Wilmington
SCANNED

TRC
Customer-Focused Solutions

ADDENDUM-
PHASE III REMEDIAL ACTION PLAN (RAP)
GROUNDWATER

Former GE Facility
RTN# 3-0518
Wilmington, Massachusetts

Submitted to:

Massachusetts Department of
Environmental Protection -- NERO
205A Lowell Street
Wilmington, Massachusetts 01887

Prepared by:

TRC Environmental Corporation
Boott Mills South, Foot of John Street
Lowell, Massachusetts 01852
(978) 970-5600

TRC Project No: E9202-6303-02120

February 2002

Massachusetts Department of Environmental Protection

Bureau of Waste Site Cleanup

SCANNED

BWSC-108

COMPREHENSIVE RESPONSE ACTION TRANSMITTAL FORM & PHASE I COMPLETION STATEMENT

Pursuant to 310 CMR 40.0484 (Subpart D) and 40.0800 (Subpart H)

Release Tracking Number: 3 | 00518

A. SITE LOCATION:

Site Name: (optional) Former General Electric Facility (Groundwater)

Street: 50 Fordham Road Location Aid:

City/Town: Wilmington ZIP Code: 01887

Related Release Tracking Numbers that this Form Addresses:

Tier Classification: (check one of the following) [X] Tier IA [ ] Tier IB [ ] Tier IC [ ] Tier II [ ] Not Tier Classified

If a Tier I Permit has been issued, state the Permit Number: 83052

B. THIS FORM IS BEING USED TO: (check all that apply)

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- [ ] Submit a **Phase I Completion Statement**, pursuant to 310 CMR 40.0484 (complete Sections A, B, C, G, H, I and J).
- [ ] Submit a **Phase II Scope of Work**, pursuant to 310 CMR 40.0834 (complete Sections A, B, C, G, H, I and J).
- [ ] Submit a final **Phase II Comprehensive Site Report and Completion Statement**, pursuant to 310 CMR 40.0836 (complete Sections A, B, C, D, G, H, I and J).
- [X] Submit a **Phase III Remedial Action Plan and Completion Statement**, pursuant to 310 CMR 40.0862 (complete Sections A, B, C, G, H, I and J).
- [ ] Submit a **Phase IV Remedy Implementation Plan**, pursuant to 310 CMR 40.0874 (complete Sections A, B, C, G, H, I and J).
- [ ] Submit a **As-Built Construction Report**, pursuant to 310 CMR 40.0875 (complete Sections A, B, C, G, H, I and J).
- [ ] Submit a **Phase IV Final Inspection Report and Completion Statement**, pursuant to 310 CMR 40.0878 and 40.0879 (complete Sections A, B, C, E, G, H, I and J).
- [ ] Submit a periodic **Phase V Inspection & Monitoring Report**, pursuant to 310 CMR 40.0892 (complete Sections A, B, C, G, H, I and J).
- [ ] Submit a final **Phase V Final Inspection & Monitoring Report and Completion Statement**, pursuant to 310 CMR 40.0893 (complete Sections A, B, C, F, G, H, I and J).

You must attach all supporting documentation required for each use of form indicated, including copies of any Legal Notices and Notices to Public Officials required by 310 CMR 40.1400.

C. RESPONSE ACTIONS:

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- [ ] Check here if any response action(s) that serves as the basis for the Phase submittal(s) involves the use of Innovative Technologies. (DEP is interested in using this information to create an Innovative Technologies Clearinghouse.)

Describe Technologies:

D. PHASE II COMPLETION STATEMENT:

Specify the outcome of the Phase II Comprehensive Sites Assessment:

- [ ] Additional Comprehensive Response Actions are necessary at this Site, based on the results of the Phase II Comprehensive Site Assessment.
- [ ] The requirements of a Class A Response Action Outcome have been met and a completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.
- [ ] The requirements of a Class B Response Action Outcome have been met and a completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.
- [ ] Rescoring of this Site using the Numerical Ranking System is necessary, based on the results of the final Phase II Report.

E. PHASE IV COMPLETION STATEMENT:

Specify the outcome of the Phase IV activities:

- [ ] Phase V operation, maintenance or monitoring of the Comprehensive Response Action is necessary to achieve a Response Action Outcome. (This site will be subject to a Phase V Operation, Maintenance and Monitoring Annual Compliance Fee.)
- [ ] The requirements of a Class A Response Action Outcome have been met. No additional operation, maintenance or monitoring is necessary to ensure the integrity of the Response Action Outcome. A completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.
- [ ] The requirements of a Class B Response Action Outcome have been met. No additional operation, maintenance or monitoring is necessary to ensure the integrity of the Response Action Outcome. A completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.

Section E is continued on the next page

COMPREHENSIVE RESPONSE ACTION TRANSMITTAL FORM & PHASE I COMPLETION STATEMENT

Pursuant to 310 CMR 40.0484 (Subpart D) and 40.0800 (Subpart H)

Release Tracking Number: 3 | 00518

E. PHASE IV COMPLETION STATEMENT: (continued)

☐ The requirements of a Class C Response Action Outcome have been met. Further operation, maintenance or monitoring of the remedial action is necessary to ensure that conditions are maintained and that further progress is made toward a Permanent Solution. A completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.

Indicate whether the operation and maintenance will be Active or Passive. (Active Operation and Maintenance is defined at 310 CMR 40.0006.):

○ Active Operation and Maintenance ○ Passive Operation and Maintenance

(Active Operation and Maintenance makes the Site subject to a Post-RAO Class C Active Operation and Maintenance Annual Compliance Fee.)

F. PHASE V COMPLETION STATEMENT

Specify the outcome of Phase V activities:

☐ The requirements of a Class A Response Action outcome have been met and a completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.

☐ The requirements of a Class B Response Action Outcome have been met. No additional operation, maintenance or monitoring is necessary to ensure the integrity of the Response Action Outcome. A completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.

☐ The requirements of a Class C Response Action Outcome have been met. Further operation, maintenance or monitoring of the remedial action is necessary to ensure that conditions are maintained and that further progress is made toward a Permanent Solution. A completed Response Action Outcome Statement (BWSC-104) will be submitted to DEP.

Indicate whether the operation and maintenance will be Active or Passive. (Active Operation and Maintenance is defined at 310 CMR 40.0006.):

○ Active Operation and Maintenance ○ Passive Operation and Maintenance

(Active Operation and Maintenance makes the Site subject to a Post-RAO Class C Active Operation and Maintenance Annual Compliance Fee.)

G. LSP OPINION:

I attest under the pains and penalties of perjury that I have personally examined and am familiar with the information contained in this transmittal form, including any and all documents accompanying this submittal. In my professional opinion and judgement based upon application of (i) the standard of care in 309 CMR 4.02(1), (ii) the applicable provisions of 309 CMR 4.02(2) and (3), and (iii) the provisions of 309 CMR 4.03(5), to the best of my knowledge, information and belief,

> if Section B indicates that a **Phase I, Phase II, Phase III, Phase IV or Phase V Completion Statement** is being submitted, the response actions(s) that is (are) the subject of this submittal (i) has (have) been developed and implemented in accordance with the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, (ii) is (are) appropriate and reasonable to accomplish the purposes off such response action(s) as set forth in the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, and (iii) complies(y) with the identified provisions of all orders, permits, and approvals identified in this submittal;

> if Section B indicates that a **Phase II Scope of Work** or a **Phase IV Remedy Implementation Plan** is being submitted, the response action(s) that is (are) the subject of this submittal (i) has (have) been developed in accordance with the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, (ii) is (are) appropriate and reasonable to accomplish the purposes of such response action(s) as set forth in the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, and (iii) complies(y) with the identified provisions of all orders, permits, and approvals identified in this submittal;

> if Section B indicates that as **As-Built Construction Report** or a **Phase V Inspection and Monitoring Report** is being submitted, the response action(s) that is (are) the subject of this submittal (i) is (are) being implemented in accordance with the applicable provisions of M.G.L. c. 21E and 310 CMR 40.0000, (ii) is (are) appropriate and reasonable to accomplish the purposes of such response action(s) as set forth in the applicable provisions of M.G. L. c. 21E and 310 CMR 40.0000, and (iii) complies(y) with the identified provisions of all orders, permits, and approvals identified in this submittal.

I am aware that significant penalties may result, including, but not limited to, possible fines and imprisonment, if I submit information which I know to be false, inaccurate or materially incomplete.

☐ Check here if the Response Action(s) on which this opinion is based, if any, are (were) subject to any order(s), permit(s) and/or approval(s) issued by DEP or EPA. If the box is checked, you MUST attach a statement identifying the applicable provisions thereof.

LSP Name: Bruce A. Hoskins LSP #: 7109 Stamp:

Telephone: (603) 893-0616 Ext.:

FAX: (optional) (603) 893-6240

Signature: B a Hoskins

Date: 2/28/02

COMMONWEALTH OF MASSACHUSETTS
BRUCE A. HOSKINS No. 7109
REGISTERED LICENSED SITE PROFESSIONAL

Massachusetts Department of Environmental Protection **BWSC-108**

Bureau of Waste Site Cleanup

COMPREHENSIVE RESPONSE ACTION TRANSMITTAL FORM & PHASE I COMPLETION STATEMENT

Pursuant to 310 CMR 40.0484 (Subpart D) and 40.0800 (Subpart H)

Release Tracking Number: 3 | 00518

H. PERSON UNDERTAKING RESPONSE ACTION(S):

Name of Organization: TRC Environmental Corporation

Name of Contact: Joseph Yeasted Title: Vice President

Street: Boot Mills South, Foot of John Street

City/Town: Lowell State: MA ZIP Code: 01852

Telephone: (978) 970-5600 Ext.: FAX: (optional) (978) 435-1995

☐ Check here if there has been a change in the person undertaking the Response Action.

I. RELATIONSHIP TO SITE OF PERSON UNDERTAKING RESPONSE ACTION(S): (check one)

☒ RP or PRP Specify: ◯ Owner ◯ Operator ◯ Generator ◯ Transporter Other RP or PRP: Other legally responsible party

☐ Fiduciary, Secured Lender or Municipality with Exempt Status (as defined by M.G.L. c. 21E, s.2)

☐ Agency or Public Utility on a Right of Way (as defined by M.G.L. c. 21E, s.5(j))

☐ Any Other Person Undertaking Response Action Specify Relationship:

J. CERTIFICATION OF PERSON UNDERTAKING RESPONSE ACTION(S):

I Joseph Yeasted, attest under the pains and penalties of perjury (i) that I have personally examined and am familiar with the information contained in this submittal, including any and all documents accompanying this transmittal form, (ii) that based on my inquiry of those individuals immediately responsible for obtaining the information, the material information contained in this submittal is, to the best of my knowledge and belief, true, accurate and complete, and (iii) that I am fully authorized to make this attestation on behalf of the entity legally responsible for this submittal. I/the person or entity on whose behalf this submittal is made am/is aware that there are significant penalties, including, but not limited to, possible fines and imprisonment, for willfully submitting false, inaccurate, or incomplete information.

By: Joseph D. Yeasted (signature) Title: Vice President

For: TRC Environmental Corporation (print name of person or entity recorded in Section H) Date: 2/28/02

Enter address of the person providing certification, if different from address recorded in Section H:

Street:

City/Town: State: ZIP Code:

Telephone: Ext.: Fax: (optional)

YOU MUST COMPLETE ALL RELEVANT SECTIONS OF THIS FORM OR DEP MAY RETURN THE DOCUMENT AS INCOMPLETE. IF YOU SUBMIT AN INCOMPLETE FORM, YOU MAY BE PENALIZED FOR MISSING A REQUIRED DEADLINE.

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Customer-Focused Solutions

TRC Reference Number E9202-6303-02120

February 28, 2002

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NORTHEAST REGIONAL OFFICE

Ms Jennifer Eck
Project Manager
Bureau of Waste Site Cleanup
Massachusetts Department of Environmental Protection
205A Lowell Street
Wilmington, MA 01887

Subject: Addendum – Phase III Remedial Action Plan (RAP) for Groundwater
Former GE Facility (RTN# 3-0518)
Wilmington, Massachusetts

Dear Ms Eck:

Enclosed please find a copy of the Addendum- Phase III Remedial Action Plan (RAP) for Groundwater for the Former GE Facility (RTN# 3-0518) located on 50 Fordham Road in Wilmington, Massachusetts.

In order to facilitate your review, we are available to meet with you to discuss this report, and any concerns or comments you may have. In the meantime, should you have any questions or comments, please feel free to call our office.

Sincerely,

Paola E. Macchiaroli, Ph.D.
Project Manager

Enclosure

cc: Jennifer Stevens, Lockheed Martin Corporation
Frank Dardeno, Jr., Wilmington Realty Trust
Frank Bomba, Wilmington Realty Trust (w/o enclosure)
Alan Shafner, Ametek
Reading Town Library Repository
Gina Snyder, Key PIP Petitioner (w/o enclosure)
James Luker, Gale Associates (w/o enclosure)

L2002-071

Boott Mills South, Foot of John Street • Lowell, Massachusetts 01852
Telephone 978-970-5600 • Fax 978-453-1995

Wilmington
50 Fordham Rd

ADDENDUM-
PHASE III REMEDIAL ACTION PLAN (RAP)
GROUNDWATER

Former GE Facility
RTN# 3-0518
Wilmington, Massachusetts

Submitted to:

Massachusetts Department of
Environmental Protection – NERO
205A Lowell Street
Wilmington, Massachusetts 01887

Prepared by:

TRC Environmental Corporation
Boott Mills South, Foot of John Street
Lowell, Massachusetts 01852
(978) 970-5600

TRC Project No: E9202-6303-02120

February 2002

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1.0 INTRODUCTION

1.1 Purpose of Report

This report presents a Phase III Remedial Action Plan (RAP) Addendum for the chlorinated volatile organic compound (VOC) contaminated portion of the aquifer at the former GE facility (site) located at 50 Fordham Road in Wilmington, Massachusetts. The site location is shown in Figure 1-1. An approximate extent of the chlorinated VOC plume in the overburden and bedrock aquifers is shown in Figures 1-2 and 1-3, respectively.

In accordance with 310CMR40.0860, this RAP:

- Provides a brief summary of site aquifer conditions;
- Reviews applicable remedial technologies;
- Assembles applicable remedial options into alternatives (i.e. defines remedial approaches);
- Assesses the alternatives;
- Selects a remedial alternative for the chlorinated VOC impacted aquifer.

1.2 Background Information

1.2.1 Site Description

The former GE property is approximately 13 acres, located east of Fordham Road and north of Concord Street, within an industrial park in Wilmington and North Reading, Massachusetts. The location of the site study area includes the former GE property and the off-property wetlands just to the east.

Prior to 1968, the property was used for gravel mining. From 1968 to 1970, the property was developed establishing three large buildings, one small building, a paved parking area, and a wastewater treatment facility. GE Aerospace Instruments began to occupy the property buildings in 1970 and operated manufacturing and supported research and development departments until 1989. Portions of the site were subsequently subleased to Converse, Inc. from 1973 to 1986 and to Hamilton Standard from 1983 to 1985. In August 1989, GE's operations were sold to Ametek, Inc, which maintains active manufacturing and testing operations at the site. The responsibility for the investigation and remediation of the site stayed with GE until 1993, when Martin Marietta (now Lockheed Martin Corporation, or LMC) acquired the GE Aerospace division, thereby transferring responsibility for site remediation to LMC.

Four underground storage tanks (Tanks D, G, H, and I), located within the Tank Farm area between Buildings 1 and 3, were in use from 1969 to 1987. Given the shallow nature of the bedrock in the area, it was necessary to install these tanks directly into an excavated area of bedrock. The tanks contained waste fuel and waste oil, solvents, Stoddard fuel, jet fuel, and methanol. The four tanks in the Tank Farm area were removed in 1987. The chlorinated VOC contamination that is the subject of this report is attributed to historical releases from these tanks.

1.2.2 Overview of Nature and Extent of Contamination & Site Conceptual Model

The release of the chlorinated solvents (primarily tetrachloroethene [PCE] and trichloroethene [TCE]) most likely occurred from the Tank Farm area and has impacted the overburden and fractured bedrock aquifers to the east. The release occurred sometime before 1975 when the facility stopped using chlorinated solvents in the operations. Although other contaminants were released into the groundwater from the Tank Farm area, this RAP Addendum addresses only the chlorinated VOC (solvent-related) contamination. Other types of contaminants with different migration properties, such as Stoddard fuel, have been addressed as separate areas of concern (AOC).

Overall, the Regional Groundwater AOC is defined by the area impacted by chlorinated solvents released into bedrock, and the associated plume that extends downgradient from the original source area. The plume extends through the overburden and fractured rock portions of the aquifer. The vast majority of chlorinated VOCs detected are either PCE or TCE with occasional detections of dichloroethenes and/or vinyl chloride, typical byproducts of PCE and TCE degradation.

In December 1978, Camp, Dresser, & McKee, Inc. (CDM), working under contract for the Town of North Reading, tested groundwater in the area of the Stickney Well, a municipal water supply well located due east of the site. Tests on the Stickney Well indicated the presence of TCE at 62 ug/L and 6 ug/L. The MADEP (formerly the DEQE) advised the Town of North Reading that the Stickney Well should not be used for public water supply purposes. The well was shut down on December 28, 1978. The Town of North Reading was subsequently compensated by GE in 1991 for the loss of the Stickney Well water supply.

A complete summary of site history is presented in the Public Involvement Plan (PIP) dated November 2000. In addition, a summary of the historical contaminant distribution data (including the most recent data collected by TRC in summer of 2001), a discussion on how the extent of the plume has changed over time, and the implications of the most recent findings are presented in the TRC report *Comprehensive Review of Groundwater Data* dated September 14, 2001.

The most recent investigation (2001) was designed to delineate the vertical extent of bedrock contamination, and the location of major water-bearing fractures that could serve as preferential flow pathways for the chlorinated VOCs to support the RAP phase of the project. As part of the June 2001 deep bedrock investigation, TRC selected two locations for deep bedrock borings. One (TRC-202R) was located in the area of well cluster EMW-11 to constrain the vertical extent of contamination previously identified in the deep bedrock, and the other (TRC-201R) was located along the southern property boundary to investigate a possible fracture that would establish a preferential flow pathway from the source area or southern portion of the site to the south side of Concord Street.

Based on the observed low-flow and no-flow conditions across the entire length of boring TRC-201R, there appears to be no fracture zone extending from the south side of Concord Street onto the southern portion of the site.

Based on the results from boring TRC-202R located near the eastern edge of the parking lot, the bulk of chlorinated VOC mass flux observed to date is located within a specific fracture system located 95-115 feet below ground surface (bgs). Given that the maximum concentrations of chlorinated VOCs in bedrock to date are observed in wells GZA-105, TRC-202R, and EMW-11R3, TRC concluded that a preferential flow pathway exists between the Tank Farm area, well GZA-105, TRC-201R, and the EMW-11 well cluster, which all fall along a direct line that is oriented approximately N85E, similar to the orientation of the fractures/joints observed in the surface outcrop located southeast of the site (Figure 1-3). Furthermore, the increasing trend of contaminant concentrations with depth is consistent with the nature of the contaminants of concern, given that they are denser than water. That is, a conceptual model of contaminant migration would have dense non-aqueous phase liquids (DNAPL) entering the bedrock at the Tank Farm area and moving downward. Water in direct contact with the DNAPL, which could exhibit exceptionally high levels of VOCs, would preferentially flow eastward along the fractures toward well cluster EMW-11.

The chlorinated VOCs in the overburden aquifer are associated with the bedrock source area. There is no separate source of chlorinated VOCs in the overburden. The overburden plume is a result of eastward migration of impacted groundwater from the shallow fractured rock in the source area (Tank Farm area) into the overburden of the Eastern Parking Lot (EPL- where the overburden deposits become ~30-40 feet in thickness), and the wetlands area (where the overburden deposits extend up to 70 feet in thickness). The chlorinated VOCs in the overburden are generally one order of magnitude less than those detected in bedrock, with the exception of well GZA-105D, where some upwhelling of impacted groundwater from bedrock into the overburden may occur. The overall contaminant plume appears to be in a steady-state condition (i.e., no appreciable fluctuation in the contaminant levels and no migration of the plume further east), and appears to be attenuating. Numerous wells in the wetland area have exhibited a significant decrease in VOC levels in recent years. The most recent distribution of chlorinated VOCs in overburden is depicted in Figure 1-2.

