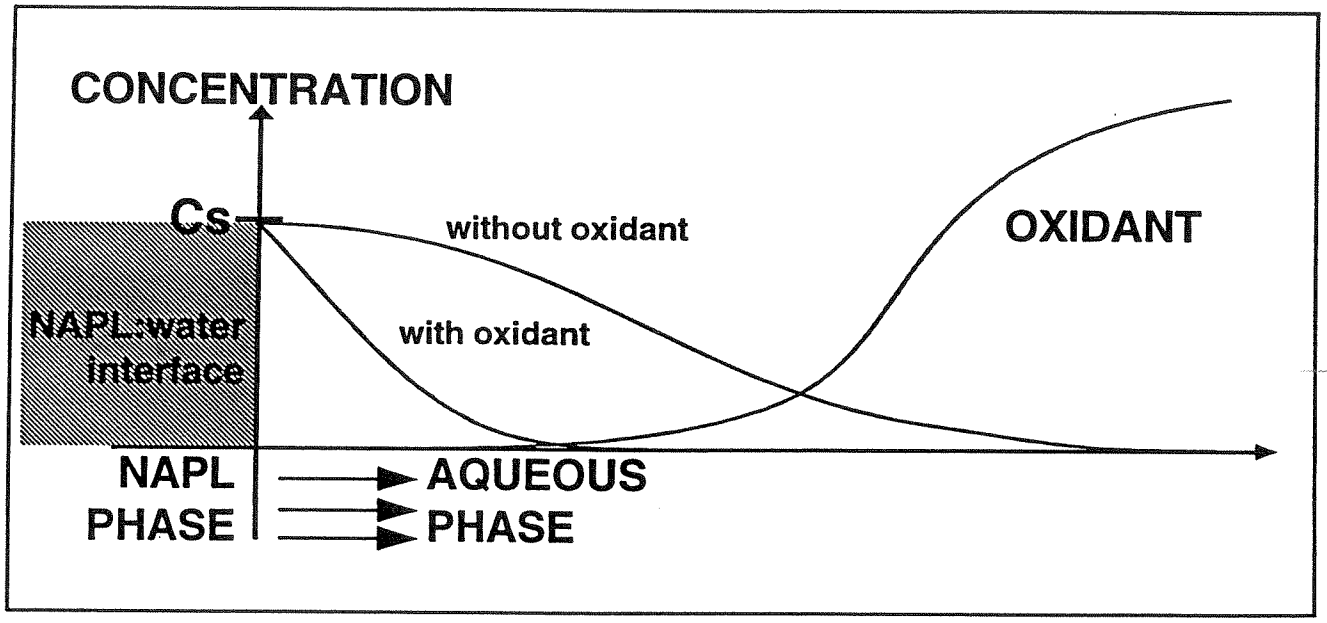

CONCENTRATION
Cs
without oxidant
with oxidant
OXIDANT
NAPL:water interface
NAPL PHASE
AQUEOUS PHASE

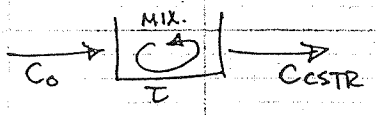
Fig 13

OBJECTIVE: Calculate the number of tanks required to meet the treatment system effluent requirement for PCE (3 µg/L).

ASSUME:
- Treatment system influent is 5000 µg/L
  based upon pilot test operation, this is a good assumption.
- Total flow to treatment system is 15 gpm.
  based upon Visual Modflow results.
- Tanks hold 1500 gallons
  based upon use during pilot test.
- Reaction rate constants are as given in the included figures, and are based on Carus laboratory testing data, which is also included.
- First tank can be represented as a CSTR, since water is pumped from it, dosed with $KMnO_4$, then pumped back in the first tank, creating a mixing effect. This effect is assumed to be similar to mixing with an agitator.
- Tanks are in series.

CALC'S: residence time, τ = 1500 gal. / 15 gpm = 1.67 hr.

for the first tank (CSTR), $\frac{C_{CSTR}}{C_o} = \frac{1}{1+k\tau}$



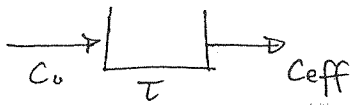
Assume C_o = 5000 µg/L, τ = 1.67 hr, k = 0.91/hr ($KMnO_4$ dose of 1 g/L)

then: $\frac{C_{CSTR}}{C_o} = \frac{1}{1+k\tau}$

$C_{CSTR} = C_o/(1+k\tau) = 5000/[1+(0.91)(1.67)] = 1987$ µg/L ✓

The rest of the tanks are unstirred, or plug-flow.

for PFRs, $\frac{C_{eff}}{C_o} = e^{-k\tau}$



for n PFRs in series, $\frac{C_{eff}}{C_o} = (e^{-k\tau})^n$

The objective is to achieve $C_{eff} \leq 3$ µg/L.

Assume $C_o = C_{CSTR} = 1987\ \mu g/L$, $\tau = 1.67$ hr, $k = 0.91/hr$, $C_{eff} = 3\ \mu g/L$.
then the number of tanks (PFRs) required to achieve 3 µg/L is:

$$\frac{C_{eff}}{C_{CSTR}} = (e^{-k\tau})^n$$

$$\frac{3}{1987} = \left(e^{-(0.91)(1.67)}\right)^n$$

$$\ln\left(\frac{3}{1987}\right) = -(0.91)(1.67)n$$

$n = 4.27 \sim 5$ PFRs required to achieve 3 µg/L (6 tanks total, including CSTR). ✓

This is too many tanks. Try a higher $KMnO_4$ dose of 1.5 g/L, thus $k = 1.365/hr$. (see "PCE $KMnO_4$ Oxidation Kinetics" figure)

Assume $C_o = 5000\ \mu g/L$, $\tau = 1.67$ hr, $k = 1.365/hr$

then for CSTR: $C_{CSTR} = C_o/(1 + k\tau)$

$$C_{CSTR} = 5000/[1 + (1.365)(1.67)] = 1527\ \mu g/L.$$

for PFRs: $\frac{C_{eff}}{C_{CSTR}} = (e^{-k\tau})^n$.

$$\frac{3}{1527} = \left(e^{-(1.365)(1.67)}\right)^n$$

$$\ln\left(\frac{3}{1527}\right) = -(1.365)(1.67)n$$

$n = 2.74 \sim 3$ PFRs required (4 total, incl CSTR) ✓

This number is more reasonable. Note that C_o will decrease with time and system flow will decrease as well since deeper zone will be treated more quickly than the shallow zone (because hydraulic conductivity is 4X greater), thus $KMnO_4$ dose will be decreased accordingly.

Therefore, the PCE effluent concentration with 1 CSTR, 3 PFRs is:

$$\frac{C_{eff}}{C_{CSTR}} = (e^{-k\bar{t}})^n$$

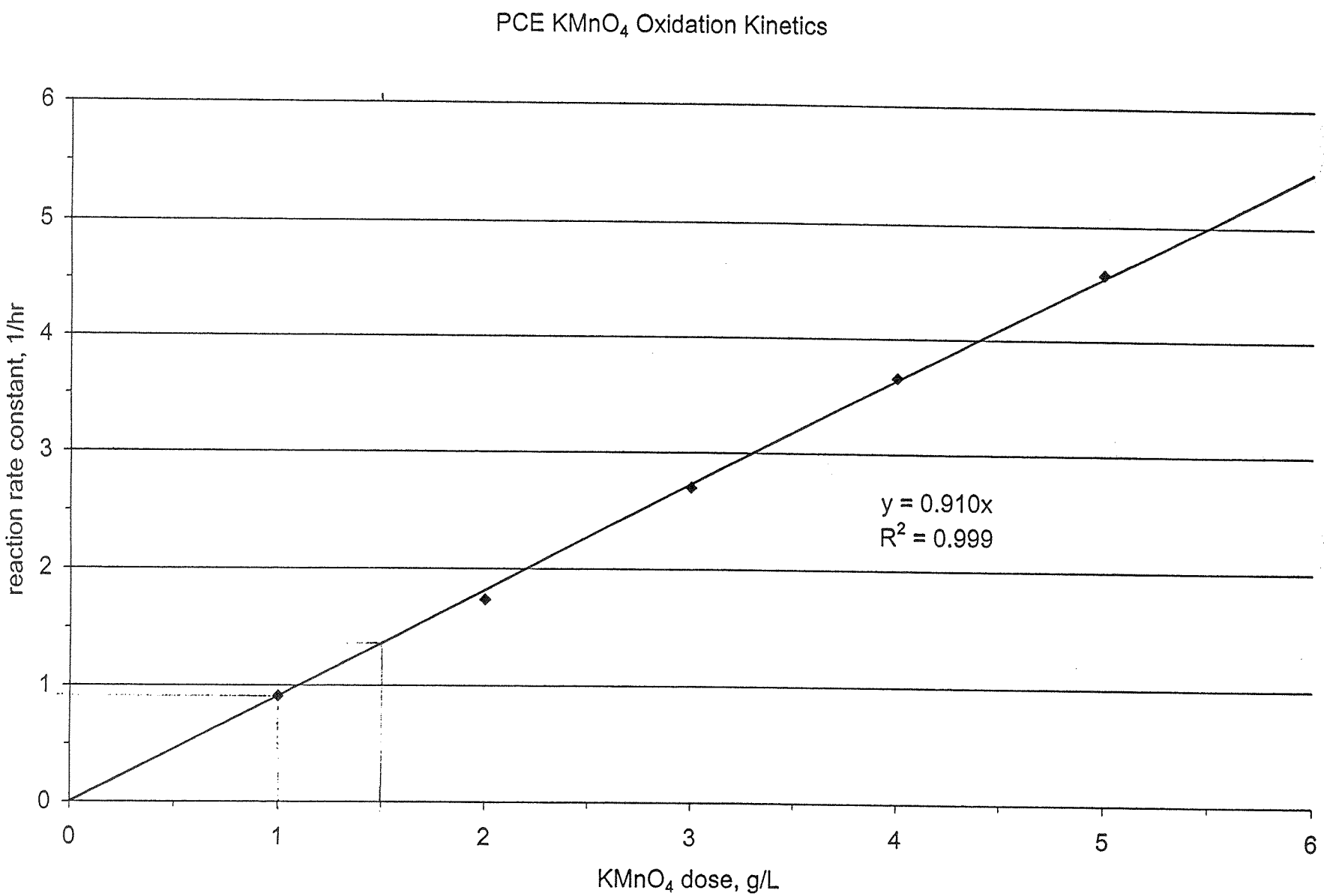
$$C_{eff} = C_{CSTR}(e^{-k\bar{t}})^n$$

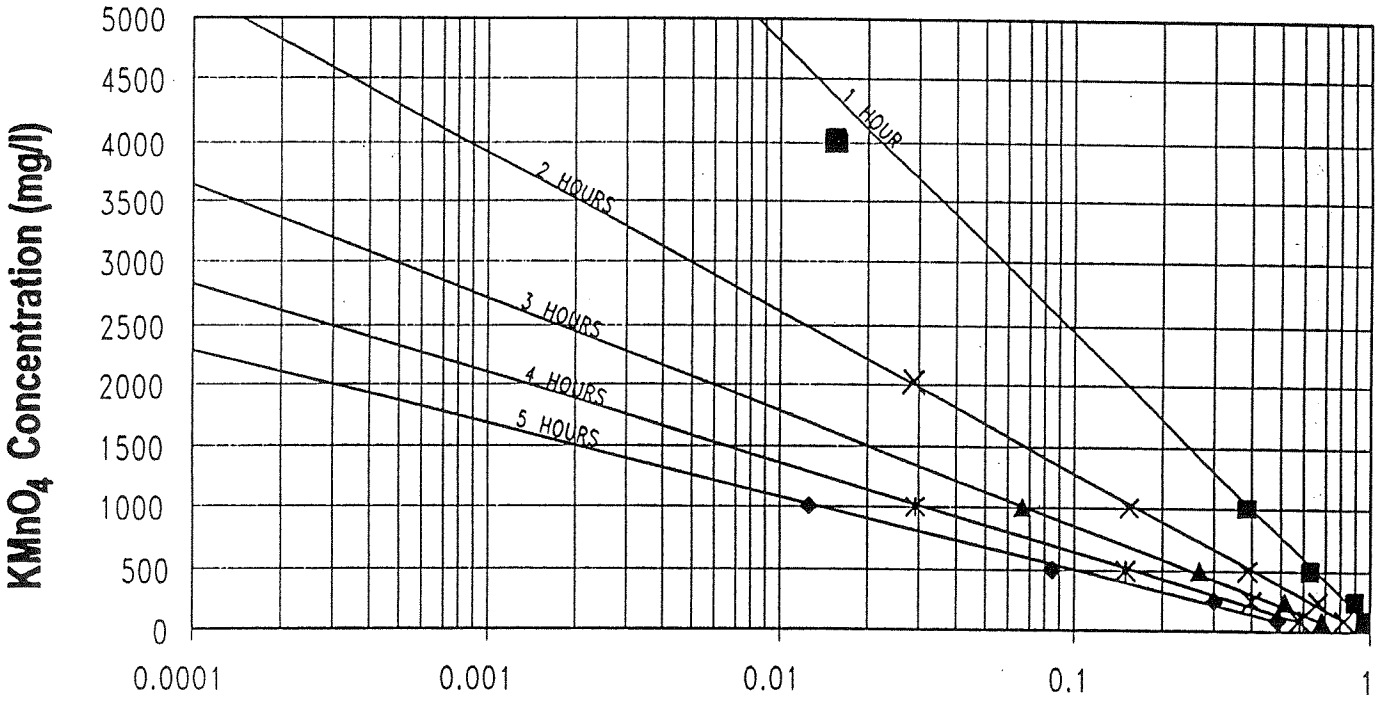
$$C_{eff} = (1527)(e^{-(1.365)(1.67)})^3$$

$$C_{eff} = 1.66\ \mu g/L$$

The objective of $\leq 3\ \mu g/L$ of PCE in the effluent will be met with 1 CSTR, 3 PFRs at a $KMnO_4$ dose of 1.5 g/L.

X
WAM


PCE KMnO4 Oxidation Kinetics
reaction rate constant, 1/hr
KMnO4 dose, g/L
y = 0.910x
R2 = 0.999
0
1
2
3
4
5
6



LEGEND

◆	5 Hours
✳	4 Hours
▲	3 Hours
×	2 Hours
■	1 Hour
mg/l	Milligrams per liter
$KMnO_4$	Potassium permanganate
PCE	Tetrachloroethene

FIGURE 2-1
PCE OXIDATION RATES

R:\02545\02545-10\IHS\02545584.DWG, VC-VC 09/03/98 14:39:09, ACAD14

TREATABILITY STUDY WORK PLAN NO. 3
DATA COLLECTION PLAN FOR ASSESSING
IN SITU CHEMICAL OXIDATION USING
POTASSIUM PERMANGANATE, OPERABLE UNIT 4
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

Harding Lawson Associates
Engineering and Environmental Services

SHEET 1 OF 5
JOB NO. 44241/02545550
DATE December 8, 1999
COMPUTED BY MMR
CHECKED BY MMM

PROJECT NTC Orlando OU4
SUBJECT CSTR Reactions

Objective: Look at $KMnO_4$/PCE reaction rates and calculate CSTR performance.

Calculate Reaction Rate Constants

Literature indicates reaction is First Order:

$$-\ln \frac{C_A}{C_{A0}} = kt$$

For 1000 mg/L $KMnO_4$ (Data from bench-scale tests)

T = 1hr; $-\ln \frac{C_A}{C_{A0}} = -\ln\left(\frac{1.225}{3.170}\right) = 0.951$

$0.951 = k(1\text{hr})$

$k = 0.951\ hr^{-1}$

T = 2hr (Data From App. B)

$\left(\ln \frac{0.486}{3.147}\right) = 1.868$

$1.868 = k(2\text{hr})$

$k = 0.934\ hr^{-1}$

T = 3hr (Data From Fig 2-1)

$-\ln(0.067) = 2.70$

$2.70 = 3k$

$k = 0.90\ hr^{-1}$

T = 4hr (Data From Fig 2-1)

$-\ln(0.029) = 4k$

$k = 0.89\ hr^{-1}$

T = 5 (Data From App. B)

$-\ln(0.0127) = 5k$

$k = 0.873\ hr^{-1}$

Ave = 0.91

Harding Lawson Associates
Engineering
and
Environmental Services

SHEET 2 OF 5
JOB NO. 44241/025455D
DATE December 8, 1999
COMPUTED BY MLR
CHECKED BY

PROJECT UTC Orlando OU4
SUBJECT CSTR Reactions

For 2000 mg/l (Pull data off Figure 2-1)

T= 1 hr; $C_A/C_0 = 0.161$

$-\ln(0.161) = k$

$k = 1.83$

T= 2 hr

$-\ln 0.029 = 2k$

$k = 1.77$

T= 5 hr

$\ln(0.0003) = 5k$

$k = 1.62$

} Ave = 1.74 ✓

For 3000 mg/l (Pull Data off Fig 2-1)

T= 1 hr

$-\ln(0.058) = k$

$k = 2.85$

T= 3 hr

$-\ln(0.00048) = 3k$

$k = 2.55$

} Ave = 2.70 ✓

For 4000 mg/l (Pull Data off Fig 2-1)

T= 1 hr

$-\ln(0.0225) = k$

$k = 3.79$

T= 2 hr

$-\ln(0.00087) = 2k$

$k = 3.53$

} k = 3.66

Harding Lawson Associates
Engineering
and
Environmental Services

SHEET 3 OF 3
JOB NO. 44241/0254550
DATE December 8, 1999
COMPUTED BY [illegible]
CHECKED BY [illegible]

PROJECT NTC Orlando OU4
SUBJECT CSTR Reactions

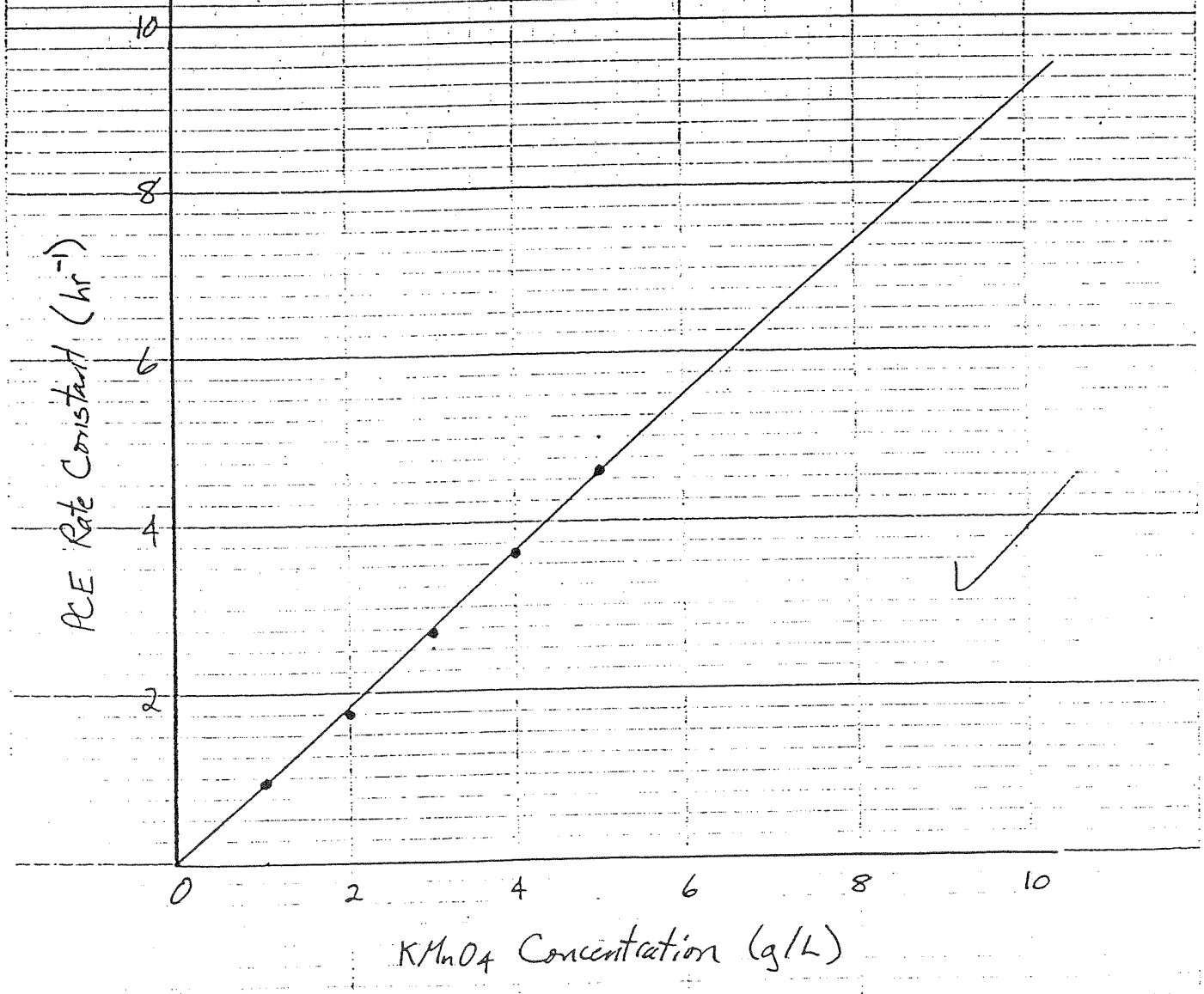
For 5000 mg/l (Pull Data Off Fig 2-1)

T = 1 hr
$-\ln(0.0085) = k$
$k = 4.77$

T = 2 hr
$-\ln(0.00015) = 2k$
$k = 4.39$

Ave = 4.58

PCE $KMnO_4$ Rate Constant



Have 4 recirc wells located around the source area.
Each approx. 40-45 feet deep.

Costs

Well Drilling
Well Vaults
Well Internals
Carbon (How long?)
Monitoring Network

O+M

Well Costs

Drill each well using cable tool @ $25K each
Each well has two piezometer pairs with Trolls.
Assume each Troll is $1500 (check with Bill Olson in Orlando)

Well Vault

Based on Cecil Field Cost from Joe Ulo

Mob/Demob $1000
Each Vault $14,400 x 4 ⇒ Total = $58,600
Ave Cost = 58,600/4 = $14,650

Well Internals

Costing Cecil Field ~ $75K to lease for 6 months.
Includes well internal installation. Not sure what the price to own would be.

Go with cost from Scott Bostiam in FGS quote dated 4/14/98.

Each UVB (Internal Hardware Only) = $52K

Well Development

Assume 3 days to develop each well.
= 90 manhours @ $35/hr = $3150

Controls

Assume $10K per well (each well is stand-alone)
Telemetry - $5K total

O+M

Recirc wells should work faster than conventional pump + treat due to the vertical flow, but how much faster?
After discussing with Willard + the OU4 team, we decided to assume 4 times faster.

∴ Achieve MCLs = $\frac{108 \text{ yrs}}{4} = 27$ years

∴ Achieve SW Standards with UA = $\frac{59}{4} = 15$ yrs

O+M Costs

We decided one recirc well $25K/yr
Each additional recirc well $15K/yr } No electricity

Assume also incl. Fe sequestering chemicals

These costs do not include carbon (see below)

Carbon

Calculate P+T would emit a max of 3.6 lb/day total VOCs.
∴ Recirc wells could release 4 × 3.6 = 14.4 lb/day, which exceeds Florida limit of 13.7 lb/day.
This emission rate will decrease over time.

Carbon cost assumes one carbon canister per recirc well. These canisters will be removed after one year.

MHD Wellesley : 1000 lb Granular GAC : $4000

DETAILED DESCRIPTION OF WORK

1. Excavate for well vault.
2. Dewater for well vault.
3. Backfill and compact around vault.

8'x8'x7' with aluminum hatch $17,800.00
8'x10'x7' with aluminum hatch $18,950.00

Post-it™ Fax Note 7671

To MARK SALVETTI	Date 12/22 # of pages ▶ 3
Co./Dept. MARK	From JOE ULLO
Phone # CK YOUR	Co.
Fax # E-MAIL	Phone #
	Fax #

CONDITIONS OR EXCLUSIONS

1. No permits included.
2. Grout filling around 10" casing not included.
3. Full opening hatch included on both bids.

We thank you for the privilege of quoting on the above described work. To indicate acceptance, please sign and return one copy.

Signed _____

By _____

Date _____

A. J. JOHNS, INC.
3225 Anniston Road
Jacksonville, Florida 32246-3696
(904) 641-2055

By [signature]

(Off. Use only Q1-wfirs-Q-HAon29.98)dlj

A. J. JOHNS, INC.

3225 Anniston Road - Jacksonville, Florida 32246 - (904) 641-2055

FACSIMILE COVER SHEET

DATE: Nov 4, 1998 TIME: 8:30 am

TO: Joe Ullo FROM: Marty Adams

FAX NUMBER: 850-656-3386 FAX NUMBER: (904) 641-2102

REGARDING: Cost Break Down on Cecil Feild Well Vault

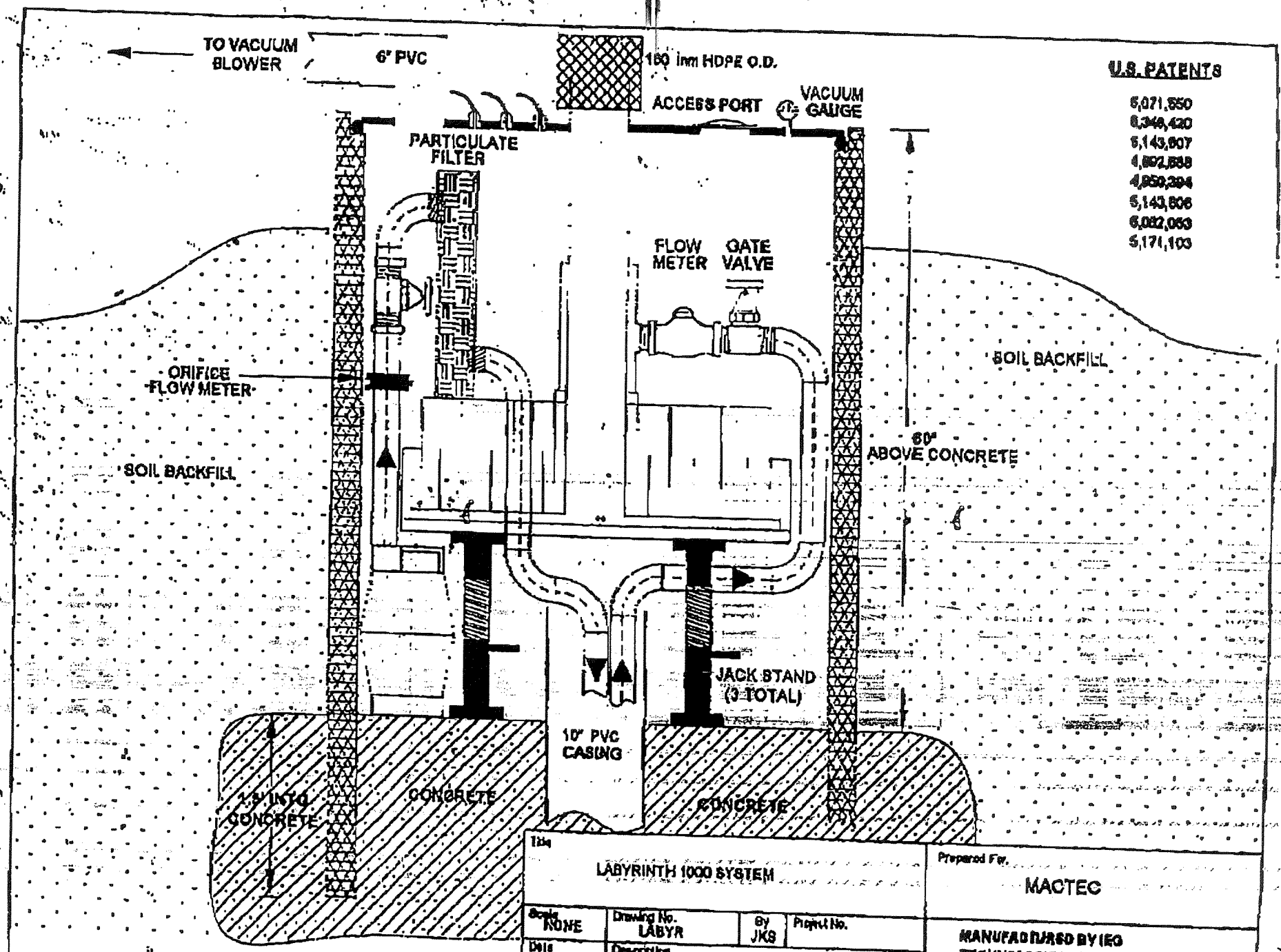
MESSAGE: Mobilize $1000.00
Set Well Vault, Excavation, Box, Hatch for 8'-8'-7' 14,400.00
Necessary Dewatering for Well Vault 2,400.00

Joe Sorry about the delay, If you have any questions give me a call. Thanks, Marty Adams

NUMBER OF PAGES INCLUDING COVER SHEET: 1

IF YOU HAVE TROUBLE RECEIVING THIS FACSIMILE, PLEASE CALL (904) 641-2055.

Marty Adams
PERSON SENDING FACSIMILE


TO VACUUM BLOWER
6" PVC
160 mm HDPE O.D.
ACCESS PORT
VACUUM GAUGE
PARTICULATE FILTER
FLOW METER
GATE VALVE
ORIFICE FLOW METER
SOIL BACKFILL
SOIL BACKFILL
60" ABOVE CONCRETE
JACK STAND (3 TOTAL)
10" PVC CASING
CONCRETE
CONCRETE
U.S. PATENTS
5,071,550
5,143,607
5,143,806
5,171,103
Title
LABYRINTH 1000 SYSTEM
Prepared For
MACTEC
Scale
NONE
Drawing No.
LABYR
By
JKS
Project No.
Date
12/2/98
Description
LABYRINTH 1000 SYSTEM
MANUFACTURED BY IEG TECHNOLOGIES CHARLOTTE, N.C. AND IEGmbh GERMANY

FGS-Jacksonville, Inc.

Environmental Evaluations • Remediation • Emergency Response • Industrial Hygiene • Training

April 14, 1998

Mr. Scott Bostian
ABB Environmental Services, Inc.
2590 Executive Center Circle East
Tallahassee, Fl 32301

RE: Conceptual Design and Budgetary Cost Estimate
Dixie Cleaners
Jacksonville, FL

Dear Mr. Bostian:

FGS-Jacksonville, Inc., (FGS-JAX), is pleased to provide **ABB Environmental Services Inc. (ABB)** with the enclosed Conceptual Design and Budgetary Cost Estimate that you requested for the referenced site cleanup project. Based on the information provided and the magnitude of this site restoration effort, FGS-JAX recommends a phased approach.

The first phase would include conducting a 1 Day Pilot/Feasibility Study in the impacted aquifer zone. The results of the pilot test will be used to evaluate the effectiveness of the proposed circulation cell remediation technology.

Based on the success of the Feasibility Study and review of additional site specific hydrogeologic and environmental impact data, a corrective final remedial design will be generated. FGS-JAX will develop the remedial action plan and specify the equipment selection based on the results of the feasibility studies, comprehensive hydrogeologic and environmental impact data and **ABB's** interpretation of the hydrogeologic conditions and extent of the contaminant plume in the vadose and saturated zone.

The second phase will involve implementation of the Full Scale Remedial Action Program.

This phased approach allows the FDEP and **ABB** to investigate and evaluate viable remedial alternatives and consider our advanced, more cost-effective technology, with limited financial exposure. Approximate costs for Full Scale Remediation are provided separately for your consideration.

Following your review of the enclosed cost proposal and conceptual design, the next step might be a meeting with **ABB** and FGS-JAX individuals to further review site-specific conditions and to discuss the proposed pilot studies and full scale remediation. If applicable, employing the patented circulation cell technology should facilitate a significant cost savings and reduction in treatment duration.

Based on the information reviewed to date, the preliminary conceptual design for full scale remediation includes one UVB-400 in the "hot spot" area to aggressively remediate the area of highest contaminant concentration. More detail of the pilot demonstration and full scale remediation are provided in the attached Conceptual Design and Budgetary Cost Proposal.

We thank you for considering FGS-JAX as a project team member in this remediation effort. Should you have any questions or comments following your review, please call the undersigned at (904) 448-4066.

Sincerely,
FGS-JACKSONVILLE, INC.

William L. Young, PhD
President

CONCEPTUAL DESIGN AND BUDGETARY COST ESTIMATE FOR ABB ENVIRONMENTAL SERVICES, INC. DIXIE CLEANERS JACKSONVILLE, FLORIDA

1.0 INTRODUCTION

Based on available site specific information, FGS-JAX, in cooperation with IEG Technologies, Inc. (IEG), submits this Conceptual Design and Budgetary Cost Estimate Proposal for a Phase I Pilot Study, Final Remedial Design (Phase II), and Phase III Implementation of Full Scale Remediation of the impacted groundwater reported at the referenced facility. Although site conditions appear to be favorable for remediation with our circulation cell technology, for technical and economical reasons, a phased approach is suggested. This will allow ABB to evaluate alternative remedial technologies while minimizing capital and operational expenditures. Upon successful completion of the Field Pilot Study and review of more comprehensive site specific data, FGS will provide ABB with a Full Scale Remedial Action Plan. This Remedial Design will include final cost estimates, proposed UVB locations, estimated project duration, an operation and maintenance plan, a system performance program, and analytical monitoring requirements.

