# KELLY AFB
# TEXAS

# ADMINISTRATIVE RECORD
# COVER SHEET

AR File Number 3270

# KELLY RESTORATION ADVISORY BOARD
# TECHNICAL REVIEW SUBCOMMITTEE
## MEETING AGENDA
### June 12, 2001, 6:30 p.m.
### Las Palmas Public Library, 515 Castroville Road

| | | | |
|---|---|---|---|
| I. | **Introduction**<br>A. Agenda Review and Handouts | **6:30 – 6:40 p.m.** | **Dr. Lene, Comm. Co-chair** |
| II. | **Presentation:**<br>**Permeable Reactive Barrier Walls** | **6:40 – 7:40 p.m.** | **Bob Mueller, ITRC** |
| III. | **Review First Draft**<br>**of Plume Maps for Public Distribution** | **7:40 – 8:15 p.m.** | **William Ryan, AFBCA** |
| IV. | **East Kelly Horizontal**<br>**Well Performance Update** | **8:15 – 8:30 p.m.** | **William Ryan, AFBCA** |
| V. | **Administrative**<br>A. BCT Update<br>B. Spill Summary Report<br>C. Documents to TRS/RAB<br>D. Action Items<br>E. Agenda/Location/Time of Next TRS Meeting | **8:30 – 8:45 p.m.** | **Dr. Lene, Comm. Co-chair** |
| VI. | **Adjournment** | **8:45 p.m.** | |

# DRAFT MEETING MINUTES

KELLLY AFB TECHNICAL REVIEW SUBCOMMITTEE (TRS)
TO THE RESTORATION ADVISORY BOARD (RAB)

12 June 2001, Las Palmas Library
515 Castroville Road
Dr. Lené TRS Chairman

Attendance
Dr. Lené, Chairman, Community Member
Mr. George Rice, Community Member
Ms. Kyle Cunningham, SAMHD
Mr. Názirite Pérez, Community Member
Mr. Scott Lampright, Community Member
Mr. William Ryan, AFBCA
Mr. Roy Botello, Community Member
Mr. Paul Person, Community Member
Mr. Nick Rodriguez
Mr. Bob Mueller, NJDEP
Ms. Vanessa Musgrave, AFBCA

**I.** **Introduction**: The meeting began at 6:42 p.m.

**II.** **Presentation on Permeable Reactive Barrier Walls**. Mr. Robert T. Mueller, NJDEP, presented information on the Interstate Technology and Regulatory Cooperation (ITRC), and technical/regulatory information on permeable reactive barriers. Several case studies outlining different environmental challenges were presented along with success rates and failures. Mr. Mueller also told members how to receive additional information on ITRC, it's resources, products and services.

Discussion:
**Q**. Mr. Scott Lampright asked about the price associated with the walls pertaining to the case studies that were presented.
A. Mr. Mueller replied that the price is determined by the wall design and that initially costs were high. However, over the years unit costs have decreased.

**Q**. Dr. Lené asked what was the iron grain size used in the walls?
**A**. Mr. Mueller replied that the grain size was similar to powder. This allowed for wider surface area coverage.

**Q**. Mr. George Rice asked if there were any types of long term permeability problems or clogging within the walls?
**A.** Mr. Mueller said the permeability of the walls could be adjusted and that site characterization and laboratory testing would alleviate those problems.

**Q**. Mr. Lampright asked if the case study examples were small compared to the Kelly plume?
**A**. Mr. Muller replied that yes these examples were small compared to the Kelly Plume. However, according to the modeling design for a plume, the design could include a number of walls to be used in conjunction with each other.

**Q**. Mr. Roy Botello, asked how the case study costs compared to other cleanup options?
**A**. Mr. Mueller said that costs were initially are high, but overall maintenance costs are low.

**Q**. Mr. Lampright asked what were the longevity of the walls?
**A**. Mr. Mueller said that longevity would be dependent on the design which would be determined by a thorough treatability study.

**Q**. Mr. George Rice asked if AFBCA was considering using these types of walls and was this technology one of the seven options presented to the public?
**A.** Mr. Ryan responded that yes, permeable barrier walls were considered in two applications for source control and plume wide treatment.

**Q**. Dr. Lené asked if the walls could be designed to withstand periods of dryness?
**A**. Mr. Mueller said that it was possible. San Antonio was not a unique situation and a similar application could have been performed elsewhere. He did not have an exact example but would forward more information to AFBCA.

**Q.** Mr. George Rice asked if there were any low limits to treatability by the walls. For example, in the case of Kelly AFB, would the walls bed able to treat below a level of 5ppb.
**A.** Mr. Mueller replied that there were not any limits regarding the treatment and yes, the walls could treat low-level contamination.

**Q.** Mr. Rice also asked if the iron in any of the walls needed to be replaced?
**A.** Mr. Mueller replied that yes the iron had to be replaced but replacement was determined by the design of the wall. Walls could be designed to treat contaminants for the life span of the plume.

**III. Review of First Draft of Plume Maps for Public Distribution.** William Ryan, AFBCA, reviewed the changes submitted by the committee members during the May TRS meeting. Members were pleased with the changes and made the additional following recommendations:

- Delete the explanation of the isoconcentration line
- Explain what realigned means, use the word transferred, and spell out acronyms such as AFBCA and GKDA. Show AFBCA's area of responsibility
- Show date of transfer from Kelly AFB to Lackland AFB
- Show the 0 and 1 ppb lines and delete the 5 ppb line (5 ppb is MCL)
- Make a note to state that estimated boundary is based on limited data
- Clarify dotted lines. The lines are confusing: both railroad tracks and plume lines use the same symbol type

- Item number six in the legend is too technical. Re-write and use an example that is more visual.
- Rewrite note number three into two statements and simplify
- Place the acronym MCL after the words Maximum Contaminant Level in the legend
- Outline council districts
- Data Sources - designate that the map is designed with 1999-2000 data and review the data sources for corrections
- List "area of AFBCA responsibility"
- Show the property that is being transferred to GKDA
- Spell-out TCE in the title
- Delete item number one in the legend
- Replace the word contours in item number three with "shaded areas"
- Review "white spots"on the map – were they intentional, and are they correct?
- In item number six, replace the last sentence to read "the shallow groundwater in this area is not used for drinking."
- Add the Kelly Public Information Line number, 925-0956, in the legend as a contact number for questions or comments.

**V. Administrative:**

A. BCT meeting update. No update.

B. Spill Report. The following reports were distributed to the members:
1. Spill of Untreated Groundwater at IRP Site S-1, KAFB
2. Release from Groundwater Bio-Augmentation Test Plot #2 near Building 360, KAFB
3. Wastewater Release at the Environmental Process Control Facility, KAFB

C. Documents delivered to RAB: ?

D. Action Items: Mr. George Rice requested a copy of the detailed notes written by Mr. John Folk Williams, facilitator, at the April TRS meeting. He asked that the notes be mailed to the committee members.

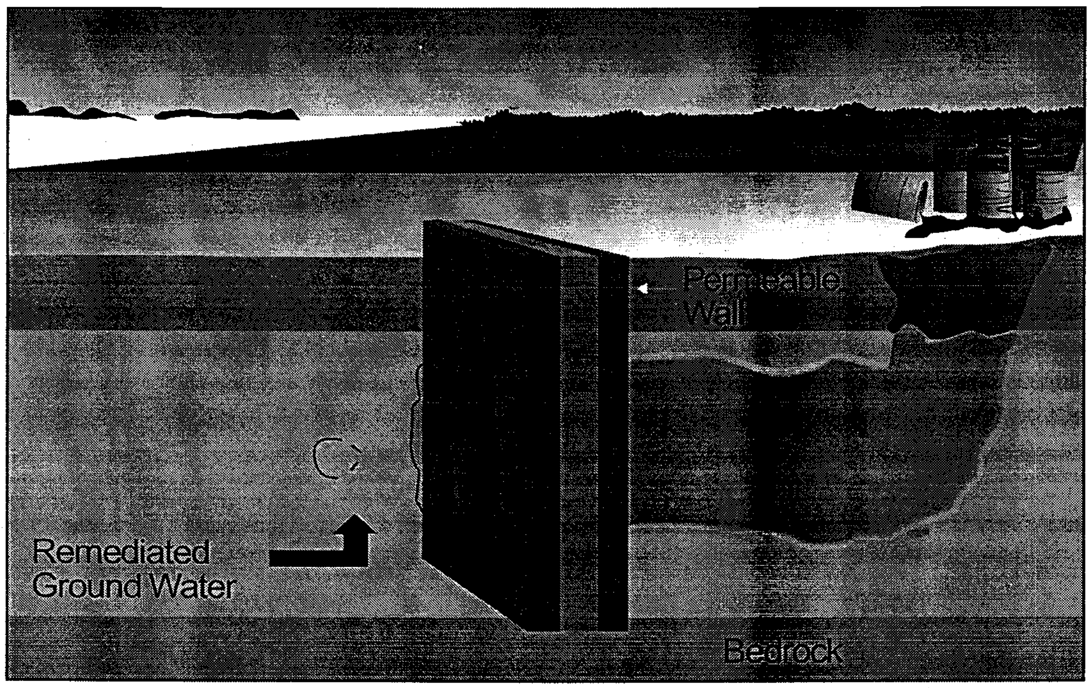
E. Agenda for Next Meeting: No items were discussed.

F. Next TRS meeting: The next TRS meeting will take place at 6:30 p.m. on August 14, 2001. Location to be determined.

**Adjournment**: The meeting adjourned at 9 p.m.

# Technical/Regulatory Guidelines

## Regulatory Guidance for Permeable Reactive Barriers Designed to Remediate Chlorinated Solvents




2nd Edition
December 1999

Prepared by
Interstate Technology and Regulatory Cooperation Work Group
Permeable Reactive Barriers Work Group

## ABOUT THE ITRC

Established in 1995, the Interstate Technology and Regulatory Cooperation Work Group (ITRC) is a state-led, national coalition of personnel from the regulatory and technology programs of more than 25 states; three federal agencies; and tribal, public, and industry stakeholders. The organization is devoted to reducing barriers and speeding interstate deployment of better, more cost-effective, innovative environmental technologies.

Various tools have been developed and services provided by the ITRC to accomplish this goal. ITRC **Technical/Regulatory Guidance** documents, each of which deals with a specific type of technology, enable faster, more thorough reviews by state agencies of permit applications and site investigation and remediation plans for full-scale deployment of such technologies. Use of these documents by states in their regulatory reviews also fosters greater consistency in technical requirements among states and results in reduced fragmentation of markets for technologies caused by differing state requirements.

Those who conduct and oversee demonstrations and verifications of technologies covered by ITRC Technical/Regulatory Guidance documents will also benefit from use of the documents. By looking ahead to the typical technical requirements for permitting/approving full-scale deployment of such technologies, they can collect and evaluate information to facilitate and smooth the permitting/regulatory approval process for deployment.

ITRC also has developed products in the categories of **Case Studies** and **Technology Overviews** (including regulatory information reports, state surveys, closure criteria documents, and formats for collection of cost and performance data); provided state input into other complementary efforts; and worked on approaches to enable state regulatory agencies to accept performance data gathered in another state as if the testing had been done in their own state.

More information about the ITRC and its available products and services can be found on the Internet at **http://www.itrcweb.org**.

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# Regulatory Guidance for Permeable Reactive Barriers Designed to Remediate Chlorinated Solvents

**2nd Edition**
**December 1999**

**Prepared by**
Interstate Technology and Regulatory Cooperation Work Group
Permeable Reactive Barriers Work Team

## ACKNOWLEDGMENTS

The members of the Interstate Technology and Regulatory Cooperation Work Group (ITRC), Permeable Reactive Barriers Work Team wish to acknowledge the individuals, organizations, and agencies that contributed to this regulatory guidance. We also wish to extend our thanks to those ITRC state representatives who took the time to review and comment on our drafts.

The Permeable Reactive Barriers Work Team effort, as part of the broader ITRC effort, is funded primarily by the United States Department of Energy. The United States Department of Defense and the United States Environmental Protection Agency have provided additional funding and support. Administrative support for grants is provided by the Environmental Research Institute of the States (ERIS), a nonprofit educational subsidiary of the Environmental Council of the States (ECOS). The Western Governors' Association (WGA) and the Southern States Energy Board (SSEB), who previously held secretariat duties for ITRC, remain involved.

The work team also wishes to recognize the individuals who were directly involved in this project, both in the initial stages of document development and the final stages of review and completion. We also wish to thank the organizations that made the expertise of these individuals available to the ITRC on this project. Appendix C lists members of the ITRC Permeable Reactive Barriers Work Team, as well as targeted reviewers, who contributed significant time and energy to this project.

The Remediation Technologies Development Forum (RTDF) provided review and consultation during many document revisions. We wish to thank the RTDF Permeable Barrier Walls Group and specifically the following individuals, who provided a significant amount of time and effort toward completion of the document:

| | |
|---|---|
| Bob Puls | U.S. Environmental Protection Agency |
| Dale Schultz | DuPont |
| Arun Gavaskar | Battelle |
| Chuck Reeter | Naval Facilities Environmental Services Command |

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## EXECUTIVE SUMMARY

The Permeable Reactive Barriers Team of the ITRC is composed of seven state regulatory agencies (New Jersey, Colorado, Florida, Massachusetts, Washington, New York, Nevada, and California) with participation from stakeholders, federal agencies, and members of the Remediation Technology Development Forum (RTDF). The Permeable Reactive Barriers Team has prepared this document to provide regulatory guidance for the implementation of permeable reactive barrier technology. The document is intended to serve as a regulatory guide for stakeholders, regulators, and technology implementors at sites where a permeable reactive barrier is being considered as a remedial alternative. The team has identified regulatory issues and recommended regulatory guidance for permeable reactive barriers wherever possible.

Because this is an evolving technology, this document is intended as a guide and should be updated periodically. Current research should always be reviewed when considering the guidelines outlined in this document. Users of this document are encouraged to study the references included in the document for further background and technical information on this technology. Recommended design guidance is contained in the reference "Design Guidance for Application of Permeable Barriers to Remediate Dissolved Chlorinated Solvents," prepared for the Air Force Armstrong Laboratory/Environics Directorate by Battelle, February 1997. The Permeable Reactive Barriers Team participated in the development of this document.

This document focuses on treating chlorinated solvents using a funnel-and-gate application, but much of the guidance provided may also be applicable to continuous permeable reactive barrier applications. In addition, there are numerous variations in media, contaminants treated, and system designs that are not covered in this document. Portions of the guidance may have some relevance to alternative systems depending upon the application. The document also addresses site characterization, bench-scale testing, modeling, and waste disposal as they pertain to permeable reactive barrier applications. Sections on permitting, monitoring, maintenance and closure criteria, stakeholder concerns, and variances are also included to address potential regulatory and technical issues during project development.

Members of the team developed the draft document. Technical and regulatory issues were discussed during conference calls and breakout sessions at ITRC meetings, and consensus was reached whenever possible. The document was distributed for peer review, and comments were received from representatives of state and federal agencies, public stakeholders, industry, consultants, and vendors. Comments were discussed, evaluated, and incorporated into the document as appropriate. This document is now under review by ITRC state agencies to determine the degree of concurrence on the technical and regulatory guidelines contained within.

The 2nd edition updates the version of this document released in December 1997.

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## APPENDICES

# REGULATORY GUIDANCE FOR PERMEABLE REACTIVE BARRIERS DESIGNED TO REMEDIATE CHLORINATED SOLVENTS

## 1.0 INTRODUCTION

As indicated by the title, this document focuses on providing regulatory guidance for permeable reactive barriers designed to remediate chlorinated solvents. Terms such as reactive barrier, funnel and gate, in situ reductive dechlorination, and metal-enhanced reductive dehalogenation have been used in the research and industrial communities to describe this technology. Although this guidance focuses on treating chlorinated solvents using a funnel-and-gate application, much of the guidance provided might also be applicable to continuous permeable reactive barrier applications. Although there are variations in media, contaminants treated, and system designs that are not covered in this document, portions of this guidance may have relevance to alternative systems depending upon the application.

The economic benefits of permeable reactive barriers have been driving the interest in the technology. At chlorinated solvent–contaminated sites, a passive technology that requires almost no annual energy or labor input (except for site monitoring) has obvious advantages over conventional groundwater treatment systems. A cost-benefit approach should be used to evaluate the economic feasibility of a permeable reactive barrier at a given site. Potential users should contact EnviroMetal Technologies, Inc. (519-824-0432), 42 Arrow Road, Guelph, Ontario Canada, 41K 1S6, the patent holder of the technology, for information regarding system installation.

Potential variations on the permeable reactive barrier technology include

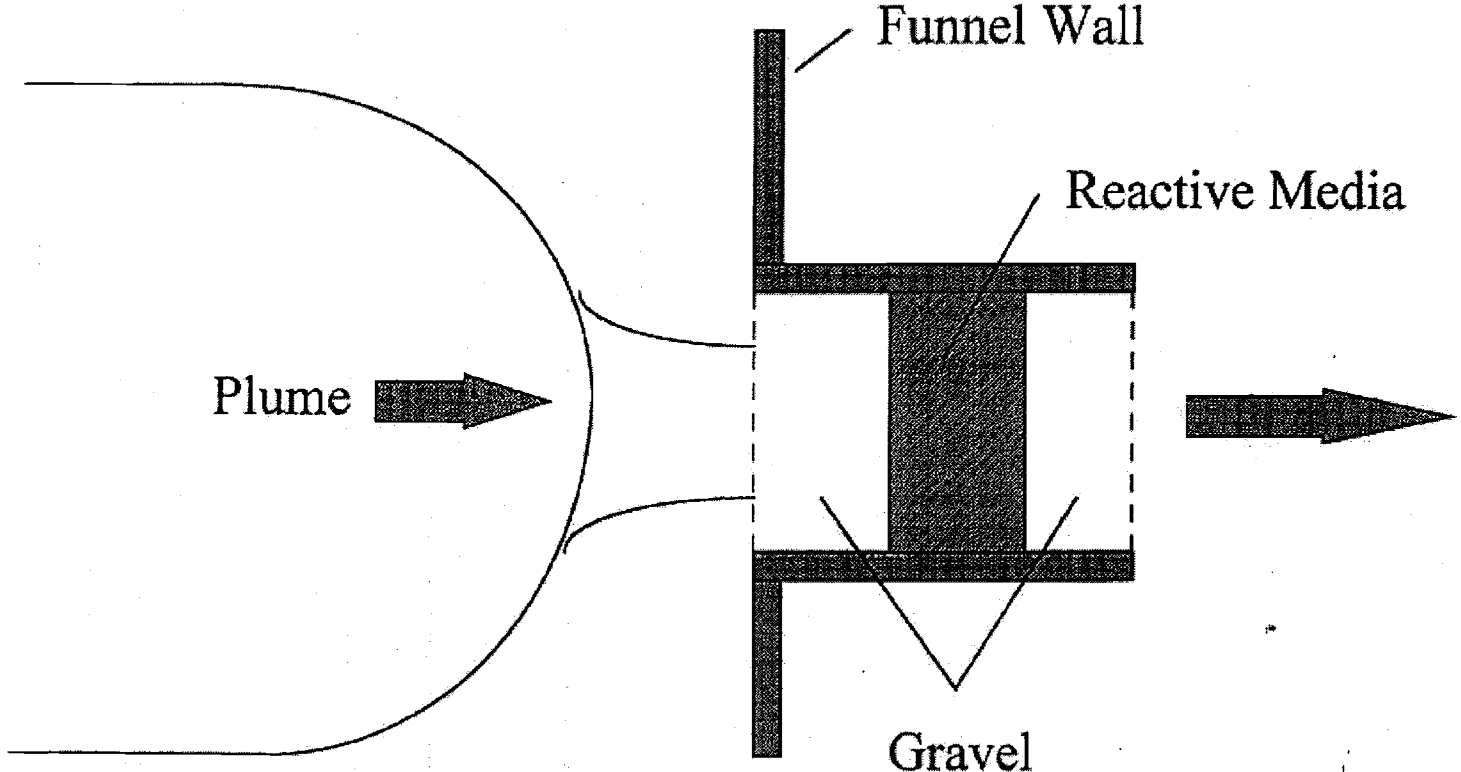
- Ex- and in-situ treatment vessels,
- Nested wells containing reactive media,
- Pressurized jetting of reactive media into aquifer sediments,
- Vertical hydrofracturing,
- Interception trenches routed to reactive media,
- Biological barriers,
- In-situ reduction of naturally occurring iron in aquifer sediments to zero-valent iron using injected reagents.