Since the original solvents have not been used at the site since 1975, and the original source (tanks in the Tank Farm) was removed in 1987, there is no longer a true source of chlorinated solvents. In fact, the Tank Farm area Interim Measure (a pump and treat system) that has been in operation since 1993 has shown a significant decrease in influent contaminant concentrations. With the limited groundwater extraction rates at the Tank Farm area (less than 1 gpm) and the lower concentrations, the amount of mass removed from the former source area has significantly decreased over time. Only about one pound of total VOC has been recovered over the past three years. Hence, TRC has recommended and the MADEP has approved that this system be decommissioned.

Based on the most recent TRC data, a much higher VOC mass flux is located at boring TRC-202R than in the wells located at the Tank Farm recovery system. As addressed in TRC's 2001, *Comprehensive Review of Groundwater Data*, the mass flux occurring at boring TRC-202R is approximately 20 pounds per year, or nearly two orders of magnitude greater than the rate of extraction from the Tank Farm area. Therefore, for the purposes of discussion in the remainder of this report, the source area of contamination (source) that can be controlled and/or remediated

will now be identified as the mass flux in the vicinity of boring TRC-202R. This is depicted on Figure 1-4.

1.3 Previous Phase III Remedial Action Plan (RAP)

In October 1993, a Phase III RAP was submitted by Wehran for the entire former GE site. The previous RAP addressed all four AOCs of the site, one of which was the chlorinated solvent contamination in groundwater. The recommended alternative for groundwater remediation in the Wehran RAP included the collection of groundwater via pumping from four overburden and nine bedrock wells located in the Tank Farm and EPL, with treatment of extracted groundwater to GW-1 standards (i.e. drinking water standards) using air stripping and activated carbon. The total pumping rate was expected to be approximately 65 gallons per minute (gpm), with treated groundwater discharged to the wetland via the existing outfalls.

In October 1996, DEP conditionally approved the groundwater remediation alternative in the Wehran RAP. In 1997, EMCON (formerly Wehran) installed additional overburden and bedrock wells along the eastern edge of the property to support the design phase of the project. However, the additional well installations led to the discovery of significantly higher chlorinated VOC concentrations in deeper portions of the bedrock aquifer than that previously observed (greater than 140 feet bgs). Given the new findings, EMCON issued a letter report on February 27, 1998 to MADEP indicating that no existing technology (including the RAP recommended alternative) could feasibly achieve the GW-1 cleanup standards for the bedrock aquifer, and therefore sought a ruling of technical impracticability (TI). They also recommended that natural attenuation become the proposed alternative.

TI can be implemented in cases where it is deemed by the MADEP that it is technically infeasible or technically impracticable to remediate the problem using existing technologies. A TI designation is considered as a temporary solution until new technologies that are capable of achieving the remedial goals become available. EMCON's letter requested TI acceptance, requested that natural attenuation be accepted as a temporary solution, and suggested that it be evaluated as a potential permanent solution.

On February 12, 1999, EMCON submitted the *Summary of Groundwater Sampling and Evaluation of Natural Attenuation Report*. This report documented that some VOC degradation had occurred in some areas of the site, but conditions observed during the study were not favorable for significant natural degradation of VOCs across the entire site.

On February 10, 2000, MADEP issued a letter that, among other topics, did not accept the temporary solution proposed by EMCON of natural attenuation and monitoring. While not rejecting this solution for the off-site VOC plume, MADEP required that further investigation be performed to define the vertical extent of chlorinated VOC contamination such that adequate source control of the impacted groundwater could be included in a remedial action alternative. This requirement led to the additional work performed by TRC as documented in the September 14, 2001 TRC *Comprehensive Review of Groundwater Data* report, and the RAP Addendum herein.

1.4 Remedial Objectives and Cleanup Goals

The cleanup goals established at this site by MADEP are the MCP Method 1 GW-1 standards. These standards are equivalent to the maximum contaminant levels (MCLs) established by EPA for drinking water. MADEP considers these standards to be applicable as the site is located within a DEP Wellhead Protection Area and is, therefore, within a drinking water aquifer. The Stickney well, located due east of the site, is no longer active. Therefore, the contamination due east of the site does not pose any current risk to human health. However, there is potential future risk if a drinking water supply well is installed and operated within the impacted portion of the aquifer.

The Town of Reading is currently considering the deep bedrock aquifer as a potential source of drinking water for the community. The area of interest is approximately 3,500 feet southeast of the site. Site-related contamination at this location is not expected due to the distance from the site, the likelihood that any fractures would be discontinuous over this distance, and the shift in orientation away from the primary fracture alignment. Testing to be conducted as part of the Town's initiative should confirm if any potential problem exists, at which time an evaluation would have to be made as to whether the Former GE site is a contributing source.

While remediation of chlorinated solvents is challenging under most circumstances, bedrock remediation is especially difficult given the fractured nature of bedrock formations. The fracture patterns are often irregular and unpredictable. Typically, fracture density is greatest at the shallowest depths where the actions of weathering are most effective. At depth, the bedrock becomes effectively competent (i.e. little to no fractures), thereby preventing further downward migration of the contaminants. When any DNAPL enters the bedrock fractures, there is the potential for the contaminants to migrate into "dead end" fractures isolated from groundwater flow. Access to the contaminants found in this class of bedrock fracture may not be possible. Under these conditions, the slow dissolution of the contaminants back into the groundwater system may persist for extensive periods of time, preventing the achievement of drinking water based cleanup standards. Based on TRC's review of currently available data, no successful remediation has been achieved at sites with similar conditions.

Due to the nature of the contaminants and the deep bedrock aquifer at the site, there is no current technology that can achieve the GW-1 standards in a timely manner. Therefore, the achievement of the GW-1 standards is considered to be technically infeasible. This fact does not change the cleanup standards, but it changes the focus of the remediation objectives. Since the GW-1 cleanup standards cannot be achieved with current technologies, the remediation goal is to try to get as close to the GW-1 standards as technically possible while at the same time minimizing future contaminant migration and potential risk.

Furthermore, given that the original release of contaminants occurred in bedrock, and the currently-defined source area of the contaminant plume is in fractured bedrock , TRC believes that all source control efforts must focus on bedrock. With active source control, the source of the contaminant plume that currently extends into the overburden will, in turn, be controlled. In

addition, with source control, the residual contaminants located downgradient should continue to undergo natural degradation and attenuation over time.

Therefore, TRC has selected the following remediation objectives:

- Source containment
- Source removal to the extent practicable
- Groundwater restoration to GW-1 standards to the extent practicable
- Prevention of human consumption of contaminated groundwater

2.0 SCREENING OF TECHNOLOGIES AND DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

In this section, various remedial technology options are screened and combined into remedial alternatives. TRC has limited the remedial technologies presented herein to those that are applicable to the media of concern (groundwater) and the contaminants of concern (chlorinated VOCs).

2.1 Identification and Screening of Technologies/Process Options

The USEPA has developed a compendium document to assist in the remedy selection process based on the degree of development of the technology (emerging or mature) and the probability of success based on available performance data. The information provided by the USEPA's Clean Up Information (CLU-IN) program includes a Fractured Bedrock Focus Area. The remedial technologies or combinations of technologies included in this section are consistent with those technologies most commonly applied at other similar sites, as summarized in CLU-IN. Figure 2-1 presents a summary of the most-commonly used technologies for fractured bedrock aquifer remediation. Table 2-1 provides a detailed list of the sites represented by the information in Figure 2-1.

Selection and screening of technologies applicable to conditions found at this site were also based on the experience of the document authors. Supplemental information was obtained from published sources, peer-reviewed literature, and information provided by technology service providers. Literature sources cited in the evaluation of technologies include the following:

- Wickramanayake, Godage B., et. al., Treating Dense Nonaqueous-Phase Liquids (DNAPLs), Battelle Press, 2000
- Freeman, Harry M., Standard Handbook of Hazardous Waste Treatment and Disposal, McGraw-Hill, 1988
- Wickramanayake, Goage B., et. al, Chemical Oxidation and Reactive Barriers: Remediation of Recalcitrant Compounds, Battelle Press, 2000
- Nyer, Evan K., et. al., In-situ Treatment Technology, Lewis Publishers, 2001
- USEPA Risk Reduction Environmental Laboratory, SITE Applications and Technology Evaluation Report, "Hydraulic Fracturing Technology", EPA/540/R-93/505, 1993

2.1.1 Grout Injection

Technology Description

This technology involves the injection of a grout material (usually a cement mixture) into the subsurface to establish a permanent barrier that prevents groundwater flow and contaminant migration. This technology can be used to isolate groundwater flow horizontally or vertically. In horizontal applications, the grout injection is used to install an artificial aquitard (a low-permeability horizontal layer) to prevent vertical migration. In vertical applications, a grout

curtain is constructed across a vertical or lateral section to prevent lateral groundwater migration. Curtains can be installed in either bedrock or overburden. Such an application has been commonly used to seal bedrock underneath dams to prevent water loss under the dam structure.

The main concern in the effectiveness of this technology is that coverage of the grout is sufficient to provide a complete wall without holes. However, there is no reliable means to confirm that the area has complete coverage. Because of the tendency of groundwater to flow around or over the grout curtain, the design (shape and size) of the curtain is also critical.

Evaluation Against Site Conditions

Given the overall lateral size and depth of the contaminant plume, a grout curtain to prevent further migration of the plume from the property is not practical. Such a curtain would have to extend at least 120 feet into bedrock as well as across a portion of the overburden located above the bedrock surface. The lateral extent of the curtain would be approximately 600-800 feet along the edge of the Eastern Parking Lot, resulting in a curtain with a face area of approximately two acres.

A more practical application of a grout curtain would be to install it in the original source area at the Tank Farm. In addition, grouting would be placed in the primary fractures along the identified preferential flow pathway between the original source area and boring TRC-202R, and a second curtain would be installed downgradient of wells TRC-202R and EMW-11 where the highest known mass of contaminants has been observed. By closing off the pathway, any contaminants in the pathway will become permanently stabilized by the grout and no future contaminant movement will occur along that flow pathway. By installing the curtains, downgradient migration of contaminants will be further minimized. Overall, this approach would bind up the contaminants and reduce off-site contaminant migration.

GW mounding issue?

Grout injection is an appropriate technology for this site in the latter application and will be retained for development into an alternative.

2.1.2 Groundwater Extraction and Ex-Situ Treatment

Technology Description

This technology involves the installation of one or more groundwater extraction wells at the site. Positioning of the wells can be in the source area of the site (where the highest dissolved contaminant concentrations are found) and/or along the leading edge of the plume. The placement and pumping rates are selected to redirect the natural groundwater flow patterns toward the extraction wells, thereby preventing future or continuing contaminant migration. Contaminant mass is removed from the subsurface in the dissolved phase. Additionally, the groundwater extraction system flushes the matrix with groundwater and slowly desorbs contaminants, bringing them to the surface for treatment. Above ground, the VOC-laden water is collected and treated for VOC removal using groundwater treatment technologies such as granular activated carbon (GAC), air stripping, or other appropriate methods.

Groundwater extraction and treatment systems have been implemented in a wide variety of site conditions. This technology was originally implemented toward the objective of restoring site conditions to those existing before a contaminant release. The technology, however, has seen limited success in achieving this goal. Typically, dissolved concentrations that initially decline reach an asymptotic level where the rate of contaminant desorption from the soil is essentially matched by the rate at which it is removed at the extraction well. Once this condition is established, little further improvement is observed. In the presence of organic carbon within the soil matrix, slow contaminant desorption is especially problematic. Essentially, the contaminants are adsorbed onto the natural organic matter where they are slow to desorb. Similar complications exist for this technology in bedrock aquifers, where wells only recover groundwater from water-bearing fractures intercepted by the wells.

Given the limitations of this technology, groundwater extraction and treatment is typically used for plume containment when the risk of off-site migration is the overriding remedial objective.

Evaluation Against Site Conditions

While remedial programs based solely on groundwater pump and treat systems have historically shown limited success at achieving final closure of a project, the technology is commonly employed as a component of an overall strategy. As described previously, the technology can also be effectively used to prevent plume migration, thereby protecting groundwater supplies otherwise at risk.

At this site, pump and treat can be used to reduce dissolved concentrations, reduce the mass of contaminants, and control the source area within the bedrock. In the fractured bedrock, there is little effective porosity in the bedrock formation. The volume of groundwater in the fractures, therefore, is very small. DNAPL, however, can coat the inside of fractures, and accumulate in dead-end fractures. The pooling and coating of DNAPL continually releases dissolved contaminants into the groundwater. Given that there is relatively little groundwater available for extraction, it takes very long periods of time to "flush out" the impacted fractures. Groundwater extraction from isolated fractures can, however, effectively truncate the downgradient migration of contaminants, and control the source area.

Given the low volume of contaminated groundwater within the bedrock and the potential for source control of dissolved contaminants, groundwater pump and treat is an appropriate technology at this site and will be retained for development into alternatives.

2.1.3 Enhanced In-Situ Biodegradation

Technology Description

In anaerobic (oxygen-starved) environments, reductive dechlorination is the most common biodegradation mechanism for chlorinated aliphatic compounds. This process involves the sequential replacement of chlorine atoms on the alkane or alkene molecule by hydrogen atoms. The anaerobic biodegradation pathways (i.e. biodegradation under oxygen-starved conditions) for PCE and TCE are shown on Figure 2-2.

The complete dechlorination of chlorinated VOCs requires the synergistic effects of a number of different microorganisms in a healthy anaerobic community. An ample supply of electron donors (i.e. a carbon source) is also required to sustain the growth of dechlorinating microorganisms, as well as the growth of organisms that supply the dechlorinating organisms with essential nutrients. A number of studies have shown that simple substrates such as lactate (an electron donor) can support a complex community of bacteria. Considerable laboratory field research and full-scale projects have shown that chlorinated VOCs can be biodegraded to non-toxic end products under appropriate anaerobic conditions (leading to the production of ethane, chlorides and carbon dioxide).

Organic compounds are known to degrade through a variety of biologically-mediated (biotic) and non-biological (abiotic) processes. The preferred degradation pathway exhibited for a given organic compound depends on the local groundwater chemistry, microbiology, and chemical properties of the compound. Detailed site characterization and treatability testing are recommended to determine the degradation pathway(s) most likely to provide successful results.

Evaluation Against Site Conditions

The technology requires the introduction and distribution of substances (referred to as amendments) to promote accelerated biodegradation processes. The smaller the plume, the fewer injection points that are needed to achieve appropriate amendment distribution. Because of the fractured nature of the formation containing the contaminant plume, success of this technology will be largely dependent on the introduction of the amendment to those fractures containing the VOCs. The complexity of the fractured bedrock remediation is well recognized and will necessitate a higher level of testing and data collection than is typically required for the remediation of an overburden aquifer.

At this site, there is sufficient evidence that natural processes are on-going to reduce the mass of contaminants. A carbon source appears to be the limiting factor under current site conditions. Based on the existing evidence, along with experience from many other sites contaminated with similar compounds, in-situ biodegradation is retained as a technology suitable for implementation at the site. The final, full-scale remedial program would be designed based on the treatability study. Recognizing the complexity of fractured-bedrock remediation, long-term monitoring and adjustments to the amendment delivery processes would be necessary to verify the expected performance of this technology.

2.1.4 In-Situ Oxidation

Technology Description

Chemical oxidation is a technology that has been used in the water and wastewater industries for many years. An oxidizing agent is used to destroy organic matter, chemically converting it to less toxic or inert compounds. In the environmental field, application of in-situ chemical oxidation for sites contaminated with VOCs is a developing site remediation technology. A primary attraction of this technology is the speed at which the process takes place. Specifically,

the oxidation reactions take place over a time frame of minutes to hours. Treatment of the contaminated zone could be accomplished over a period of weeks to months (depending on the number of applications required) rather than years typical of many remedial approaches.

The in-situ oxidation technology has been applied to a wide variety of sites impacted with VOCs. The most common oxidizers used for this technology are potassium permanganate ($KMnO_4$) and Fenton's reagent.

While the reaction mechanisms of chemical oxidation are well documented, the successful application of this technology for treatment of contaminants in-situ is complicated by several factors. Of particular consideration is the reaction rate of the process. As described previously, the oxidation reactions are rapid, occurring over a short time frame. The oxidizer must come in contact with the contaminant for the reaction to take place. A dense network of injection points is often required to achieve the degree of contact necessary for adequate treatment of the contaminants. Where the contaminants are found at depth, the cost of the injection network can render this technology economically prohibitive. Secondly, oxidizers are non-specific and will react with available organic and inorganic compounds found within the treatment zone. Therefore, the oxidizer will be consumed by reactions with non-targeted compounds, thereby increasing the cost and decreasing the effectiveness of the process.

When using certain reagents, the formation can also be plugged by the precipitation of insoluble material. Should this occur, oxidant access to the targeted contaminant can be impeded, again resulting in incomplete treatment. Finally, health and safety concerns also exist with this technology. The oxidation reactions are exothermic (producing heat) and gas generating. Subsurface explosions have been reported at sites where excessive oxidizer was supplied to the subsurface.

Evaluation Against Site Conditions

At this time, the database of successful and unsuccessful in-situ chemical oxidation projects is limited, as the technology has only recently been used in this application. Despite the limited knowledge base, the applicability of the technology to site conditions can still be broadly characterized. At this site, in-situ oxidation has limited applicability primarily due to the depth of the targeted contamination, extending more than 100 feet below ground surface. Also, the nature of the impacted media (fractured bedrock) further limits the applicability of this technique due to the distribution problems previously discussed.

On the basis of the geologic complexity of the site, combined with the developmental nature of this technology, in-situ chemical oxidation will not be retained as a technology suitable for implementation at the site.

2.1.5 Fracturing and Soil Vapor Extraction (SVE)

Technology Description

Hydraulic or pneumatic fracturing and soil vapor extraction (SVE) represent a combination of technologies designed to remove contaminants from the subsurface. The fracturing process involves the injection of fluids under pressure into the formation targeted for fracturing. To initiate the fracture, the pressure of the fluid must be sufficient to overcome the overburden pressure and the ultimate strength of the formation material. Fractures typically initiate and propagate through previously existing fractures (in particular within a bedrock formation), but can be generated in previously non-fractured formations. Hydraulic fracturing is included as the fracturing variant most applicable to conditions at this site.

The second component of this remedial program is conventional soil vapor extraction. This technology involves the withdrawal of vapors from an impacted zone in the subsurface. The withdrawal of vapors upsets the natural equilibrium conditions within the subsurface and promotes enhanced volatilization of the contaminants as conditions attempt to re-equilibrate. An above-ground blower is typically used to generate the subsurface air flow and the contaminants are removed and treated in the vapor phase.

The final component of this remedial program is groundwater extraction. This component is necessary to dewater the impacted materials. Saturated material does not have open pathways for movement of vapors within the subsurface. Without this dewatering, SVE would be ineffectual. Consistent with the previous discussion of the pump and treat technology, dewatering would be accomplished using a series of vertically-inclined wells each fitted with a submersible pump. Treatment of the groundwater using adsorptive or physical mechanisms (e.g. air stripping) would be necessary before its ultimate discharge.

Evaluation Against Site Conditions

As described previously, the zone targeted for remediation at this site is found in the fractured bedrock nearly 95 to 115 feet bgs. While fracturing can be accomplished at great depths, it is difficult to control with the precision that would be needed in this application to target a very discrete and localized impact. There is a high potential that created fractures would actually be detrimental to contaminant migration and the eventual cleanup of the site by creating undesirable flow pathways.

Based on the uncertainties of performance for the technologies described, fracturing and SVE will not be retained as a technology suitable for implementation at the site.

2.1.6 Dual-Phase Extraction (DPE) and Ex-Situ Treatment

Technology Description

Dual-phase extraction (DPE) is essentially a combination of conventional SVE and groundwater pump-and-treat remediation and can be used as a means of 1) controlling contaminant migration in the dissolved phase; 2) reducing dissolved concentrations by dilution; 3) exposing contaminant-impacted media (soil and rock); and 4) removing contaminants in the vapor phase from the vadose zone and from dewatered areas. This technology typically requires treatment systems for both vapor and groundwater streams before atmospheric or effluent discharge.

As described above, DPE promotes contaminant mass removal from the subsurface through several mechanisms. Typically, the dominant mass removal mechanism is enhanced volatilization. The enhancement of oxygen concentrations within the treatment area can also occur as contaminated vapors are withdrawn from the soil. Under certain conditions, an elevation of oxygen levels can promote higher biodegradation rates of compounds susceptible to aerobic (oxygen-rich) degradation. However, highly chlorinated compounds such as PCE and TCE are not degraded aerobically, and thus their degradation is not positively influenced by elevated oxygen.