2.0 OPERATIONAL CHARACTERISTICS AND PERFORMANCE STANDARDS

UVB System General Operation

The vacuum vaporizer well (UVB, in German) is an in-situ groundwater and soil remediation system, which remediates contaminants in impacted aquifers using a combination of both physical and biological processes. The UVB system creates a circulation cell that mobilizes the dissolved phase and residual free-phase contaminants to a central well casing for treatment. The treatment methodology is primarily air stripping, and secondarily bioremediation. An in-situ or ex-situ bioreactor component(s) can also be added to the UVB system.

The UVB system consists of a specially adapted groundwater well with double cased and bridge slot screens, floating horizontal stripping reactor, a support pump, and an above ground centrifugal blower, which creates a vacuum to recover soil and groundwater volatiles.

During operation, the water level rises inside the air tight UVB well due to a reduced atmospheric pressure generated by the vacuum. Atmospheric air enters the well through a fresh air pipe connected to the stripping reactor, which floats near the raised groundwater surface, and creates a pressure equilibrium. The incoming fresh air creates bubbles as it is jetted through the sparge plate of the stripping reactor, into the groundwater in the well casing. The rising air bubbles leaving the sparge plate create an air lift "pump" that establishes the suction effect pulling water upward from

the well bottom. A support pump allows for a known volume of water to pass into the stripping reactor, thus allowing control of the air/water ratio and contaminant removal rate.

Groundwater is pumped from the lower part of the well and is discharged in the upper section. Thus, a vertical circulation cell develops with water entering the lower screen of the well, or the base of the well shaft and leaving through the upper screen segment. The expected VOC removal concentration, based on empirical data, is 90 to 99 percent of the influent contaminant concentrations.

The majority of the treated groundwater leaving the upper section of the well circulates through the entire sphere of influence, and returns to the lower screen a number of times before exiting the circulation cell. Since the treated groundwater leaving the UVB well is saturated with oxygen, the effluent groundwater enriches the phreatic zone with dissolved oxygen, thus enhancing aerobic biodegradation throughout the circulation cell. A bioreactor and/or nutrient addition system can be added to further stimulate microbial activity, thereby enhancing biological metabolization of the contaminants of concern.

Capture Zone and Circulation Cell of the UVB

The capture zone and circulation cell will be estimated for each UVB system at the referenced site using the results of the pilot demonstration and equations and graphical solutions developed by Dr. Bruno Herrling (1992) of the Groundwater Research Group, Hydromechanic Institute, University of Karlsruhe, Germany.

3.0 BACKGROUND INFORMATION

The site specific information received from **ABB** was used for this conceptual design:

a. The groundwater in the shallow aquifer flows generally east-northeast.

b. Horizontal hydraulic conductivity is approximately 0.3 ft/day in the shallow aquifer and 0.2 ft/day in the deep aquifer.

c. Vertical hydraulic conductivity is estimated at 0.03 ft/day.

d. The horizontal hydraulic gradient of the shallow aquifer is approximately 0.009 ft/ft.

e. Groundwater is approximately 2 ft bls in the study area.

f. The vertical extent of impacted groundwater is 32 ft bls.

g. Vadose zone remediation is not required.

h. No free product has been reported.

4.0 *IN-SITU* VERTICAL CIRCULATION CELL PILOT DEMONSTRATION

The proposed 24 hour pilot demonstration consists of two tests, which include: 1) Circulation Cell Hydraulics; and 2) In-Situ Air Stripper Treatment potential. These tests can be conducted from a single 6-inch diameter test well (TW) and monitored with two transducer piezometers (TP). FGS-JAX will review the most current site plan, monitor well locations, and well construction details to determine if existing wells can be employed for the proposed pilot demonstration.

An existing 6-inch well can be used for this test if it is constructed such that the well screen extends from < 5 feet above the static water level to a minimum of 10 feet below the soil/groundwater interface. If an existing test well is unavailable, a 6-inch inner diameter well should be installed with an upper screen and a lower screen. The upper screened interval should have an estimated interval of 7 feet with approximately 3.5 feet above the water table and 3.5 feet below the water table, and should have a slot size of 0.040 inch. The lower screen interval should be 3 feet in length, terminated at the base of the contamination, and should have a slot size of 0.025 inch.

Circulation Cell Hydraulics Test

This test will require two transducer/piezometer nests. The nests should be in a straight line radiating outward from the test well, and should consist of a shallow and deep screened interval matching the shallow and deep test well screened intervals. The placement of these piezometers should be at approximately 5 to 10 foot intervals. The construction details of these piezometers should be 2-inch inner diameter with a screen slot size of at least 0.010 inch. Existing monitor wells can be used as transducer points if they meet minimum criteria.

FGS-JAX will conduct a 24 hour Pilot Study to demonstrate the effectiveness of the proposed circulation cell remedial technology, assess the recovery performance, evaluate system performance, and model the zones of capture. The general objectives of the Pilot Demonstration are as follows:

Circulation Cell Hydraulics Test:

1) Determine if a circulation cell can be established;
2) Estimate the total head difference between the upper and lower zones of the circulation cell system at various monitoring points; and
3) Establish "Q" pumping range from the Test Well.

In-situ Air Stripper Treatment Test

1) Determine if the contaminants of concern can be stripped;
2) Measure dissolved oxygen (D.O.), if possible, in the UVB test well;
3) Estimate total (vadose and phreatic zone) off-gas concentration from the air stripping unit; and
4) Estimate total (vadose and phreatic zone) off-gas volume from the air stripping unit.

The electrical requirements for this pilot test are as follows:

Blower - 220 volt, single phase with 30 amp breaker.
Pump - 110 volt, single phase with 15 amp breaker.

5.0 COST ESTIMATE FOR PHASE I PILOT STUDIES AND PHASE II REMEDIAL DESIGN

5.1	Phase I (1 Day) Pilot Demonstration (does not include well installation)	$12,500
5.2	Phase II Full Scale Remedial Design and Remedial Action Plan	$14,000
	TOTAL	**$26,500**

6.0 CONCEPTUAL DESIGN AND BUDGETARY COST ESTIMATE FOR FULL SCALE SITE REMEDIATION

Based on the results of the Pilot Demonstration discussed above, FGS-JAX will generate a Remedial Action Plan and estimated cost for the Full Scale Remedial Design. Based on the information received to date, FGS-JAX has developed the following conceptual design and budgetary cost estimate. Assuming an estimated ROI of 90 to 100 feet for the UVB-400, one system is recommended to effectively remediate the reported "hot spot" area (Figure 1). Please note that the UVB systems may be placed in a building or treatment compound with or without off gas treatment. Due to the high water table conditions at the site, an aboveground treatment unit installation will be required at the UVB well.

6.1 Budgetary Cost Estimate for Phase III Full Scale Site Cleanup

6.1.1 Equipment

a. One UVB-400 including blower (5 hp, 208v, 3-phase), support pump, HDPE blower enclosure with moisture knock-out, air stripper, well screens, plus standard connections and control panel for installation within 5 feet of the well.		42,000
b. Miscellaneous piping, fittings, fence, etc.		10,000
	Subtotal	**52,000**

6.1.2 Construction

a. Project Management		$ 4,500
b. Project Scheduling & Mobilization/Demobilization/Per Diem		8,600
c. Engineering Oversight		5,500
d. UVB Well Installation (Cable Tool @ $25K Each)		~~3,500~~
e. Well Development		2,400
f. System Installation/Manufacturer Supervision		35,000
g. Year 1 O&M/System Monitoring/Reporting (Monthly Electricity Not Included)		25,000
	Subtotal	**$ 84,500**

6.1.3 Annual O&M, System Monitoring (influent/effluent) and Reporting

a. Two additional years System Operation and Maintenance System Monitoring and Reporting($20,000 per year) (Monthly Electricity Not Included)	$40,000
TOTAL ESTIMATED FGS-JAX PROJECT COST	**$176,500**

7.0 SERVICES PROVIDED BY FGS:

- supervising drilling of the boreholes;
- installing the remediation systems according to the results obtained from the borehole logs and the pilot study results;
- adjusting the UVB systems at time of installation;
- monthly maintenance and adjustment of UVB systems for one year and quarterly O&M for two years; and
- hook-up of provided electricity, plus wiring (does not include monthly electricity).

8.0 SERVICES NOT INCLUDED IN PRICING BY FGS-JAX/IEG INCLUDE:

- obtaining permits for drilling and off gas treatment, if required;
- disposal of contaminated soil and groundwater from drilling and well development;
- off gas treatment system, if required; and
- all required sampling and analyticals, other than system influent/effluent.

FIGURE 1 : PROPOSED UVB LOCATION

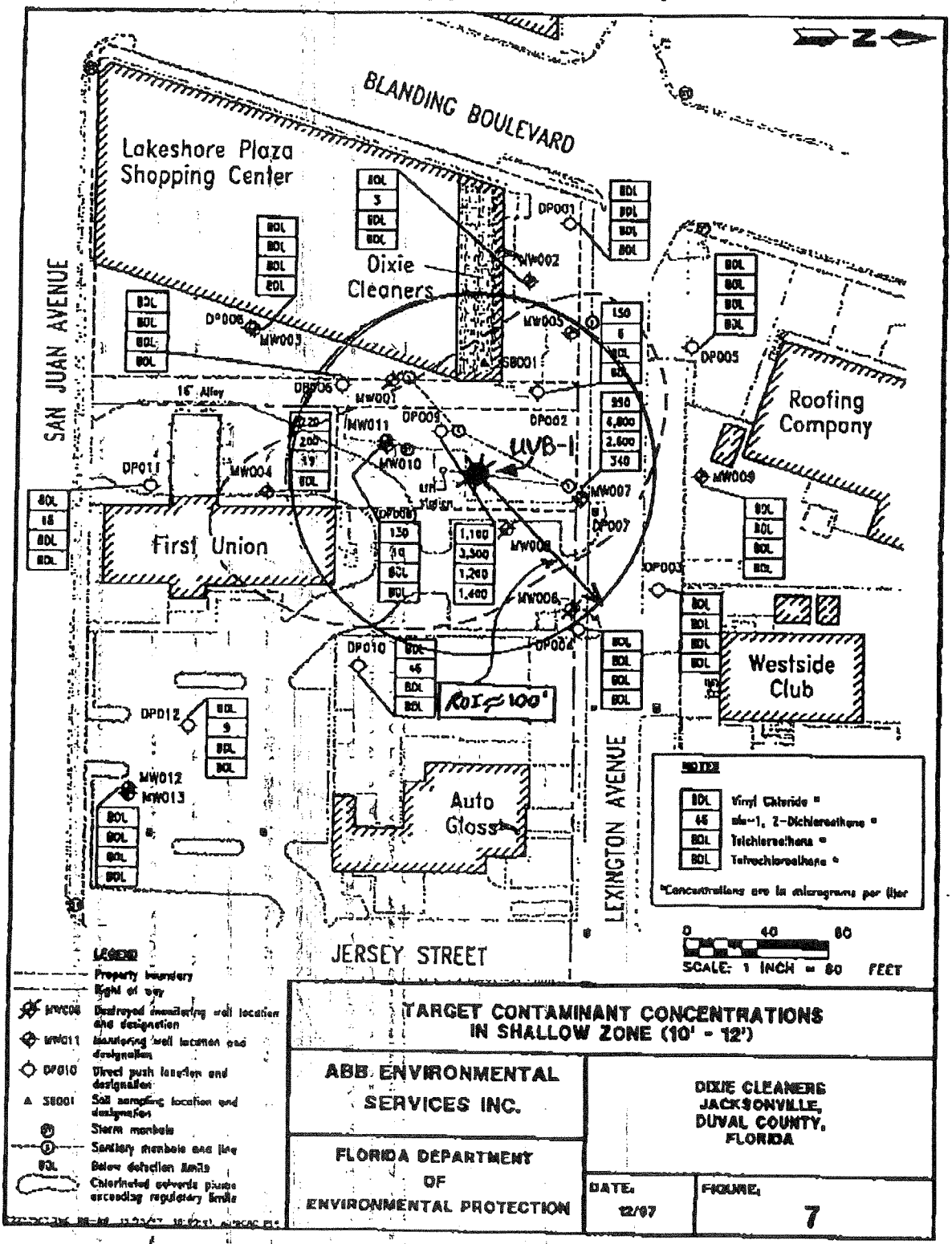
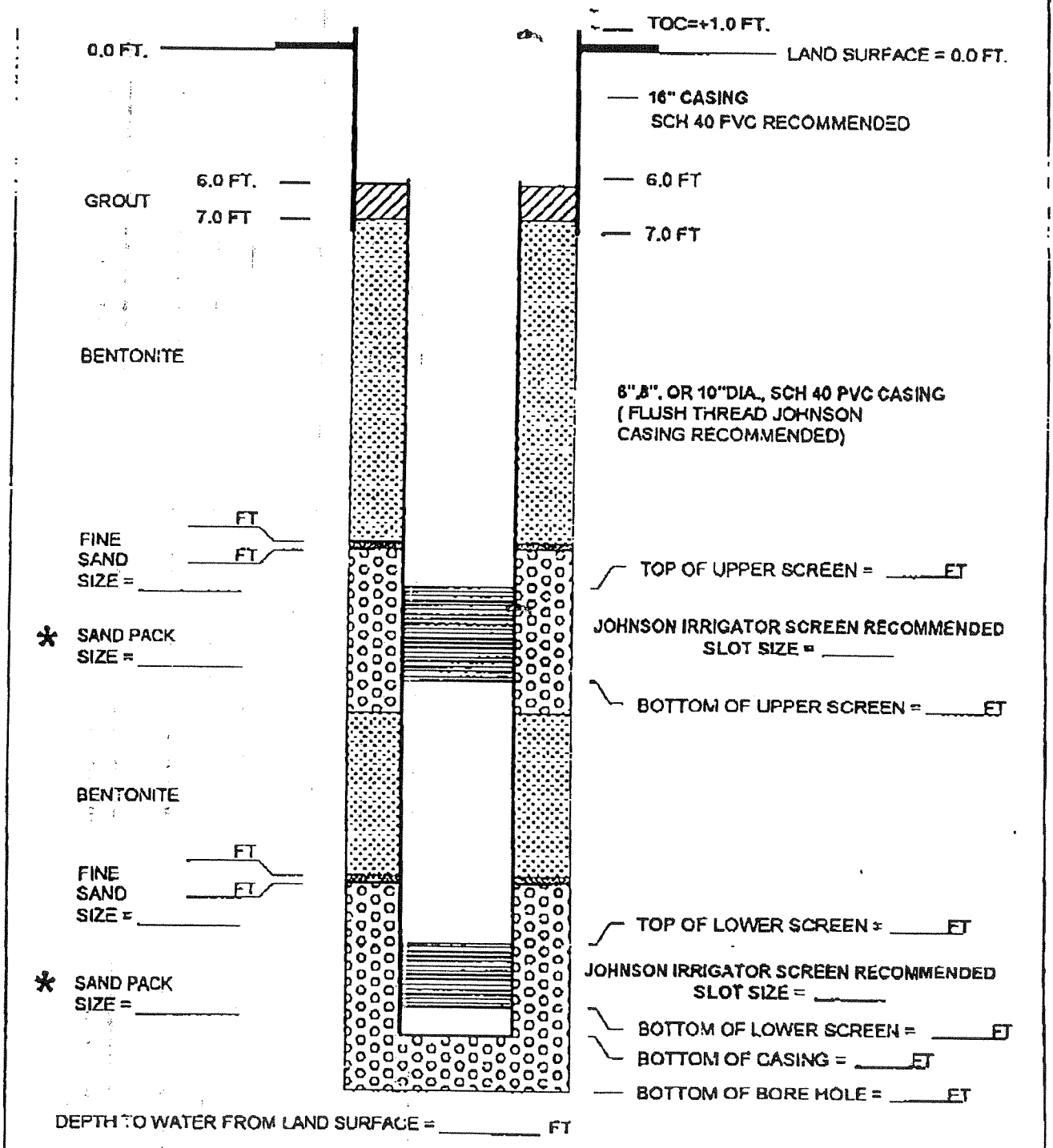


FIGURE 2: TYPICAL WELL SCHEMATIC



* SAND PACK WILL EXTEND 1' ABOVE AND BELOW SCREEN SECTIONS

Title: CANNISTER UVB - 400 CIRCULATION WELL ORDER FORM				Prepared For: IEG INSTALLATION AND MAINTENANCE DEPARTMENT
Scale: NOT TO SCALE	Drawing No.: CANNIST	By: JKS	Project No.:	IEG TECHNOLOGIES CORP.
Date: 1/9/98	Description: STANDARD CANNISTER UVB 400 SCHEMATIC			

Onion Enterprises

7385 Stonegate Naples FL 34109

Date: Thursday, December 24, 1998
To: Harding Lawson Associates
MarkTordaro Bill Olson
Phone: 407-895-8845
Fax: 407-896-6150

From: Onion Enterprises
Barry Zvibleman
Phone: 941-566-7007
Fax: 941-596-3768

Pages: 3

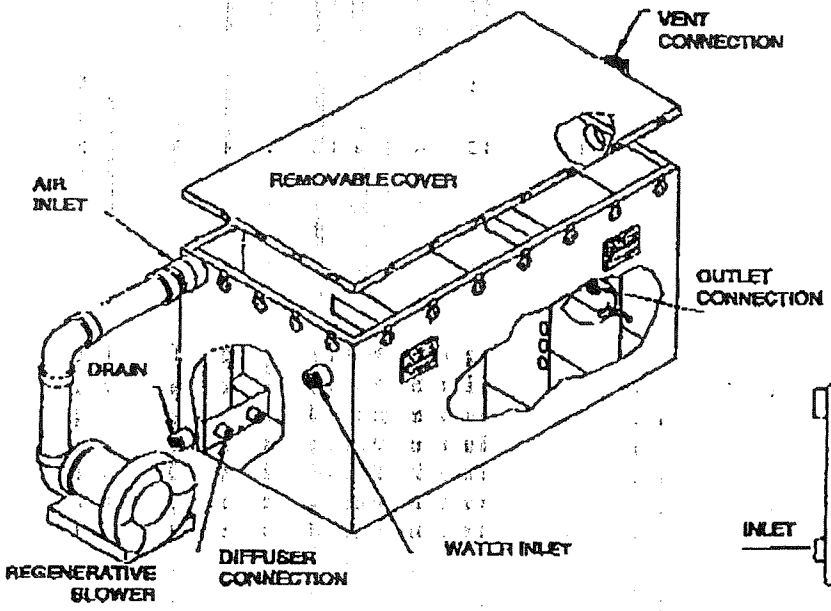
Subject: Air Stripper

The price is $14,000

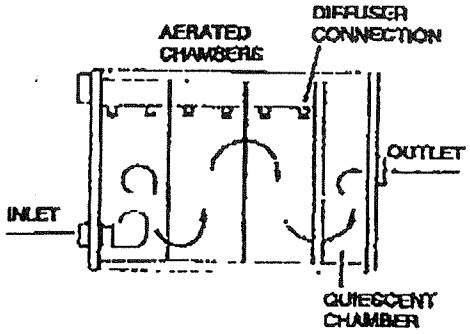
Series 6 - Assume plastic
Flow rate up 170GPM,
360 cfm air flow.

Designed For Flexibility And Ease Of Operation.

The BREEZE air stripper consists of either a high strength polypropylene or stainless steel tank, an air blower, internal air header and patented non-fouling all stainless steel CYCLONE diffusers. The blower delivers air to the diffusers, which release specifically sized air bubbles. Rising bubbles and turbulence provide the air-to-water interface needed for excellent stripping and contaminant removal without the need for packing or media. The BREEZE air stripper provides superior performance with water containing high levels of dissolved and suspended solids. The heavy duty removable cover and latch system provide a sure seal and easy access to diffusers.



Serpentine water flow maximizes detention time and increases the air to water contact.



	Tank Dimensions			Water Port		Air Port		Recommended	Max.	Shipping
	Length	Width	Height	Inlet	Outlet	Inlet	Outlet	Flow Range	cfm	Weight
SERIES 3	45" 114	34" 86	35" 89 (cm)	3" NPT	4" NPT	4" NPT	6" NPT	1-75 gpm	180	305 lbs 138 kg
SERIES 6	81" 206	34" 86	35" 89 (cm)	3" NPT	4" NPT	4" NPT	6" NPT	1-170 gpm	360	510 lbs 231 kg
SERIES 9	117.25" 298	34" 86	35" 89 (cm)	3" NPT	4" NPT	4" NPT	6" NPT	1-180 gpm	540	715 lbs 324 kg

Ask About The Full Aeration Line.

AEROMIX manufactures a complete line of specialized aeration and mixing equipment for treating water and wastewater in industrial, municipal and freshwater markets. Call today to learn more about the AEROMIX aeration solutions best for your application.

Onion Enterprises
941-566-7007

Rental units available.

Covered by United States Patent Nos. 324,279 and Patents Pending.

Onion Enterprises
941-566-7007

SUBJECT: *HLA PROJECT*

Recommendations on your design requirements

A) 1500 SCFM @ 1-3"Hg vacuum

SIEMENS Model# 2BH19431GK28Z Regenerative Blower
Net Price (with TEFC motor).....$ 13,500
Net Price (with XP motor).....$ 14,000

The above blower will handle 1500 CFM @ 1"Hg vacuum (1350 CFM @ 3"Hg vacuum). It will be supplied with a 20 HP motor.

B) 360 SCFM @ 25 PSIG

LeRoi Rotary Screw Compressor.....$ 24,000

The above compressor will produce 360 SCFM @ 25 PSIG, and will use a 75 HP motor.

C) 900 SCFM @ 10 PSIG

Sutorbilt Model# 7MP Positive Displacement (Rotary Lobe) Blower
Net Price.....$ 12,000

The above blower will produce 900 SCFM @ 10 PSIG, and will use a 60 HP motor.

Above pricing includes pump(blower) with motor and baseframe(if necessary).
No additional equipment is included in pricing.
Best regards,

Barry Zvibleman

TOTAL P.01

Post-It™ brand fax transmittal memo 7671 | # of pages ▸ 4

To DAVE HEISLER	From MIKE DONAWAY
Co. HLA	Co. CCC
Dept.	Phone # 925 526 4646
Fax # 761 246 5060	Fax # 925 526 3467

Daniel J. Dolan
12/14/98 04:41 PM

To: Michael J. Donaway/HQPGH/CCC@CCC
cc:
Subject: Estimate for Orlando/HLA

PRELIMINARY EVALUATION AS REQUESTED.

Mike,

Rec'd and reviewed customer PAF. Assuming no other organics are present, we may be able to treat w/ a 30 kW Rayox from the 'AVE' concentrations down to the specified limits at 80 gpm. Depending on how they want to design the system, I would say that they have 3 options. All are sized w/ PCE as the controlling compound:

Option 1: UV/Ox for AVE conditions

As discussed, this would be a 30 kW unit. Capital and operating costs as follows:

Capital: US$87,000

Operating:	**$/1000gal**	**$/yr**
UV Power (@$0.10/kWh)	0.62	25,109
Lamp Replacement	0.13	5,243
50% Peroxide (100 ppm@$0.34/lb)	0.57	22,883
TOTAL	1.32	53,235

Option 2: UV/Ox for MAX conditions

This would likely require a 90 kW Rayox plus more peroxide. Capital & operating costs are estimated as follows:

Capital: US$151,500

Operating:	**$/1000gal**	**$/yr**
UV Power (@$0.10/kWh)	1.87	75,326
Lamp Replacement	0.39	15,728
50% Peroxide (300 ppm@$0.34/lb)	1.30	52,495
TOTAL	3.56	143,549

Option 3: UV/Ox + A/S Hybrid for MAX conditions

This would appear to make the most sense. Use a 30 kW Rayox for Bulk destruction, followed by a small A/S. UV/Ox would destroy > 90% of the specified VOC's (approx. 2 lb/d entering the A/S). This could be stripped off with a Model ShallowTray A/S, to well below the 13.7 lb/d emissions limit for VOC's (therefore, no off-gas treatment req'd). Capital & Operating costs for this option are estimated as follows:

Capital: US$87,000 (30 kW Rayox)
US$28,500 (ShallowTray A/S, Model #2641)

Operating:	**$/1000gal**	**$/yr**
UV Power (@$0.10/kWh)	0.62	25,109
Lamp Replacement	0.13	5,243

50% Peroxide (200 ppm@$0.34/lb)	1.14	45,766
TOTAL	1.89	76,118

I have gone with an intermediate peroxide dose for this option. It may be possible to further reduce peroxide to lower operating costs (at the expense of higher VOC emissions, although still below the emissions limit).

Note, IRON was identified at concentrations up to 490. Presumably this is 'ppb'. If it is ppm, it will have to be filtered out.

Hopefully, that covers everything for this water.

Dan.

GEO-CHEM TECHNOLOGIES™
PRODUCTS FOR A CLEANER WORLD

57436 Gearharts Landing Road
Three Rivers, Michigan 49093

Telephone: (616) 244-5373
Fax: (616) 244-1266
E-mail: jcwilli@net-link.net

December 4, 1998

Fax Transmission To:
(407) 896-6150

Mr. Mark Todaro
Harding Lawson Associates, Inc.
4763 South Conway Road
Orlando, FL 32812

Subject: Preliminary Cost Estimate

Dear Mr. Todaro:

I have developed some preliminary costs regarding the use of the Neutral Process for remediation of groundwater contaminated with antimony. The facts and assumptions I used regarding the project are as follows:

1. Groundwater will be extracted at the a rate of 10 gpm.
2. The project will last 5 years.
3. The target metal is antimony (Sb) which ranges in concentration from 2 to 20 ppb and averages 12 ppb.
4. Discharge criterion for antimony is 6 ppb max.
5. Other groundwater constituents are:
   - pH..... 6.5
   - TDS.....20 mg/l (believed to be primarily Ca/Mg hardness)
   - TSS .....BDL
   - VOCs .....Present
   - Other heavy metals .....BDL

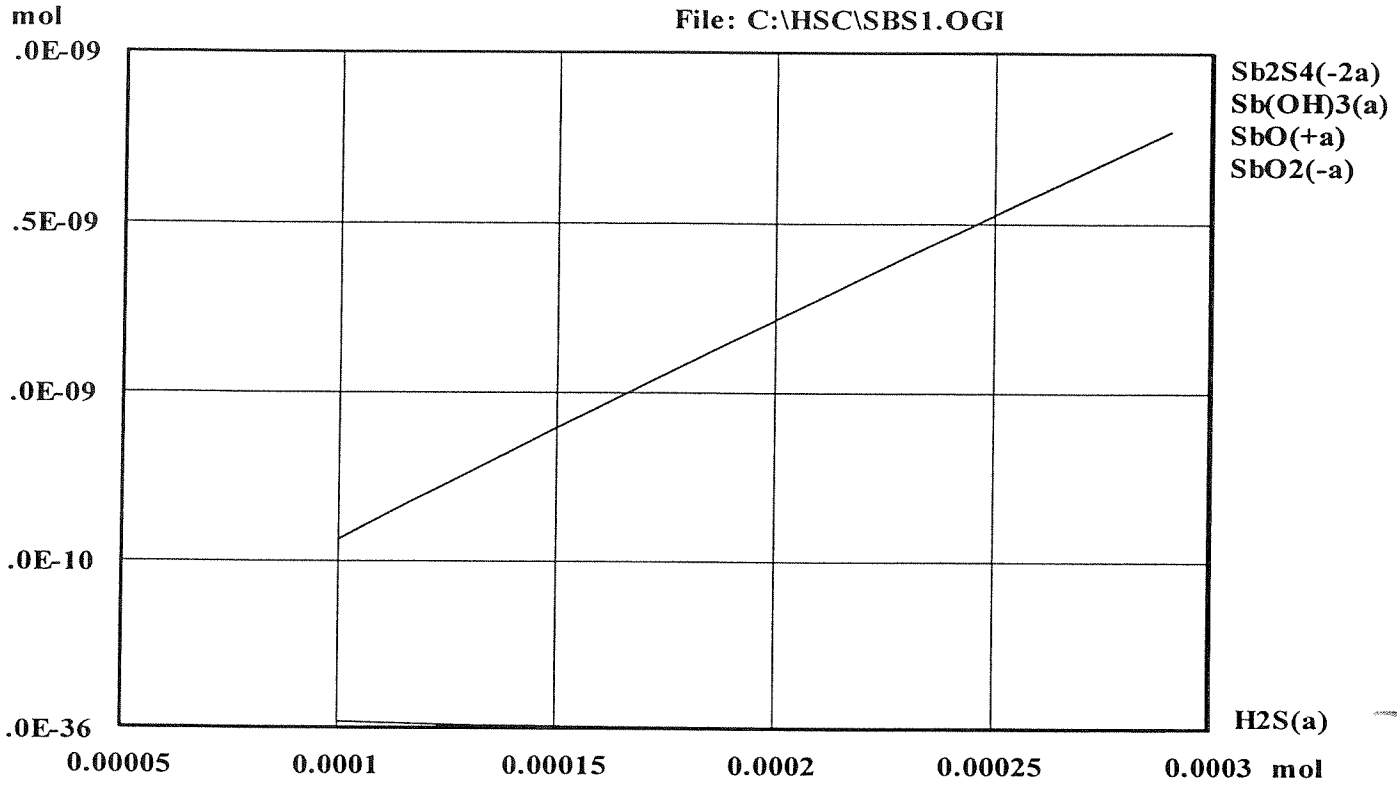
Significant capital costs and factors directly related to O&M costs are estimated to be:

1.	NP-7010 (10 gpm unit) 50 gpm unit	$126,500 $225,000
2.	Chemicals	less than $500/year
3.	Sludge generation (presumed not to be hazardous)	less than 1,000 lbs/year
4.	Labor (monitoring, chemical levels, sludge accumulation, etc.)	2-4 hours/week

Note that filter membranes (these are ceramic membranes) typically last 3 to 5 years under much more demanding conditions involving high strength industrial wastewater. Therefore, I have assumed that the no replacement of the membrane will be necessary during the 5-year life of the project.

Sulfide precipitation of antimony ions

K. Prisbrey, Dec 3, 1998



The above figure shows that sulfide precipitation will reduce antimony to 1 ppb. However, adding only tiny amounts of sulfide ion to the mixture is essential. The sulfide control strategy ERAD has already developed is the technology that will ensure success. As excess sulfide is added, expressed in terms of initial H2S(a) in the graph above, the amount of sulfide-complexed antimony increases in solution, thus threatening to exceed 1ppb. The species distributions below confirm that a controlled sulfide process would work.