Alternative media selections include

- Bimetallic media,
- Palladized iron,
- Colloidal iron,
- Dithionite,
- Oxygen release compound.

To provide consistency, Figure 1-1 on the following page illustrates the terms used in this document.

# Figure 1-1 Permeable Reactive Barrier




Permeable Reactive Barrier refers to the entire system
In-Situ Treatment Zone (ISTZ) refers to the permeable treatment area comprised of the media and gravel
Reactive Media refers to the media (i.e., iron) portion of the ISTZ
Funnel Wall refers to the impermeable portion of the system

# 2.0 SITE CHARACTERIZATION

## 2.1 Data Requirements

The data requirements for characterization can be divided into two main categories:

1) Initial site characterization

2) Data requirements during and after emplacement of the treatment barrier

A brief description of the major data requirements for the initial phase activities is given below. Since our emphasis is on requirements for the barrier and the determination of its success as a remedial alternative, a detailed description of data needs during and after emplacement is presented in Table 2-1.

### 2.1.1 Initial Site Characterization

Measurement of presystem emplacement baseline conditions should be initiated and established such that postsystem-emplacement effects on concentrations, distributions, and aquifer levels can be determined. This should include, but is not limited to, the following information.

**Geological Data**
Site-specific geological data incorporating details on physical setting, stratigraphy, aquifer heterogeneity, structure, and sedimentology should be provided based on a survey of existing literature, remedial investigations, and feasibility studies. Site-specific data from activities such as drilling and sampling must be included to obtain essential information necessary for system design.

**Contaminant Plume(s)**
Information regarding the contaminant plume(s) and source should be provided. The nature and concentration of all contaminants, their vertical and lateral distributions, and all pertinent degradation characteristics should be included (i.e., degradation by metallic media, natural attenuation, biodegradability, etc.). Of particular relevance to permeable reactive barriers are specific areas of high concentrations and the presence of any contaminants that may not be susceptible to dechlorination, such as 1,2 dichloroethane (DCA).

**Hydrogeologic Data**
All relevant hydrogeologic and aquifer characteristics should be identified. These may include groundwater levels, temperatures, pH, flow velocity, porosity, hydraulic conductivity, site heterogeneity, depth to aquitard, and aquitard continuity, thickness, and competence. All major controlling influences on groundwater flow should be defined (e.g., bedrock, production wells, tidal and seasonal influences, surface features, infiltration). Information from aquifer tests should be synthesized into a conceptual site model.

**Geochemical Data**
Both organic and inorganic geochemical information along with groundwater chemistry should be evaluated for their potential to affect the functionality of the treatment barrier. The nature and concentrations of chlorinated solvents should be defined to select the amount and type of treatment media to be used.

**Microbiologic Data**
Microbial data may be needed on a site-specific basis. The role of microbes relative to permeable reactive barriers is currently under review. More information on microbiological data requirements will be determined through ongoing research.

2.1.2 Data Requirements during and after Placement of the Barrier

The majority of data vital to the success of the permeable reactive barrier are obtained during the remedial investigation and feasibility study. Details of data collection are included in Tables 2-1, 2-2, and 2-3. The primary objectives of data collection are to

- Evaluate performance of the reactive media in destroying chlorinated solvents relative to the laboratory bench and column testing data using samples of site-specific contaminated groundwater. (State-specific guidelines and regulations should be adhered to.)
- Define hydrogeologic characteristics of the permeable reactive barrier to determine initial and long-term performance.
- Determine constructability of the ISTZ relative to the reactive media.
- Evaluate costs associated with design, installation, operation, maintenance, and monitoring. This information can also be used for cost comparisons with other remedial technologies. The economic evaluation is crucial for CERCLA/Superfund sites in particular. The Federal Remediation Technology Roundtable offers guidance for the collection of these data.

Table 2-1 identifies activities recommended to achieve the data requirements. This table addresses the primary objectives, detailed sub-objectives, data analysis methods, and timing of the activities. Table 2-2 identifies data gathering activities to support the data requirements. This table addresses the activity, the main purpose, and the data provided.

## 2.2 Analytical Methods

EPA-approved methodologies should be employed for compliance samples. Volatile organic compounds (VOCs) in groundwater sampling can be analyzed by USEPA SW-846 (3rd Edition) Methods 8240 or 8260a, as well as USEPA Method 624. GC methods may be substituted for GC/MS methods after the identities of compounds of interest, including breakdown products, have been established. These GC methods may include USEPA SW-846 Methods 8015a, 8020a, and 8021a.

Inorganic analytes should be measured by EPA-approved methods. These methods provide valuable information on the chemistry of the local groundwater and its effects on the performance of the reactive media. State-specific protocols should be reviewed to determine whether filtered or unfiltered samples should be collected.

Table 2-3 identifies the field and laboratory parameters that should be monitored. The table addresses analyte or parameter, analysis method, sample volume, storage container, preservation method, and sample holding time.

## Table 2-1 Activities Suggested to Achieve Objectives

| Primary Objective | Detailed Sub-objective | Data Analysis Method | Timing of Activity |
|---|---|---|---|
| Evaluate performance of reactive media | Evaluate reactivity of media. Determine reaction rate and compliance with state-specific cleanup standards. Identify the potential need for alternative cleanup standards or technologies if compounds cannot be treated to compliance levels. | Batch and column experiments. | Before construction and during system operation |
| Define hydrogeologic characteristics | Evaluate impact of permeable reactive barrier on aquifer and ensure capture of contaminants. | Compare pre- and postemplacement aquifer hydrologic tests and water quality information across ISTZ and entire PRB. | Design, emplacement and system operation |
| | Hydrologic performance evaluation including contaminant degradation capability, system longevity (i.e., compaction, plugging, precipitate formation and migration, by-product formation, etc.) and subsurface characteristics. | Compare postemplacement and final aquifer hydrologic tests across the ISTZ using site investigation techniques.<br>Evaluate precipitate formation from geochemical data and modeling. | Bench-scale longevity testing, feasibility, design, and system operation |
| | Evaluate groundwater gradient. | Collection of water levels. | Before construction and during system operation |
| Determine constructability of the ISTZ* | Evaluate the ability to achieve design depth and width. | Observe, boreholes, cone penetrometer testing. | Before construction |
| | Evaluate ability to emplace reactive media without abrading, crushing, or mixing with fines from excavated and surrounding materials. | Observe.<br>Review proposed construction method. | Before and during construction |
| | Evaluate the ability of the method to control and provide QA of design parameters. | Review design package. | Before and during construction |
| | Identify operational issues in the following categories: environmental, cultural, health and safety. | Review proposed design package/construction method. | Before and during construction |
| | Identify any other construction issues and ideas for improvement. | Observe. | During construction |
| Evaluate Costs | Determination of design and installation costs. | Obtain quotes and cost estimates. | During procurement process, feasibility and design |
| | Determine any operation/maintenance and monitoring costs. | Obtain quotes and cost estimation tools. | Feasibility and design |
| | Develop information for cost comparisons with other remedies. | Obtain quotes and cost estimation tools, perform Benefit/Cost Analysis. | Feasibility and design |
| | Obtain information to document final Cost & Performance. | Federal Remediation Technology Roundtable | Throughout project |

*ISTZ (In-situ treatment zone)

**Table 2-2 Data Gathering Activities to Support Objectives**

| | Activity | Main Purpose | Data Provided |
|---|---|---|---|
| A | Up and downgradient monitoring well installation. | Hydrologic testing and characterization. Water quality monitoring. | CS delineation, lithology, water level monitoring to determine groundwater flow vectors. |
| | | Determine flow direction in and around treatment zone. | Water level measurements for sampling and tracer tests. |
| B | CS* and water quality baseline. | Establish trends and baseline dissolved phase CS concentrations in monitoring wells. | Groundwater concentration of CS, other contaminants of concern, pH, conductivity, Eh, DO, and other ions in solution (see Table 2-3). |
| C | Pre-emplacement hydrologic tests, water levels, hydraulic conductivity, transmissivity monitoring, and geologic conceptual site model. | Determine geologic properties of site prior to treatment zone installation. | Hydrologic conductivity, storativity, vertical anisotropy, transmissivity, location and geologic nature of confining unit(s). |
| D | Batch and column experiments. | Determine characteristics of reactive media. | Reactions and rates of reactions, by-products, effects on water quality, reactive media thickness, hydraulic performance, stability, cost analysis. |
| E | Modeling and measurement of the aquifer. | Determine permeable reactive barrier configuration and placement. | Prediction of plume capture and effect of system on aquifer characteristics. Transmissivity and flow determinations and predictions. |

*CS (Chlorinated Solvents)

## Table 2-3 Field and Laboratory Parameters

| Analyte or Parameter | Recommended Analysis Method[a] | Sample Volume[b] | Storage Container | Sample Preservation | Sample Holding Time |
|---|---|---|---|---|---|
| *Field Parameters* | | | | | |
| Water Level | In-hole Probe | None | None | None | None |
| pH | In-hole Probe or Flow-thru Cell | None | None | None | None |
| Groundwater Temperature | In-hole Probe | None | None | None | None |
| Redox Potential | Flow-thru Cell | None | None | None | None |
| Dissolved Oxygen | Flow-thru Cell | None | None | None | None |
| Specific Conductance | Field Instrument | None | None | None | None |
| Turbidity | Field Instrument | None | None | None | None |
| Salinity | Field Instrument | None | None | None | None |
| *Organic Analytes* | | | | | |
| Volatile Organic Compounds (VOCs)[c] | EPA 8240 | 40 mL | Glass VOA vial | 4°C, pH <2 or No pH adjust. | 14d 7d |
| | EPA 8260a (modified) | 40 mL | Glass VOA vial | 4°C, pH <2 or No pH adjust. | 14d 7d |
| | EPA 624 | 40 mL | Glass VOA vial | 4°C, pH <2 or No pH adjust. | 14d 7d |
| *Inorganic Analytes* | | | | | |
| Metals[d]: K, Na, Ca, Mg, Fe, Al, Mn, Ba | 200.7 | 100mL | Polyethylene | 4°C, pH<2, ($HNO_3$) | 180d |
| Anions: $SO_4$, Cl, Br, F | 300.0 | 100mL | Polyethylene | 4°C | 28d |
| $NO_3$ | 300.0 | 100mL | Polyethylene | 4°C | 48h |
| Alkalinity | 310.1 | 100mL | Polyethylene | 4°C | 14d |
| Other | | | | | |
| TDS | 160.2 | 100 mL | Glass, Plastic | 4°C | 7d |
| TSS | 160.1 | 100 mL | Glass, Plastic | 4°C | 7d |
| TOC | 415.1 | 40 mL | Glass | 4°C, pH <2 ($H_2SO_4$) | 28d |
| DOC | 415.1 | 40 mL | Glass | 4°C, pH <2 ($H_2SO_4$) | 28d |

d - days h - hours
[a] - If <1.0 mg/L, use photometric field kit for analysis.
[b] - See Section 6.4 of this report, "Sampling," for variances in sample volumes.
[c] - GC methods may be substituted once identity of compounds and breakdown products are verified.
[d] - Other metal analytes that are characteristic of the media should be included.

**For a list of applicable acronyms and abbreviations, see Appendix A.**

## 2.3 QA / QC

During site characterization and monitoring, state-specific groundwater quality objectives should be identified and used to determine the appropriate analytical methods based upon the goals and cleanup standards applicable to the site. All QA/QC required by the analytical method should be completed. At a minimum, lab QA/QC summary documentation (including nonconformance summary report and chain of custody) should be submitted with analytical results. QA/QC deliverables as specified by the analytical method should be maintained and made available upon request for at least three years. QA/QC requirements and reporting requirements should be determined by project-specific data quality objectives. Ultimate responsibility for QA/QC documentation belongs with the responsible party of a site or the vendor conducting a demonstration. However, the responsible party may contract with another entity, such as an analytical laboratory, to house the actual QA/QC data. In addition, all state-specific reporting requirements should be adhered to.

QA/QC may also be applied to the construction of permeable and impermeable barriers. Construction activities may consist of the following items:

- Impermeable barrier placement,
- Placement and sealing of sheet pilings,
- Trenching and slurry placement,
- Mixture of slurry and backfill,
- Submittal of as-built diagrams.

Additional considerations and guidance for various types of barriers can be found in Battelle's "Design Guidance for Application of Permeable Barriers to Remediate Dissolved Chlorinated Solvents" (Battelle, 1997).

## 2.4 Waste Disposal

During the investigation of the site, investigation-derived waste may be generated. Any contaminated soil should be classified in accordance with state and federal Hazardous Waste Regulations prior to disposal. The classification of the soil will determine the disposal method. State-specific requirements should be followed for sample parameters and frequency to ensure the soil is properly classified prior to disposal. In cases where the generated soil is classified as hazardous, state and/or federal waste regulations will dictate the disposal method. State-specific requirements may also regulate the disposal of nonhazardous waste if the material is contaminated.

Water may be generated during well installation and sampling. Any contaminated water should be disposed of in accordance with state-specific requirements. Several options may apply; water can be disposed of at a permitted off-site commercial facility, a publicly owned treatment works, or on site in accordance with NPDES regulations.

## 3.0 BENCH-SCALE TESTING FOR PERMEABLE REACTIVE BARRIER DESIGN

Following site characterization, bench-scale treatability testing is usually performed to aid in permeable reactive barrier design. The primary objective of bench-scale testing is to estimate the half-life of the degradation reaction. Other objectives of bench-scale testing include

- Screening and selecting a suitable reactive media (iron, zeolites, etc.) for the ISTZ,
- Determining the flowthrough thickness of the ISTZ,
- Determining byproduct and water quality issues,
- Estimating costs,
- Determining potential precipitation/plugging of reactive media.

Bench-scale tests can be conducted in batch or column (continuous) mode. Batch testing can be useful as an initial screening tool to evaluate half-lives, different reactive media, and degradation of recalcitrant contaminants.

Column testing provides more reliable reaction rate parameters than batch testing. Column testing provides information from dynamic flow conditions. Sampling ports placed along the column provide more information on changing contaminant and inorganic concentrations over distance than can be determined by batch sampling. High groundwater velocities may require use of longer columns or multiple columns in series.

Various types of water can be used for bench-scale testing:
- Deionized water spiked with contaminants of concern,
- Clean groundwater from the site spiked with contaminant(s) of concern,
- Contaminated groundwater from the site.

Groundwater from the site (clean or contaminated) should be used during bench-scale tests so that water chemistry effects on the treatment media can be evaluated. If clean water from the site is used, ensure the general water chemistry is similar to that of the targeted contaminated water.

## 4.0 MODELING

### 4.1 Conceptual Site Model

The conceptual site model is developed based on site-specific and modeling data and should depict site conditions (e.g., contaminant migration pathways, subsurface geology, groundwater flow, etc.). The conceptual site model should be updated as data is collected and the hydrogeologic models are refined. Regardless of the type of model selected, a conceptual model of the aquifer will need to be developed. Information useful in developing the site conceptual model includes
- Sketches, cross sections, and block diagrams,
- Flow nets in map view and cross-section,
- Aquifer geometry and distribution of geologic materials both laterally and vertically,
- Nature of the underlying bedrock,

- Description of lateral aquifer boundaries,
- Discussion of major withdrawals or recharge to the aquifer,
- Leakage from overlying bodies of water, wetlands, or underlying aquifers,
- The nature of any confining units that might be present,
- The gaining or losing nature of any streams or rivers within or adjacent to the aquifer,
- Horizontal and vertical hydraulic gradients,
- Hydraulic conductivity and storativity of the different geologic materials in the aquifer,
- Distribution of natural recharge across the aquifer,
- Data presentation and analysis of redox potential, alkalinity, and other geochemical parameters that could affect performance.

The more complex the site, the greater the level of effort required to evaluate the hydrogeology and the more detailed the conceptual model becomes.

### 4.2 Hydrogeologic Models

Hydrogeologic models include groundwater flow, contaminant transport, and geochemistry models. Hydrogeologic modeling is used to aid in designing the permeable reactive barrier and in developing a conceptual site model. As data is collected and incorporated, the conceptual site model becomes more refined.

Hydrogeologic modeling is necessary for the following reasons:

- Determine an approximate location and configuration of the permeable reactive barrier with respect to groundwater flow, plume movement, and flow velocity through the ISTZ,
- Determine the dimensions of the permeable reactive barrier and ISTZ,
- Estimate hydraulic capture zone,
- Determine location and sample frequency of monitoring wells,
- Evaluate the hydraulic effects of potential losses in porosity, flow bypass, underflow, overflow, or flow across aquifers.

A number of hydrogeologic models are available commercially[1]. Some states may have specific requirements to use a particular model. Flow and transport models range from simple 2-D models to more complex 3-D models. Model selection should be based on site-specific information and established project objectives. The model must be capable of solving for transport and transformation processes found at the site. At some sites, the processes may be relatively simple and a basic model will provide adequate results. Complex sites may require a more complex model.

Qualitative geochemical calculations and geochemical modeling can be used to evaluate potential precipitation impacts to the reactive media. Geochemical modeling attempts to interpret and predict groundwater chemistry based on assumed chemical reactions. Geochemical methods can be used to

[1]Examples include MODFLOW (McDonald and Harbaugh, 1988), MODPATH (Pollock, 1989), FLONET (Guiguer et al, 1992) and FLOWPATH (Waterloo Hydrogeologic, Inc., 1996). Examples of Geochemical models include EQ3, PHREEQE, and PHREEQC.

evaluate pH and alkalinity changes from installation of the permeable reactive barrier treatment media that could lead to calcium and magnesium carbonate precipitation. In the absence of geochemical modeling, arithmetic comparisons of calcium and magnesium before and after the reactive media can provide information on potential reactions.

Modeling requires an in-depth understanding of groundwater flow and begins with collection of comprehensive data on the aquifer being studied. If aquifer data is limited and does not contain significant information with which to compare and verify the response of a model, it may lead to erroneous conclusions. With larger sites, the model should be periodically updated as new field data is obtained. The primary objective of hydrogeologic modeling is to simulate site-specific processes with a high degree of confidence using an adequate number of representative data points.

Modeling results should reflect conditions provided from the actual monitoring results at the site. Whenever a model is used, it is important to ensure that the model is calibrated and continually validated.

Calibration is an iterative process of adjusting model parameters (i.e., hydraulic conductivity, transmissivity, dispersivity, and contaminant concentrations) so the model adequately approximates the groundwater system. The model parameters should be compared to the field data. Ultimately, the ability of the model to simulate the real system is based on the quality and quantity of site-specific data provided.

Validation is the process of comparing the calibrated model to an independent data set for the groundwater regime. Failure of a model to approximate a validation data set indicates a need for recalibration of the model.

Integration of monitoring and modeling results should provide confidence that adequate monitoring exists. When a model has been selected, calibrated, and validated, it may be used to simulate future groundwater flow, contaminant distribution, and water chemistry conditions.

Use of a groundwater model allows for evaluation of different designs, site parameters, and performance scenarios to aid in selecting an appropriate design for the site. Models can also be used to optimize well placement and sample frequency for evaluation of the permeable reactive barrier. Groundwater modeling results and model prediction scenarios should be presented in a clear graphical and narrative form. The presentation should include

- A statement of purpose and objectives of the selected model;
- A conceptual presentation of the selected model, incorporating information from the conceptual model; rationale as to why the model was used; and a discussion of any deficiencies or limitations of the model;
- An explanation of data collection and analysis and the level of confidence in the resulting parameter identification;
- A description of the selected model (software) and justification for its selection;
- A description of the hydraulic and transport values and conditions assigned throughout the model and justification for such;
- A description of the model calibration, results of the final calibration run, and any departures from

the calibration targets;
- Results of the model validation;
- A determination of what parameters of the model have the greatest influence on the model results (i.e., a sensitivity analysis);
- A description of pre- and postprocessing of model input data;
- A presentation of the model output of all predictive scenarios, including the effects of model sensitivity and uncertainty on the predicted results;
- A discussion of how well the model represents the physical and chemical processes of the environment being simulated, both in technical and nontechnical terms;
- Model records should be maintained to provide the following:
  - The version of the source code selected,
  - Input parameters, boundary, and initial conditions,
  - The final calibration run (input and output files),
  - All predictive runs (input and output files).

