

# **RCRA CORRECTIVE ACTION CONFERENCE**

**March 26 - 28, 1996**



**U.S. Environmental Protection Agency**

**Region IX**



**1996 RCRA CORRECTIVE ACTION CONFERENCE**  
**U.S. Environmental Protection Agency**  
**Region IX**

**AGENDA**

**Tuesday, March 26**

- 8:00 - 9:00 Registration
- 9:00 - 9:05 Logistics/Conference Structure
- 9:05 - 9:20 Opening Remarks (*Laura Yoshii, EPA Region 9*)
- 9:20 - 10:15 National Perspective-Subpart S, HWIR (*Guy Tomassoni, EPA Headquarters*)
- 10:15-10:30 Region 9 Corrective Action Universe (*Larry Bowerman, EPA Region 9*)
- 10:30-10:45 Break
- 10:45-11:15 State Perspectives (*Calif: Watson Gin, Cal-EPA/DTSC*)
- 11:15-11:45 Community Involvement (*Denny Larson, Communities for a Better Environment*)
- 11:45- 1:00 LUNCH
- 1:00 - 1:30 Ecological Toxicity Overview (*Clarence Callahan, EPA Region 9*)
- 1:30 - 1:45 Human Health Toxicity Overview (*Patrick Wilson EPA Region 9*)
- 1:45 - 2:10 Preliminary Remediation Goals (*Dan Stralka, EPA Region 9*)
- 2:10 - 2:30 Cal/TOX and PRGs in California (*Jeffrey Wong, Cal-EPA/DTSC*)
- 2:30 - 2:45 Permit Writers Perspective on Cal/TOX (*Sarah Picker, Cal-EPA/DTSC*)
- 2:45 - 3:15 Risk/Exposure Assessment Case Study (*Ravi Arulanantham, Cal-EPA/RWQCB*)
- 3:15 - 3:30 Break
- 3:30 - 4:30 RCRA Containment Methods (*Jeffrey Dunn and Harold Tuchfeld, Geosyntec Consultants*)
- 4:30 - 5:00 Corrective Action Case Study: Metals Contamination at Square D Company  
(*Mohinder Sandhu, Karen Baker, Cal-EPA/DTSC; Gladys Thomas, Square D*)
- 5:00 - 5:30 Open Discussion with EPA HQ (*Guy Tomassoni, EPA Headquarters*)

**Wednesday, March 27**

- 8:30 - 10:00 Vadose Zone Contaminant Transport (*Ron Sims, Utah State University*)
- 10:00-10:30 Waste Burial in Arid Regions (*Brian Andraski, US Geological Survey*)
- 10:30-10:45 Break
- 10:45-11:15 Accelerated Site Characterization (*Richard McJunkin, Cal-EPA/DTSC*)
- 11:15-11:45 Water Isotopes as Tracers (*Brian Smith, Lawrence Berkeley Laboratory*)
- 11:45-12:15 Soil VOC Methanol Preservation (*Kurt Zeppetello, AZ Dept. of Env. Quality*)
- 12:15- 1:30 LUNCH
- 1:30 - 2:00 Bacterial Dechlorination of TCE & PCE (*Ned Black, EPA Region 9*)
- 2:00 - 2:45 Leaking Underground Fuel Tank (LUFT) Remediation (*David Rice, LLNL*)
- 2:45 - 3:00 Break
- 3:00 - 3:30 Technical Impracticability w/Case St. (*Matt Hagemann, EPA Region 9*)
- 3:30 - 4:00 Containment Zones (*Steve Morse, Cal-EPA/RWQCB*)
- 4:00 - 4:30 IT-Vine Hill Case Study (*Valerie Heusinkveld, Cal-EPA/DTSC; Jane Zevely, IT Vine Hill*)
- 4:30 - 4:45 Closing Remarks (*Michael Feeley, EPA Region 9*)
- 4:45 - 5:15 Open Mike



**Thursday, March 28 (Regulators Only)**

8:30 - 9:00 Importance of Field Oversight (*Brian Lewis, Cal-EPA/DTSC*)  
9:00 -10:00 Laboratory Data Interpretation (*Kathy Baylor, Ray Saracino, EPA Region 9*)  
10:00-10:15 Break  
10:15 -12:00 State-Specific Issues (*Paula Bisson, EPA Region 9*)  
12:00 Conference Ends





# DINING OUT

## AMERICAN

- 1 BRASS ELEPHANT**  
GROSVENOR HOTEL  
380 SOUTH AIRPORT BLVD.  
873-3200  
L: \$5.00-\$8.00  
D: \$10.00-\$15.00
- 2 BURGER KING**  
972 EL CAMINO REAL  
583-7092  
L,D: \$2.00-\$5.00
- 3 CAFE ON THE PARK**  
RAMADA INN  
245 SOUTH AIRPORT BLVD.  
589-7200  
L: \$5.00-\$7.00  
D: \$10.00-\$18.00
- 4 CITY CAFE**  
HOLIDAY INN  
275 SOUTH AIRPORT BLVD.  
873-3550  
L: \$5.00-\$7.00  
D: \$8.00-\$12.00
- 5 HUNGRY HUNTER**  
180 SOUTH AIRPORT BLVD.  
873-5131  
L: \$5.00-\$8.00  
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- 6 JO ANN'S CAFE**  
1131 EL CAMINO REAL  
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L: \$6.00-\$9.00
- 7 LYON'S RESTAURANT**  
10 AIRPORT BLVD.  
871-5885  
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- 8 ST. MAMES BAR & GRILL**  
CROWN STERLING  
250 GATEWAY BLVD.  
589-3400  
L: \$8.00-\$12.00  
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## DELICATESSEN

- 9 D & M LIQUOR & DELI**  
211 SPRUCE AVE.  
583-4121  
L,D: \$3.00-\$6.00
- 10 DARBY DANS GOURMET SANDWICH**  
733 AIRPORT BLVD.  
876-0122  
L,D: \$4.00-\$7.00
- 11 LA TAPATIA**  
411 GRAND AVE.  
589-5881  
L,D: \$4.00-\$8.00
- 12 LIBERTY DELI-MART**  
812 LINDEN AVE.  
583-7892  
L,D: \$3.00-\$6.00
- 13 LITTLE LUCCA DELI**  
724 EL CAMINO REAL  
589-8916  
L,D: \$4.00-7.00

## FRENCH/BASQUE

- 14 BASQUE CULTURAL CENTER**  
599 RAILROAD AVE.  
583-8091  
L: \$8.00-\$12.00  
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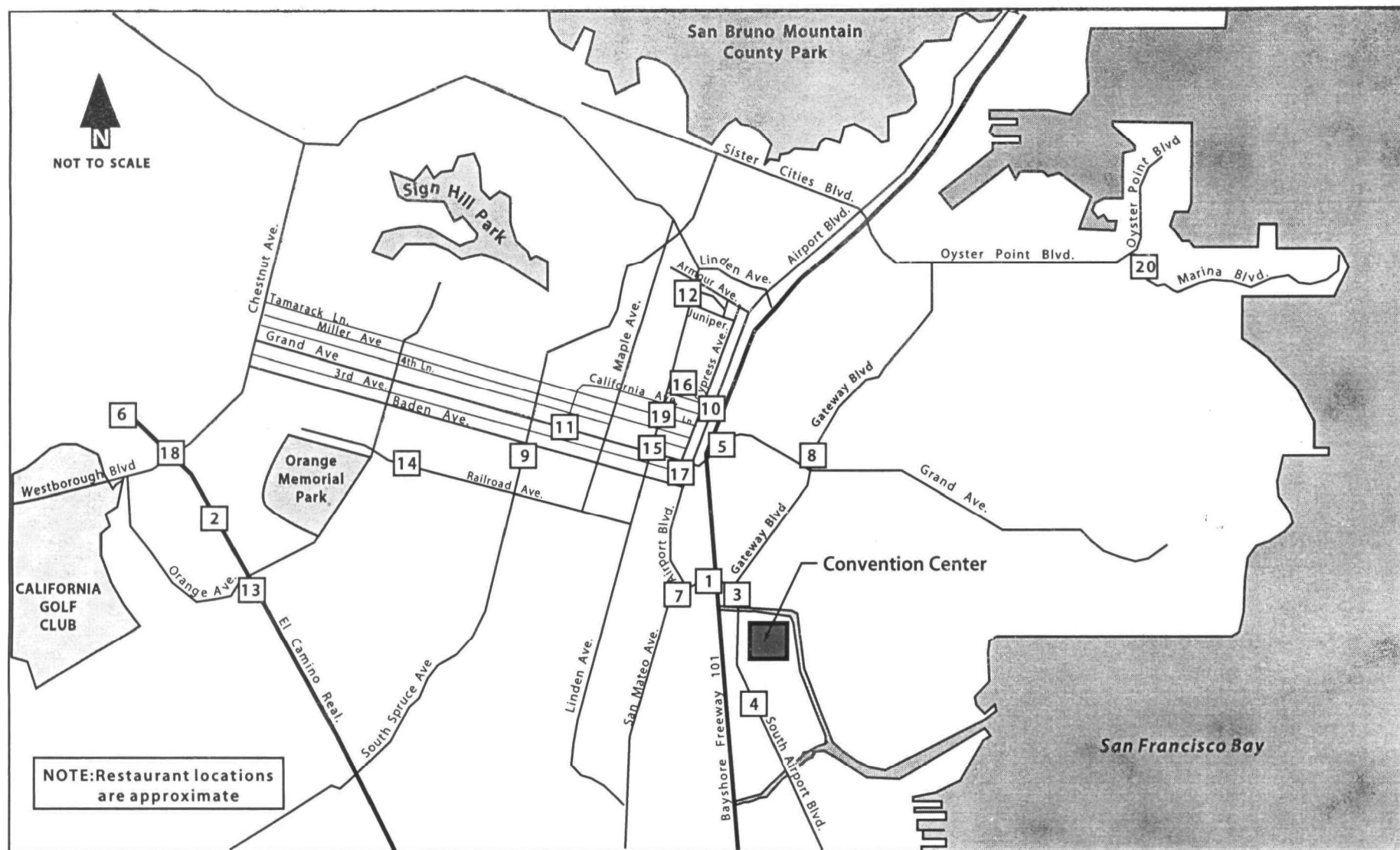
## MEXICAN

- 15 EL CHARRO**  
257 GRAND AVE.  
873-1993  
L,D: \$4.00-\$8.00

## ITALIAN

- 16 BERTOLUCCI'S RESTAURANT**  
421 CYPRESS AVE.  
588-1625  
L: \$8.00-\$12.00  
D: \$15.00-\$20.00
- 17 BUON GUSTO RESTAURANT**  
224 GRAND AVE.  
742-9777  
L: \$8.00-\$12.00  
D: \$12.00-\$18.00
- 18 CAPRI RESTAURANT**  
1129 EL CAMINO REAL  
588-6078  
D: \$8.00-\$12.00
- 19 DI NAPOLI PIZZA/PASTA**  
608 LINDEN AVE.  
873-5252  
L: \$5.00-\$9.00  
D: \$8.00-\$12.00
- 20 PASTA MOON EAST, INC.**  
425 MARINA BLVD.  
876-7090  
L: \$8.00-\$12.00  
D: \$12.00-\$18.00







# **RCRA CORRECTIVE ACTION CONFERENCE**

**March 26 - 28, 1996**

**South San Francisco, CA**



**U.S. Environmental Protection Agency**  
**Region IX**



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## INTRODUCTION

Welcome to the EPA Region 9 1996 RCRA Corrective Action Conference. We believe the conference is an excellent forum for people working on corrective action from all over the region to meet each other and share their ideas and experiences. Thank you for attending.

Corrective action is a very large and important program throughout EPA Region 9. In general, corrective action is the process of investigating and cleaning-up chemical releases from hazardous waste management facilities. The Resource Conservation and Recovery Act (RCRA), as amended, provides EPA with the legal authority to require corrective action at hazardous waste management facilities. The corrective action process involves many disciplines, including, hydrogeology, toxicology, ecology, treatment processes and many others. The speakers at the conference will discuss many of these interesting areas along with a number of case studies.

The primary purpose of this document is to provide participants at the conference with a compilation of speakers notes. Not all of the speakers have provided material for inclusion into this compilation. For easier reference, the notes are listed in the same sequence as the presentations on the conference agenda.

## DISCLAIMER

The presenters' notes or outlines in this document have been supplied by the speakers and have not been peer reviewed by EPA. Views expressed either in the notes or in the presentations are strictly those of the individual speakers and do not necessarily represent Federal, State or local policy. EPA is not responsible for any errors in the notes or presentations. Moreover, mention of trade names, commercial products, or publications does not constitute endorsement or recommendation for use.

## ACKNOWLEDGMENTS

This conference was planned and organized by the following individuals from U.S. EPA Region 9:

<u>Planning Committee</u>		<u>Management</u>	<u>Contractor **</u>
Katherine Baylor (Co-Chair)		Laura Yoshii	Suzanne Kraft
Ron Leach (Co-Chair)		Michael Feeley	Neil Munro
		Larry Bowerman	
		Paula Bisson	
Mary Blevins	Carmen Santos		
Susan Chiu	Ray Saracino		
Tom Kelly	Vicky Semones*		
Steve Linder	Carl Warren	* Office of Community Relations	
Elaine Ngo	Nahid Zoueshtiagh	** PRC Environmental Management, Inc.	





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# **EPA HEADQUARTERS ISSUES**

**presented at**

## **REGION IX CORRECTIVE ACTION CONFERENCE**

**by**

**Guy Tomassoni  
USEPA, Office of Solid Waste  
703/308-8622**

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# EPA ISSUES

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- Subpart S Initiative
- HWIR-Contaminated Media Rule
- Post-Closure Rule
- Legislative Activities
- Miscellaneous
- Summary



# Subpart S Initiative

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- Five primary objectives
  1. Create a consistent, holistic approach to cleanup at RCRA facilities
  2. Establish protective, practical cleanup expectations
  3. Shift more of the responsibilities for achieving cleanup goals to the regulated community
  4. Focus on opportunities to streamline and reduce costs
  5. Increase opportunities for meaningful public involvement throughout corrective action





## Subpart S Initiative (cont.)

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- Issue Advance Notice of Proposed Rulemaking (ANPR), developed through EPA/State Workgroup
- ANPR has three purposes:
  - Open a dialogue on program development and improvement (i.e., introduces strategy for initiative and seeks broad-based comments to help identify and develop program improvements)
  - To provide context for comments, includes a general status report on program and how it has evolved since 1990 proposal
  - Emphasizes areas of current flexibility



## Subpart S Initiative (cont.)

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- Some of the key messages conveyed in ANPR
  - No one approach to cleanup is appropriate for all corrective action facilities
  - Focus on results rather than a prescribed mechanistic cleanup process
  - Focus resources first on controlling unacceptable exposures and stabilizing continuing releases
  - Corrective action obligations should be addressed using the most appropriate tool for any given facility, including RCRA orders or permits, state cleanup orders, and voluntary programs



## Subpart S Initiative (cont.)

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- Summarizes key elements of 1990 proposal, recent policy developments, and areas of flexibility, including:

Principle of parity between RCRA and Superfund

Role of voluntary cleanup

Cleanup of non-SWMU releases

Use of data quality objective (DQO) concept

Use of innovative site characterization techniques

Role of human health and ecologic risk assessment

Formal corrective measures study not always needed

Role of action levels

Natural attenuation

Technical impracticability

Media cleanup standards and points of compliance

Recognizing non-residential land use assumptions

Stabilization initiative and relat. to interim measures

Use of presumptive remedies

Phasing corrective action



## Subpart S Initiative (cont.)

- ANPR requests comment on:

General implementation of CA program

Scope and form of final corrective action regulations

Elements of 1990 proposal needing additional notice/comment

Self-implementing corrective action, including third-party oversight

Land use assumptions and institutional controls

Point of compliance issues

Measuring and enforcing performance standards

Focusing less on SWMU

State authorization and role of EPA in authorized states

Life of corrective action permits

Affect of property transfer on CA requirements (selling of SWMU)

Financial assurance

Expanding opportunities for public involvement

Voluntary cleanup

Applicability of ASTM RBCA approach

Life of corrective action permits





## Subpart S Initiative (cont.)

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- Next Steps
  - Publish ANPR in federal register and place on Internet; 90 day comment period
  - Assess comments and develop strategy for developing guidance and re-proposing/finalizing corrective action regulations
    - Target, strategy by fall 1996
    - Target, re-proposal/final rule by fall 1997
- HQ contact Guy Tomassoni 703/308-8622 or Hugh Davis 703/308-8633



# HWIR-Contaminated Media Rule

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- Official title “Requirements for the Management of Hazardous Contaminated Media” -- commonly referred to as the “Hazardous Waste Identification Rule for Contaminated Media or (HWIR-media)”
- Rule would establish a “bright line”
  - Contaminated media above bright line would remain subject to Subtitle C
  - Below bright line, EPA and authorized states would have authority to exempt media from Subtitle C
- Rule will modify RCRA requirements (e.g., LDRs, MTRs, and permitting) for contaminated media



## HWIR-Contaminated Media Rule (cont.)

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- HWIR-media does not set cleanup standards
  - Rule addresses contaminated media generated by cleanup; Subpart S addresses when, how and to what extent cleanup should be conducted.
- Would withdraw Corrective Action Management Unit (CAMU) regulations
  - CAMUs approved prior to final HWIR-media rule (which would officially withdraw CAMU - expected June 1997) would be “grandfathered”
- Proposal expected March/April 1996; HQcontact: Carolyn Hoskinson 703/308-8626



# Post-Closure Rule

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- Proposed November 1994
  1. Remove the Post-Closure (PC) Permit Requirement
    - Would remove requirement to obtain permit for post-closure period and allow EPA/authorized State to use other authorities to address PC provisions
  2. Remove closure requirements at regulated units for facilities that require corrective action
    - Would allow EPA discretion to address those units through the corrective action process
- HQ contact: Barbara Foster 703/308-7057



# Legislative Reform

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- Reform negotiations for both RCRA and Superfund continue
- RCRA “Rifleshots” may clarify requirements for managing contaminated media
- Superfund Re-authorization
  - EPA has committed to substantive consistency between RCRA and Superfund cleanups
  - Superfund legislative reforms may affect RCRA requirements for remedy selection, how clean is clean





## Miscellaneous Issues (cont.)

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- RCRA/CERCLA Integration Guidance; plan to issue memo in April '96 addressing:
  1. coordination among EPA RCRA, EPA CERCLA and state cleanup programs;
  2. concept of parity between RCRA corrective action and CERCLA and state programs; and
  3. coordination of closure of regulated units with other cleanup activities.
- HQ contact: Hugh Davis 703/308-8622



## Miscellaneous Issues (cont.)

- Use of Area of Contamination (AOC) concept during RCRA cleanups; plan to issue guidance memorandum in very near future.
  - Memo conveys that under certain conditions, hazardous wastes may be moved within broad areas of contamination without triggering RCRA LDRs and MTRs
  - Memo also describes distinctions between final CAMU regulations and the AOC approach
  - Not the same issue as area of concern under RCRA CA
  - HQ contact: Hugh Davis



## Miscellaneous Issues (cont.)

- “Environmental Indicators” as a new approach for measuring results rather than process
  - Currently, two indicators: Human Exposures Controlled and Ground Water Releases Controlled
  - Guidance on these indicators is available in the RCRIS Data Element Dictionary under codes CA725 and CA750
  - Interested in feedback on successes/problems
  - Goal of FY ‘97 for evaluating all facilities currently being addressed by corrective action
  - HQ contact: Sue Parker 703/308-8653



# Summary

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- EPA and States have made considerable progress
- Improvements are still necessary
- Goal is to improve speed, efficiency, protectiveness and responsiveness, and to focus program more clearly on environmental results
- Communication of our experiences is paramount







## **The Corrective Action Universe for EPA Region 9**

By Larry Bowerman, Chief  
Corrective Action Section  
(415) 744-2051

## **Corrective Action Topics to be Covered**

- Program goals and authorities.
- Universes (facilities subject to corrective action).
- Environmental Priorities Initiative (EPI).
- Stabilization Initiative.
- Corrective Action Pipeline.

2-1

## **RCRA Corrective Action Program Goals**

- Focus resources at high priority facilities.
- Complete assessments at all TSDFs by the end of FY96.
- Emphasize the stabilization initiative.
- Enhance State capabilities through effective work-sharing arrangements.
- Tailor oversight of corrective action activities based on facility specific conditions.