Temperature	298.15	K
Pressure	1	bar
Volume	0.000E+00	m3 (NPT)
Reaction enthalpy	7.000E-03	kJ

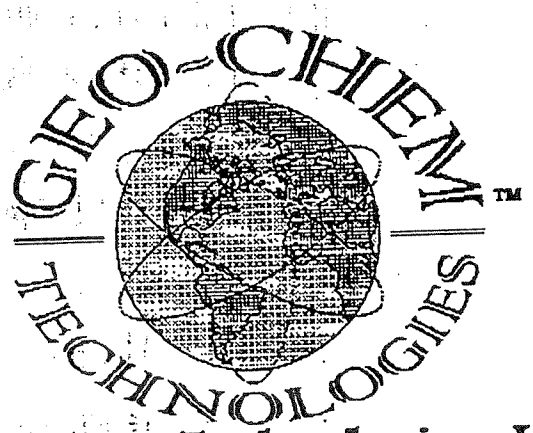
Reaction entropy -2.417E-02 J/K
Iterations 14 (Limit = 100)

	INPUT AMOUNT mol	EQUIL AMOUNT mol	MOLE FRACT	ACTIVITY COEFFICI	ACTIVITY
PHASE 1:					
SO3	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
SbO2	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Sb2O3	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Sb2O3(O)	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Sb2O4	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Sb2O5	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Sb4O6	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Sb2(SO4)3	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Total :	0.0000E+00	0.0000E+000	0.000E+00		
PHASE 2 :			MOLE FRACT		
Sb2S3	0.0000E+00	4.9411E-008	1.000E+00	1.00E+00	1.000E+00
Total :	0.0000E+00	4.9411E-008	1.000E+00		
PHASE 3 :			MOLE FRACT		
S	0.0000E+00	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Sb	1.0000E-07	0.0000E+000	0.000E+00	1.00E+00	0.000E+00
Total :	1.0000E-07	0.0000E+000	0.000E+00		
PHASE 4 :			MOLE FRACT		
H2O	5.5000E+01	5.5000E+001	1.000E+00	1.00E+00	1.000E+00
H2(a)	0.0000E+00	4.0554E-012	7.373E-14	1.00E+00	7.373E-14
H(+a)	1.0000E-04	3.7322E-004	6.786E-06	1.00E+00	6.786E-06
H2S(a)	1.0000E-04	7.2438E-005	1.317E-06	1.00E+00	1.317E-06
HS(-a)	0.0000E+00	2.3647E-008	4.299E-10	1.00E+00	4.299E-10
H2SO3(a)	0.0000E+00	4.0146E-015	7.299E-17	1.00E+00	7.299E-17
H2SO4(a)	0.0000E+00	3.7455E-012	6.810E-14	1.00E+00	6.810E-14
H2S2O4(a)	0.0000E+00	9.2125E-067	0.000E+00	1.00E+00	0.000E+00
H2S2O8(a)	0.0000E+00	8.3540E-081	0.000E+00	1.00E+00	0.000E+00
HSO3(-a)	0.0000E+00	1.7581E-013	3.197E-15	1.00E+00	3.197E-15
HSO4(-a)	0.0000E+00	9.6520E-007	1.755E-08	1.00E+00	1.755E-08
HS2O4(-a)	0.0000E+00	1.0521E-063	0.000E+00	1.00E+00	0.000E+00
HSbO2(a)	0.0000E+00	2.4274E-011	4.413E-13	1.00E+00	4.413E-13
O2(a)	0.0000E+00	4.4888E-070	0.000E+00	1.00E+00	0.000E+00
OH(-a)	0.0000E+00	2.6917E-011	4.894E-13	1.00E+00	4.894E-13
S(-2a)	0.0000E+00	7.4233E-018	1.350E-19	1.00E+00	1.350E-19
S2(-2a)	0.0000E+00	2.3517E-017	4.276E-19	1.00E+00	4.276E-19
S3(-2a)	0.0000E+00	6.1815E-017	1.124E-18	1.00E+00	1.124E-18
S4(-2a)	0.0000E+00	9.1564E-017	1.665E-18	1.00E+00	1.665E-18
S5(-2a)	0.0000E+00	8.5834E-017	1.561E-18	1.00E+00	1.561E-18
SO2(a)	0.0000E+00	3.7570E-015	6.831E-17	1.00E+00	6.831E-17
SO3(a)	0.0000E+00	5.9043E-009	1.073E-10	1.00E+00	1.073E-10
SO4(-2a)	0.0000E+00	2.6416E-005	4.803E-07	1.00E+00	4.803E-07
S2O3(-2a)	0.0000E+00	3.1234E-012	5.679E-14	1.00E+00	5.679E-14
S2O4(-2a)	0.0000E+00	4.0091E-031	7.289E-33	1.00E+00	7.289E-33
S2O8(-2a)	0.0000E+00	5.8920E-074	0.000E+00	1.00E+00	0.000E+00
S4O6(-2a)	0.0000E+00	9.3530E-022	1.701E-23	1.00E+00	1.701E-23
SbO(+a)	0.0000E+00	6.5858E-018	1.197E-19	1.00E+00	1.197E-19
SbO2(-a)	0.0000E+00	3.2361E-036	5.884E-38	1.00E+00	5.884E-38
Sb(OH)3(a)	0.0000E+00	2.3566E-011	4.285E-13	1.00E+00	4.285E-13
Sb2S4(-2a)	0.0000E+00	5.6515E-010	1.028E-11	1.00E+00	1.028E-11
e-	1.0000E-04	3.1940E-004	5.807E-06	1.00E+00	5.807E-06
Total :	5.5000E+01	5.5001E+001	1.000E+00		

ERAD

NP (Neutral Process) SYSTEMS

WASTEWATER TREATMENT SYSTEMS FOR HEAVY METALS



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PRODUCTS FOR CLEANER WORLD

NP (Neutral Process) SYSTEM

Cross-Flow MicroFiltration Membrane Heavy Metal Wastewater Treatment System

NP System is effective on
Chromium, Cadmium, Copper, Lead, Nickel, Zinc, Aluminum, Mercury, Gold, Silver, Cobalt, Iron, Arsenic, Strontium, More

Industrial Applications

Electronics
- Printed Circuit Board Wastewater
- Component Assembling Wastewater

Chemical and Petrochemical
- Chemical Production Heavy Metal Laden Wastewater
- Petrochemical Heavy Metal Laden Wastewater

Equipment Refurbishing
- Aircraft Engine Refurbishing Wastewater
- Aircraft Exterior Cleaning Washwaters
- Marine Engine Refurbishing Wastewater
- Trucks & Other Heavy Equipment Refurbishing Wastewater
- Electronic & Electrical Equipment Refurbishing Wastewater

Mining and Mineral Processing
- Mineral Processing Wastewater
- Mine Drainage
- Metal Recovery

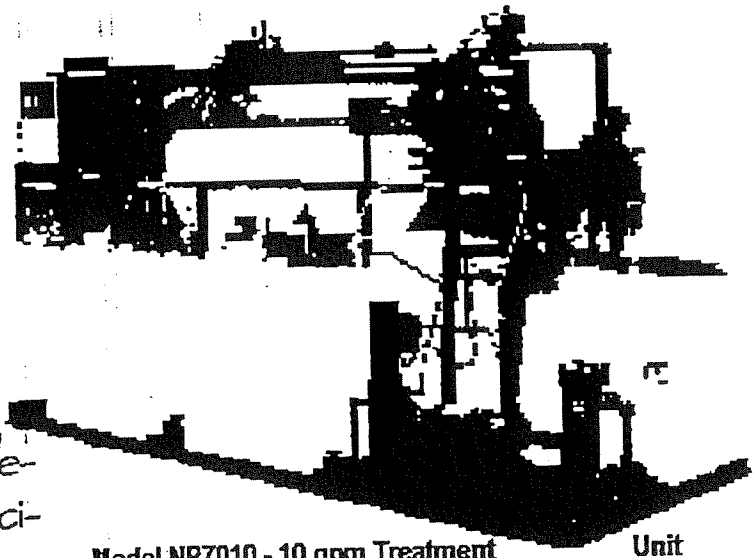
Metal Surface Finishing
- Metal Plating Wastewater
- Metal Surface Finishing Wastewater

Leather
- Leather Tanning Wastewater

Merchant Marine
- Bilge Water Treatment

All Heavy-Metal-Wastewater Producing Industries

NP-7000 System



Model NP7010 - 10 gpm Treatment Unit
(8 feet long x 4 feet deep x 6 feet high)

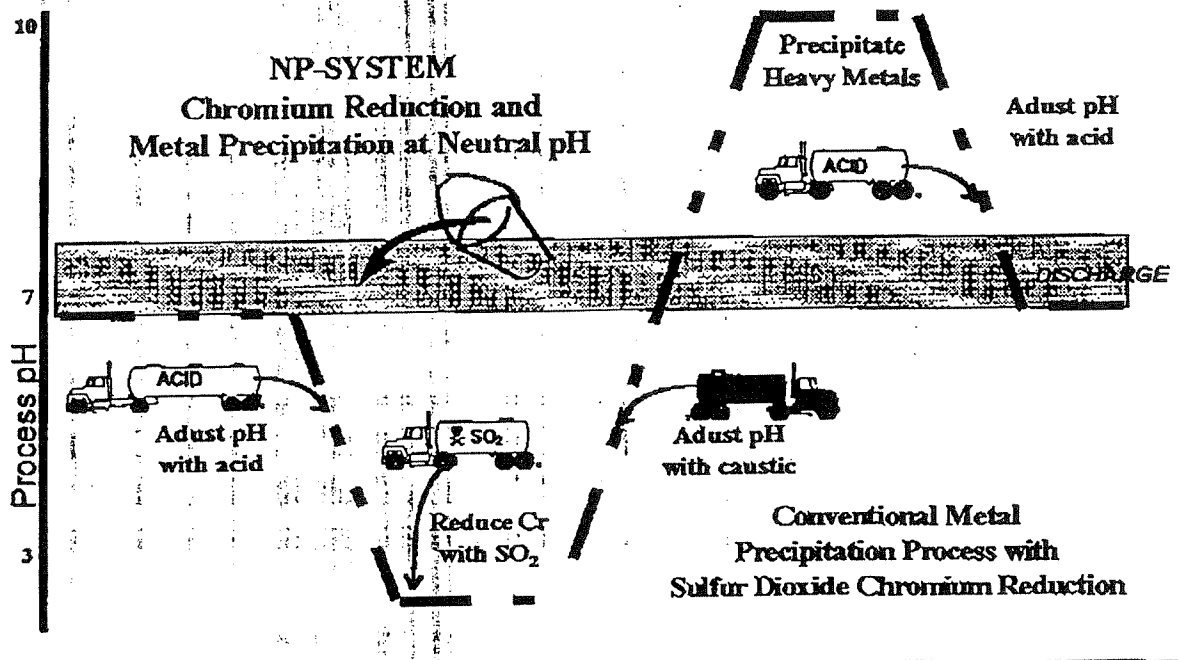
The NP-7000 Series Metal Removal System is a 10 to 50 gpm compact skid-mounted unit that removes hexavalent chromium and other heavy metals from industrial wastewater using neutral pH precipitation chemistry and Cross-Flow MicroFiltration. The system is fully capable of achieving all regulatory effluent discharge standards. The dewatered chemical sludge cake can be disposed of as hazardous waste or industrial process waste, as appropriate, or can be processed to reclaim valuable metals.

NP-1000 System

The NP-1000 Series Metal Removal System is a small, 1 to 10 gpm capacity, skid-mounted unit that removes hexavalent chromium and other heavy metals from industrial wastewater also using our neutral pH precipitation chemistry and Cross-Flow Micro-Filtration. The system is fully capable of achieving all regulatory effluent discharge standards.

Model NP1000 - 1 gpm Treatment Unit
(4 feet long x 3 feet deep x 5.5 feet high)

ULTIMATE CHOICE FOR YOUR Cr^{+6} and HEAVY METAL WASTEWATER TREATMENT NEEDS



Conventional System vs NP-System

The most commonly used conventional process to treat heavy metal wastewater is lime precipitation and caustic precipitation. This process requires bi-directional pH adjustment to create both acidic and alkaline conditions and generates large amounts of residual waste sludge.

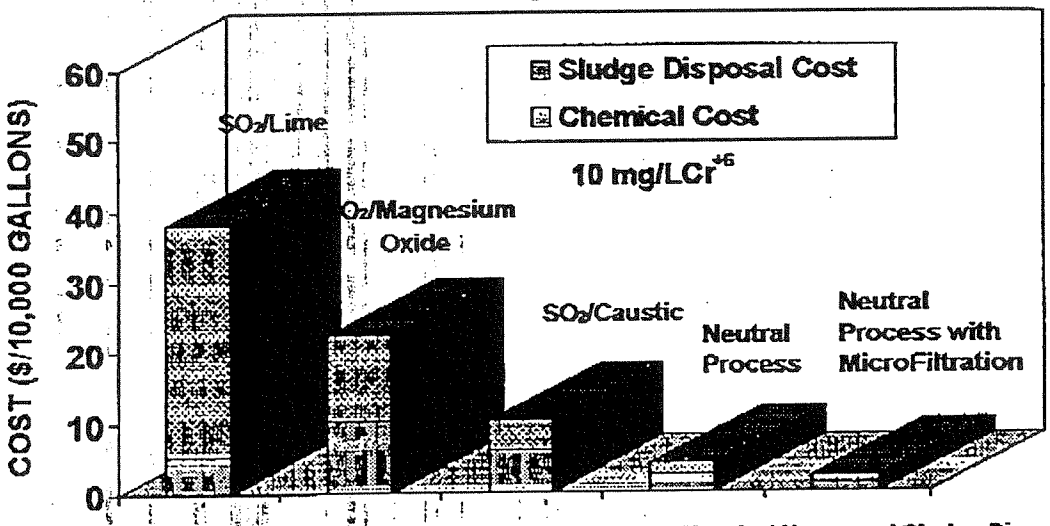
In addition, when treating hexavalent chromium, the process first requires the reduction of hexavalent chromium to the trivalent form with sulfur dioxide or other reducing agents in an acidic environment. This further increases chemical cost and the generation or sludge.

In the Neutral Process, the reaction occurs at the neutral pH, all heavy metals precipitate, and a clean, recyclable effluent is consistently achieved via the Cross-Flow Micro-Filtration Membrane System.

Hexavalent chromium is reduced and all heavy metals present are precipitated and removed at the neutral pH.

With far less chemicals required for treatment, the Neutral Process substantially reduces chemical cost, sludge generation and handling, and waste disposal costs.

Chemical Treatment and Sludge Disposal Cost Comparison



The Neutral Process Results in Significant Cost Savings from reduced Chemical Usage and Sludge Disposal.

Treatment Costs for NP-7000 Series Cross-Flow MicroFiltration Membrane Heavy Metal Wastewater Treatment System Tobyhanna Army Depot (TYAD)

Chemical	Use	Cost/Unit (U.S. $)	Cost (U.S. $)	Conventional Treatment Cost (U.S. $)
Sodium Metabisulfite	None	–	None	⇩
Sulfuric Acid	30 gals/yr	$3.50/gallon	$105/yr	⇩
ERF-60	96 lbs/yr	$0.29/lb	$28/yr	⇩
ERS-150	156 lbs/yr	$1.00/lb	$156/yr	⇩
Polymer	None	–	None	⇩
Caustic Soda (50 %)	30 gals/yr (1 drum)	$115/drum	$115/yr	⇩
Total Chemical Costs	⇨	⇨	$447/yr	$4,634/yr
Sludge Disposal Cost	3,000 lbs/yr	$0.729/lb	$2,187/yr	$9,398/yr
Total	⇨	⇨	$2,634/yr	$14,032/yr

Costs are based on the treatment of 4,620,066 gallons of heavy metal contaminated wastewater from August 1993 through July 1994.
Cost Savings of over 80 percent achieved compared to the same amount of wastewater treated by the Sulfur Dioxide Reduction method of conventional treatment.

Advantages of Neutral Process Over Conventional Heavy Metal Treatment Processes

- ✓ The system's small footprint saves space.
- ✓ The faster reaction kinetics allow the NP System to eliminate mixing tanks, lowering system and operational costs.
- ✓ Eliminates the need for clarifiers reducing capital cost and size.
- ✓ Proven performance record meeting low discharge limits.
- ✓ Chemical reaction, metal precipitation, and effluent discharge at Neutral pH.
- ✓ Equally effective as a batch or continuous process.
- ✓ Eliminates the need for polymers or flocculation aids; thus reduced costs.
- ✓ Automatic controls, thus reduced labor time and skill level.
- ✓ State of the art ceramic membranes.
- ✓ Not adversely affected by surfactants and chelating agents.
- ✓ Effluent water is recyclable.

NP System's Effluent Quality for an Industrial Wastewater Treatment Plant (1.5 MGD)

Sample	Cadmium (mg/L)	Copper (mg/L)	Chromium (mg/L)	Lead (mg/L)	Nickel (mg/L)	Zinc (mg/L)
1	0.005	0.01	0.02	0.05	0.02	0.008
2	0.005	0.02	0.02	0.05	0.02	0.014
3	0.005	0.01	0.01	0.05	0.02	0.036
4	0.005	0.03	0.03	0.05	0.02	0.014
5	0.005	0.01	0.01	0.05	0.02	0.005

The high reactivity of the complexing agents with heavy metal ions in the neutral process produces low solubility metal complexes. The result is a cleaner effluent meeting the stringent requirements for surface discharges.

Chromium Reduction and Heavy Metal Precipitation at Neutral pH with the Neutral Process

The Neutral Process, which reduces hexavalent chromium using sulfide catalyzed by ferrous iron, reduces hexavalent chromium at a neutral pH while all heavy metals are precipitated at pH's of 7.4 to 8.4. The reaction kinetics for the chromium reduction are rapid, i.e. within seconds with the Neutral Process while conventional reduction at acidic pH's takes about 15 minutes or more.

The Neutral Process, a process patented by the U.S. Air Force, is used to treat heavy metal-containing wastewaters. Further process development has been performed by ERD, Inc., including process controls development along with coupling the treatment process to Cross-Flow MicroFiltration, which eliminates the need for large clarifiers. This research was funded by the U.S. Army Construction Engineering Research Laboratory. The resulting treatment units have small footprints—a 10 gpm unit is 8 ft long by 4 ft deep by 6 ft high. Doubling the capacity of the unit does not double the size as only the membrane capacity needs to be increased.

Background

The most commonly used conventional treatment system for heavy metal-containing wastewaters is the hydroxide precipitation process with heavy metal precipitation at pH's ranging from 8 to 12. Hexavalent chromium cannot be precipitated without prior reduction to trivalent chromium; reduction with sulfur dioxide is the most commonly used method, which requires reduction at acidic pH's of 2 to 3. Other acidic reduction methods include the use of sodium bisulfite, and ferrous compounds, however the ferrous ion is not efficient by itself in reducing hexavalent chromium as only one electron is available per iron atom and a large quantity of iron hydroxide sludge is produced. The quantity of sludge produced by the different reducing agents can vary dramatically.

When the ferrous ion is present together with sulfide, the hexavalent chromium is rapidly reduced at neutral and alkaline pH. The theoretical basis for ferrous and sulfide reduction of hexavalent chromium is based on the 1983 research by Higgens and Sater. The ferrous ion appears to catalyze the sulfide reduction. At a neutral pH, the proposed reaction is:

$$3HS^- + 6FeSO_4 + 4CrO_4^{-2} + 13H_2O + OH^- \rightarrow$$

$$6Fe(OH)_{3(s)} + 4Cr(OH)_{3(s)} + 6SO_4^{-2} + 3S_0$$

Most metal hydroxides have a relatively high solubility, with increased solubility of the metal hydroxide at high pH. Hydroxide precipitation of all heavy metals is not reliable as the minimum solubility of the mixed heavy metal hydroxides does not occur at the same pH—many of the metal hydroxide precipitates are amphoteric in nature and dissolve at high pH values. In addition, the presence of complexing agents, such as ammonia or ethylenediamine tetraacetate (EDTA), prevents effective heavy metal removal.

Metal precipitation by soluble sulfides requires a sulfide source more soluble than the metal to be precipitated such as sodium sulfide. Sodium sulfide disassociates readily into the sodium and sulfide ions such that the free sulfide can react to precipitate a heavy metal.

Advantages of the sulfide process include the extreme low solubilities of most metal sulfides, the sulfide ability to reduce hexavalent chromium in the presence of the ferrous ion, and its increased ability to precipitate metals complexed with at least some of the complexing agents. The high reactivity of sulfides with heavy metal ions and the low solubility of heavy metal sulfides over a broad pH range are attractive features when compared to the hydroxide precipitation process. The metal sulfides tend to be at least 4 or 5 orders of magnitude less soluble than their corresponding metal hydroxides.

NP-1000 SERIES
Cross-Flow MicroFiltration Membrane
Heavy Metal Wastewater Treatment System

Specifications

Model	Capacity (gpm)	Influent Pump (gpm)	Cross-Flow Pump (gpm)	Membrane Module	Automatic Control	Solids Monitor	Chemical Feed Control	pH Control	Air (SCFM)
NP-1001	1.0	3	20	8	yes	no	yes	yes	3
NP-1003	3.0	9	50	6	yes	no	yes	yes	3
NP-1005	5.0	10	80	10	yes	no	yes	yes	4

NP-7000 SERIES
Cross-Flow MicroFiltration Membrane
Heavy Metal Wastewater Treatment System

Specifications

Model	Capacity (gpm)	Influent Pump (gpm)	Cross-Flow Pump (gpm)	Membrane Module	Automatic Control	Solids Monitor	Chemical Feed Control	pH Control	Air (SCFM)
NP-7010	10	20	400	1	yes	yes	yes	yes	5
NP-7020	20	40	400	2	yes	yes	yes	yes	7
NP-7030	30	57	400	3	yes	yes	yes	yes	9
NP-7050	50	75	1500	5	yes	yes	yes	yes	10
NP-7120	120	150	1400 X 2	16	yes	yes	yes	yes	15

* Systems over 100 gpm requires custom design

OTHER SYSTEM REQUIREMENTS

- **Electrical power supply available at 110 1Φ 220/440 3Φ**
- **Some potable water**

CASE HISTORY

Tobyhanna Army Depot U S Army Pennsylvania

Average Influent and Effluent Wastewater Analysis for NP-7010 Tobyhanna Army Depot (TYAD)		
Constituent	Influent	Effluent
pH Units	5.84	7.26
Turbidity (FTU)	42.8	0
Cr^{+6} (mg/L)	0.02	BDL*
Cr Total (mg/L)	0.14	0.029
Cd (mg/L)	0.296	0.094
Cu (mg/L)	0.37	0.116
Fe (mg/L)	0.68	0.208
Pb (mg/L)	0.246	0.076
Ni (mg/L)	5.21	0.158
Zn (mg/L)	0.21	0.104

* below detection limit

Background:

Tobyhanna Army Depot (TYAD) manufactures and refurbishes medical and communication equipment for the US Army. TYAD generates inorganic wastewater from electronics and metal finishing operations.

Problem:

TYAD was experiencing high treatment and disposal costs from the treatment of its 4 million gallons per year heavy metal contaminated wastewaters. These wastewaters were treated to achieve the required discharge limit in their SO_2/Caustic precipitation waste treatment plant at a cost of $4,630 per year for chemicals and $9,400 per year for sludge disposal (total cost $14,030 per year).

Solution:

With lowering cost as the main objective, the MicroFiltration Cross-Flow Membrane Inorganic Treatment System (NP-7010) was developed.

Results:

Based on 1994 operational data, (4,620,066 gallons of wastewater were treated), the patented Neutral Process has provided an immense reduction in treatment costs. The usage of large quantities of acid and caustic were eliminated for pH adjustments, thus the chemical cost was reduced to an estimated $623 per year (a reduction of 87%). The MicroFiltration technology eliminated the need for coagulation/flocculation polymers and a clarifier. Sludge generation and the associated disposal costs were reduced by 77% to $2,187 per year. Despite the tremendous savings, effluent quality was maintained well below surface discharge requirements.

The Neutral Process-Overview

The Neutral Process utilizes sulfide catalyzed by ferrous iron to reduce hexavalent chromium and sulfide to precipitate heavy metals at a pH of 7.4 to 8.4. Chromium cannot be precipitated as a sulfide, but is precipitated as the hydroxide at the minimum solubility of chromium hydroxide.

Process evaluation shows the reaction kinetics of this process to be very rapid in contrast to the conventional chromium reduction process, which means a wastewater treatment unit for this process does not require the large reaction tanks associated with conventional treatment plants. Hexavalent chromium is reduced to below detection in seconds with this process.

All the reactions and heavy metal precipitation processes occur at pH 7.4 to 8.4 with this process, eliminating lowering the pH to 2 to 3 for the chromium reduction process followed by raising the pH to 8.5 to 12 for the heavy metal precipitation. Process chemical requirements are reduced as the sulfide and ferrous are added based on the heavy metal concentrations in the wastewater, reducing chemical costs by 40 to 80% over conventional methods. Sludge generation is also reduced.

Treatment Benefits

The Neutral Process, which exceeds current EPA NPDES discharge limits, has the following treatment benefits:

- Hexavalent chromium reduction is not limited at low concentrations of 0.1 mg/L or less.
- Since the reduction of hexavalent chromium is instantaneous, multiple, large retention tanks are not required.
- Because hexavalent chromium reduction occurs at a near neutral pH, less acid and caustic have to be purchased and stored on site.
- Operation at neutral pH instead of at acidic conditions reduces tank corrosion and increases tank life.
- The process reduces hexavalent chromium that can slip through from other feed streams, avoiding potential discharge limit violations.
- Implementation into existing Industrial Wastewater Treatment Plants (IWTP) allows the removal of large sulfur dioxide tanks, eliminating a safety hazard.
- Flocculants and coagulants are not needed in the process with Cross-Flow MicroFiltration, and chelating agents and soaps do not interfere with the metal precipitation process.
- The process reduces chromium at low concentrations which may hinder acidic chromium reduction.

Process Applications

Albany, GA. This process was implemented in the Albany, GA Marine Corps Logistic Base IWTP in the summer of 1997. The base is a major supply and maintenance depot serving the U.S. Marine Corps. The IWTP is designed to process 200 to 250 gpm of industrial wastewater from processing wastes, washwaters, and rinsewater from maintenance and test shop operations, all of which is normally low in pollutants. Concentrated wastes such as waste caustic solutions, waste chromic acid solutions, and waste acid solutions are segregated and trucked to the plant where they are loaded into holding tanks and metered into the industrial wastewater for treatment. Groundwater is also pumped to the IWTP for treatment. Prior to implementation, the IWTP was using the sulfur dioxide caustic process for wastewater treatment.

Implementation of the Neutral Process into the existing IWTP required changing location of the acid and caustic feed lines, installation of a zeta potential detector, turbidity monitor, and sludge depth meter. Note, the latter three would have been beneficial to the original treatment process. The pH of the influent wastewater is maintained greater than 7.2 with the addition of waste alkali and commercial caustic as required. The alkali pump is shut off at pH 8.0. The pH is maintained less than 8.5 with waste acid, which reduces the volume of acid required later in the process and also helps the operation of the Dissolved Air Flotation Unit used for oil and grease removal. Waste chromic acid is fed as available.

At the first reaction tank sulfide solution is fed and at the second reaction tank ferrous sulfate and sulfuric acid is fed. The pH is maintained between 7.4 and 8.4, with chromium reduction occurring in the second reaction tank. Cationic and anionic polymers are added to coagulate and flocculate the precipitate. The cationic polymer feed is controlled with the zeta potential control. The solids are settled in the Upflow Clarifier where the treated wastewater flows up through the sludge blanket. Sludge recirculation is used to buoy up the sludge bed and help with pin floc removal. The wastewater now meets discharge requirements as shown in Table 1. The estimated cost savings for chemical usage and sludge disposal is approximately $116,500 or 47% compared to the old process.

Keyport, WA. The IWTP at the Naval Undersea Warfare Center (NUWC) at Keyport, WA was selected for a full-scale demonstration of the process. The IWTP had been using the sulfur dioxide caustic process, and based on jar tests and prior pilot plant tests conducted at NAS Pensacola, feeds of chemical were optimized and design modifications were implemented at Keyport with start-up in September 1995. The new process was evaluated over a nine-month operational period.

The process treated the NUWC industrial wastewater with hexavalent chromium as high as 310 mg/L , meeting current and proposed EPA discharge limits. A cost comparison of the new process with the old process indicated a 59% reduction in chemical cost and a 31% reduction in sludge disposal costs. On an annual basis, the total cost savings amounted to $31,950 or 34% over the old treatment process. At concentrations of hexavalent chromium greater than 100 mg/L, sludge generation and disposal costs were reduced by 17%. The IWTP treated batches of wastewater up to 39,000 gallons over a two-day period. In addition, a reduction in processing time was realized, as the Keyport operators were able to treat and clarify the 39,000-gallon batch of wastewater in one shift during the day.

Tobyhanna Army Depot. The process coupled with Cross-Flow MicroFiltration was pilot tested at a 10 gpm treatment unit at Tobyhanna Army Depot Metal Pretreatment Plant, which manufactures and refurbishes medical and communications equipment. Wastewaters containing heavy metals are generated from their electronics and metal finishing operations. The hexavalent chromium containing wastewater was segregated for treatment with sulfuric acid and sodium sulfite to reduce the chromium. Following chromium reduction, the wastewater was mixed with the remaining wastewater, and the pH was adjusted to 9 to 10 with caustic. Ferrous sulfate was added as a coagulant and as needed, sulfide was added to precipitate the heavy metals to discharge requirements. Chemical costs for the operation was $4,630 per year and sludge disposal was $9,400. Operation of the 10 gpm Neutral Treatment Unit demonstrated a projected chemical cost of $623 per year and a sludge disposal cost of $1,560 per year. The overall cost reduction for sludge disposal and chemical cost was 70%.

The unit operates automatically with process controls to monitor and control the pH and chemical feeds. The chemical feeds are controlled with a continuous analyzer, which colorimetrically determines excess treatment chemicals in the effluent and controls the concentration at 0.005 mg/L. Maintenance requirements include maintaining and calibrating the pH probes and ensuring chemicals are present. The ceramic membrane is cleaned as needed with a citric acid cleaning cycle. A solids monitor/controller controls the solids in the recirculating cross flow at 2 to 4%. Solids are wasted to a sludge tank, and the thickened sludge is filtered using a plate and frame filter press, which is mounted on the skid mounted treatment unit.

Albuquerque, NM. This process is applicable to the treatment of a number of industrial wastewater containing heavy metals. If cyanide is present, cyanide pretreatment is required prior to heavy metal precipitation. The process can be coupled to oil/water separation and organic treatment processes. Kirkland AFB in Albuquerque, NM has purchased three treatment units for the treatment of washwater from wipes used in aircraft and vehicle maintenance. The wipes are contaminated with heavy metals, oils, and some light solvents. Disposal of the rags as a hazardous waste costs one shop $120,000 per year. Washing the wipes will eliminate the associated disposal costs, and the wipes can be reused. The treatment unit consists of oil/water separation with Cross-Flow MicroFiltration, the Neutral Process, and ozone to degrade the solvent. The treatment unit will have a six-month pay back period.

Table 1. Discharge Limits Before and After the Neutral Process

Parameter	Discharge Limits (mg/L)	Neutral Process (mg/L)
Cadmium, Total	0.036	0.010
Chromium, Hexavalent		BDL[1]
Chromium, Total	0.600	BDL
Copper, Total	0.113	BDL
Iron, Total		0.194
Lead, Total	0.380	0.044
Nickel, Total	2.400	0.080
Zinc, Total	1.500	0.092

[1]BDL=Below Detection Limits

For Additional Information about how you can implement the Neutral Process at your facility Contact:

James C. Williamson, CEP, CHMM
Geo-Chem Technologies, Inc.
Phone: 616 244-5373 or
E-mail: jcwilli@net-link.net

Harding Lawson Associates
Engineering
and
Environmental Services

SHEET 1 OF 4
JOB NO. 02545.51
DATE Dec 10, 1998
COMPUTED BY MAR
CHECKED BY

PROJECT NTC Orlando OU4 FS
SUBJECT Alternative Duration Calculations

Need to determine pumping duration for the groundwater extraction option for the OU4 source area.

Assumptions

Total Mass PCE = 6,000 lb
Ave Fraction TOC = 0.006 (From OU4 RI) 6000 mg/kg

K_{oc}

PCE = 364 ml/g DCE = 49 ml/g
TCE = 126 ml/g VC = 57 ml/g

$1 + \frac{\rho}{\theta} f_{oc} (K_{oc})$

GW Concentration at Source

Assume 30 lb/yr enters lake. Assume all PCE.

Source cross-section is approximately 50 feet wide, 35 feet deep = 1050 ft^2 ← This is for 30' wide!
A = 1750 ft^2 for 50'

Gradient (from WHPA simulation) = 0.008 ft/ft

Velocity = (40 ft/day)(0.008)/0.30 = 1 ft/day

Flow = (1050 ft^2)(1 ft/day) = 1050 ft^3/day or 1750 cfd

$\left(\frac{1050 ft^3}{day}\right)\left(\frac{365 d}{yr}\right)\left(\frac{7.48 gal}{ft^3}\right)\left(\frac{3.78 l}{gal}\right) = 1.084 \times 10^7 l/yr$ or $1.807 l/yr$

$(30 lb/yr)(454 g)\left(\frac{1 \times 10^6 \mu g}{g}\right) = 1.36 \times 10^{10} \mu g/yr$ enters lake

∴ Ave GW conc. @ source = $\frac{1.36 \times 10^{10}}{1.084 \times 10^7}$ = 1255 µg/l or 754 µg/l

Seems too low.

Method!

Input is direct function of assumptions

Calculate Retardation Factor

Based on K_{oc}, PCE retards more than any of the other VOCs.

$$R_f = 1 + \frac{\rho (f_{oc})(K_{oc})}{\theta}$$

$$= 1 + \frac{(1.7)(0.006)(364)}{0.3} = 13$$

From RI, average TOC for aquifer = 6,000 mg/kg.

$f_{oc} = \frac{6000\ mg}{1 \times 10^6\ mg} = 0.006$

Change in VOC Concentrations

Assume VOC concentration decreases logarithmically during pumping:

$$C = C_o e^{-\alpha T}$$

Assuming need to achieve MCLs; $\therefore C = 3\ \mu g/l$ @ $T = t$

$$3 = C_o e^{-\alpha T}$$

$$\ln \frac{3}{C_o} = -\alpha T$$

$$\alpha = \frac{\ln C_o/3}{T}$$

$$C = C_o e^{-\left[\frac{\ln C_o/3}{T}\right] t}$$

$$\bar{C} = \int_o^T C_o e^{-\left[\frac{\ln C_o/3}{T}\right] t}$$

$$= C_o \left[\frac{-T}{\ln C_o/3}\right] e^{-\left[\frac{\ln C_o/3}{T}\right] t} \Bigg|_o^T$$

$$= C_o \left[\frac{-T}{\ln C_o/3}\right] \left(e^{-\ln C_o/3} - 1\right)$$

$$Mass = Q \times C_o \left[\frac{T}{\ln C_o/3}\right] \left(1 - e^{-\ln C_o/3}\right)$$

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SHEET 3 OF 4
JOB NO. 02545.51
DATE Dec 14, 1998
COMPUTED BY MJS
CHECKED BY [illegible]

PROJECT NTC Orlando OU4
SUBJECT Alternative Duration Calcs

C_o = STO 1
Mass = STO 2
Flow = STO 3
C = STO 4
↑ μg/l

$$T = \frac{Mass}{Q\,C_o} \ln \frac{C_o}{3}\left[\frac{1}{1-e^{-\ln C_o/3}}\right]$$

$$\frac{Mass}{Q\,C_o} = \frac{lb}{(gal/min)(\mu g/l)} \cdot \left(\frac{454g}{lb}\right)\left(\frac{1\times10^6\,\mu g}{g}\right) \Big/ \left(\frac{3.78\,l}{gal}\right)\left(\frac{1440\,min}{day}\right)$$

$$= 83,400$$

$$T(days) = 83,400\left[\frac{Mass\,(lb)}{Q\,(gpm)\,C_o\,(\mu g/l)}\right] \ln \underset{\uparrow\, C}{\frac{C_o}{3}}\left[\frac{1}{1-e^{-\ln C_o/\underset{\uparrow\, C}{3}}}\right]$$

Have 2 extraction wells (from WHPA simulation), each running at 40 GPM. One well is in the source area north of the surge tank. The other is along the north wall of the laundry building.