## 5.0 PERMITTING

Relatively few permitting issues are associated with permeable reactive barriers. Major issues that may arise during installation are the National Pollution Discharge Elimination System (NPDES) permits, Underground Injection Control (UIC) requirements, and Air Quality Permitting considerations, all of which are addressed below. In addition to these major considerations, a thorough review of all permitting issues should be conducted on a site-specific basis. State-specific regulations and municipal requirements should be reviewed to ensure compliance. For instance, many states require a permit for the installation of a well. In some cases, the location of the site may trigger the need for permits. An example is an installation close to or within a wetlands. In addition to permits, states may have alternative approval processes, including submittal of a work plan for state review and/or approval of a corrective action plan under RCRA.

A UIC permit will typically not be required for the installation of a permeable reactive barrier. However, monitoring for leachability of the reactive media (Fe, etc.) in downgradient water quality should be a requirement of the site-specific monitoring plan in most instances. The only consideration in determining the applicability of a UIC permit is the installation technique. When the installation involves excavation and the construction of a barrier, a UIC permit will not be required. Furthermore, similar techniques of emplacement (caisson, mandrel, continuous trencher, etc.) will not trigger the need for a UIC permit. An installation of this type will not necessarily meet the definition of a well under UIC regulations. Furthermore, when the reactive media is emplaced in the ground in solid form, a UIC permit is not needed. However, if the reactive media is installed by a high-pressure jetting technique or by vertical hydraulic fracturing, a permit may, in some circumstances, be required. The need for a permit under these conditions will be a state-by-state determination. A review of the pertinent regulations should be conducted during initial design stages of the project.

A NPDES permit may be required to dispose of excess water generated during installation. The need for a NPDES permit is addressed in Section 7.0, Disposal of Waste During Barrier Placement.

Air permits will not typically be required for the release of VOCs during the installation of a permeable reactive barrier. These barriers are usually installed downgradient of the contamination source in an area where aqueous contamination is the major concern. The concentrations of organic compounds released under these conditions are typically below levels that would require permitting. However, an evaluation is usually required to determine the need for health and safety monitoring and to ensure that there are no off-site excursions of fugitive emissions.

## 6.0 MONITORING

The major objective of groundwater monitoring is to ascertain compliance with state standards. The following sections provide general guidance that is applicable across the states. It may be necessary to identify alternative concentration limits (ACLs) or to incorporate supplemental technologies to address contaminants that may be above criteria at a particular site.

### 6.1 Monitoring Well Construction

#### 6.1.1 Aquifer Wells

State-specific requirements should be followed for the installation of monitoring wells that are intended to monitor groundwater quality and/or levels. Many states have well installation standards or guidelines or require a permit for the installation of a well. The permit process may require an application and a fee.

#### 6.1.2 Wells within the Permeable Reactive Barrier

The design of monitoring wells installed within the ISTZ will differ significantly from the typical well construction criteria. These wells will not incorporate a sand pack or grouting into the design, as is typically required in state installation requirements. ISTZ wells will be surrounded by the backfilled reactive media and can be finished at the surface similar to aquifer wells. The monitoring wells are usually constructed using smaller diameter (1 or 2 inch) PVC casing. Smaller diameters are preferred to limit the purge volume. The diameter must be sufficient to accommodate sampling equipment. In the case of a funnel-and-gate configuration, ISTZ wells can be suspended in the excavation prior to backfilling. These wells can be supported by a metal framework that is removed during backfilling of the ISTZ. For other configurations, wells may be pushed into the ISTZ. The wells may have a long screen or may be positioned in clusters with small screen intervals for sampling discrete areas and various depths.

### 6.2 Monitoring Well Placement

Groundwater modeling should be used as a tool for the determination of monitoring well locations. Groundwater monitoring wells should be installed both upgradient and downgradient (on both sides) of the permeable reactive barrier. At a minimum, selection of monitoring well screen intervals and lengths should consider

- Site geology,
- Aquifer thickness,
- Aquifer flow (horizontal and vertical) characteristics,
- Presence of multiple aquifers,
- Nature of contamination,
- Construction details of the permeable reactive barrier,
- Conformance with state guidance and regulations.

Installation of monitoring well clusters (multiple discretely screened wells within a single boring) may be appropriate if more than one aquifer is present.

Monitoring wells should also be placed within the ISTZ and at the ends of the funnel wall to ensure that contaminants are not migrating through or around the permeable reactive barrier (refer to Section 6.5 of this report). While an aquifer may be homogeneous, the installation of multilevel or cluster wells is recommended within the ISTZ, since it has the potential for developing heterogeneities due to compaction of the iron fines and the development of corrosion products or precipitates within the ISTZ pore space. It is important that some wells be screened at the bottom of the excavation of the ISTZ to monitor for potential contaminant migration beneath the barrier. In addition, when employing a funnel-and-gate system or variation thereof, monitoring wells should be installed near the walls of the ISTZ, as the groundwater velocity tends to be greater at these points. Note that when assessing optimum well locations, contaminant breakthrough may very well occur along the ISTZ walls and not necessarily within the middle of the ISTZ. Refer to Section 6.8 and Figures 6-1 and 6-2, which graphically depict the monitoring well placement concepts outlined in this section.

The appropriate number of monitoring wells will be determined by the size and geometry of the contaminant plume, the size of the permeable reactive barrier, groundwater flow rate, and the heterogeneities of the surrounding media and the ISTZ. It is important when considering the number and location of wells that all aspects of the contaminant plume are characterized and conceptually understood. The number and location of wells must be sufficient to quantify reductions in contaminant levels over time as a measure of performance of the permeable reactive barrier.

### 6.3 Analytical Parameters and Methods

EPA methodologies should be employed for analysis. Section 2.2 of this report lists methods, preservatives, and holding times. Table 2-3 identifies the field and laboratory parameters. The table addresses analyte or parameter, analysis method, sample volume, storage container, sample preservation, and sample holding time.

### 6.4 Sampling

Sampling of wells close to the ISTZ or within the ISTZ requires special considerations in order to obtain a representative sample. Typical well purging methods and volumes will not apply to these wells. To obtain a representative groundwater sample, the residence time of the groundwater within the ISTZ must not change. The volume of groundwater removed and the rate at which it is removed must not change residence time within the ISTZ. A very low-flow purge rate and a small volume of groundwater (significantly less than three well volumes) should be purged to ensure that the groundwater being sampled has had sufficient time to react within the ISTZ. Alternatives for sampling include use of a low-flow sampling procedure, dedicated submersible pumps, and packers or other specialized sampling devices for reducing the purge and sample volume. There are currently no guidelines on the amount or rate at which groundwater should be purged. This is an issue that must be determined on a case-by-case basis. Keep in mind, however, that a slower and smaller purge will have the least effect on residence time, thus providing a more representative sample of ISTZ performance.

Conventional purging and sampling can be used on monitoring wells positioned away from the ISTZ, provided the purging and sampling will not influence groundwater flow through the ISTZ.

### 6.5 Monitoring Frequency

Groundwater flow velocity is a key component in designing and establishing a monitoring schedule. Rates of groundwater flow can be quite variable for permeable reactive barriers. If the groundwater flow rate is high, a more frequent schedule is applicable as there are more rapid changes occurring; if the groundwater flow rate is low, a less frequent schedule may be applicable as changes are occurring less rapidly within the aquifer. If a permeable reactive barrier is built downgradient of a plume, it may take weeks or months for the plume to reach the barrier, especially when groundwater flow velocities are low. Measuring organic parameters before the plume reaches the barrier may be unnecessary. Table 6-1 provides monitoring frequency guidance for permeable reactive barriers; as always, site-specific considerations and professional judgement should be used to determine frequencies and parameters.

In general, during the first quarter after the plume reaches the barrier, monthly sampling of field parameters and organic and inorganic constituents should be performed on wells within and close to the ISTZ. These data will help evaluate the effect of the permeable reactive barrier installation on the surrounding aquifer. It should be noted that monitoring during the first quarter will not be representative of the performance of the permeable reactive barrier after equilibrium is reached. Disturbances caused by the installation process have been known to create changes in the concentration of groundwater contaminants. These changes should be monitored and recorded until this process is better understood.

Initial placement of a permeable reactive barrier has been reported to temporarily increase the levels of groundwater contaminants in some instances. The increase may be due to desorption of contamination from the installation technique, changes in groundwater flow velocity, or some unknown phenomenon. The potential exists for the placement of a permeable reactive barrier to create a vector of groundwater contamination that may affect noncontaminated wells. These scenarios are transitory effects from the installation process. The overall performance of the permeable reactive barrier system should not be affected over a longer time period. In some instances, enhanced performance of the permeable reactive barrier has been reported during the first few months following system startup, after which performance tends to reach equilibrium. As more experience with permeable reactive barriers is gained, the initial monitoring program may be subject to modification.

After the first quarter, samples for chemical analyses should be collected on a quarterly basis from the wells within the ISTZ and selected upgradient and downgradient wells. Wells along and at the ends of the funnel wall(s) should also be sampled quarterly to evaluate movement under and around the wall. In establishing monitoring requirements for the first year, evaluation of modeling data should be performed to identify the most useful data points. Monitoring should be designed to evaluate the sensitivities of a variety of parameters over the first year of operation at a site. A strategy may then be developed to reevaluate the monitoring parameters, locations, and analytical data on a continuing basis to ensure that the sampling locations and parameters are appropriate. This may result in the elimination of redundant monitoring points or certain parameters at specific sampling locations from the quarterly monitoring plan.

Continual adjustments based upon an increased understanding of the performance of the system and recalibration of the model should drive decisions on establishing the frequency and locations of monitoring. Based on the long-term performance of the barrier and a reevaluation of the monitoring plan and operational data, a reduction from the quarterly sampling schedule may be instituted after the first or second year of operation.

Gathering groundwater level data is a relatively inexpensive analysis, which can provide a great deal of information regarding the performance of the system. During the first quarter, groundwater level data should be collected on a weekly basis for all wells associated with the permeable reactive barrier to determine and observe any changes in the components of groundwater flow after permeable reactive barrier installation. Measurement of groundwater levels during the first and second year of operation should be conducted on a quarterly basis, during which evaluation of the data will indicate where the frequency can be reduced or where monitoring wells can be eliminated from the monitoring program. Groundwater level data should be collected even if the plume has not yet reached the barrier to ensure that equilibrium is being reached and that no damming of the aquifer is occurring. This schedule of groundwater monitoring takes into account seasonal variations in groundwater levels.

**Table 6-1 Permeable Reactive Barrier Monitoring Frequency**

| Parameter | Frequency |
|---|---|
| **A - First Quarter After Installation** | |
| Field Parameters | Monthly |
| Organic Analytes | Monthly |
| Inorganic Analytes | Monthly |
| Groundwater Levels | Weekly (until equilibrium is reached) |
| **B - Initial Monitoring Program (1 - 2 years)** | |
| Field Parameters | Quarterly |
| Organic Analytes | Quarterly |
| Inorganic Analytes | Quarterly |
| Groundwater Levels | Monthly, then to be determined |
| **C – Long-Term Monitoring** | |
| Field Parameters | Quarterly (may be reduced based upon operational stability) |
| Organic Analytes | |
| Inorganic Analytes | |
| Groundwater Levels | |
| **D – Postclosure Monitoring** | |
| Inorganic Parameters (Fe and other leachable constituents) | To be determined based upon data collected during operation |

* Refer to Table 2-3 for analysis method.
** Groundwater levels should be measured to 0.01 feet.

## 6.6 Hydraulic Evaluation

Several tools are available for hydraulic evaluation. Information on residence time, heterogeneities in flow rate, and long-term changes in flow rate can be evaluated with these techniques. Slug tests may be used to determine media flow characteristics within and around the permeable reactive barrier. These tests can provide information on hydraulic conductivity within various media. Caution should be employed in and around the ISTZ, where the test could change the residence time within the reactive media. In-situ flow meters or groundwater velocity probes are also available for the determination of flow rates. These field instruments can provide real-time data on the permeable reactive barrier without affecting residence time. Tracer tests may also be utilized to provide information on flow rate through the ISTZ. Whether a permit is required for the injection of the tracer material will be a state-specific determination.

## 6.7 Long-Term Monitoring

One of the benefits of using a permeable reactive barrier is the potential for substantial reduction in monitoring requirements in relation to those of other remedial systems (e.g., pump and treat). A reduction in the quarterly monitoring for field parameters and organic and inorganic constituents and in monthly hydraulic monitoring can be instituted once the performance of the permeable reactive barrier is documented over an extended period. Evaluation should occur on a yearly basis to determine the adequacy of monitoring frequencies and locations.

## 6.8 Examples of Monitoring Scenarios

Figures 2 and 3 are provided to graphically depict monitoring issues discussed in this document. Expected groundwater flow lines are shown on each diagram. The purpose of the drawings is to provide hypothetical examples of monitoring well placement. Site-specific conditions should always dictate the placement of monitoring wells.

Appendix B also provides monitoring scenarios from a permeable reactive barrier that has been installed as a treatment system. These figures provide examples of how systems are monitored in real applications. Again, site-specific conditions should always dictate the placement of monitoring wells.

### 6.8.1 Rationale behind Monitoring Well Placement

The following key pertains to the monitoring scenarios illustrated in Figures 6-1 and 6-2 on pages 21 and 22:

**A** Monitoring well placement to determine downgradient groundwater quality by sampling organic parameters.

**B** Monitoring well placement to ensure treatment and determine groundwater flow rate by sampling field, inorganic, and organic parameters.

**C** Monitoring well placement to determine treatment, groundwater flow rate, and precipitate formation through field, inorganic, and organic parameters. Note wells B, C, and D are located along lines through the ISTZ to monitor flow paths. Monitoring wells are placed at both the sides and the middle of the ISTZ to monitor differences in flow.

**D** Monitoring well placement to determine upgradient concentration of contaminants, precipitation formation, and groundwater flow rate through field, inorganic, and organic parameters.

**E** Monitoring well placement to determine breakthrough, underflow, or overflow across the funnel wall through field and organic parameters.

**F** Monitoring well placement to ensure plume capture and determine whether contaminant is migrating around the funnel wall through field and organic parameters.

Figure 6-1 Funnel-and-Gate Monitoring Diagram

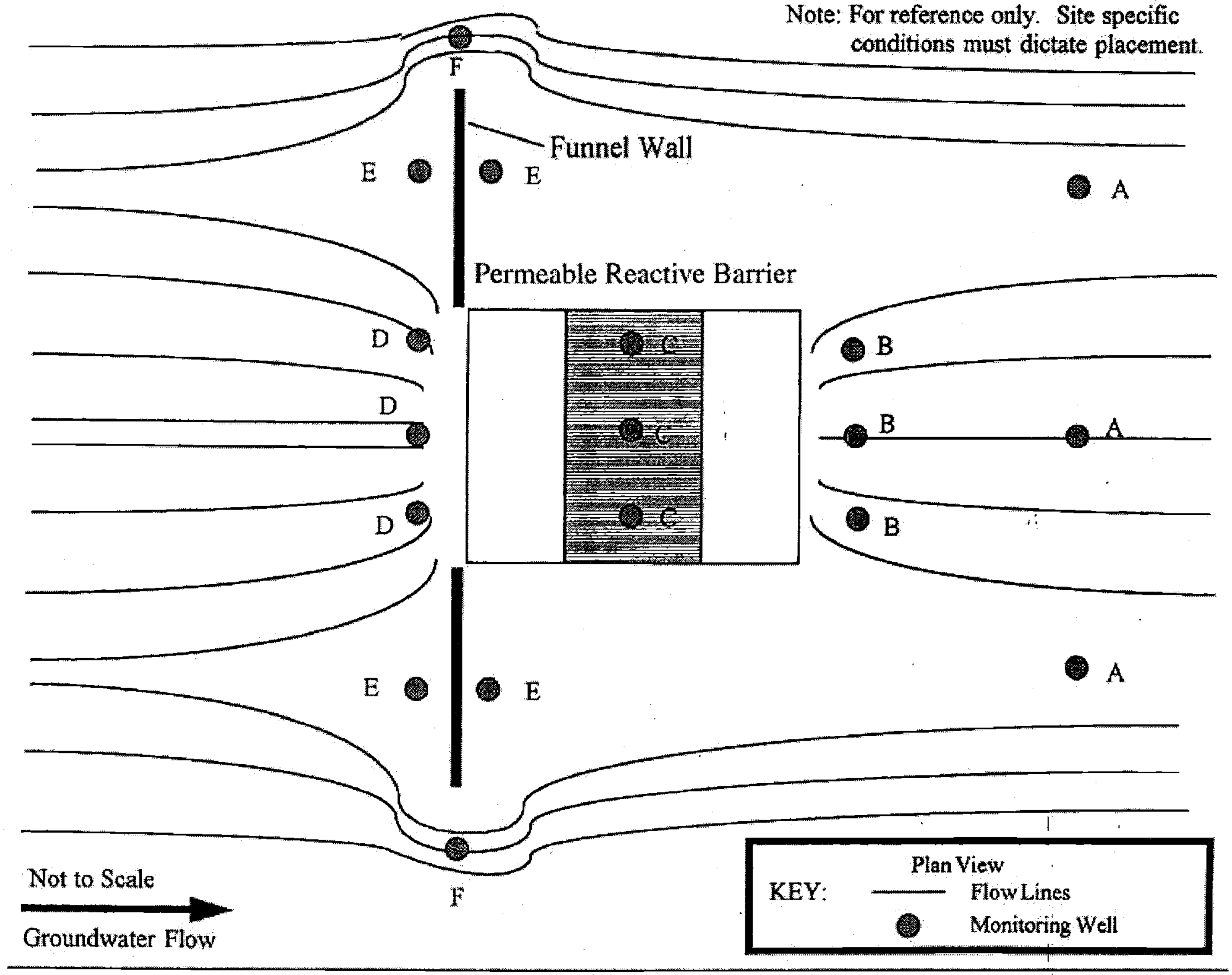



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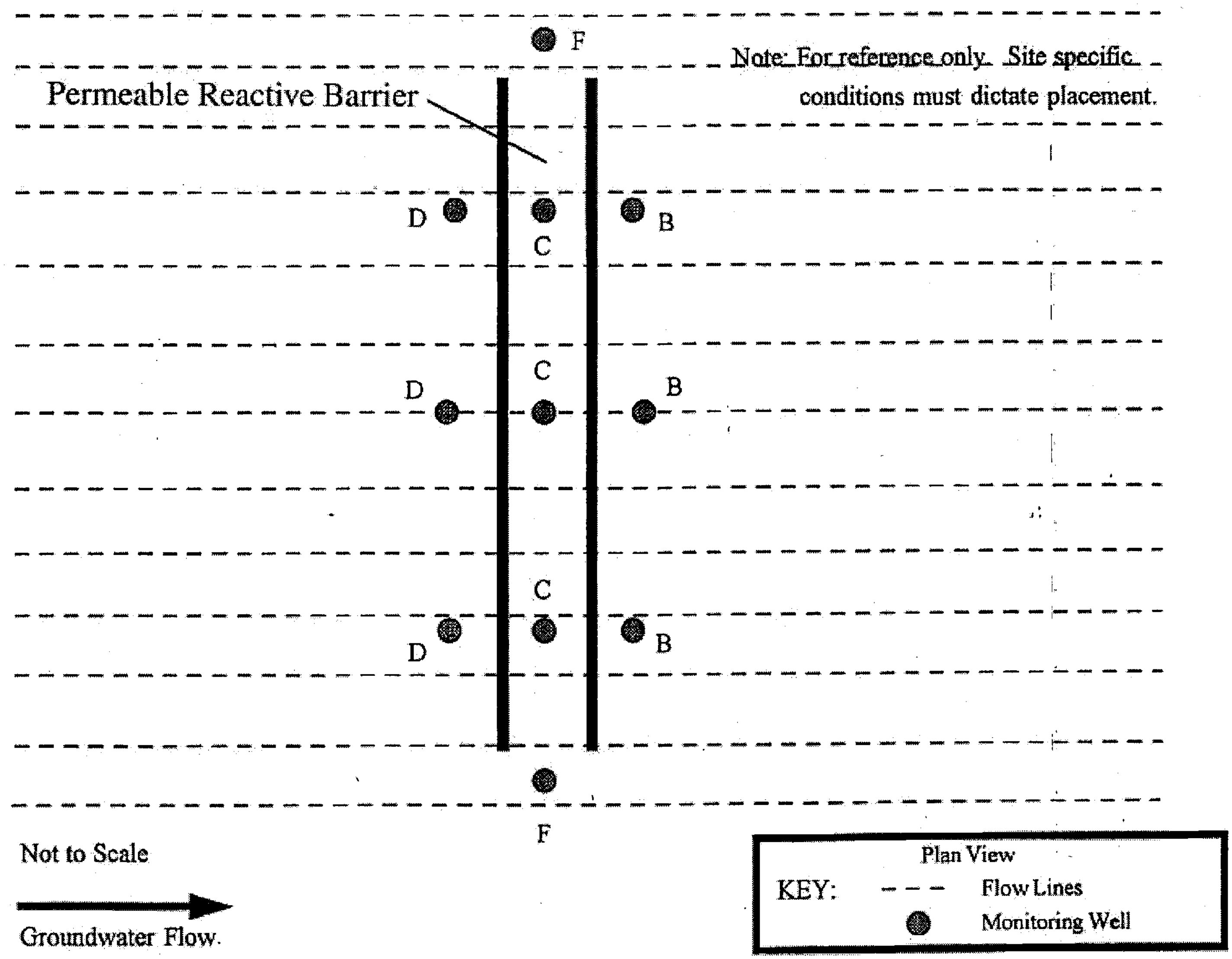
Figure 6-2 Continuous Permeable Reactive Barrier Monitoring Diagram