The DPE technology requires an above-ground blower to withdraw vapors from the subsurface collection point (typically a vertically-inclined well). Removal of liquids (groundwater and non-aqueous phase liquids- NAPL) from the collection point is accomplished using either air lift or a submersible electric or pneumatic pump. The vapor and liquid streams are typically treated above ground before their discharge. The processes used to treat these streams are similar to those employed for conventional pump and treat and SVE techniques. Specifically, air stripping and/or carbon adsorption are generally used for the treatment of organic contaminants in the liquid phase. Oxidation or adsorptive technologies are typically applied to the vapor phase.

Evaluation Against Site Conditions

DPE shares many of the same benefits of fracturing and SVE, without the creation of fractures to improve subsurface flow characteristics. In this technology, an applied vacuum is used to improve the flow of liquids into the extraction well simultaneous with the removal of volatile contaminants in the vapor phase.

The dual phase extraction technology also shares many of the limitations of the fracturing/SVE technologies. Specifically, the effectiveness of dewatering and vapor flow within the formation is difficult to predict due to the uncertainties regarding fracture/overburden interconnectivity and water yield. DPE is typically applied at sites with low to moderate permeability. The applicability of DPE for the deeper impact within bedrock is unpredictable without additional knowledge regarding fracture characteristics of this media.

explain better

On the basis of the limitations inherent with this technology under conditions encountered at this site, combined with the uncertainties associated with water yield, this technology will not be retained as a technology suitable for implementation at the site.

2.1.7 Soil flushing

Technology Description

The process involves the controlled injection or percolation of a surfactant solution into the affected zone within the aquifer. By design, surfactant-based flushing increases the solubilization and mobility of the contaminants as a means of improving contaminant recovery rates. The microemulsion created by the injected surfactant solution is recovered above ground, typically by one or more groundwater recovery wells. Above ground, the surfactant, groundwater and NAPL emulsion are treated. Where appropriate, the surfactant solutions are recovered and reused.

Assuming proper application of the technology, surfactant-based flooding can be expected to perform best in a permeable formation, where access to the contaminants can be achieved. In highly stratified or fractured formations, control of the injected surfactant is more difficult. In these cases, areas of incomplete treatment can result, and the removal of only a fraction of the contaminants may not sufficiently improve conditions within the subsurface. Additional treatment would therefore be required to achieve the final closure.

Because of this approach, there is a hazard that relatively stable NAPL droplets could spread, thereby worsening the problem as an undesirable consequence of the cleanup. Containment of the injected fluids, therefore, is a requirement of the technology. Both physical barriers (such as sheet piling) and hydraulic barriers (containment by groundwater extraction) have been employed. Given the depth to the targeted zone at this site, only the hydraulic containment option is practical.

Evaluation Against Site Conditions

Surfactant flushing is best applied in cases where positive control over the injected surfactants and mobilized contaminants can be assured. In the absence of this control mechanism, a stable plume configuration can be destabilized resulting in an unwanted expansion of the plume. The effectiveness of the technology also requires direct contact between the surfactants and the targeted contaminants. Without this contact, incomplete treatment will occur.

At this site, the introduction of a surfactant into bedrock would be difficult to control. Furthermore, there is the potential that mobilization of the targeted constituents could drive the contaminants deeper into the bedrock formation further complicating the eventual cleanup of the site. Based on the limitations of this technology in relation so site-specific considerations, this technology will not be retained as a technology suitable for implementation at the site.

2.1.8 Summary

Based on conditions found at this site, the following technologies have been retained for further consideration and incorporation into remedial alternatives:

- Grout injection
- Groundwater extraction and ex-situ treatment
- Enhanced in-situ biodegradation

Given that all of the available technologies are unable to remediate fractured bedrock aquifers in relatively short time-frames, the contaminant plume at the site will still pose a risk (as defined by the MCP) to human health and the environment. Therefore, TRC has considered the use of institutional controls to further minimize and/or control the risk factors. Institutional controls, such as deed restrictions (or Activity Use Limitations per the MCP), prevent access and/or use of the impacted groundwater, and are considered to be valid and appropriate measures for minimizing risk under the MCP.

Therefore, MCP-type institutional controls will be incorporated into the alternatives, as needed to protect public health by preventing access to and ingestion of the subsurface contaminants. Furthermore, TRC will continue to work with MADEP to evaluate alternative institutional control measures (that are not defined under the MCP) to further minimize the risk posed by the impacted groundwater, particularly at off-property locations. These alternative institutional controls are not considered herein, but will be evaluated along a parallel track to that of this Phase III RAP.

2.2 Development of Alternatives

Using the retained technologies, the following seven alternatives have been developed for the site:

- **Alternative 1** – Monitored Natural Attenuation
- **Alternative 2** – Source Containment Via Grouting
- **Alternative 3** – Source Removal and Containment Via Groundwater Extraction and Treatment
- **Alternative 4** – Source Removal Via In-Situ Treatment
- **Alternative 5** – Source Removal and Containment Via In-Situ Treatment and Groundwater Extraction and Treatment
- **Alternative 6** – Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment
- **Alternative 7** – Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment and In-Situ Treatment

All seven alternatives include institutional controls and long-term groundwater monitoring. In developing these alternatives, consideration was given to the balance of cost-effectiveness against the levels of human health and environmental protection achieved. In particular, the seven alternatives provide a range of options that achieve one or more of the following:

- Eliminate the need for long-term management at the site, to the extent feasible;
- Use treatment as a primary component to reduce the toxicity, mobility, or volume of contaminated materials;
- Involve containment to prevent potential exposure and/or to reduce the mobility of contaminants;
- Involve institutional actions to prevent potential exposure to contaminants.

3.0 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This section presents the detailed analysis of the seven remedial alternatives presented in Section 2.0 for addressing the site. Each alternative is evaluated based on cost and non-cost criteria.

3.1 Analysis Criteria

In accordance with the MCP, the following criteria were used to analyze and evaluate each of the remedial alternatives:

- Effectiveness
- Short-Term and Long-Term Reliability
- Implementability
- Cost
- Risk
- Benefits
- Timeliness
- Non-Pecuniary Interests

3.1.1 Effectiveness

This criterion is used to determine how each alternative complies with achieving a permanent or temporary solution. This criterion discusses how the alternative reuses, recycles, destroys, detoxifies, or treats the contaminants of concern, and to what extent the alternative reduces the levels of contaminants to achieve or approach background conditions.

3.1.2 Short-Term and Long-Term Reliability

This evaluation criterion addresses the degree of uncertainty for success of the alternative, as well as the effectiveness of any measures required to manage residues, remaining wastes, discharges, or emissions to the environment.

3.1.3 Implementability

This criterion establishes the technical and administrative feasibility of implementing a technology. Technical aspects evaluated for each technology include construction and operation activities, ease of undertaking additional remedial action (if needed), and monitoring after completion of activities. Administrative concerns include necessary approvals of appropriate agencies to implement remedial actions (i.e., obtaining permits or approval for construction and operation of a treatment unit). Availability of necessary materials and equipment are other factors that must be considered when evaluating the implementability of a technology.

3.1.4 Cost

This evaluation criterion provides information as to the capital and operation, maintenance, and monitoring (OM&M) costs of the alternative. All costs are estimated in 2002 dollars, with OM&M costs discounted to net present value. Capital costs include direct and indirect costs. The direct costs include the equipment, labor and materials to implement the remedial alternative. The indirect costs include engineering, analytical and reporting necessary to implement and complete the alternative.

OM&M costs pertain to post-construction activities necessary to fulfill the obligations to successfully implement and complete each alternative. The costs generally cover maintenance of equipment, materials, labor, administration, data collection and analysis, and reporting. In accordance with industry standards, OM&M costs are valued at their present worth assuming a project duration of 30 years (where applicable) and an interest rate of 5%.

The costs associated with each alternative are inclusive of a 25% contingency. Additional cost considerations could include environmental restoration of wetlands, surface waters, and wildlife disrupted by remediation activities. However, these considerations are not applicable for this remediation effort at the site.

3.1.5 Risk

This evaluation criterion addresses the short-term and long-term on-site and off-site risks from excavation, transport, disposal, containment, construction, operation, or discharges from remedial systems. This criterion also includes consideration of the potential risk to human health or to the environment posed by any contaminants remaining after completion of the remedial action.

3.1.6 Benefits

This criterion establishes the benefits of the alternative, including the benefits of restoring natural resources; providing for the productive reuse of the site; avoiding costs of relocating residents, businesses, or utilities; and avoiding lost value of the site.

3.1.7 Timeliness

This criterion establishes the timeliness of the alternative in terms of eliminating any uncontrolled sources of oil and/or hazardous material and achieving a level of no significant risk (achieving remedial cleanup goals).

3.1.8 Non-pecuniary Interests

This criterion evaluates the relative effect of the alternative upon non-pecuniary interests, such as aesthetic values.

3.2 Evaluation of Alternative 1 – Monitored Natural Attenuation (MNA)

3.2.1 Description of Alternative 1

This alternative includes the following:

- Class C Response Action Outcome (RAO) for a temporary solution
- Long-term groundwater monitoring
- Institutional controls

In this alternative, a Class C RAO under the MCP (a temporary solution) would be filed. This class of RAO would require regular monitoring and 5-year reviews to evaluate new technologies that could provide a permanent solution. No active measures would be taken and the contaminants in groundwater would remain in place. This alternative relies on natural attenuation, which is the cumulative result of dilution by natural groundwater flow and the effectiveness of naturally-occurring microorganisms to degrade the chlorinated solvents. Under natural attenuation, neither oxygen nor nutrients are added to facilitate the degradation process. Because site data indicates that steady-state conditions have been achieved, natural attenuation does not further impact the site or surrounding areas and generates no waste streams. The rate of natural attenuation is determined via groundwater monitoring at regular intervals. At this site, there is an existing groundwater monitoring program that could be modified for the purposes of monitoring for natural attenuation. The program would be modified to include annual monitoring of five wells in the Eastern Parking Lot and Tank Farm areas and 15 off-property wells (including wetland areas) for five years, and biannually thereafter. Analysis parameters would include volatile organic compounds (including ethene), dissolved oxygen (DO), oxidation-reduction potential (ORP), and pH.

Institutional controls are also included in this alternative. The institutional control option for this site is a Grant of Environmental Restriction (GER), which is a deed restriction that is attached to a defined parcel of land. The GER is defined in the MCP under 310 CMR 40.1071 as a type of Activity and Use Limitation (AUL) whereby, in this case, any use of the contaminated groundwater aquifer that would cause a significant risk to human health or the environment would be prohibited. These restrictions would remain in place until contaminant concentrations in the groundwater decreased to levels of no significant risk. The GER would prohibit activities such as installation or operation of public or private drinking water supply wells in the contaminated aquifer. The GER must be approved by MADEP before it can be placed on the site. Use of the GER would be limited to the former GE property. The GER could be utilized for the entire contaminated aquifer area; however, this would require the cooperation of all property owners within the contaminated aquifer area to accept a GER for their respective properties.

The implementation of this alternative is expected to achieve the following:

- Bedrock and overburden groundwater quality improvement over the long term.
- Protection of human health by reducing the potential consumption of impacted groundwater.

3.2.2 Assessment of Alternative 1

Effectiveness

Under this alternative, the contaminants remain in place. The alternative does not involve the active treatment or destruction of the contaminants. Contaminant reduction would only be achieved through natural attenuation and degradation. In the long-term, this alternative could achieve a permanent solution; however, the required duration to achieve the desired cleanup goals is very long and essentially unquantifiable due to the DNAPL source. Potential exposure to contaminants is effectively reduced only if the GER is placed on the site and maintained.

Short-Term and Long-Term Reliability

This alternative would not be reliable in achieving the cleanup goals in the short-term. They might be eventually achieved via natural attenuation in the long-term. No waste management is required for this alternative. Use of the GER would achieve the remediation objective of prevention of impacted groundwater consumption on site.

Implementability

This alternative would be readily implementable as no active measures would be taken. MADEP would be required to review and approve the GER prior to implementation.

Cost

The cost (present worth value) for this alternative totals approximately $261,000. The costs include performing the annual groundwater monitoring program as an annual OM&M cost, as well as a one-time capital cost of $15,000 to place the GER on the site. The cost of the monitoring program will be $16,000 per sampling event. A detailed breakdown of the cost estimate is presented in Table 3-1.

Risk

Because the site contaminants remain, this alternative does not achieve the remedial action objective except by natural attenuation processes over an extended period of time. Because the contaminated bedrock and overburden aquifers are not currently being used for any purpose, there is no current risk to human health or the environment. Potential future risk remains, but is reduced if the GER is implemented on site.

Benefits

This alternative does not include any additional benefits other than eliminating the potential future risk from use of contaminated groundwater. Since the former GE site area is an industrial site, and will remain as such in the foreseeable future, there are no alternate productive uses and no changes in site value gained from this alternative.

Timeliness

The time necessary to achieve the remedial goals is indeterminate since this relies on natural attenuation.

Non-pecuniary Interests

This alternative will have no impacts on site aesthetics.

3.3 Evaluation of Alternative 2 – Source Containment via Grouting

3.3.1 Description of Alternative 2

This alternative includes the following:

- Installation of a grout curtain in the original source area and the current source area, with injection of grout along the preferential flow pathway
- Institutional controls
- Long-term OM&M

In this alternative, two vertical grout curtains are placed on the site to inhibit the further migration of contaminants. A lean mixture of Portland cement and water is used for the grout. In this case, one lateral curtain would be located downgradient of the original source area (Tank Farm area), the other downgradient of the current source area (well TRC-202R). In addition, grout would be injected along the identified preferential pathway in fractured bedrock that extends from the Tank Farm to well TRC-202R. These installations would extend from 150 feet bgs upward to the bedrock surface. The grout would be installed by injection along a line of injection nodes that are laterally spaced every three to four feet. Refer to Figure 3-1 "Alternative 2" for a preliminary layout of Alternative 2.

No treatment measures are taken. However, the contaminants that are presently located in the source area will be contained and/or bound into the grout matrix. This alternative does not have any active impact on contaminants that have already migrated to the overburden or to off-site areas. It does, however, immobilize and solidify the bulk mass of contamination, thereby limiting the potential for the source material to dissolve into groundwater and migrate further downgradient. This alternative relies on natural attenuation to degrade the residual chlorinated VOCs outside of the grouted zone.

In addition to the grouting, institutional controls are included in this alternative.

The implementation of this alternative is expected to achieve the following:

- Immobilize source area contamination (at least partially)
- Eliminate source area migration of contaminants
- Improve bedrock and overburden groundwater quality over the long term
- Protect human health by reducing the potential consumption of impacted groundwater on-site

3.3.2 *Assessment of Alternative 2*

- GW mounding
- GW flow go around grouted zone?

Effectiveness

Under this alternative, the contaminants remain in place but are immobilized within the grouted zone. Although the grout curtain would prevent further migration of contaminants from the source area in bedrock, the alternative does not involve the active treatment or destruction of the contaminants. Furthermore, the injection of grout could potentially displace the contaminants into other fractures, and therefore increase the potential for cross-contamination into previously unimpacted areas of the aquifer. Long-term application of this alternative could achieve a permanent solution via natural attenuation. With the lack of additional contaminant migration from the source area, the required time for natural attenuation to achieve the cleanup should be significantly reduced from that of MNA alone (i.e. Alternative 1). Potential exposure to contaminants is reduced if the GER is placed on the site and maintained.

Short-Term and Long-Term Reliability

This alternative would not be reliable in achieving the cleanup goals in the short-term, although they could eventually be achieved via natural attenuation in the long-term. The alternative does, however, have the greatest potential for an immediate positive impact by binding up contaminants and DNAPL along the length of the preferred pathway. This potential benefit is offset by the risk of spreading contamination and DNAPL during grout placement into the saturated fractures. No waste management is required for this alternative. Use of the GER would achieve the remediation objective of reducing the potential for impacted groundwater consumption.

Implementability

This alternative is readily implementable as the installation of the curtain relies on existing technologies. However, the large number of injection points and the significant depth of injection present implementation problems that may not result in a complete elimination of contaminant migration.

MADEP would be required to review and approve the GER prior to implementation.

Cost

The cost (present worth value) for this alternative totals approximately $2,125,375. The costs include performing the annual groundwater monitoring program as an annual OM&M cost as well as a one-time capital cost of $1,864,372 to install the grout curtain, and $15,000 to place the GER on the site. The cost of the monitoring program will be $16,000 per sampling event. A detailed breakdown of the cost estimate is presented in Table 3-2.

Risk

The displacement of material currently in the fractures and the development of new fractures (during grout installation) could allow the uncontrolled release and migration of impacted groundwater into previously uncontaminated areas of the bedrock aquifer. In addition, impacted groundwater could flow around the grout curtains over time as the hydraulic pressure increases. Because the impacted aquifer is not currently being used for any purpose, there is no current risk to human health or the environment. However, potential future risk remains that can be reduced if the GER is implemented.

Benefits

This alternative reduces the potential future risk from use of contaminated groundwater on site. Since the former GE site area is an industrial site, and will remain as such in the foreseeable future, there are no alternate productive uses and no changes in site value gained from this alternative.

Timeliness

The time necessary to achieve the remedial goals is indeterminate since this relies on natural attenuation. The grout curtain should allow off-site areas to achieve the cleanup goals faster than the time required for Alternative 1.

Non-pecuniary Interests

This alternative will have no impacts on site aesthetics.

3.4 Evaluation of Alternative 3 – Source Removal and Containment via Groundwater Extraction and Treatment

3.4.1 Description of Alternative 3

This alternative includes the following:

- Groundwater recovery through extraction wells
- Underground piping installation
- Ex-situ treatment of the recovered groundwater
- Institutional controls
- Long-term OM&M

Under this alternative, the existing bedrock well TRC-202R will be utilized as a recovery well. Based on pump test results, the expected flow rate of the recovered groundwater will be relatively small (< 5 gpm). The recovered groundwater will be treated aboveground. The likely treatment process will be liquid phase granular activated carbon (GAC) adsorption. If required, measures to reduce the liquid-phase GAC loading will be taken. Such measures may include air stripping, UV oxidation, or filtration. An existing treatment system building (see Figure 3-1,

"Alternative 3") will be used to house the treatment equipment. Underground piping between the recovery wells and the treatment system building will be installed as shown on Figure 3-1. The treated groundwater will be discharged into the storm sewer. An application for a National Pollutant Discharge Elimination System (NPDES) permit will be submitted to USEPA for approval to discharge the treated groundwater.

Institutional controls will be implemented to reduce the potential for consumption of the impacted groundwater on site.

The implementation of this alternative is expected to achieve the following:

- Hydraulically control the chlorinated VOC bedrock plume at the site.
- Reduce the chlorinated VOC mass at the source area.
- Improve bedrock groundwater quality in the source area.
- Improve overburden groundwater quality in the source area.
- Reduce loading of contaminants to downgradient/off-site areas, thus accelerating the attenuation process.
- Protect human health by eliminating potential consumption of impacted groundwater

3.4.2 Assessment of Alternative 3

Effectiveness

This alternative achieves partial removal and subsequent destruction of contaminants in the source area. It also reduces contaminant transport downgradient of the source area. Long-term application of this alternative would achieve a permanent solution via contaminant removal and natural attenuation. However, the duration needed to achieve the cleanup goals is substantial, and remains unquantifiable due to the DNAPL source. Potential exposure to contaminants is reduced if a GER is implemented and maintained. The effectiveness of Alternative 3 is deemed much higher than for Alternative 1 because contaminants are actively removed from the environment and the overall time to achieve the clean-up goals is expected to be considerably shortened, particularly in off-site areas.

Short-Term and Long-Term Reliability

This alternative would not be reliable in achieving the clean-up goals in the short-term, although they would be achieved eventually via contaminant removal and natural attenuation. The reliability of a groundwater extraction and treatment system to remove contaminants within the zone of influence is high, with continued performance easy to maintain from a system reliability standpoint. The greatest uncertainty is whether the withdrawal rates and mass removal can be sustained over time in the fractured flow environment. A small amount of waste, mainly in the form of spent carbon, will have to be managed.

Implementability

This alternative will be readily implementable as the remedial technology (pump and treat) is well proven and no additional deep extraction wells will be required. A new NPDES discharge permit application will be filed.

MADEP will be required to review and approve the GER prior to implementation. Overall implementability of this alternative is evaluated as high.

Cost

The cost (present worth value) for this alternative totals approximately $1,787,250. The costs include a capital cost for treatment system installation of $236,250 and an average annual OM&M cost of $100,879. The costs for this alternative include the same costs for institutional controls as presented in Alternative 1. A detailed breakdown of the cost estimate is presented in Table 3-3.