Assume C_o Well 1 = 5000 μg/l, and Mass = 4000
∴ Well 2 Mass = 2000 ; $C_o = \left(\frac{2000}{\cancel{6000}\ 4000}\right)(5) = \cancel{1,667}\ 2,500\ \mu g/l$ 12/21/98 MJS

Solve for T 12/21 MJS — why not $\frac{2000}{4000}$??

$T_{Well\,1}$ = 12382 days = 34 yrs

$T_{Well\,2}$ = ~~15,838~~ 11,232 days = ~~43~~ 31 yrs 12/21/98 MJS

However, K of the first 20 feet = 10 ft/day
K of next 20 feet = 40 ft/day

So of the 40 gpm, 8 gpm is from the shallow aquifer, and 32 gpm is from the ~~shallow~~ deep. And most of the source mass is located in the low conductivity zone.

Assume 2/3 of the mass is shallow (10 ft/day)

Recalculate times with consideration of the source distribution.

$T_{well\,1} = (34\,yrs)(2/3)(\frac{40}{8}) = 113$ yrs

$T_{well\,2} = (\frac{31}{45}\,yrs)(2/3)(\frac{40}{8}) = \frac{103}{144}$ yrs 12/21/98 MJS

Now recalculate durations assuming C = 500 µg/l (Assuming this concentration is adequate for NA

$$T = 83{,}400\left[\frac{Mass\,(lb)}{Q\,(gpm)\,C_o\,(\mu g/l)}\right] \ln \frac{C_o}{500}\left[\frac{1}{1 - e^{-\ln C_o/500}}\right]$$

Again, C_o Well 1 = 5000, Mass = 4000

C_o Well 2 = $\frac{2500}{1667}$, Mass = 2000 12/21/98 MJS

$T_{well\,1} = 4267$ days $= 11.7$ yrs

$T_{well\,2} = \frac{3356}{4302}$ days $= \frac{9.2}{11.8}$ yrs 12/21/98 MJS

Now adjust for source distribution

$T_{well\,1} = (11.7)(2/3)(40/8) = 39$ yrs

$T_{well\,2} = (\frac{9.2}{11.8})(2/3)(40/8) = \frac{31}{39}$ yrs 12/21/98 MJS

12/29/98 MJS NA Recalc

Assume need C = 80 µg/l

$T_{well\,1} = (19.2\,yrs)(2/3)(40/8) = 64$ yrs

$T_{well\,2} = (16.2\,yrs)(2/3)(40/8) = 54$ yrs

> Ave = 59 yrs

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SHEET 1 OF 1
JOB NO. 02545.51
DATE January 27, 1999
COMPUTED BY MJL
CHECKED BY WAM

PROJECT NTC Orlando OU4
SUBJECT Duration of IRA Operation

Problem: Several of the OU4 remedial alternatives focus on the VOC source area at the north end of Bldg 1100. Meanwhile, the southern VOC plume is addressed via enhanced bioremediation.
A portion of VOC contaminated GW between the existing IRA (recirc wells) and Building 1100 will continue to migrate towards the lake untreated.

How long must the IRA operate after OU4 remediation has begun to treat this portion of the plume?

K = 40 ft/day
Gradient (at Port Hueneme Ave) = 0.0046
Assume Porosity = 0.3

Seepage Velocity = (40 ft/day)(0.0046)/0.3 × 365 day
= 224 ft/yr ✓

Retardation Factor For PCE = 13 (See Appendix H)
Contaminant Vel = $\frac{224}{13}$ = 17 ft/yr

Average Length of Untreated Plume (Between IRA and Building 1100) = 170 ft

$$\boxed{\text{IRA Duration} = \frac{170\text{ ft}}{17\text{ ft/yr}} = 10\text{ yrs}}$$ ✓

Sonic Drilling Costs – Boart Longyear (Mark Prueher). 11/2000

Mob/Demob	$500-10,000	
2" ID, vertical	$55/ft	(typical construction). Sch. 40 PVC, casing, screen, annular fill matl's.
2" ID, angled	$85-90/ft	
4" ID, vertical	$65/ft	
4" ID, angled	$~100/ft	

- said point of entry ~12' ft from edge of building if no foundation is present below ground surface.

TerraProbe Costs – Harding ESE (Pat Craine)

Mob/Demob — Mark said $150.00

Rate $300-400/day

can install 4-5/day w/ concrete pads, vaults

6-7/day w/o pads, vaults

expendables $18 anchor pt.

$12 connector

$135 15 ft screen ($45/3 ft screen).

S. GIESE 11/2000.

We still need day rates. Call Pat Craine in Orlando, leave him a voicemail saying you & I are working on FS cost estimate for more probe work (wells) at OU4. We have expendable costs, but what should we use for day rates to install (how many) wells?

EQUIPMENT /SUPPLY REQUEST

FROM:	Patrick Craine	JOB NAME	Orlando OU4
DATE REQUESTED:	10/22/99	TO:	Mark Salvetti
DATE REQUIRED	11/10/99	JOB #	44241-0254510
SHIP TO ADDRESS	6500 all american blvd/Orlando	ACCT.#/CHARGE#:	550.2
SHIP ATTN: TO:	Patrick Craine/Bill Olson		

Detailed Description of order	Estimate date of return	QTY	Part #/ Catalog #	Unit Cost	Estimate Cost	vendor
Expendable Anchor Points One/well		7	GW-2040	$18.00	$126	Geoprobe 1-800436-7762
Snap Lock Connector One/well		7	GW-2030	$12.00	$84	Geoprobe 1-800436-7762
Double Pack Screen (Each is 3' long)		21	GW-2010	$45.00	$945	Geoprobe 1-800436-7762
Vinyl Slip Cap		7	AT-441	$0.25	$2	Geoprobe 1-800436-7762
5'x.5 Schd. 80 riser		15	GW-2050	$7.50	$113	Geoprobe 1-800436-7762
30/65 sand		3		$5.00	$15	local
20/30 Sand		3		$5.00	$15	local
Issco pump		1				
Micro-tip (PID)		1				
Micro-tip cal kit		1				
LEL		1				
LEL Cal kit		1				
Scale (Measurements to .01 of gram)		1				
Weighing boats(tins)		100				
Spatulas		100			$0	
500 mil graduated cylinder		3			$0	
500 mil beakers		3			$0	
525nm spectrophotometer (Hach DR/700		1			$0	
with 5201 Filter Module)					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
					$0	
TOTAL ESTIMATE COST OF SUPPLIES					$1,299	

Dave, please see the attached email for info regarding dates we need the lab equip and PID/LEL.

Project manager signature

** This an authtorsation for procurement to expend funds from account # 44241/0254510 550.20 to procure the listed supplies.

NATIONAL RENT-A-FENCE, CO.

P.O. Box 620757
Orlando, FL 32862
(800) 352-5675 • (407) 381-2727
Fax # (800) 756-3529

FAX TRANSMITTAL SHEET

Post-it® Fax Note 7671	Date 1-10-99	# of pages ▸ 3
To Mark Salvetti	From Bill Olson	
Co./Dept. Wakefield	Co.	
Phone #	Phone #	
Fax #	Fax #	

DATE: 1/1

COMPANY:

ATTN: Bi

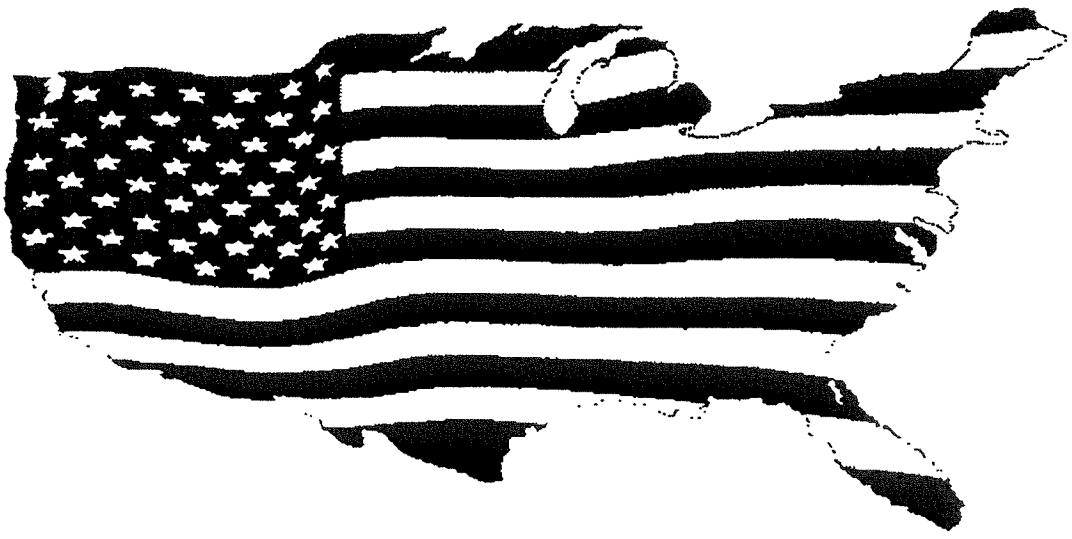
UDING COVER SHEET)

MESSAGES:

Our next available installation date is 1/14/00.
Let me know if you wish to schedule.
Thanks!

FROM: Denise Owens

" Service From Coast to Coast "



NATIONAL RENT-A-FENCE, CO.

SPECIALIZING IN
TEMPORARY FENCE • TEMPORARY PANELS

(800) 352-5675

"SERVICE FROM COAST TO COAST"

BID FORM

COMPANY: Harding Lawson Assoc.
ATTN: Bill Olson
PHONE #: 407-522-7570
FAX: 407-522-7576
JOB SITE ADDRESS: NTC Orlando.
CITY: Orlando, FL
JOB PHONE:

TODAY'S DATE: 1/10/00
CUST. REP. Denise Owens
EST. START DATE:

THE LARGEST TEMPORARY FENCE CO. IN AMERICA SERVING THE CONSTRUCTION INDUSTRY SINCE 1962

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL
250	6' high chain link fence	$1.59 plf	$251.59
1	6x12 gate	$95.00 ea.	95.00
250	Core Drill	$0.50 plf	125.00
262'	Barbed Wire - 3 strands	$0.75 plf	196.50

SUB TOTAL	$668.09
TAX 6%	40.08
TOTAL	$708.17

LENGTH OF RENTAL : ☒ 6 MOS ☐ 1 YR

THERE IS A $ 400.00 MINIMUM FOR THIS JOB SITE

EXTRA CHARGES INCLUDE: TRIP CHARGES, HARD GROUND, HILLSIDE, CORE DRILL, HANDCARRY, INACCESSIBLE, BARBED WIRE

ANY EXTRA CHARGES ARE TO BE AGREED UPON BETWEEN BOTH COMPANIES' FIELD REPRESENTATIVES ON SITE

The price on this bid includes a one time installation and a one time removal.

We are an open shop. Any & all union charges are extra.

THIS QUOTE IS VALID FOR 30 DAYS. SUBJECT TO TERMS AND CONDITIONS

NATIONAL RENT-A-FENCE, CO.

SPECIALIZING IN
TEMPORARY FENCE • TEMPORARY PANELS

(800) 352-5675

"SERVICE FROM COAST TO COAST"

BID FORM

COMPANY: Harding Lawson Assoc.
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PHONE #: 407-522-7570
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JOB SITE ADDRESS: NTC Orlando
CITY: Orlando, FL
JOB PHONE:

TODAY'S DATE: 1/10/00
CUST. REP.: Denise Owens
EST. START DATE:

THE LARGEST TEMPORARY FENCE CO. IN AMERICA
SERVING THE CONSTRUCTION INDUSTRY SINCE 1962

QUANTITY	DESCRIPTION	UNIT PRICE	TOTAL
250'	8' high chain link fence	$3.59 plf	$897.50
1	8x12 gate	$245.00 ea	$ 245.00
250'	Core Drill	$0.50 plf	$ 125.00

SUB TOTAL	$1267.50
TAX 6%	76.05
TOTAL	$1343.55

LENGTH OF RENTAL: ☒ 6 MOS ☐ 1 YR

THERE IS A $ 400.00 MINIMUM FOR THIS JOB SITE

EXTRA CHARGES INCLUDE: TRIP CHARGES, HARD GROUND, HILLSIDE, CORE DRILL, HANDCARRY, INACCESSIBLE, BARBED WIRE

ANY EXTRA CHARGES ARE TO BE AGREED UPON BETWEEN BOTH COMPANIES' FIELD REPRESENTATIVES ON SITE

This price on this bid includes a one time installation and a one time removal.

We are an open shop. Any & all union charges are extra.

THIS QUOTE IS VALID FOR 30 DAYS. SUBJECT TO TERMS AND CONDITIONS

APPENDIX F

APPENDIX F

HYDROGEN RELEASE COMPOUND (HRC) DESIGN CALCULATIONS

Source Area Inject (Only)

HRC Injection for Source Area Treatment

Basic Site Characteristics

Length of Plume (ft)	55
Width of Plume (ft)	45
Thickness of Saturated Zone (ft)	40
Porosity	0.3
Click on button to find applicable porosity if unknown	
Total Treatment Zone Volume (cu. ft.)	29,700

Contaminant Levels	ppm	# Contam	# H_2 Req
PCE (ppm)	0.80	1.481	0.0705
TCE (ppm)	0.50	0.926	0.0421
DCE (ppm)	0.00	0.000	0.0000
VC (ppm)	0.00	0.000	0.0000
Weighted Average of Contaminants	1.28	2.360	0.1124

ADDITIONAL DEMAND FACTORS (ADFs)

Competing Electron Acceptors (CEA)	ppm	# CEA	# H_2 Req
Oxygen (ppm)	1.00	1.85	0.23
Nitrate (ppm)	0.00	0.00	0.00
Ferrous Iron (Fe^{2+}) (ppm)	0.00	0.00	0.00
Sulfate (SO_4) (ppm)	16.00	29.62	2.47
Totals of Competing Electron Acceptors		31.47	2.70
CEA:Contaminant Ratio			24.02

(Ratio of H2 demand for CEA vs. H2 demand Solvents)

Safety Factor for Interstitial Contaminants and Uncertainties (enter a value between 1 and 4) *(Default = 1.0)*	1
ADF for Competing Microbial Processes (CMP) (enter a value between 2 and 4) *(Default = 3.0)*	3
ADF for Hydrophobic Sorbtion (HS) *(Default = 3.0)*	10.4

If you do not know your HS ADF you can calculate it by inputing the values for the specific variables

Soil Bulk Density (kg/L)	1.7
Click on button to find applicable Bulk Density Value	
Partition Coefficient (L/kg)	277
Click on button to find applicable Koc Value	
Fraction Organic Carbon	0.006
Click on button to find applicable Foc Value	
Calculated ADF for Hydrophobic Sorbtion	10.4

If you calculate HS using specific values please re-enter calculated value here

Note: this cell needed for calc; do not erase. ok to cut and paste somewhere else.

#REF!

Calculated HRC Requirements and Spacing

Hydrogen Required (lbs)	0.11
HRC Required (lbs)	5.06
Adjusted HRC (lbs)	405
Adjusted / Required Ratio	80.07
Unit cost of HRC ($ / lb)	$ 11.00
Total Cost of HRC ($)	$ 4,455

THIS IS THE COST BASED ON CALCULATED NEED, HOWEVER, AN ACTUAL APPLICATION WILL REQUIRE A SPECIFIC AMOUNT OF HRC TO FILL A DESIGNATED SERIES OF HOLES.
MAKE SURE THE VOLUMETRIC/CALCULATED RATIO GIVEN BELOW = 1.00; THIS MEANS ALL HOLES ARE FILLED.
IF THE V/C RATIO IS < 1.00 THEN CONSIDER MORE HOLES, LARGER HOLES AND INJECTION AS OPTIONS.
IF THE V/C RATIO IS > 1.00, PLACE THAT NUMBER IN THE APPLICATION MULTIPLE CELL (v/c ratio will then = 1)
ONCE HOLES ARE FILLED (at v/c ratio = 1) ADDITIONAL MULTIPLES CAN BE INJECTED IF DESIRED.
FOR INJECTIONS SEE LAST INPUT SECTION USING "MATRIX MULTIPLES" FROM 1X FOR CLAY TO 6X FOR SAND.

Volumetric Requirements

Hole Spacing (ft)	12
Number of Holes in Grid	17
HRC per Hole (lbs)	23.82
HRC per Linear Foot (lbs)	0.60
Application Multiple	1.67

Consult the Volumetric/Calculated ratio below.
If the ratio is > 1.00, place this value in the Application Multiple cell.

THE ADJUSTED HRC COST =	$ 7,440
Total Pounds of HRC Required	676.35
Pounds HRC per hole w/o injection	39.78
Max. per linear foot (lb / ft)	0.99
"CALCULATED HRC"	
This value should = VOLUMETRIC HRC value below	

× 3 yr injections = 2029 lbs

Application Calculations for Hole Filling

Depth of Hole (ft)	20
Hole Diameter (in)	1.50
Volume of Hole (cc)	6946
Volume of Hole (cu in)	423.9
Volume of Hole (cu ft)	0.25
Volume of Hole (gallons)	1.84
Density of HRC (g/cc)	1.3

HRC (sorbitol) = 1.1 g/cc, HRC - Primer (glycerol) = 1.3 g/cc

Amount of HRC per Hole(lbs)	19.9
HRC per linear Foot (lbs/ft)	0.99
"VOLUMETRIC HRC"	

Ratio of Volumetric HRC per Hole to Calculated HRC per Hole	1.00

When this ratio is 1.0 or greater it means that you must add more HRC to fill the dimensions of the chosen holes. Place this value in the Application Multiple cell and convert the Ratio to 1.00. If the value is under 1.00 then more holes are needed and/or the hole diameter must be increased until the value is greater than or equal to 1.00. Alternatively, just inject using a multiple (reciprocal of the V/C Ratio), however, the matrix must be able to receive the multiple using the guidelines described (clay = 1; sand = 6)

INJECTION MULTIPLE CALCULATION FOR RATIOS < 1.00

Instead of adding holes or increasing hole diameter you may simply inject the following multiple of the hole volume

[ ] With this application the V/C Ratio is 1.00 and additional multiples can be made with the calculation below

OPTIONAL MATRIX MULTIPLE CALCULATIONS WHEN RATIO = 1

After hole filling requirements are met (V/C Ratio = 1.00), injection can be considered.
Using 1 for clay and 6 for sand, add multiples as required.

MATRIX MULTIPLE	1
Injection HRC Cost is	$ 7,440
Pounds of HRC if Injecting =	676.35

Actual installation may be w/ smaller diameter borehole and "sand" injection. Keep as shown for costing purposes.

HRC Injection into a Source Area for Plume Control

Basic Site Characteristics

Length of Plume (ft)	540
Width of Plume (ft)	150
Thickness of Saturated Zone (ft)	40
Porosity	0.3

...utton to find applicable porosity if unknown

...inant Levels	ppm	# Contam	# H_2 Req
PCE (ppm)	0.80	48.472	2.3082
TCE (ppm)	0.50	30.295	1.3770
DCE (ppm)	0.00	0.000	0.0000
VC (ppm)	0.00	0.000	0.0000
Weighted Average of Contaminants	1.28	77.252	3.6786

ADDITIONAL DEMAND FACTORS (ADFs)

Competing Electron Acceptors (CEA)	ppm	# Contam	# H_2 Req
Oxygen (ppm)	1.00	60.59	7.57
Nitrate (ppm)	0.00	0.00	0.00
Ferrous Iron (Fe^{2+}) (ppm)	0.00	0.00	0.00
Sulfate (SO_4) (ppm)	16.00	969.43	80.79
Totals of Competing Electron Acceptors		1030.02	88.36
CEA:Contaminant Ratio			24.02

(Ratio of H2 demand for CEA vs. H2 demand Solvents)

ADF for Hydrophobic Sorbtion (HS) ***(Default = 3.0)*** 10.4

If you do not know your HS ADF you can calculate it by inputing the values for the specific variables

Soil Bulk Density (kg/L)	1.7
Click on button to find applicable Bulk Density Value	
Partition Coefficient (L/kg)	277
Click on button to find applicable Koc Value	
Fraction Organic Carbon	0.006
Click on button to find applicable Foc Value	
Calculated ADF for Hydrophobic Sorbtion	10.4

if you calculate HS using specific variables please re-enter calculated value here

Safety Factor for Interstitial Contaminants and Uncertainties 1

(...alue between 1 and 4)

A... Competing Microbial Processes (CMP) 3

(e... alue between 2 and 4)

MODELING FACTORS

Seepage Velocity (ft/yr) 224

If you do not know your seepage velocity you can calculate it by inputing the values for the specific variables below

Hydraulic Conductivity (k) (ft/day)	40.000
Gradient (ft/ft)	0.0046
Effective Porosity *same as above*	0.300
Velocity [ft/day]	0.613
Seepage Velocity (ft/yr)	224

if you calculate seepage velocity using specific variables, please re-enter calculated value here

Source Width Perpendic. to GW (ft)	150	
Modeled Area Length (ft)	540	
Lactate concentration from Barrier (mg/L) *(calculated lab number)*	175	
Year Source Material Released (yyyy)	1945	
Natural Decay Rate (per yr) *(calculated through "Goal Seek for Lamda" below)*	0.104	0.30
Year Start RHRC Treatment (yyyy)	1998	
Concentration at edge (mg/L): *(MCL value required at edge of plume)*	0.003	
Hole Spacing Minimum (ft)	8	
Hole Spacing Maximum (ft)	12	
Cost of HRC per pound ($/lb)	$ 11.00	

Hole Filling Data

Depth of Hole (ft)	40
Hole Diameter (in)	2.0
Volume of Hole (cc)	24699
Density of HRC (g/cc)	1.2
Weight of HRC (lbs)	65
Minimum HRC (lbs/ft)	1.63
Matrix Multiple	3

This value used on output sheet

Enter matrix injection multiple between 1 and 6

A value of 1 represents a tight matrix (eg, clay)

A value of 6 represents a loose matrix (eg, sand)

Maximum HRC (lbs/ft) 4.90

You must click on the "Calibrate Model to Actual Plume Length" button to calculate this sheet

Years After HRC Application (maximum of 3)	1
Number of Downgradient Barriers Added Automatically (maximum of 7)	1
Total Number of Barriers (includes manual barriers entered below)	3

Distance From Source (ft)	0	0.1	9	18	27	37	48	60	72	85	99	115
Calculated Barrier Placement	yes	yes					yes					
Concentration Chlor (ppm) : No Hydrogen Addition	1.275	1.275	1.223	1.171	1.119	1.066	1.014	0.961	0.908	0.855	0.801	0.746
Concentration Chlor (ppm) : With H2 Addition												
RECOMMENDATION: Add Manual barrier if concentration level is > 0.05	0.102	0.102	0.050	0.356	0.794	0.967	0.001	0.001	0.093	0.530	0.702	0.722
Manual Barriers (Type 'yes" if manual barrier is desired)							yes					

Number of Barriers: 3

Number of Barriers Added Manually: 2

	Primary Barrier	Downgrad Barriers										
Width of Barrier (ft)	150	150					143					
#'s per year for primary b. (used for years after year 1)	32											
# Sorbed Contam. Dngrad. of Barriers		5.4					7.6					
# Dissolved Contam. Upgradient of Barriers		32.0					0.6					
# of H2 Req. Just For Sorbed Contam. Downgrad. of Barrier		0.3					0.4					
# of H2 Req. Just For Disolved Contam. Upgrad. of Barrier	1.5	1.5					0.0					
Contaminant Ratio (CEA)	24.0	24.0					24.0					
ADF for Hydrophobic Sorb. (HS)	0	10.4					10.4					
Safety Factor for Interstitial Contaminant (SF)	1	1					1					
ADF for Competing Microbial Processes (CMP)	3	3					3					
Total Hydrogen Required (lbs)	42.7	86.5					11.6					
HRC Required (lbs)	1922	3893					520					
Hole Spacing (ft)	12	8					12					
Number of Holes in Barrier	13	19					12					
HRC per Hole (lbs)	147.8	204.9					43.4					
HRC required (lbs/ft)	3.70	5.12					1.08					
Minimum HRC Injected (lbs/ft)	1.63	1.63					1.63					
Maximum HRC Injected (lbs/ft)	4.90	4.90					4.90					
Actual HRC Injected (lbs/ft)	3.70	4.90					1.63					
Actual HRC Injected (lbs)	1922	3721					783					
Number of Iterations (not connected)		1					1					
HRC Unit Cost	$ 11.00	$ 11.00					$ 11.00					
Total Cost of HRC	$ 21,139	$ 40,932					$ 8,617					

Distance From Source (ft)	132	150	171	195	222	255	294	345	417	540
Calculated Barrier Placement		yes								
Concentration Chlor. : No Hydrogen Addition	0.691	0.635	0.578	0.519	0.459	0.397	0.331	0.262	0.186	0.104
Concentration Chlor (ppm) : With H2 Addition										
RECOMMENDATION: Add Manual barrier if concentration level is > 0.05	0.687	0.001	0.001	0.001	0.134	0.298	0.307	0.257	0.186	0.103
Manual Barriers (Type 'yes" if manual barrier is desired)		yes								

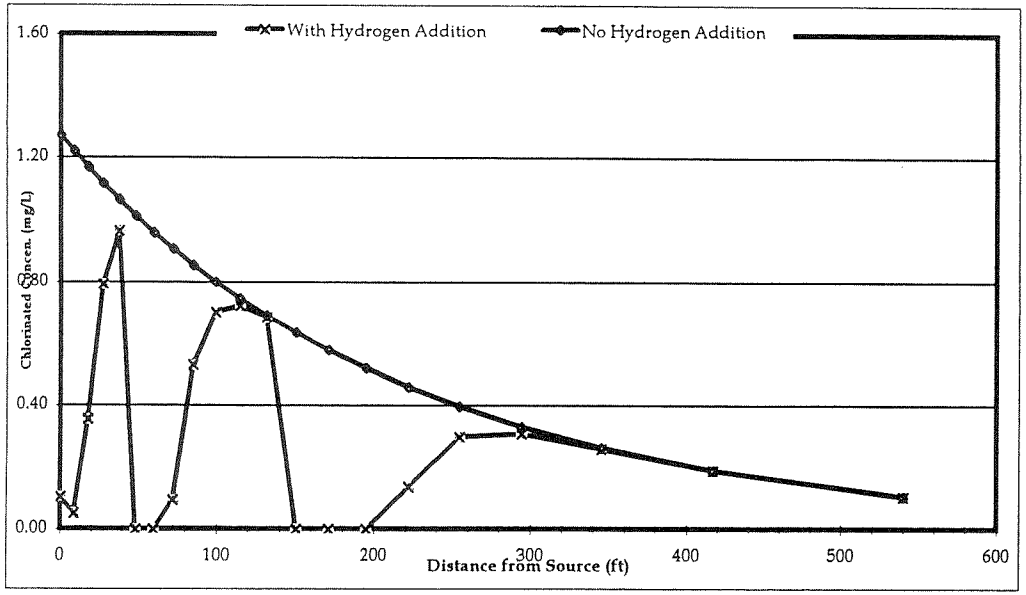
Number of Barriers: 3

Manual Barriers: 2

Width of Barrier (ft)	127									
# of Contaminants Dngrad. of Barrier	7.6									
# of H2 Required	0.4									
CEA:Contaminant Ratio	24.0									
ADF for Hydrophobic Sorbtion (HS) A36	10.4									
ADF for Interstitial Contaminant (IC)	1									
ADF for Competing Microbial Processes (CMP)	3									
Hydrogen Required (lbs)	12.1									
HRC Required (lbs)	545									
Hole Spacing (ft)	12									
Number of Holes in Barrier	11									
HRC per Hole (lbs)	49.5									
HRC per foot	1.24									
Minimum HRC Injected (lbs/ft)	1.63									
Maximum HRC Injected (lbs/ft)	4.90									
Actual HRC Injected (lbs/ft)	1.63									
Actual HRC Injected (lbs)	718									
Number of Iterations (not connected)	1									
HRC Unit Cost	$ 11.00									
Total Cost of HRC	$ 7,899									

Total HRC Needed in first year: 5,223

HRC required for each additional year: 1,922


With Hydrogen Addition
No Hydrogen Addition
1.60
1.20
0.80
0.40
0.00
Chlorinated Concen. (mg/L)
0
100
200
300
400
500
600
Distance from Source (ft)

Years After HRC Application (maximum of 3)	2
Number of Downgradient Barriers Added Automatically (maximum of 7)	1
Total Number of Barriers (includes manual barriers entered below)	3

Distance From Source (ft)	0	0.1	9	18	27	37	48	60	72	85	99	115
Calculated Barrier Placement	yes	yes					yes					
Concentration Chlor (ppm) : No Hydrogen Addition	1.275	1.275	1.223	1.171	1.119	1.066	1.014	0.961	0.908	0.855	0.801	0.746
Concentration Chlor (ppm) : With H2 Addition												
RECOMMENDATION: Add Manual barrier if concentration level is > 0.05	0.102	0.102	0.050	0.007	0.096	0.323	0.001	0.001	0.001	0.001	0.045	0.286
Manual Barriers (Type 'yes" if manual barrier is desired)							yes					

Number of Barriers: 3

Number of Barriers Added Manually: 2

	Primary Barrier	Downgrad Barriers										
Width of Barrier (ft)	150	150					143					
#'s per year for primary b. (used for years after year 1)	32											
# Sorbed Contam. Dngrad. of Barriers		5.4					7.6					
# Dissolved Contam. Upgradient of Barriers		32.0					0.6					
# of H2 Req. Just For Sorbed Contam. Downgrad. of Barrier		0.3					0.4					
# of H2 Req. Just For Disolved Contam. Upgrad. of Barrier	1.5	1.5					0.0					
Contaminant Ratio (CEA)	24.0	24.0					24.0					
ADF for Hydrophobic Sorb. (HS)	0	10.4					10.4					
Safety Factor for Interstitial Contaminant (SF)	1	1					1					
ADF for Competing Microbial Processes (CMP)	3	3					3					
Total Hydrogen Required (lbs)	42.7	86.5					11.6					
HRC Required (lbs)	1922	3893					520					
Hole Spacing (ft)	12	8					12					
Number of Holes in Barrier	13	19					12					
HRC per Hole (lbs)	147.8	204.9					43.4					
HRC required (lbs/ft)	3.70	5.12					1.08					
Minimum HRC Injected (lbs/ft)	1.63	1.63					1.63					
Maximum HRC Injected (lbs/ft)	4.90	4.90					4.90					
Actual HRC Injected (lbs/ft)	3.70	4.90					1.63					
Actual HRC Injected (lbs)	1922	3721					783					
Number of Iterations (not connected)		2					2					
HRC Unit Cost	$ 11.00	$ 11.00					$ 11.00					
Total Cost of HRC	$ 21,139	$ 40,932					$ 8,617					

Distance From Source (ft)	132	150	171	195	222	255	294	345	417	540
Calculated Barrier Placement		yes								
Concentration Chlor. : No Hydrogen Addition	0.691	0.635	0.578	0.519	0.459	0.397	0.331	0.262	0.186	0.104
Concentration Chlor (ppm) : With H2 Addition										
RECOMMENDATION: Add Manual barrier if concentration level is > 0.05	0.449	0.001	0.001	0.001	0.001	0.001	0.001	0.020	0.077	0.062
Manual Barriers (Type 'yes" if manual barrier is desired)		yes								

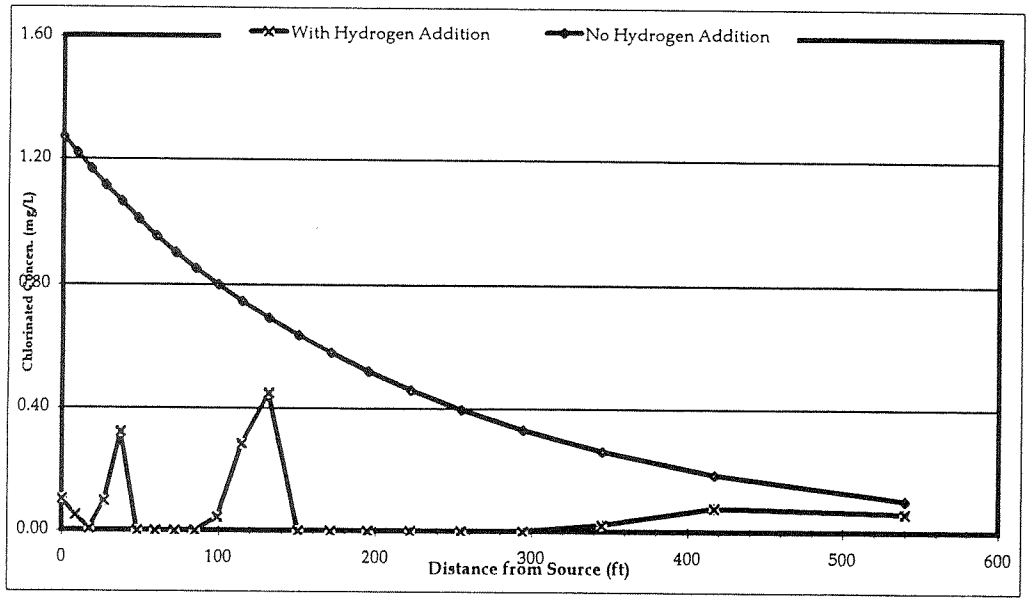
Number of Barriers: 3

Manual Barriers: 2

Width of Barrier (ft)		127								
# of Contaminants Dngrad. of Barrier		7.6								
# of H2 Required		0.4								
CEA:Contaminant Ratio		24.0								
ADF for Hydrophobic Sorbtion (HS) A36		10.4								
ADF for Interstitial Contaminant (IC)		1								
ADF for Competing Microbial Processes (CMP)		3								
Hydrogen Required (lbs)		12.1								
HRC Required (lbs)		545								
Hole Spacing (ft)		12								
Number of Holes in Barrier		11								
HRC per Hole (lbs)		49.5								
HRC per foot		1.24								
Minimum HRC Injected (lbs/ft)		1.63								
Maximum HRC Injected (lbs/ft)		4.90								
Actual HRC Injected (lbs/ft)		1.63								
Actual HRC Injected (lbs)		718								
Number of Iterations (not connected)		2								
HRC Unit Cost		$ 11.00								
Total Cost of HRC		$ 7,899								