## 7.0 DISPOSAL OF WASTES DURING BARRIER PLACEMENT

Contaminated soils may be generated during installation. Any contaminated soil should be classified in accordance with state and federal Hazardous Waste Regulations prior to disposal. The classification of the soil will determine the disposal method. Classification can occur in situ through the use of soil borings and waste classification sampling prior to removal of the soil from the installation site. An alternative is to stockpile the soil on site during installation and collect classification samples prior to disposal. In either situation, state-specific requirements should be followed for sample parameters and frequency to ensure the soil is properly classified prior to disposal. In cases where the generated soil is classified as hazardous, state and/or federal regulations will dictate the disposal method. Land Disposal Restrictions and listed hazardous waste requirements should be adhered to where applicable. State-specific requirements may also regulate the disposal of nonhazardous waste if the material is contaminated.

Contaminated groundwater may be generated from the dewatering of the excavation during the installation process. Any contaminated water shall be disposed of in accordance with state-specific requirements. Several options may apply; water can be disposed of at a permitted off-site commercial facility, a publicly owned treatment works, or on site in accordance with a NPDES permit. The use of continuous trencher or jetting installation techniques can often reduce the total volume of contaminated soil and groundwater requiring treatment/disposal.

## 8.0 MAINTENANCE AND CLOSURE CRITERIA

The long-term maintenance and closure requirements for permeable reactive barriers are not well defined because the technology has only recently been employed full scale. One concern is the loss of hydraulic conductivity (clogging) over time. Standard monitoring of field parameters and inorganic constituents along with groundwater elevation data can provide an indication of loss of permeability within the barrier. If the performance of the permeable reactive barrier is affected by loss of permeability or routine monitoring indicates a potential problem, monitoring frequency of all parameters should be increased to identify the effects on groundwater contaminant concentrations and hydraulics.

If the loss of conductivity is severe, special monitoring considerations such as coring of the reactive media can be employed to better understand the problem. Coring of the media is not a technique that should be employed on a regular basis. It may, however, play a role in determining the source and extent of clogging. Core samples should be obtained from the top several inches of the middle of the media and from the bottom of the media, being careful not to allow oxygen to come in contact with the cores prior to analysis. The number of locations to sample will depend on the size of the ISTZ. Boreholes should be backfilled with fresh media. Various microscopic imaging techniques are available to determine the presence of precipitates. These include scanning electron microscopy, energy dispersive x-ray spectroscopy, and powder x-ray diffractometry.

Maintenance issues of regulatory concern involve the regeneration of the reactive media and the restoration of the hydraulic permeability of the permeable reactive barrier. If the barrier is being repaired or reconstructed, contaminated reactive media or soil may be generated. Any material generated should be properly classified and disposed of in accordance with state and federal Hazardous Waste Regulations. Another mechanism to reestablish the reactivity of the media and/or the barrier permeability could involve a reagent flush. The use of reagents (i.e., acid solutions) to rejuvenate the permeable reactive barrier is currently under investigation. A flushing procedure may require a permit, careful monitoring, and a contaminated groundwater extraction process. State-specific requirements will dictate where and how reagents can be introduced. Any flushing procedure should be reviewed on a case-specific basis to ensure proper regulatory controls.

Closure of a permeable reactive barrier will typically not occur until the upgradient and downgradient aquifer meets the applicable groundwater quality standards or cleanup goals. As a result, permeable reactive barriers will often remain active for an extended period of time. Upon closure, there would usually be no need to remove the permeable reactive barrier; in a few circumstances, state-specific requirements may dictate removal. One such scenario involves the clogging of the barrier over time, forming an impermeable barrier that may affect groundwater flow conditions. In cases where the permeable reactive barrier will remain in place after closure, concern may arise regarding the long-term solubility of the reactive media and its effect on downgradient water quality. Dissolved iron or other elements from the barrier could possibly impact water quality. The need for postclosure downgradient monitoring of iron or other reactive media components should be based on the inorganic data collected during operation of the permeable reactive barrier. Depending on the concentration of inorganic parameters detected during operation of the permeable reactive barrier, consideration may be given to reducing or eliminating future monitoring. Any reduction should be based on a thorough understanding of the dynamics of the system. In addition, consideration should be given to the proper decommissioning of those monitoring wells that will no longer be needed or used.

## 9.0 HEALTH AND SAFETY

A site-specific Health and Safety Plan should be developed and implemented in accordance with the Occupation Safety and Health Administration (OSHA) regulations 20 CFR 1910.120, the Hazardous Waste Operations and Emergency Response Rule. The Plan should address the following issues:

- Key Personnel
- Health and Safety Risks
- Training
- Protective Equipment
- Medical Surveillance
- Spill Containment
- Air Monitoring
- Site Control
- Decontamination
- Emergency Response
- Confined Space Entry
- Underground Utility Mark-out
- Trench Entry
- Accident Procedures

## 10.0 STAKEHOLDER CONCERNS

A stakeholder is any nonregulatory affiliated party with interest in a particular site or technology. Stakeholders within the community in which the permeable reactive barrier will be deployed should be properly informed, educated, and involved in the decision making process and consulted regarding the utilization of the technology. This may require holding public meetings or information sessions, distributing informative bulletins, or developing a neighborhood-canvassing program. The document entitled "A Guide to Tribal and Community Involvement in Innovative Technology Assessment" explains the need for community involvement during site planning and implementation and should be used as a reference tool in forming a community outreach program. The EPA has developed a citizen's guide entitled "A Citizen's Guide to Treatment Walls," which can be ordered directly from EPA.

Stakeholders close to the installation of a permeable reactive barrier may have the following concerns:

- truck traffic,
- noise,
- heavy equipment operation,
- work hours,
- off-site excursion of dust,
- off-site excursion of organic compounds,
- proper site control and access restrictions,
- potable well contamination,
- groundwater quality data,
- effectiveness,
- contingency remedial plans.

## 11.0 VARIANCES

As this technology develops, innovation in sampling and analytical methods may result in proposals to utilize alternative methods. Methods other than those outlined in this guidance may be proposed as a variance. State regulatory agencies should evaluate the applicability of a variance based upon the following criteria:

- The method has previously been used successfully under similar site conditions, as documented by a regulatory agency.
- The method has been tested successfully by an independent, nonregulatory verification entity.
- The method is approved by the agency, based upon site-specific conditions or technology modifications.

## 12.0 REFERENCES

"Citizen's Guide to Treatment Walls," U.S. Environmental Protection Agency, Technology Innovation Office, EPA 542-F-96-016, Sep. 1996.

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"Design Guidance for Application of Permeable Barriers to Remediate Dissolved Chlorinated Solvents," prepared for Armstrong Laboratory/Environics Directorate by Battelle, Feb. 1997.

"Discrete-Level Ground-Water Monitoring System for Containment and Remedial Performance Assessment Objectives," Bob Puls, J. Environ. Engineering, June 1996.

"Draft Design Protocol for Permeable Barriers To Remediate Chlorinated Solvents," prepared for Armstrong Laboratory/Environics Directorate (AL/EQ) by Arun Gavaskar et al., Nov. 1996.

"Performance Monitoring Plan for a Pilot-Scale Permeable Barrier at Moffett Federal Airfield," prepared for Naval Facilities Engineering Service Center, Port Hueneme, CA by Battelle, Dec. 1996.

"Final Report Remedial Implementation Interim Corrective Measure Containment System," Federal Highway Administration, Denver Federal Center, prepared for USACE by IT Corp., July 1996.

"Guide to Documenting Cost and Performance for Remediation Projects," member agencies of the Federal Remediation Technology Roundtable, EPA-542-B-95-002, Mar. 1995.

"In Situ Remediation Technology Status Report: Treatment Walls," U.S. Environmental Protection Agency, Technology Innovation Office, EPA-542-K-94-004, April 1995.

"Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures," Bob Puls and Michael Barcelona, USEPA Ground Water Issue, April 1996, EPA/540/S-95/504.

"Research on Permeable Barriers," Stan Morrison and Robert Spanger, Rust Geotech for the RTDF Permeable Barrier Walls Working Group, Nov. 1995.

"Second Quarter Monitoring Results, 1997 Interim Groundwater Remediation Measure Denver Federal Center," prepared for Federal Highway Administration by US Geological Survey, Sep. 1996.

"Technology Evaluation Report: Treatment Walls," prepared for Groundwater Remediation Technologies Analysis Center, Pittsburgh, PA by University of Pittsburgh, Oct. 1996.

# APPENDIX A

## Acronyms and Abbreviations

| | |
|---|---|
| 2-D | 2-dimensional |
| 3-D | 3-dimensional |
| Ba | barium |
| $^{o}C$ | degrees Celsius |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| Cl | chlorine |
| CFR | Code of Federal Regulations |
| Al | aluminum |
| Br | bromine |
| Ca | calcium |
| CS | chlorinated solvents |
| d | days |
| DCE | dichloroethylene |
| DO | dissolved oxygen |
| DOC | dissolved organic carbon |
| Eh | redox potential |
| EPA | Environmental Protection Agency |
| Fe | iron |
| F | flourine |
| GC/MS | gas chromatograph / mass spectrometry |
| h | hours |
| $HNO_3$ | nitric acid |
| $H_2SO_4$ | sulfuric acid |
| ISTZ | in-situ treatment zone |
| ITRC | Interstate Technology and Regulatory Cooperation Work Group |
| K | potassium |
| Mg | magnesium |
| mg/l | milligrams/liter |
| mL | milliliter |
| Mn | manganese |
| Na | sodium |
| $NO_3$ | nitrate |
| NPDES | National Pollution Discharge Elimination System |
| NSF | National Sanitation Foundation |
| OSHA | Occupational Safety and Health Administration |
| PCE | tetrachloroethylene, perchloroethylene |
| ppb | parts per billion |
| PVC | polyvinyl chloride |
| QA | quality assurance |
| QC | quality control |

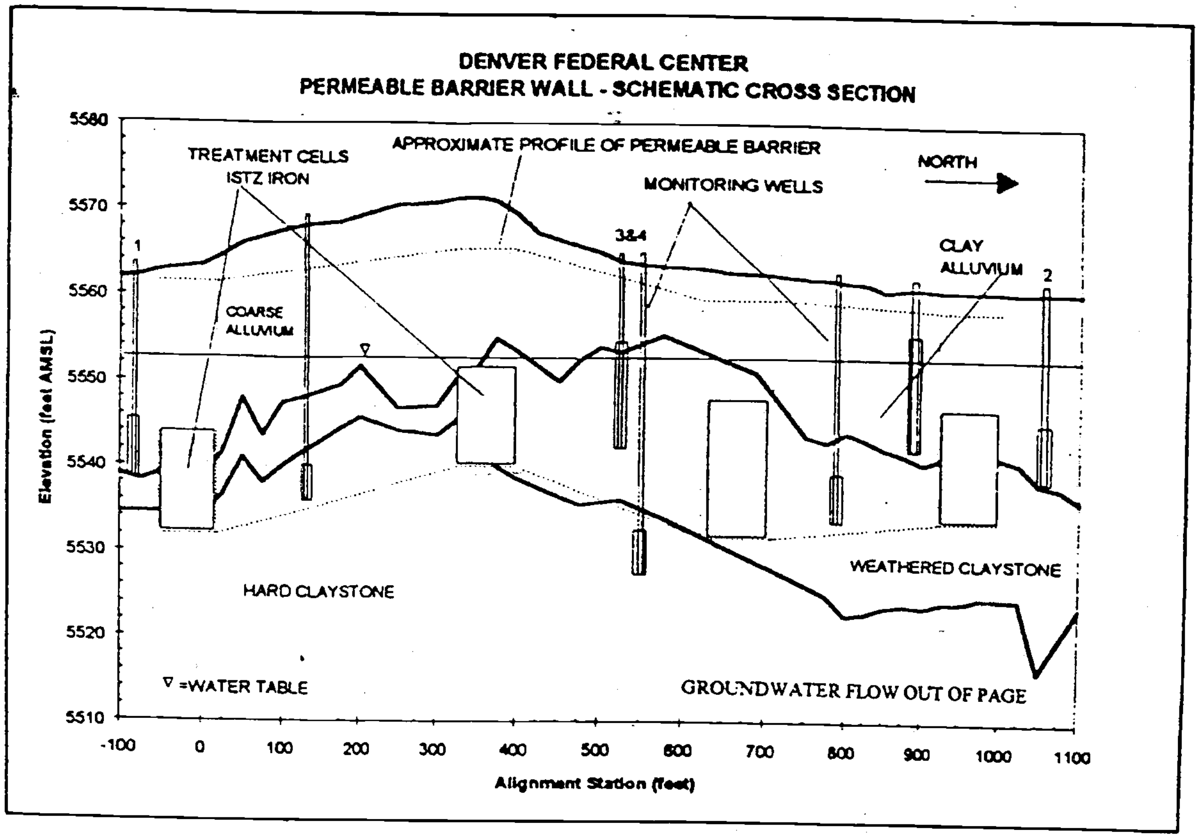
| | |
|---|---|
| RCRA | Resource Conservation and Recovery Act |
| $SO_4$ | sulfate |
| TBD | to be determined |
| TCE | trichloroethene, trichloroethylene |
| TDS | total dissolved solids |
| TOC | total organic carbon |
| TSS | total suspended solids |
| VOA | volatile organic analyte |
| UIC | underground injection control |
| VOC | volatile organic compound |

# APPENDIX B

## Denver Federal Center Permeable Barrier

# Denver Federal Center Permeable Barrier

## Schematic Cross Section



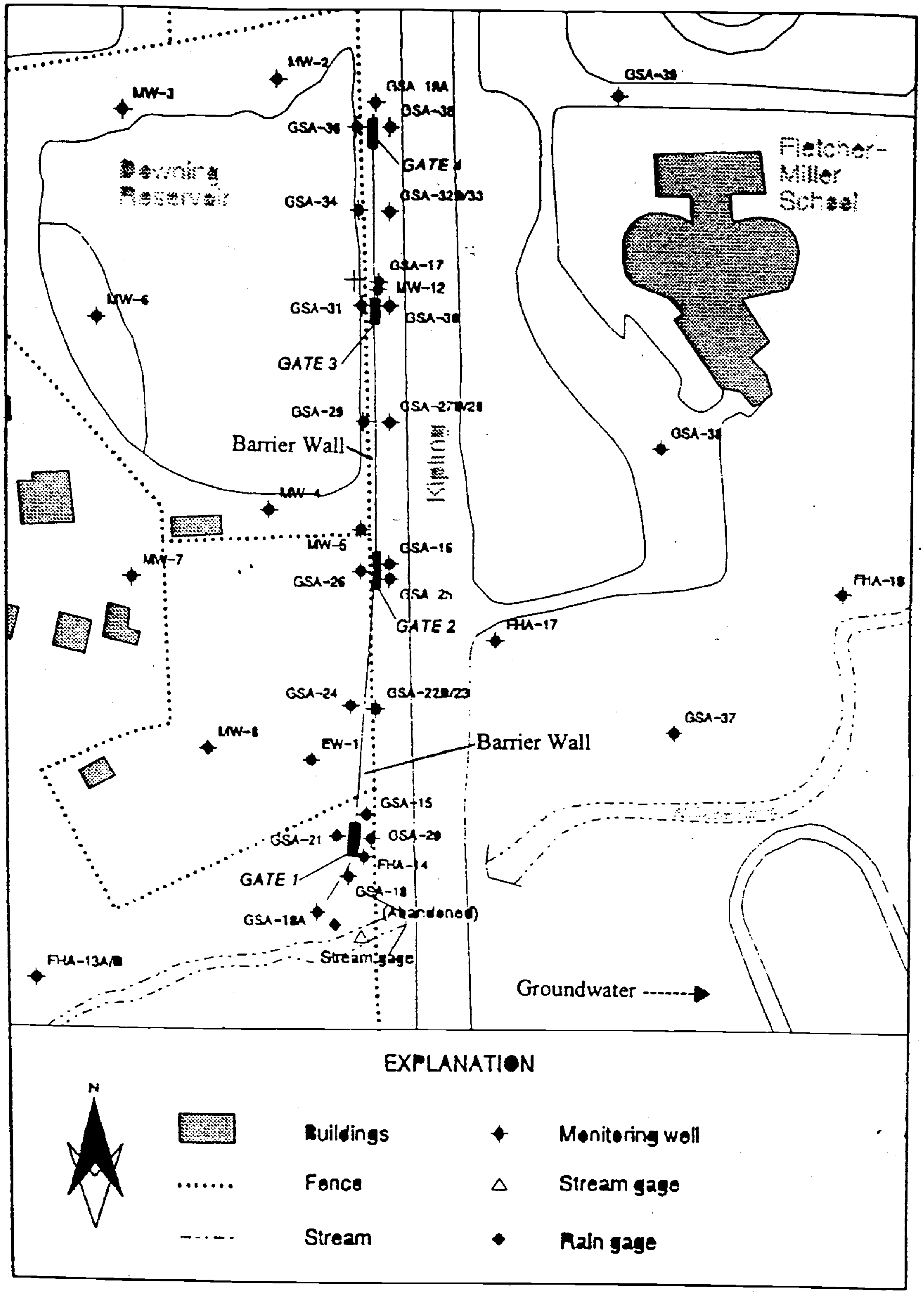

The diagram above conceptually illustrates in cross section, the groundwater monitoring system for the Denver Federal Center (DFC) funnel-and-gate system. The aquifer at DFC consists of three lithologic units of decreasing permeability with depth: alluvium, weathered claystone, and hard claystone.

To achieve maximum containment, the base of the containment system should be keyed into the unit with the lowest permeability (at DFC, this would be the hard claystone). However, at the north end of the DFC system, it was not technically feasible to drive sheet piling to this horizon (a depth greater than 45 feet). This situation is mitigated by a decrease in transmissivity in the alluvium to the north, as it transitions from sand and silt south of the weathered claystone high, to clay north of the high.