Risk

The risks posed during implementation of the alternative will be fairly low because no additional deep bedrock extraction wells will be installed (which could cause further cross-contamination of the aquifer). Because the contaminated aquifer is not currently used for any purpose, there is no current risk to human health or the environment. Potential future risk remains because the site contaminants remain in the subsurface for a long time. However, this risk is reduced if the GER is implemented on site. The overall risk of Alternative 3 is deemed lower than for Alternative 1 because contaminants are actively removed from the environment and the overall time to achieve the clean-up goals is expected to be shorter than for the Alternative 1, particularly for off-site areas.

Benefits

This alternative does not include any immediate benefits other than eliminating the potential future risk from use of contaminated groundwater on site. Since the site is an industrial site, and will remain as such in the foreseeable future, there are no alternative productive uses and no changes in site value gained from this alternative.

Timeliness

The time necessary to achieve the remedial goal is difficult to determine. However, it is likely to be considerably shorter than for Alternative 1 since contaminants are actively removed from the subsurface.

Non-pecuniary Interests

This alternative will have no impacts on site aesthetics.

3.5 Evaluation of Alternative 4 – Source Removal Via In-Situ Treatment

3.5.1 Description of Alternative 4

This alternative includes the following:

- Treatability study
- Pilot test
- Installation of injection system and wells
- Injection of amendments via the injection wells
- Institutional controls
- Long-Term OM&M

A groundwater treatability study and a pilot test will be conducted to determine the most feasible way to alter the site conditions to favor reductive de-chlorination. Possible amendments may include hydrogen reducing compounds (HRC), lactate, phosphate, or bio-augmented water. Several injection wells will be installed at the site to inject amendments into the subsurface. Care will be taken to inject amendments within the narrow target intervals in the bedrock to avoid cross-contamination. Refer to Figure 3-1 "Alternative 4" for a preliminary layout of the injection wells.

To deliver amendments, a permanent injection system may be required. However, periodic batch injections may be more cost-effective. Institutional controls will also be implemented to prevent consumption of impacted groundwater on site.

The implementation of this alternative is expected to achieve the following:

- Reduce chlorinated VOC mass at the source area.
- Improve bedrock groundwater quality in the source area
- Improve overburden groundwater quality in the source area
- Reduce loading of contaminants to downgradient/off-site areas, thus accelerating the attenuation process.
- Protect human health by reducing the potential for consumption of impacted groundwater

3.5.2 Assessment of Alternative 4

Effectiveness

This alternative achieves partial treatment of contaminants in the source area. Long-term application of this alternative could achieve a permanent solution via contaminant destruction and natural attenuation. However, this alternative is not expected to be significantly more effective than Alternative 1 due to difficulties in distributing amendments in the site bedrock. Potential exposure to contaminants is reduced if a GER is placed on the site and maintained. The effectiveness of Alternative 4 is deemed to be marginally better than Alternative 1 because contaminants are treated in-situ in the source area and the overall time to achieve the clean-up goals is shorter than for the Alternative 1.

Short-Term and Long-Term Reliability

This alternative would not be reliable in achieving the clean-up goals in the short-term, although they could eventually be achieved via contaminant destruction and natural attenuation. The reliability of Alternative 4 is highly dependent on the success in distributing the amendments throughout the impacted zone. This is a limiting factor in that there is no practical way to ensure that distribution occurs or to even measure the degree to which it has occurred.

Implementability

This alternative would be implementable. However, additional bedrock injection wells will be required and difficulties related to amendment injection may be encountered. MADEP will be required to review and approve the GER prior to implementation.

Cost

The cost (present worth value) for this alternative totals approximately $1,366,500. The costs include a capital cost for injection system installation of $302,500 and an average annual OM&M cost of $69,190. The costs for this alternative include the same costs for institutional controls as presented in Alternative 1. A detailed breakdown of the cost estimate is presented in Table 3-4.

Risk

The risks posed during implementation of the alternative will be moderate because several additional deep bedrock injection wells will be required, thereby increasing the potential of cross-contaminating portions of the aquifer (i.e. fracture zones) that were previously uncontaminated. Amendment injection is typically performed at very low pressures, thereby minimizing the risks associated with contaminant displacement. Because the contaminated bedrock and overburden aquifers are not currently used for any purpose, there is no current risk to human health or the environment. However, potential future risk remains because the site contaminants remain in the subsurface for a long time. However, this risk is reduced if the GER is implemented on-site. The overall risk of Alternative 4 is deemed slightly lower than for Alternative 1 because contaminants are actively removed from the environment and the overall time to achieve the clean-up goals is shorter than for Alternative 1.

Benefits

This alternative does not include any immediate benefits other than eliminating the potential future risk from use of contaminated groundwater. Since the site is an industrial site, and will remain as such in the foreseeable future, there are no alternative productive uses and no changes in site value gained from this alternative.

Timeliness

The time necessary to achieve the remedial goal is unquantifiable. It is anticipated to be marginally faster than that of Alternative 1 due to the control of off-site release.

Non-pecuniary Interests

This alternative will have no impacts on site aesthetics.

3.6 Evaluation of Alternative 5 – Source Removal and Control via In-situ Treatment and Groundwater Extraction and Treatment

3.6.1 Description of Alternative 5

This alternative includes the following:

- Groundwater recovery using extraction wells
- Underground piping installation
- Ex-situ treatment of the recovered groundwater
- Treatability study
- Pilot test
- Installation of injection system and wells
- Injection of amendments via the injection wells
- Institutional controls
- Long-Term OM&M

This alternative is a combination of Alternatives 3 and 4. It retains all the benefits and features of Alternative 3 and adds an in-situ bioremediation component (Alternative 4). Groundwater recovery (via pumping) is expected to increase the effectiveness of bioremediation because it will induce the amendments to move through the aquifer. The number of injection points for bioremediation will decrease compared to Alternative 4 because of the improved distribution of amendments. Refer to Figure 3-1 "Alternative 5" for a preliminary layout of Alternative 5.

The implementation of this alternative is expected to achieve the following:

- Hydraulically control the chlorinated VOC plume in bedrock at the site.
- Reduce the chlorinated VOC mass at the source area.
- Treat the chlorinated VOCs at the source area.
- Improve bedrock groundwater quality in the source area and ultimately downgradient.
- Improve overburden groundwater quality.
- Protect human health by reducing the potential for consumption of impacted groundwater

3.6.2 Assessment of Alternative 5

Effectiveness

This alternative achieves partial mass removal and in-situ treatment of contaminants in the source area. It also reduces contaminant transport downgradient of the source area. Long-term application of this alternative would achieve a permanent solution via contaminant removal, destruction, and natural attenuation. The required duration may still be over 25 years to achieve the desired clean-up goals due to the long-term DNAPL source and low migration velocities. Potential exposure to on-site contaminants is reduced only if a GER is placed on the site and maintained. The effectiveness of Alternative 5 is deemed higher than for Alternatives 3 or 4 (individually) because contaminants are both actively removed and treated in-situ and the overall time to achieve the clean-up goals is expected to be shorter than for Alternatives 3 or 4.

Short-Term and Long-Term Reliability

This alternative would not be reliable in achieving the clean-up goals in the short-term, although they would be achieved eventually via contaminant removal and natural attenuation. A small amount of waste mainly in the form of spent carbon will have to be managed. The reliability of Alternative 5 is deemed higher than for Alternatives 3 or 4 because contaminants are actively removed and treated in-situ.

Implementability

This alternative would be readily implementable as the remedial technologies are well proven and only a small number of bedrock injection wells will be required. An existing groundwater discharge permit will have to be modified. MADEP will be required to review and approve the GER prior to implementation. Overall implementability of this alternative is evaluated as high.

Cost

The cost (present worth value) for this alternative totals approximately $2,627,250. The costs include a capital cost for treatment system installation of $431,250 and an average annual OM&M cost of $142,874. The costs for this alternative include the same costs for institutional controls as presented in Alternative 1. A detailed breakdown of the cost estimate is presented in Table 3-5.

Risk

The risks posed during implementation of the alternative will be low to moderate because fewer bedrock injection wells will be necessary. Because the contaminated bedrock and overburden aquifers are not currently used for any purpose, there is no current risk to human health or the environment. However, potential future risk remains because the site contaminants remain in the subsurface for a long time. On-site risk is reduced if the GER is implemented. The overall risk of Alternative 5 is deemed lower than for Alternatives 3 and 4 because contaminants are actively removed and treated in-situ so the overall time to achieve the clean-up goals is shorter.

Benefits

This alternative does not include any immediate benefits other than eliminating the potential future risk from use of contaminated groundwater. Since the site is an industrial site, and will remain as such in the foreseeable future, there are no alternative productive uses and no changes in site value gained from this alternative.

Timeliness

The time necessary to achieve the remedial goal is difficult to determine. However, it is likely to be shorter than for Alternatives 3 and 4 since contaminants are actively removed and treated in-situ.

Non-pecuniary Interests

This alternative will have no impacts on site aesthetics.

3.7 Evaluation of Alternative 6 – Source Removal and Control and Downgradient Restoration via Groundwater Extraction and Treatment

3.7.1 Description of Alternative 6

This alternative includes the following:

- Installation of additional bedrock recovery wells downgradient of TRC-202R (in the wetlands area)
- Underground piping installation
- Treatment system installation
- Groundwater recovery
- Ex-situ treatment of the recovered groundwater
- Institutional controls
- Long-Term OM&M

Four additional recovery wells in the wetlands area and the on-site existing bedrock well TRC-202R are assumed for this alternative. For the purposes of this RAP, it is assumed that the wells will extend 120 feet bgs, comparable to the depth at well TRC-202R where the bulk mass of VOCs was encountered. Based on the earlier pump tests, it is expected that the total rate of groundwater recovery will not exceed 30 gpm. The recovered groundwater will be treated aboveground. The likely treatment process will be air stripping with liquid phase GAC adsorption for groundwater and steam regenerable GAC for vapor treatment, assuming that the additional recovery wells are installed in productive, contaminated factures. Refer to Figure 3-1 "Alternative 6" for a preliminary layout of Alternative 6.

A new treatment system building will be installed on site to house the treatment equipment. Underground piping between the recovery wells and the treatment system building will be

installed as shown on Figure 3-1. The treated groundwater will be discharged into the storm sewer. An application for an NPDES discharge permit will be filed.

Institutional controls will be implemented to prevent potential consumption of impacted groundwater.

This alternative has the following disadvantages:

- Installation will certainly disturb and/or damage the wetlands
- Drilling in bedrock can cause cross-contamination of the aquifer and increase the impacted zone
- Downgradient bedrock wells may not intercept preferential pathways (i.e. primary fractures with contamination), thereby necessitating additional drilling of borings
- Pumping downgradient may worsen plume conditions by pulling the plume in that direction

The implementation of this alternative is expected to achieve the following:

- Hydraulically control the chlorinated VOC plume in bedrock at the site
- Reduce the chlorinated VOC mass at the source area and downgradient
- Treat the chlorinated VOCs at the source area and downgradient
- Improve bedrock groundwater quality in the source area and downgradient
- Improve overburden groundwater quality in the source area and downgradient
- Protect human health by eliminating potential consumption of impacted groundwater on site

3.7.2 Assessment of Alternative 6

Effectiveness

This alternative achieves removal and subsequent destruction of contaminants in the source area, and reduces contaminant transport downgradient of the source area.

Given the complex nature of fractures in crystalline bedrock formations (i.e. random orientation and occurrence), the probability of intercepting contaminants rapidly decreases with distance from the source area. Therefore, any new extraction well located downgradient of well TRC-202R has a reduced probability of intercepting the contaminant-laden fractures. As a result, a significant number of bedrock wells may have to be installed before one intersects the impacted zone, if present. Furthermore, as stated previously, each additional attempt at drilling in bedrock will increase the potential of establishing new conduits for groundwater flow, and further cross-contaminate the aquifer system.

Long-term application of this alternative could achieve a permanent solution. However, natural attenuation may be negatively affected by downgradient pumping of the groundwater (due to oxygenation of the groundwater), and the VOC plume can be expanded (both vertically and horizontally) in the downgradient direction. Therefore, the required duration may be similar to or longer than that of Alternatives 3 and 4. Potential exposure to contaminants is reduced if a

GER is placed on the site and maintained. The effectiveness of Alternative 6 is deemed similar to Alternatives 3 and 4.

Short-Term and Long-Term Reliability

This alternative would not be reliable in achieving the clean-up goals in the short-term, although they could be achieved eventually via contaminant removal. The reliability of this alternative will be dependent on the degree of success in intersecting primary fractures that are connected back to the source area. Sustaining a significant rate of contaminant removal from the downgradient wells is also a reliability concern given that the flow and contaminant source are being cut off by the upgradient pumping. Certain amounts of waste, mainly in the form of spent carbon, will have to be managed. The reliability of Alternative 6 is deemed similar to Alternative 4.

Implementability

This alternative would be difficult to implement because additional deep extraction wells will be installed in the wetlands. Special drilling equipment and methods will be required, possibly including constructing a temporary access area into the wetlands. Approval from the local Conservation Commission would be required to install wells in the wetlands. A new groundwater NPDES discharge permit will have to be obtained. MADEP will be required to review and approve the GER prior to implementation. Overall implementability of this alternative is evaluated as low.

Cost

The cost (present worth value) for this alternative totals approximately $3,481,250. The costs include a capital cost for additional recovery wells (up to 120 feet in depth) and treatment system installation of $706,250, $15,000 for the GER, and an average annual OM&M cost of $179,448. The costs for this alternative include the same costs for institutional controls as presented in Alternative 1. A detailed breakdown of the cost estimate is presented in Table 3-6.

Risk

The risks posed during implementation of this alternative will be comparatively high because installation of deep bedrock extraction wells will be required in the wetlands. Those risks are related to actual installation of the new wells and underground utilities in the wetlands, and possible cross-contamination of the bedrock aquifer by the drilling operations. Because the contaminated bedrock and overburden aquifers are not currently used for any purpose, there is no current risk to human health or the environment. However, potential future risk remains because the site contaminants remain in the subsurface for a long period of time. Risk on site is reduced if the GER is implemented.

Benefits

This alternative does not include any additional benefits other than eliminating the potential future risk from use of contaminated groundwater. Since the site is an industrial site, and will remain as such in the foreseeable future, there are no alternative productive uses and no changes in site value gained from this alternative.

Timeliness

The time necessary to achieve the remedial goal by this alternative is difficult to determine. It could be similar to Alternatives 3 and 4, but could be shortened if the downgradient wells can sustain a significant level of contaminant removal.

Non-pecuniary Interests

This alternative will have negative impacts on site aesthetics due to the short-term disturbance of wetlands.

3.8 Evaluation of Alternative 7 – Source Removal and Control and Downgradient Restoration via Groundwater Extraction and Treatment and In-situ Treatment

3.8.1 Description of Alternative 7

This alternative includes the following:

- Installation of additional recovery bedrock wells in the wetlands area
- Treatment system installation
- Underground piping
- Groundwater extraction and ex-situ treatment.
- Groundwater treatability study
- Bioremediation pilot test
- Installation of injection system and wells
- Amendments addition
- Institutional controls
- Long-term OM&M.

This alternative is a combination of Alternatives 4 and 6. It retains all features and risks of Alternative 6 and adds an in-situ bioremediation component (Alternative 4). However, bioremediation is not expected to significantly change the overall effectiveness of this alternative compared to Alternative 6 because of the potential oxygenation of the groundwater. The implementation of this alternative is expected to achieve the following:

- Hydraulically control the chlorinated VOC plume in bedrock at the site
- Reduce the chlorinated VOC mass at the source area
- Reduce the chlorinated VOC mass downgradient from the source area
- Treat the chlorinated VOCs at the source area

- Improve bedrock groundwater quality in the source area and downgradient
- Improve overburden groundwater quality
- Protect human health by reducing the potential for consumption of impacted groundwater

3.8.2 Assessment of Alternative 7

Effectiveness

This alternative achieves partial removal and subsequent destruction of contaminants in the source area and possibly downgradient in the wetlands area. Similar to Alternative 6, the bedrock wells could result in cross-contamination within the aquifer. Long-term application of this alternative could achieve a permanent solution via contaminant removal. However, natural attenuation may be negatively affected by downgradient pumping that causes oxygenation of the groundwater. Therefore, the required duration may be similar to that of Alternatives 3 and 4. Potential exposure to on-site contaminants is reduced if a GER is placed on the site and maintained. The effectiveness of Alternative 7 is deemed similar to Alternatives 3 and 4 unless sufficient contaminant mass is removed from the downgradient wells to measurably reduce the time to achieve the cleanup goals.

Short-Term and Long-Term Reliability

This alternative would not be reliable in achieving the clean-up goals in the short-term, although they would be achieved eventually via contaminant removal and control. Certain amounts of waste, mainly in the form of spent carbon, will have to be managed. The reliability of Alternative 7 is similar to that described for Alternative 6.

Implementability

This alternative would be difficult to implement because additional deep extraction wells will be required in the wetlands. Special drilling equipment and methods will be required, possibly including constructing a temporary access area into the wetlands. Approval from the local Conservation Commission would be required to install wells in the wetlands. An application for an NPDES discharge permit will be filed. MADEP will be required to review and approve the GER prior to implementation. Overall implementability of this alternative is evaluated as low.

Cost

The cost (present worth value) for this alternative totals approximately $4,455,500. The costs include a capital cost for treatment system installation and institutional controls of $907,500 and an average annual OM&M cost of $230,791. The costs for this alternative include the same costs for institutional controls as presented in Alternative 1. A detailed breakdown of the cost estimate is presented in Table 3-7.

Risk

The risks posed during implementation of this alternative will be comparatively high because installation of additional deep bedrock extraction wells in the wetlands will be required. Those risks are related to installation of the new wells and underground utilities in the wetlands. Because the contaminated aquifer is not currently used for any purpose, there is no current risk to human health or the environment. However, potential future risk remains because the site contaminants remain in the subsurface for a long time. However, this risk is reduced if the GER is implemented.

Benefits

This alternative does not include any immediate benefits other than eliminating the potential future risk from use of contaminated groundwater. Since the site is an industrial site, and will remain as such in the foreseeable future, there are no alternative productive uses and no changes in site value gained from this alternative. There may be certain property value loss in the wetlands due to restrictions posed by underground utilities.

Timeliness

The time necessary to achieve the remedial goal by this alternative is difficult to determine. However, it is likely to be similar to Alternatives 3 and 4, but could be shortened if the downgradient wells can sustain a significant level of contaminant removal.

Non-pecuniary Interests

This alternative will have negative impacts on site aesthetics due to the short-term disturbance of the wetlands.

4.0 COMPARISON OF ALTERNATIVES AND ALTERNATIVE SELECTION

In accordance with current MCP regulations and procedures, this section provides a comparison of the alternatives evaluated in Section 3 with respect to non-cost and cost elements. Based on this comparison, an alternative is selected, and future action plans are evaluated.

4.1 Comparison of Alternatives

A summary of the comparison of the alternatives, using each of the analysis criteria used for the evaluation, is presented in Table 4-1. In addition, a numerical ranking of the alternatives is presented in Table 4-2. The criteria are ranked using "1" for the worst-case, and "5" for the best-case. Therefore, the highest total score corresponds to the more favored ("best case") alternative(s).

4.2 Selection of Remedial Alternative

Based on the comparison of the alternatives, and the associated ranking of the comparative criteria, Alternative 5 (Source Removal and Control via In-situ Treatment and Groundwater Extraction and Treatment) represents the most appropriate approach and best alternative that will meet the project objectives of:

- Source containment
- Source removal to the extent practicable
- Groundwater restoration to GW-1 standards to the extent practicable
- Prevention of human consumption of contaminated groundwater

Alternative 5 is more effective, reliable, and implementable when compared to the other alternatives. It is comparatively moderate in terms of benefits and timeliness, and will result in relatively lower overall risk.

Alternative 3 (Source Removal and Control via Groundwater Extraction and Treatment) ranks lower by only one (1) point. Therefore, this alternative would prevail in the event that the bio-augmentation treatability study of Alternative 5 indicates that enhanced biodegradation is not feasible at the site. That is, Alternative 5 (Source Removal and Control via In-situ Treatment and Groundwater Extraction and Treatment) would revert to Alternative 3 (Source Removal and Control via Groundwater Extraction) without the bio-augmentation component.

4.3 Proposed Monitoring Program

4.3.1 Objectives

The objectives of the proposed groundwater monitoring program for the site are two fold. First, at a minimum, the program should provide adequate data that will allow for an evaluation of the recovery and treatment system effectiveness. Specifically, the number and location of monitoring wells should provide adequate information regarding plume (or impacted zone) capture, as well as enhanced biodegradation (in the fractured bedrock). Second, per MADEP's

letter dated October 30, 2001, the monitoring program "...must determine if groundwater contamination from the Former GE site is migrating via deep bedrock fractures to the Town of Reading well field".