## **RCRA Corrective Action Authorities**

- 3004(u) - Continuing releases at permitted facilities (including Solid Waste Management Units, or SWMUs)
- 3004(v) - Corrective Action Beyond Facility Boundary
- 3008(h) - Interim Status Corrective Action Orders
- 7003 - Imminent Hazard

## **Corrective Action Workload Universe (Tier 1)**

- 376 facilities in Region 9.
- Active and closing TSDFs.
- TSDFs closed with waste in place.
- Facilities referred to Superfund.
- Abandoned facilities.
- Delay of closure facilities.

## **Other Facilities Subject to Corrective Action (Tier 2)**

- About 300 additional facilities in Region 9.
- Clean closed facilities.
- 90 day converters.
- Illegal Units.
- Permit by Rule.

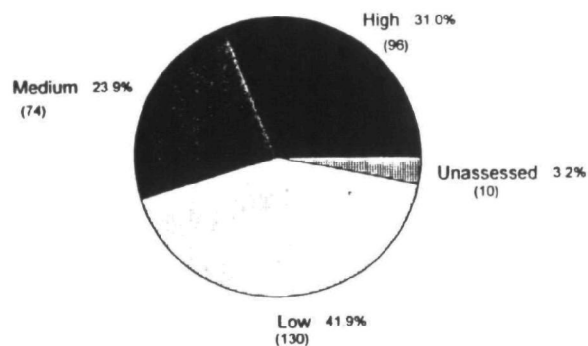
## **Environmental Priorities Initiative (EPI) Goals**

- Assess and rank all TSDFs by end of FY1996.
- Address the worst release problems first.
- Ensure all high priority facilities are being addressed.

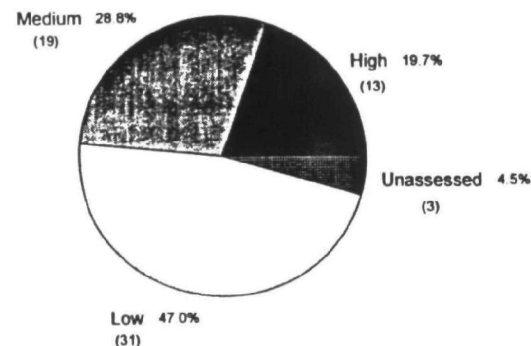
## **EPI Activities in Region 9**

- 96% of TSDFs have been assessed and ranked as of 9/30/95; the remaining 13 facilities will be assessed in FY1996.
- About two thirds of the "Tier 2" facilities have also been ranked; we are exploring whether we have the resources to rank the remaining 100 facilities.
- In general all known high and medium priority facilities are being addressed by EPA and/or states.
- We are currently reviewing high priority sites to ensure appropriate follow-up is occurring.
- We are continuing our efforts to ensure that this information is accurately reflected in RCRIS.

**RCRA Corrective Action  
NCAPS ASSESSMENT**  
California Workload Universe = 310  
September 30, 1995



**RCRA Corrective Action  
NCAPS ASSESSMENT**  
HANG Universe = 66  
September 30, 1995



## Stabilization Initiative Goals

- Control or abate threats to human health and/or the environment from releases at RCRA facilities.
- Prevent or minimize the further spread of contamination while long-term remedies are pursued.
- Work with authorized states to ensure implementation of the Stabilization Initiative.
- Develop an accurate tracking system for stabilization activities.

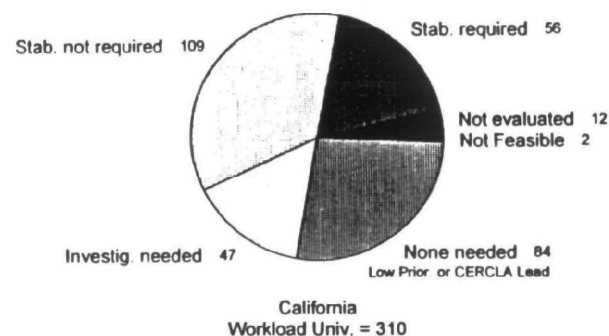
## Stabilization Activities in Region 9

- 96% of TSDFs have been evaluated as of 9/30/95; the remaining 15 facilities will be evaluated in FY1996.
- Where further investigation is needed, we will ensure that the investigation is conducted by the facility, state and/or EPA.
- Where stabilization is found to be necessary and appropriate, we will ensure that stabilization is actually implemented by the facility, state and/or EPA.
- We are continuing our efforts to ensure that this information is accurately reflected in RCRIS.

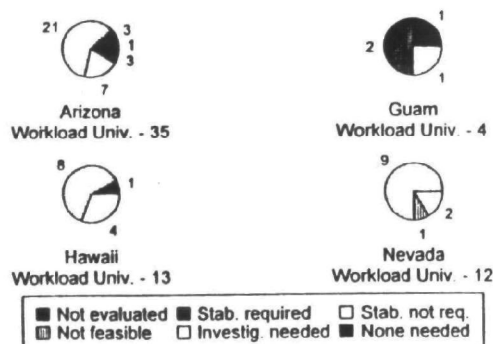
## Stabilization Initiative - Lessons Learned

- We should devote more time and effort to the Stabilization Initiative.
- Of 62 facilities requiring stabilization:
  - 58 (93%) have stabilization imposed
  - 46 (74%) have implemented measures
- Need to follow-up on the 60 facilities where further investigation is needed.
- Consider evaluating the approx. 300 Tier 2 facilities; many may not require an evaluation.

## RCRA Corrective Action Stabilization Evaluations September 30, 1995



## RCRA Corrective Action STABILIZATION EVALUATIONS September 30, 1995



## Corrective Action Pipeline Status and Issues

- The pipeline graphics are based on RCRIS data.
- The pipeline consists of activities from the RCRA Facility Assessment (RFA) to Corrective Measures Implementation (CMI).
- Are all high priority facilities being adequately addressed?
  - Yes, in fact, with only a few exceptions, all known high and medium priority facilities are being addressed by EPA, DTSC, RWQCBs or local agencies.
  - The Analogous Project provides a way for EPA and DTSC to become familiar with other agency's clean-up activities at TSDFs and to record them in RCRIS.

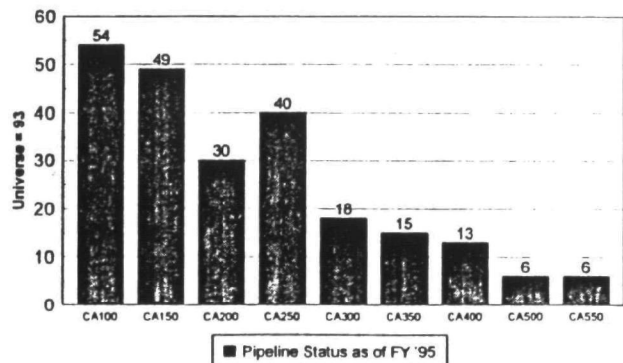
## RCRA Analogous Project

- Goal: recognize work at sites deferred to non-RCRA agencies.
- Accomplishments:
- Better understanding and management of RCRA universe; we reviewed a total of 86 SMP and RWQCB sites.
- RCRIS data greatly expanded.
- Tangible measure of SMP and RWQCB contributions.
- Duplication of effort minimized.
- Facility deferral effective.

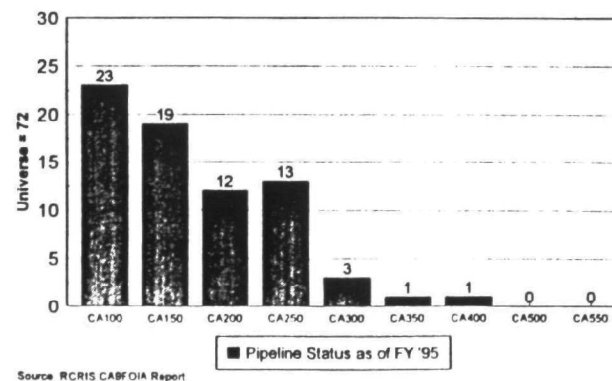
## Corrective Action Pipeline Status and Issues (cont.)

- The universe is not static; rankings can change based on new information, clean-ups or stabilization actions.
- Are we appropriately disinvesting in low/medium priority and/or stabilized facilities to focus more attention on unstabilized and other high priority facilities?
- Are facilities moving through the "pipeline" fast enough? Can combine RFI/CMS Workplans and Reports to increase efficiency.
- Are states adequately implementing corrective action?
- Is EPA adequately guiding, assisting and training states to implement the corrective action program?

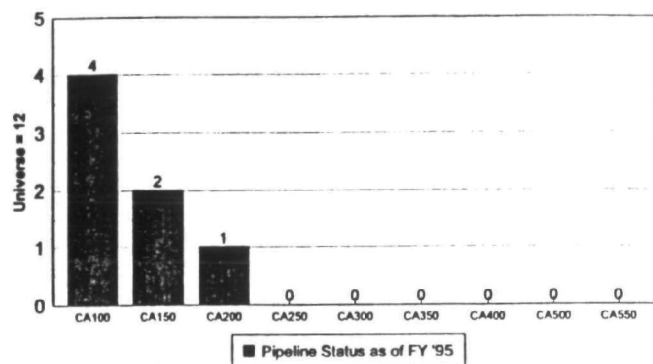
## California High Priority Sites



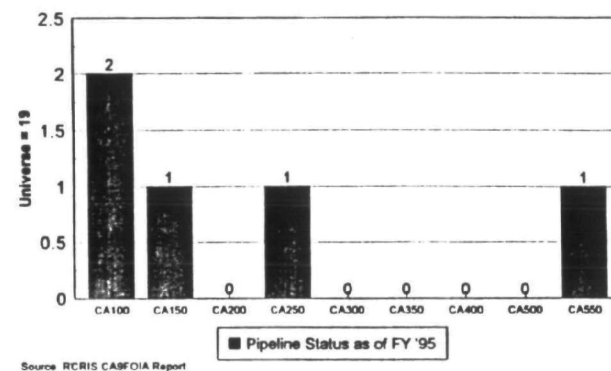
## California Medium Priority Sites



## HANG States High Priority Sites



## HANG States Medium Priority Sites





**DRAFT**

# **U.S. Environmental Protection Agency Region 9 Ecological Risk Assessment Guidance for Superfund Sites**

**Clarence A. Callahan and B. Douglas Steele (H-9-3)  
U.S. Environmental Protection Agency  
Region 9  
75 Hawthorne Street  
San Francisco, CA 94105**

## **ABSTRACT**

Ecological Risk Assessment at Superfund sites is an iterative process with phases that builds a database with the integration of information at each step. This document provides guidance that is integral to the Remedial Investigation/Feasibility Study activities as part of the overall Superfund process. The guidance includes checkpoints for deciding the adequacy and interpretation of data gathered for interpreting potential ecological exposure, ecological impact and risk characterization. All available data are summarized in the site Scoping Phase (Phase 1) for use in a Preliminary Impact Assessment (Phase 2); relevant site-specific data are gathered, integrated and interpreted in the Confirmatory Phase (Phase 3) and the Risk Characterization Phase (Phase 4); and finally, focused and comprehensive data are collected in the Remedial Guidance Phase (Phase 5) to direct the remedial action. This guidance material is adapted from Agency material from the Superfund program and publications in the open literature. Issues include the description of assessment and measurement endpoints, background or reference data, identification of chemicals of concern, site receptors, site conceptual models, detection limits, and approaches for the impact assessment of contaminants. This guidance material stresses the interaction of all participants throughout the process of ecological risk assessment at Superfund sites.

**Key Words:** Superfund, Ecological, Risk, Assessment, Remediation

**DRAFT**



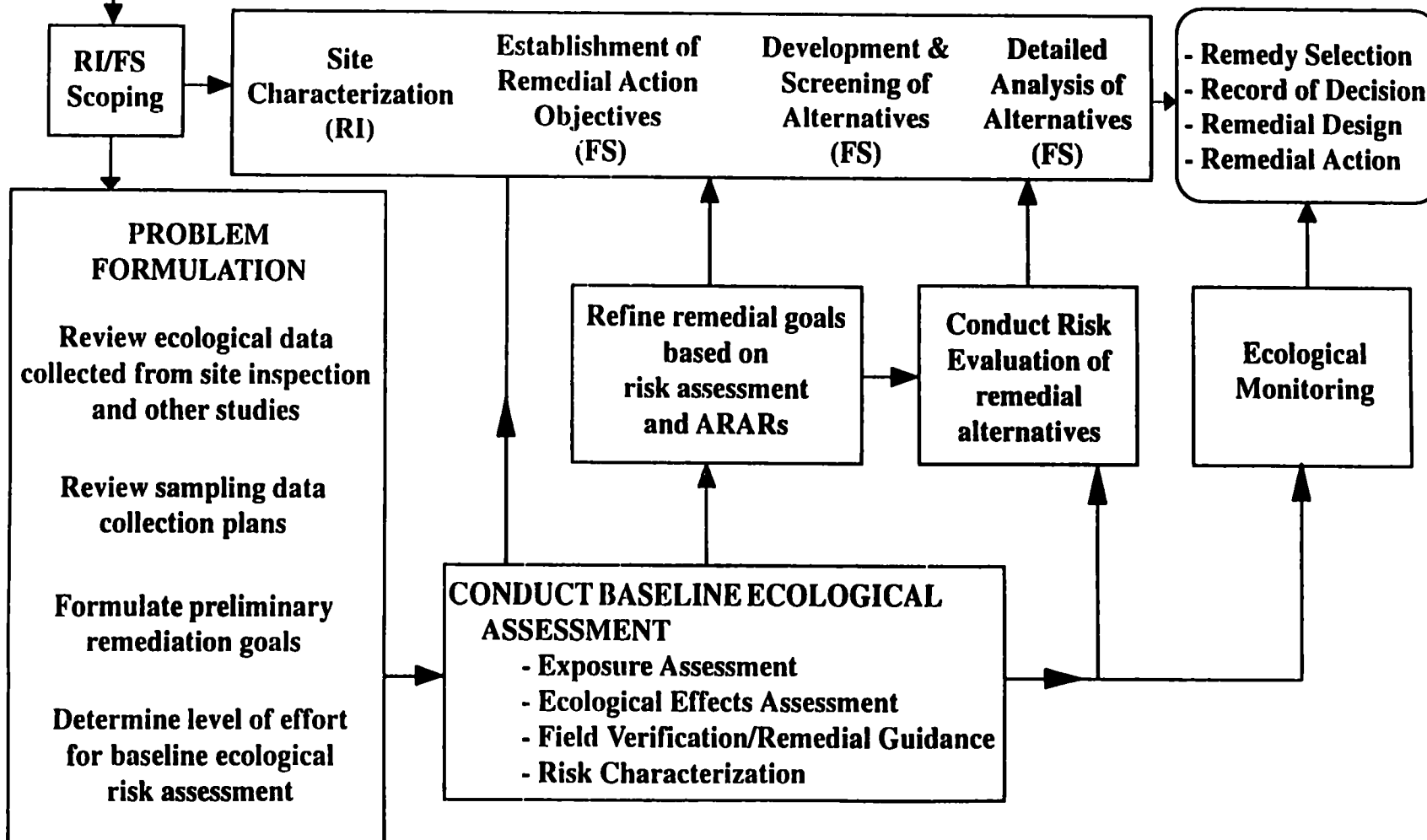
# **FUNDAMENTALS OF ECOLOGICAL RISK ASSESSMENT**

**by**

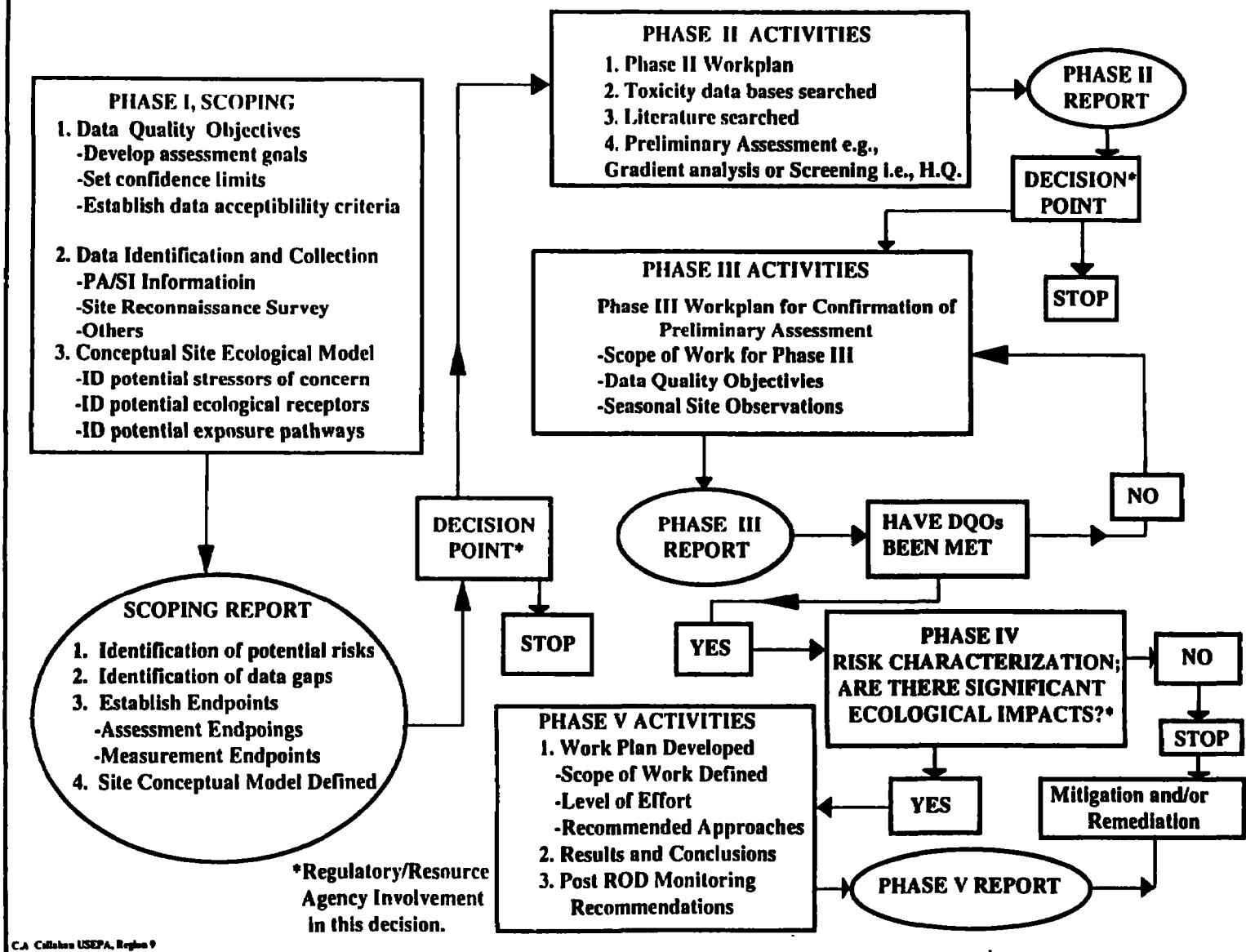
**Clarence A. Callahan, PhD  
BTAG Coordinator  
USEPA Region 9  
San Francisco, California 94105  
Phone 415/744-2314  
FAX 415/744-1916**

- Preliminary Assessment
- Site Inspection
- NPL Listing

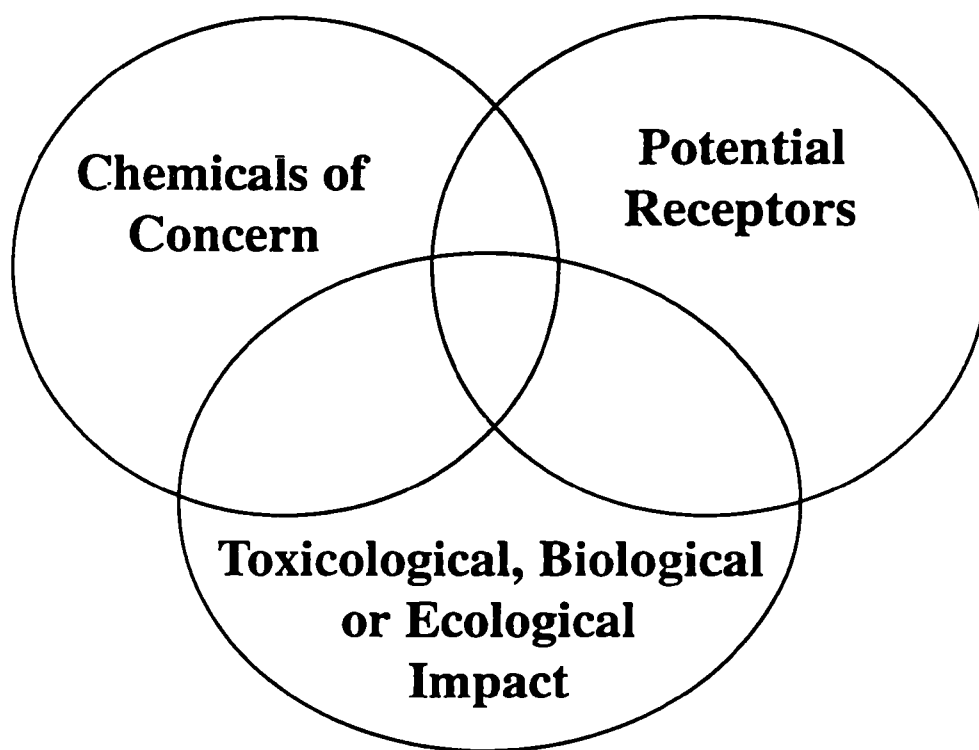
## Ecological Assessment in the RI/FS Process