Ideally, monitoring wells should be installed to monitor groundwater levels and chemistry at strategic locations in each unit. Wells, numbered 1 and 2 on the diagram, are located to monitor for by-pass at either end of the permeable reactive barrier (these would correspond to GSA-18a and 19a on the site map).

Twin monitoring wells, screened to monitor vertical gradients between the alluvium and the underlying confining layers, were located at points midway between the treatment cells and are represented by wells on the diagram numbered 3 and 4 (these would correspond to well pairs GSA-23, 22D; GSA-28, 27D; GSA-33, 32D on the site map).

Wells located in the treatment cells (the permeable sections of the barrier containing zero-valent iron) are not represented on this schematic.


MW-2
MW-3
GSA-39
GSA-36
GATE 4
Fletcher-Miller School
GSA-34
GSA-17
MW-12
MW-6
GSA-31
GATE 3
GSA-29
Barrier Wall
MW-4
MW-5
GSA-16
MW-7
GSA-26
GATE 2
FHA-17
GSA-24
GSA-37
MW-8
EW-1
Barrier Wall
GSA-15
GSA-21
GATE 1
(Abandoned)
FHA-13A/B
Stream gage
Groundwater
EXPLANATION
N
Buildings
Monitoring well
Fence
Stream gage
Stream
Rain gage

# APPENDIX C

## ITRC Contacts, ITRC Fact Sheet, ITRC Product List, and Document Evaluation Survey

**ITRC Permeable Reactive Barriers Team**
**Project Contacts**

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**Dan Sogorka**
**PBW Team Project Support**
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Reston, VA 20190
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F 703-481-9125
dsogorka@remedial.com

# Permeable Barrier Walls

"Design Guidance for Application of Permeable Barriers to Remediate Dissolved Chlorinated Solvents"

Prepared for

Air Force Research Lab/Environics Directorate (AL/EQ), Tyndall AFB, Florida

by

BATTELLE, Columbus, Ohio

"Regulatory Guidance for Permeable Barrier Walls Designed to Remediate Chlorinated Solvents"

&

"Regulatory Guidance For Permeable Reactive Barriers Designed to Remediate Inorganic and Radionuclide Contamination"

by

Permeable Reactive Barrier Wall Team of the ITRC

1

RTDF

# Today's Instructor

★ **Robert T. Mueller**

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- bmueller@dep.state.nj.us

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## Presentation Overview

- ★ About the ITRC
- ★ Technical/regulatory information on Permeable Reactive Barriers
- ★ Questions and Answers
- ★ Wrap-up and Links to additional information and resources

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## ITRC: A state regulator-led, national coalition of the environmental community

**Goals:**


- ★ Achieve better environmental protection through innovative technologies
- ★ Reduce the technical/regulatory barriers to the use of new environmental technologies
- ★ Build confidence about using new technologies
- ★ Improve regulatory permitting processes and speed implementation of new environmental technologies

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## Who Is Involved?

- ★ 38 State Environmental Agencies
- ★ Industry Representatives
- ★ Academia
- ★ Public Stakeholders
- ★ U.S. Federal Agencies

U.S. Department of Energy

U.S. Environmental Protection Agency

U.S. Department of Defense

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Host Organization

ECOS — Environmental Council of States

State Organizations

Western Governors' Association

Southern States Energy Board

## ITRC Organizational Structure

**ECOS/ERIS**

*State institutional support*
*Enable state staff participation*
*Funding support*
*Fiscal agent*

**State Engagement**

State Point of Contact Network (38 POCs)

- Ensure state awareness/ use of ITRC products
- Coordinate training on ITRC products
- Coordinate concurrence on ITRC products
- Coordinate concurrence on ITRC products

**Board of Directors**

Two Public Stakeholders *(Industry, Env)*

Co-Chairs *State*

Federal Partners EPA DOE DOD *Ex-Officio*

State Engagement Coordinator

Team Leader Liaison - *State*

Association Affiliates WGA & SSEB *Ex-Officio*

***Program Director***

**Technical Teams**

- ★ Bioremediation
- ★ Diffusion Samplers
- ★ DNAPLs
- ★ DOE Gate 6 Technologies
- ★ In Situ Chemical Oxidation
- ★ MTBE
- ★ Permeable Reactive Walls
- ★ Phytotechnologies
- ★ Radionuclides
- ★ Sampling & Characterization
- ★ Sediments
- ★ Small Arms Ranges
- ★ Unexploded Ordnance

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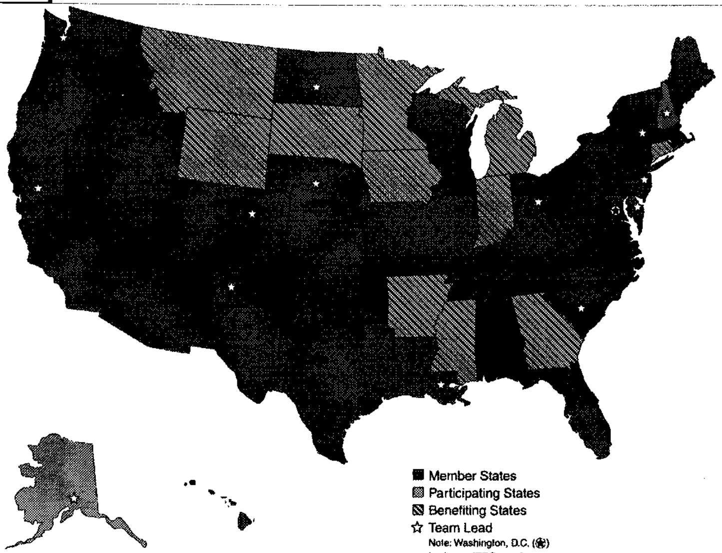
## State Participation

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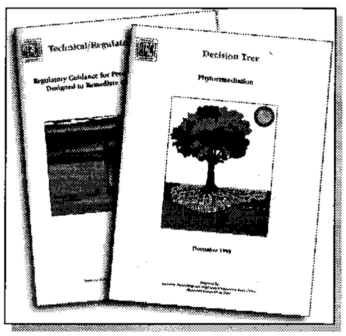
## Products & Services

- ★ Regulatory and Technical Guidelines
- ★ Technology Overviews
- ★ Case Studies
- ★ Peer Exchange
- ★ Technology Advocates
- ★ Classroom Training Courses
- ★ Internet-Based Training Sessions

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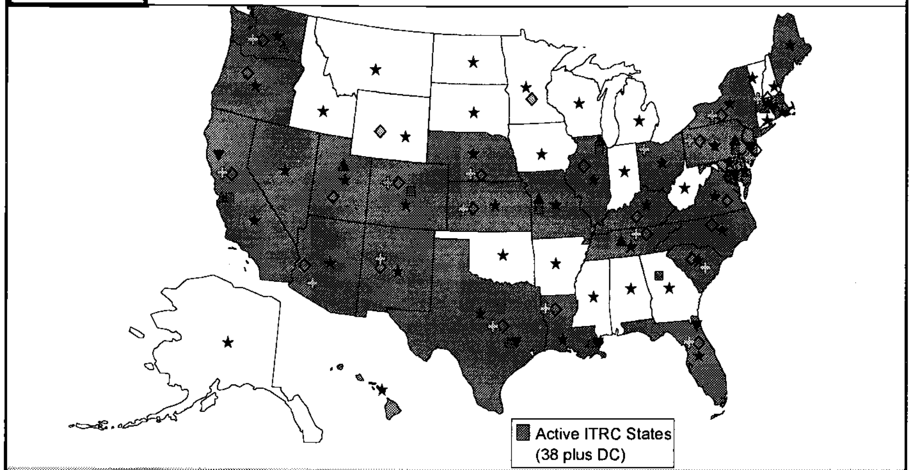
## Nationwide Success




▲ Natural Attenuation Training Course
▼ Accelerated In Situ Bioremediation Training Course
■ Permeable Reactive Barriers Training Course
★ Students Trained
✚ Product Use at a Site
◆ Institutional Success

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## ITRC Contacts

ITRC Web Site: http://www.itrcweb.org

**ITRC Co-Chairs**

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ITRC Program Manager
Rick Tomlinson
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# ITRC Regulatory Documents

★ ITRC Documents can:
- **Provide Information on PRB deployment**
- **Identifies regulatory & stakeholder issues**
- **Provides technical & regulatory & design guidance**
- **Builds technical and regulatory consensus**
- **Streamlines regulatory approval process**
- **Educates stakeholders, regulators, technology implementers**

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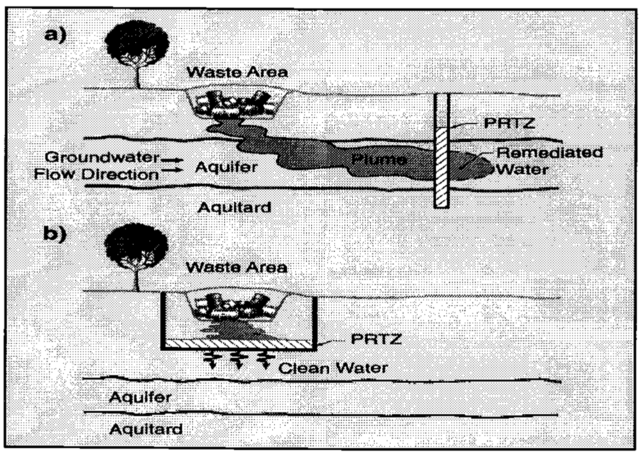
# What Is A Permeable Reactive Barrier?

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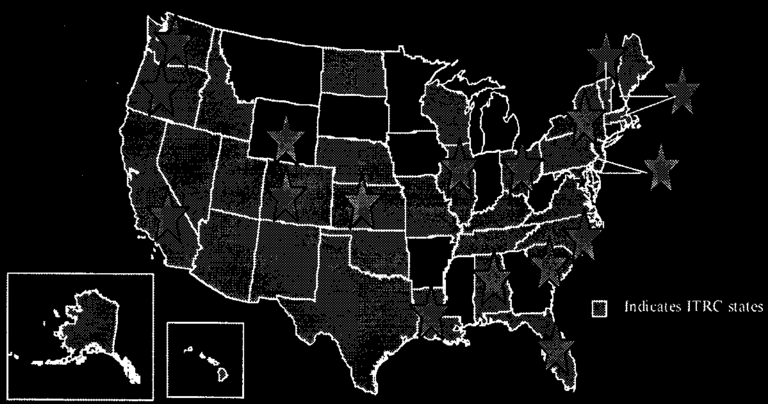
INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

## Existing States Using or Testing PRBs for In Situ VOC Destruction (end of 1999)

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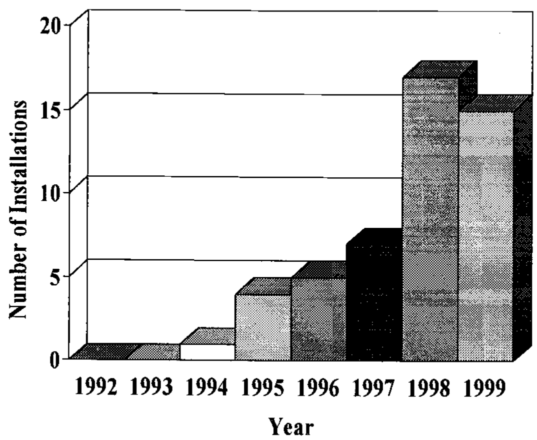
INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

## Technology Acceptance (end of 1999)

## Technology Acceptance

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INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

## Advantages Of Permeable Barriers

- ★ Treatment occurs in the subsurface
- ★ Typical treatment is passive
- ★ Potentially lower operation and maintenance costs
- ★ Allows full economic use of a property
- ★ No above ground structures or routine day-to-day labor attention required
- ★ Monitoring can be focused

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INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

## Treatment Mechanisms

- ★pH Control
- ★Chemical Precipitation
- ★Oxidation-Reduction Reactions
- ★Zero-Valent Metal Induced Dehalogenation
- ★Biological Degradation Reactions
- ★Sorption Reactions

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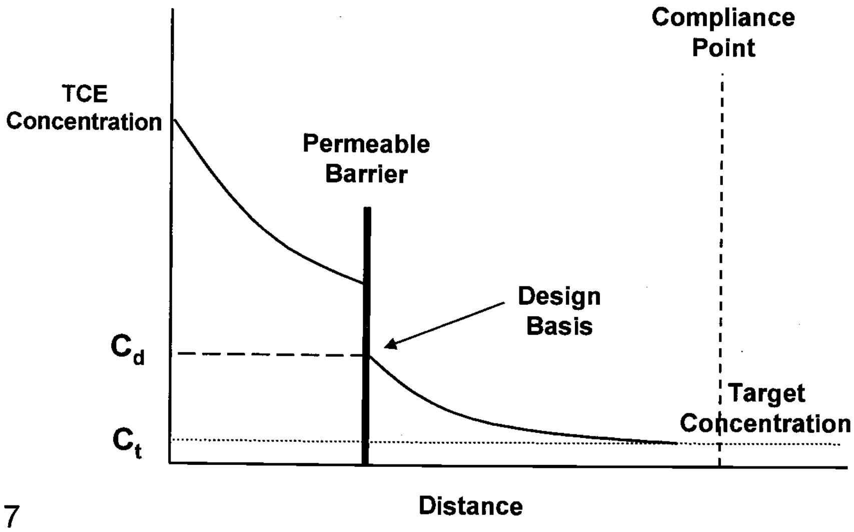
## Synergy with other Alternatives Example - Natural Degradation

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## Common Terminology

★**Treatment Matrix / Reactive Media-**
- zone of material that promotes treatment

★**Hydraulic control system-**
- routes affected groundwater through the treatment zone
- prevents migration around treatment zone
- provides the affected groundwater with sufficient residence time in the treatment zone

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## Reactive Media Selection Guidance

**Treatment Material and Treatable Contaminants**

| Treatment Material | Target Contaminants | Status |
|---|---|---|
| Zero-Valent Iron | Halocarbons, Reducible metals | In Practice |
| Reduced Metals | Halocarbons, Reducible Metals | Field Demonstration |
| Metals Couples | Halocarbons | Field Demonstration |
| Limestone | Metals, Acid Water | In Practice |
| Soptive Agents | Metals, Organics | Field Demonstration, In Practice |
| Reducing Agents | Reducible Metals, Organics | Field Demonstration, In Practice |
| Biological Electron Acceptors | Petroleum Hydrocarbons | In Practice, Field Demo |

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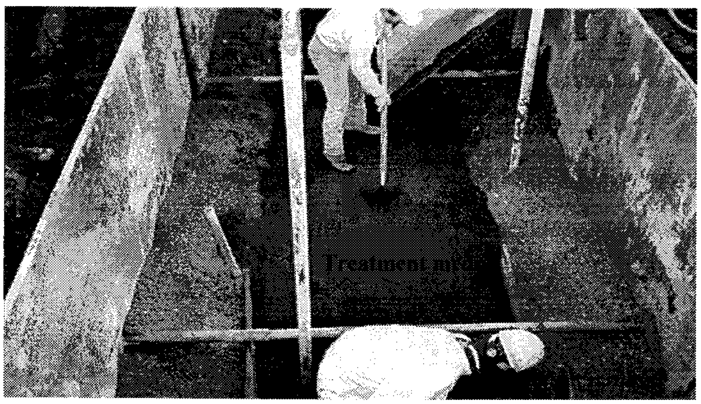
## Permeable Reactive Barrier Composed of Fe(0)



Journal of Environmental Engineering, June 1998

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## Contaminants Treated by the Most Common Reactive Medium -- Iron

- **Inorganics:**
  - Cr, As, Hg, Cd, U, Tc
    Nitrate, Sulfate
- **Organics:**
  - Chlorinated Methanes (CT)
    Chlorinated Ethanes (TCA)
    Chlorinated Ethenes (TCE)
    Nitroaromatics (TNT, RDX)

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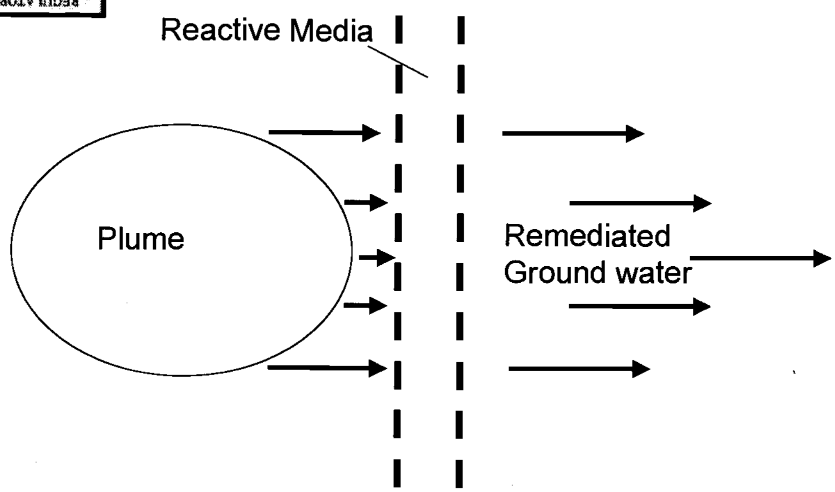
## PRB Configuration - Continuous Wall

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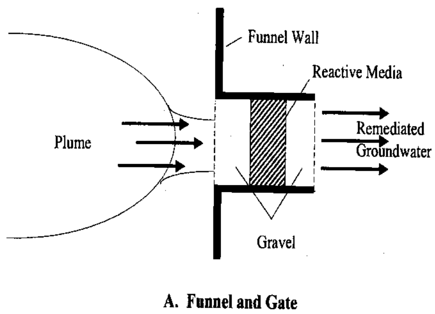
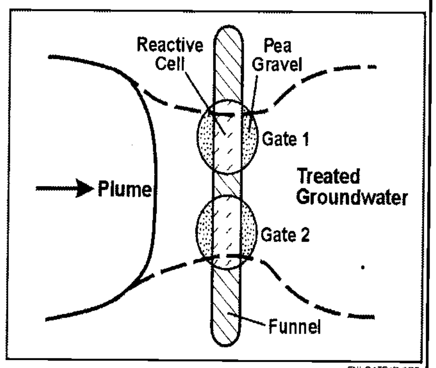
## PRB Configuration

## Funnel & Gate(s)




***Single Gate***

***Multiple Gates***

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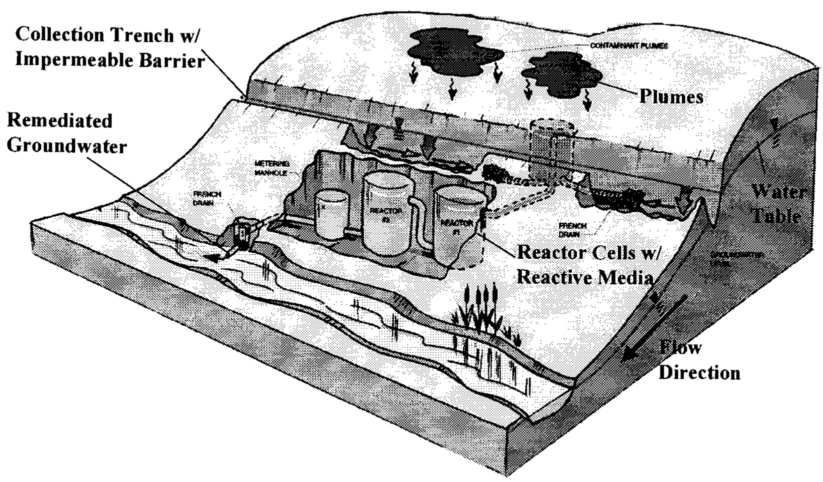
## PRB Configuration - Passive Collection with Reactor Cells