4.3.2 Contaminant Distribution and Migration Pathways

As stated previously, the release of chlorinated VOCs occurred sometime before 1975 in the former Tank Farm area directly into bedrock. Today, the associated groundwater plume extends downgradient (due east) of the source area, impacting both the overburden and bedrock portions of the aquifer. A cross sectional view of the site and the wetland area (due east of the site), with the location of monitoring wells and the most recent total VOC concentrations, is provided in Figure 4-1. This section follows the generalized direction of a buried valley (described in the *Data Evaluation and Proposed Work Plan for Groundwater Investigation and Containment, March 9, 2000*) and is parallel to the direction of groundwater flow in the overburden.

As shown on Figure 4-1, VOCs have impacted the overburden deposits in the deep, intermediate, and shallow portions of the wetland area. The contaminant plume extends due east, across the wetland area, in the direction of groundwater flow. In addition, it appears that the low levels of chlorinated VOCs found in the overburden deposits are related primarily to the lateral migration of impacted groundwater from overburden deposits and the shallower portions of the bedrock aquifer on site. Based on the data collected to date, these contaminant levels have generally decreased over time, and it appears that the plume in the overburden is slowly collapsing.

Also shown on Figure 4-1 is the location and depth of well TRC-202R. Based on data collected to date, the bulk mass flux of chlorinated VOCs is located approximately 95 to 115 feet bgs. Assuming that this mass is able to migrate laterally (due east) in the aquifer (i.e. the simplest potential flow pathway), the impacted groundwater in the deep bedrock would remain below the base of the overburden deposit within the wetland area due east of the site. This is a somewhat conservative interpretation, given that most of the fractures observed in the subsurface have moderate to high angles, and the potential for a direct lateral migration pathway is very low.

4.3.3 Program Design Considerations- Objective 1

TRC believes that the existing bedrock monitoring wells at the site, along with the proposed injection wells that will be installed for amendment addition, will provide an adequate array of groundwater monitoring wells to maintain and evaluate system effectiveness. Specifically, the well clusters EMW-11 and EMW-10, located downgradient and cross gradient of well TRC-202R, respectively, can provide adequate information to confirm the capture of contaminants and possible changes in bedrock groundwater flow patterns. Previous studies have already established that a hydraulic connection exists between some of these wells. Further, the wells are in close enough proximity to effectively monitor the impacts of pumping, yet far enough apart to effectively evaluate long-term trends in contaminant levels. Monitoring well GZA-105, located along the inferred preferential flow pathway, coupled with the additional bedrock injection wells, should provide information regarding site conditions upgradient of the extraction well TRC-202R.

Details of the groundwater monitoring program for system operations analysis will be developed as part of the Phase IV Remedy Implementation Plan (RIP). In particular, the Phase IV Plan will outline the monitoring parameters and frequency necessary for proper system operations analysis. Given the complex nature of fractured bedrock, and the possible changes that can occur under pumping conditions in bedrock aquifers, program enhancements may be needed after system start-up. This need will be evaluated as part of the Phase V OM&M efforts.

4.3.4 Program Design Considerations- Objective #2

The second objective, to develop a monitoring program capable of ascertaining whether the plume originating at the former GE site has the potential to impact the Town of Reading well-field, must be viewed from the vantage point of both the existing well-field and the potential development of new well-fields in the future. In either case, there are fundamental difficulties in predicting fracture networks and groundwater flow pathways in fractured crystalline bedrock. Not only are the fracture networks random and unpredictable, but even the discovery of primary fractures at two locations in the general direction of groundwater flow does not necessarily mean that a connection exists due to the discontinuous nature of bedrock fractures. In cases where there is a specific set of contaminant-laden fractures targeted for remediation, as is the case at the former GE site, it becomes exponentially more difficult to locate the targeted fractures the further away one goes from the source area.

To date, TRC has been able to maximize the probability of intersecting contaminant-laden fractures by relating existing contaminant distribution data, fracture trace information, rock outcrop measurements, and geophysical data, but only for areas within 300 feet of the source area at the Tank Farm. Even when various indicators point to an understanding of fracture patterns at a local scale, however, misrepresentations can occur. For example, data collected from various studies indicated the presence of a significant fracture zone extending across the southern side of the site. An attempt was made to investigate this fracture zone, but subsequent drilling efforts disproved its presence in that area.

Existing Town of Reading Well-Field: The fact that the existing Town of Reading well-field is screened in the deep overburden within the buried river valley significantly decreases the risk of contamination from the deep bedrock aquifer. In this case, because groundwater flow patterns are more predictable, strategically placed monitoring wells that are located within the overburden deposits in locations relatively close to the water supply well(s) of concern can serve as effective "sentinel wells." Such wells would provide an early warning system in the event that contaminants migrate toward and threaten the water supply system. In addition to serving as an early warning system with demonstrated reliability, wells located close to the water supply wells can detect contaminant contributions from sources other than the former GE site.

Currently, TRC maintains an overburden groundwater monitoring program (as part of the Long-Term Groundwater Monitoring Program) that includes such sentinel wells. Two of the wells (W-1 and W-2) are located immediately adjacent to one of the Town's well fields. Any impacts that may be attributed to contaminant movement through the overburden system or due to upwelling from bedrock should be captured by this system.

In addition, this network is supported by other overburden groundwater monitoring programs conducted by neighboring sites along Concord Street located to the south and southeast of the site.

Potential Future Town of Reading Well-Field: A key future concern is the Town of Reading's desire to expand its water supply to include deep bedrock wells. As a result, TRC shares MADEP's concerns of potential future impacts from deep bedrock contamination that has not been effectively characterized at off-site locations. For several reasons, however, any program that incorporates the installation of multiple wells in fractured bedrock as a primary means of locating and evaluating impacted groundwater fractures as a protection against future impacts is not recommended. These reasons include:

- A "trial and error" approach in a fractured bedrock environment is costly and has little chance of yielding meaningful results for reasons cited previously in this section.

- The newly installed wells can unintentionally establish new conduits for groundwater flow, which in turn can result in cross-contamination of the aquifer (to previously unimpacted areas), as well as complicate the flow regime. The latter could ultimately reduce the chance of isolating and containing the bulk mass of contamination along the flow pathway(s) that existed prior to any bedrock drilling effort. The potential for potentially cross-contaminating the aquifer has already been illustrated by MADEP's concern regarding well BRW-1, a bedrock well that is fully screened from the bedrock-overburden interface (approximately 40 feet bgs) down to approximately 169 feet bgs. As documented in the *Comprehensive Review of Groundwater Data*, dated September 14, 2001, there appears to be a hydraulic connection between the deepest portion of BRW-1, and the shallow portion of TRC-202R (above the impacted fracture zone). Although there appears to be no immediate threat to cross-contamination, the unexpected connection between the two wells at greatly different depths underscores the potential for problems to develop. TRC intends to close (i.e. grout) this well once all of the treatability and design studies are complete.

- The location of future productive Town of Reading wells has not yet been established, so any plan to provide an effective sentry well network is premature.

- There remains uncertainty as to whether the Town of Reading will ever develop the deep bedrock aquifer as a potable water source. Two test wells installed by the Town have produced less than 100 gpm of flow. Initial results from the test wells completed to date had no detectable VOC levels. Again, any plan for TRC to install monitoring wells targeted toward future water supply wells would be premature.

For the above reasons, TRC recommends that any decision to install deep bedrock monitoring wells at off-site locations be postponed until the results of the Town's deep well testing program are available. TRC is committed to protecting the Town of Reading's water supply wells, and will work with MADEP at an appropriate time to determine the most appropriate location and depth for a bedrock sentry well.

4.3.5 Conclusions

TRC recommends that the existing groundwater monitoring program for the site continue at this time, as we believe that it provides an effective early-warning system and will provide a reliable performance monitoring network for the proposed remedial alternative. Refinements to the monitoring program will be proposed as part of the Phase IV RIP to address the specific needs of the remediation system selected herein. In addition, TRC will work with MADEP to further evaluate the optimal location and depth of a bedrock sentry monitoring well at an appropriate time, thereby enhancing the effectiveness of a regional early warning monitoring network.

4.4 Action Plans

Based on the information contained herein, TRC recommends that a bio-augmentation treatability study be conducted at the site to evaluate the efficacy of the enhanced biodegradation component of Alternative 5. In addition, a Phase IV Remedy Implementation Plan should be prepared. The pump and treat portion of the design would be the same for both Alternatives 5 and 3 and thus this portion of the design can proceed prior to completion of the treatability study. Following completion of the treatability study, the final elements of the design phase could then be completed. Development of a specific institutional control plan could also proceed simultaneously.

4.5 Licensed Site Professional Opinion

In accordance with 310 CMR 40.0861, this report meets the requirements of a Phase III RAP. After a complete analysis of the alternatives presented, Alternative 5 was selected as being the optimal alternative to achieve the remedial action objectives and a possible Permanent Solution while being cost-effective. Additional MCP response actions will include the Phase IV RIP for the selected alternative followed by alternative implementation and operation.

Table 4-1 Comparison of Alternatives

Criteria	ALTERNATIVE 1 Monitored Natural Attenuation	ALTERNATIVE 2 Source Containment Via Grouting	ALTERNATIVE 3 Source Removal and Containment Via Groundwater Extraction and Treatment	ALTERNATIVE 4 Source Removal Via In-Situ Treatment	ALTERNATIVE 5 Source Removal and Containment Via In-Situ Treatment and Groundwater Extraction and Treatment	ALTERNATIVE 6 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment	ALTERNATIVE 7 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment and In-Situ Treatment
Effectiveness							
✓ Achieving a Permanent or Temporary Solution	Achieves a temporary solution but requires continual enforcement of GER. Could achieve a permanent solution in the long-term.	Achieves a temporary solution but requires continual enforcement of GER and/or SAM. Would achieve a permanent solution in the long-term.	May achieve a permanent solution in the long-term.	May achieve a permanent solution in the long-term. Requires a pilot study to determine effectiveness.	May achieve a permanent solution in the long-term. In-situ component requires a pilot study to determine effectiveness.	May achieve a permanent solution in the long-term.	May achieve a permanent solution in the long-term. In-situ component requires a pilot study to determine effectiveness.
✓ Reusing, Recycling, Destroying, Detoxifying, or Treating Hazardous Material	None. Contaminants remain in place.	Contaminants within grout curtain are permanently stabilized. Other contaminants remain in place.	Contaminants are removed from groundwater and treated.	Contaminants are destroyed and detoxified in-situ.	Contaminants are removed from groundwater as well as destroyed and detoxified in-situ.	Contaminants are removed from groundwater and treated.	Contaminants are removed from groundwater as well as destroyed and detoxified in-situ.
✓ Reducing Levels of Contaminants that Achieve or Approach Background	Does not reduce levels of contaminants except through natural degradation and attenuation.	Does not reduce levels of contaminants except through natural degradation and attenuation.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.
Short-Term and Long-Term Reliability							
✓ Degree of Uncertainty of Alternative Success	Success could be achieved only in the long-term.	Success would be achieved only in the long-term	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.
✓ Management of Residues or Remaining Wastes	None.	None.	Requires management of treatment residuals (e.g. carbon).	None.	Requires management of treatment residuals (e.g. carbon).	Requires management of treatment residuals (e.g. carbon).	Requires management of treatment residuals (e.g. carbon).
Implementability							
✓ Technical Complexity	No technical complexity.	Very complex.	Moderately complex.	Moderately complex.	Moderately complex.	Complex.	Complex.
✓ Integration with Existing Operations	Not applicable.	Could require relocation of utilities.	Could require temporary relocation of utilities.	Not applicable.	Could require temporary relocation of utilities.	Could require temporary relocation of utilities.	Could require temporary relocation of utilities.
✓ OM&M, or Access Requirements	Long-term groundwater monitoring required.	Long-term groundwater monitoring required.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.
✓ Availability of Services, Equipment, or Specialists	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.
✓ Availability of Off-Site TSD Facility	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Not applicable.
✓ Meets Regulatory Requirements for Permits, Approvals, or Licenses	MADEP approval of GER required.	MADEP approval of GER required.	MADEP approval of GER required. NPDES permit needed for discharge.	MADEP approval of GER required.	MADEP approval of GER required. NPDES permit needed for discharge.	MADEP approval of GER required. NPDES permit needed for discharge. Local Conservation Commission approval needed in wetlands.	MADEP approval of GER required. NPDES permit needed for discharge. Local Conservation Commission approval needed in wetlands.

Table 4-1 (Continued) Comparison of Alternatives

Criteria	ALTERNATIVE 1 Monitored Natural Attenuation	ALTERNATIVE 2 Source Containment Via Grouting	ALTERNATIVE 3 Source Removal and Containment Via Groundwater Extraction and Treatment	ALTERNATIVE 4 Source Removal Via In-Situ Treatment	ALTERNATIVE 5 Source Removal and Containment Via In-Situ Treatment and Groundwater Extraction and Treatment	ALTERNATIVE 6 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment	ALTERNATIVE 7 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment and In-Situ Treatment
Cost							
Capital Cost	$15,000	$1,879,372	$236,250	$302,500	$431,250	$721,250	$907,500
Annual O&M Cost	$16,000	$16,000	$100,879	$69,190	$142,874	$179,448	$230,791
Present Worth Cost	$261,000	$2,125,375	$1,787,250	$1,366,500	$2,627,250	$3,481,250	$4,455,500
Risk							
✓ On-Site and Off-Site Due to Implementation	Existing potential future risk remains.	Existing potential future risk remains.	Existing potential future risk remains. Increased potential for construction-related accidents. No change in site risk.	No change in site risk. Existing potential future risk remains.	No change in site risk. Existing potential future risk remains.	Moderate implementation risk from installing wells and utilities in wetland.	Moderate implementation risk from installing wells and utilities in wetland.
✓ On-Site and Off-Site Due to Operation	Not applicable.	Not applicable.	Minimal.	Minimal.	Minimal.	Minimal to moderate due to construction in wetlands.	Minimal to moderate due to construction in wetlands.
✓ Risk to Human Health and the Environment after Completion of Actions	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.
Benefits							
✓ Restoring Natural Resources	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.
✓ Site Productive Reuse	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.
✓ Avoided Cost of Relocation of People, Businesses, or Utilities	None.	None.	None.	None.	None.	None.	None.
✓ Avoided Lost Value of Site	None.	None.	None.	None.	None.	None.	None.
Timeliness							
✓ Time Required to Eliminate Uncontrolled Sources and Achieve a Level of No Significant Risk	Indeterminate.	Indeterminate, but possibly less than Alternative 1.	Indeterminate, but expected to be less than Alternatives 1.	Indeterminate, but expected to be less than Alternative 1.	Indet/erminate, but expected to be less than Alternatives 3 and 4.	Indeterminate, but expected to be less than Alternatives 3.	Indeterminate, but expected to be less than Alternatives 3 and 4.
Non-pecuniary Interests							
✓ Aesthetic Values	No impact on site aesthetics.	Minimal impact on aesthetics during implementation.	Minimal impact on aesthetics during implementation.	Minimal impact on aesthetics during implementation.	Minimal impact on aesthetics during implementation.	Negative impacts during implementation from disturbance of wetlands.	Negative impacts during implementation from disturbance of wetlands.

TABLES

Table 4-2 Comparative Ranking[1] of Remedial Alternatives
Former GE Site
50 Fordham Road
Wilmington, MA

	Alternative 1 Monitored Natural Attenuation	**Alternative 2** Source Containment via Grouting	**Alternative 3** Source removal & Containment via groundwater extraction and treatment	**Alternative 4** Source Removal via In-situ Treatment	**Alternative 5** Source Removal & Containmentvia In-situ Treatment and Groundwater Extraction	**Alternative 6** Source Removal & Containment and Downgradient Restoration via Groundwater Extraction and Treatment	**Alternative 7** Source Removal & Containment and Downgradient Restoration via Groundwater Extraction and Treatment, and In-situ Treatment
Effectiveness	1	2	3	3	4	3	4
Reliability	1	2	4	3	4	4	4
Implementabilty	5	2	5	4	5	2	2
Cost Effectiveness[2]	5	3	4	4	2	1	1
Risk	2	1	3	3	4	2	2
Benefits	3	3	3	3	3	3	3
Timeliness	1	2	3	3	4	4	4
Non-pecuniary Interests	5	5	4	4	4	3	3
Total	**23**	**20**	**29**	**27**	**30**	**22**	**23**

Notes:

[1]Ranking is based on scale of 1 ("worst case") to 5 ("best case")

[2]Based on ratio of: cost of Alternative 7 to cost of the respective alternative

Table 2-1: CLU-IN Summary of Fractured Bedrock Sites

Site	Status	Selected Remedial Technology	Contaminant	Notes	Technology Waiver
Abilene PWS	Characterization Studies (Post ROD)	Groundwater Pump and Treat	Freon/Chlor. VOCs	In-well stripping	No
Clifton, NJ	Active Remedial Phase (> 2 yrs)	In-Situ Oxidation	Chlor. VOCs	Hydrogen peroxide, iron catalyst, acid addition	No
Beale AFB	Under Construction	Groundwater Pump and Treat	BTEX, MTBE, TPH		No
Caldwell Trucking	Active Remedial Phase (> 2 yrs)	Bioremediation	Chlor. VOCs	Zero valent iron PRB, hydrofracing	No
Salisbury, NC	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat	Chlor. VOCs	Possible system replacement w/ bio method	No
Colorado DOT	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat & Bioremediation	Chlor. VOCs	MNA component (not accelerated)	No
DOE Y-12 Plant	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat & Bioremediation	Chlor. VOCs	Deep (300-500' bgs) delivery system for bioaugmentation in design phase.	No
Dallas Drycleaners	Active Remedial Phase (> 2 yrs)	In-Situ Oxidation	Chlor. VOCs	Fracturing	No
NY Facility	No Information	Flushing, In-Situ (Polymer / Water)	PCBs	Separate Polymer and Water Floods	No
Kansas City, MO	Active Remedial Phase (> 2 yrs)	Vacuum Vapor Extraction / In-Situ Oxidation	Chlor. VOCs	Chlorine dioxide	No
Chester Cty, PA	Characterization Studies (Post ROD)	Groundwater Pump and Treat	Chlor. VOCs		No
Warminster, PA	Under Construction	Groundwater Pump and Treat	Chlor. VOCs		No
Smithville PCB Site	Pre-ROD Characterization Studies	None	PCBs, Chlor. VOCs		No
PVC Mfr, NJ	Pre-ROD Characterization Studies	Fracturing	PVC, Chlor. VOCs		No
Sterling Site, MA	Active Remedial Phase (> 2 yrs)	Vacuum Vapor Extraction / Groundwater Pump and Treat	Chlor. VOCs		No
Ft. Campbell, TN	Pre-ROD Characterization Studies	Vacuum Vapor Extraction / Dual Phase / Bioremediation	Jet Fuel and Solvent		No
Ogle Cty, IL	No Information	None	BTEX		No
GE Gas Turbine, SC	No Information	None	Chlor. VOCs		No
Hoe Creek, WY	Active Remedial Phase (> 2 yrs)	Bioremediation	Coal gas	Injection zones referenced, no further info	No
Wayne, NJ	No Information	In-Situ Oxidation	Chlor. VOCs	Injection wells b/w 77-100' bgs	No
Industrial Facility, SC	Under Construction	In-Situ Oxidation	Chlor. VOCs	CleanOX process pilot test, in TI process	No
Industrial Facility, MA	Active Remedial Phase (> 2 yrs)	Vacuum Vapor Extraction / In-Situ Oxidation	Chlor. VOCs	CleanOX process bench and pilot test	No
ITT Night Vision, VA	Active Remedial Phase (> 2 yrs)	Bioremediation	Chlor. VOCs		No
Jim Dandy, CA	Active Remedial Phase (> 2 yrs)	In-Situ Oxidation	Chlor. VOCs	Ozone injection	No
LUST, ME	Active Remedial Phase (> 2 yrs)	None	BTEX, MTBE, TPH		No
LUST, ME	Active Remedial Phase (> 2 yrs)	Vacuum Vapor Extraction / Groundwater Pump and Treat	BTEX, MTBE		No
Lehigh Valley Derail	No Information	Vacuum Vapor Extraction / Groundwater Pump and Treat	Chlor. VOCs		No
Leonard Chem. Co.	Pre-ROD Characterization Studies	None	VOCs		No
Letterkenny Army Depot	Active Remedial Phase (> 2 yrs)	In-Situ Oxidation	Chlor. VOCs		No
Mallory Capacitor	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat	PCBs, Chlor. VOCs		No
Mfr, MA	Under Construction	Vaccum Vapor Extraction / In-Situ Oxidation	Chlor. VOCs	Fenton's Reagent and SVE system: 345 lbs of CVOCs in 10 weeks	No
Mfr, Australia	Active Remedial Phase (> 2 yrs)	Bioremediation	Chlor. VOCs		No
Medley Farm, SC	Active Remedial Phase (> 2 yrs)	Vacuum Vapor Extraction / Groundwater Pump and Treat / Dual Phase	Chlor. VOCs		No
Modern Landfill	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat	VOCs		No
Monroe Auto, GA	Active Remedial Phase (> 2 yrs)	In-Situ Oxidation / Groundwater Pump and Treat	Chlor. VOCs	Permanganate addition	No
NASA Dryden	Active Remedial Phase (> 2 yrs)	In-Situ Oxidation	Chlor. VOCs	Permanganate addition	No
Norden Systems, CT	No Information	None	Chlor. VOCs	Dual Phase Extraction Pilot Study	No
Parachem Southern	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat	Chlor. VOCs		No
Piedmont, SC	No Information	Groundwater Pump and Treat / Fracturing / In-Situ Vaporization / Vacuum Vapor Extraction / Dual Phase	Chlor. VOCs		No
R&D Facility, NJ	No Information	None	Chlor. VOCs		No
Rock Springs, WY	Active Remedial Phase (> 2 yrs)	Fracturing / Bioremediation	BTEX, Chlor. VOCs		No
RTI, NJ	No Information	In-Situ Oxidation	Freon, Chlor. VOCs	No details provided.	No
Pease, NH	Active Remedial Phase (> 2 yrs)	Bioremediation	Chlor. VOCs	Source containment with vertical barrier and gw extraction	Yes
Solvent Recycler, KY	Active Remedial Phase (> 2 yrs)	Vacuum Vapor Extraction	Chlor. VOCs	Interceptor trench keyed to top of bdrk to prevent discharge to stream.	No
Stewart-Hall, NY	Active Remedial Phase (> 2 yrs)	In-Situ Flushing / Fracturing / Groundwater Pump and Treat	Chlor. VOCs	Soil excavation to remove source, containment w/ pulsed gw P&T, clean-up goal at 500 ug/l	No
Gas Stn, Quantico, VA	Active Remedial Phase (> 2 yrs)	Bioremediation	BTEX		No
INEEL, ID	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat / Bioremediation	Chlor. VOCs	Natural attenuation (lab studies indicate that slow co-metabolic degradation of TCE is occurring)	No
Tetrahydrofuran Spill, MA	No Information	Groundwater Pump and Treat / Fracturing	Tetrahydrofuran		No
UST, CA	Active Remedial Phase (> 2 yrs)	Dual Phase Extraction	BTEX		No
Mfr Facility, WI	Active Remedial Phase (> 2 yrs)	Groundwater Pump and Treat / Vacuum Vapor Extraction	Chlor. VOCs		No