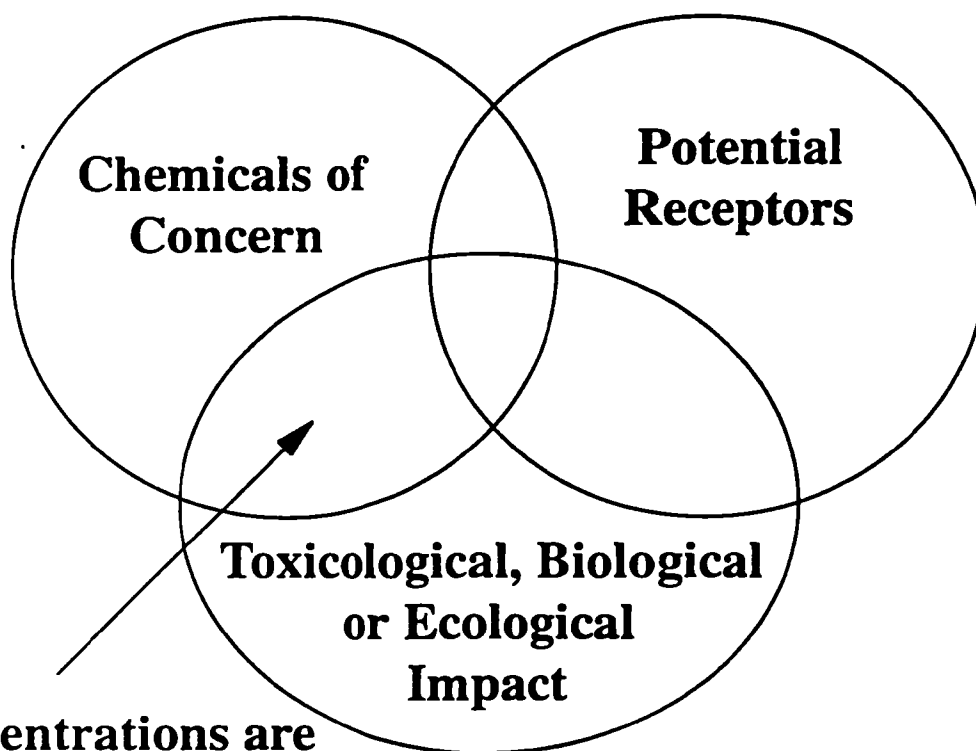
# PHASED APPROACH FOR ECOLOGICAL ASSESSMENT



# **Ecological Risk Assessment Fundamentals**



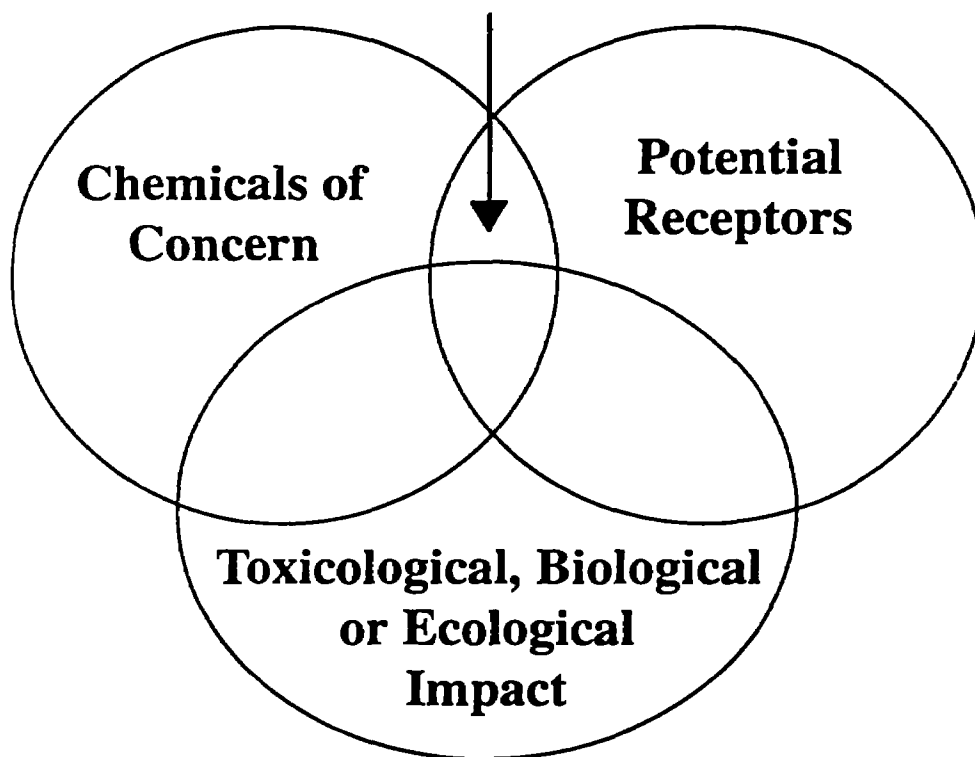
# Ecological Risk Assessment Fundamentals



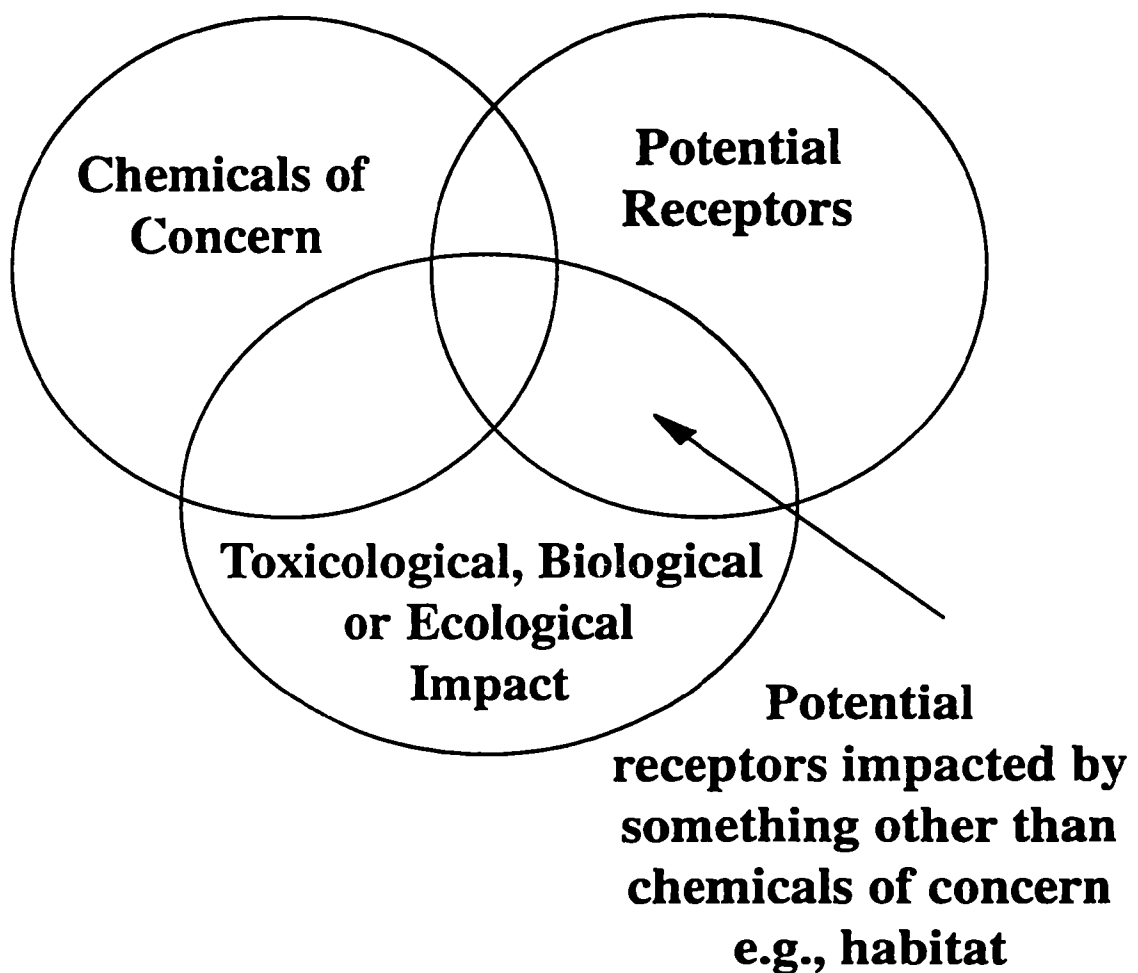
**Concentrations are  
high enough, but  
potential receptors  
are lacking**

# **Ecological Risk Assessment Fundamentals**

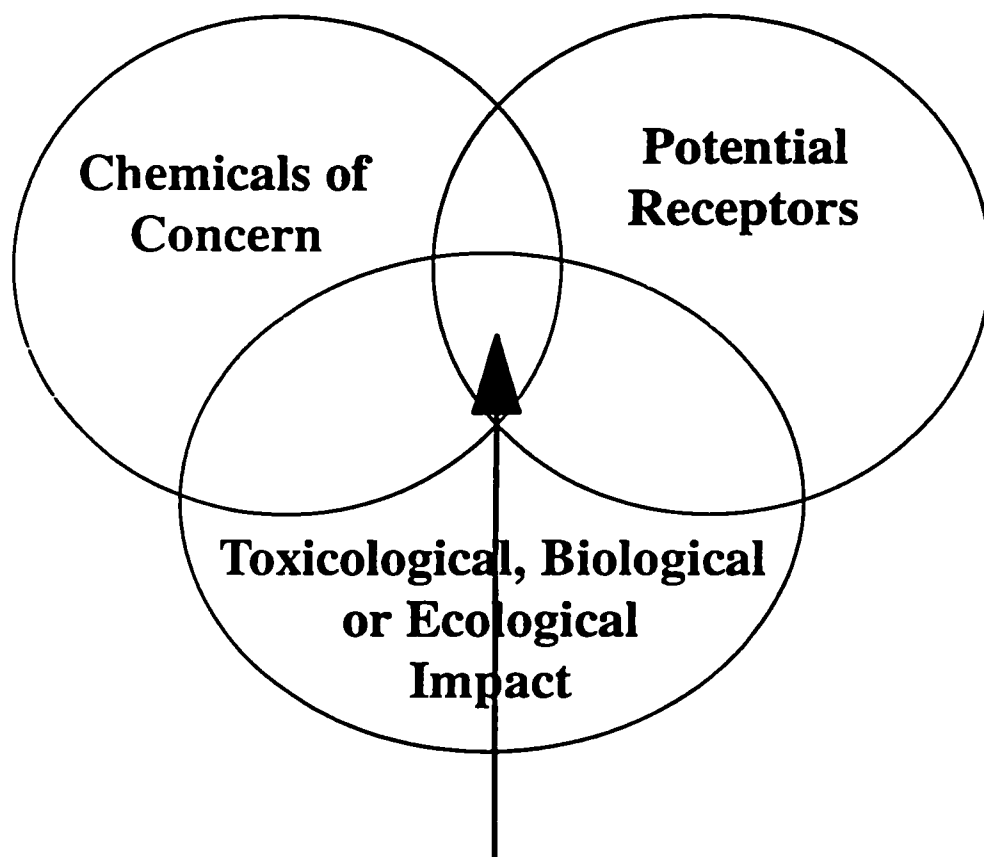
**Chemicals of Concern and receptors are present, but concentrations are not high enough for biological or ecological impact**



# Ecological Risk Assessment Fundamentals



# **Ecological Risk Assessment Fundamentals**

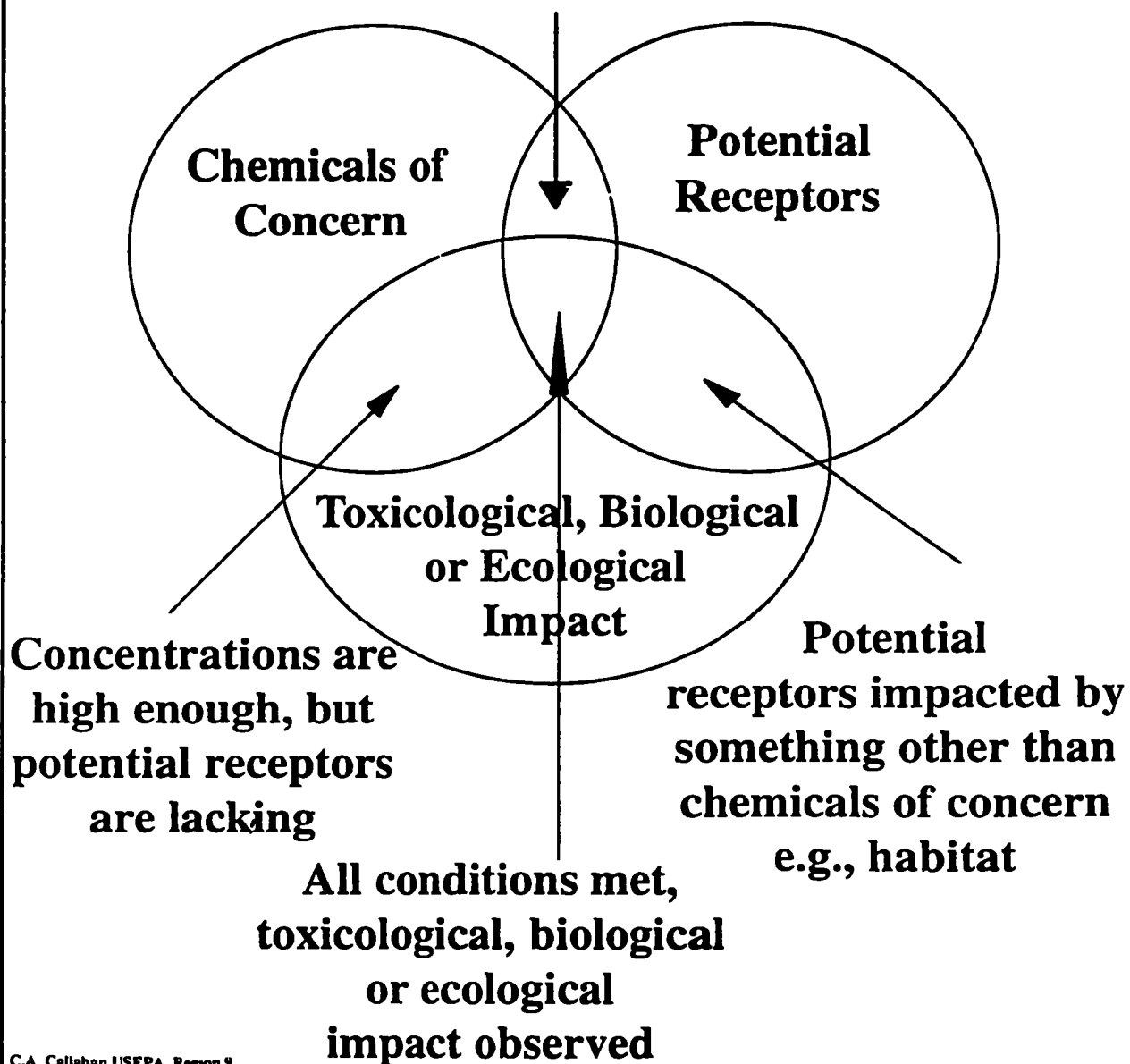


**All conditions met,  
toxicological, biological  
or ecological  
impact observed**



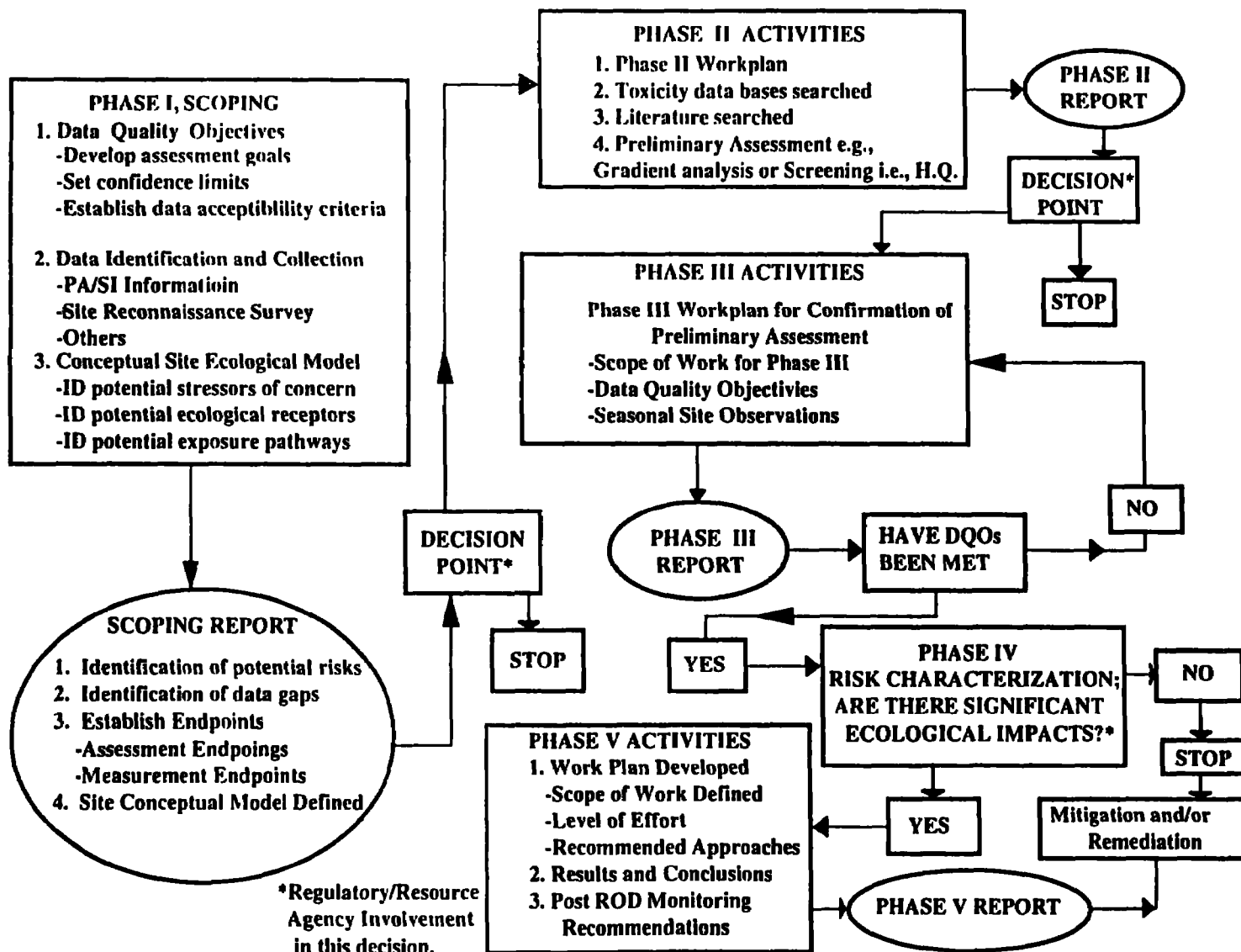
# Ecological Risk Assessment Fundamentals

**Chemicals of Concern and receptors are present, but concentrations are not high enough for biological or ecological impact**



C.A. Callahan USEPA, Region 9

# PHASED APPROACH FOR ECOLOGICAL ASSESSMENT



# TOXICITY QUOTIENT METHOD<sup>1</sup>

$$TQ = \frac{EPCs}{C_{\text{end-point}}}$$

Where:

TQ = Toxicity Quotient

EPCs = Exposure Point Concentration

$C_{\text{end-point}}$  = Concentration associated with a particular biological effect based on the Effects Assessment for indigenous or closely related species.