*USDOE Rocky Flats Mound Site Plume, Tetra Tech EM, Inc. 1998*

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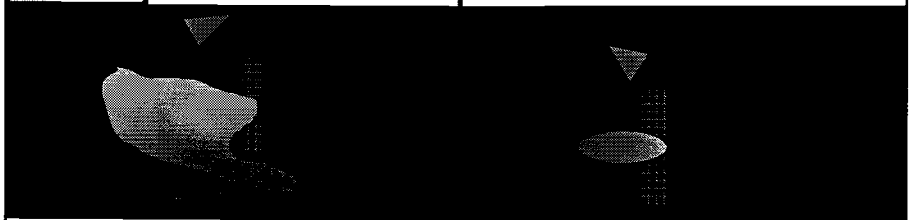
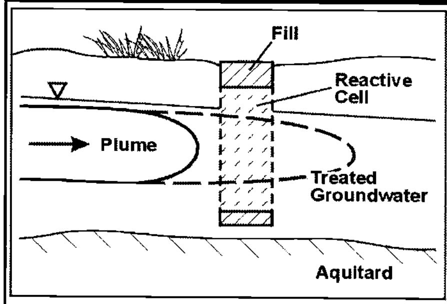
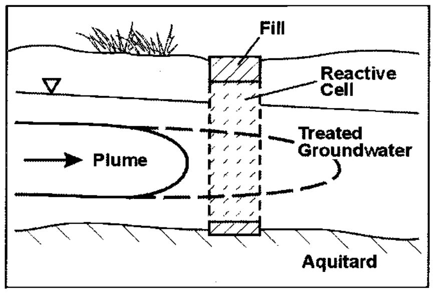
INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

**_Barrier Hanging above Aquitard_**

**_Barrier Keyed to Aquitard_**



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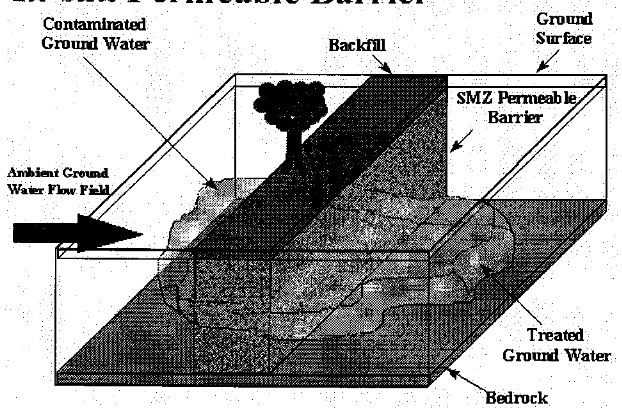
INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

# _Question & Answers_

## _In-situ_ Permeable Barrier




Oregon Graduate Institute and New Mexico Tech

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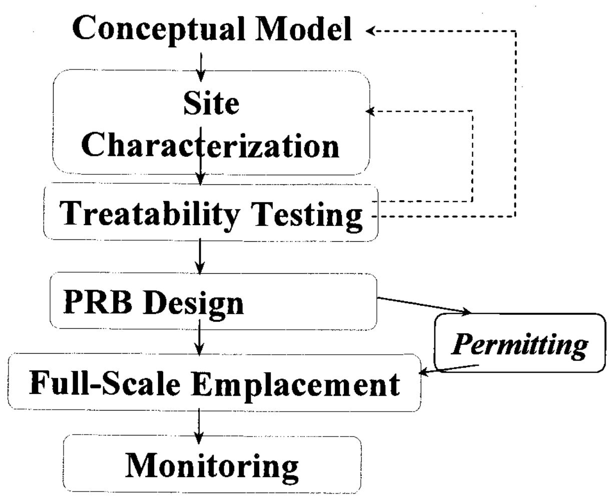
## PRB Application Methodology

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## Conceptual Model
## (Using available information to determine if a PRB is suitable at a given site)

★ The suitability of a contaminated site for PRB treatment is affected by the following factors:
- Contaminant type
- Plume size and distribution in 3 dimensions
- Depth of aquitard
- Geotechnical considerations
- Constructibility
- Groundwater flow characteristics
- Ground water geochemistry

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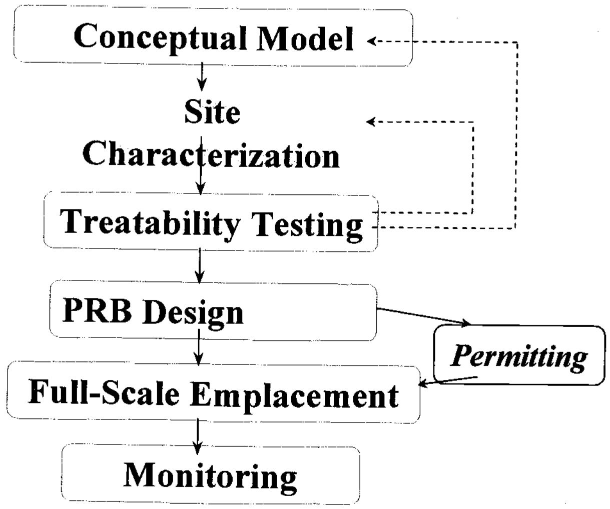
## PRB Application Methodology

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## Site Characterization and Design Information

- ★ **Need to Know**
  - **Composition of the Groundwater**
    - Types and concentrations of contaminants
    - Plume distribution
    - Geochemistry of groundwater (e.g., pH, DO, Ca, etc.)
  - **Hydrogeology of the Affected Aquifer**
    - Stratigraphy
    - Groundwater flow velocity and direction
- ★ **Used to**
  - **Select the appropriate reactive media,**
  - **Conduct treatability tests, and**
  - **Design the thickness of the wall**

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# PRB Application Methodology

Conceptual Model

Site Characterization

Treatability Testing

PRB Design

*Permitting*

Full-Scale Emplacement

Monitoring

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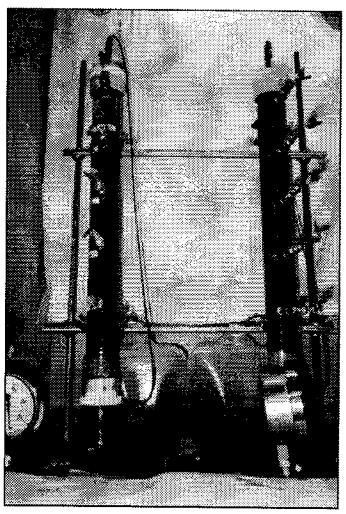
## *Treatability Testing for Reactive Media Selection and Design Information Gathering*



- ★ **Batch tests**
  - Quick screening of multiple reactive media
- ★ **Column tests**
  - Final selection of reactive media
  - Obtaining design information (contaminant half-lives or reaction rates)

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## Degradation of CVOCs with Iron - A strong reducing agent (electron donor)

$$Fe^0 \longrightarrow Fe^{+2} + 2e^-$$

$$2H_2O \longrightarrow 2H^+ + 2OH^-$$

$$2H^+ + 2e^- \longrightarrow H_{2(g)}$$

$$X\text{-}Cl + H^+ + 2e^- \longrightarrow X\text{-}H + Cl^-$$

$$C_2HCl_3 + 3H^+ + 6e^- \longrightarrow C_2H_4 + 3Cl^-$$

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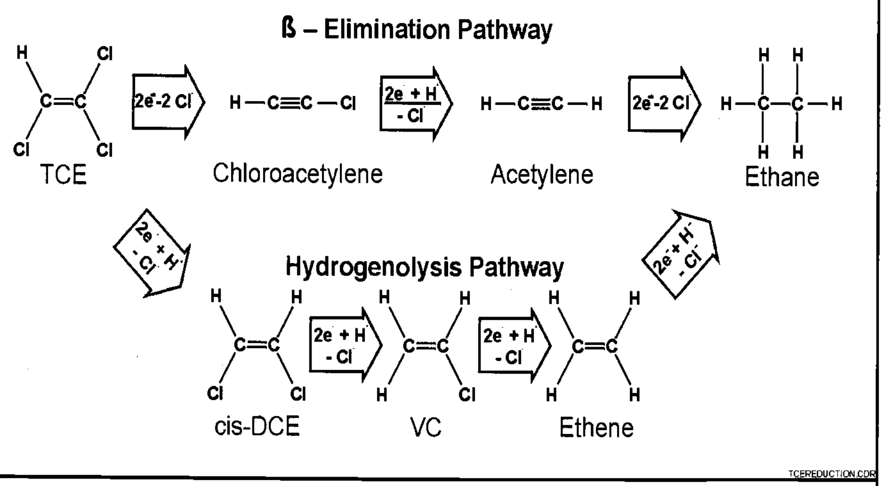
## Degradation of CVOCs with Iron - Beta-elimination (major pathway) and Hydrogenolysis (minor pathway)

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Roberts, A. L., et. al, 1996 Reductive Elimination of Chlorinated Ethylene by Zero-Valent Metals. Environmental Science and Technology,

## Using column test results and site characterization information to determine PRB thickness

- Half-lives (or reaction rate constants) of the contaminants for a given reactive medium
  - Based on column tests
  - Used to determine residence time in the reactive medium to reduce contaminants to target levels
- The flow-through thickness of the reactive cell
  - Is determined by residence time requirement and estimated groundwater velocity through the reactive cell
  - Adjusted for groundwater temperatures and the potentially lower field bulk *density* of the reactive medium

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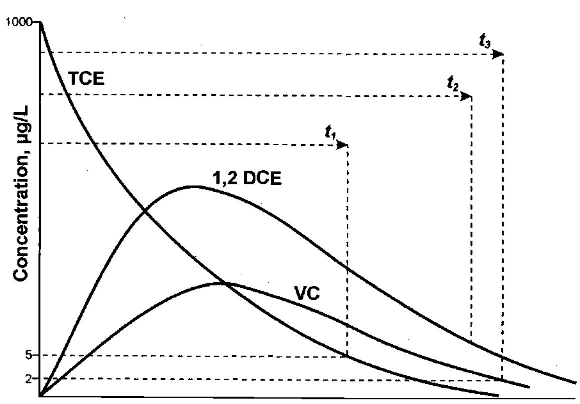
## Sizing the PRB for the Byproducts




ETI, ca. 1996, various sources
[$t_3$ is the required residence time] [not to scale]

- Do column feasibility study.
- Compare results to MCLs.
- Select $t_C$ for the last byproduct CoC to reach its MCL (e.g., $t_3$).

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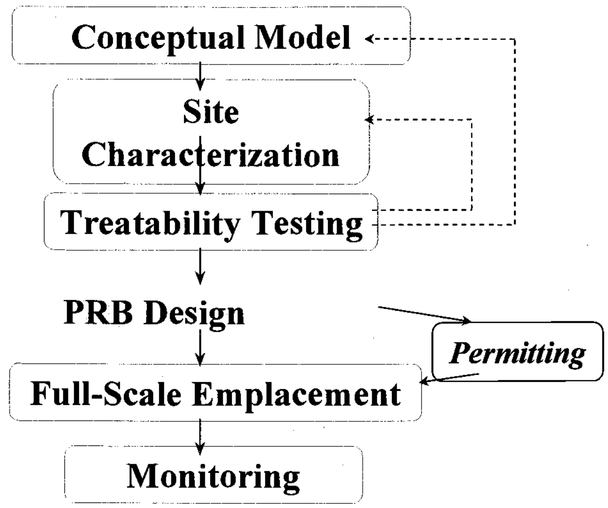
## PRB Application Methodology

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## PRB Design Objectives and Role of Groundwater Modeling

- ★ Determine suitable location, orientation, and configuration of PRB
- ★ Determine required thickness of PRB (for specified residence time)
- ★ Determine required width of PRB (for specified capture zone)
- ★ Plan monitoring well locations and frequencies

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**ITRC** INTERSTATE TECHNOLOGY REGULATORY COOPERATION

***Addressing longevity issues***
***-- Geochemistry factors that may limit the life of the iron medium through loss of reactivity and/or plugging (Requires long term monitoring of PRB)***

- ★ **Oxygen concentration**
  - **high dissolved $O_2$, increased $Fe(OH)_3$ precipitation (rust)**
  - **$Fe^0 + 1.5O_2 + 6H^+ > Fe(OH)_3 + 1.5H_2$**
- ★ **Carbonate alkalinity**
  - **precipitation of Fe, Ca, and Mg carbonates**
- ★ **Sulfate concentration**
  - **possible sulfide formation on iron**

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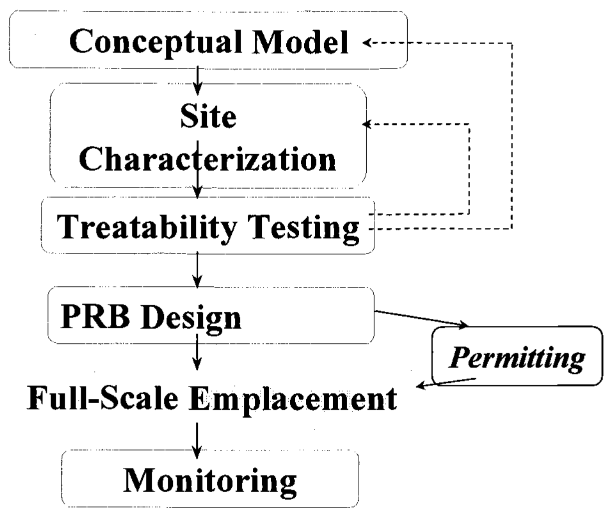
**ITRC** INTERSTATE TECHNOLOGY REGULATORY COOPERATION

## *PRB Application Methodology*

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INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

## PRB Emplacement Methods

- ★ Conventional Excavation (Backhoe)
- ★ Continuous Trencher
- ★ Caisson - cylinder driven into ground
- ★ Tremie Tube / Mandrel - 30 ft long 4" wide
- ★ Deep Soil Mixing
- ★ High Pressure Grouting (Jetting)
- ★ Vertical Hydraulic Fracturing
- ★ Geochemical Manipulation

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INTERSTATE TECHNOLOGY REGULATORY COOPERATION ITRC

## PRB Full-Scale Systems

- ★ Construction methods by end of 1999:
  - 20 continuous reactive walls
    - conventional excavation
    - continuous trencher
    - hydrofracturing
    - jetting
  - 5 funnel and gate systems
    - slurry wall
    - sheet piling
    - HDPE impermeable wall
  - In Situ Reaction Vessels

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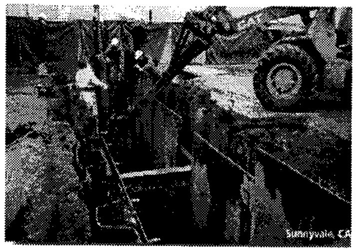
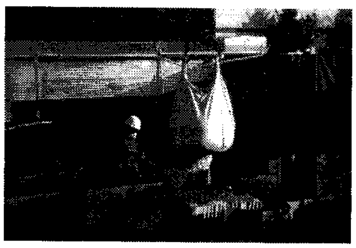
6/12/01

## Conventional Excavation (Backhoe)

Simplest Method



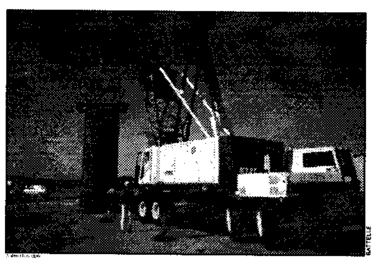



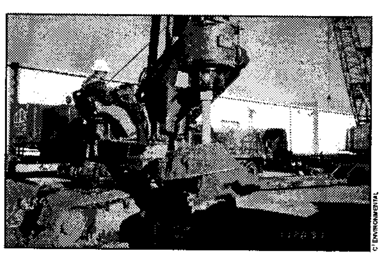
- ⋆Intersil Site, Sunnyvale, Ca., 1995
- ⋆30 Feet Deep
- ⋆Trench Gate (backhoe) and slurry funnel wall

cost $ 1 mil
grain size in litho powder

43

## Caisson-Based Emplacement





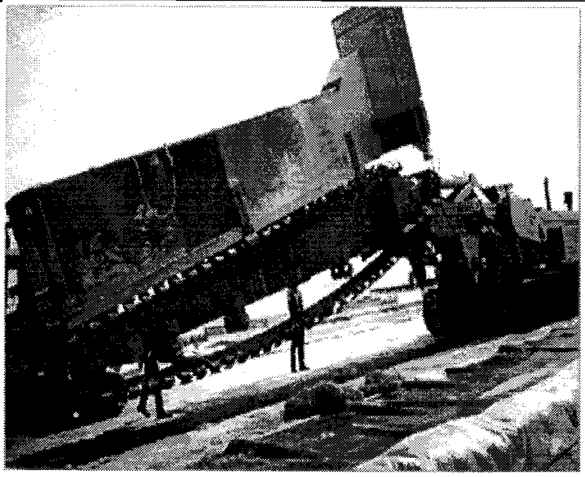
- ⋆Dover Air Force Base, Dover, De., 1997
- ⋆Keyed 40 ft (bgs) into clay aquitard
- ⋆Sheet pile funnel & two 8-foot diameter caisson gates

— Treatability approach — PCE 800
DCE 829

90-95% reduction

44

## Continuous Trencher (Elizabeth City *Photo)* – North Carolina)



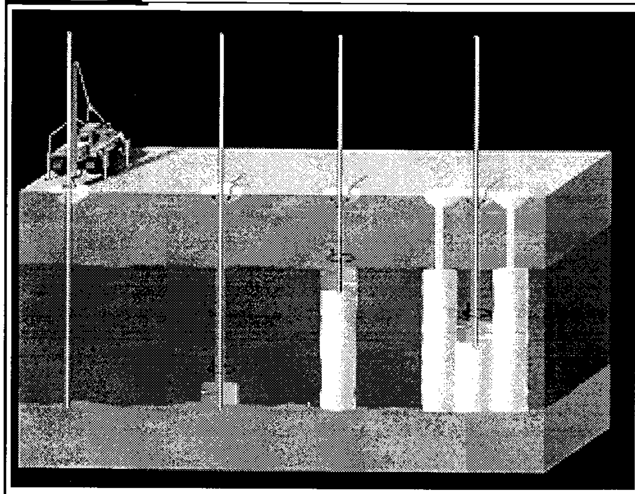
★Coast Guard site, Elizabeth City, NC 1996

★25 feet deep wall, hanging wall configuration – 2ft thick wall 150 ft long

★Continuous wall using continuous trencher

45

## Schematic of Jetting Process



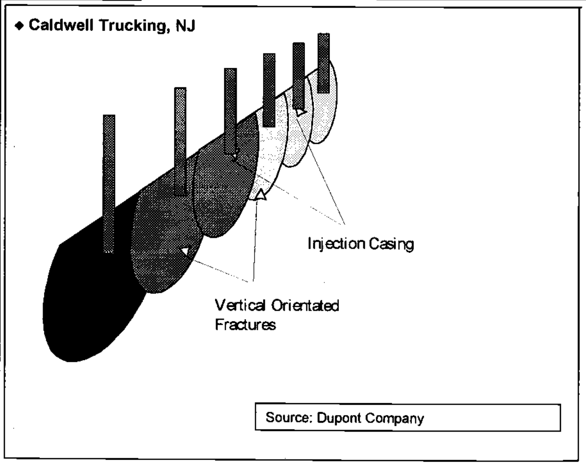
★Travis Air Force Base, Ca. 1999

★50 feet deep; overlapping injection – push rod down dry soil iron through rod -

★iron slurry injected at high pressure through nozzles

46

## Hydraulic Fracturing




- ★Caldwell Trucking site, NJ
- ★vertical (overlapping) hydraulic fractures created
- ★fractures filled w/ iron slurry (3-4" thick barrier)

15-50 feet
removing 95% of TCE
developed by John Surring

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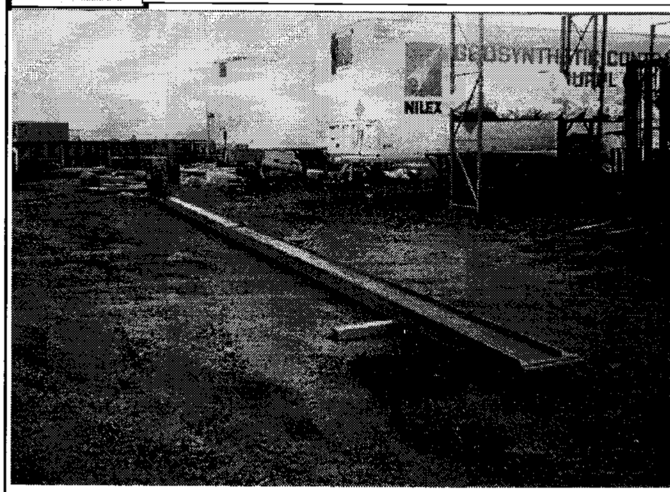
## Tremie Tube / Mandrel



- **★Pilot Test at Cape Canaveral, Fl. 1997**
- **★43 feet deep, mandrel driven into ground at overlapping locations**
- **★granular iron tremied into hole (4" barrier)**

deeper depths
insures reactive media
is placed properly.