Total HRC Needed in first year: 5,223

HRC required for each additional year: 1,922


With Hydrogen Addition
No Hydrogen Addition
1.60
1.20
0.80
0.40
0.00
Chlorinated Concen. (mg/L)
0
100
200
300
400
500
600
Distance from Source (ft)

Years After HRC Application (maximum of 3)	3
Number of Downgradient Barriers Added Automatically (maximum of 7)	1
Total Number of Barriers (includes manual barriers entered below)	3

Output

Distance From Source (ft)	0	0.1	9	18	27	37	48	60	72	85	99	115
Calculated Barrier Placement	yes	yes					yes					
Concentration Chlor (ppm) : No Hydrogen Addition	1.275	1.275	1.223	1.171	1.119	1.066	1.014	0.961	0.908	0.855	0.801	0.746
Concentration Chlor (ppm) : With H2 Addition RECOMMENDATION : Add Manual barrier if concentration level is > 0.05	0.102	0.102	0.050	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manual Barriers (Type 'yes" if manual barrier is desired)							yes					

Number of Barriers: 3

Number of Barriers Added Manually: 2

Use Grid Riders

	Primary Barrier	Downgrad Barriers										
Width of Barrier (ft)	150	150					143					
#'s per year for primary b. (used for years after year 1)	37											
# Sorbed Contam. Dngrad. of Barriers		5.4					7.6					
# Dissolved Contam. Upgradient of Barriers		32.0					0.6					
# of H2 Req. Just For Sorbed Contam. Downgrad. of Barrier		0.3					0.4					
# of H2 Req. Just For Disolved Contam. Upgrad. of Barrier	1.5	1.5					0.0					
Contaminant Ratio (CEA)	24.0	24.0					24.0					
ADF for Hydrophobic Sorb. (HS)	0	10.4					10.4					
Safety Factor for Interstitial Contaminant (SF)	1	1					1					
ADF for Competing Microbial Processes (CMP)	3	3					3					
Total Hydrogen Required (lbs)	42.7	86.5					11.6					
HRC Required (lbs)	1922	3893					520					
Hole Spacing (ft)	12	8					12					
Number of Holes in Barrier	13	19					12					
HRC per Hole (lbs)	147.8	204.9					43.4					
HRC required (lbs/ft)	3.70	5.12					1.08					
Minimum HRC Injected (lbs/ft)	1.63	1.63					1.63					
Maximum HRC Injected (lbs/ft)	4.90	4.90					4.90					
Actual HRC injected (lbs/ft)	3.70	4.90					1.63					
Actual HRC injected (lbs)	1922	3721					783					
Number of Iterations (not connected)		3					3					
HRC Unit Cost	$ 11.00	$ 11.00					$ 11.00					
Total Cost of HRC	$ 21,139	$ 40,932					$ 8,617					

Distance From Source (ft)	132	150	171	195	222	255	294	345	417	540
Calculated Barrier Placement		yes								
Concentration Chlor. : No Hydrogen Addition	0.691	0.635	0.578	0.519	0.459	0.397	0.331	0.262	0.186	0.104
Concentration Chlor (ppm) : With H2 Addition RECOMMENDATION: Add Manual barrier if concentration level is > 0.05	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manual Barriers (Type 'yes" if manual barrier is desired)		yes								

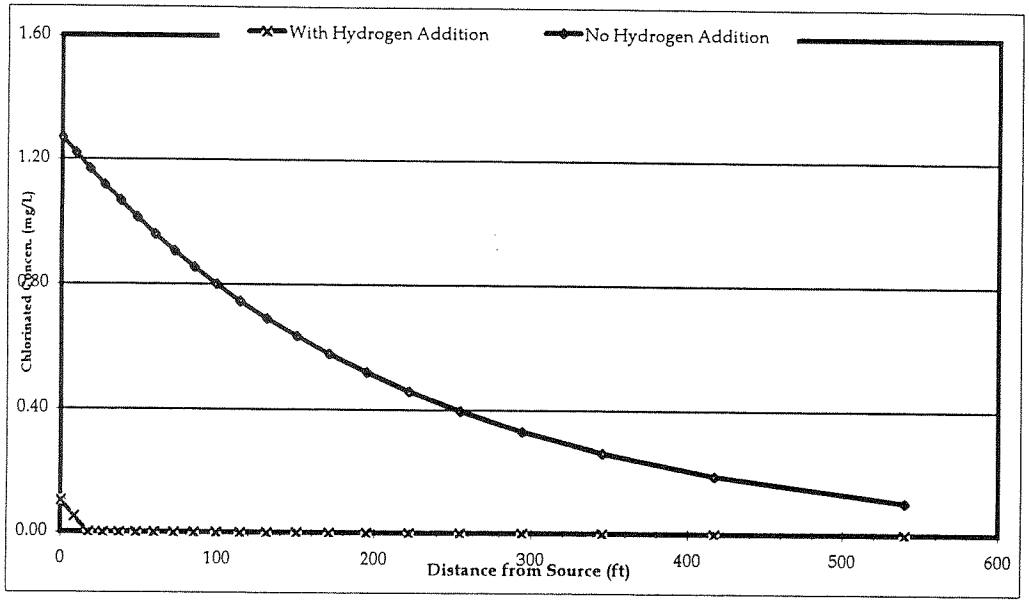
Number of Barriers: 3

Manual Barriers: 2

Width of Barrier (ft)		127								
# of Contaminants Dngrad. of Barrier		7.6								
# of H2 Required		0.4								
CEA:Contaminant Ratio		24.0								
ADF for Hydrophobic Sorbtion (HS) A36		10.4								
ADF for Interstitial Contaminant (IC)		1								
ADF for Competing Microbial Processes (CMP)		3								
Hydrogen Required (lbs)		12.1								
HRC Required (lbs)		545								
Hole Spacing (ft)		12								
Number of Holes in Barrier		11								
HRC per Hole (lbs)		49.5								
HRC per foot		1.24								
Minimum HRC Injected (lbs/ft)		1.63								
Maximum HRC Injected (lbs/ft)		4.90								
Actual HRC injected (lbs/ft)		1.63								
Actual HRC injected (lbs)		718								
Number of Iterations (not connected)		3								
HRC Unit Cost		$ 11.00								
Total Cost of HRC		$ 7,899								

Total HRC Needed in first year: 5,223

HRC required for each additional year: 1,922


With Hydrogen Addition
No Hydrogen Addition
1.60
1.20
0.80
0.40
0.00
Chlorinated Concen. (mg/L)
0
100
200
300
400
500
600
Distance from Source (ft)

Total Product Cost for HRC Barrier System

The following costs are a summation of the individual HRC barriers recommened to effectively remediate your contaminated site. These costs are for HRC only and do not include other costs such as installation, monitoring, engineering, etc.

Cost of HRC to Cleanup Plume *(all downgradient barriers)*	$ 57,449
Cost of HRC per Year to Stop Upgradient Flow *(one primary barrier)*	$ 21,139
Number of years needed for upgradient control via primary barrier after 1 year treatment period (for first year cost enter "0")	0
Total Cost of HRC for Primary Barrier(s)	$ -
Total Cost for All Barriers in Total Project Duration	$ 57,449
Total HRC Needed to Clean up the plume (lbs)	5,223
HRC Required to Stop Upgradient Flow After 1 year treatment period	-

Check: (From Output Sheet)
#'s at Barrier 1 = 3721#
#'s at Barrier 2 (48') = 783#
#s at " 3 (150') 718#
5,222# O.K.

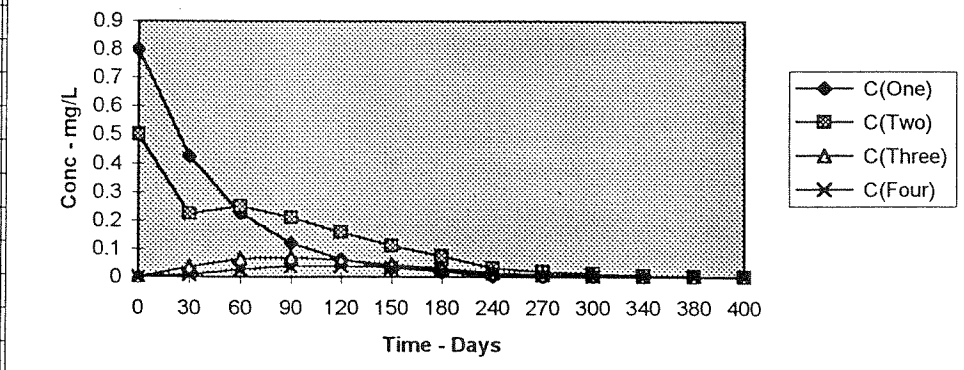
Spreadsheet to calculate time dependent concentrations for up to four successive first-order reactions k1, k2, k3, k4 not equal

Constituent	Molecular weight	rate const per day	Reference Compounds	MW	rate	(from RT3D)
One	165.8	0.021	PCE	165.8	0.00068 to 0.54	
Two	131.36	0.0176	TCE	131.36	0.0001 to 0.021	
Three	96.9	0.0418	DCE	96.9	0.00016 to 0.026	
Four	62.45	0.0443	VC	62.45	0.0003 to 0.012	

If interested in less than four compounds, i.e., TCE to VC, enter rate constants as zero beginning at four

Initial conc (mg/L) = 0.8 4.8251E-06 mol/L

Time, days	C(One)	C(Two)	C(Three)	C(Four)	Total VOCs, mg/L	
0	0.8	0.5	0	0	1.3	
30	0.426073	0.223893	0.035239	0.00832869	0.693535	
60	0.226923	0.251292	0.06539	0.02717479	0.57078	
90	0.120857	0.211716	0.069696	0.03834454	0.440614	
120	0.064368	0.158691	0.059789	0.03890851	0.321756	
150	0.034282	0.111607	0.045814	0.03325974	0.224963	
180	0.018258	0.075419	0.032811	0.02567429	0.152162	
240	0.005179	0.031969	0.014944	0.01282363	0.064915	
270	0.002758	0.020304	0.009714	0.00858313	0.041359	
300	0.001469	0.012747	0.006209	0.00561137	0.026037	
340	0.000634	0.006757	0.003353	0.00309926	0.013843	
380	0.000274	0.003537	0.00178	0.00167328	0.007264	
400	0.00018	0.00255	0.001291	0.0012214	0.005241	
420	0.000118	0.001834	0.000933	0.00088832	0.003773	Note: Plot not include this point
MCL Surface water	3	8	3	80	70 --	1 1
Final conc	1.09E-09	1.94E-08	1.33E-08	1.9558E-08	5.34E-08	molar basis



APPENDIX G

APPENDIX G

VISUAL MODFLOW AND WELLHEAD PROTECTION AREA MODELING

Visual MODFLOW Input Parameters

Grid

X	600 ft	
Y	400 ft	
Z	60 ft	12 layers at 5' each

Boundaries

2 north-south constant head boundaries at the east and west borders of the grid impose a hydraulic gradient under pre-pumping conditions of 0.005 ft/ft.
The north and south boundaries of the grid are assumed to be no-flow boundaries.

Properties

	Layers 1-4 (Upper 20', Shallow Zone)	Layers 5-12 (Lower 40', Deep Zone)
Hydraulic Conductivity, Kx	10 ft/day	40 ft/day
Hydraulic Conductivity, Ky	10 ft/day	40 ft/day
Vertical Hydraulic Conductivity, Kz	3.3 ft/day	13.3 ft/day
Effective Porosity	0.30	0.30
Total Porosity	0.33	0.33
Specific Storage	0.0005 1/ft	0.0005 1/ft
Specific Yield	0.25	0.25

Wells

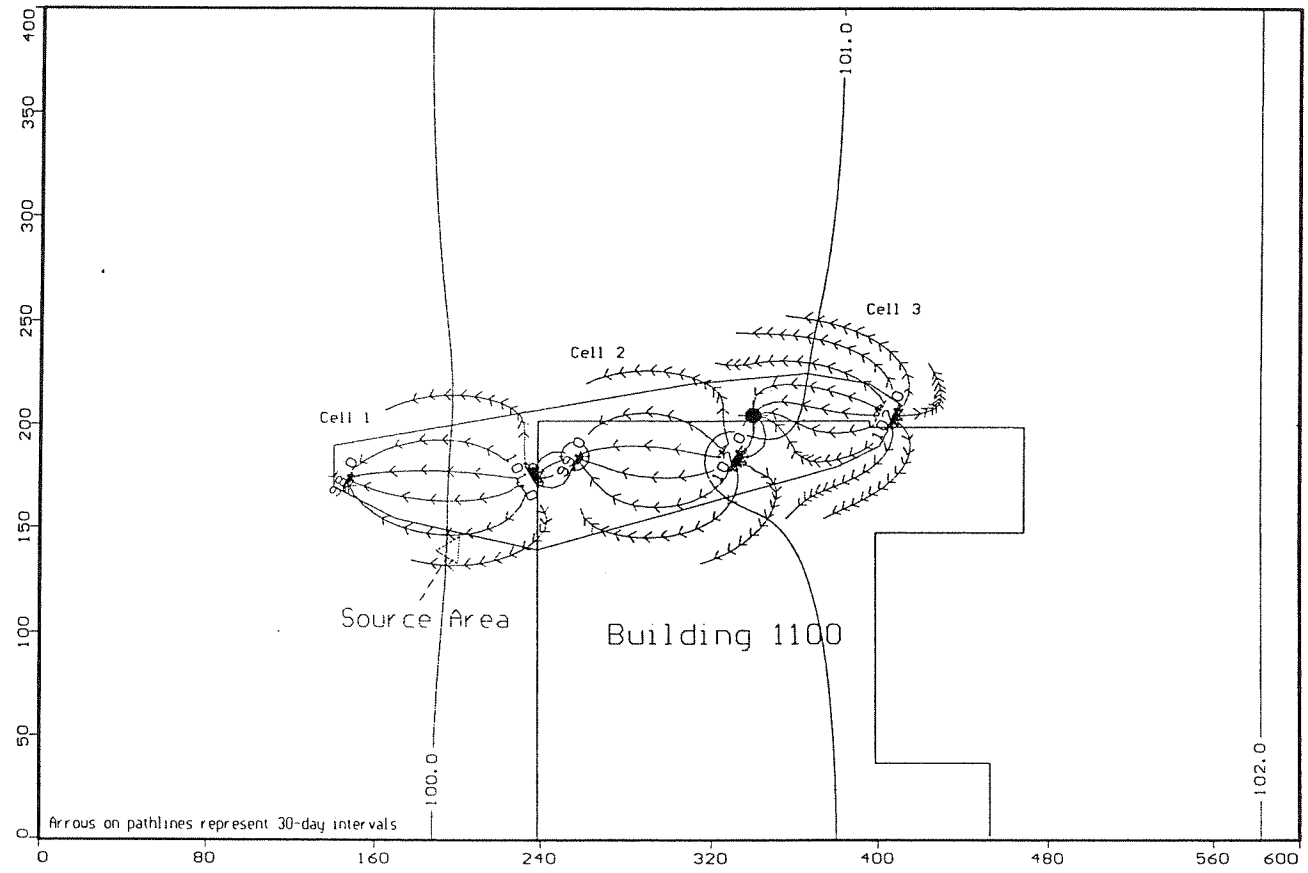
2 wells were installed at each injection and extraction point. One was screened through the entire shallow layer (layers 1-4, 0-20' bgs) and the other was screened 10 feet through the deep layer (layers 5-6, 20-30' bgs).
The easternmost injection/extraction well pair is pumping @ 1 gpm in the shallow zone and 2 gpm in the deep zone. The other two injection/extraction pairs are pumping at 2 gpm in the shallow zone and 4 gpm in the deep zone.

Particles

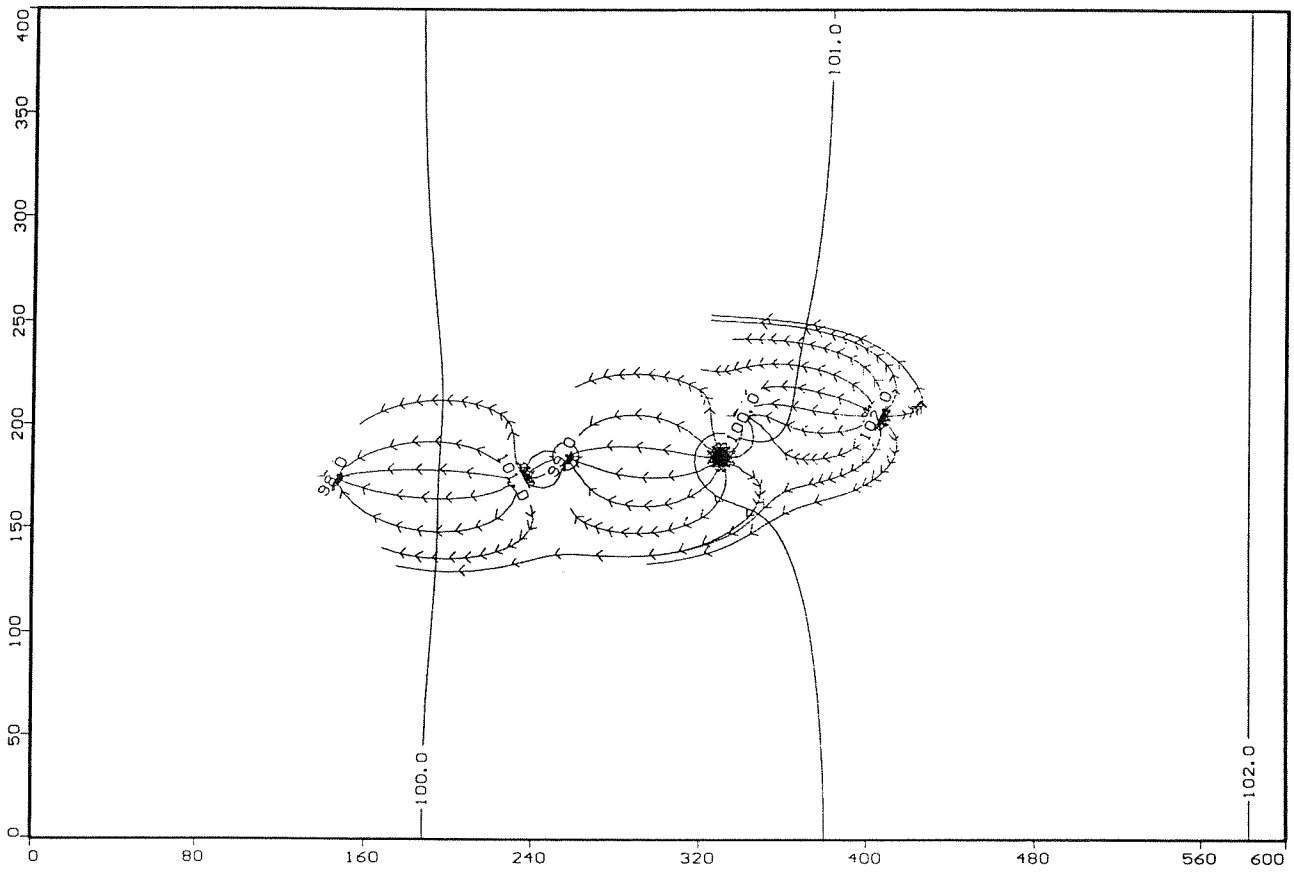
10 particles were released at time zero from each injection point in the 1st, 3rd, 5th and 6th layers to delineate the treatment area.

Run Mode

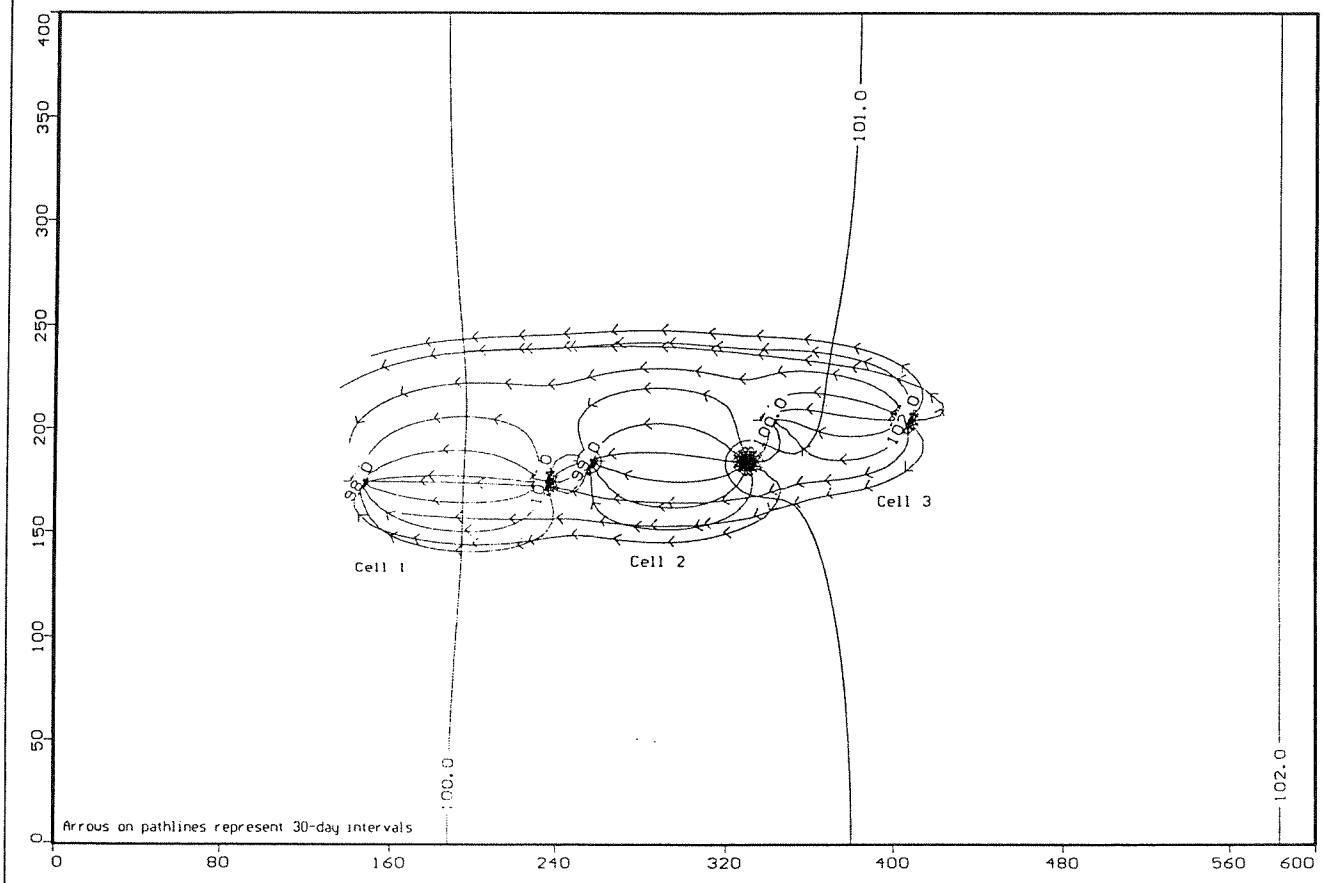
The model was run at steady state, given an initial hydraulic gradient of 0.005 ft/ft. Particles in the attached figures (representative of the shallow and deep layers) are tracked every 30 days for one year.



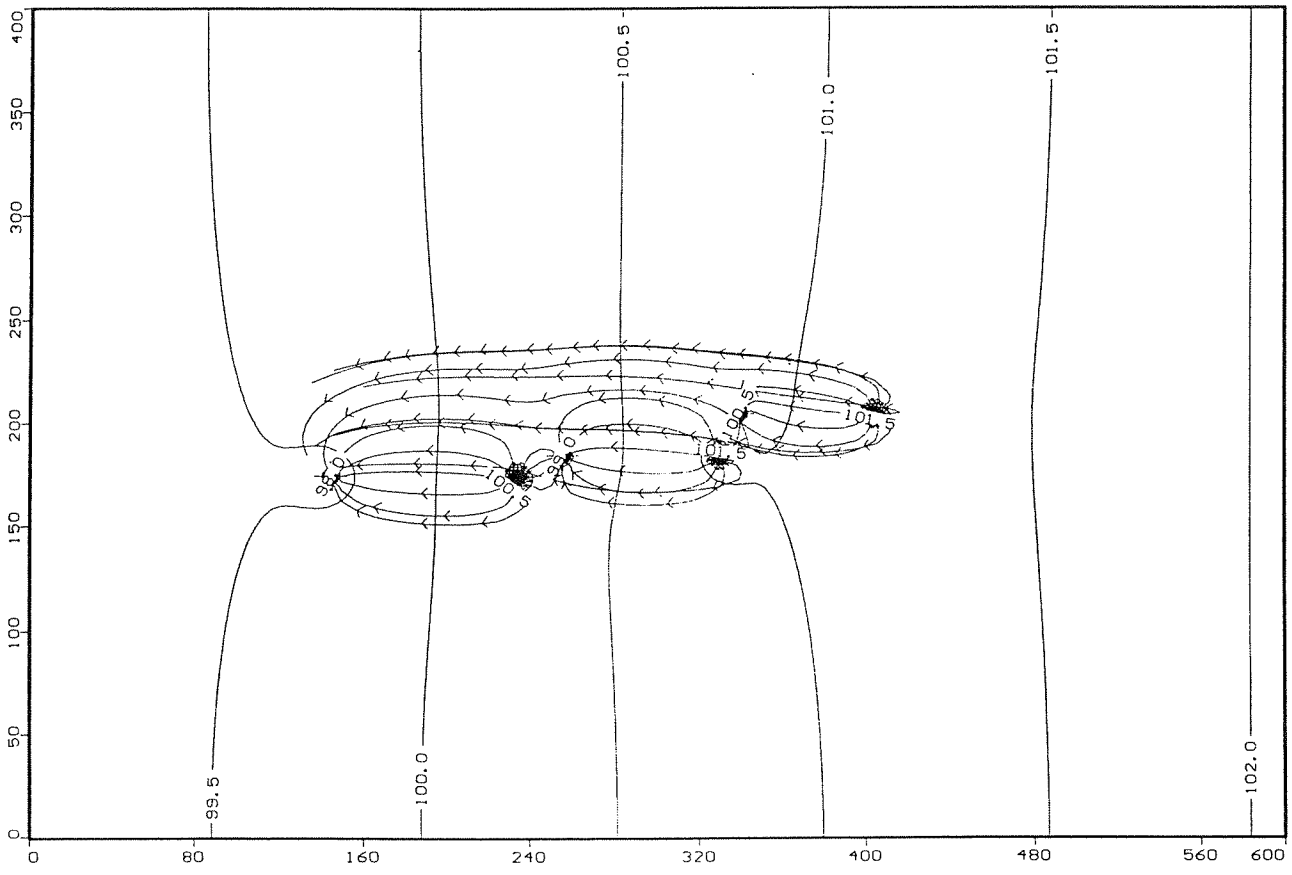
Harding ESE Project: NTC Orlando OU4 Description: KMnO4 Injection Pathlines Modeller: Steven Giese 18 Jan 01	Visual MODFLOW v.2.7.1, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 92 NR: 48 NL: 12 Current Layer: 1



Harding ESE Project: NTC Orlando OU4 Description: KMnO4 Injection Pathlines Modeller: Steven Giese 18 Jan 01	Visual MODFLOW v.2.7.1, (C) 1995–1997 Waterloo Hydrogeologic, Inc. NC: 92 NR: 48 NL: 12 Current Layer: 3

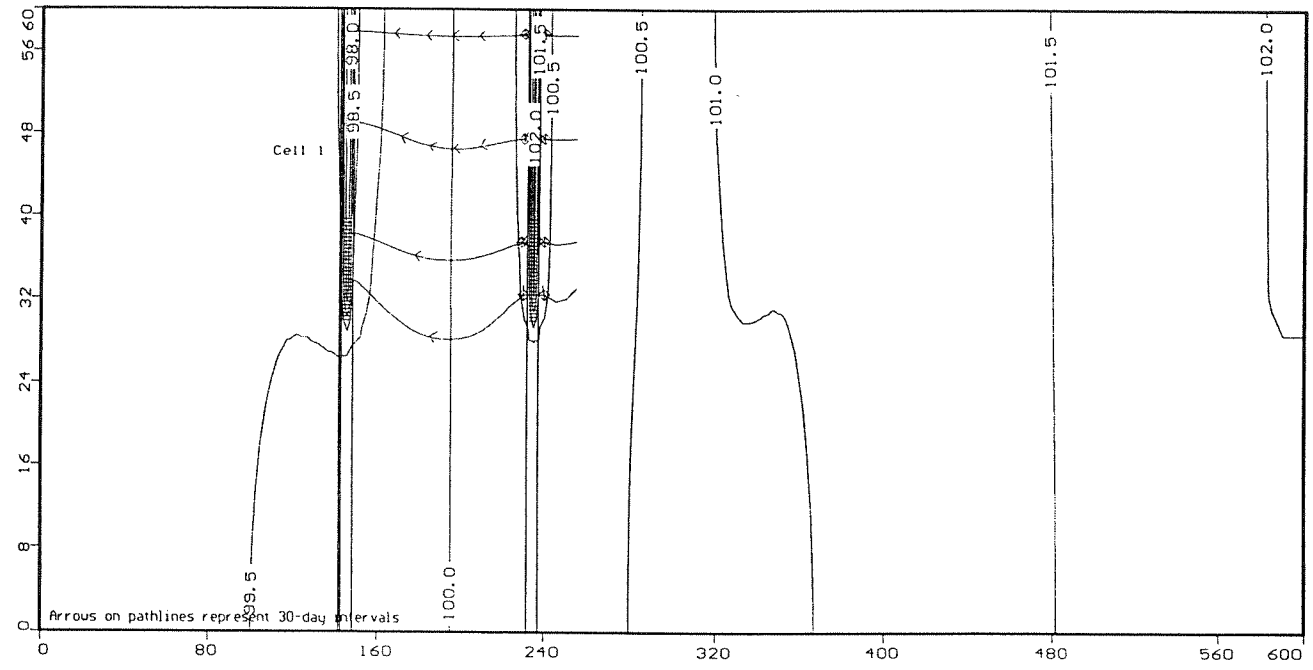


Harding ESE Project: NTC Orlando OU4 Description: KMnO4 Injection Pathlines Modeller: Steven Giese 18 Jan 01	Visual MODFLOW v.2.7.1, (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 92 NR: 48 NL: 12 Current Layer: 5



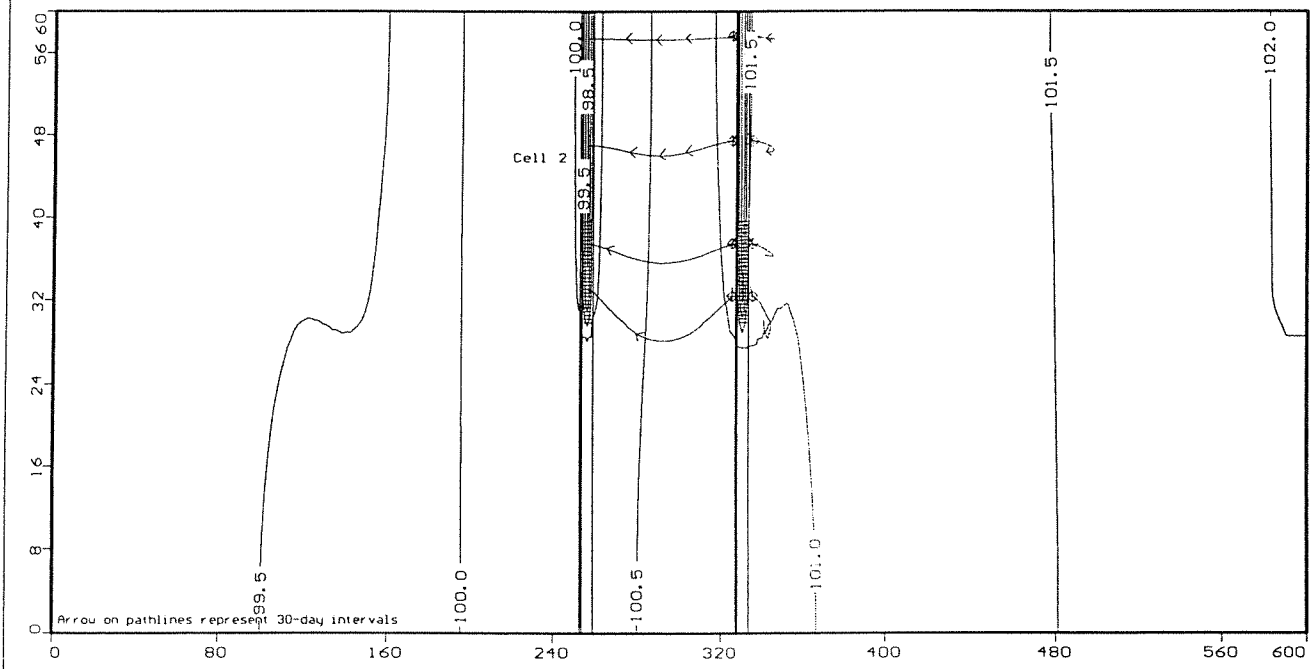
Harding ESE
Project: NTC Orlando OU4
Description: KMnO4 Injection Pathlines
Modeller: Steven Giese
18 Jan 01