Requirements:

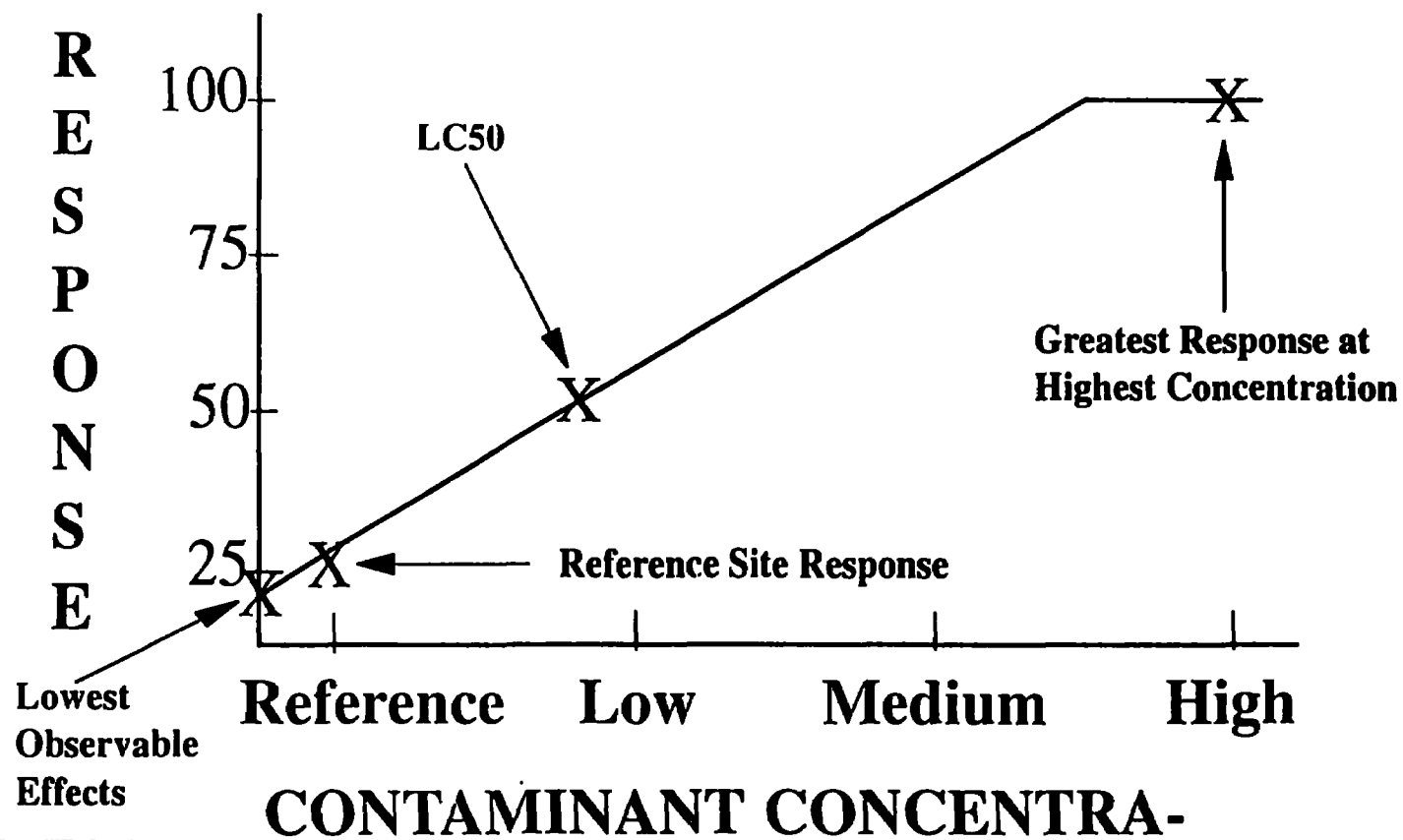
- EPCs are the measured concentrations on the site;
- $C_{\text{end-point}}$  is based on the potential receptors for the site being assessed. It is not advisable to substitute species nor to extrapolate to other species or genera without exposure response relationships for the surrogate and the particular chemical of concern.

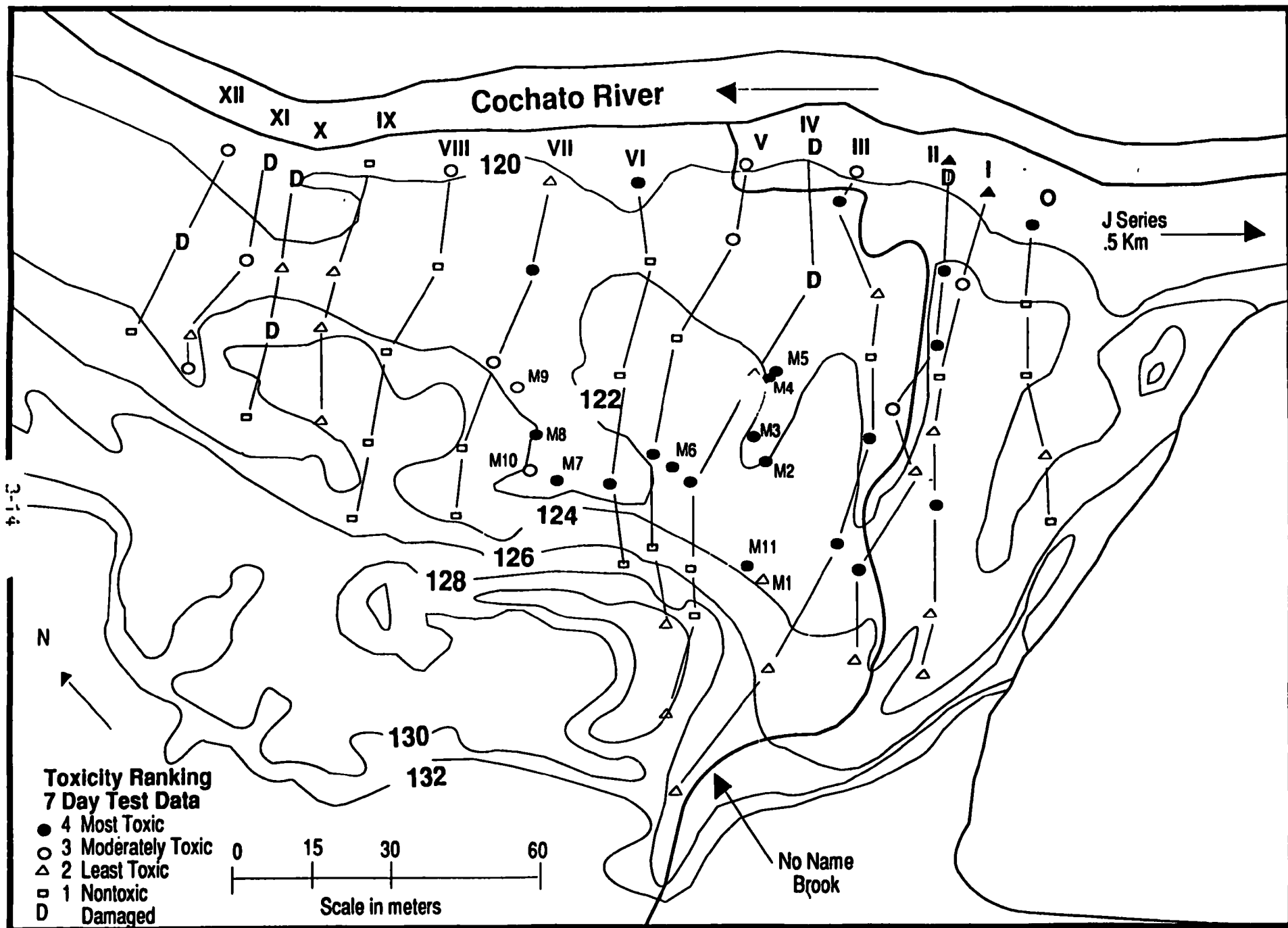
Interpretation:

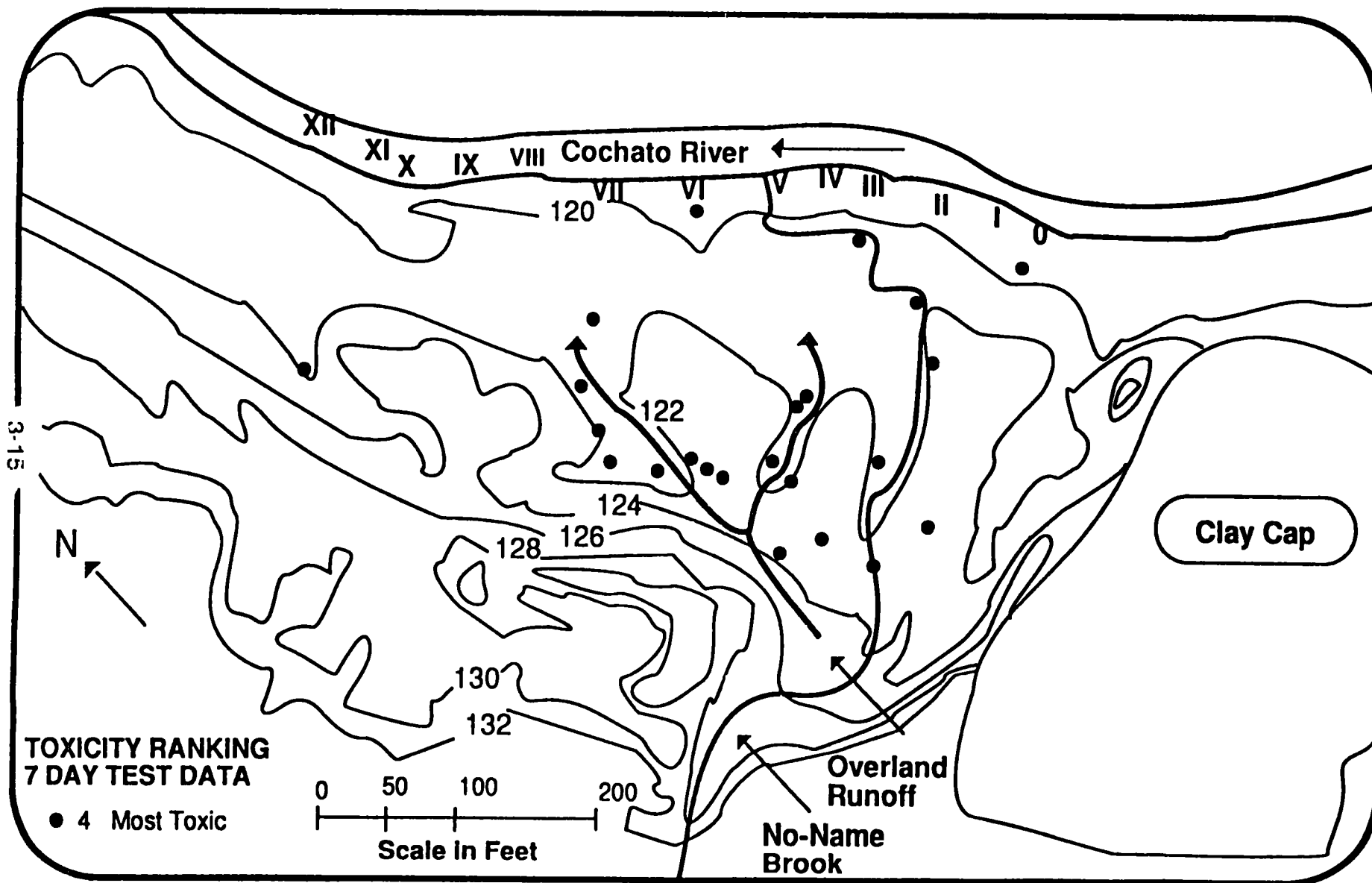
- Interpretation of the TQ is the goal of this assessment and comparisons of the potential effects are compared to the TQ for concentrations obtained in the reference area(s).

<sup>1</sup> Menzie and Cura, 1991

# BIOASSAY STRATEGY FOR MEASUREING TOXICOLOGICAL OR BIOLOGICAL EFFECTS







**DRAFT**

**ECOLOGICAL RISK ASSESSMENT  
GUIDANCE FOR SUPERFUND:**

**PROCESS FOR DESIGNING AND CONDUCTING  
ECOLOGICAL RISK ASSESSMENTS**

**DRAFT**

**U.S. Environmental Protection Agency  
Environmental Response Team  
Edison, NJ**

**DRAFT**

**September 26, 1994  
Review Draft**

# California

*California*  
75 HAWTHORNE ST., H-93  
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## Department of Toxic Substances Control

### GUIDANCE FOR ECOLOGICAL RISK ASSESSMENT AT HAZARDOUS WASTE SITES AND PERMITTED FACILITIES

### PART B: SCOPING ASSESSMENT



State of California  
California Environmental Protection Agency

Department of Toxic Substances Control  
Office of Scientific Affairs  
Human and Ecological Risk Section

SEPTEMBER, 1994

THIS GUIDANCE IS FOR REVIEW AND COMMENT ONLY



# Development of Ecological Exit Criteria for the Hazardous Waste Identification Project

Review Draft



April 1994

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Prepared for

U.S. Environmental Protection Agency  
Office of Solid Waste  
Contract No. 68-D2-0065

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Prepared by



Research Triangle Institute  
Project 5810-43

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# ECO Update

Office of Emergency and Remedial Response  
Hazardous Site Evaluation Division (OS-230)

Intermittent Bulletin  
Volume 1, Number 2

## Ecological Assessment of Superfund Sites: An Overview

This document is the second issue of the *ECO Update* series of Intermittent Bulletins, published by the Toxics Integration Branch, Hazardous Site Evaluation Division, Office of Emergency and Remedial Response. Practical experience with the process of ecological assessment at Superfund sites has pointed to the need for information and guidance concerning both the scientific and management aspects of ecological assessment. The *ECO Update* series is intended to fill this need.

*Ecological Assessment of Superfund Sites: An Overview* is an updated framework for ecological assessment in the Superfund program. As such, it offers a description of ecological assessment components and a discussion of how they fit into the Remedial Investigation and Feasibility Study (RI/FS) process. Ecological assessment in the removal process will be addressed in a future *ECO Update*.

Limiting each Bulletin to a specific topic allows flexibility for the user to select only those Bulletins that are applicable to the site in question or the user's needs. For example, some sites do not require toxicity tests, so investigators would not need to consult Bulletins specific to testing. A user who needs only general information on Natural Resource Trustees can refer to a specific Bulletin on that topic and not have to look through a larger document containing other, less relevant information.

The Bulletin series is written for both general and technical audiences, which includes EPA site managers and staff, contractors, State personnel, and anyone else involved in the performance, supervision, or evaluation of ecological assessments in Superfund.

Ecological assessment involves considerable professional judgment. The *ECO Updates* assume that readers will confer with qualified scientists for site-specific advice. These Bulletins are not step-by-step guides on how to accomplish an assessment. The series supplements the advisory process involving Regional Biological Technical Assistance Groups (BTAGs). EPA staff should consult their BTAG coordinator for more detailed information on ecological assessment in their Region.

### The *ECO Update* Series

*ECO Updates* are a series of Intermittent Bulletins intended to facilitate ecological assessment of Superfund sites. Each Bulletin focuses on one aspect of ecological studies or ecological assessment in the remedial process. Individual Bulletins may discuss either technical methods or the management of ecological assessments.

### IN THIS BULLETIN

Background .....	2
What is an Ecological Assessment? .....	2
Ecological Assessment in the RI/FS Process .....	6

*ECO Update* is a Bulletin series on ecological assessment of Superfund sites. These Bulletins serve as supplements to *Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual* (EPA/540-1-89/001). The information presented is intended as guidance to EPA and her government employees. It does not constitute rulemaking by the Agency, and may not be relied on to create a substantive or procedural right enforceable by any other person. The Government may take action that is at variance with these Bulletins.



# ECO Update

Office of Emergency and Remedial Response  
Hazardous Site Evaluation Division (OS-230)

Intermittent Bulletin  
Volume 1, Number 4

## Developing A Work Scope For Ecological Assessments

This Bulletin is intended for Remedial Project Managers (RPMs), to help them plan and manage ecological assessments of sites as part of the Remedial Investigation and Feasibility Study (RI/FS) process.<sup>1</sup> As used here, the generic term work scope describes the process of specifying the work to be done for the ecological assessment, as part of the overall RI Work Plan. The term encompasses project scoping, development and approval of the Work Plan, and preparation of the Statement of Work (SOW) for contractors (at Fund-lead sites).

The outcome of a successfully executed work scope should be an ecological assessment that includes four essential components: problem formulation, exposure assessment, ecological effects assessment, and risk characterization.<sup>2</sup> A work scope should also provide for close oversight of individual tasks. This will ensure that the assessment accomplishes its objectives within reasonable budget and schedule limitations.

### Need for Clarity, Specificity, and Completeness

SOWs and Work Plans should clearly state the studies needed at each phase of the assessment. In addition, they should include other parameters concerning an assessment, such as sample collection, data analysis, and reports. Specifically, SOWs and Work Plans should describe:

- Which studies should be conducted;
- Why they should be conducted;
- When and where they should be conducted;
- What data should be collected;
- How samples should be collected, handled, and analyzed;
- How data should be evaluated; and
- What reports should be produced.

### IN THIS BULLETIN

#### The Role Of The Biological Technical Assistance

Group .....	2
Points To Consider In Developing A Work Scope .....	2
Elements Of An Ecological Assessment Work Scope .....	4
Ensuring Contractor Capability To Do Work .....	7
Review Of Interim And Final Products .....	8
Sample Work Scope .....	9
Conclusion .....	9
Appendix .....	11

<sup>1</sup> Although the primary focus of this document is on the RI/FS process, On-Scene Coordinators may find much of the information useful in evaluating sites during the removal process.

<sup>2</sup> *Ecological Assessment of Superfund Sites: An Overview* (ECO Update Vol. 1, No. 2).

ECO Update is a Bulletin series on ecological assessment of Superfund sites. These Bulletins serve as supplements to Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual (EPA/540-1-89/001). The information presented is intended as guidance to EPA and other government employees. It does not constitute rulemaking by the Agency, and may not be relied on to create a substantive or procedural right enforceable by any other person. The Government may take action that is at variance with these Bulletins.



The Use of US EPA Region 9  
Preliminary Remediation Goals in Site Evaluation

Daniel Stralka, PhD  
Regional Toxicologist

The Use of Preliminary Remediation Goals for Site Evaluation

A. What are PRGs?

- a. Generic chemical-specific concentrations of concern.
- b. Human health endpoints.
- c. Select pathways.
- d. Combined pathways for each media.

B. The Site Conceptual Model

- a. How have you defined the site?
- b. What is the extent of your data?
- c. Have you characterized the site?
- d. Is your data consistent with your model?

C. Evaluate the use of Generic vs. Site-specific PRGs

- a. Are there other pathways not evaluated in the generic PRGs?
- b. Are the assumptions used in the generic PRGs relevant for the site?
- c. How refined a risk assessment is required?

D. Exposure Point Concentration Term

- a. Does the data characterize the site?
- b. How was the data collected, composite or individual?
- c. Maximum hit screening vs. statistical methods, point of compliance?

E. Examples

F. Advantages and Disadvantages

- a. Standardize equations and default assumptions.
- b. Most common human exposure pathways.
- c. Flexible framework.
- d. Must have a conceptual site model.
- e. Not walk away numbers.