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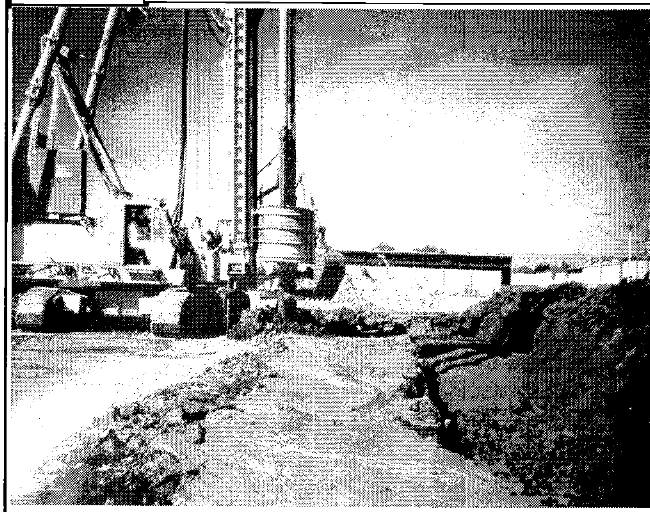
## Deep Soil Mixing

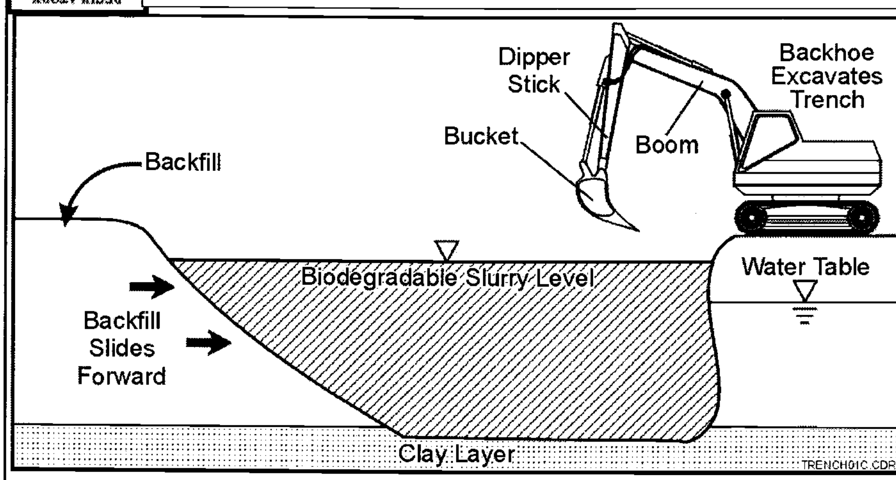


- ★Iron slurry fed through hollow stem augers
- ★iron-soil mixture created in subsurface
- ★overlapping penetrations

49

## Bioslurry

***Pease Airforce Base, NH, 1999***




50

Quick method - excavate & backfilling w/ the iron.

## PRB Economics

- Capital Investment
  - **Site Characterization/Treatability Test/Design**
  - **Reactive Medium and Construction**
- Annual O&M Costs
  - **Monitoring**
- Reactive Medium Maintenance Cost (may be required in the future for reactive medium replacement or regeneration)
  - **Frequency depends on longevity of reactive medium**
  - **Iron medium could last for several years**

51

Most costs are in characterization + monitoring - (personnel, operators - O&M costs)

## PRB Economics
*Cost-Benefit Analysis*

- Present Value Analysis (PV)
  - **estimate long-term costs of PRB**
- Multiple cost scenarios for varying life expectancies
- Compare PV of PRB w/ PV of other options (rather than comparing Capitol Investment and O&M Costs)
- Evaluate Costs of PRB against Benefits
  - **No annual operating requirements**
  - **no above ground structures**
  - **no above ground waste streams**

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## PRB Application Methodology

Conceptual Model

Site Characterization

Treatability Testing

PRB Design

*Permitting*

Full-Scale Emplacement

Monitoring

53

## Monitoring

★ **Compliance Monitoring Objective**
- Determine compliance with the applicable groundwater standard or criteria
- Regulatory requirements for monitoring

★ **Performance Monitoring Objective**
- Verification of performance of wall as designed
- Not typically considered regulatory monitoring requirements

54

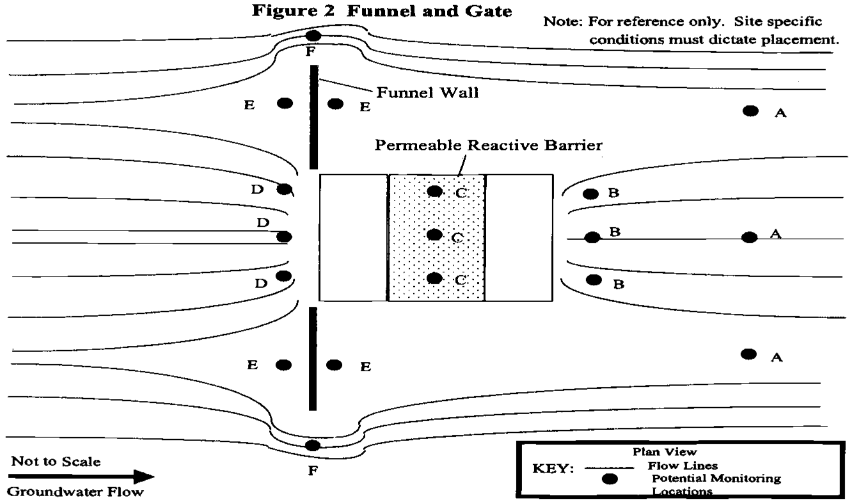
With these types of system one needs to consider Compliance & Performance

ITRC — Interstate Technology Regulatory Cooperation

# Hypothetical Monitoring Well Placement

**Figure 2 Funnel and Gate**

Note: For reference only. Site specific conditions must dictate placement.




55

Good idea to have wells on outer edges as well.

Gather as much data in the beginning.

ITRC — Interstate Technology Regulatory Cooperation

# Monitoring Frequency

- ★ 1st quarter after installation - **Monthly**
- ★ 1-2 years after installation - **Quarterly**
- ★ Long term - **Quarterly (may be modified/decreased based on performance)**
- ★ Post Closure - **TBD (based on closure method and parameters)**

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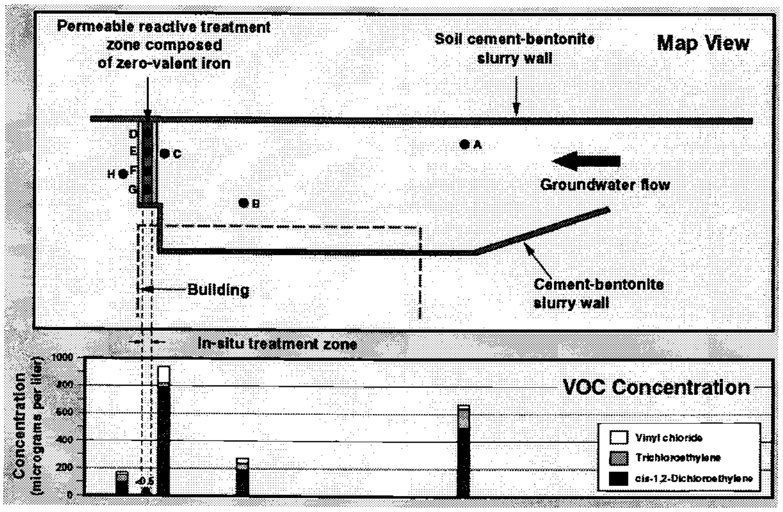
# Monitoring Results - Sunnyvale, Calif.

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# Permitting

- ★ **NPDES** - triggered by excess generated groundwater
- ★ **UIC** - triggered by reactive media placement
- ★ **Air Quality** -triggered by emission generation during installation
- ★ **RCRA Land Disposal Restrictions** (LDRs) - triggered by waste generated during site investigation or PRB installation
- ★ **Other** site-specific permits may apply (i.e. wetlands)

"Thorough review of all site/state-specific permitting issues is necessary"

58

- involvement depends on State -
Concerns - AQ -
RCRA -
Not a deal breaker.

Need to have some sort of M+A + Contingency plan - Plan in place to correct problems.

## Maintenance and Closure

★ Operation and Maintenance Plan
- **Contingency Sampling Plan (necessary in the event the PRB fails to meet performance or compliance criteria)**
- **Reactive media restoration or replacement**

★ Closure plan
- **Address whether the wall will remain in place or be removed after remediation goals have been met**

often times left in place

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ITRC tries to get stakeholders involved. Contamination is not a simple thing to remove. Walls are effective + will be in place for years.

## Stakeholder Issues

★ Long periods for treatment

★ Wall performance, & effectiveness

★ Reactive material disposal

★ Land access and deed restrictions

★ Radionuclide concentration ← not concern here

depends on what has been remediated, there may be concern as to what might be left.

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INTERSTATE TECHNOLOGY REGULATORY COOPERATION
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## Summary and Lessons Learned

### Technical Presentation Wrap-up w/ Q&A

- ★ *A PRB is a cost-effective long-term viable alternative for treating contaminants (VOCs and metals) in situ (compared to pump and treat and other active remedies)*
- ★ *The chemistry of treating VOCs using iron is well known*
- ★ *PRBs are being installed to depths approaching 120 feet*
- ★ *"Failures" in PRB performance have been due generally to failure of the hydraulic system: e.g., incomplete plume capture, residence time not maintained; incomplete site characterization*

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The reactive media that the treatment be affected through the passage of the water.

Chemistry is well known + there is no rush in the application

INTERSTATE TECHNOLOGY REGULATORY COOPERATION
ITRC

## Thank You!

ITRC Web Page

www.itrcweb.org
www.rtdf.org

remedial technologies development forum

& recent case studies + bibliography on

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**Incident Report for 04 June 2001 - Spill of Untreated Groundwater at IRP Site S-1**

**NOTIFICATION:** TNRCC was notified at approximately 1000 hrs on 06/04/01, point of contact was Ms. Abbi Power.

**REPORTED BY**: Mr. Chuck Meshako, AFBCA/DK

**DATE:** 06/04/2001

**TIME:** 0753 hrs

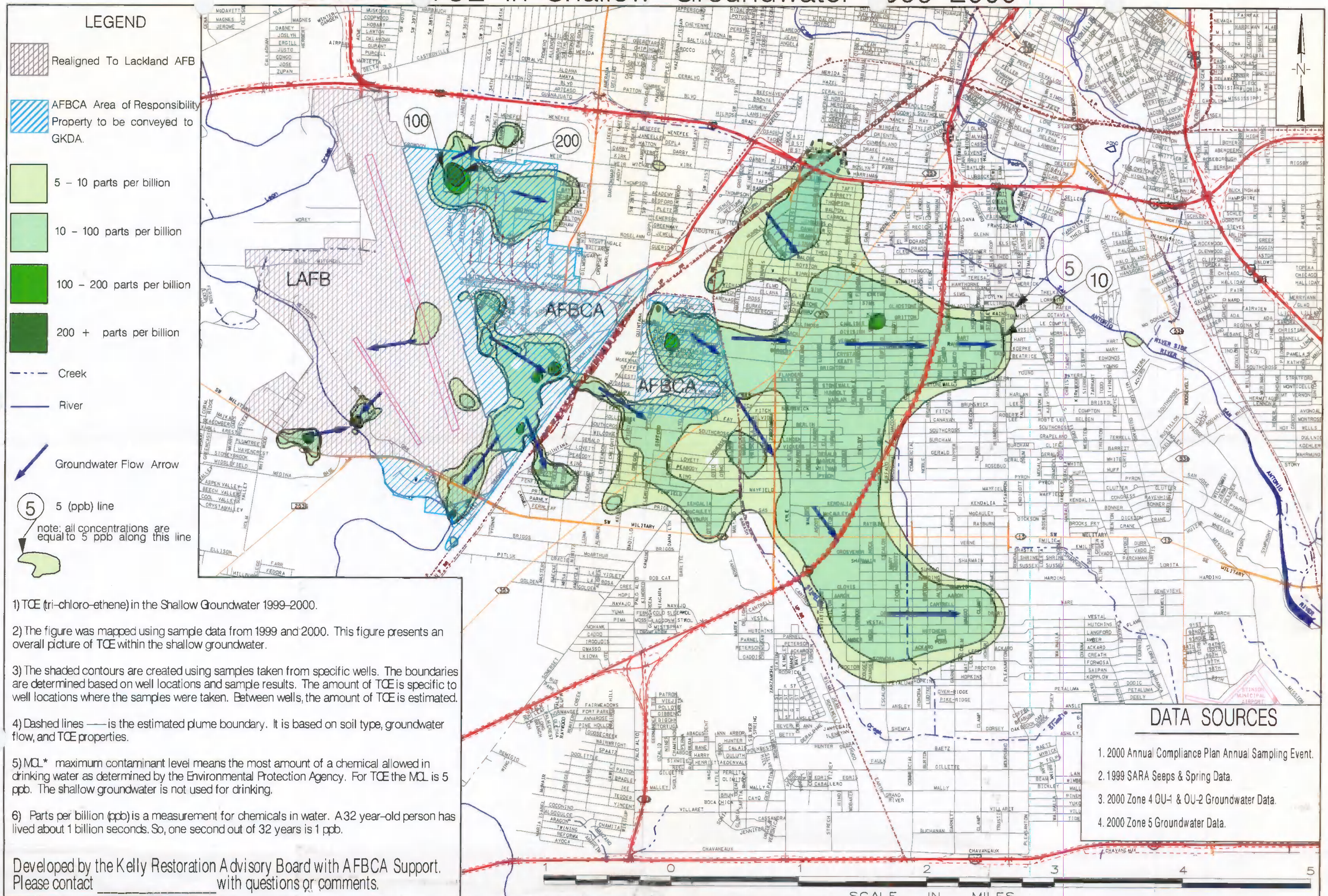
**TYPE:** Release of untreated groundwater from IRP Site S-1 treatment system to the grassy area surrounding the site. Worst case estimate for release is 15,000 gallons. Groundwater is primarily contaminated with chlorobenzene and benzene. Other significant contaminants include tetrachloroethene, tricholorethene, and dichloroethene. Extent of the spill is believed to be limited to the grassy area adjacent to the treatment plant and extend no closer than approximately 40 feet from storm sewer inlet.

**CAUSE:** Improper shutdown of system by operator caused the system to fail and overflow at the system's oil water separator over the weekend.

**LOCATION:** IRP Site S-1, Near Former 1592 Fuel Storage Tank Farm

**REQUIRED ACTION:** Standing water was recovered and placed in the secondary containment system at the site. One sample of standing water has been taken and it is being evaluated for volatile organic compounds. A second sample of a film (possible sheen) was taken and it is being evaluated for oils and greases. Soil samples are to be taken of the impacted area. All operators of the S-1 treatment system are to be trained in proper shutdown procedures. A follow-up written report will be sent to TNRCC Region 13. Attn: Abbi Power.

# DRAFT TCE in Shallow Groundwater 1999–2000




1) TCE (tri-chloro-ethene) in the Shallow Groundwater 1999-2000.

2) The figure was mapped using sample data from 1999 and 2000. This figure presents an overall picture of TCE within the shallow groundwater.

3) The shaded contours are created using samples taken from specific wells. The boundaries are determined based on well locations and sample results. The amount of TCE is specific to well locations where the samples were taken. Between wells, the amount of TCE is estimated.

4) Dashed lines ——is the estimated plume boundary. It is based on soil type, groundwater flow, and TCE properties.

5) MCL* maximum contaminant level means the most amount of a chemical allowed in drinking water as determined by the Environmental Protection Agency. For TCE the MCL is 5 ppb. The shallow groundwater is not used for drinking.

6) Parts per billion (ppb) is a measurement for chemicals in water. A 32 year-old person has lived about 1 billion seconds. So, one second out of 32 years is 1 ppb.

Developed by the Kelly Restoration Advisory Board with AFBCA Support.
Please contact ______________ with questions or comments.

## DATA SOURCES

1. 2000 Annual Compliance Plan Annual Sampling Event.
2. 1999 SARA Seeps & Spring Data.
3. 2000 Zone 4 OU-1 & OU-2 Groundwater Data.
4. 2000 Zone 5 Groundwater Data.

**DEPARTMENT OF THE AIR FORCE**
**AIR FORCE BASE CONVERSION AGENCY**

Air Force Base Conversion Agency
143 Billy Mitchell Blvd
Kelly AFB, Texas 78241

11 June 2001

Texas Natural Resource Conservation Commission
Attn: Ms. Abbi Power
Region 13
14250 Judson Rd.
San Antonio, Texas 78233-4480

RE: Release from Groundwater Bio-Augmentation Test Plot #2 near Building 360, Kelly AFB on April 10, 2001

Dear Ms Power

This letter supercedes our previous letter dated 10 May 01, same subject. We have added some additional information.

On April 10, 2001, Mr. Chuck Meshako of this office reported a leak of Zone 3 Groundwater to your office. The following information is submitted to meet the reporting requirements for this incident.

(1) Date and time of incident: The release was reported on April 10, 2001 at 1100. AFBCA contract personnel arrived at Zone 3 bio-augmentation test plot #2 at 1115 hrs and turned off the groundwater extraction system effectively ending the release.

(2) Identity and quantity of released material: 210 gallons of untreated groundwater pumped from the recirculation housing from 0930 hrs to 1115 hrs April 10, 2001.

(3) Cause of incident: The leak was the result of a ½-inch diameter recirculation pipe damaged by lawn maintenance equipment.

(4) Extent of contamination: The spill originally reported as covering 100 sq feet was investigated and determined to have covered a 25 to 35 sq. foot area of grass covered soil to a depth not greater than one foot, adjacent to Building 360, in the northwestern corner of the horseshoe see site map, Attachment 1.

(5) Contamination documentation: A sample was taken of the groundwater at extraction well E-5 and submitted for analysis on April 11, 2001. The results are provided as Attachment 2.

(6) Site Map: A site map of the Building 360 horseshoe area with the location of well E-5 is provided as Attachment 1.

(7) Analytical results: A groundwater sample was collected from the E-5 pipe that was damaged on April 11, 2001 and was analyzed for Volatile Organic Compounds (VOC's). Copies of the analytical results are included as Attachment 2. A summary of the results are provided in the following table:

| **Compound** | **Sample Results (micrograms/liter)** |
|---|---|
| Cis-1,2-Dichloroethene | 36.7 |
| Tetrachloroethene | 110 |
| Trichloroethene | 5 |
| Vinyl Chloride | <1.0 |
| Chloroform | 0.76 |

(8) Disposal: No groundwater was recovered and no disposal took place.

(9) Corrective Action: The pump was turned off at 1115 hrs and repairs were made.. Based on the limited volume of groundwater released and relatively low concentrations of contaminants no significant soil contamination is believed to have occurred and no further action is anticipated. Any potentially contaminated groundwater in the vicinity is being addressed as part of the Zone 2/3 Corrective Measures currently being conducted by the Air Force in Accordance with Compliance Plan No. CP-50310.