Table 3-1

Former GE Site, 50 Fordham Road, Wilmington, MA
Remedial Alternatives Cost Estimation

ALTERNATIVE 1: MONITORED NATURAL ATTENUATION

			Unit/Lump Cost	Annual Cost	No. of Years	Present Worth (at 5%)
Routine GW Monitoring and Institutional Controls						
Well Monitoring	12 wells (avg)	1 x year @	$300	$3,600	30	$55,000
Reporting	1 report	1 x year @	$5,000	$5,000	30	$77,000
Labor	70 hrs (avg)	1 x year @	$60	$4,200	30	$65,000
GER	1 lump sum		$15,000			$15,000
Contingency	25%			$3,200	30	$49,000
subtotal:				**$16,000**		**$261,000**

Alternative 1 Total: **$261,000**

Table 3-2

Former GE Site, 50 Fordham Road, Wilmington, MA
Remedial Alternatives Cost Estimation

ALTERNATIVE 2: SOURCE CONTAINMENT VIA GROUTING

			Unit/Lump Cost	Annual Cost	No. of Years	Present Worth (at 5%)
Routine GW Monitoring and Institutional Controls						
Well Monitoring	12 wells (avg)	1 x year @	$300	$3,600	30	$55,000
Reporting	1 report	1 x year @	$5,000	$5,000	30	$77,000
Labor	70 hrs (avg)	1 x year @	$60	$4,200	30	$65,000
GER	1 lump sum		$15,000			$15,000
Contingency	25%			$3,200	30	$49,000
subtotal:				**$16,000**		**$261,000**
Grout Curtain						
Design/engineering	1 lump sum		$10,000			$10,000
Overburden Drilling	230 points	4600 ft @	$30			$138,000
Rock Drilling	230 points	13800 ft @	$75			$1,035,000
Materials	230 points	230 pts @	$600			$138,000
Labor	230 days	10 hrs/day	$60			$138,000
Waste Disposal	130 tons	soil @	$250			$32,500
Contingency	25%					$372,875
subtotal:						**$1,864,375**
Alternative 2 Total:						**$2,125,375**

Table 3-3

Former GE Site, 50 Fordham Road, Wilmington, MA
Remedial Alternatives Cost Estimation

ALTERNATIVE 3: SOURCE REMOVAL VIA GROUNDWATER EXTRACTION AND TREATMENT

			Unit/Lump Cost	Annual Cost	No. of Years	Present Worth (at 5%)
Routine GW Monitoring and Institutional Controls						
Well Monitoring	12 wells (avg)	1 x year @	$300	$3,600	30	$55,000
Reporting	1 report	1 x year @	$5,000	$5,000	30	$77,000
Labor	70 hrs (avg)	1 x year @	$60	$4,200	30	$65,000
GER	1 lump sum		$15,000			$15,000
Contingency	25%			$3,200	30	$49,000
subtotal:				**$16,000**		**$261,000**
Pump and Treat (Source only, approximately 5 gpm)						
Design/engineering	1 lump sum		$40,000			$40,000
New wells	1 wells	150 ft @	$75			$11,250
Treatment plant	1 lump sum		$150,000			$150,000
Discharge permit	1 lump sum		$20,000			$20,000
Annual operations						
Labor	40 hrs	12 x year @	$100	$48,000	30	$738,000
Utilities	35,040 kwh/year	$0.1 per kw		$3,504	30	$54,000
Carbon (10 mg/L inlet)	2,200 lb/yr	$2.0 per lb		$4,399	30	$68,000
Analytical	1 lump sum	12 x year @	$1,000	$12,000	30	$184,000
Contingency	25%			$16,976	30	$261,000
subtotal:				**$84,879**		**$1,526,250**
Alternative 3 Total:						**$1,787,250**

Table 3-4

Former GE Site, 50 Fordham Road, Wilmington, MA
Remedial Alternatives Cost Estimation

ALTERNATIVE 4: SOURCE REMOVAL VIA IN-SITU TREATMENT

				Unit/Lump Cost	Annual Cost	No. of Years	Present Worth (at 5%)
Routine GW Monitoring and Institutional Controls							
Well Monitoring		12 wells (avg)	1 x year @	$300	$3,600	30	$55,000
Reporting		1 report	1 x year @	$5,000	$5,000	30	$77,000
Labor		70 hrs (avg)	1 x year @	$60	$4,200	30	$65,000
GER		1 lump sum		$15,000			$15,000
Contingency		25%			$3,200	30	$49,000
subtotal:					**$16,000**		**$261,000**
Souce In-situ Bio							
Treatability study, engineering		1 lump sum		$60,000			$60,000
New wells		10 wells	150 ft @	$75			$112,500
Injection Equipment		1 lump sum		$75,000			$75,000
Injection permit		1 lump sum		$40,000			$40,000
Annual operations							
	Labor	24 hrs	12 x year @	$100	$28,800	30	$443,000
	Utilities	17,520 kwh/year	$0.1 per kw		$1,752	30	$27,000
	Amendments	10 wells	12 x year @	$100	$12,000	30	$184,000
	Contingency	25%			$10,638	30	$164,000
subtotal:					**$53,190**		**$1,105,500**
Alternative 4 Total:							**$1,366,500**

Table 3-5

Former GE Site, 50 Fordham Road, Wilmington, MA
Remedial Alternatives Cost Estimation

ALTERNATIVE 5: SOURCE REMOVAL VIA IN-SITU TREATMENT AND GRONDWATER EXTRACTION AND TREATMENT

			Unit/Lump Cost	Annual Cost	No. of Years	Present Worth (at 5%)
Routine GW Monitoring and Institutional Controls						
Well Monitoring	12 wells (avg)	1 x year @	$300	$3,600	30	$55,000
Reporting	1 report	1 x year @	$5,000	$5,000	30	$77,000
Labor	70 hrs (avg)	1 x year @	$60	$4,200	30	$65,000
GER	1 lump sum		$15,000			$15,000
Contingency	25%			$3,200	30	$49,000
subtotal:				**$16,000**		**$261,000**
Pump and Treat (Source only, approximately 5 gpm) and source bio						
Bio Treatability study, engineering	1 lump sum		$60,000			$60,000
Pump & treat design/engineering	1 lump sum		$40,000			$40,000
New wells	5 wells	150 ft @	$75			$56,250
Treatment plant	1 lump sum		$200,000			$200,000
Discharge and Injection permit	1 lump sum		$60,000			$60,000
Annual operations						
Labor	64 hrs	12 x year @	$100	$76,800	30	$1,181,000
Utilities	43,800 kwh/year	$0.1 per kw		$4,380	30	$67,000
Carbon (8 mg/L inlet)	1,760 lb/yr	$2.0 per lb		$3,519	30	$54,000
Analytical	1 lump sum	12 x year @	$1,000	$12,000	30	$184,000
Amendments	5 wells	12 x year @	$100	$6,000	30	$92,000
Contingency	25%			$24,175	30	$372,000
subtotal:				**$126,874**		**$2,366,250**
Alternative 5 Total:						**$2,627,250**

Table 3-6

Former GE Site, 50 Fordham Road, Wilmington, MA
Remedial Alternatives Cost Estimation

ALTERNATIVE 6: SOURCE REMOVAL AND DOWNGRADIENT RESTORATION VIA GROUNDWATER EXTRACTION AND TREATMENT

			Unit/Lump Cost	Annual Cost	No. of Years	Present Worth (at 5%)
Routine GW Monitoring and Institutional Controls						
Well Monitoring	12 wells (avg)	1 x year @	$300	$3,600	30	$55,000
Reporting	1 report	1 x year @	$5,000	$5,000	30	$77,000
Labor	70 hrs (avg)	1 x year @	$60	$4,200	30	$65,000
GER	1 lump sum		$15,000			$15,000
Contingency	25%			$3,200	30	$49,000
subtotal:				**$16,000**		**$261,000**
Pump and Treat (Source and wetlands, approximately 25 gpm)						
Design/engineering	1 lump sum		$100,000			$100,000
New wells	5 wells	150 ft @	$75			$56,250
Treatment plant	1 lump sum		$500,000			$500,000
Discharge permit	1 lump sum		$50,000			$50,000
Annual operations						
Labor	80 hrs	12 x year @	$100	$96,000	30	$1,476,000
Utilities	87,600 kwh/year	$0.1 per kw		$8,760	30	$135,000
Carbon (5 mg/L inlet)	5,499 lb/yr	$2.0 per lb		$10,998	30	$169,000
Analytical	1 lump sum	12 x year @	$1,250	$15,000	30	$231,000
Contingency	25%			$32,690	30	$503,000
subtotal:				**$163,448**		**$3,220,250**
Alternative 6 Total:						**$3,481,250**

Table 3-7

Former GE Site, 50 Fordham Road, Wilmington, MA
Remedial Alternatives Cost Estimation

ALTERNATIVE 7: SOURCE REMOVAL AND DOWNGRADIENT RESTORATION VIA GROUNDWATER EXTRACTION AND TREATMENT AND IN-SITU TREATMENT

			Unit/Lump Cost	Annual Cost	No. of Years	Present Worth (at 5%)
Routine GW Monitoring and Institutional Controls						
Well Monitoring	12 wells (avg)	1 x year @	$300	$3,600	30	$55,000
Reporting	1 report	1 x year @	$5,000	$5,000	30	$77,000
Labor	70 hrs (avg)	1 x year @	$60	$4,200	30	$65,000
GER	1 lump sum		$15,000			$15,000
Contingency	25%			$3,200	30	$49,000
subtotal:				**$16,000**		**$261,000**
Pump and Treat (Source and wetlands, approximately 25 gpm) and Source Bio						
Bio treatability study, engineering	1 lump sum		$60,000			$60,000
Pump & treat design, engineering	1 lump sum		$100,000			$100,000
New wells	10 wells	150 ft @	$75			$112,500
Treatment plant	1 lump sum		$550,000			$550,000
Discharge and Injection permit	1 lump sum		$70,000			$70,000
Annual operations						
Labor	104 hrs	12 x year @	$100	$124,800	30	$1,918,000
Utilities	96,360 kwh/year	$0.1 per kw		$9,636	30	$148,000
Carbon (5 mg/L inlet)	8,799 lb/yr	$2.0 per lb		$17,597	30	$271,000
Analytical	1 lump sum	12 x year @	$1,250	$15,000	30	$231,000
Amendments	5 wells	12 x year @	$100	$6,000	30	$92,000
Contingency	25%			$41,758	30	$642,000
subtotal:				**$214,791**		**$4,194,500**
Alternative 7 Total:						**$4,455,500**

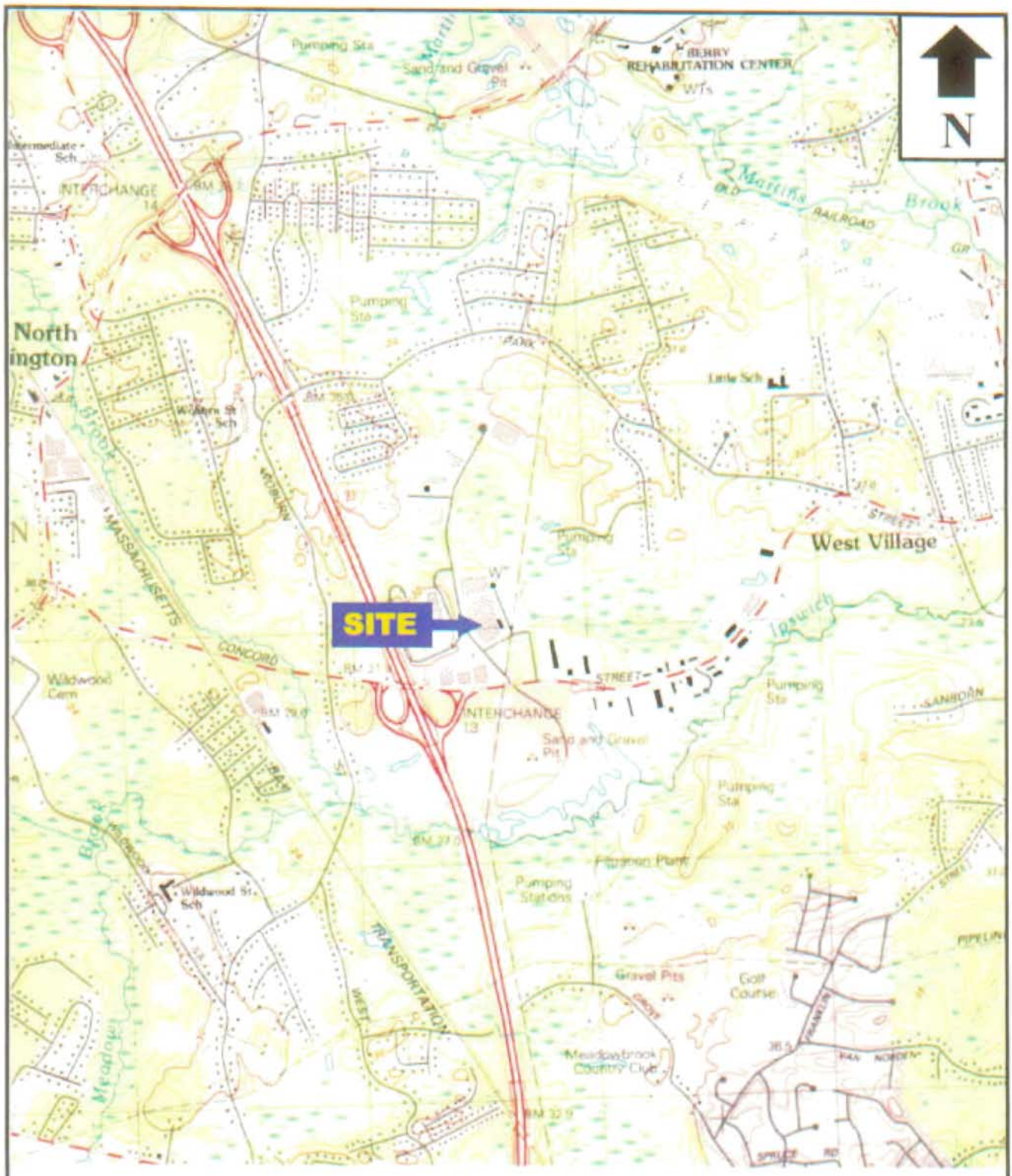
Table 4-1 Non-cost Comparison of Alternatives

Criteria	ALTERNATIVE 1 Monitored Natural Attenuation	ALTERNATIVE 2 Source Containment Via Grouting	ALTERNATIVE 3 Source Removal and Containment Via Groundwater Extraction and Treatment	ALTERNATIVE 4 Source Removal Via In-Situ Treatment	ALTERNATIVE 5 Source Removal and Containment Via In-Situ Treatment and Groundwater Extraction and Treatment	ALTERNATIVE 6 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment	ALTERNATIVE 7 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment and In-Situ Treatment
Effectiveness							
✓ Achieving a Permanent or Temporary Solution	Achieves a temporary solution but requires continual enforcement of GER. Could achieve a permanent solution in the long-term.	Achieves a temporary solution but requires continual enforcement of GER and/or SAM. Would achieve a permanent solution in the long-term.	May achieve a permanent solution in the long-term.	May achieve a permanent solution in the long-term. Requires a pilot study to determine effectiveness.	May achieve a permanent solution in the long-term. In-situ component requires a pilot study to determine effectiveness.	May achieve a permanent solution in the long-term.	May achieve a permanent solution in the long-term. In-situ component requires a pilot study to determine effectiveness.
✓ Reusing, Recycling, Destroying, Detoxifying, or Treating Hazardous Material	None. Contaminants remain in place.	Contaminants within grout curtain are permanently stabilized. Other contaminants remain in place.	Contaminants are removed from groundwater and treated.	Contaminants are destroyed and detoxified in-situ.	Contaminants are removed from groundwater as well as destroyed and detoxified in-situ.	Contaminants are removed from groundwater and treated.	Contaminants are removed from groundwater as well as destroyed and detoxified in-situ.
✓ Reducing Levels of Contaminants that Achieve or Approach Background	Does not reduce levels of contaminants except through natural degradation and attenuation.	Does not reduce levels of contaminants except through natural degradation and attenuation.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.	Could reduce levels of on-site contaminants to no significant risk level or to background in the long-term.
Short-Term and Long-Term Reliability							
✓ Degree of Uncertainty of Alternative Success	Success could be achieved only in the long-term.	Success would be achieved only in the long-term	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.	Success could be achieved only in the long-term.
✓ Management of Residues or Remaining Wastes	None.	None.	Requires management of treatment residuals (e.g. carbon).	None.	Requires management of treatment residuals (e.g. carbon).	Requires management of treatment residuals (e.g. carbon).	Requires management of treatment residuals (e.g. carbon).
Implementability							
✓ Technical Complexity	No technical complexity.	Very complex.	Moderately complex.	Moderately complex.	Moderately complex.	Complex.	Complex.
✓ Integration with Existing Operations	Not applicable.	Could require relocation of utilities.	Could require temporary relocation of utilities.	Not applicable.	Could require temporary relocation of utilities.	Could require temporary relocation of utilities.	Could require temporary relocation of utilities.
✓ OM&M, or Access Requirements	Long-term groundwater monitoring required.	Long-term groundwater monitoring required.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.	Long-term groundwater monitoring required as well as treatment system OM&M.
✓ Availability of Services, Equipment, or Specialists	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.	Readily available.
✓ Availability of Off-Site TSD Facility	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Not applicable.
✓ Meets Regulatory Requirements for Permits, Approvals, or Licenses	MADEP approval of GER required.	MADEP approval of GER required.	MADEP approval of GER required. NPDES permit needed for discharge.	MADEP approval of GER required.	MADEP approval of GER required. NPDES permit needed for discharge.	MADEP approval of GER required. NPDES permit needed for discharge. Local Conservation Commission approval needed in wetlands.	MADEP approval of GER required. NPDES permit needed for discharge. Local Conservation Commission approval needed in wetlands.