G. How do you access the table?

California Regional Water Board's BBS 510-286-0404  
file name- PRG2ND.ZIP

via internet "gofer.epe.gov" menu selection  
"EPA Offices and Regions: Region 9; Superfund Program"

# Highlight 1: Key Attributes of the PRG Framework

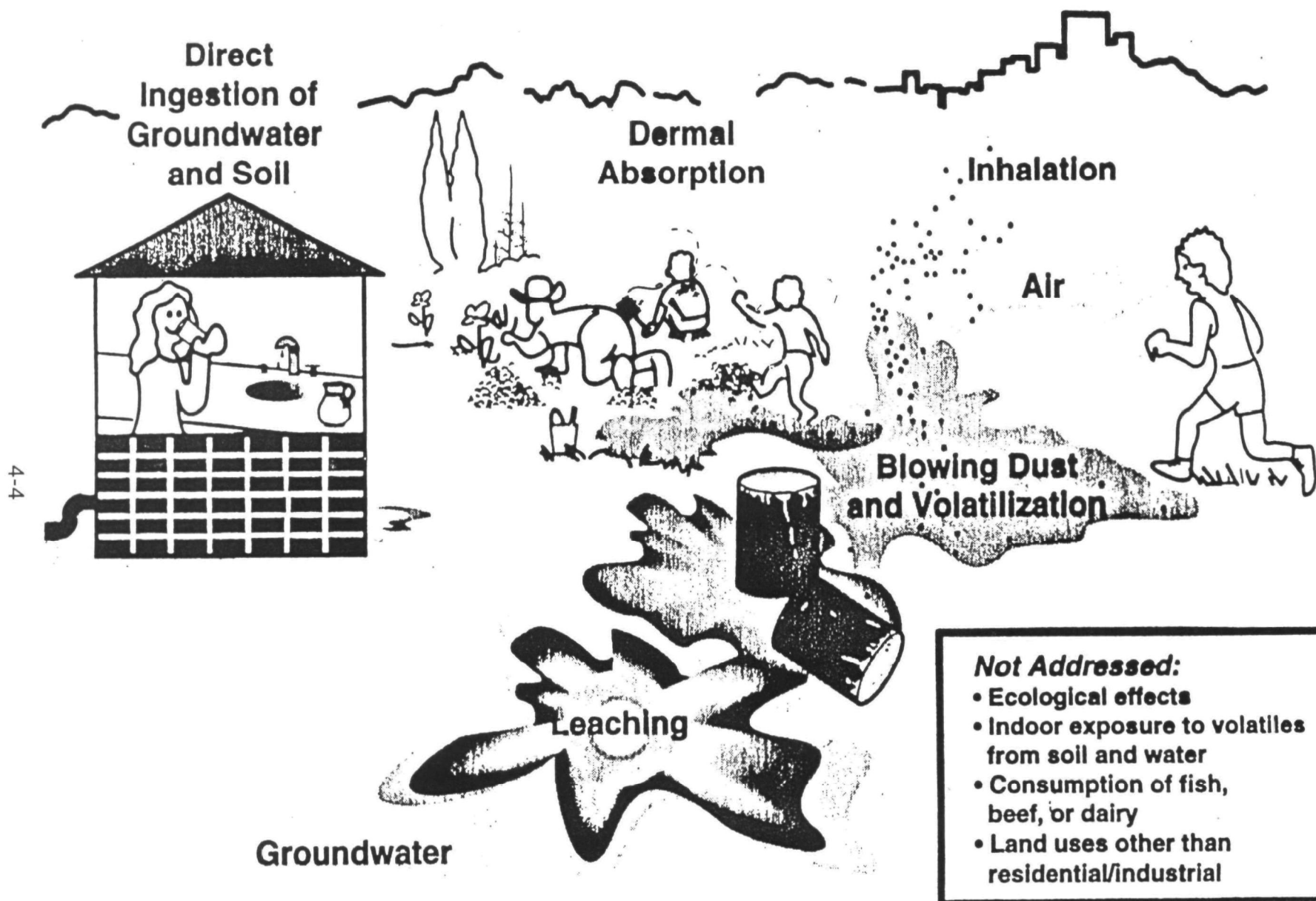
- Standardized equations and default concentrations (PRGs) are presented to address most common human exposure pathways.
- Conceptual site model for each site is used to determine the applicability of generic PRGs and identify data gaps.
- Framework is flexible and allows both generic and site-specific inputs into the standardized equations.

# Pathways Addressed by Region IX PRGs

1. Ingestion of Soil
2. Dermal Contact with Soil
3. Inhalation of Volatiles and Fugitive Dust
4. Migration of Contaminants to an Underlying Potable Aquifer

$$\text{Soil PRG (mg/kg)} = \frac{\text{Target "Safe" Dose}}{\text{Add Exposures } 1 + 2 + 3}$$

# Pathways Addressed by Preliminary Remediation Goals (PRGs)





# Decisions to Move from Generic to Site-Specific PRGs Consider:

- Do pathways at the site match up with pathways used to derive generic PRGs?
- Are the assumptions used in the PRGs appropriate, relative to site conditions?
- Are site-specific goals established from collecting additional data likely to be less costly to achieve?

# **PRELIMINARY RISK GOALS MAY CHANGE WHEN CONSIDERING ADDITIONAL FACTORS**

## **■ Exposure Factors**

- cumulative effect of multiple chemicals
- exposures from additional pathways
- potential impacts on environmental receptors
- cross-media impacts of remedial alternatives

## **■ Technical Factors**

- detection/quantification limits
- ability to monitor and control movement of contaminants
- background levels of contaminants

## **■ Uncertainty Factors**

- reliability of alternatives
- weight of scientific evidence concerning exposures and health effects

Analytical Method	Detected Chemical	# of Hrs	# of Samples	Frequency of Detection %	Maximum Concentration (mg/kg)	Residential Soil				Industrial Soil							
						Cancer PRG (mg/kg)	Cancer Risk(s)	Percentage Contribution %	Noncancer PRG (mg/kg)	Hazard Quotient(s)	Percentage Contribution %	Cancer PRG (mg/kg)	Cancer Risk(s)	Percentage Contribution %	Noncancer PRG (mg/kg)	Hazard Quotient(s)	Percentage Contribution %
VOCs																	
OLM01 PV	1,1,1 Trichloroethane	3	25	12	3.0E-03				3.2E-03	0.5E-07	0.00			1.0E+04	1.0E-07	0.00	
OLM01 PV	2 Butanone	8	25	24	1.3E-02				8.7E-03	1.5E-06	0.00			3.0E+04	3.0E-07	0.00	
OLM01 PV	Acetone	10	25	40	1.0E-01				2.0E-03	0.0E-05	0.00			0.4E+03	0.1E-05	0.00	
OLM01 PV	Styrene	1	25	4	7.0E-03				6.4E-03	1.1E-06	0.00			3.1E+04	2.2E-07	0.00	
OLM01 PV	Toluene	2	25	5	1.0E-03				1.0E-03	5.2E-07	0.00			0.0E+03	1.0E-07	0.00	
OLM01 PV	Trichloroethane	3	25	12	2.0E-03	7.1E+00	2.0E-10	0.00	0.1E+01	3.3E-05	0.00	1.7E+01	1.2E-10	0.00	3.2E+02	0.0E-06	0.00
BVOCs																	
OLM01 OS	2,4-Dimethylphenol	1	111	1	5.0E-01				1.3E-03	3.0E-04	0.00			1.4E+04	3.7E-05	0.00	
OLM01 OS	4-Methylphenol	1	111	1	3.0E-01				3.2E-02	0.2E-04	0.00			3.4E+03	0.0E-05	0.00	
OLM01 OS	Acenaphthene	2	111	2	5.1E-02				3.0E-03	1.7E-05	0.00			3.1E+04	2.4E-06	0.00	
OLM01 OS	Anthracene	2	111	2	7.5E-02				1.0E-04	3.0E-06	0.00			1.0E+05	4.0E-07	0.00	
OLM01 OS	Benzo(a)anthracene	13	111	12	2.1E-01	0.1E-01	3.4E-07	0.17				2.0E+00	0.1E-04	0.24			
OLM01 OS	Benzo(a)pyrene	10	111	17	0.0E-01	0.1E-02	1.1E-05	5.50				2.5E-01	2.5E-06	7.10			
OLM01 OS	Benzo(b)fluoranthene	17	111	16	0.3E-01	0.1E-01	0.7E-07	0.44				2.0E+00	2.0E-07	0.01			
OLM01 OS	Benzo(k)fluoranthene	14	111	13	1.7E-01	0.1E+00	2.0E-08	0.01				2.0E+01	0.5E-06	0.03			
OLM01 OS	Butylbenzylphthalate	22	111	20	4.0E+00				1.3E+04	3.1E-04	0.00			1.4E+06	2.0E-05	0.00	
OLM01 OS	Carbazene	2	111	3	4.0E-02	2.2E+01	3.2E-09	0.00				0.5E+01	6.0E-10	0.00			
OLM01 OS	Chrysene	15	111	14	1.1E+00	0.1E+01	1.0E-06	0.01				2.0E+02	4.2E-06	0.01			
OLM01 OS	Di-n-Butylphthalate	14	111	13	4.2E-01				0.5E-03	0.4E-05	0.00			0.0E+04	6.2E-06	0.00	
OLM01 OS	Di-n-Octyl Phthalate	3	111	3	1.0E+00				1.3E-03	1.4E-03	0.00			1.4E+04	1.3E-04	0.00	
OLM01 OS	Dipentyl(4,4')biphenylene	5	111	5	3.0E-01	0.1E-02	0.2E-06	3.10				2.0E-01	1.5E-06	4.37			
OLM01 OS	Dipentyl ether	1	111	1	2.3E-02				2.0E-02	0.0E-05	0.00			3.7E+03	0.4E-06	0.00	
OLM01 OS	Dimethylphthalate	2	111	2	7.0E-02				0.5E-05	1.7E-07	0.00			0.0E+06	1.2E-08	0.00	
OLM01 OS	Fluoranthene	10	112	10	0.4E-01				2.0E-02	2.5E-04	0.00			2.7E+04	2.3E-05	0.00	
OLM01 OS	Fluorene	2	111	2	4.3E-02				2.0E-03	1.7E-05	0.00			2.0E+04	1.0E-08	0.00	
OLM01 OS	Indeno(1,2,3-cd)Pyrene	16	111	14	1.5E+00	0.1E-01	2.5E-06	1.25				3.0E+00	5.0E-07	1.73			
OLM01 OS	Isophorene	1	111	1	2.1E-02	4.7E-02	4.9E-11	0.00				2.0E+03	1.0E-11	0.00			
OLM01 OS	Parachlorophenol	3	110	3	1.5E+01	2.5E+00	5.0E-06	3.00				7.0E+00	1.0E-04	5.05			
OLM01 OS	Phenol	1	111	1	2.1E-01				3.0E-04	5.4E-06	0.00			0.1E+06	1.5E-07	0.00	
OLM01 OS	Pyrene	27	112	24	0.7E-01				2.0E-03	4.0E-04	0.00			2.0E+04	4.3E-05	0.00	
OLM01 OS	Is(2-Ethylbenzyl)phthalate	40	111	43	0.0E+00	3.2E+01	1.0E-07	0.00				1.4E+02	4.0E-04	0.12			
Metals																	
ILM02 0	Aluminum	40	40	80	0.3E+04				7.7E+04	1.1E+00	2.00			1.7E+06	4.0E-02	1.10	
ILM02 0	Antimony	33	40	87	0.3E+01				3.1E+01	2.1E+00	7.22			0.0E+03	0.3E-02	2.25	
ILM02 0	Arsenic	40	40	80	0.0E+01	3.2E-01	1.5E-04	70.02				3.0E+00	3.4E-05	72.03	3.0E-02	1.0E-01	
ILM02 0	Boron	40	40	100	7.7E+01				6.3E+03	1.4E-02	0.05			1.2E+06	0.7E-04	0.02	
ILM02 0	Beryllium	30	40	81	1.5E+00	1.4E-01	1.1E-05	5.33				1.1E+00	1.4E-04	0.05	0.0E+03	1.0E-04	
ILM02 0	Cadmium	40	40	84	1.2E+01	1.4E+03	0.4E-08	0.00				1.1E+04	1.2E-08	0.00	0.0E+03	1.0E-02	
ILM02 0	Chromium	40	40	100	7.4E+02	7.1E+02	2.5E-04	1.70				1.0E+03	4.7E-07	1.41			
ILM02 0	Cobalt	40	40	84	7.5E-01				2.1E+00	3.0E-05	0.00			0.7E+00	1.1E-05	0.00	
ILM02 0	Copper	40	40	100	0.1E+01				2.0E+02	3.2E-02	0.11			0.3E+04	1.4E-03	0.03	
ILM02 0	Lead	40	40	100	3.2E+03				4.0E+02	7.0E-01	27.02			1.0E+03	3.2E+00	70.03	
ILM02 0	Manganese	40	40	100	0.1E+03				3.0E-02	1.2E-01	47.00			0.3E+03	0.2E-01	15.03	
ILM02 0	Mercury	30	40	80	0.7E-01				2.2E+01	3.0E-02	0.13			0.1E+03	1.7E-03	0.04	
ILM02 0	Nickel	40	40	80	1.0E+02				1.5E+03	1.2E-01	0.43			3.4E+04	0.4E-03	0.13	
ILM02 0	Selenium	10	20	80	1.1E+00				1.0E+02	2.0E-03	0.01			0.5E+03	1.3E-04	0.00	
ILM02 0	Silver	0	0	00	2.0E+00				3.0E+02	7.0E-03	0.03			0.5E+03	3.0E-04	0.01	
ILM02 0	Thallium	12	40	24	4.7E+00				0.1E+00	7.7E-01	2.70			1.4E+02	3.0E-02	0.01	
ILM02 0	Vanadium	40	40	84	2.4E+02				0.4E+02	4.0E-01	1.55			1.2E+04	2.0E-02	0.08	
ILM02 0	Zinc	40	40	100	4.7E+02				2.2E+04	2.4E-02	0.07			0.1E+05	0.2E-04	0.02	
PCBs																	
OLM01 0P	Aroclor 1260	4	25	10	1.0E-01	0.1E-02	2.4E-06	1.23				3.4E-01	4.7E-07	1.01			
Total						2E-04 100.00				2E-01 00.00				4E+00 100.00			

\* All sample depths are included in this screen

Note: (a) For cancer risk estimation, divide the site specific concentration by its respective cancer PRG and multiply the value by 1E-6 to estimate chemical specific risk, and sum them for multiple chemicals (USEPA 1994)

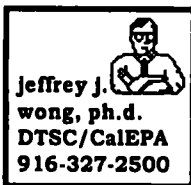
(b) For noncancer hazard estimation, divide the concentration by its respective noncancer PRG and sum the ratios for multiple chemicals (USEPA 1994)

CANCER AND NONCANCER EFFECTS DETERMINED BY THE USEPA REGION IX RESIDENTIAL AND INDUSTRIAL PROGS (USEPA 1995)  
USING RME CHEMICAL CONCENTRATIONS

Analytical Method	Detected Chemical	# of Hds	# of Samples	Frequency of Detection %	RME Concentration (mg/kg)	Residential Soil				Industrial Soil							
						Cancer PRG (mg/kg)	Cancer Risk(s)	Percentage Contribution %	Noncancer PRG (mg/kg)	Hazard Quotient(s)	Percentage Contribution %	Cancer PRG (mg/kg)	Cancer Risk(s)	Percentage Contribution %	Noncancer PRG (mg/kg)	Hazard Quotient(s)	Percentage Contribution %
Metals																	
ILM03 0	Aluminum	76	76	100	8.1E+04				7.7E+04	1.1E+00	16.81				1.7E+06	4.8E-02	18.50
ILM03 0	Antimony	37	76	49	1.6E+01				3.1E+01	3.0E-01	8.06				6.8E+02	2.3E-02	3.05
ILM03 0	Arsenic	73	76	96	2.0E+01	3.8E-01	5.4E-05	86.58	2.2E+01	9.3E-01	14.86	2.4E+00	8.5E-06	82.45	3.8E+02	3.4E-02	11.82
ILM03 0	Barium	53	76	70	1.7E+01				3.3E+02	3.3E-02	0.05				1.1E+05	1.4E-04	0.03
ILM03 0	Beryllium	43	76	57	6.2E-01	1.4E-01	4.4E-06	7.08	3.8E+02	1.4E-03	0.03	1.1E+00	5.4E-07	5.43	8.5E+03	7.7E-05	0.02
ILM03 0	Cadmium	46	73	63	2.0E+00	1.4E+03	1.4E-09	0.00	3.8E+01	3.3E-02	0.83	3.0E+03	6.7E-10	0.01	8.5E+02	2.4E-03	0.32
ILM03 0	Chromium	76	76	100	3.0E+02	2.1E+02	1.4E-06	2.27				4.5E+02	6.6E-07	6.36			
ILM03 0	Cobalt	52	76	68	1.3E+01				4.6E+03	2.7E-03	0.04				9.7E+04	1.3E-04	0.63
ILM03 0	Copper	68	76	89	5.2E+01				2.8E+03	1.8E-02	0.28				6.3E+04	8.7E-04	0.18
ILM03 0	Lead(c)	61	76	80	1.7E+02				4.0E+02	4.2E-01	6.73				1.0E+03	1.2E-01	36.99
ILM03 0	Manganese	76	76	100	1.3E+03				3.8E+02	3.0E+00	47.64				7.8E+03	1.4E-01	31.96
ILM03 0	Mercury(d)	39	76	51	1.3E-01				2.3E+01	4.6E-03	0.07				3.1E+02	2.1E-04	0.05
ILM03 0	Nickel	64	76	84	1.1E+02				1.5E+01	7.0E-02	1.12				3.4E+04	3.1E-03	4.68
ILM03 0	Silver	17	76	22	1.4E+00				3.8E+02	3.7E-03	0.06				8.5E+03	1.6E-04	0.04
ILM03 0	Vanadium	73	76	96	1.0E+02				5.4E+02	1.9E-01	2.96				1.3E+04	8.5E-03	1.83
ILM03 0	Zinc	72	76	95	7.3E+01				3.3E+04	3.3E-01	0.05				5.1E+05	1.4E-04	0.03
PCBs																	
OLM01 0P	Aroclor-1260	8	76	11	2.4E-02	6.6E-02	3.7E-07	0.60				3.4E-01	7.2E-08	0.70			
OLM01 0P	Aroclor 1254	3	76	4	2.5E-01				1.4E+00	1.8E-02	0.29				1.9E+01	1.3E-03	0.29
VOCs																	
OLM01 0V	1,2-Dichloroethane	11	56	20	1.4E-02				8.7E+03	1.4E-06	0.00				3.4E+04	4.1E-03	0.00
OLM01 0V	Acetone	33	56	39	1.8E-01				2.0E+03	5.3E-05	0.00				8.4E+03	1.1E-05	0.00
OLM01 0V	Styrene	1	56	2	2.0E-03				6.4E+03	3.1E-07	0.00				3.1E+04	6.5E-08	0.00
OLM01 0V	Tetrachloroethene	1	56	2	1.0E-03	7.1E+00	1.4E-10	0.00	6.1E+01	1.6E-05	0.00	1.7E+01	5.9E-11	0.00	2.2E+02	4.3E-06	0.00
SVOCs																	
OLM01 0B	Acenaphthene	1	115	1	1.0E-01				3.0E+03	3.1E-01	0.00				2.1E+04	4.8E-06	0.00
OLM01 0B	Anthracene	1	115	1	2.0E-01				1.9E+04	1.1E-01	0.00				1.9E+05	1.1E-08	0.00
OLM01 0B	Benzo(a)Anthracene	3	115	3	1.4E-01	6.1E-01	2.3E-07	0.37				2.8E+00	5.4E-08	0.52			
OLM01 0B	Benzo(a)Pyrene	6	115	5	8.5E-01	6.1E-01	1.4E-06	2.16				2.6E-01	3.3E-07	1.10			
OLM01 0B	Benzo(b)Fluoranthene	9	115	8	1.3E-01	6.1E-01	2.1E-07	0.34				2.6E+00	4.9E-08	0.48			
OLM01 0B	Benzo(k)Fluoranthene	2	115	2	8.4E-02	6.1E+00	3.4E-08	0.02				2.6E+01	3.2E-09	0.03			
OLM01 0B	Carbazole	1	115	1	6.1E-02	2.2E+01	2.8E-09	0.00				9.5E+01	6.4E-10	0.01			
OLM01 0B	Chrysene	6	115	5	1.9E-01	6.1E+01	3.2E-09	0.01				2.6E+02	7.5E-10	0.01			
OLM01 0B	Dibenzophthalate	15	115	13	3.4E-02				6.5E+03	8.3E-06	0.00				8.8E+04	8.0E-07	0.00
OLM01 0B	Dibenzofuran	1	115	1	8.1E-02				2.6E+02	3.1E-01	0.00				2.7E+03	3.0E-05	0.01
OLM01 0B	Dibenzophthalate	1	115	1	3.9E-02				3.2E+04	1.3E-06	0.00				5.5E+05	1.1E-07	0.00
OLM01 0B	Fluoranthene	6	115	5	2.1E-01				3.6E+03	8.0E-05	0.00				2.7E+04	2.7E-06	0.00
OLM01 0B	Fluorene	1	115	1	1.8E-01				2.5E+03	7.2E-05	0.00				3.3E+04	2.8E-06	0.00
OLM01 0B	Indeno(1,2,3-cd)Pyrene	1	115	1	3.3E-02	6.1E-01	9.0E-08	0.15				2.6E+00	2.1E-08	0.21			
OLM01 0B	Naphthalene	1	115	1	9.0E-02				1.6E+03	5.6E-05	0.00				9.5E+03	9.5E-06	0.00
OLM01 0B	Pentachlorophenol	2	115	2	3.1E-01	3.3E+00	2.1E-07	0.33	1.6E+03	3.2E-04	0.01	1.9E+00	6.5E-08	0.63	1.0E+04	5.1E-05	0.01
OLM01 0B	Pyrene	4	115	3	2.0E-01				2.0E+02	1.0E-04	0.00				2.0E+04	1.0E-05	0.00
Total							6E-01	100.00		6.2E+00	100.00		1E-05	100.00		3E-01	100.00

Note: (a) For cancer risk estimates, divide the site-specific concentration by its respective cancer PRG and multiply this ratio by 1E-6 to determine chemical-specific risk, and sum them for multiple chemicals (USEPA 1995).  
 (b) For noncancer hazard estimates, divide the concentration by its respective noncancer PRG and sum the ratios for multiple chemicals (USEPA 1995).  
 (c) The residential PRG value for lead is based on the Uptake Bioassay Model result (USEPA 1995).  
 (d) The PRG value for mercury chloride is used for mercury for conservative purposes.