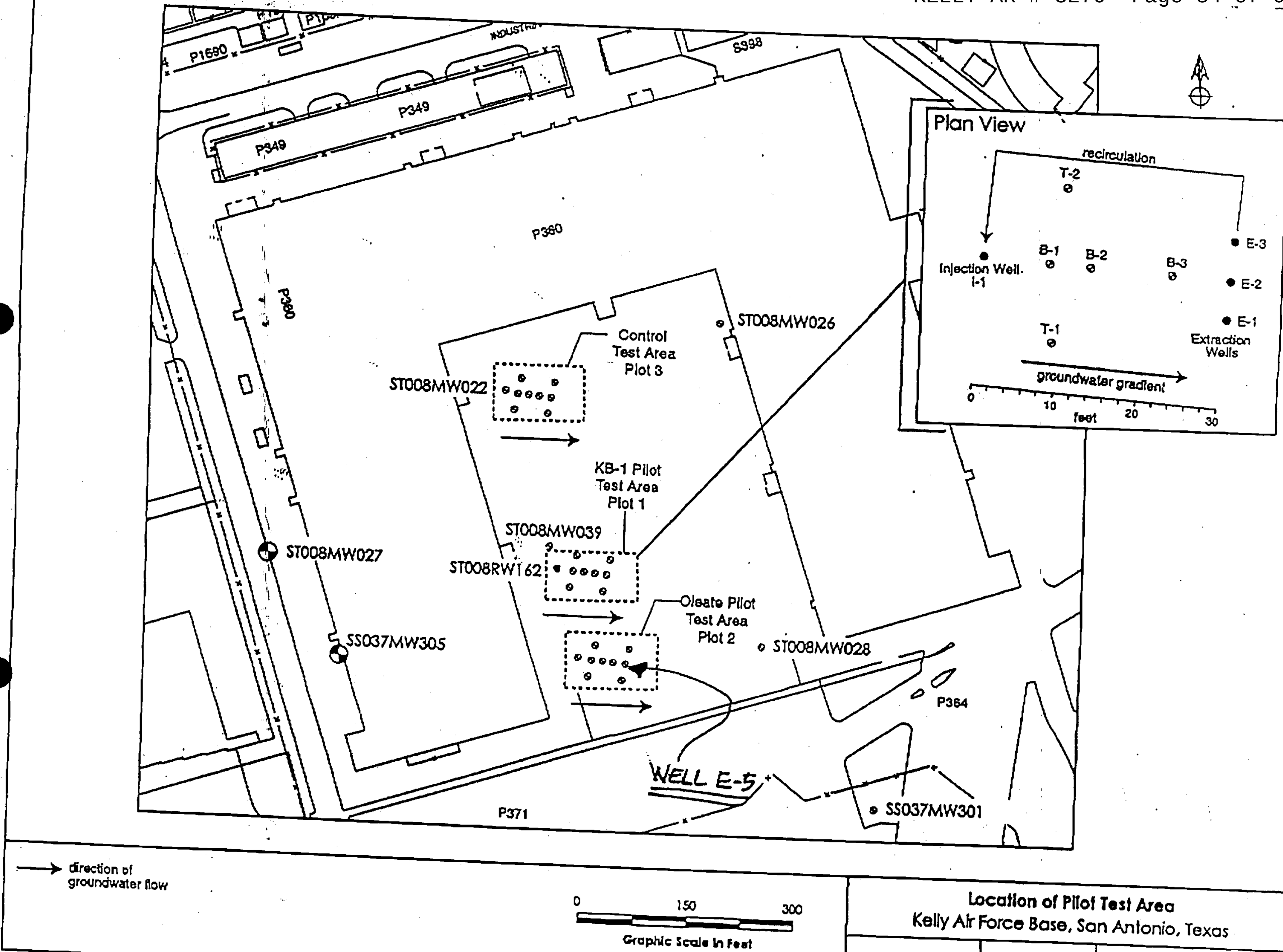
Please address any further questions or comments to Mr. Kenneth St. John at (210) 925-0195.

Sincerely

Chuck Meshako

CHUCK MESHAKO
Acting Chief, Environmental Compliance

Attachments:
1. Site Map 1
2. Copy of Analytical Report




**Location of Pilot Test Area**
Kelly Air Force Base, San Antonio, Texas

| Jan. 2001 | Figure: 2 | GeoSyntec Consultants |
|---|---|---|

**Incident Report for 04 June 2001 - Spill of Untreated Groundwater at IRP Site S-1**

**NOTIFICATION:** TNRCC was notified at approximately 1000 hrs on 06/04/01, point of contact was Ms. Abbi Power.

**REPORTED BY**: Mr. Chuck Meshako, AFBCA/DK

**DATE:** 06/04/2001

**TIME:** 0753 hrs

**TYPE:** Release of untreated groundwater from IRP Site S-1 treatment system to the grassy area surrounding the site. Worst case estimate for release is 15,000 gallons. Groundwater is primarily contaminated with chlorobenzene and benzene. Other significant contaminants include tetrachloroethene, tricholorethene, and dichloroethene. Extent of the spill is believed to be limited to the grassy area adjacent to the treatment plant and extend no closer than approximately 40 feet from storm sewer inlet.

**CAUSE:** Improper shutdown of system by operator caused the system to fail and overflow at the system's oil water separator over the weekend.

**LOCATION:** IRP Site S-1, Near Former 1592 Fuel Storage Tank Farm

**REQUIRED ACTION:** Standing water was recovered and placed in the secondary containment system at the site. One sample of standing water has been taken and it is being evaluated for volatile organic compounds. A second sample of a film (possible sheen) was taken and it is being evaluated for oils and greases. Soil samples are to be taken of the impacted area. All operators of the S-1 treatment system are to be trained in proper shutdown procedures. A follow-up written report will be sent to TNRCC Region 13. Attn: Abbi Power.

**DEPARTMENT OF THE AIR FORCE**
**AIR FORCE BASE CONVERSION AGENCY**

Air Force Base Conversion Agency
143 Billy Mitchell Blvd
Kelly AFB, Texas 78241

11 June 2001

Texas Natural Resource Conservation Commission
Attn: Ms. Abbi Power
Region 13
14250 Judson Rd.
San Antonio, Texas 78233-4480

RE: Wastewater Release at the Environmental Process Control Facility on April 11, 2001 at Kelly AFB

Dear Ms Power

This letter supercedes our previous letter dated 11 May 01 same subject. We have added some additional information.

On April 11, 2001, Mr. Chuck Meshako of this office reported a release of wastewater at the EPCF to your office. The following information is submitted to meet the reporting requirements for this incident.

(1) Date and time of incident: The release was identified at 06:30 on April 11, 2001.

(2) Identity and quantity of released material: 1000 to 5000 gallons of partially treated wastewater at the EPCF Temporary "Unipure" Package Treatment Plant. Analytical results are attached.

(3) Cause of incident: The release was the result of failure of the overflow switch in a catch tank to shutdown the influent pump, causing the partially treated wastewater to overflow the tank and containment area (Attachment 1).

(4) Extent of contamination: The spill covered an 200 sq. foot area of grass covered sand to a depth not greater than one foot, extending approximately 90 feet southwest of the tank (Attachment 2).

(5) Contamination documentation: Samples were taken of the wastewater in the overflow tank and submitted for analysis on April 6, 2001. The analytical results are found in the attached analytical report (Attachment 3).

(6) Site Map & Photographs: A site map of the Kelly EPCF area and spill-sampling tank is provided in attachment 2. Photographs are included in attachment 2 as Figures 1 through 3.

(7) Analytical results: Two samples of the wastewater for this system were taken on 16 April 2001. A sample of the influent wastewater was sampled and analyzed for metals, pesticides/PCBs, volatile organic compounds, and semi-volatile organic compounds. Results for pesticides/PCBs, semi-volatile compounds, and volatile compounds were all non-detect. A sample of the wastewater from the tank that overflowed, the "Black Tank", was taken and analyzed for metals. Results for pesticides/PCBs, semi-volatile compounds, and volatile compounds were all non-detect. Results for metals are listed in the following table:

| **Compound** | **Black Tank Sample Results (mg/L** | **Influent Sample Results (mg/L)** |
|---|---|---|
| Arsenic | <0.05 | Did not Analyze |
| Beryllium | <0.005 | <0.005 |
| Cadmium | <0.001 | <0.001 |
| Chromium | <0.01 | <0.01 |
| Lead | <0.005 | 4.78 |
| Manganese | 0.163 | 0.176 |
| Mercury | <0.0002 | <0.0002 |
| Nickel | 0.07 | 0.07 |
| Silver | <0.002 | <0.002 |
| Thallium | <0.01 | <0.01 |

Copies of the analytical results are included as attachment 3.

(8) Disposal: The containment area was pumped out and the wastewater reintroduced to the catch tank. No other disposal action has been taken.

(9) Corrective Action: The influent pump was shutdown at 0630 hrs. The limit switch was rewired to prevent the influent pump from pumping during an overflow situation. The work was completed and tested. Additional project supervision during off-hours has also been implemented. Based on the analytical results of the untreated wastewater, no significant soil contamination is suspected and no further action is anticipated. Any potentially contaminated groundwater in this vicinity is being addressed as part of the Zone 2/3 Corrective Measures currently being conducted by the Air Force in accordance with Compliance Plan No. CP-50310.

Please address any further questions or comments to Mr. Kenneth St. John at (210) 925-0195.

Sincerely

Chuck Meshako

CHUCK MESHAKO
Acting Chief, Environmental Compliance

Attachments:
1. Figures 1 through 3
2. Site Map 1
3. Chemical Analysis Results

FILE

DEPARTMENT OF THE AIR FORCE
AIR FORCE BASE CONVERSION AGENCY

Air Force Base Conversion Agency
143 Billy Mitchell Blvd
Kelly AFB, Texas 78241

June 01, 2001

Texas Natural Resource Conservation Commission
Attn: Ms. Abbi Power
Region 13
14250 Judson Rd.
San Antonio, Texas 78233-4480

RE: Chromium Release near Kelly AFB Building 301

Dear Ms Power

On April 24, 2001, Mr. Chuck Meshako of this office reported a release from the building 301 plating shop decommissioning effort into the Kelly AFB Storm Sewers near Building 301 to Ms. Melissa Story of your office. The following information is submitted to meet the reporting requirements for this incident.

(1) Date and time of incident: The release was reported to AFBCA Kelly at 10:45a.m. April 23, 2001.

(2) Site Map & Photographs: A site map of the Building 301 area showing chromium scrubber locations, trench and spill-sampling locations is Attachment 1. Photographs referenced are included as Attachment 2.

(3) Identity and quantity of released material: Initial estimates indicated the release was approximately 2 to 3 gallons of a black/green oily substance covering a puddle of rainwater about 60 square feet in surface area. However, approximately five and a quarter inches of rain fell during the response. The substance contained chromium, which dissolved into the rainwater turning it green. A quantification of chromium released is not possible due to the numerous unknown variables. These variables include amount of rainwater in contact with material, leachate rates and levels, amount of on-site infiltration and amount of mixing with other rainwater before entering storm drains.

(4) Cause of incident: A trench created during the cleanup of a previous spill event on 02 April 1997 from the chromium scrubbers was discovered to be about three quarters full with a thin layer of black/green oily substance on rainwater. (See Figure 1.) The trench continued to fill with rainwater and began to overflow during the five and a quarter inch rain event. This trench is approximately twenty feet long by three feet wide by two feet deep. Originally, existing

soil contamination in the trench was suspected of releasing the substance and contaminating the rainwater. Visual inspection of the site on 24 April 2001 at 0815 hrs identified the level of potential chromium contamination in the water was indicative of a new release and probably not just from previously existing soil contamination as previously believed. The most likely suspect based on staining is that rainwater came into contact with a recently dismantled chromium scrubber system and scrubber pad (concrete) causing a release of chromium. (See Figures 2, 3, 4 and 5.)

Inspection of the site identified several depressions with staining in the vicinity indicating contamination, including at a lined and covered roll-off container. While the roll-off was leaking water, the area where the leak pooled may have been contaminated by the release next to the scrubber pad during the rain event. (See Figure 5.) It was not definitively determined if this contamination came from the roll-off container or the scrubber area. The roll-off's contents (primarily piping) were power washed before being placing into the roll-off container.

(5) Extent of contamination: Given the presence of puddles on the pavement in the area on the morning of 24 April and the report of a "minimal amount of liquid" not being contained on 23 April, the volume of potentially contaminated rainwater that may have entered the storm drain and Leon Creek is not known. The full nature and extent of any potential soil contamination will be evaluated as part of the Building 301 Removal Project currently on-going and scheduled for completion by March 2002.

(6) Contamination documentation and Analytical results: Spilt samples of the water from the trench and two soil sample locations in front of the adjacent storm water drains were collected for RCRA 8 total metals plus Nickel analysis on April 24, 2001. (See Figures 6 and 7.) Total Hydrocarbon (TPH) analysis was added later to one set of the samples. There was no detection of TPH at 50 mg/Kg. The spilt water sample had chromium at about 7 mg/Kg and conflicting results for low levels of arsenic, barium and lead. Soil samples showed levels of arsenic, cadmium, chromium, lead, and nickel above both background and Risk Reduction Standard 2 (RRS2) for Groundwater Protective Industrial (GWP-Ind). SPLP analysis indicated these metals would not leach above the RRS2 Groundwater Industrial (GW-Ind). While mercury was below the GWP-Ind for soil, the SPLP slightly exceeded the GW-Ind. A summary of metal results is included as Attachment 3 and copies of the reports are included as Attachment 4.

(7) Corrective Action: Booms were used to contain all of the material and most of the rainwater in the trench until a vacuum truck was able to pump the trench. (See Figure 8.) Absorbent pads were used to recover the greenish water standing on the pavement. Due to the heavy rains, the vacuum truck was called out a second time. In all, the vacuum truck removed 3800 gallons of contaminated water and the floating material from the trench area. An additional 75 gallons of contaminated water was removed from the trench area and placed in the building 301 sumps.

The scrubbers were sent to disposal. Initially, light plastic was placed over the scrubber pads to prevent additional releases. It was determined the light plastic was not sufficient to remain intact until the concrete is removed in September 2001. Therefore, the light plastic was replaced with 20 mil HDPE with sand covering 100% of the perimeter and safety grating covering holes in the concrete adding additional weight to the center. The trench was backfilled with sand tapered from the top of the scrubber pad on one side to grade on the other side. (See Figures 10, 11, 12 and 13.)

Approximately 30 cubic yards of soil were excavated from the release area and the excavation backfilled with red clay to prevent rainwater from further contacting contaminated soils. (See Figure 14.)

Absorbent pads were placed under the leak until the contents of the leaking roll-off container were placed in a hazardous waste roll-off and disposed of at a licensed disposal facility. (See Figure 15.) The leaking roll-off was decontaminated in the decon area of building 301.

(8) Disposal: 3800 gallons of contaminated water/material and the contents of the leaking roll-off container were disposed of by Texas Ecologist at Robstown, TX. An additional 75 gallons of contaminated water was pumped from the trenches and placed in the building 301 sumps for disposal with additional decon and demolition cleanup waters. Soil disposal is anticipated to occur about 30 June 2001, pending analytical results. During the interim, the soil is being staged at the excavation on plastic and covered with plastic. (See Figure 16.)

(9) Future Actions: Demolition and removal of building 301 is ongoing. Soil sampling will occur this summer to determine the extent of soil contaminated as a result of this incident. Soil requiring removal will be excavated when the building 301 basement and scrubber pads are excavated. The excavation is currently scheduled for September 2001, but is contingent on the decontamination and removal of the building. Therefore, we respectfully request a six-month extension to complete the response action.

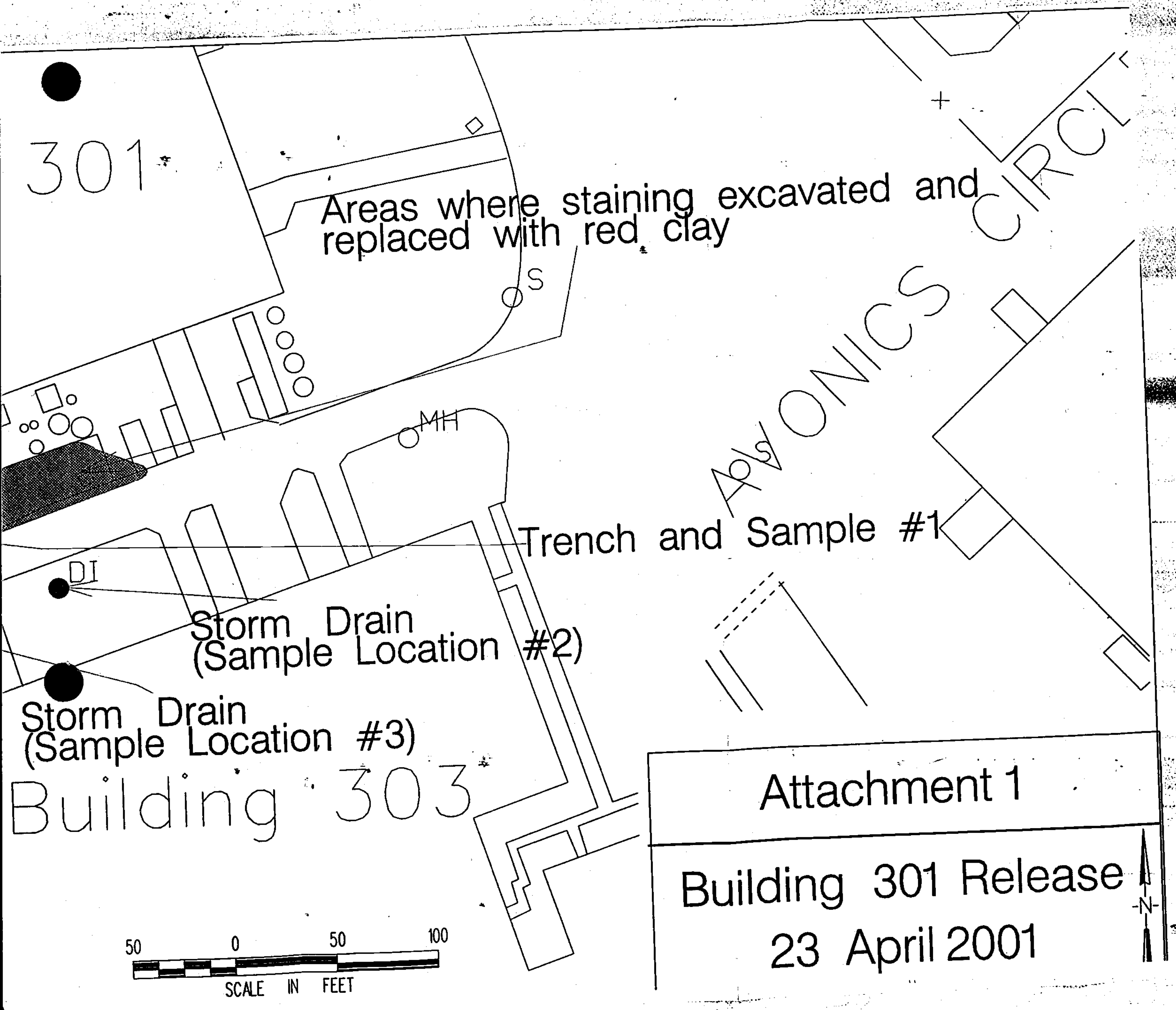
We look forward to working with you as we continue to remedy the environmental impacts of this incident. Please address any further questions or comments to Mr. Kenneth St. John at (210) 925-0195.

Sincerely

Adam G. Antwine

ADAM G. ANTWINE
Acting Senior Representative

Attachments:
1. Site Map
2. Figures
3. Chemical Analysis Results Summary
4. Chemical Analysis Results Reports




Attachment 1

Building 301 Release
23 April 2001

# REPORTS FOR ST MARY'S

| | REPORTS LISTED BELOW WERE TAKEN TO THE ST. MARY'S LIBRARY - BCT On 12 June 2001 | Status | Date | ADM |
|---|---|---|---|---|
| 460 | Installation of Groundwater Recovery & Treatment System, Zone 4 | Final | Feb 01 | Inf |

Date: June 12, 2001

Signature: [signature]

# FINAL PAGE

ADMINISTRATIVE RECORD

FINAL PAGE