Table 4-1 (Continued) Non-cost Comparison of Alternatives

Criteria	ALTERNATIVE 1 Monitored Natural Attenuation	ALTERNATIVE 2 Source Containment Via Grouting	ALTERNATIVE 3 Source Removal and Containment Via Groundwater Extraction and Treatment	ALTERNATIVE 4 Source Removal Via In-Situ Treatment	ALTERNATIVE 5 Source Removal and Containment Via In-Situ Treatment and Groundwater Extraction and Treatment	ALTERNATIVE 6 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment	ALTERNATIVE 7 Source Removal and Containment and Downgradient Restoration Via Groundwater Extraction and Treatment and In-Situ Treatment
Cost							
Capital Cost	$15,000	$1,879,372	$236,250	$302,500	$431,250	$721,250	$907,500
Annual O&M Cost	$16,000	$16,000	$100,879	$69,190	$142,874	$179,448	$230,791
Present Worth Cost	$261,000	$2,125,375	$1,787,250	$1,366,500	$2,627,250	$3,481,250	$4,455,500
Risk							
✓ On-Site and Off-Site Due to Implementation	Existing potential future risk remains.	Existing potential future risk remains.	Existing potential future risk remains. Increased potential for construction-related accidents. No change in site risk.	No change in site risk. Existing potential future risk remains.	No change in site risk. Existing potential future risk remains.	Moderate implementation risk from installing wells and utilities in wetland.	Moderate implementation risk from installing wells and utilities in wetland.
✓ On-Site and Off-Site Due to Operation	Not applicable.	Not applicable.	Minimal.	Minimal.	Minimal.	Minimal to moderate due to construction in wetlands.	Minimal to moderate due to construction in wetlands.
✓ Risk to Human Health and the Environment after Completion of Actions	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.	No reduction in site risk except through GER until cleanup goals achieved.
Benefits							
✓ Restoring Natural Resources	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.	Drinking water aquifer not restored until contaminants attenuated below cleanup goals.
✓ Site Productive Reuse	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.	Not applicable as area to remain an industrial site.
✓ Avoided Cost of Relocation of People, Businesses, or Utilities	None.	None.	None.	None.	None.	None.	None.
✓ Avoided Lost Value of Site	None.	None.	None.	None.	None.	None.	None.
Timeliness							
✓ Time Required to Eliminate Uncontrolled Sources and Achieve a Level of No Significant Risk	Indeterminate.	Indeterminate, but possibly less than Alternative 1.	Indeterminate, but expected to be less than Alternatives 1.	Indeterminate, but expected to be less than Alternative 1.	Indet/erminate, but expected to be less than Alternatives 3 and 4.	Indeterminate, but expected to be less than Alternatives 3.	Indeterminate, but expected to be less than Alternatives 3 and 4.
Non-pecuniary Interests							
✓ Aesthetic Values	No impact on site aesthetics.	Minimal impact on aesthetics during implementation.	Minimal impact on aesthetics during implementation.	Minimal impact on aesthetics during implementation.	Minimal impact on aesthetics during implementation.	Negative impacts during implementation from disturbance of wetlands.	Negative impacts during implementation from disturbance of wetlands.

FIGURES



BASE MAP IS A PORTION OF THE FOLLOWING 7.5' x 15' USGS TOPOGRAPHIC QUADRANGLE: READING, MA 1987

0 1000 2000

Scale in Feet

QUADRANGLE LOCATION

E9202/PHASE3/TOPO

TRC
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FIGURE 1-1
SITE LOCATION MAP

Date: 2/02	Project No. E9202

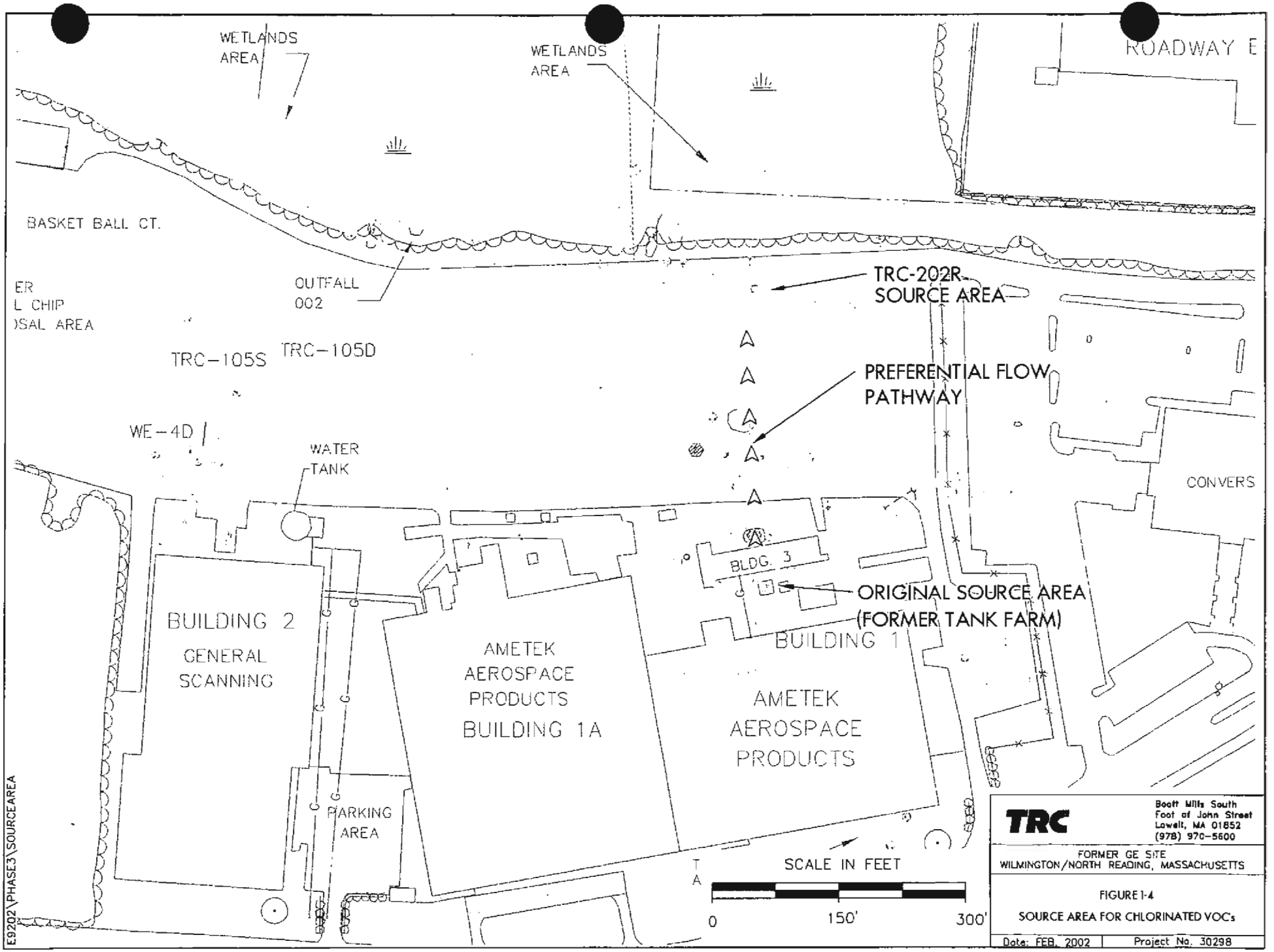
WETLANDS AREA
WETLANDS AREA
ROADWAY E
BASKET BALL CT.
OUTFALL 002
TRC-202R SOURCE AREA
TRC-105S
TRC-105D
PREFERENTIAL FLOW PATHWAY
WE-4D
WATER TANK
CONVERS
BLDG. 3
ORIGINAL SOURCE AREA (FORMER TANK FARM)
BUILDING 2
GENERAL SCANNING
AMETEK AEROSPACE PRODUCTS BUILDING 1A
BUILDING 1
AMETEK AEROSPACE PRODUCTS
PARKING AREA
SCALE IN FEET
0
150'
300'
E9202\PHASE3\SOURCEAREA
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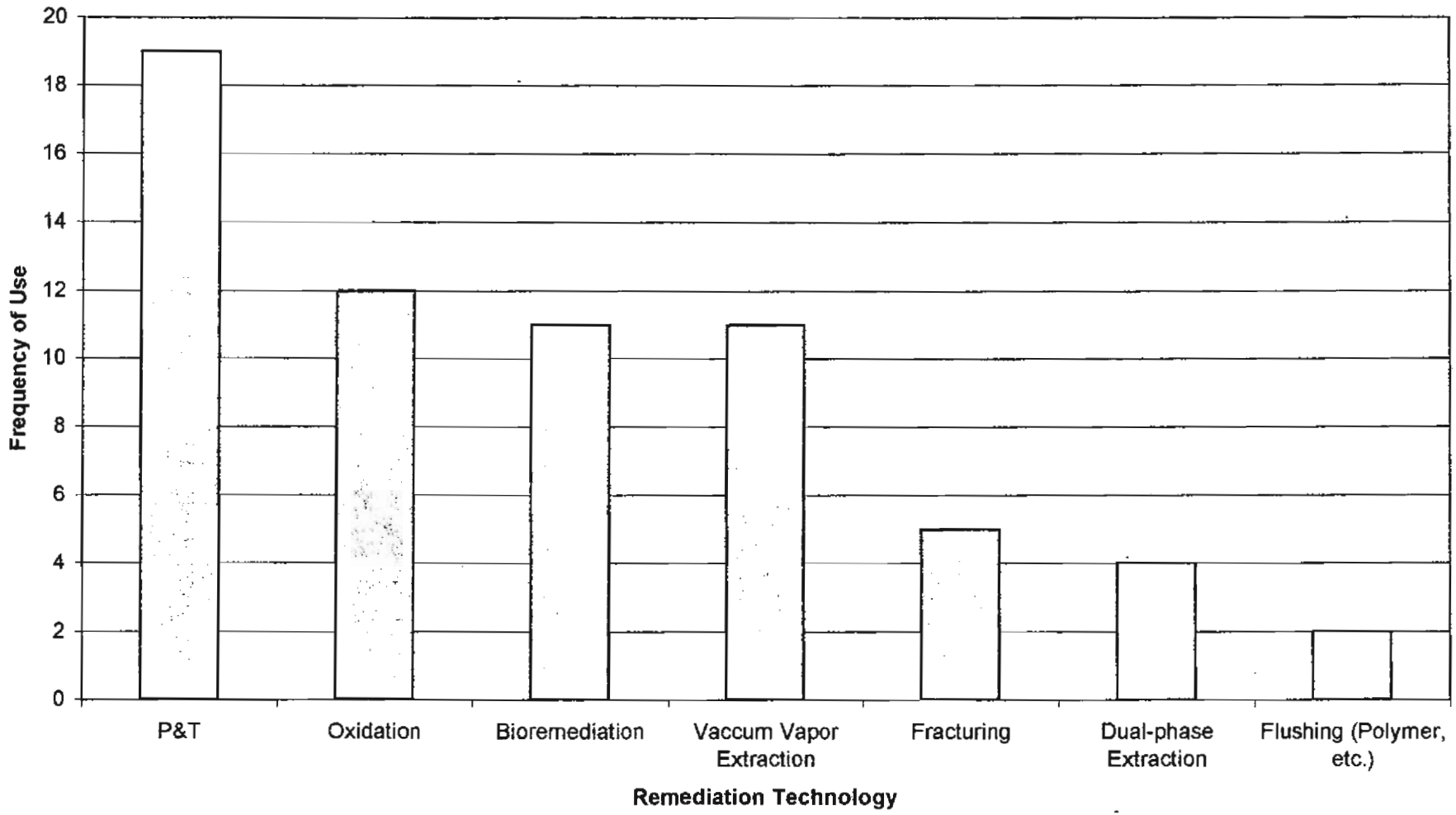
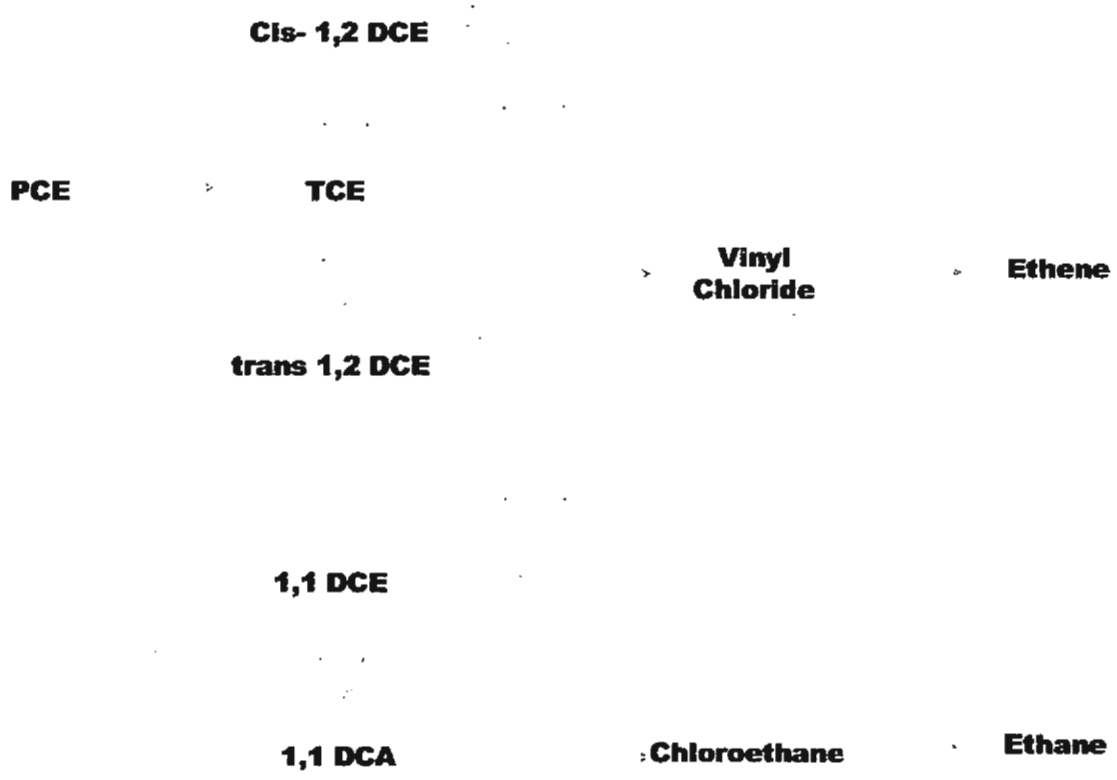
FIGURE 1-4
SOURCE AREA FOR CHLORINATED VOCs
Date: FEB. 2002
Project No. 30298

Figure 2-1
Remediation Technologies
Applied at Fractured Rock Sites
Source: CLU-IN Fractured Bedrock Focus Area





PCE- TETRACHLOROETHANE
TCE- TRICHLOROETHYLENE
DCE- DICHLOROETHYLENE
(VARIOUS FORMS INDICATED BY PREFIX)
DCA- DICHLOROETHANE

E9202\PHASE3\PATHWAYS

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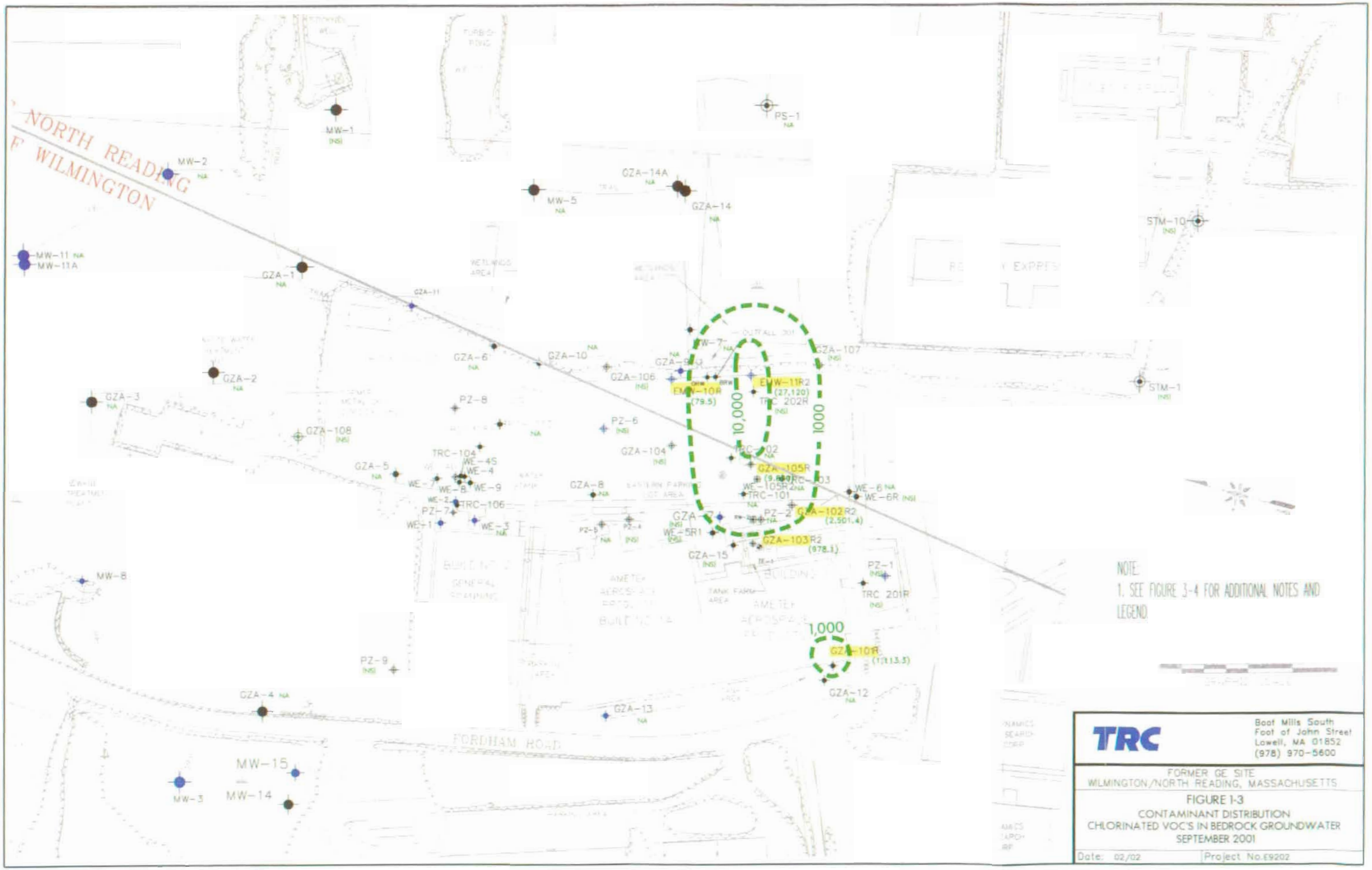
Figure 2-2
TRANSFORMATION PATHWAYS FOR VARIOUS CHLORINATED VOLATILE ORGANIC COMPOUNDS (VOC's)

Date: 2/02 | Project No. E9202



NOTE:
1. SEE FIGURE 3-4 FOR ADDITIONAL NOTES AND LEGEND.