Visual MODFLOW v.2.7.1, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 92 NR: 48 NL: 12
Current Layer: 6

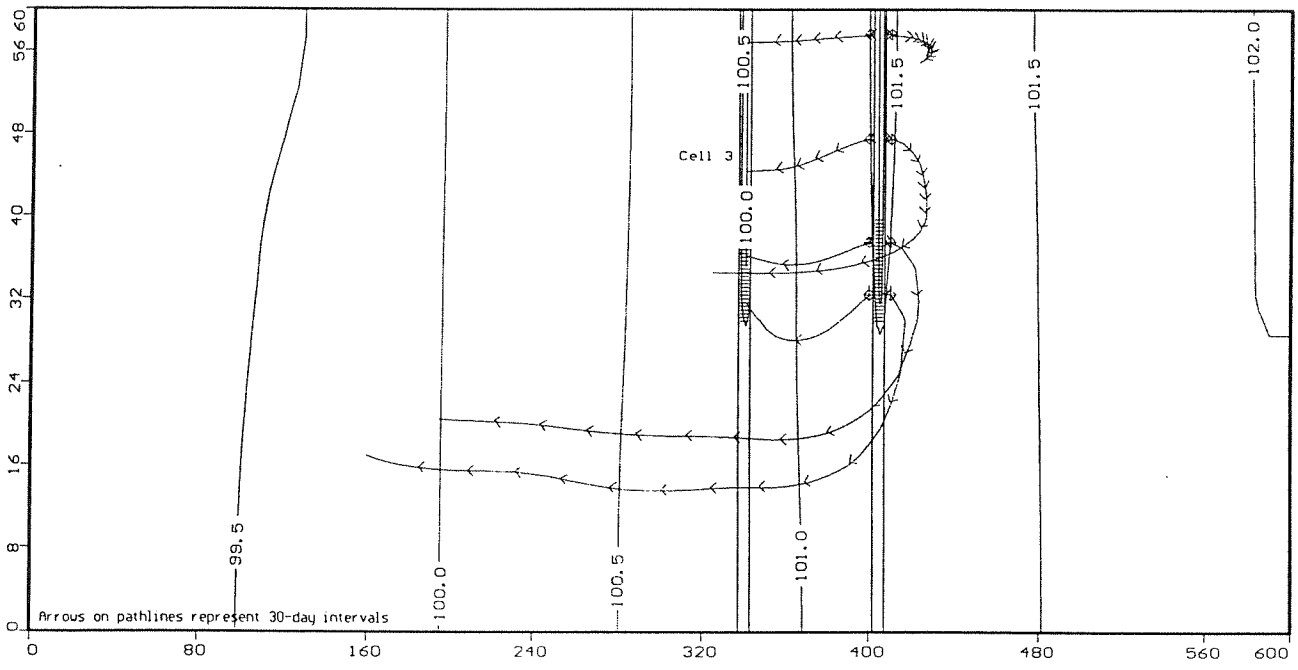


Harding ESE
Project: NTC Orlando OU4
Description: KMnO4 Injection Pathlines
Modeller: Steven Giese
18 Jan 01

Visual MODFLOW v.2.7.1, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 92 NR: 48 NL: 12
Current Row: 28



Harding ESE Project: NTC Orlando OU4 Description: KMnO4 Injection Pathlines Modeller: Steven Giese 18 Jan 01	Visual MODFLOW v.2.7.1, (C) 1995-1997 Waterloo Hydrogeologic, Inc. NC: 92 NR: 48 NL: 12 Current Row: 25



Harding ESE
Project: NTC Orlando OU4
Description: KMnO4 Injection Pathlines
Modeller: Steven Giese
18 Jan 01

Visual MODFLOW v.2.7.1, (C) 1995–1997
Waterloo Hydrogeologic, Inc.
NC: 92 NR: 48 NL: 12
Current Row: 20

Batch Flush Model

$$PV = -R \ln\left(\frac{C_f}{C_i}\right)$$

Where: PV = number of pore volumes
C_f = final concentration
C_i = initial concentration
R = retardation Factor

$$R = 1 + \frac{\rho K_d}{\theta}$$

ρ = soil bulk density (g/cm^3)
θ = soil porosity (assume 0.3)
K_d = distribution coefficient

Antimony K_d

Range of K_d from USEPA Soil Transport + Fate Database

32 ml/g (sandy loam)	93 ml/g (sandy loam)
689 ml/g (clayey soil)	708 ml/g (clay)
13.6 ml/g (loamy sand)	168 ml/g (silty loam)
695 ml/g (clay)	71 ml/g (sandy loam)
695 ml/g (loam)	

Average of sandy soils: 52 ml/g

$$R = 1 + \frac{(1.7)(52)}{0.3}$$

$$R = 295 \quad \checkmark$$

Ave. concentration of wells within plume >6 µg/l

$$\frac{20.7 + 15.7 + 7.1 + 12.7}{4} = 14 \text{ µg/l}$$

$C_f = 6$ µg/l = MCL

$$PV = -295 \ln\left(\frac{6}{14}\right)$$

$$PV = 250 \quad \checkmark$$

This means 250 pore volumes must be flushed before antimony concentrations reach MCLs

Based on WHPA simulation, one pore volume flushes in 100 days. ← @ 20 gpm!?

$$\text{Total P\&T duration} = \frac{(250)(100)}{365}$$

$$= 68 \text{ yrs}$$

If we take the minimum K_d, (13.6 ml/g for loamy sand) since the aquifer consists of clean sands,

$$R = 1 + \frac{1.7(13.6)}{0.3} = 78$$

$$R.V. = 66$$

Duration = 18 yrs which may be more reasonable.

If pumped @ 40 gpm, could possibly be done in 9 yrs!

RESSQC PROBLEM SUMMARY

Simulation Option:	capture zones
Number of Pumping Wells:	1
Number of Recharge Wells:	0
Transmissivity:	2200. ft**2/d
Hydraulic Gradient:	0.003000 ft/ft
Angle of Ambient Flow:	180.00 degrees
Aquifer Porosity:	0.30 dimensionless
Aquifer Thickness:	55. ft
Simulation Time:	100. days
No. of Capture Zone Times:	0

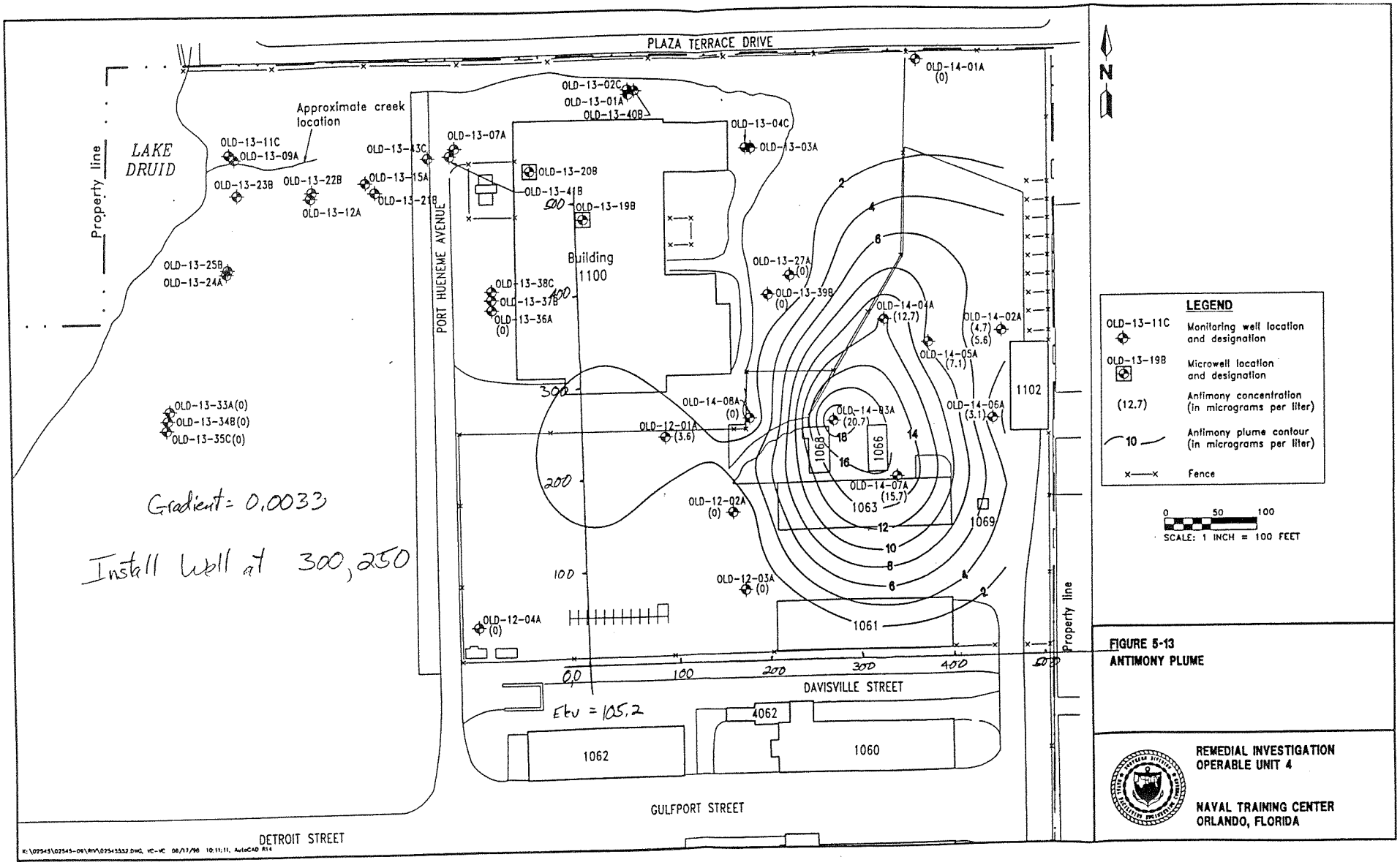
PUMPING WELL #1 PARAMETERS

X Coordinate:	300. ft
Y Coordinate:	250. ft
Well Discharge Rate:	7700. ft**3/d
Number of Pathlines:	20
Pathline Plotting Interval:	1

Basis For Antimony Spider Plot.

SbP+T40.DAT

SbP+T40.PLT



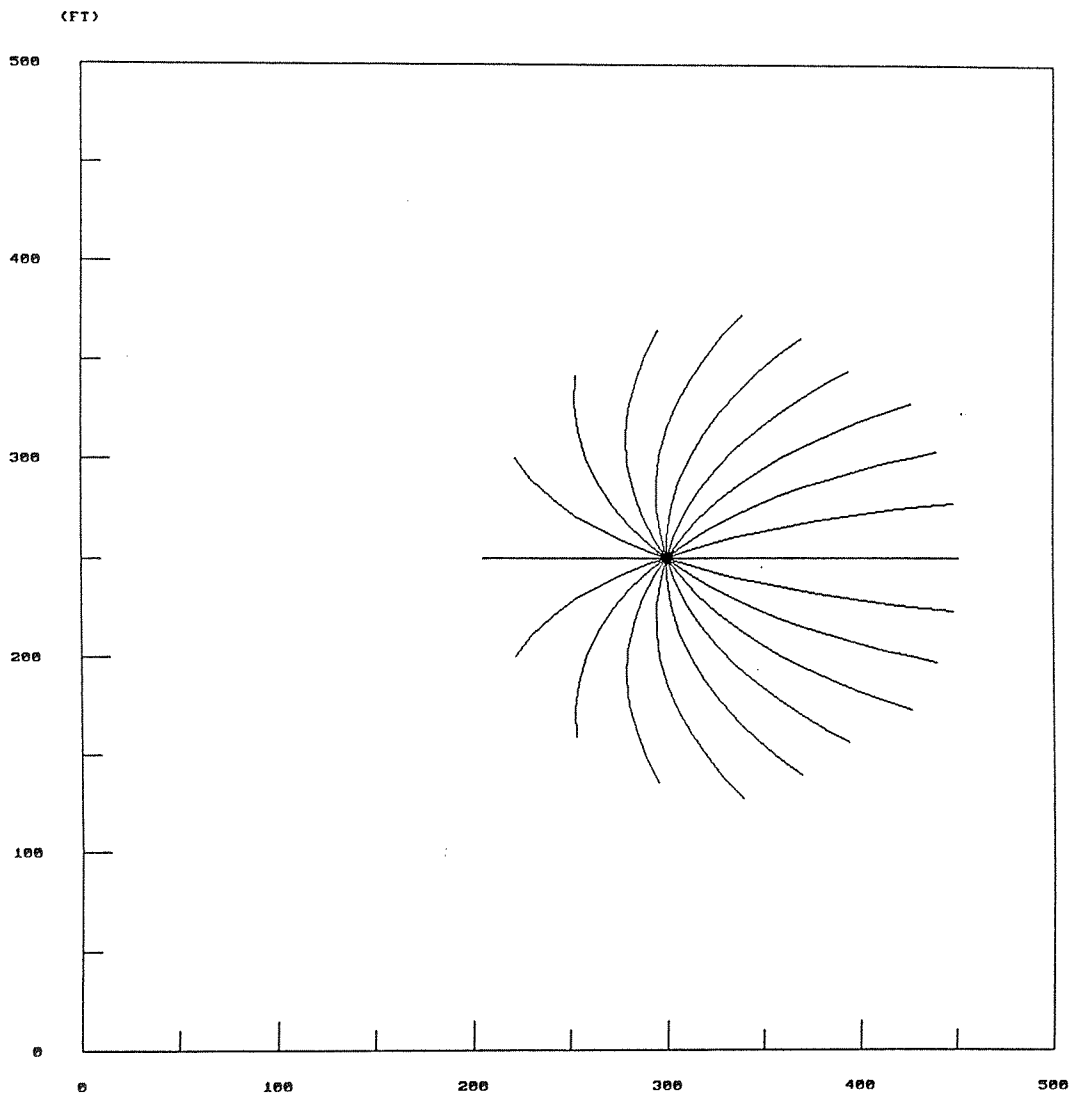
Gradient = 0.0033

Install Well at 300,250

FIGURE 5-13
ANTIMONY PLUME

REMEDIAL INVESTIGATION
OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA



Antimony

Flow = 40 GPM

1" = 100'

(Scale Factor 0.84)

APPENDIX H

APPENDIX H

AIR STRIPPING EMISSIONS CALCULATIONS

Harding Lawson Associates
Engineering
and
Environmental Services

SHEET 1 OF 1
JOB NO. 02545.51
DATE Dec 23, 1998
COMPUTED BY MJB
CHECKED BY

PROJECT NTC Orlando OU4 FS
SUBJECT VOC Mass Emissions from P+T Alternative

Pump and treat duration calculations make the following assumptions:

Well 1: 40 GPM, Initial VOC concentration = 5,000 µg/l

Well 2: 40 GPM, Initial VOC concentration = 2500 µg/l

From Well 1

$$\left(\frac{40\ gal}{min}\right)\left(\frac{1440\ min}{day}\right)\left(\frac{3.785\ l}{gal}\right)\left(\frac{5000\ \mu g}{l}\right)\left(\frac{g}{10^6\ \mu g}\right)\left(\frac{lb}{454\ g}\right) = 2.4\ lb/day$$ ✓

Emissions from Well 2 are half of Well 1 = 1.2 lb/day

Total VOC Emissions = 3.6 lb/day

This is at initial startup. Concentrations (and therefore emissions) will decrease from that point on.

Recirc Wells (Alternative V-5)

For this FS, have assumed recirc wells will be 4 times faster at remediating the source area.

∴ Potential Emissions = (3.6 lb/day)(4) = 14.4 lb/day

Exceeds 13.7 lb/day Limit

APPENDIX I

APPENDIX I

PLUME MIGRATION CALCULATIONS

Harding Lawson Associates
Engineering
and
Environmental Services

SHEET 1 OF 1
JOB NO. 02545.51
DATE January 11, 1999
COMPUTED BY MJS
CHECKED BY WMK

PROJECT NTC Orlando OU4
SUBJECT Antimony Migration

This calc will look at changes in antimony concentrations at OU4 between site screening (April 1995) and the RI (February 1998). Four wells were installed during site screening:

	Antimony Concentration (µg/l)	
	4/95	2/98
OLD-14-01A	2.5U	2.5U
OLD-14-02A	10.1B	4.7J
OLD-14-03A	17.6	20.7J
OLD-14-04A	10.6B	12.7J
OLD-12-01A	2.5U	3.6J

Well OLD-12-01A is approximately 190 feet downgradient of OLD-14-03A.

Groundwater Gradient = $\frac{0.6\ ft}{190\ ft} = 0.0032$

Assume K = 10 ft/day (shallow)

April 1995 to February 1998 ≈ 1035 days

$$\text{Seepage Velocity} = \frac{(10\ ft/day)(0.0032)}{0.3} = 0.107\ ft/day$$

$$(0.107\ ft/day)(1035\ days) = 110\ ft$$

If $k_d = 13.6$,

$$R = 1 + \frac{(1.7)(13.6)}{0.3} = 78$$

So, if this R is correct, plume would have only moved:

$$\frac{110}{78} = 1.5\ ft! \quad (\text{In } 1035 \text{ Days})$$

In One Year: $(1.5\ ft)\left(\frac{365\ days}{1035\ day}\right) = 0.5\ ft$

APPENDIX J

APPENDIX J

DETAILED FUTURE WORTH COST BREAKDOWNS OF ALTERNATIVES

TABLE J-1

ALTERNATIVE V-1: FUTURE WORTH NO ACTION ALTERNATIVE
OPERATION AND MAINTENANCE (O&M) COSTS (annual)

	Quantity	Unit	Unit Cost	Total Cost
IRA System (annual for 30 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Future Worth IRA System O&M Costs @ i = 3%, n = 30 yrs				**$2,026,771**
GW Monitoring of IRA Plume (annual costs)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	24	hours	$45.00	$1,080
ODCs (PPE, sampling equip, expendibles)	1	LS	$500.00	$500
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual GW Monitoring Costs				**$9,430**
Future Worth IRA GW Monitoring @ i = 3%, n = 30 yrs				**$448,632**
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600

TABLE J-1

ALTERNATIVE V-1: FUTURE WORTH NO ACTION ALTERNATIVE
OPERATION AND MAINTENANCE (O&M) COSTS (annual)

	Quantity	Unit	Unit Cost	Total Cost
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Annual Cost				**$18,220**
Future Worth 5-Yr Site Review @ i = 3%, n = 5, 10..30 yrs				**$189,277**
GW Monitoring for Five-Year Site Review (every 5 years for 30 years)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	24	hours	$60.00	$1,440
Technician	24	hours	$45.00	$1,080
ODCs (PPE, sampling equip, expendibles)	1	LS	$500.00	$500
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal GW Monitoring Annual Costs				**$9,070**
Future Worth GW Monitoring for Site Reviews @ i = 3%, n = 5,10..30 yrs				**$94,223**
TOTAL FUTURE WORTH O&M COSTS				**$2,758,903**
CONTINGENCY @10 PERCENT				**$275,890**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-1				**$3,034,793**

TABLE J-2

ALTERNATIVE V-2: FUTURE WORTH LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	$10,000
TOTAL DIRECT COSTS				**$10,000**
INDIRECT COSTS				
Health and Safety				$500
Administrative Fees				$1,000
Engineering and Design				$4,000
Construction Support Services				$1,000
TOTAL INDIRECT COSTS				**$6,500**
TOTAL CAPITAL COSTS				**$16,500**
IRA System (annual for 30 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Future Worth IRA System O&M Costs @ i = 3%, n = 30 yrs				**$2,026,771**
GW Monitoring for IRA Downgradient Plume (annual costs)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual GW Monitoring Costs				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 30 yrs				**$506,674**

TABLE J-2

ALTERNATIVE V-2: FUTURE WORTH LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Annual Costs				**$18,220**
Future Worth 5 Year Site Review @i = 3%, n =5, 10..30 yrs				**$189,277**
GW Monitoring for Five-Year Site Review (every 5 years for 30 years)				
GW Sampling & Monitoring Program within IRA Capture Area (30 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	24	hours	$60.00	$1,440
Technician	24	hours	$45.00	$1,080
ODCs (PPE, sampling equip, expendibles)	1	LS	$500.00	$500
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Sub-total GW Monitoring Annual Costs				**$9,070**
Future Worth GW Monitoring for Site Review @ i = 3%, n = 5, 10..30 yrs				**$94,223**
TOTAL FUTURE WORTH O&M COSTS				**$2,816,944**
TOTAL CAPITAL COSTS AND O&M COSTS				**$2,833,444**
CONTINGENCY @10 PERCENT				**$283,344**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-2				**$3,116,789**

TABLE J-3

ALTERNATIVE V-3: FUTURE WORTH IN-SITU CHEMICAL OXIDATION AND ENHANCED BIODEGRADATION TO TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization [Northern Plume]				
Storage Trailer	0	month	$150.00	$0
Office Trailer	12	month	$250.00	$3,000
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 30')	0	LS	$4,000.00	$0
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	0	month	$2,000.00	$0
Utility Connections for trailer, sys equip, controls	1	LS	$4,000.00	$4,000
Toilet/water cooler service	52	wks	$50.00	$2,600
Miscellaneous Equipment	1	LS	$1,000.00	$1,000
Decon Equipment and Pad:				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	2	days	$320.00	$640
Foreman/Superintendent (1 man @ 10 hrs/day)	1	days	$600.00	$600
Subtotal Site Preparation/Mobilization [Northern Plume]				**$15,052**
In-Situ Chemical Oxidation System [Northern Plume]				
(3 extraction well pairs pumping @ 6, 6, and 3 gpm each; 3 injection well pairs at same flows)				
Groundwater Extraction Wells				
Sonic Mob/Demob (drillers and equip)	1	each	$2,000.00	$2,000
DPT Mob/Demob (drillers and equip)	1	each	$150.00	$150
Vert. Well Sonic Install. (8 wells @ 4" ID, PVC, 20'/35' bls)	220	ft	$65.00	$14,300
Angled Well Sonic Install. (4 wells @ 4" ID, PVC, 42'/50' lf)	184	lf	$100.00	$18,400
Vert. Well Sonic Install. (1 well @ 2" ID, PVC, 35' bls)	35	ft	$55.00	$1,925
Angled Well Sonic Install. (3 wells @ 2" ID, PVC, 40' lf)	120	lf	$90.00	$10,800
MicroWell DPT Installation (15 wells, 20' bls)	4	days	$400.00	$1,600
Extraction Well Vault	6	each	$2,500.00	$15,000
Extraction Pumps	6	pumps	$1,000.00	$6,000
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	0	poles	$550.00	$0
Power Cable	25	ft	$10.00	$250
Telephone line for Telemetry	100	ft	$10.00	$1,000
Water Service Connection	0	each	$1,000.00	$0
Gauge, curb box, appurtenances	0	each	$1,000.00	$0

TABLE J-3

ALTERNATIVE V-3: FUTURE WORTH IN-SITU CHEMICAL OXIDATION AND ENHANCED BIODEGRADATION TO TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	400	ft	$20.00	$8,000
Equalization Tank Rental (Incl. Mob/demob; 12 months)	12	mo	$300.00	$3,600
Treatment System Rental (includes the following):	12	mo	$10,000.00	$120,000
KMnO4 Mix Tank Rental (Incl. Mob/demob; 4 tanks)	0	mo	$500.00	$0
Centrifugal Feed Pumps (25 GPM each)	0	each	$5,000.00	$0
KMnO4 Feed System (12 mo. rental + $4K mob/demob)	0	mo	$1,800.00	$0
Rotary Drum Filter	0	each	$3,000.00	$0
Flow Meters	0	each	$300.00	$0
Valves, piping, controls, gauges, etc.	0	LS	$5,000.00	$0
Instrumentation Controls	0	LS	$20,000	$0
Labor				
1 Carus Technician	5	days	$1,200.00	$6,000
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Chemical Oxidation System [Northern Plume]				**$239,175**
TOTAL DIRECT COSTS [Northern Plume]				**$264,227**
INDIRECT COSTS [Northern Plume]				
Health and Safety				$1,000
Administrative Fees				$7,500
Engineering and Design				$20,000
Construction Support Services				$20,000
TOTAL INDIRECT COSTS [Northern Plume]				**$48,500**
TOTAL CAPITAL COSTS [Northern Plume]				**$312,727**
ENHANCED BIODEGRADATION				
Site Prep and Mobilization [Southern Plume]				
Decon Equipment and Pad:				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Subtotal Site Prep/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000

TABLE J-3

ALTERNATIVE V-3: FUTURE WORTH IN-SITU CHEMICAL OXIDATION AND ENHANCED BIODEGRADATION TO TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test of HRC				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
OPERATION & MAINTENANCE COSTS				
In-Situ Chemical Oxidation System O&M (12 months operation)				
Chemicals				
KMnO4 Cost (Dosage @ 1 g/l)	51,970	lb	$1.19	$61,844
KMnO4 Freight Cost	3	deliveries	$4,500.00	$13,500
Utilities				
Groundwater Extraction Pumps	12	month	$300.00	$3,600
Treatment System	12	month	$400.00	$4,800
System Maintenance				
Labor (1 operator @ 4 hrs/day, 7 days/wk, 52 weeks)	365	days	$180.00	$65,700
KMnO4 Feed System	12	month	$500.00	$6,000
Subtotal Chemical Oxidation System O&M				**$155,444**
Sampling and Monitoring				
(Includes 2 QA/QC Samples for each sampling event)				
Treatment System Influent Grab Samples (1 per month):				
TCL VOCs	14	samples	$150.00	$2,100
Treatment System Effluent Grab Samples (1 per month):				
TCL VOCs and TAL Inorganics	14	samples	$300.00	$4,200
Monitoring Well Samples (1 every two months, 21 wells)				
TCL VOCs	138	samples	$150.00	$20,700
Subtotal GW Sampling and Monitoring				**$27,000**
Future Worth Chemical Oxidation O&M Cost (12 mo.)				**$182,444**

TABLE J-3

ALTERNATIVE V-3: FUTURE WORTH IN-SITU CHEMICAL OXIDATION AND ENHANCED BIODEGRADATION TO TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal Annual HRC Treatment O&M (yrs 2 and 3)				**$19,110**
Future Worth HRC O&M @ i = 3%, n = 2-3 yrs				**$39,959**
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Staff Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal HRC Annual Monitoring Costs (yrs 1-3)				**$17,550**
Future Worth HRC Monitoring @ i = 3%, n = 3 yrs				**$54,247**
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Future Worth IRA System O&M @ i = 3%, n = 10 yrs				**$488,385**
GW Monitoring within Downgradient Plume (annual costs - 10 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (years 1-10)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800

TABLE J-3

ALTERNATIVE V-3: FUTURE WORTH IN-SITU CHEMICAL OXIDATION AND ENHANCED BIODEGRADATION TO TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	7	samples	$150.00	$1,050
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Staff Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,200**
Future Worth IRA GW Monitoring @ i = 3%, n = 10 yrs				**$116,933**
Monitored Natural Attenuation O&M (annual costs - 30 yrs)				
GW Sampling & Monitoring Program for Natural Attenuation within the entire VOC plume (yrs 11-40)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Analysis-TCL Organics (VOCs only)	20	samples	$150.00	$3,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Staff Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA Costs				**$18,250**
Future Worth MNA O&M @ i = 3%, n = 11 to 40 yrs				**$1,166,850**
Five-year Site Reviews (every 5 years for 40 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Staff Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Costs				**$18,220**
Future Worth 5-Yr Site Reviews @ i = 3%, n = 5,10,..40 yrs				**$299,981**

TABLE J-3

ALTERNATIVE V-3: FUTURE WORTH IN-SITU CHEMICAL OXIDATION AND ENHANCED BIODEGRADATION TO TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
TOTAL FUTURE WORTH O&M COSTS				**$2,348,800**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$2,845,902**
CONTINGENCY @10 PERCENT				**$284,590**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-3				**$3,130,492**

*The total amount of $KMnO_4$ required is 65,650 lbs. There are already 42 drums of $KMnO_4$ (330 lbs ea.) at the site left over from the pilot test. Thus, the amount of $KMnO_4$ required to make up this difference is costed here.

TABLE J-4

ALTERNATIVE V-4: FUTURE WORTH AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for Equipment/Controls (30' x 30')	630	ft	$2.84	$1,789
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Sub-total Site Preparation/Mobilization				**$58,061**
Air Sparging/SVE system costs				
Piping and Equipment				
SVE piping(4"ID, PVC)	1800	ft	$25.00	$45,000
Shallow sparge wells(SCH 40,2" ID, PVC)	1800	ft	$20.00	$36,000
Deep sparge wells(SCH 40,2" ID,PVC)	1,500	ft	$20.00	$30,000
Deep sparge holes	500	ft	$10.00	$5,000
Miscellaneous Steel Piping for Connections	500	ft	$20.00	$10,000
Air Flow Meters	130	each	$78.70	$10,231
Pressure Gauges	130	each	$13.50	$1,755
Pressure Relief Valves	130	each	$16.50	$2,145
Vacuum Gauges for SVE	90	each	$18.50	$1,665
Compressors	1	each	$24,000	$24,000
Positive Displacement Blower	1	each	$12,000	$12,000
Regenerative Blower	1	each	$14,000	$14,000
Groundwater Monitoring Well Installation	2	each	$1,500.00	$3,000
Investigation Derived Wastes (soil and dev. Water)	2	rolloffs	$15,000.00	$30,000
Telemetry System	1	LS	$10,000.00	$10,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE J-4

ALTERNATIVE V-4: FUTURE WORTH AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Air Sparging/SVE Collection System				**$269,496**
Vapor Phase Off-gas Carbon Adsorption				
Vapor Phase Carbon Unit (10,000 lb. unit)	2	each	$16,000	$32,000
Carbon Disposal (no refill - use for 1 year only)	2	each	$850.00	$1,700
Analytical for Carbon Disposal	2	units	$500.00	$1,000
Profile Fee	1	LS	$1,200.00	$1,200
Transportation Fee	1	LS	$1,000.00	$1,000
Subtotal Vapor Phase Off-gas Treatment				**$36,900**
TOTAL DIRECT COSTS (NORTHERN PLUME)				**$374,457**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS (NORTHERN PLUME)				**$105,000**
TOTAL CAPITAL COSTS (NORTHERN PLUME)				**$479,457**
ENHANCED BIODEGRADATION				
Site Preparation and Mobilization [Southern Plume]				
Decon Equipment and Pad: (Initial cost included in Northern Plume)				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Sub-total Site Preparation/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000

TABLE J-4

ALTERNATIVE V-4: FUTURE WORTH AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
TOTAL CAPITAL COSTS ALTERNATIVE V-4 [Northern and Southern Plumes]				**$663,832**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (annual for 2 years)				
Utilities				
Treatment System	12	month	$500.00	$6,000
System Maintenance				
Labor (1 operators @ 8 hrs/day, 52 weeks/year)	416	hrs	$45.00	$18,720
Aeration System Components	12	month	$500.00	$6,000
Off-gas Treatment System Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$36,720**
Sampling and Monitoring				
Monitoring Well Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
GAC Influent/Effluent Analyses (2 sample, 1 per month)	24	samples	$150.00	$3,600
Subtotal GW Sampling and Monitoring				**$21,600**
Total Annual Treatment System O&M Cost				**$58,320**
Future Worth Treatment System (O&M) Costs @ i = 3%, n = 2 yrs				**$118,390**

TABLE J-4

ALTERNATIVE V-4: FUTURE WORTH AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal Annual HRC O&M				**$19,110**
Future Worth HRC (O&M) Costs @ i = 3%, n = 2-3 yrs				**$39,959**
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual HRC Monitoring Costs				**$17,550**
Future Worth HRC Yrly Mon. Costs @ i = 3%, n = 3 years				**$55,879**
IRA System (annual for 12 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Future Worth IRA System O&M Costs @ i = 3%, n = 12 yrs				**$604,602**
GW Monitoring within Downgradient Plume (annual costs - 12 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (years 1-12)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900

TABLE J-4

ALTERNATIVE V-4: FUTURE WORTH AIR SPARGING/ SOIL VAPOR EXTRACTION, AND ENHANCED BIOREMEDIATION

	Quantity	Unit	Unit Cost	Total Cost
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 12 yrs				**$151,145**
Monitored Natural Attenuation O&M (annual costs - 30 yrs)				
GW Sampling & Monitoring Program for Natural Attenuation within the entire VOC plume (yrs 13-42)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-TCL Organics (VOCs only)	20	samples	$150.00	$3,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA Costs				**$18,250**
Future Worth MNA O&M Costs @ i = 3%, n = 13 to 42 years				**$1,237,916**
Five-year Site Reviews (every 5 years for 42 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five-Year Site Review Costs				**$18,220**
Future Worth 5 Year Site Review @ i = 3%, n =5,10,..40 yrs				**$299,981**
TOTAL FUTURE WORTH O&M COSTS				**$2,507,872**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$3,171,703**
CONTINGENCY @10 PERCENT				**$317,170**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-4				**$3,488,874**