# PROBLEM SET: MANAGEMENT OF HAZARDOUS WASTE?

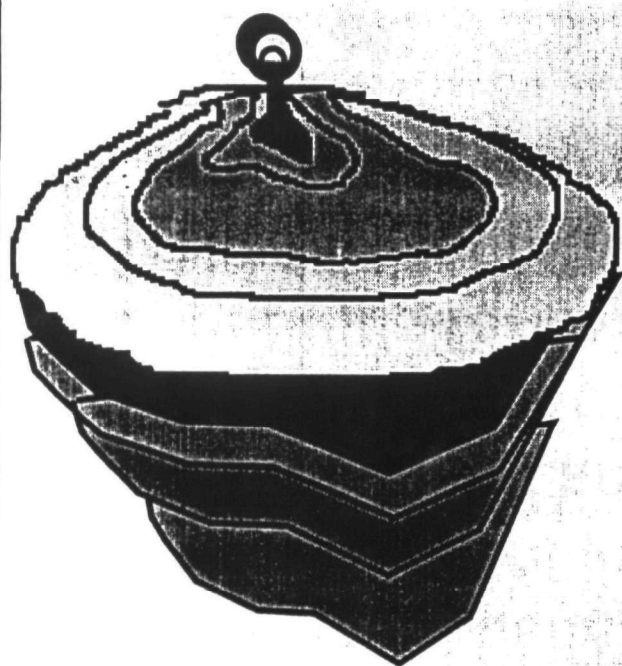
1. Has there been harm? Is there a potential for harm? How to relate an environmental concentration of a contaminant and risk? Assumptions? Where in the heck did that data come from?
2. Methods for calculation? Assumptions?
3. How to compute a soil cleanup, correction action or closure goal for a site or facility?
4. How to make a risk management decision?  
What is the acceptable risk level?



# Risk Assessment:

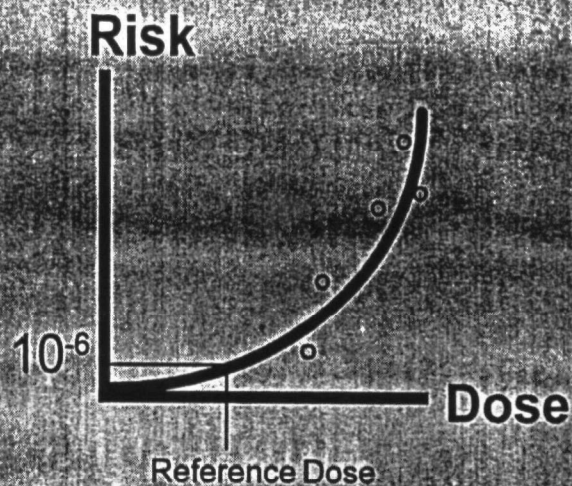
## Simple Conceptual Components

### Source Assessment



Hazard ID

### Toxicity Assessment

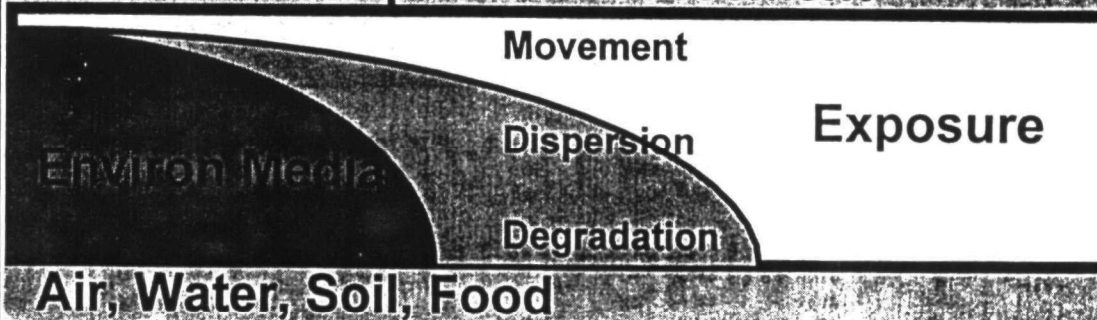


Risk  
Characterization

Calculated Risk

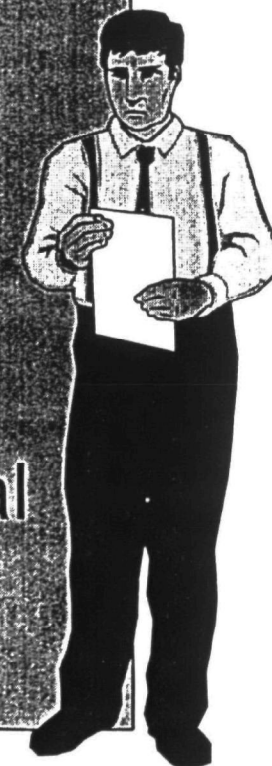
Acceptable Risk

### Exposure Assessment



# What does risk assessment do for me?

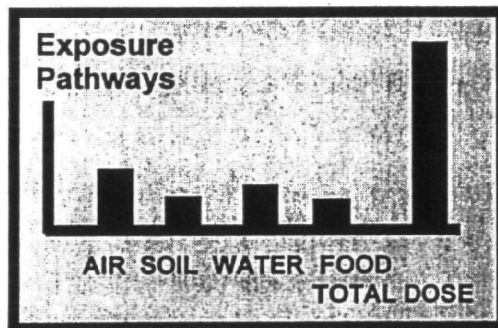
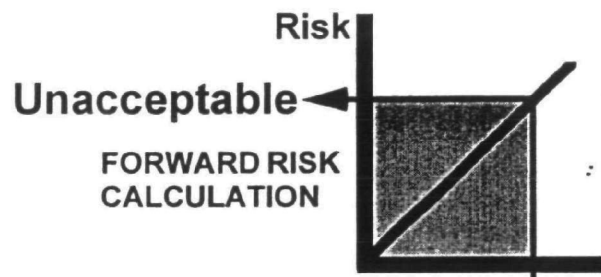
- **Ca/EPA & US EPA**
  - Determine need for action.
  - What can be left behind?
  - Provide basis to compare various solutions.
  - Consistent process for evaluating & documenting public health/ecological threats.





# RISK-BASED SOLUTIONS

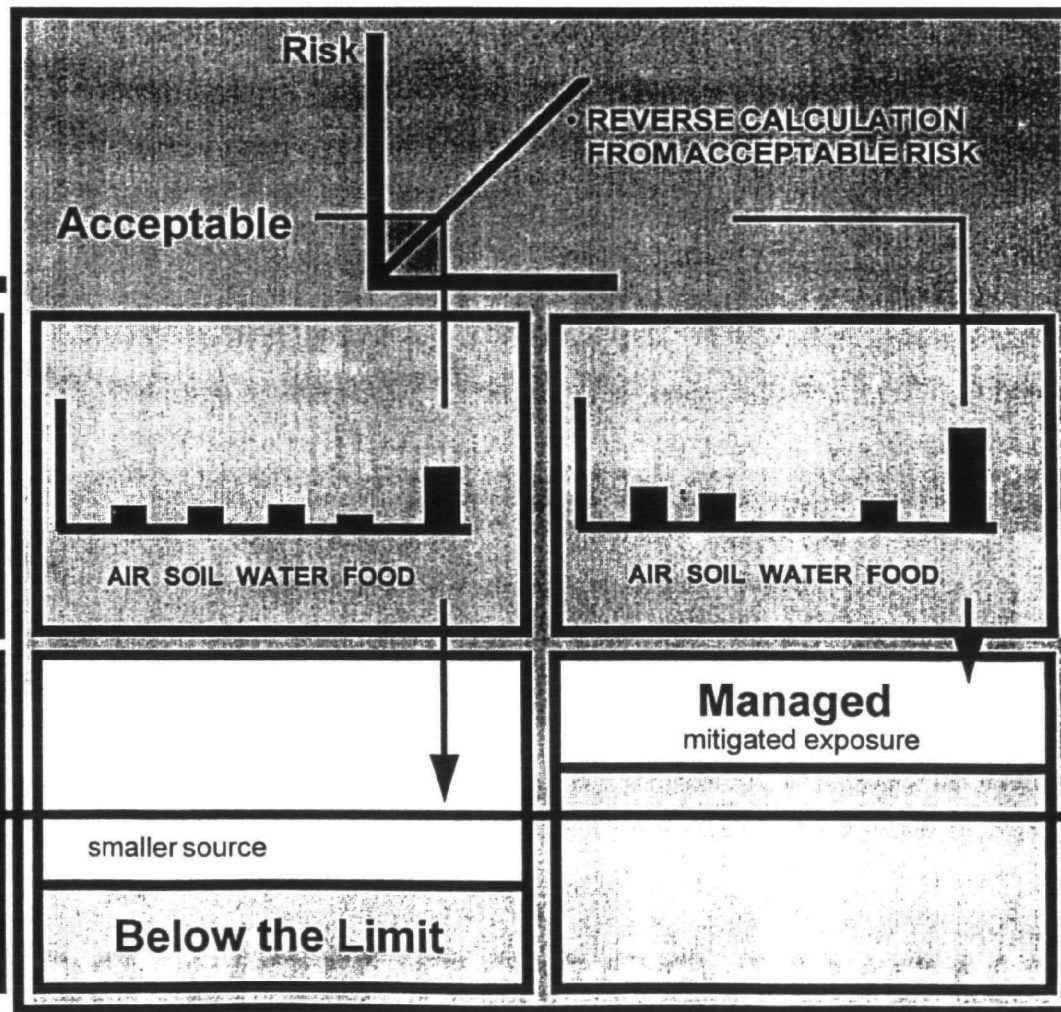
Solutions



Limit

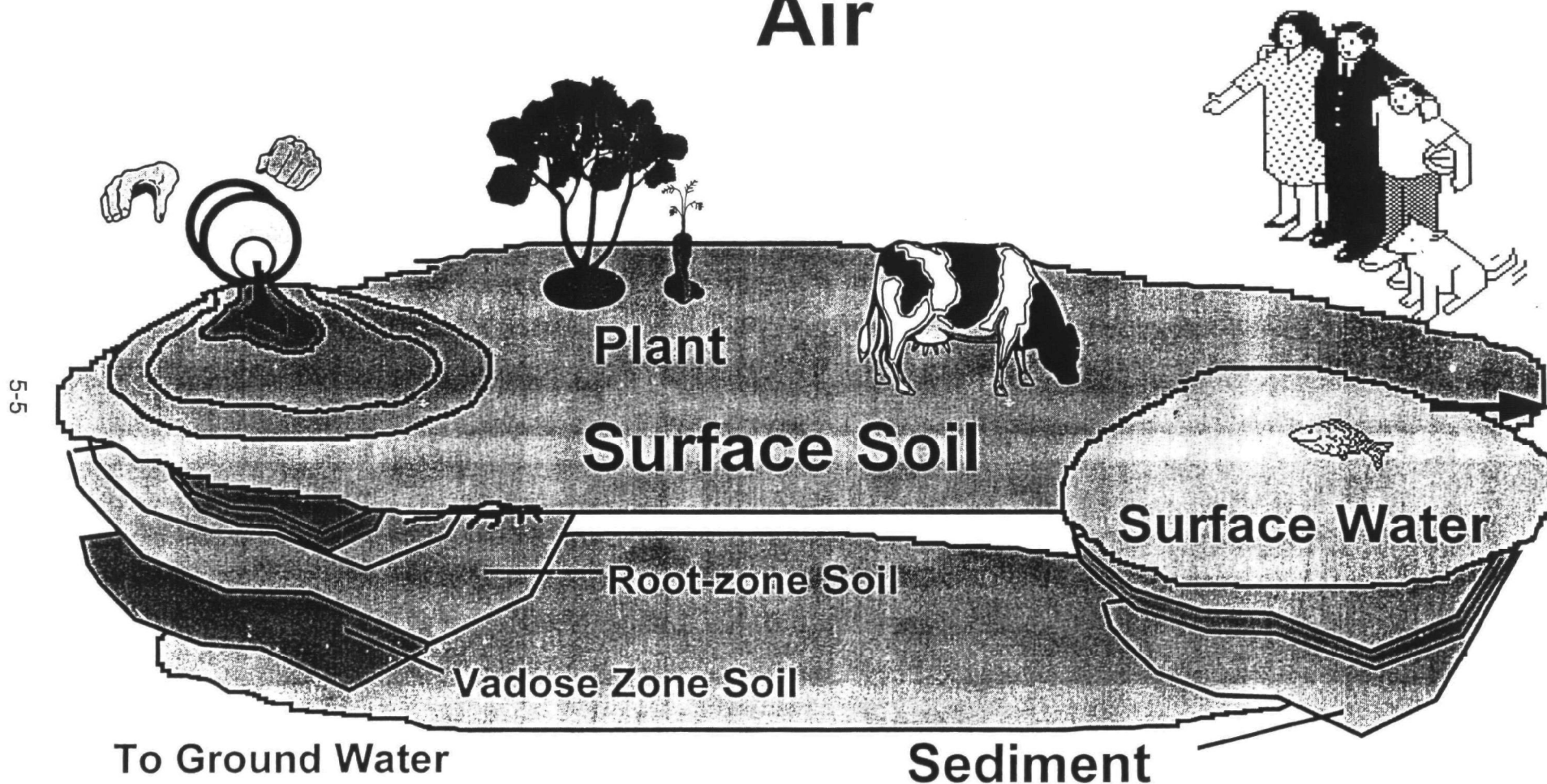
**Above the Limit**

**Problem**



# A Simple World

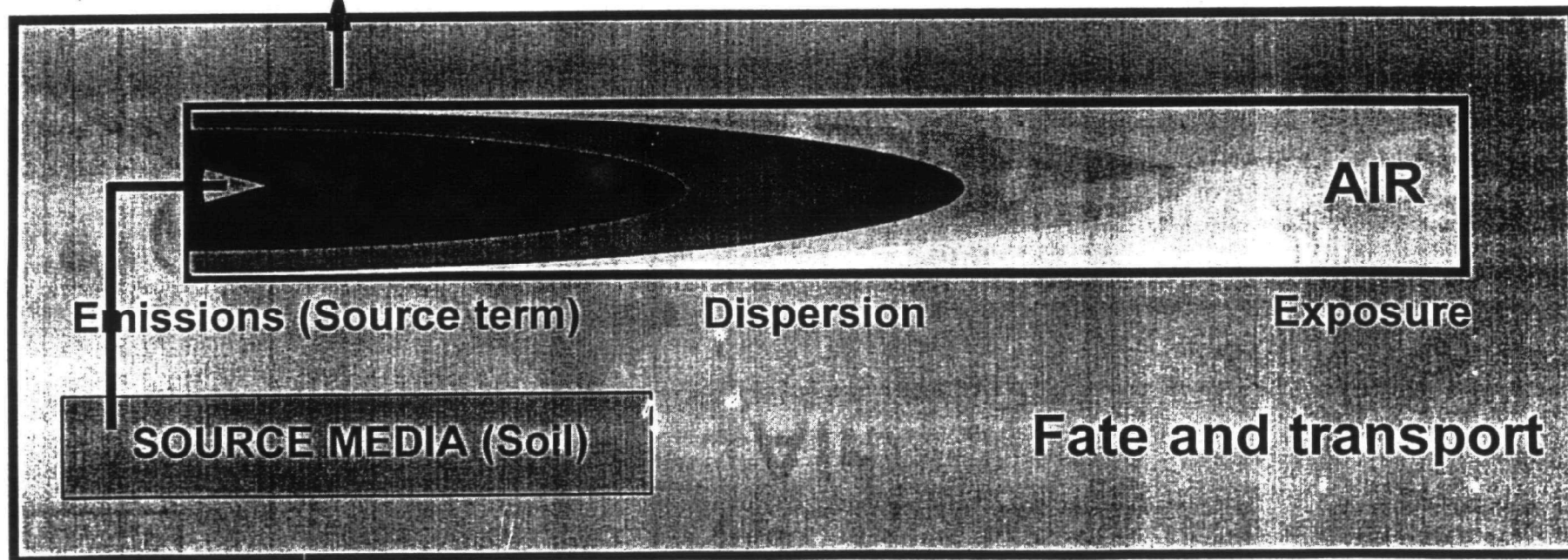
## Air



# MATHEMATICS: Basic Exposure Model

$$C_k \times \left[ \frac{TF}{\text{Transformation/Transport}} \right] \times \left[ \frac{ED \times EF}{AT} \right] \times \left[ \frac{IU}{BW} \right] = ADD = DOSE$$

Exposure



# Biological/Toxicological Uncertainty

- Toxicity Assessment

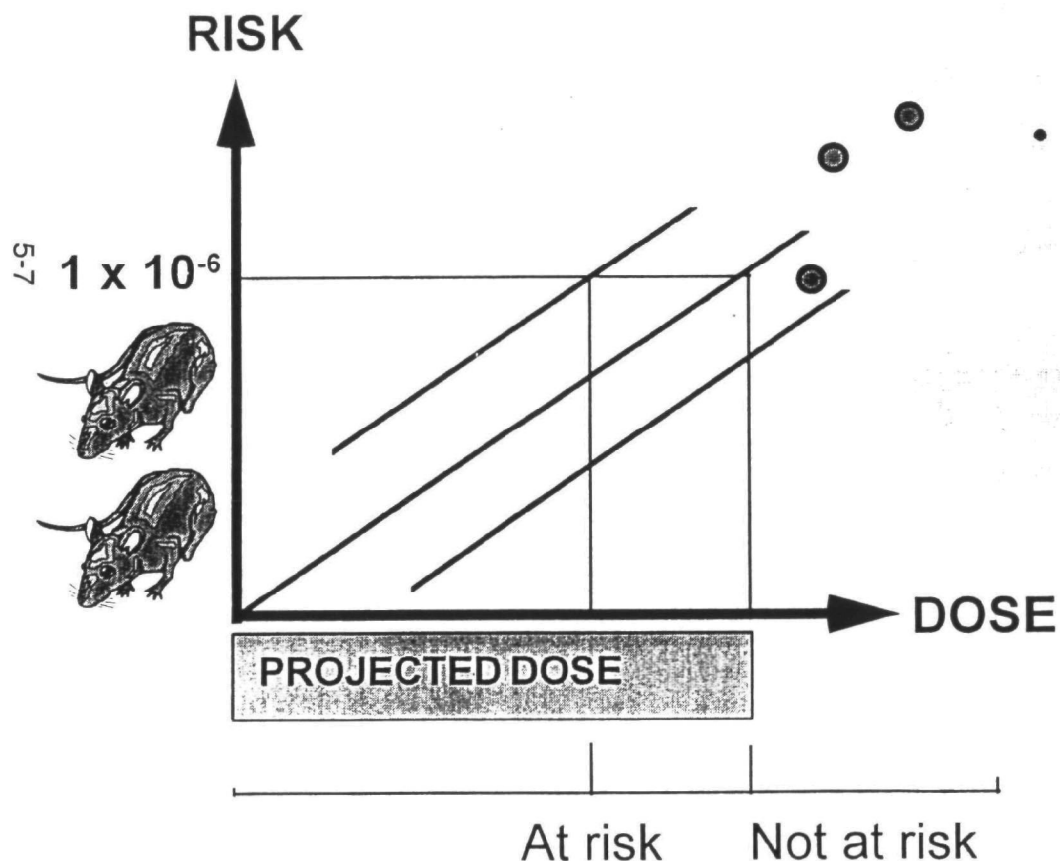
- Toxicity data

- Animal extrapolation -  
Do rats = man?