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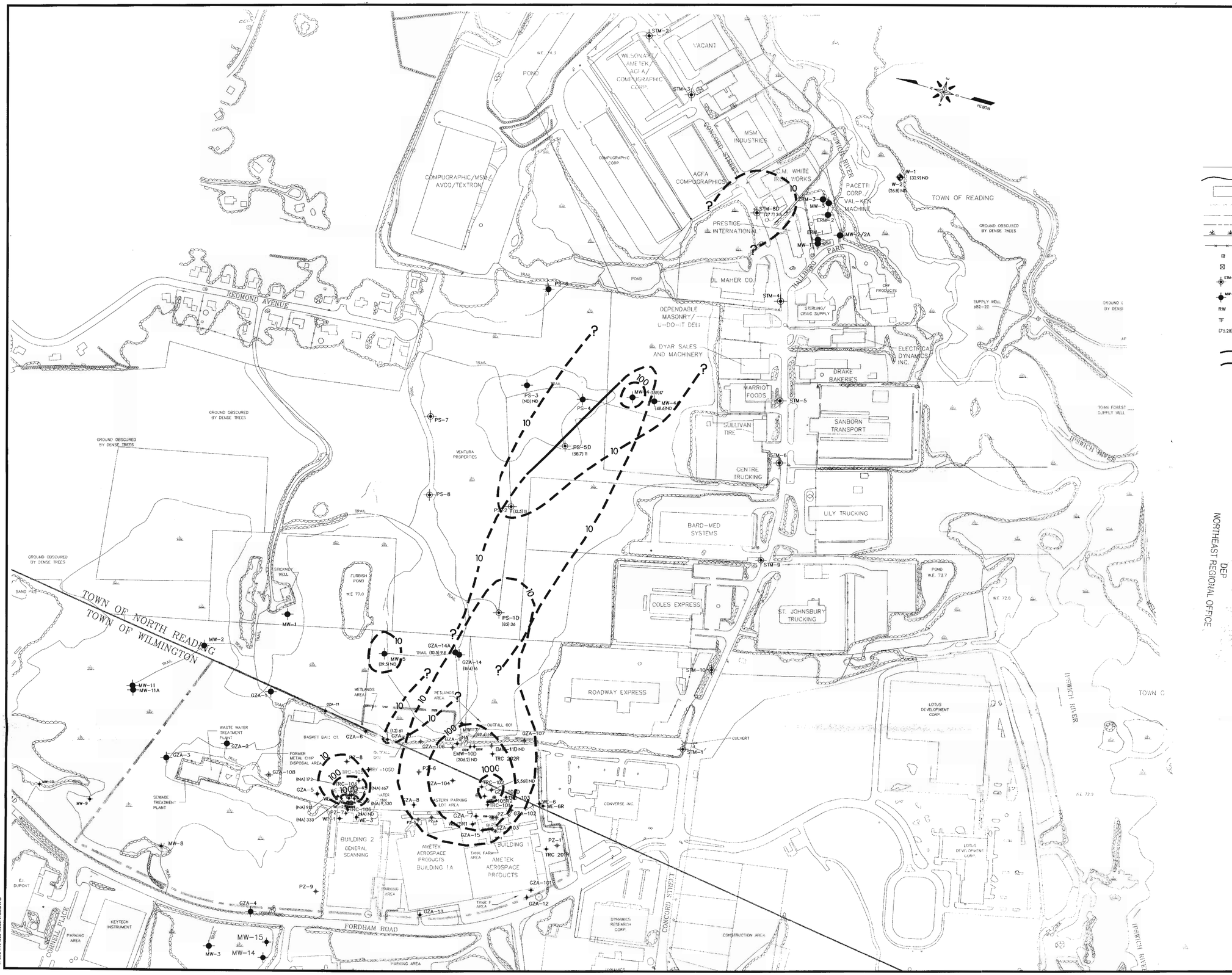
FIGURE 1-3
CONTAMINANT DISTRIBUTION
CHLORINATED VOC'S IN BEDROCK GROUNDWATER
SEPTEMBER 2001

Date: 02/02 | Project No. E9202

E9202\PHASE3\RECONTBEDROCK



LEGEND

- GROUND WATER CONTOUR
- BUILDING
- APPROXIMATE SITE PROPERTY LINE
- APPROXIMATE PROPERTY LINE
- APPROXIMATE EDGE OF WATER/STREAM
- APPROXIMATE EDGE OF WETLANDS/SWAMP
- FENCE LINE
- CATCH BASIN
- WATER SUPPLY WELL
- STM-5 — MULTI-LEVEL MONITORING WELL/PIEZOMETER LOCATION
- MW-4A — SINGLE-LEVEL MONITORING WELL/PIEZOMETER LOCATION
- RW — RECOVERY WELL
- TF — GROUNDWATER RECOVERY WELL
- (75.28) — GROUNDWATER ELEVATION, FT. ABOVE MSL
- GW-1 EXCEEDANCE
- TOTAL VOC (EXCLUDING BTEX AND MTBE COMPOUNDS)
- BTEX, MTBE AND NAPHTHALENE COMPOUNDS
- ND NOT DETECTED
- NA NOT ANALYZED
- N/A NOT APPLICABLE
- (139) TOTAL VOC CONCENTRATION IN ug/l
- 17 BTEX AND MTBE CONCENTRATION IN ug/l

NOTES

1. TOPOGRAPHIC AND PLANIMETRIC FEATURES SHOWN WERE COMPILED PHOTOGRAMMETRICALLY FROM AERIAL PHOTOGRAPHY DATED APRIL 16, 1992 BY EAST COAST MAPPING INC., CONCORD, NEW HAMPSHIRE. MAPPING GROUND CONTROL ESTABLISHED BY FIELD SURVEYS CONDUCTED IN APRIL 1992.
2. THE GRID SYSTEM DEPICTED ON THIS PLAN IS BASED ON THE MASSACHUSETTS STATE PLAN COORDINATE SYSTEM NORTH AMERICAN DATUM OF 1929.
3. ELEVATIONS ARE BASED ON THE NATIONAL GEODETIC VERTICAL DATUM OF 1929.
4. MONITORING WELL LOCATIONS ARE APPROXIMATE.
5. PROPERTY AND TOWN LINE BOUNDARIES WERE ADAPTED FROM "REGIONAL EXPLORATION PLAN, GENERAL ELECTRIC COMPANY, 50 FORDHAM ROAD PROPERTY, WILMINGTON/NORTH READING, MASS., BY GOLDBERG – ZONO & ASSOCIATES, INC., DATED APRIL 1990.

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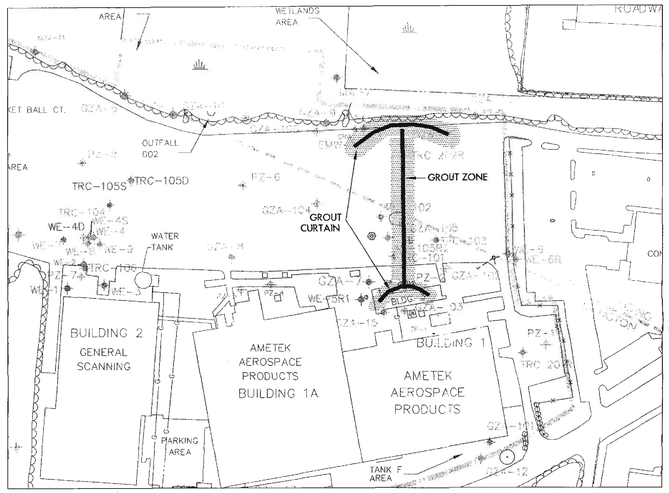
FIGURE 1-2
CONTAMINANT DISTRIBUTION IN OVERBURDEN GROUNDWATER – SEPTEMBER 2001

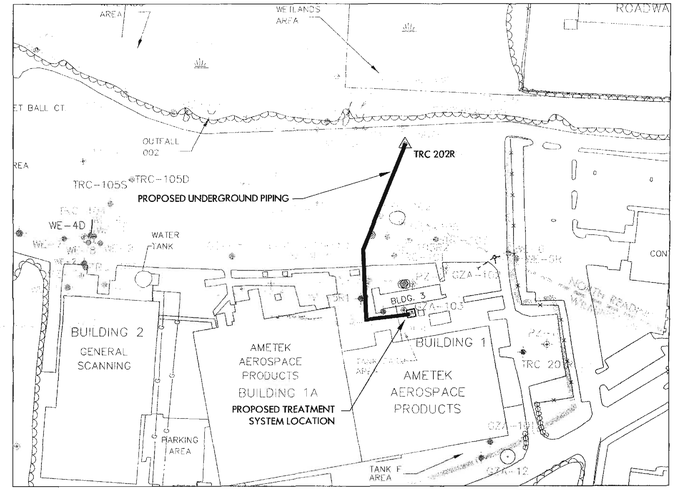
Date: 02/02 | Project No.E9202

E9202 PHASE3 RECnTFOLD.DWG



ALTERNATIVE 2

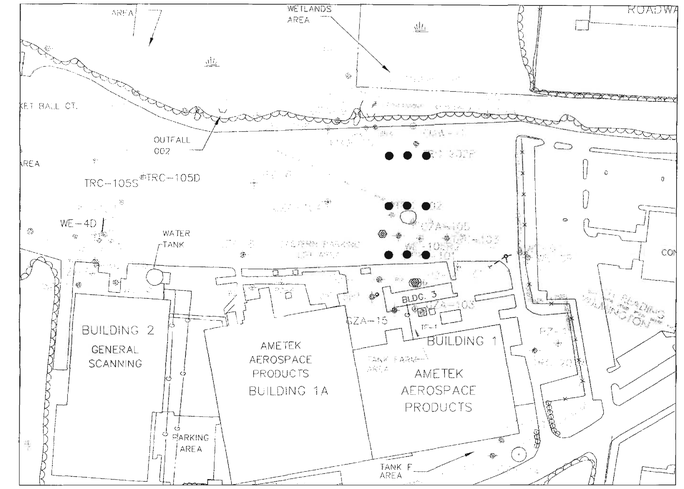
0' 75' 150' 300'
APPROXIMATE SCALE



△ RECOVERY WELL

ALTERNATIVE 3

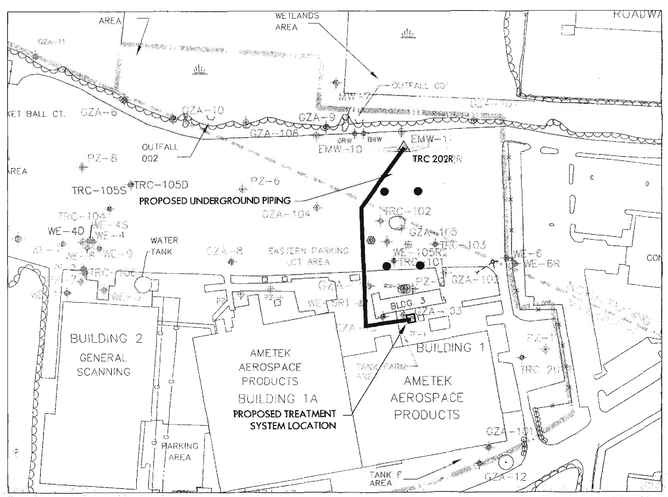
0' 75' 150' 300'
APPROXIMATE SCALE



● INJECTION POINT

ALTERNATIVE 4

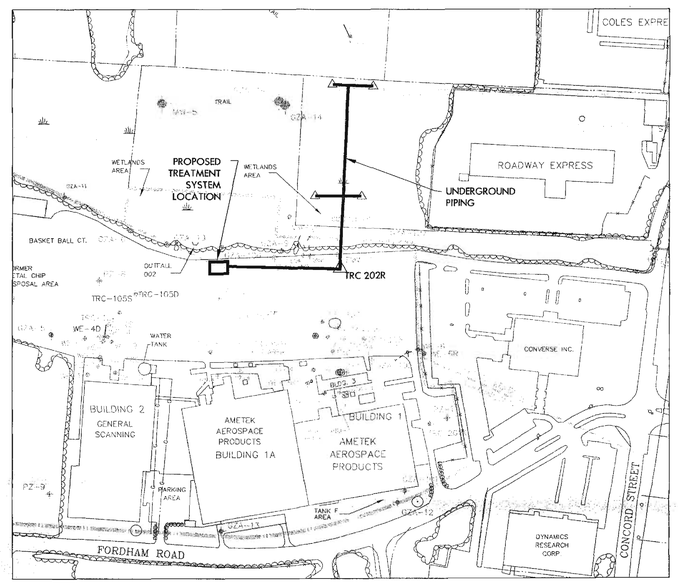
0' 75' 150' 300'
APPROXIMATE SCALE



● INJECTION POINT
△ RECOVERY WELL

ALTERNATIVE 5

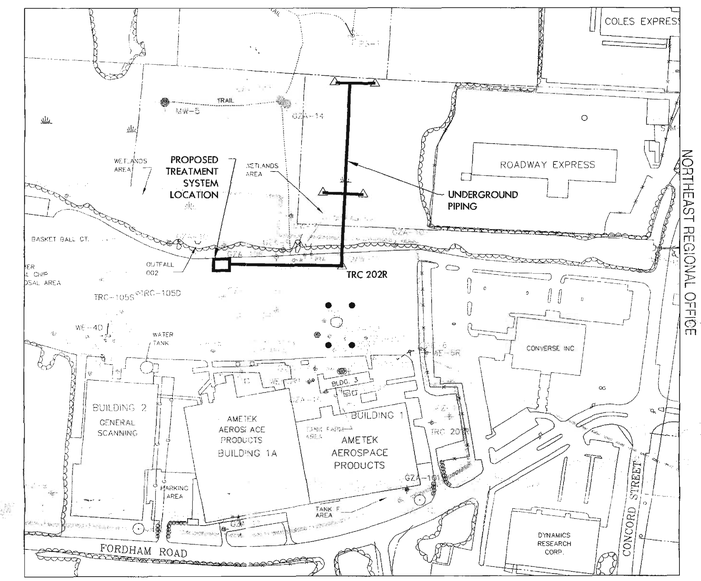
0' 75' 150' 300'
APPROXIMATE SCALE



△ RECOVERY WELL

ALTERNATIVE 6

0' 100' 200' 400'
APPROXIMATE SCALE



● INJECTION POINT
△ RECOVERY WELL

ALTERNATIVE 7

0' 100' 200' 400'
APPROXIMATE SCALE

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NOTES

1. TOPOGRAPHIC AND PLANIMETRIC FEATURES SHOWN WERE COMPILED PHOTOGRAMMETRICALLY FROM AERIAL PHOTOGRAPHY DATED APRIL 16, 1992 BY EAST COAST MAPPING INC., CONCORD, NEW HAMPSHIRE. MAPPING GROUND CONTROL ESTABLISHED BY FIELD SURVEYS CONDUCTED IN APRIL 1992.
2. THE GRID SYSTEM DEPICTED ON THIS PLAN IS BASED ON THE MASSACHUSETTS STATE PLAN COORDINATE SYSTEM NORTH AMERICAN DATUM OF 1927.
3. ELEVATIONS ARE BASED ON THE NATIONAL GEODETIC VERTICAL DATUM OF 1929.
4. MONITORING WELL LOCATIONS ARE APPROXIMATE.
5. PROPERTY AND TOWN LINE BOUNDARIES WERE ADAPTED FROM "REGIONAL EXPLORATION PLAN, GENERAL ELECTRIC COMPANY, 50 FORDHAM ROAD PROPERTY, WILMINGTON/NORTH READING, MASS., BY GOLDBERG – ZOINO & ASSOCIATES, INC., DATED APRIL 1990.

LEGEND

- BUILDING
- APPROXIMATE OFF-SITE PROPERTY LINE
- SITE PROPERTY LINE
- APPROXIMATE EDGE OF WETLANDS/SWAMP
- APPROXIMATE EDGE OF PAVEMENT
- FENCE LINE
- CATCH BASIN
- WATER SUPPLY WELL
- MULTI-LEVEL MONITORING WELL/PIEZOMETER LOCATION
- SINGLE-LEVEL MONITORING WELL/PIEZOMETER LOCATION
- RECOVERY WELL
- GROUNDWATER RECOVERY WELL

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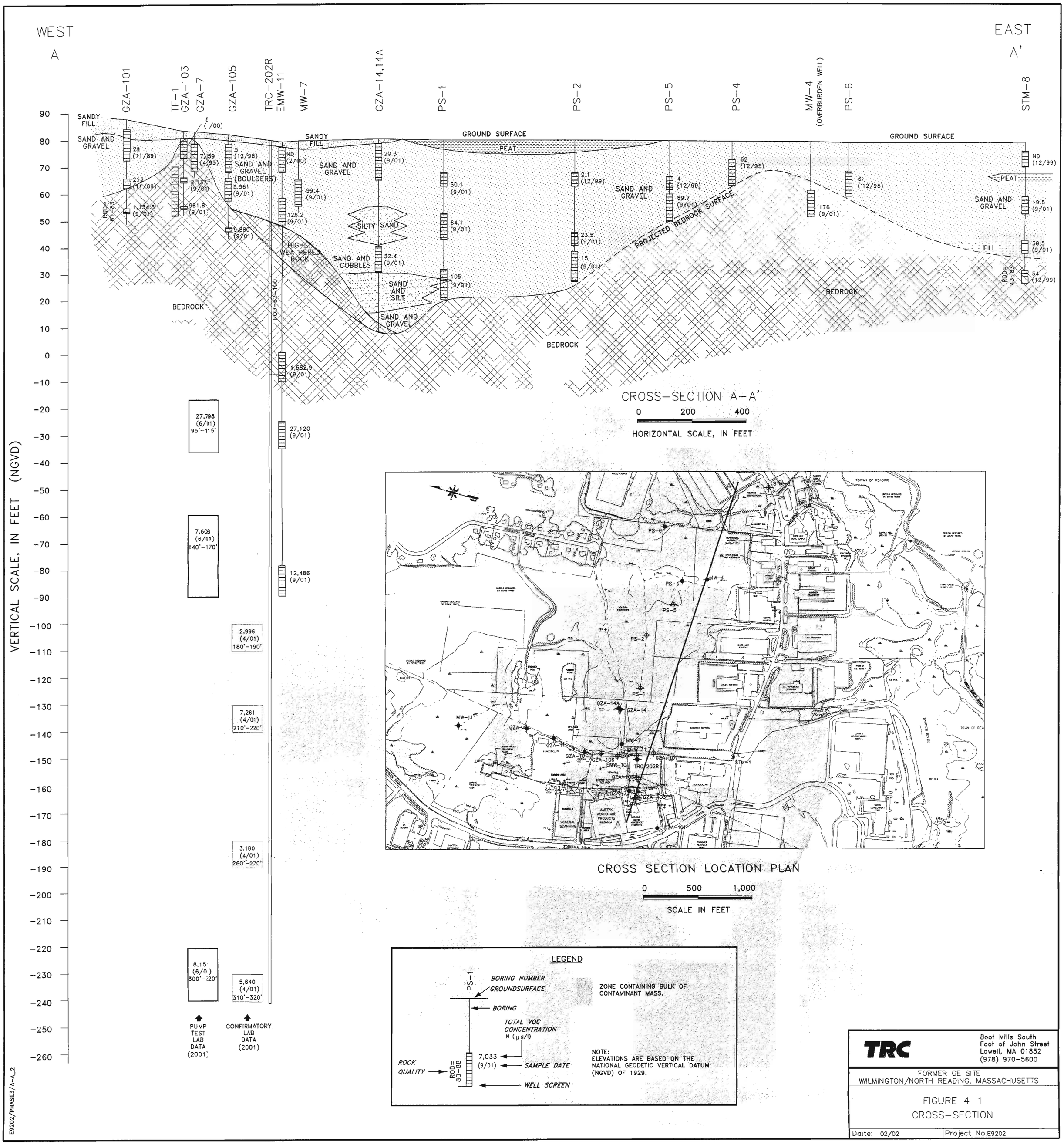
FIGURE 3-1
CONCEPTUAL LAYOUT OF REMEDIAL ALTERNATIVES

Date: 02/02 | Project No.E9202

E9202\dwg\ALTERNATIVES


WEST
A
EAST
A'
GZA-101
TF-1
GZA-103
GZA-7
GZA-105
TRC-202R
EMW-11
MW-7
GZA-14,14A
PS-1
PS-2
PS-5
PS-4
MW-4 (OVERBURDEN WELL)
PS-6
STM-8
SANDY FILL
SAND AND GRAVEL
GROUND SURFACE
PEAT
SAND AND GRAVEL (BOULDERS)
SILTY SAND
HIGHLY WEATHERED ROCK
SAND AND COBBLES
SAND AND SILT
PROJECTED BEDROCK SURFACE
TILL
BEDROCK
VERTICAL SCALE, IN FEET (NGVD)
CROSS-SECTION A-A'
0 200 400
HORIZONTAL SCALE, IN FEET
CROSS SECTION LOCATION PLAN
0 500 1,000
SCALE IN FEET
PUMP TEST LAB DATA (2001)
CONFIRMATORY LAB DATA (2001)
LEGEND
BORING NUMBER
GROUNDSURFACE
BORING
TOTAL VOC CONCENTRATION IN (µg/l)
SAMPLE DATE
WELL SCREEN
ROCK QUALITY
ZONE CONTAINING BULK OF CONTAMINANT MASS.
NOTE:
ELEVATIONS ARE BASED ON THE NATIONAL GEODETIC VERTICAL DATUM (NGVD) OF 1929.
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FORMER GE SITE
WILMINGTON/NORTH READING, MASSACHUSETTS
FIGURE 4-1
CROSS-SECTION
Date: 02/02
Project No.E9202
E9202/PHASE3/A-A_2