TABLE J-5

ALTERNATIVE V-5A: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Sub-total Site Preparation/Mobilization				**$50,112**
Recirculation Well System (4 wells pumping @ 10 gpm each)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (4 wells @10" ID, PVC, 40' bls, cable tool)	4	each	$25,000.00	$100,000
Piezometers (4 per well, 60 feet total depth per pair, 2" PVC)	480	ft	$50.00	$24,000
Per Diem/Lodging (3 men @ 24 days)	72	days	$100.00	$7,200
Well Development (Recirc)	4	each	$3,150.00	$12,600
IDW Disposal (Drill Cuttings & Development Water)	1	LS	$30,000.00	$30,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500
Piping and Equipment				
Recirc Well Internals	4	each	$52,000.00	$208,000
Recirc Well Vault	4	each	$14,650.00	$58,600
In-Situ TROLLS	16	each	$1,500.00	$24,000
Instrumentation Controls	4	LS	$10,000.00	$40,000
Telemetry System	1	LS	$10,000.00	$10,000

TABLE J-5

ALTERNATIVE V-5A: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Vapor Phase Off-gas Carbon Adsorption (One year only)				
Vapor Phase Carbon Unit (One 1000-lb Vessel Per Well)	4	each	$4,000.00	$16,000
Analytical for Carbon Disposal	4	units	$500.00	$2,000
Spent Carbon Disposal (4000 lb total)	2	tons	$170.00	$340
Profile Fee	1	LS	$1,200.00	$1,200
Transportation Fee	1	LS	$1,000.00	$1,000
Labor				
3 men @ 6 weeks @ 50 hrs/week	900	hr	$32.00	$28,800
1 Engineer/Foreman @ 6 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Recirculation Well System				**$588,540**
TOTAL DIRECT COSTS (NORTHERN PLUME)				**$648,652**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS (NORTHERN PLUME)				**$105,000**
TOTAL CAPITAL COSTS (NORTHERN PLUME)				**$753,652**
ENHANCED BIODEGRADATION				
Site Preparation and Mobilization [Southern Plume]				
Decon Equipment and Pad: (Initial cost included in Northern Plume)				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Sub-total Site Preparation/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**

TABLE J-5

ALTERNATIVE V-5A: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
TOTAL CAPITAL COSTS [Northern and Southern Plume]				**$938,027**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (annual for 27 years)				
Utilities				
Treatment System ($400/mo per recirc well)	12	month	$1,600.00	$19,200
System Maintenance				
Inspections/Service/Consumables ($25K one well, and $15K each additional well)	1	LS	$70,000.00	$70,000
Subtotal Treatment System O&M				**$89,200**
Sampling and Monitoring				
Recirc Well Influent Grab Samples (4 wells, 1 per quarter):				
TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Effluent Grab Samples (4 wells, 1 per quarter):				
TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Subtotal GW Sampling and Monitoring				**$4,800**
Total Annual O&M Cost (Treatment System 27 Yrs)				**$94,000**
Future Worth Treatment System (O&M) Costs @ I = 3%, n = 27				**$3,826,740**
Recirc Well Source Area GW Monitoring O&M (annual for 27 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples	= 12	samples		
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual Costs				**$11,550**
Future Worth GW Monitoring Costs @ I = 3%, n = 27 yrs				**$470,201**

TABLE J-5

ALTERNATIVE V-5A: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal Annual HRC Treatment O&M (yrs 2 and 3)				**$19,110**
Future Worth HRC O&M Costs @ i = 3%, n = 2 and 3 yrs				**$41,736**
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal HRC Yearly Monitoring Costs (years 1-3)				**$17,550**
Future Worth Annual HRC Monitoring @ i = 3%, n = 3 yrs				**$55,879**
IRA System (annual for 15 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Future Worth IRA (O&M) Costs @ i = 3%, n = 15 yrs				**$792,343**
GW Monitoring within Downgradient Plume (annual costs - 15 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (years 1-15)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200

TABLE J-5

ALTERNATIVE V-5A: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 15 yrs				**$198,078**
Monitored Natural Attenuation O&M (annual costs for 10 years)				
GW Sampling & Monitoring Program for Natural Attenuation within the Dwongradient Plume (years 16-25)				
6 Wells + 1QA/QC = 7 Samples				
Associate Scientist	24	hrs	$60.00	$1,440
Technician	30	hrs	$45.00	$1,350
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Natural Attenuation Parameters	10	samples	$200.00	$2,000
TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA Costs				**$11,840**
Future Worth MNA O&M Costs @ i = 3%, n = 16 to 25 years				**$211,467**
Five-year Site Reviews (every 5 years for 27 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Five-Year Site Review Costs				**$18,220**
Future Worth 5-yr Reviews @ i = 3%, n = 5,10..27 yrs				**$145,051**
TOTAL FUTURE WORTH O&M COSTS				**$5,741,496**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$6,679,523**
CONTINGENCY @10 PERCENT				**$667,952**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-5A				**$7,347,475**

TABLE J-6

ALTERNATIVE V-5B: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION, TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$50,112**
Recirculation Well System (4 wells pumping @ 10 gpm each)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (4 wells @10" ID, PVC, 40' bls, cable tool)	4	each	$25,000.00	$100,000
Piezometers (4 per well, 60 feet total depth per pair, 2" PVC)	480	ft	$50.00	$24,000
Per Diem/Lodging (3 men @ 24 days)	72	days	$100.00	$7,200
Well Development (Recirc)	4	each	$3,150.00	$12,600
IDW Disposal (Drill Cuttings & Development Water)	1	LS	$30,000.00	$30,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500
Piping and Equipment				
Recirc Well Internals	4	each	$52,000.00	$208,000
Recirc Well Vault	4	each	$14,650.00	$58,600
In-Situ TROLLS	16	each	$1,500.00	$24,000
Instrumentation Controls	4	LS	$10,000.00	$40,000
Telemetry System	1	LS	$10,000.00	$10,000

TABLE J-6

ALTERNATIVE V-5B: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION, TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
Vapor Phase Off-gas Carbon Adsorption (One year only)				
Vapor Phase Carbon Unit (One 1000-lb Vessel Per Well)	4	each	$4,000.00	$16,000
Analytical for Carbon Disposal	4	units	$500.00	$2,000
Spent Carbon Disposal (4000 lb total)	2	tons	$170.00	$340
Profile Fee	1	LS	$1,200.00	$1,200
Transportation Fee	1	LS	$1,000.00	$1,000
Labor				
3 men @ 6 weeks @ 50 hrs/week	900	hr	$32.00	$28,800
1 Engineer/Foreman @ 6 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Recirc Well System				**$588,540**
TOTAL DIRECT COSTS (NORTHERN PLUME)				**$648,652**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS (NORTHERN PLUME)				**$105,000**
TOTAL CAPITAL COSTS (NORTHERN PLUME)				**$753,652**
ENHANCED BIODEGRADATION				
Site Preparation and Mobilization [Southern Plume]				
Decon Equipment and Pad: (Initial cost included in Northern Plume)				
Pressure Washer with Water Tank	0	month	$500.00	$0
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	0	LS	$3,000.00	$0
Subtotal Site Preparation/Mobilization [Southern Plume]				$0
HRC Injection System (Initial Injection) [Southern Plume]				
HRC Injection Points				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (59 borings @1.5" & 2" ID, 45' bls)	2655	ft	$10.00	$26,550
HRC	5900	lb	$5.75	$33,925
HRC Injection Equipment (tank/pumps)	2	wks	$1,000.00	$2,000
Per Diem/Lodging (3 men @ 10 days)	30	days	$100.00	$3,000
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
HRC Monitoring Network				
Mob/Demob [included in Injection System]	0	each	$1,500.00	$0
Well Installation (11 wells @2" ID, PVC, 45' bls)	495	ft	$20.00	$9,900
Per Diem/Lodging (3 men @ 5 days)	15	days	$100.00	$1,500
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
TOTAL DIRECT COSTS [Southern Plume]				**$84,375**

TABLE J-6

ALTERNATIVE V-5B: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION, TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
INDIRECT COSTS [Southern Plume]				
Health and Safety				$10,000
Administrative Fees				$15,000
Pilot Test				$25,000
Engineering and Design				$20,000
Construction Support Services				$30,000
TOTAL INDIRECT COSTS [Southern Plume]				**$100,000**
TOTAL CAPITAL COSTS [Southern Plume]				**$184,375**
TOTAL CAPITAL COSTS [Northern and Southern Plumes]				**$938,027**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (annual for 15 years)				
Utilities				
Treatment System ($400/mo per recirc well)	12	month	$1,600.00	$19,200
System Maintenance				
Inspections/Service/Consumables ($25K one well, $15K eac	1	LS	$70,000.00	$70,000
Subtotal Treatment System O&M				**$89,200**
Sampling and Monitoring				
Recirc Well Influent Grab Samples (4 wells, 1 per quarter):				
TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Effluent Grab Samples (4 wells, 1 per quarter):				
TCL Organics (VOCs only)	16	samples	$150.00	$2,400
Subtotal GW Sampling and Monitoring				**$4,800**
Total Annual Treatment System O&M Cost				**$94,000**
Future Worth Treatment System (O&M) Costs @ i = 3%, n = 15 yrs				**$1,748,306**
Recirc Well Source Area GW Monitoring O&M (annual for 15 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples = 12 samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual Costs				**$11,550**
Future Worth GW Monitoring Costs @ i = 3%, n = 15 yrs				**$214,817**

TABLE J-6

ALTERNATIVE V-5B: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION, TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
HRC O&M (Injection in Source Area Only for Year 2 and 3)				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Advance boreholes (17 borings @1.5" & 2" ID, 45' bls)	765	ft	$10.00	$7,650
HRC	680	lb	$7.00	$4,760
HRC Injection Equipment (tank/pumps)	1	wks	$1,000.00	$1,000
Per Diem/Lodging (3 men @ 4 days)	12	days	$100.00	$1,200
Decontamination	10	hrs	$100.00	$1,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Subtotal Annual HRC Treatment O&M (years 2 and 3)				**$19,110**
Future Worth HRC System (O&M) Costs @ i = 3%, n =2 and 3 yrs				**$39,959**
HRC Monitoring O&M (annual for 3 years)				
16 Wells + 2QA/QC = 18 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-HRC Parameters	18	samples	$200.00	$3,600
Analysis-TCL Organics (VOCs only)	18	samples	$150.00	$2,700
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal HRC Yearly Monitoring Costs (years 1-3)				**$17,550**
Future Worth HRC Yrly Mon. Costs @ i = 3%, n = 3 years				**$54,247**
IRA System (annual for 15 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Future Worth IRA O&M Costs @ i = 3%, n = 15 yrs				**$792,343**
GW Monitoring within Downgradient Plume (annual costs - 15 yrs)				
GW Sampling & Monitoring Program within IRA Capture Area (years 1-15)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950

TABLE J-6

ALTERNATIVE V-5B: FUTURE WORTH RECIRCULATION WELLS AND ENHANCED BIOREMEDIATION, TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS.

	Quantity	Unit	Unit Cost	Total Cost
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 15 yrs				**$198,078**
GW Sampling & Monitoring for Natural Attenuation within the entire VOC Plume (years 16-45)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Analysis-TCL VOCs	20	samples	$150.00	$3,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Natural Attenuation Annual Costs				**$18,250**
Future Worth NA Yrly Mon. Costs @ i = 3%, n = 16 to 45 yrs				**$1,352,564**
Five-year Site Reviews (every 5 years for 45 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal Five Year Site Review Cost				**$18,220**
Future Worth 5-yr Reviews @ i=3%, n=5,10..45 yrs				**$368,880**
TOTAL FUTURE WORTH O&M COSTS				**$4,769,195**
TOTAL CAPITAL COSTS AND PRESENT WORTH O&M COSTS				**$5,707,222**
CONTINGENCY @10 PERCENT				**$570,722**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-5A				**$6,277,945**

TABLE J-7

ALTERNATIVE V-6A: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	LS	$5,000.00	$5,000
Treatment Building (20' x 30')	1	LS	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$62,112**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vaults	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Wastes (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	100	ft	$10.00	$1,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE J-7

ALTERNATIVE V-6A: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	300	ft	$20.00	$6,000
Discharge to Lake Druid (2" ID, PVC)	500	ft	$20.00	$10,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Temperature Gauges	2	each	$80.00	$160
Instrumentation Controls	1	LS	$10,000	$10,000
Discharge Pump	1	each	$3,000	$3,000
Telemetry	1	LS	$10,000	$10,000
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Extraction System				**$109,893**
Ex-situ Diffused Aeration System				
Equalization Tank (1,000 gal)	1	each	$500	$500
Adjustable Flow Feed/Transfer Pump	2	each	$2,000	$4,000
Diffused Aeration System w/ Blower	1	LS	$14,000	$14,000
Subtotal Diffused Aeration System				**$18,500**
TOTAL DIRECT COSTS				**$200,505**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$305,505**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	0	1,000 gals	$1.90	$0
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$32,615**
Future Worth IRA System O&M @ i = 3%, n = 10 yrs				**$373,901**

TABLE J-7

ALTERNATIVE V-6A: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Treatment System O&M (YEARS 1-108 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200
Treatment System	12	month	$150.00	$1,800
System Maintenance				
Labor (1 operators @ 8 hrs/wk, 52 weeks/year)	416	hrs	$45.00	$18,720
Aeration System Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$27,720**
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$18,000**
Total Annual Treatment System O&M				**$45,720**
Future Worth Treatment System O&M @ i = 3%, n = 108 yrs				**$35,579,304**
GW Monitoring O&M (annual COSTS)				
GW Sampling & Monitoring Program for VOCs within the source area during pump and treat (years 1- 108) :				
10 wells + 2 QA/QC samples = 12 samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Source Area Monitoring Costs				**$11,550**
Future Worth Source Area GW Monitoring @ i=3%, n=108 yrs				**$8,988,210**

TABLE J-7

ALTERNATIVE V-6A: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
GW Sampling & Monitoring Program within IRA Capture Area (years 1-10)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 10 yrs				**$122,092**
GW Sampling & Monitoring Program for Natural Attenuation within the IRA Capture Area (years 11-20)				
6 Wells + 1QA/QC = 7 Samples				
Associate Scientist	30	hrs	$60.00	$1,800
Technician	30	hrs	$45.00	$1,350
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Natural Attenuation Parameters	10	samples	$200.00	$2,000
Analysis - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA O&M				**$12,200**
Future Worth IRA MNA O&M @ i = 3%, n = 11-20 yrs				**$187,958**
Five-year Site Reviews (every 5 years for 108 yrs)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Cost for Five Year Annual Review				**$18,220**
Present Worth 5 Yr Rev. @ i = 3%, n = 5,10..108 yrs				**$2,821,988**

TABLE J-7

ALTERNATIVE V-6A: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
TOTAL FUTURE WORTH O&M COSTS				$48,073,453
TOTAL CAPITAL COSTS AND O&M COSTS				$48,378,958
CONTINGENCY @10 PERCENT				$4,837,896
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-6A				$53,216,854

TABLE J-8

ALTERNATIVE V-6B: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	LS	$5,000.00	$5,000
Treatment Building (20' x 30')	1	LS	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 40')	120	ft	$2.84	$341
Trailer Area (40' x 80')	240	ft	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$62,112**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vault	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Waste (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone line for Telemetry	100	ft	$10.00	$1,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	300	ft	$20.00	$6,000
Discharge to Lake Druid (2" ID, PVC)	500	ft	$20.00	$10,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Telemetry	1	LS	$10,000.00	$10,000
Temperature Gauges	2	each	$80.00	$160
Instrumentation Controls	1	LS	$10,000.00	$10,000
Discharge pump	1	each	$3,000.00	$3,000

TABLE J-8

ALTERNATIVE V-6B: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Extraction System				**$109,893**
Ex-situ Diffused Aeration System				
Equalization Tank (1,000 gal)	1	each	$500.00	$500
Adjustable Flow Feed/Transfer pump	2	each	$2,000.00	$4,000
Diffused Aeration System w/ Blower	1	LS	$14,000.00	$14,000
Subtotal Diffused Aeration System				**$18,500**
TOTAL DIRECT COSTS				**$200,505**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$305,505**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Site-Specific Remedial Goals				
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$42,602**
Future Worth IRA System @ i = 3%, n = 10 yrs				**$488,385**
Treatment System O&M (annual for 59 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200
Treatment System	12	month	$150.00	$1,800
System Maintenance				
Labor (1 operators @ 8 hrs/week, 52 weeks/year)	416	hrs	$45.00	$18,720
Aeration System Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$27,720**
Sampling and Monitoring				

TABLE J-8

ALTERNATIVE V-6B: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$18,000**
Future Worth System O&M Costs @ i = 3%, n = 59 yrs				**$7,193,128**
GW Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program within IRA Capture Area (1-10 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 10 yrs				**$122,092**
GW Sampling & Monitoring Program within source area during pump and treat (years 1-59):				
10 wells + 2 QA/QC samples = 12 samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual Source Area GW Monitoring				**$11,550**
Future Worth Source Area GW Monitoring @ i = 3%, n = 59 yrs				**$1,817,162**

TABLE J-8

ALTERNATIVE V-6B: FUTURE WORTH GROUNDWATER EXTRACTION, DIFFUSED AERATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE-SPECIFIC REMEDIAL GOALS

	Quantity	Unit	Unit Cost	Total Cost
GW Sampling & Monitoring Program for Natural Attenuation within the entire Area (years 60-89)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA O&M				**$15,250**
Future Worth MNA O&M @ i = 3%, n = 60-89 yrs				**$4,150,059**
Five-year Site Reviews (every 5 years for 89 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Subtotal 5-yr Site Reviews				**$18,220**
Future Worth 5-Year Site Review @ i = 3%, n = 5, 10..89 yrs				**$1,503,274**
TOTAL FUTURE WORTH O&M COSTS				**$15,274,098**
TOTAL CAPITAL COSTS AND O&M COSTS				**$15,579,603**
CONTINGENCY @10 PERCENT				**$1,557,960**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-6B				**$17,137,564**

TABLE J-9

ALTERNATIVE V-7A: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	lump sum	$5,000.00	$5,000
Treatment Building (20' x 30')	1	lump sum	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 40')	140	feet	$2.84	$398
Trailer Area (40' x 80')	240	feet	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	lump sum	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	lump sum	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	lump sum	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Sub-total Site Preparation/Mobilization				**$62,169**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vault	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Wastes (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	lump sum	$2,000.00	$2,000
Utility Connections (Electrical and Potable Water)				
Utility Pole	1	poles	$550.00	$550
Power Cable	25	ft	$10.00	$250
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	100	ft	$10.00	$1,000
Water Service Connection	1	lump sum	$1,000.00	$1,000
Gauge, curb box, appurtenances	1	lump sum	$1,000.00	$1,000

TABLE J-9

ALTERNATIVE V-7A: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	350	ft	$20.00	$7,000
Discharge to Lake Druid (2" ID, PVC)	250	ft	$20.00	$5,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Temperature Gauge	1	each	$80.00	$80
Instrumentation Controls	1	lump sum	$10,000.00	$10,000
Discharge Pump	1	each	$3,000.00	$3,000
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Collection System				**$93,063**
Ex-situ UV/Oxidation with Hydrogen Peroxide				
Equalization Tank (1,000 gal)	1	each	$500.00	$500
Adjustable Flow Feed pump	1	each	$2,000.00	$2,000
Skid-mounted 30 KW Rayox UV/Oxidation Unit	1	lump sum	$100,000.00	$100,000
Telemetry for Off-site Monitoring	1	each	$10,000.00	$10,000
Compressor for Lamp Cleaner	1	each	$3,000.00	$3,000
Emergency Eye Wash Shower	1	each	$1,000.00	$1,000
Subtotal UV/Oxidation System				**$116,500**
TOTAL DIRECT COSTS				**$281,732**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$386,732**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	5,256	1,000 gals	$1.90	$9,986
Misc Supplies	1	LS	$1,000.00	$1,000

TABLE J-9

ALTERNATIVE V-7A: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Subtotal IRA System O&M				**$42,602**
Future Worth IRA O&M Costs @ i = 3%, n = 10 yrs				**$561,532**
Treatment System O&M (years 1-108)				
UV Lamp Replacement and Hydrogen Peroxide				
Lamp Replacement ($0.40/1000 gal)	42048	1000 gal	$0.40	$16,819
(115,200 gpd x 365 d/1000 gal) = 42,048				
Hydrogen Peroxide (100 ppm, $/1000 gal)	42048	1000 gal	$0.60	$25,229
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200
Treatment System ($0.10/kWhr,$/1000 gal)	42048	1000 gal	$0.62	$26,070
System Maintenance				
Labor (1 operators @ 8 hrs/day, 52 weeks/year)	416	hrs	$45.00	$18,720
Misc. UV/Oxidation and Chemical Feed Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$94,038**
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal UV System O&M				**$18,000**
Future Worth System O&M @ i = 3%, n = 108 yrs				**$87,187,785**
GW Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program for VOCs within the Source area during pump and treat (year 1-108):				
10 Wells +2 QA/QC = 12 Samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Treatment System Annual Costs				**$11,550**
Future Worth GW Monitoring @ i = 3%, n = 108 yrs				**$8,988,210**

TABLE J-9

ALTERNATIVE V-7A: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
GW Sampling & Monitoring Program within IRA Capture Area (years 1-10)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 10 yrs				**$122,092**
GW Sampling & Monitoring Program for Natural Attenuation within the IRA Capture Area (yrs 11-20)				
6 Wells + 1QA/QC = 7 Samples				
Associate Scientist	30	hrs	$60.00	$1,800
Technician	30	hrs	$45.00	$1,350
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Natural Attenuation Parameters	10	samples	$200.00	$2,000
Analysis - TCL Organics (VOCs Only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal MNA O&M				**$12,200**
Future Worth IRA NA Monitoring @ i = 3%, n = 11-20 yrs				**$187,953**
Five-year Site Reviews (every 5 years for 108 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Five Year Site Review Annual Cost				**$18,220**
Future Worth O&M @ i = 3%, n = 5, 10...108 years				**$2,821,988**

TABLE J-9

ALTERNATIVE V-7A: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
TOTAL FUTURE WORTH O&M COSTS				$99,869,560
TOTAL CAPITAL COSTS AND O&M COSTS				$100,256,292
CONTINGENCY @10 PERCENT				$10,025,629
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-7A				$110,281,921

TABLE J-10

ALTERNATIVE V-7B: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	6	month	$150.00	$900
Office Trailer	6	month	$250.00	$1,500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Treatment System Concrete Pad (30' x 40')	1	lump sum	$5,000.00	$5,000
Treatment Building (20' x 30')	1	lump sum	$15,000.00	$15,000
Fencing:				
Treatment Area for equip/controls (30' x 40')	140	feet	$2.84	$398
Trailer Area (40' x 80')	240	feet	$2.84	$682
Gates	2	each	$95.00	$190
Office Equipment Rental	6	month	$2,000.00	$12,000
Utility Connections for trailer, sys equip, controls	1	lump sum	$10,000.00	$10,000
Toilet/water cooler service	26	wks	$50.00	$1,300
Miscellaneous Equipment	1	lump sum	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	3	month	$500.00	$1,500
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	lump sum	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$62,169**
Groundwater Extraction System (2 wells pumping @ 40 gpm each)				
Groundwater Extraction Wells				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (2 wells @4" ID, PVC, 40' bls)	80	ft	$75.00	$6,000
Extraction Well Vault	2	each	$2,500.00	$5,000
Extraction Pumps (40 gpm per well)	2	pumps	$5,000.00	$10,000
Per Diem/Lodging (3 men @ 3 days)	9	days	$100.00	$900
Decontamination	10	hrs	$100.00	$1,000
Investigation Derived Waste (soil and dev. Water)	1	LS	$10,000.00	$10,000
Misc. Equipment and Supplies	1	lump sum	$2,000.00	$2,000
Utility Connections (Electrical and Potable Water)				
Utility Pole	1	poles	$550.00	$550
Power Cable	25	ft	$10.00	$250
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	100	ft	$10.00	$1,000
Water Service Connection	1	lump sum	$1,000.00	$1,000
Gauge, curb box, appurtenances	1	lump sum	$1,000.00	$1,000

TABLE J-10

ALTERNATIVE V-7B: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	350	ft	$20.00	$7,000
Discharge to Lake Druid (2" ID, PVC)	250	ft	$20.00	$5,000
Flow Meters	2	each	$300.00	$600
Pressure Gauges	2	each	$16.50	$33
Temperature Gauge	1	each	$80.00	$80
Instrumentation Controls	1	lump sum	$10,000.00	$10,000
Discharge Pump	1	each	$3,000.00	$3,000
Labor				
3 men @ 3 weeks @ 50 hrs/week	450	hr	$32.00	$14,400
1 Engineer/Foreman @ 3 weeks @ 50 hrs/week	150	hr	$75.00	$11,250
Subtotal Groundwater Extraction System				**$93,063**
Ex-situ UV/Oxidation with Hydrogen Peroxide				
Equalization Tank (1,000 gal)	1	each	$500.00	$500
Adjustable Flow Feed pump	1	each	$2,000.00	$2,000
Skid-mounted 30 KW Rayox UV/Oxidation Unit	1	lump sum	$100,000.00	$100,000
Telemetry for Off-site Monitoring	1	each	$10,000.00	$10,000
Compressor for Lamp Cleaner	1	each	$3,000.00	$3,000
Emergency Eye Wash Shower	1	each	$1,000.00	$1,000
Subtotal UV/Oxidation System				**$116,500**
TOTAL DIRECT COSTS				**$281,732**
INDIRECT COSTS				
Health and Safety				$10,000
Administrative Fees				$15,000
Engineering and Design				$40,000
Construction Support Services				$40,000
TOTAL INDIRECT COSTS				**$105,000**
TOTAL CAPITAL COSTS				**$386,732**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Site Specific Remedial Goals				
IRA System (annual for 10 years)				
Engineer (8 hr/mo data analysis, reporting)	96	hr	$85.00	$8,160
Technician (12 hr/mo O&M site visits, reporting)	144	hr	$60.00	$8,640
Air Samples - Lab (1 sample/quarter, TO12)	4	each	$120.00	$480
Influent/Effluent Samples - Lab (3 samples/mo, 8012)	36	each	$150.00	$5,400
Electrical (5 hp and (2) 1 hp pumps, 10 hp blower)	111,690	kw-hr	$0.08	$8,935
POTW Discharge Fee (operational flow rate of 10 gpm)	0	1,000 gals	$1.90	$0
Misc Supplies	1	LS	$1,000.00	$1,000
Subtotal IRA System O&M				**$32,615**
Future Worth Costs IRA System @ i = 3%, n = 10 yrs				**$373,901**

TABLE J-10

ALTERNATIVE V-7B: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
Treatment System O&M (annual for 59 years)				
UV Lamp Replacement and Hydrogen Peroxide				
Lamp Replacement ($0.40/1000 gal)	42048	1000 gal	$0.40	$16,819
(115,200 gpd x 365 d/1000 gal) = 42,048				
Hydrogen Peroxide (100 ppm, $/1000 gal)	42048	1000 gal	$0.60	$25,229
Utilities				
Groundwater Extraction Pumps	12	month	$100.00	$1,200
Treatment System ($0.10/kWhr,$/1000 gal)	42048	1000 gal	$0.62	$26,070
System Maintenance				
Labor (1 operators @ 8 hrs/day, 52 weeks/year)	416	hrs	$45.00	$18,720
Misc. UV/Oxidation and Chemical Feed Components	12	month	$500.00	$6,000
Subtotal Treatment System O&M				**$94,038**
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TCL Organics (VOCs only)	24	samples	$150.00	$3,600
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$18,000**
Future Worth System O&M Costs @ i = 3%, n = 59 yrs				**$17,626,901**
GW Monitoring O&M (annual costs)				
GW Sampling & Monitoring Program within IRA Capture Area (1-10 years)				
6 Wells + 1 QA/QC = 7 Samples				
Associate Scientist	30	hours	$60.00	$1,800
Technician	40	hours	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	LS	$1,000.00	$1,000
Analyses - TCL Organics (VOCs only)	10	samples	$150.00	$1,500
Summary Data Report:				
Mid-Level Engineer	20	hours	$75.00	$1,500
Senior Scientist	10	hours	$90.00	$900
Associate Engineer	20	hours	$60.00	$1,200
ODCs	1	LS	$950.00	$950
Subtotal Annual IRA Capture Area GW Monitoring				**$10,650**
Future Worth IRA GW Monitoring @ i = 3%, n = 10 yrs				**$122,092**
GW Sampling & Monitoring Program for VOCs within the Source area during pump and treat (year 1-59):				
10 Wells +2 QA/QC = 12 Samples				
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TCL Organic Analyses (VOCs only)	12	samples	$150.00	$1,800

TABLE J-10

ALTERNATIVE V-7B: FUTURE WORTH GROUNDWATER EXTRACTION, UV/OXIDATION, AND SURFACE WATER DISCHARGE TO LAKE DRUID. TREAT GW TO SITE SPECIFIC REMEDIAL GOAL

	Quantity	Unit	Unit Cost	Total Cost
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Source Area Annual Monitoring Costs				**$11,550**
Future Worth Monitoring Source Area @ i = 3%, n = 59 yrs				**$1,817,162**
GW Sampling & Monitoring Program for Natural Attenuation within the entire Area (years 59-89)				
18 Wells + 2QA/QC = 20 Samples				
Associate Scientist	50	hrs	$60.00	$3,000
Technician	60	hrs	$45.00	$2,700
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
Analysis-Natural Attenuation Parameters	20	samples	$200.00	$4,000
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Subtotal Annual MNA O&M Costs				**$15,250**
Future Worth MNA O&M @ i = 3%, n = 60-89 yrs				**$4,150,059**
Five-year Site Reviews (every 5 years for 89 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Annual Five Year Site Review Costs				**$18,220**
Future Worth 5 Year Site Review @ i=3%, n=5, 10..89 yrs				**$1,503,274**
TOTAL FUTURE WORTH O&M COSTS				**$25,593,387**
TOTAL CAPITAL COSTS AND O&M COSTS				**$25,980,119**
CONTINGENCY @10 PERCENT				**$2,598,012**
TOTAL FUTURE WORTH COST OF ALTERNATIVE V-7B				**$28,578,131**

TABLE J-11

ALTERNATIVE A-1: FUTURE WORTH NO ACTION

	Quantity	Unit	Unit Cost	Total Cost
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Five Year Site Review Annual Costs				**$18,220**
Future Worth 5 Year Site Review @ i = 3%, n = 5,10..30 years				**$189,277**
GW Monitoring for Five-Year Site Review (annual for 30 years)				
GW Sampling & Monitoring Program: 12 wells + 2 QA/QC samples	= 14	samples		
Associate Scientist	40	hrs	$60.00	$2,400
Technician	50	hrs	$45.00	$2,250
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$12,000**
Future Worth O&M @ i = 3%, n = 5, 10..30 years				**$124,661**
TOTAL FUTURE WORTH O&M COSTS				**$313,937**
TOTAL CAPITAL COSTS AND O&M COSTS				**$313,937**
CONTINGENCY @10 PERCENT				**$31,394**
TOTAL FUTURE WORTH COST OF ALTERNATIVE A-1				**$345,331**

TABLE J-12

ALTERNATIVE A-2: FUTURE WORTH LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions until RAO's achieved	1	lump sum	$10,000.00	$10,000
TOTAL DIRECT COSTS				**$10,000**
INDIRECT COSTS				
Health and Safety				$500
Administrative Fees				$1,000
Engineering and Design				$4,000
Construction Support Services				$1,000
TOTAL INDIRECT COSTS				**$6,500**
TOTAL CAPITAL COSTS				**$16,500**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
GW Monitoring O&M (annual for 30 years)				
GW Sampling & Monitoring Program: 12 wells + 2 QA/QC samples	= 14 samples			
Associate Scientist	32	hrs	$60.00	$1,920
Technician	32	hrs	$45.00	$1,440
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$500.00	$500
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$10,210**
Future Worth O&M @ i = 3%, n = 30 years				**$485,741**
Five-year Site Reviews (every 5 years for 30 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Five Year Site Review Annual Costs				**$18,220**
Future Worth 5 Year Site Review @ i = 3%, n = 5,10..30 years				**$189,277**

TABLE J-12

ALTERNATIVE A-2: FUTURE WORTH LIMITED ACTION

	Quantity	Unit	Unit Cost	Total Cost
TOTAL FUTURE WORTH O&M COSTS				**$675,017**
TOTAL CAPITAL COSTS AND O&M COSTS				**$691,517**
CONTINGENCY @10 PERCENT				**$69,152**
TOTAL FUTURE WORTH COST OF ALTERNATIVE A-2				**$760,669**

TABLE J-13

ALTERNATIVE A-3: FUTURE WORTH GROUNDWATER EXTRACTION AND DISCHARGE TO ORLANDO STP, TREAT GW TO DRINKING WATER STANDARDS.

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	60	ft	$2.84	$170
Trailer Area (40' x 80')	120	ft	$2.84	$341
Gates	2	each	$95.00	$190
Treatment System Concrete Pad	1	LS	$4,000.00	$4,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Sub-total Site Preparation/Mobilization				**$34,601**
Groundwater Extraction System (1 well pumping @ 40 gpm)				
Groundwater Extraction Well				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (1 wells @4" ID, PVC, 40' bls)	40	ft	$75.00	$3,000
Extraction Well Vault	1	each	$2,500.00	$2,500
Extraction Pump (40 gpm)	1	pumps	$5,000.00	$5,000
Per Diem/Lodging (3 men @ 3 days)	3	days	$100.00	$300
Decontamination	2	hrs	$100.00	$200
Investigation Derived Waste (soil and dev. Water)	1	LS	$5,000.00	$5,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,000.00	$1,000
Gauge, curb box, appurtenances	1	each	$1,000.00	$1,000

TABLE J-13

ALTERNATIVE A-3: FUTURE WORTH GROUNDWATER EXTRACTION AND DISCHARGE TO ORLANDO STP, TREAT GW TO DRINKING WATER STANDARDS.