- Dose-response

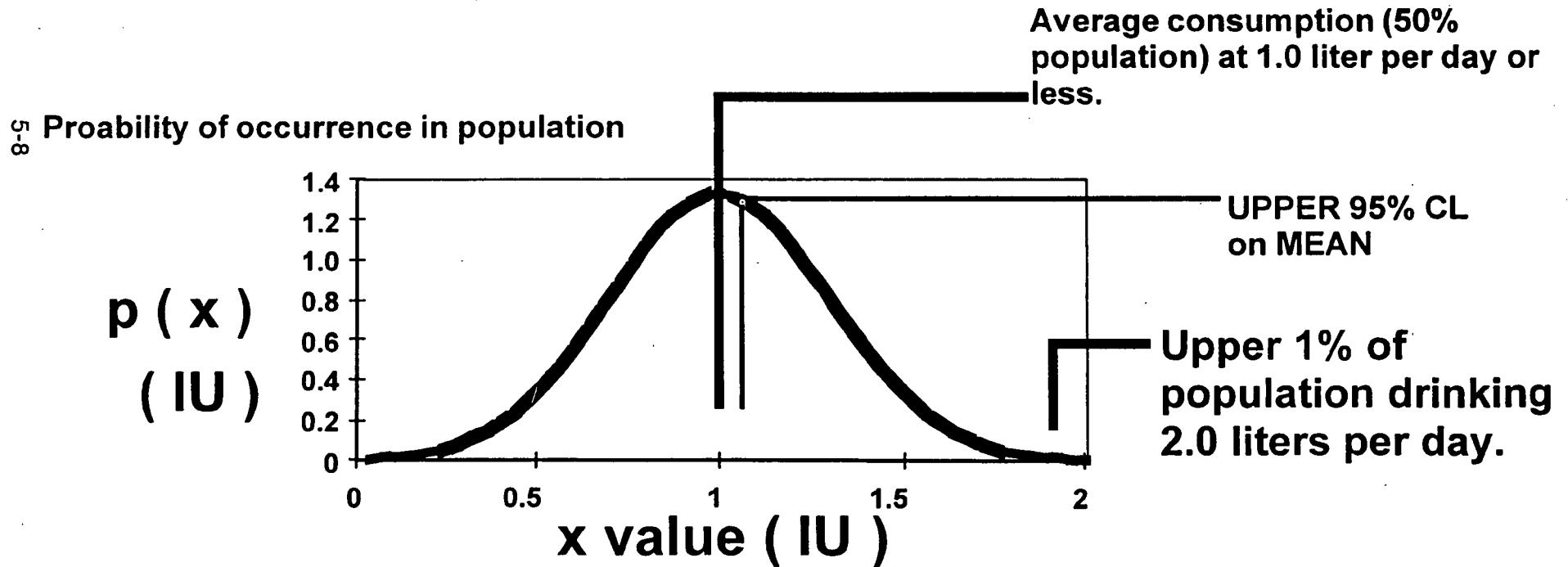
- Extrapolation model -  
Right model?

- Conservative assumptions -  
Right assumptions?



# Parameter Uncertainty

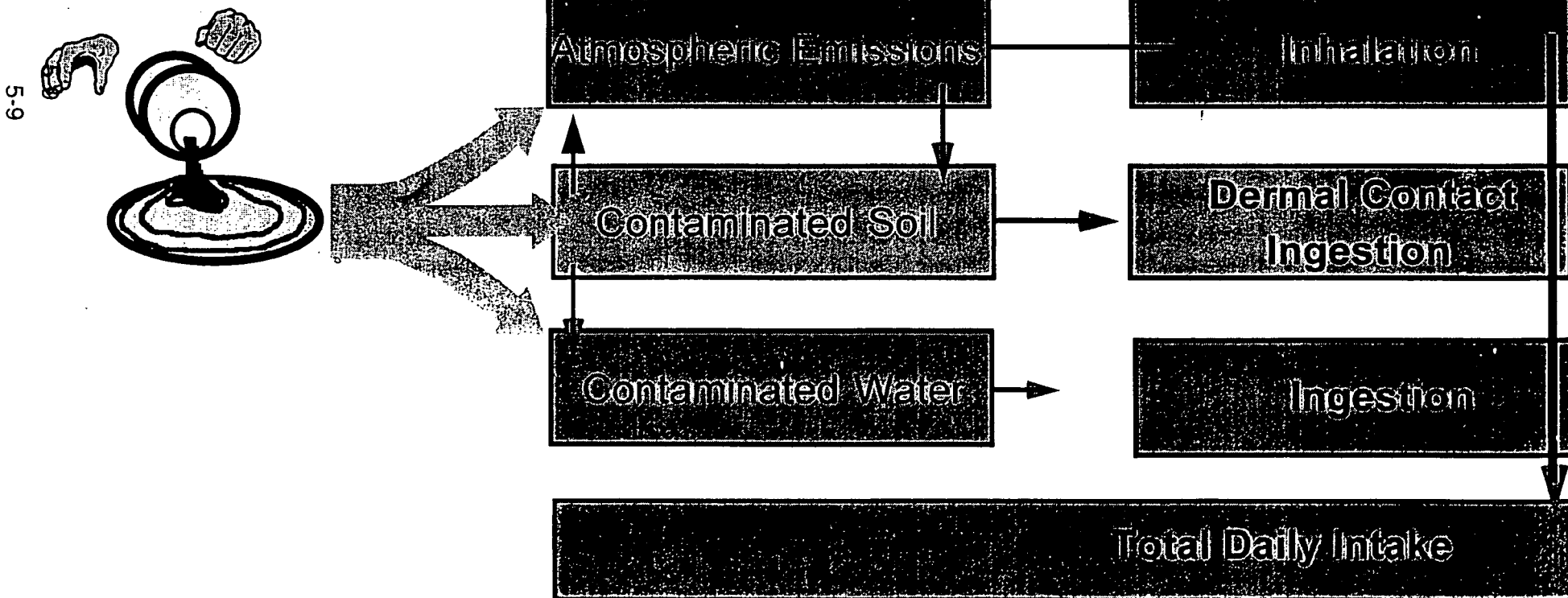
$$\text{DOSE} = \left[ \frac{\text{IU}}{\text{BW}} \right] \times \frac{\text{EF} \times \text{ED}}{\text{AT}} \times \left[ \text{TF} \right] \times \text{Ck}$$



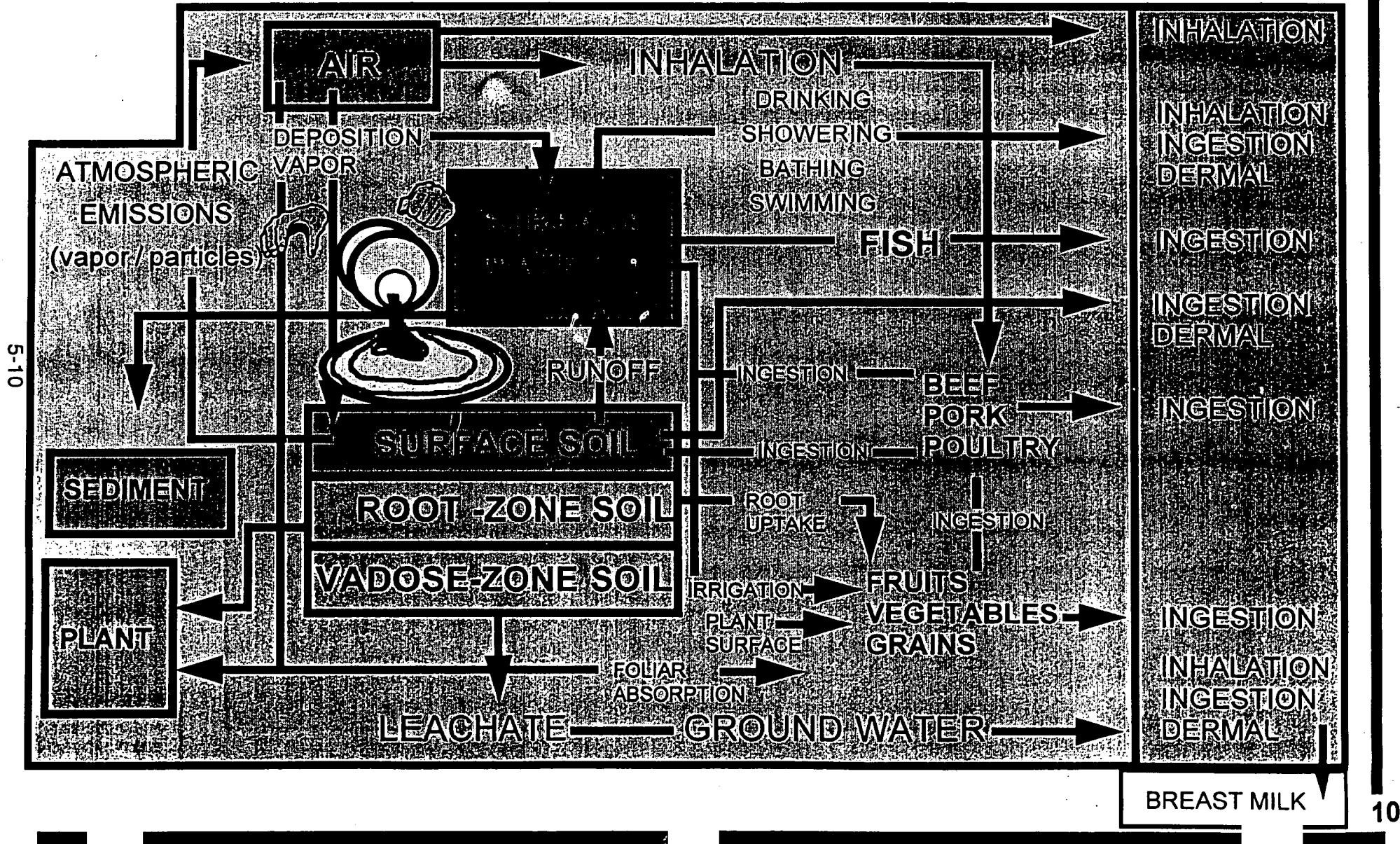


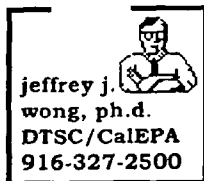
# Simple Exposure Scenario

- Inhalation
- Direct Soil Contact and Ingestion
- Ingestion of Water



# REAL WORLD COMPLEXITY

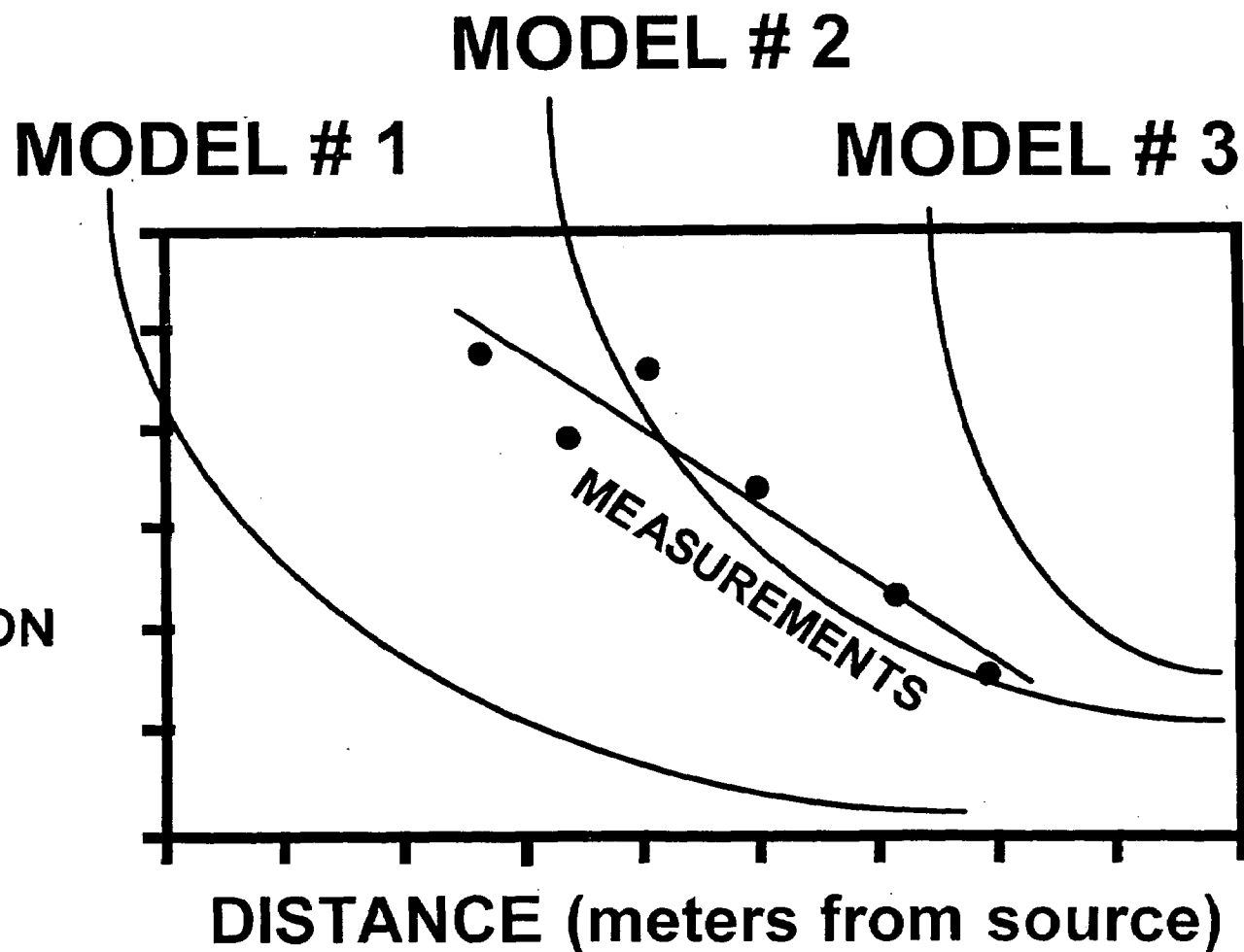




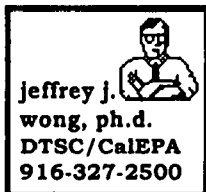
# Which Fate & Transport Model?



MEDIA  
CONCENTRATION  
(mg / m<sup>3</sup> air)

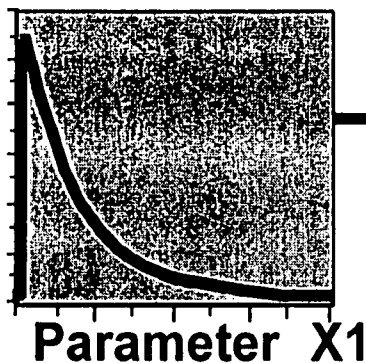




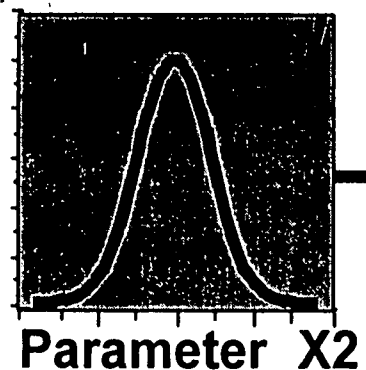


# Monte Carlo Analysis

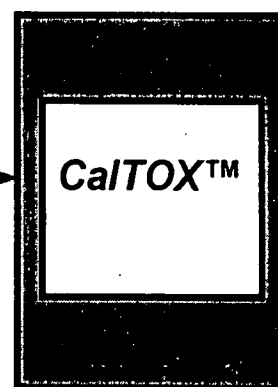
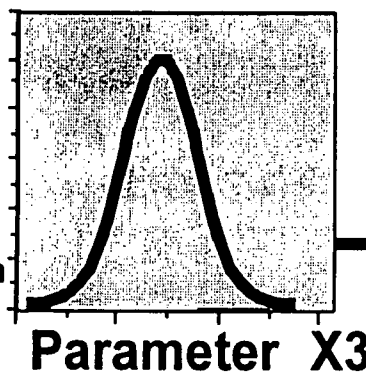
Exposure Data:  
Breathing Rate



Environmental  
Data: Rainfall

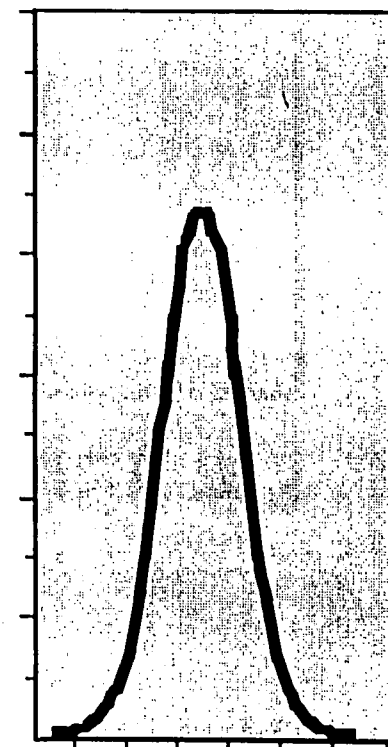


Sampling Data:  
Soil Concentration



Fate &  
Transport  
Model 1  
 $Y1 = f1(X1, X2, X3)$

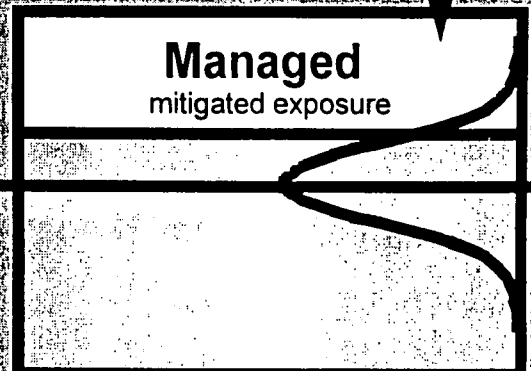
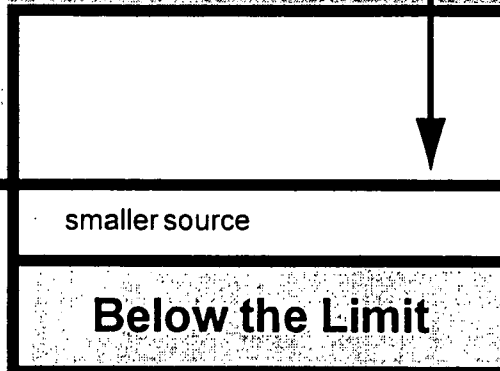
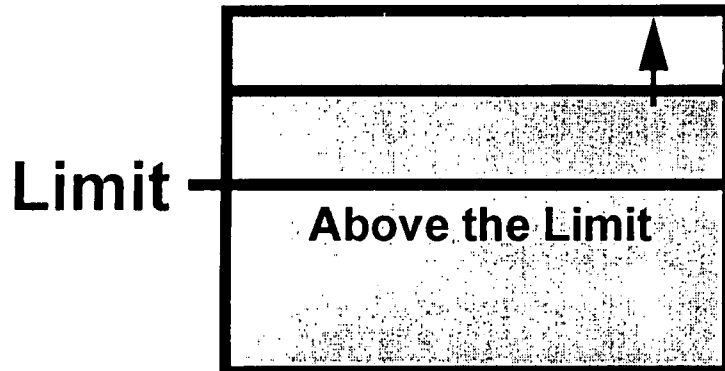
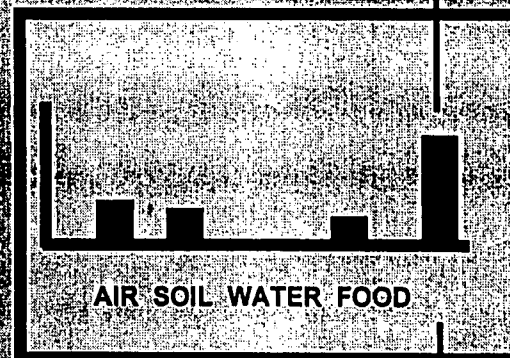
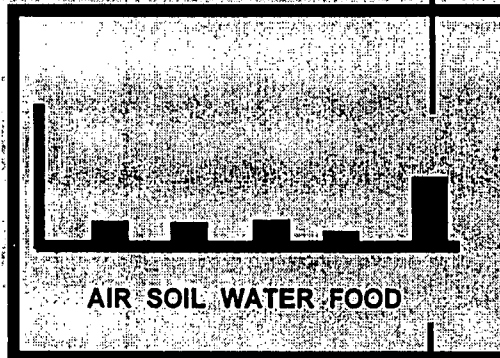
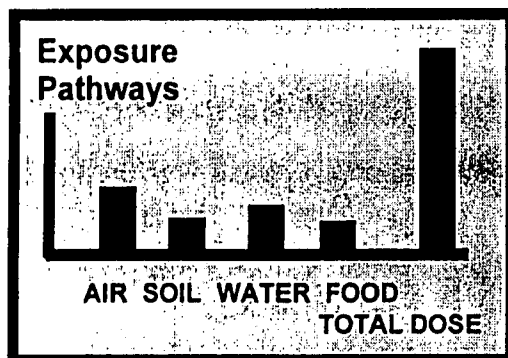
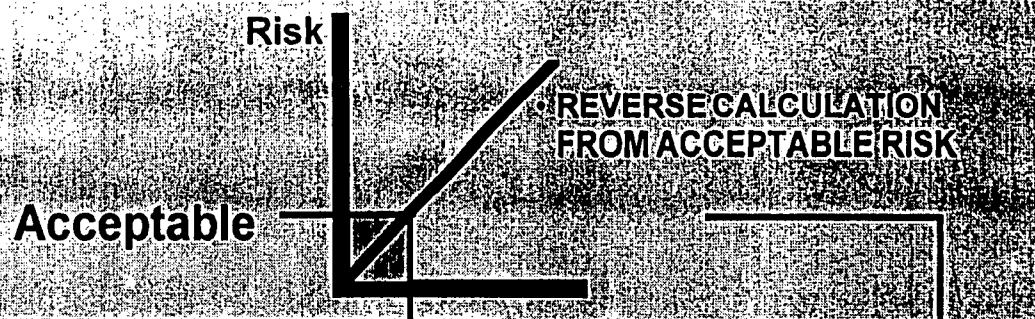
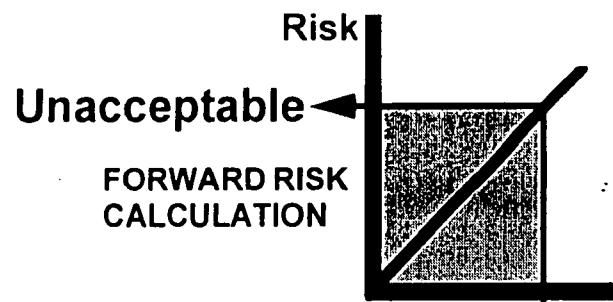
PROBABILITY