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
Discharge to Sanitary Sewer (2" ID, PVC)	400	ft	$20.00	$8,000
Flow Meters	1	each	$300.00	$300
Pressure Gauges	2	each	$16.50	$33
Temperature Gauges	1	each	$80.00	$80
Instrumentation Controls	1	LS	$5,000.00	$5,000
Telemetry	1	LS	$5,000.00	$5,000
Labor				
3 men @ 2 weeks @ 50 hrs/week	300	hr	$32.00	$9,600
1 Engineer/Foreman @ 2 weeks @ 50 hrs/week	100	hr	$75.00	$7,500
Subtotal Groundwater Extraction System				**$63,063**
TOTAL DIRECT COSTS				**$107,664**
INDIRECT COSTS				
Health and Safety				$5,000.00
Administrative Fees				$10,000.00
Engineering and Design				$15,000.00
Construction Support Services				$20,000.00
TOTAL INDIRECT COSTS				**$50,000**
TOTAL CAPITAL COSTS				**$157,664**
Future Worth for Delayed Capital Costs @ i = 3%, n = 10 yrs				**$208,446**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (delayed start for 10 years then annual for the next 9 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$50.00	$600
POTW Discharge Fee @ $1.90/1000 Gallons	21,024	1000 gal	$1.90	$39,946
System Maintenance				
Labor (1 operators @ 4 hrs/week, 52 weeks/year)	208	hrs	$45.00	$9,360
Subtotal Treatment System O&M				**$49,906**
Sampling and Monitoring				
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Subtotal GW Sampling and Monitoring				**$14,400**

TABLE J-13

ALTERNATIVE A-3: FUTURE WORTH GROUNDWATER EXTRACTION AND DISCHARGE TO ORLANDO STP, TREAT GW TO DRINKING WATER STANDARDS.

	Quantity	Unit	Unit Cost	Total Cost
Total Annual Treatment System O&M				**$64,306**
Future Worth O&M Costs @ i = 3%, n = 11 to 19 yrs				**$877,964**
GW Monitoring O&M (annual for 19 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples	= 12 samples			
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$11,550**
Future Worth GW Monitoring Costs @ i = 3%, n = 19 yrs				**$290,101**
Five-year Site Reviews (every 5 years for 19 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Annual Five Year Site Review Costs				**$18,220**
Future Worth 5 Year Site Review @ i = 3%, n = 5,10..19 yrs				**$105,944**
TOTAL FUTURE WORTH O&M COSTS				**$1,274,010**
TOTAL CAPITAL COSTS AND O&M COSTS				**$1,482,455**
CONTINGENCY @10 PERCENT				**$148,246**
TOTAL FUTURE WORTH COST OF ALTERNATIVE A-3				**$1,630,701**

TABLE J-14

ALTERNATIVE A-4: FUTURE WORTH GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
DIRECT COSTS				
Groundwater Use Restrictions	1	LS	$10,000.00	**$10,000**
Site Preparation and Mobilization				
Storage Trailer	2	month	$150.00	$300
Office Trailer	2	month	$250.00	$500
Trailer Delivery, Setup, Removal	2	each	$1,000.00	$2,000
Fencing:				
Treatment Area for equip/controls (30' x 30')	60	ft	$2.84	$170
Trailer Area (40' x 80')	120	ft	$2.84	$341
Gates	2	each	$95.00	$190
Treatment System Concrete Pad (30' x 30')	1	LS	$4,000.00	$4,000
Treatment System Building	1	LS	$15,000.00	$15,000
Office Equipment Rental	2	month	$2,000.00	$4,000
Utility Connections for trailer, sys equip, controls	1	LS	$10,000.00	$10,000
Toilet/water cooler service	8	wks	$50.00	$400
Miscellaneous Equipment	1	LS	$2,500.00	$2,500
Decon Equipment and Pad:				
Pressure Washer with Water Tank	2	month	$500.00	$1,000
Plastic Sheeting, Drums, Pumps, Hoses, Supplies	1	LS	$3,000.00	$3,000
Labor (Site Preparation)				
Laborers (2 men @ 5 days @ 10 hrs/day)	10	days	$320.00	$3,200
Foreman/Superintendent (1 man @ 10 hrs/day)	5	days	$600.00	$3,000
Subtotal Site Preparation/Mobilization				**$49,601**
Groundwater Extraction System (1 well pumping @ 40 gpm)				
Groundwater Extraction Well				
Mob/Demob (drillers and equip)	1	each	$1,500.00	$1,500
Well Installation (1 well @4" ID, PVC, 40' bls)	40	ft	$75.00	$3,000
Extraction Well Vault	1	each	$2,500.00	$2,500
Extraction Pumps (40 gpm per well)	1	pumps	$5,000.00	$5,000
Per Diem/Lodging (3 men @ 3 days)	3	days	$100.00	$300
Decontamination	2	hrs	$100.00	$200
Investigation Derived Waste (soil and dev. Water)	1	LS	$5,000.00	$5,000
Misc. Equipment and Supplies	1	LS	$2,000.00	$2,000
Electric Power Supply and Water Supply for H&S				
Utility Pole	1	poles	$550.00	$550
Power Cable	200	ft	$10.00	$2,000
Transformer	1	each	$1,500.00	$1,500
Telephone Line for Telemetry	200	ft	$10.00	$2,000
Service Connection	1	each	$1,500.00	$1,500
Gauge, curb box, appurtenances	1	each	$1,500.00	$1,500

TABLE J-14

ALTERNATIVE A-4: FUTURE WORTH GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Piping and Equipment				
RWs to treatment system (2" ID, PVC)	300	ft	$20.00	$6,000
Discharge to Lake Druid (2" ID, PVC)	1,350	ft	$20.00	$27,000
Flow Meters	1	each	$300.00	$300
Pressure Gauges	2	each	$16.50	$33
Temperature Gauges	1	each	$80.00	$80
Instrumentation Controls	1	LS	$10,000.00	$10,000
Discharge Pump	1	each	$3,000.00	$3,000
Telemetry	1	LS	$10,000.00	$10,000
Labor				
3 men @ 2 weeks @ 50 hrs/week	300	hr	$32.00	$9,600
1 Engineer/Foreman @ 2 weeks @ 50 hrs/week	100	hr	$75.00	$7,500
Subtotal Groundwater Collection System				**$102,063**
NP Treatment System				
NP 7050 System	1	LS		$225,000
Subtotal Treatment System				**$225,000**
TOTAL DIRECT COSTS				**$386,664**
INDIRECT COSTS				
Health and Safety				$5,000.00
Administrative Fees				$10,000.00
Engineering and Design				$20,000.00
Construction Support Services				$20,000.00
TOTAL INDIRECT COSTS				**$55,000**
TOTAL CAPITAL COSTS				**$441,664**
Future Worth of Delayed Capital Costs @ i = 3% and n = 10 yrs				**$590,114**
OPERATION AND MAINTENANCE (O&M) COSTS (annual)				
Treatment of Groundwater to Drinking Water Standards				
Treatment System O&M (delayed start for 10 years then annual for the next 9 years)				
Utilities				
Groundwater Extraction Pumps	12	month	$50.00	$600
Treatment System	12	month	$150.00	$1,800

TABLE J-14

ALTERNATIVE A-4: FUTURE WORTH GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
System Maintenance				
Labor (1 operators @ 4 hrs/week, 52 weeks/year)	208	hrs	$45.00	$9,360
Chemicals	1	LS	$500.00	$500
Sludge Disposal	1	LS	$1,000.00	$1,000
Subtotal Treatment System O&M				**$13,260**
Sampling and Monitoring				
Extraction Well Influent Grab Samples (2 wells, 1 per month):				
TAL Inorganics	12	samples	$150.00	$1,800
Effluent Grab Samples (1 per month):				
Full Suite Discharge Requirements	12	samples	$1,200.00	$14,400
Sub-total GW Sampling and Monitoring				**$16,200**
Total Annual O&M Cost (Treatment System Yr 11-19)				**$29,460**
Future Worth Treatment System O&M @ i = 3%, n = 11 to 19 yrs				**$402,217**
GW Monitoring O&M (annual for 19 years)				
GW Sampling & Monitoring Program: 10 wells + 2 QA/QC samples	= 12	samples		
Associate Scientist	40	hrs	$60.00	$2,400
Technician	40	hrs	$45.00	$1,800
ODCs (PPE, sampling equip, expendibles)	1	lump sum	$1,000.00	$1,000
TAL Inorganic Analyses	12	samples	$150.00	$1,800
Summary Data Report:				
Mid-level Engineer	20	hrs	$75.00	$1,500
Senior Scientist	10	hrs	$90.00	$900
Associate Engineer	20	hrs	$60.00	$1,200
ODCs	1	lump sum	$950.00	$950
Total Annual Groundwater Monitoring Costs				**$11,550**
Future Worth GW Monitoring O&M Costs @ i = 3%, n = 19 yrs				**$290,101**
Five-year Site Reviews (every 5 years for 19 years)				
Meetings (attendance only)				
Senior Scientist	8	hrs	$90.00	$720
Mid-level Engineer	8	hrs	$75.00	$600
ODCs	1	lump sum	$100.00	$100
Evaluate Data/Current Situation				
Senior Scientist	20	hrs	$90.00	$1,800
Mid-level Engineer	40	hrs	$75.00	$3,000
ODCs (includes photocopying, etc.)	1	lump sum	$500.00	$500

TABLE J-14

ALTERNATIVE A-4: FUTURE WORTH GROUNDWATER EXTRACTION, NP MICROFILTRATION TREATMENT, AND DISCHARGE TO LAKE DRUID. TREAT GW TO DRINKING WATER STANDARDS

	Quantity	Unit	Unit Cost	Total Cost
Five-year Report				
Senior Scientist	40	hrs	$90.00	$3,600
Mid-level Engineer	60	hrs	$75.00	$4,500
Associate Engineer	40	hrs	$60.00	$2,400
ODCs (includes photocopying, etc.)	1	lump sum	$1,000.00	$1,000
Total Annual Five Year Site Review Cost				**$18,220**
Future Worth 5 Year Review @ i = 3%, n = 5,10..19 yrs				**$105,944**
Equipment Replacement				
Replacement NP 7050 System	1	lump sum	$225,000	$225,000
Future Worth Equipment Replacement @ i = 3%, n = 15 yrs				**$350,543**
TOTAL FUTURE WORTH O&M COSTS				**$1,148,805**
TOTAL CAPITAL COSTS AND O&M COSTS				**$1,738,919**
CONTINGENCY @10 PERCENT				**$173,892**
TOTAL FUTURE WORTH COST OF ALTERNATIVE A-4				**$1,912,811**

APPENDIX K

APPENDIX K

RESPONSES TO PROJECT REVIEW COMMENTS

PROJECT REVIEW COMMENTS

FEASIBILITY STUDY
OPERABLE UNIT 4, STUDY AREAS 12, 13, AND 14 – AREA C
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

U.S. Environmental Protection Agency, Region 4 – Nancy Rodriguez

1. **The description of the remedial measures in Section 4 states that there are two sub-options for each of these remedial measures. For example, the description of Alternative V-6 (FS, p. 4-40) states that the groundwater extraction wells could be operated:**

   (1) until groundwater concentrations reach MCLs or (2) could be operated until concentrations are reduced sufficiently to allow natural attenuation to reduce levels before groundwater reaches Lake Druid.

   Both options are said to be evaluated in this FS, but both options and the related costs are not apparent in Table 5-8 or 6-1. The individual cost summary tables in Section 5 describe the estimated duration of the active remedial measures and the estimated duration for Monitored Natural Attenuation. The cost for operating the remedial measures until groundwater concentrations reach MCLs is not clearly stated. Please clarify the text if just one cost option is presented.

   The two treatment level options will be labeled "A" and "B" to enhance their identity, as has been done in Figures 6-1 and 6-2. The two options exist for Alternatives V-5, V-6 and V-7. Therefore, on tables for these alternatives, they will be referred to as V-5A and V-5B (or V-6A and V-6B, or V-7A and V-7B). Furthermore, in the text where these alternatives are discussed, the appropriate label of Option A or Option B will be used in the discussion. For example, Alternative V-6 (Groundwater Treated to Drinking Water Standards) presented in Table 5-8, will now be labeled Alternative V-6A, and Alternative V-6 (Groundwater Treated to Site-Specific Remedial Goals) presented in Table 5-9, will now be labeled Alternative V-6B. In Table 6-1 the differences between the options (where applicable) in the Alternative columns V-5, V-6 and V-7 will be more fully explained in footnotes 2 and 3. Cost breakdowns are presented separately in Appendix D in Tables D-5 through D-10, where the options are identified with the labels "A" and "B". The text on page 5-76 under Cost for Alternative V-6 states that the present worth costs are presented in Tables 5-8 and 5-9, depending on the remedial goal of the air stripper system, either Florida drinking water standards (Table 5-8) or a site-specific concentration along with natural attenuation to ultimately achieve these standards (Table 5-9). The text under Cost for Alternatives V-5 and V-7 on pages 5-59 and 5-93 will be modified to state the same. It was noted when preparing this response that Table 5-6 inadvertently references Natural Attenuation Monitoring for 37 years, and Tables 5-8 and 5-10 inadvertently reference Natural Attenuation Monitoring for 108 years. These will be changed to "groundwater monitoring" to reflect the text and backup costs presented in Tables D-5, D-7 and D-9 for VOC groundwater monitoring.

2. **(From EPA's letter dated December 8, 1998, OU4 RI Comments)** ***...some VOC concentrations in groundwater were approximately 20 percent of the solubility limit for PCE, which is strongly suggestive of NAPL presence. The text also states that a residual source for***

PCE probably has migrated downward in the aquifer beneath the source area and has become immobile (RI, p.7-4). These observations are restated in the FS on page1-15.

The possible source area for DNAPL under Building 1100 is addressed by remedial measures V-3 through V-7. But all of these measures require more than 30 years to reduce contaminant concentrations to drinking water standards (p.6-5 and Table 6-1), which indicates that the proposed remedial measures are not effective in a reasonable time frame. The cleanup time estimates for the PCE plume are not well documented in the report, so EPA can not comment on the results. However, the estimated cleanup times are so long for the estimated costs, that these may not be appropriate remedial measures for this site. The cleanup time estimates may be correct, but EPA can not confirm them with the data presented. Additional comments regarding one of the methods used to estimate the cleanup times are presented in the next comment.

Cleanup times for ex-situ treatment technologies were inadvertently excluded from the appendix material but are attached to this Response to Comments package and will be included in the appendix of the final FS report. Although the durations are lengthy, they represent the estimated time necessary to achieve drinking water standards in OU 4 groundwater. Numerous case studies have frequently demonstrated how difficult remediation of DNAPL source areas can be. Pump and treat systems operating for decades have been unable to permanently achieve drinking water standards. We believe the durations estimated in the FS represent reasonable cleanup times for the remedial technologies available today and evaluated in the FS.

3. Regarding the Batch Flush Model cleanup time calculations in Appendix G and Appendix I, the Kd for antimony is given first in Appendix G as 52 mg/L. Then the Kd value was changed to 13.6, apparently because the resulting calculated cleanup time looked more reasonable according to notes written on Appendix G, p. 2/2, 12/14/98. The Kd used in Appendix I is also assumed to be 13.6 without supporting data.

The original Kd estimate agrees closely with a value of 45 mg/L in the EPA Guidance Document (TBD, Part 5, Table 43). Kd is a basic physical parameter which should not be altered because the result looks more reasonable without supplying site specific supporting data.

The velocity and the distance to the discharge area (length of contaminant travel) in the Batch Flush calculations in Appendix G can be controlled by the remedial measure. Under natural conditions, a pore volume flushes at a rate depending on the hydraulic conductivity, porosity and hydraulic gradient. Cleanup time estimates are based on the number of dilutions required to flush out the contaminant with clean water. Wells installed for a remedial measure replace the natural discharge area and become man-made discharge areas. Pumping changes the natural hydraulic gradient and groundwater velocity near the wells, accelerating

the natural flush rate upgradient from the well. This reduces the calculated flush time, so changing the velocity in the Batch Flush calculation is both more defendable and more manageable than changing the Kd without supporting data. The velocity and distance used for cleanup time estimates becomes a function of the number of wells used and the average distance to the nearest well.

Flush time estimates remain proportional to the assumptions used in Appendix G, so the cleanup time estimates presented in Appendix G are not unreasonable. I make these points, in part, because the cleanup time calculations for the PCE plume in the northern part of this area are not well documented in the report and the calculated cleanup times for the PCE plume are very long.

HLA uses a K_d value of 13.6 mg/L derived from the USEPA Soil Transport and Fate Database for a loamy sand, which is believed to be more representative of site soils than sandy loam (32 to 93 mg/L). The 45 mg/L referenced by the commentor is from a range reported by Atomic Energy of Canada, Limited (AECL) and presents a range from 10 to 550 with geometric mean of 45 (no specific soil descriptions are provided other than that they represent four major soil types – sand, silt, clay and organic material).

Although increasing the velocity in the Batch Flush calculation would decrease the estimated cleanup time, there are limits to the allowable well discharge, and hence velocity, based on avoiding excessive drawdown. It is also reasonable to assume that site-specific K_d values could be determined prior to final design of a pumping system to address the antimony contamination. However, as it is recommended that groundwater VOCs be addressed prior to the antimony, the design and installation of an antimony remedial system is several years away.

As previously discussed, cleanup time calculations for the PCE plume were inadvertently excluded from the appendix but have been attached for reference and will be included in the final FS report.

4. **The calculations presented in Appendix I, Plume Migration Calculations, include an estimate of the duration of the IRA operation dated January 27, 1999. The retardation factor for PCE is given as 13. The source cited for this factor is Appendix H. Appendix H contains Air Stripping Emissions Calculations and does not include an estimate of the retardation factor for PCE. VOCs seem to be relatively mobile in this aquifer. From TBD Part 5, Table 39, it is estimated that the retardation factor for PCE to be between 3 and 6 depending the fraction of organic carbon (f_{oc}) in the aquifer. This would decrease the IRA duration estimate. Site specific estimates for the parameters needed to get a site specific retardation factor of PCE are not presented. Further, a retardation factor was not found in Appendix H as indicated in the report.**

Calculations for the retardation factor of PCE were inadvertently excluded from the appendix material, but are discussed below and will be included in the appendix of the final FS report. The retardation factor for PCE was calculated based on an average total organic carbon content at the site of 6,000 mg/kg (from the RI Report), a K_{oc} value of 364 ml/g for PCE, soil porosity of 0.3, and bulk density of 1.7. The retardation factor derivation is included with the attached cleanup time calculations for the ex-situ treatment alternatives.

Florida Department of Environmental Protection – David Grabka

1. **Natural Attenuation at this site has been through reductive dechlorination of PCE and TCE. The treatment alternatives V-3 (In Situ Treatment by Chemical Oxidation), V-4 (In Situ Treatment by Air Sparging), and V-5 (Recirculation Wells) for the northern plume VOC source areas will apparently change the conditions in the treatment area from anaerobic to aerobic for the amount of time the treatment systems are operating, potentially longer. Source reduction to levels where natural attenuation, as calculated in the treatability study, will complete treatment prior to groundwater discharging to Lake Druid is a component of several of the treatment alternatives. The potential upset in the natural attenuation already occurring at the site by oxygenating a portion of the aquifer should be considered in the report.**

   Any upsets to natural attenuation from source area treatment are expected to be localized and temporary (during implementation and a short period after). Alternatives V-4 (air sparging) and V-5 (recirculation wells) would only temporarily increase dissolved oxygen content in the source area. However, natural attenuation is a downgradient remedy. Chemical oxidation treatment byproducts are carboxolic acids, water, and chloride. It is also recognized potassium permanganate can act as a biocide. Based on the potassium permanganate pilot study, aquifer pH will not significantly decrease, likely due to the natural buffering capacity of the aquifer. Although the microbial population within the source area will likely be reduced by the potassium permanganate, this effect will not occur in downgradient of the treatment zone, and bacteriological populations should increase after treatment is completed.

   While it is likely that biological activity will temporarily cease within the source area, the relatively small volume of chemicals added to a large volume of water does not significantly alter background conditions. Air sparging and recirculation wells will create aerobic conditions within the source area for the source area treatment duration (2 years and 15 years, respectively), but will revert back to background conditions well within the 10 year period before monitored natural attenuation commences. Additional wording with respect to natural attenuation impacts will be added to the text.

2. **The report should discuss in more detail the operational history of the IRA recirculation wells, including problems encountered, lessons learned and whether any of the problems encountered would make the use of recirculation wells technically infeasible. The latest**

information verbally related by Bechtel casts some doubt as to the long term effectiveness of using recirculation wells.

The IRA recirculation wells have been shut down due to operational problems. The IRA system is now a pump and treat system, where extracted water is pumped into an air stripper, and the treated water is then discharged into Lake Druid. Operational difficulties with the IRA recirculation wells are discussed in more detail in Section 2.3 of the FS report. The "Implementability" paragraph in the Detailed Analysis of Alternative V-5 will be expanded in include the IRA discussion in Chapter 2 and to discuss the problems that might make the use of recirculation wells as a final OU 4 remedy technically infeasible.

3. **The first paragraph on page 1-6 states that "monitoring well and direct-push technology have shown that (the northern) plume is likely confined to Area C along the northern property line, and does not extend into the condominium property located north of OU 4." Any groundwater monitoring that occurs at the site will have to confirm that the plume is confined to Area C and that a treatment system does not cause the plume to migrate onto the condominium property.**

Groundwater monitoring along the property line should be performed to confirm that the plume is confined to Area C. Reference to this monitoring will be added to the text. However, this component is considered to be a design detail and capital and O&M costs are considered incidental to the existing costs in the FS for each alternative. Well installations and monitoring costs would be relatively small and similar for all alternatives (V-2 through V-7), and would not affect selection of the preferred alternative.

4. **There are a few areas of the report that still specify Florida SCGs instead of SCTLs. These should be corrected. On page 3-14, beryllium is identified as being detected at concentrations exceeding the SCGs. Beryllium was not detected at concentrations exceeding the SCTLs.**

The text will be updated to reflect the revised risk assessment, which used 1999 SCTLs. All references to SCG values will be changed to 1999 SCTL values.

5. **The addition of the 5-year site review costs for the VOC treatment alternatives and for the antimony plume treatment alternatives may overestimate costs. It is assumed that 5-year reviews will be conducted for the entire OU 4 site and not for each component of the site. This should be explained in the text.**

There are redundancies in 5-year site review costs for the VOC and antimony treatment alternatives. As noted by the commentor, the redundancies may overestimate costs associated with review of the entire site when treatment alternative costs are combined. The text in Section 5.0 will be expanded to explain that total treatment alternative costs are for comparative purposes only and are not necessarily representative of the entire site.

Florida Department of Environmental Protection – Bill Neimes

1. **Executive Summary – Figures ES-2 and ES-3 have been inadvertently misplaced for each other. Figure ES-2 should represent the future worth costs for VOC alternatives V-1 through V-7 and Figure ES-3 should show the present worth costs for Antimony alternative A-1 through A-4.**

   Agreed. Figures ES-2 and ES-3 will be corrected to correspond with the text.

2. **Section 5.0, State's Acceptance – This report notes that since the State has participated in partnering team meetings and have concurred with the issuance of this report, the State has accepted the Feasibility Study. I would have to disagree in that the State, through its partnering meetings, have only conceptually accepted the recommended technology of choice. In reviewing this report in detail there are several assumptions which require further explanation before the State will approve of this Feasibility Study.**

   It is assumed that once comments have been addressed to the regulators' satisfaction, all team members will be in agreement with the contents of the report. If there are any unresolved issues at the time of issuing the final report, the text will be revised accordingly.

3. **Section 5.1.3.1 (Page 5-21), $KMnO_4$ Injection. Petition for Variance – As we discussed and you are aware, prior to injection of potassium permanganate, the Department would require the facility to submit the proper documentation to petition for a variance for violating the secondary standards of color, manganese, and pH. Since these are all secondary standards and no primary standards should be violated via this process, there should be no difficulties in obtaining a variance from the Department for these constituents. I have worked with OGC several times on this process and can assist you through this paperwork process.**

   Primary drinking water standards will not be violated, but a petition for variance of secondary standards will need to be submitted as noted. Discussion regarding a need for petition for variance will be added to the "Compliance with ARARs" paragraph in Detailed Analysis of Chemical Oxidation (p 5-27). HLA has petitioned for and has been granted a variance for the pilot test. It is also recognized that the variance is company-specific and another variance will be required by the firm responsible for the full-scale remedial action.

4. **Section 5.1.3.1 (Page 5-21), $KMnO_4$ Injection. Groundwater Model – The groundwater model (Wellhead Protection Area) assumes a homogeneous aquifer with a hydraulic conductivity of 40 ft/day. This report notes that the hydraulic conductivity in the upper portion of this aquifer (down to 25 feet below land surface) is only 10 ft/day. The consultant should run the model with this lower conductivity value to determine what effects a lower conductivity would have on this model.**

More formal modeling that recognizes the various permeability strata has been performed in preparation for the pilot test. Pilot test results and a more rigorous modeling will be incorporated into this report for use in the alternative evaluation. Decreasing the permeability will likely result in a lower pumping flow rate but also will result in an extended treatment time. The increased treatment time will probably be offset by the decrease in chemical costs related to dosing a lower flow rate.

5. **Section 5.1.3.1 (Page 5-21), $KMnO_4$ Injection. Injection Well – Page 5-21 of the report mentions that a PVC cased well will be installed to a depth of 40 feet. Please explain how the potassium permanganate will be distributed through the aquifer if the injection well is not screened throughout the aquifer.**

The text in Section 5.1.3.1 has been revised to reflect the experience gained during the KMnO4 pilot study. Because of the varying hydraulic conductivity with depth, separate injection wells will be installed to treat the shallow and deep portions of the plume. These wells will each be screened to overlap the portion of the aquifer targeted by each well. It is assumed that the potassium permanganate will be evenly distributed along the full length of the screen, which is valid based upon pilot test results. The text will be clarified accordingly.

6. **Section 5.1.6.1, Alternative V-6 – The length of time estimated to cleanup the groundwater to achieve MCL's via pump and treat was given at 108 years. Such a time frame appears to be quite excessive, especially since there was no justification of this to support such a time frame. A groundwater model and the assumptions for this model would be necessary to justify these apparent excessive time frames. It also is ironic that Alternative V-6B (which specifies pump and treat for 59 years and natural attenuation for 30 years) would require less time overall than a more aggressive pump and treat alternative (89 years versus 108 years). How can one justify natural attenuation taking less time than pump and treat?**

Calculations were inadvertently left out of the FS Report appendix but have been attached to this Response to Comments package for reference and will be included in the appendix of final FS report. Calculations were performed using the Wellhead Protection Area model (WHPA) and a batch flush model to support the 108-year cleanup duration (to achieve MCLs). They required an estimate of the total source area mass (6,000 pounds), the vertical and horizontal distribution of this mass, and the initial concentrations of VOCs in extracted groundwater. Calculations were performed assuming that 2 groundwater extraction wells will be installed, each pumping at a flow rate of 40 gpm. Please note that the treatment time for Alternative V-6B is 59 years of active treatment and 30 plus years of natural attenuation (inferring that the upper-end of this range is undefined and actual total time will be longer than the 108 years total for Alternative 6A). Extending natural attenuation costs longer than 30 years was not considered relevant for present worth computations.

7. **Appendix D, Tables D-9 and D-10 – The present worth calculation for Alternative V-7A and V-7B omitted the treatment system O&M cost. Thus the actual cost for operating this system will be much more expensive than that indicated in this report. I have included a table noting this difference.**

Present Worth Costs for Alternative V-7				
	Reported Alternative V-7A Costs	Actual Alternative V-7A Costs	Reported Alternative V-7B Costs	Actual Alternative V-7B Costs
O&M Costs UV Oxidation	$299,214	$1,862,407	$290,286	$1,806,837
Total O&M Costs	$929,115	$2,492,308	$921,106	$2,437,657
Total Capital and O&M Costs	$1,318,678	$2,881,871	$1,310,669	$2,827,220
Total Costs	$1,450,545	$3,170,058	$1,441,736	$3,109,942

From this table we see that the total present worth costs for Alternative V-7A and V-7B have more than doubled from the costs reported in this document. These costs would appear to be more representative of this technology as it is highly unlikely that the costs for this type of treatment would be less expensive than the costs for a conventional air stripper under Alternative V-6A and Alternative V-6B. (The present worth costs for Alternative V-6A and Alternative V-6B was reported as $1,868,725 and $1,843,974, respectively.

The present worth costs for Alternative V-7A and V-7B will be corrected and subsequent discussions and cost presentations within the report adjusted accordingly. Fortunately, the increased costs for Alternatives V-7A and V-7B only affirm the preference for the less costly in-situ remedial alternatives.

The costs of virtually all of the alternatives will be revised for the final report, as changing the IRA from recirculation wells to groundwater extraction and disposal must be addressed. The chemical oxidation alternative will also be revised to incorporate the experience gained during the KMnO4 pilot study.

8. **Appendix D, Table D-14 – There are some costs items that have been omitted from Alternative A-4. These items include: (1) <u>Cost for a Replacement NP Treatment System</u> – The cost data includes an original NP treatment system. However, vendor information indicates that this system will last for a period of five years at most. Based on an estimated operational period of nine years, this cost data should include two NP treatment systems. (2) <u>System Maintenance</u> – The labor cost to operate and maintain this system is estimated to be the same as that to operate and maintain the system with a direct discharge to the POTW. However, vendor information notes that it will take 2-4 hours per week of labor to maintain this system. Therefore, the O&M costs for this alternative should be more than O&M costs for pumping and discharging directly to the POTW.**

The capital costs presented in Table D-14 will be refined to include replacement costs for the NP-7050 unit (5 years after start-up) and O & M costs will be updated to reflect the anticipated additional weekly labor hours (4) for general maintenance of the system as requested.

9. **Appendix E, NP-7050 Unit – The assumption for groundwater influent information appear to be low. For example do you expect there will not be any suspended solids when pumping raw groundwater directly to the microfiltration unit. In addition, the dissolved solids value of 20 mg/l appears to be low. Information should be collected during a pump test to determine specifics for TDS and TSS.**

The assumptions for groundwater influent information are based upon pumping tests that were performed at OU4 in the vicinity of the IRA wells. For confirmation, an additional pumping test would be performed in the antimony plume prior to design of the system. However, the assumptions used in the FS are adequate to properly evaluate this alternative.

10. **Appendix F, Hydrogen Release Compound Design Calculations, Spreadsheet – Although I could follow many of the spreadsheet calculations provided in this appendix, there were a few computations which I could not derive. It would be beneficial if either the consultant or Regenesis could provide the Department a copy of this spreadsheet program so that we can determine if all the assumptions provided are reasonable.**

A copy of the current version of this program and explanations of the basis for the models may be found on the Regenesis web page (www.regenesis.com). The current version is different than the one used for the draft FS, and there is yet another new version undergoing beta testing now. Regenesis is constantly upgrading and improving this software to reflect the current state of knowledge regarding this developing technology. Although the specific amounts of HRC may be different and will alter the costs slightly, this portion of the total cost of the alternative is relatively small and will not affect the comparative analysis.

11. **Appendix F, Hydrogen Release Compound Design Calculations, Safety Factor – I have noted a safety factor of 130X (676 lbs/5 lbs.) when computing the required HRC poundage for the source area. I realize that this safety factor is based on the necessity to fill all boreholes with HRC, however this factor of safety appears to be excessive. Are there methods of diluting HRC so that the applied dosage of HRC per borehole could be somewhat less than 40 pounds?**

There is a "safety factor" or overage included (1.67 times increase) for borehole size, but not nearly as great as that inferred by the commentor (130 times increase). The required number of pounds (5 lbs.) is the stoichiometric quantity of HRC necessary to provide the required hydrogen for reaction with the PCE and TCE. The adjusted HRC mass (405 lbs.) is the

stoichiometric quantity multiplied by hydrophobic sorption and competing microbial process factors, and other uncertainties provided by the model. The overage of 1.67 can be reduced by using a smaller diameter borehole or by mixing HRC with other materials. However, for FS costing purposes, this safety factor seems reasonable, especially considering that injection of the HRC from the borehole into the saturated overburden to enable a more widespread contact with the contaminated groundwater may also be considered in the design.

A site-specific pilot during the design phase will likely be required to support a more accurate estimation of the necessary HRC mass. However, the assumptions used in the FS are reasonable and adequate to evaluate this remedial technology.

12. **Precipitation of Antimony – With the addition of a reducing agent within the antimony plume, it is likely that the concentration of sulfate in the groundwater will be reduced to hydrogen sulfide. Any dissolved hydrogen sulfide may combine with the dissolved antimony to form an antimony sulfide precipitate (Sb_2S_3 or stibnite). Metal sulfide precipitates typically have very low solubility products. Thus the addition of HRC may not only mitigate the dissolved chlorinated groundwater plume but also may mitigate the dissolved antimony plume. The consultant should review the chemistry of this to determine what effects a reducing environment will have on antimony precipitation.**

Factors requiring consideration would be whether the sulfate reduction actually happens and to what degree, and what are the possible affects from the presence of other competing metals (Fe, Mn, As, etc). These are difficult to assess in theory and apply to a field scenario with any accuracy. HLA is unaware of any fixation technologies for antimony that have been fully demonstrated to be permanent remedial technologies. However, as part of the pilot test for HRC application in the adjacent southern VOC plume, measurements of antimony, sulfate, sulfide, and other indicators can be measured to more readily observe the effects of HRC within the antimony plume.