RISK  
Output Y1

# RISK-BASED SOLUTIONS

## Solutions



Problem

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# **RISK-BASED APPROACH TO DERIVE SOIL CLEANUP GOALS PROTECTIVE OF HEALTH AND WATER QUALITY - A Case Study**

by Ravi Arulanantham, Ph.D.<sup>a</sup>, Kenneth E. Eichstaedt, P.E.<sup>b</sup>, and Eddy P. So, P.E.<sup>c</sup>

## **Abstract**

Soil and groundwater pollution often pose a threat, to varying extent, to either human health or water quality or both. Cleanup of this pollution is a lengthy process and requires significant economic resources, and the elimination of all risks at an impacted site is not often possible. Considerable time, effort, and resources spent for cleanup may not always be justified technically and economically in light of the uncertainty and inconsistency encountered by the responsible parties during their cleanup process. This paper provides a methodology to derive site-specific cleanup goals which are protective of public health and water quality. The suggested approach also provides (i) predictability to the overall decision-making process; (ii) the opportunity for responsible parties to participate in the decision-making process during the establishment of soil cleanup goals; and (iii) consistency while ensuring flexibility in the remediation and management of pollution problems.

The methodology consists of: (1) completion of site characterization; (2) initial risk-based screening of contaminants; (3) derivation of health and/or ecological risk-based cleanup goals; (4) derivation of groundwater quality-based cleanup goals; (5) site cleanup goals and site remediation; and (6) risk management decisions. The approach was recently used at a site in Newark, California. The pollutants of concern in soil were petroleum hydrocarbons as weathered diesel, oil and grease, lead, and copper. The lead agency for this site was the San Francisco Bay Regional Water Quality Control Board with assistance on human health issues provided by the Alameda County Health Agency. The approach is technically defensible and can be a valuable tool to provide cost-effective solutions in the complex decision making process of site cleanup.

---

<sup>a</sup> Staff Toxicologist, San Francisco Bay Regional Water Quality Control Board

<sup>b</sup> Project Engineer, URS Consultants, Inc., San Francisco

<sup>c</sup> Associate Water Resources Control Engineer, San Francisco Bay Regional Water Quality Control Board

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**Risk/Exposure Assessment Case Study  
March 26, 1996  
1996 RCRA Corrective Action Conference**

**Ravi Arulanantham, Ph.D.**  
California Regional  
Water Quality Control Board  
San Francisco Bay Region

**Ken Eichstaedt, P.E.**  
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San Francisco, CA

**Eddy So, P.E.**  
California Regional  
Water Quality Control Board  
San Francisco Bay Region

***RISK EXPOSURE/ASSESSMENT CASE STUDY***

---

**ISSUES**

**Soil and groundwater contamination can cause varying degrees of threat to either human health/environment and/or water quality.**

**Soil and groundwater cleanup can be a very lengthy process requiring significant economic resources.**

**Eliminating all risks at a contaminated site is often not possible, even after cleanup.**

**Different agencies with different responsibilities are involved during the overall reclamation process.**

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URS Consultants, Inc.***

## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

---

### **OBJECTIVES**

- 1. To derive cleanup or remediation goals that are protective of both land use issues and water quality issues based on site-specific conditions and risk.**
- 2. To ensure that the cost of overall remediation efforts is truly relevant to the protection of human health and safety and other natural resources.**

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## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

---

### **SITE SETTING**

**Former foundry on 10 acres of a 37-acre parcel**

**Located in East Bay (San Francisco Bay) / Alameda County**

**Consisted of 2.5-acre (106,450 sq. ft.) building with associated furnaces, extrusion form press, pickling baths, and bag house**

**Manufactured brass and bronze metal products from 1957 to 1986**

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## **RISK EXPOSURE/ASSESSMENT CASE STUDY**

### **SITE HISTORY**

**Premanufacturing (pre-1957): Cultivation of hay**

**Manufacturing (1957 - 1986): Processed raw brass and bronze ingots into housing fixtures (plumbing, hardware, etc.). Facility consisted of extrusion form press, furnaces, bag house, coil pickling vats, acid storage tanks, caustic storage tanks, solvent (TCE), and diesel fuel.**

**Postmanufacturing (post-1986): Land fallow. RWQCB/Alameda County and owner agree to Site Cleanup Order in 1991. RI completed in 1992. Soil remediation completed in 1993. Groundwater remediation began in 1994.**

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URS Consultants, Inc.*

## **RISK EXPOSURE/ASSESSMENT CASE STUDY**

### **LAND USE**

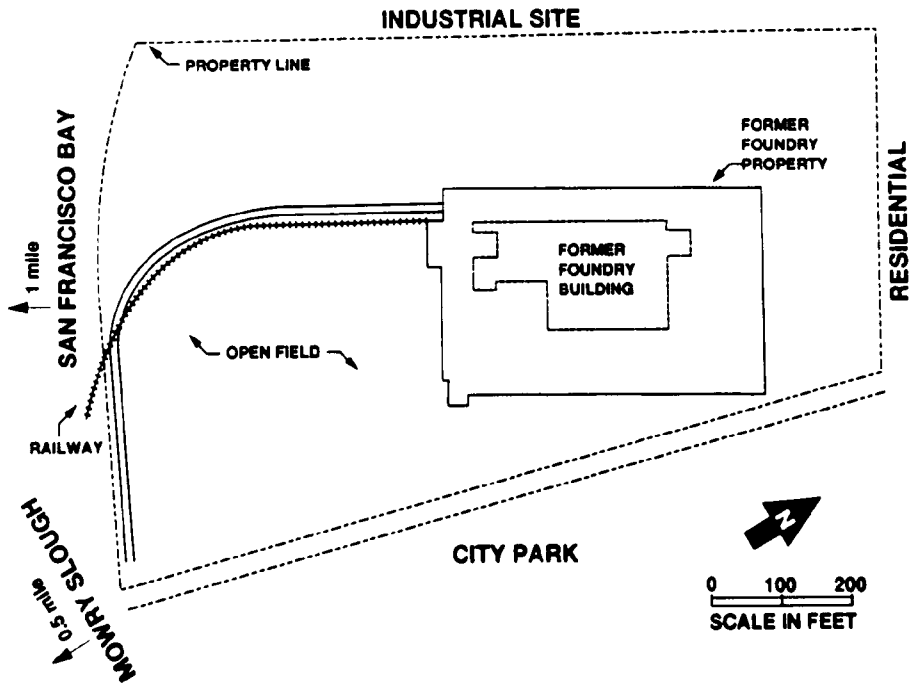
**Adjacent land use:**   **South - City Park**  
                              **East - Residential Housing**  
                              **North - Industrial Facility**  
                              **West - Railway line and**  
                                      **San Francisco Bay**  
                                      **(approximately 1 mile away)**

**Zoned in municipal master plan as commercial/industrial**

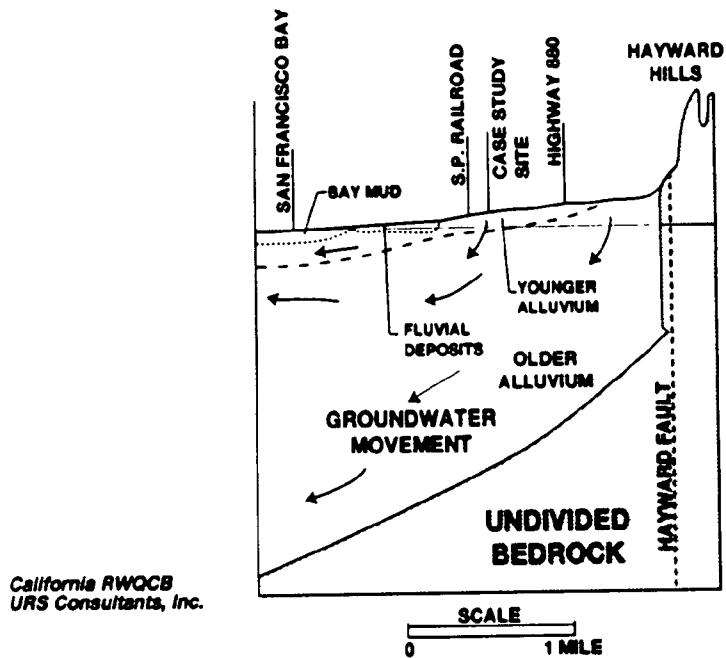
**Current residential use and city park within 500 feet of site**

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URS Consultants, Inc.*

## RISK EXPOSURE/ASSESSMENT CASE STUDY

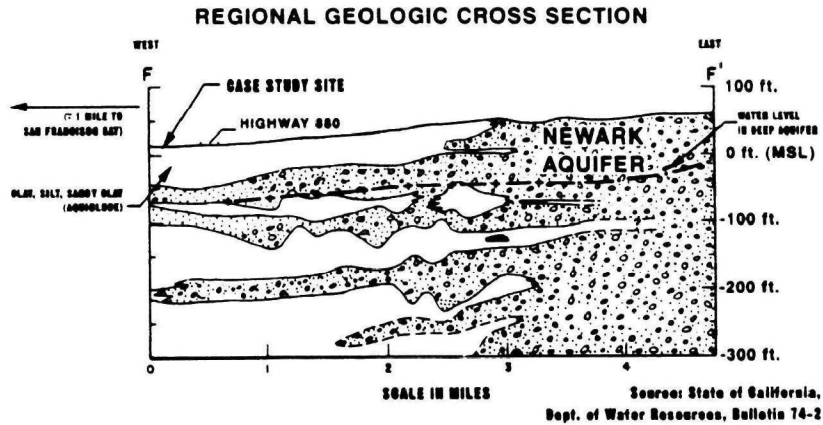


## RISK EXPOSURE/ASSESSMENT CASE STUDY



## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

---



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## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

---

### **SENSITIVE WATER BODIES**

**San Francisco Bay ( $\approx$  1 mile away)**

**Mowry Slough ( $\approx$  1/2 mile away)**

**Shallow Aquifer (10 to 30 feet bgs)**

**Newark Aquifer (potential drinking water aquifer);**

- 50-feet below ground surface
- Municipal drinking water well within 1/2-mile east of site

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## **RISK EXPOSURE/ASSESSMENT CASE STUDY**

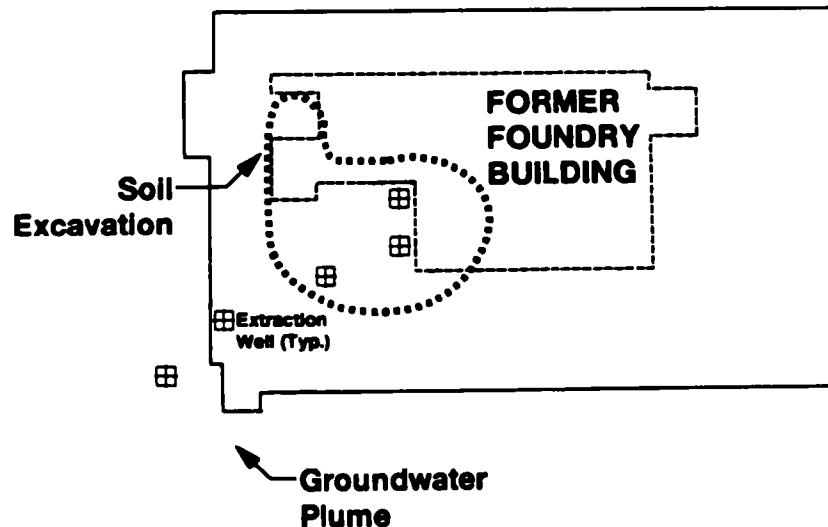
### **DISTRIBUTION OF CONTAMINANTS**

<b>SOIL</b>			<b>Maximum*</b>	<b>Average*</b>
<b>Metals:</b>			<b>Concentration</b>	<b>Concentration</b>
	<b>Lead</b>	<b>0 to 2 ft.</b>	<b>2,950</b>	<b>900</b>
	<b>Copper</b>	<b>0 to 2 ft.</b>	<b>11,000</b>	<b>1,500</b>
<b>Hydrocarbons:</b>				
	<b>TPH/diesel</b>	<b>0 to 10 ft. bgs</b>	<b>6,200</b>	<b>1,000</b>
	<b>Oil &amp; Grease</b>	<b>0 to 5 ft. bgs</b>	<b>22,000</b>	<b>1,700</b>
<b>GROUNDWATER (Shallow aquifer &lt; 10 ft. bgs)</b>				
	<b>Total VOCs (Primarily TCE, TCA, DCE, and DCAs)</b>	<b>7</b>		<b>&lt;2</b>
	<b>TPH/diesel</b>	<b>6</b>		<b>&lt;0.5</b>

California RWQCB  
URS Consultants, Inc.

\* (ppm)

## **RISK EXPOSURE/ASSESSMENT CASE STUDY**



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## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

---

### **PUBLIC HEALTH RISKS**

**Dominant Exposure scenario:**

- |                         |  |
|-------------------------|--|
| <b>Future on-site</b>   | <b>- Residential use</b>                               |
| <b>Current off-site</b> | <b>- Nearby park provides potential child exposure</b> |

**Exposure routes: ingestion, dermal, and inhalation**

**The risk associated with drinking shallow G.W. was not evaluated**

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URS Consultants, Inc.***

## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

---

### **ENVIRONMENTAL RISKS**

**Environmental risk posed by potential leaching of soil contaminants to groundwater**

**Environmental risk evaluated by modified TCLP test to assess leachability**

**Comparison of leaching extract to the following criteria:**

**Suggested No Adverse Response Levels (Secondary MCLs)**

**LUFT Field Manual**

**State of Washington *Model Toxics Control Act Cleanup Regulations***

**RWQCB's Water Quality Control Plan (Basin Plan), Toxic**

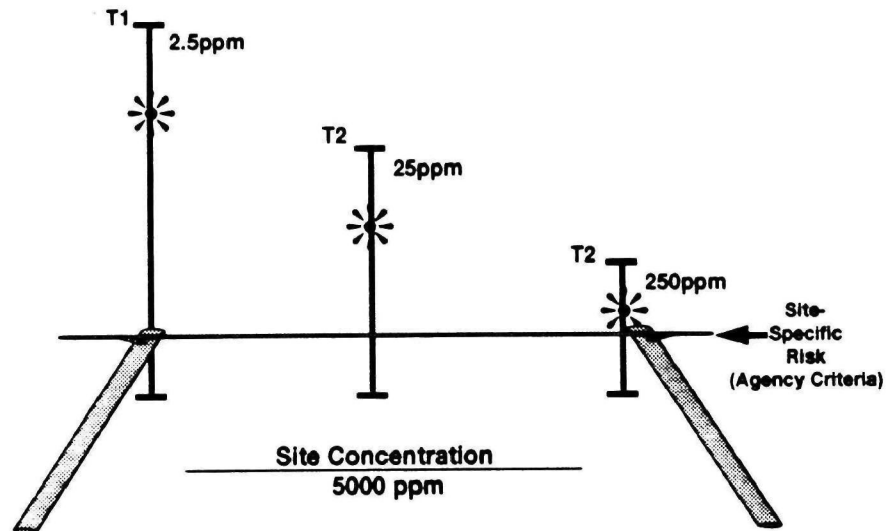
**Pollutant Accumulation guidelines**

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## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

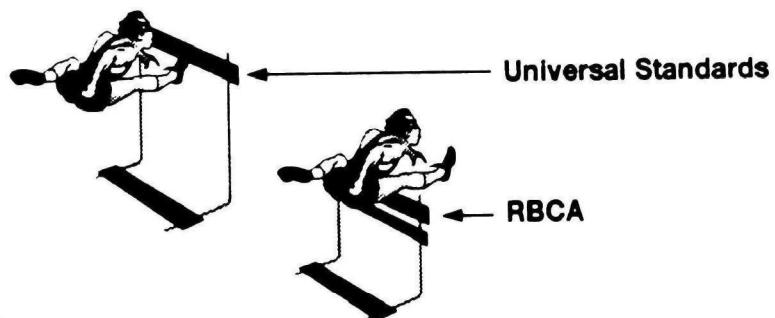
### **HYPOTHETICAL CLEANUP STRATEGY**

☼ ND/Background/Order



## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

### **Corrective Action Strategies**



## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

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### **PUBLIC HEALTH PROTECTIVE CLEANUP GOALS**

- Followed U.S. EPA 1990 UBK model for lead.
- Followed U.S. EPA RAGS for Cu and TPH-D.
- Standard dose equations using deterministic exposure parameters for on-site/off-site exposure.
- Reverse calculations of allowable soil concentrations for Cu and TPH-D using the following exposure parameters:

Ingestion rate 200 mg/day  
Fraction ingested from contaminated soil = 1  
Exposure frequency = 265 days/year  
Exposure duration = 6 years  
Body weight = 15 kg  
Skin surface area available for soil contact = 9,500 sq. cm  
Target risk level was a HI = 1

Adherence of soil to skin = 1.45 mg/cm  
Fraction of Cu adsorbed through the skin = 0.05  
Particulate emissions factor =  $4.63 \times 10^{-9}$  cu. meters/kg  
Inhalation rate = 15 cu. meters/day

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## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

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### **RESULTS**

Calculate health-risk-based soil cleanup goals protective of children:

**Pb: 225 mg/kg of soil**

**Cu: 860 mg/kg of soil**

<b>TPH</b>	<b>General</b>	<b>Children</b>
<b>Ing.</b>	<b>2190 mg/kg</b>	<b>625 mg/kg</b>
<b>Derm.</b>	<b>180 mg/kg</b>	<b>80 mg/kg</b>

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## **RISK EXPOSURE/ASSESSMENT CASE STUDY**

### **ENVIRONMENTAL CLEANUP GOALS**

**Contaminants leaching from soil to groundwater**

**Used modified TCLP test to assess leachability**

**Comparison of leachate to the following criteria:**

**MCLs for copper and lead**

**Secondary MCLs for TPH-Diesel and TOG**

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## **RISK EXPOSURE/ASSESSMENT CASE STUDY**

### **RESULTS**

<b>Lead</b>	<b>100 mg/kg</b>
<b>Copper</b>	<b>&gt;1600 mg/kg</b>
<b>TPH as diesel</b>	<b>&gt; 130 mg/kg</b>
<b>TOG</b>	<b>&gt; 100 mg/kg</b>

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## **RISK EXPOSURE/ASSESSMENT CASE STUDY**

### **SITE WIDE RISK BASED CLEANUP GOALS**

COC	Maximum Site Concentration	Calculated Health-Based Goal mg/kg of Soil	Leechability-Based Water Quality Goal mg/kg of Soil	Cleanup Goal Selected mg/kg of Soil
<b>SOIL</b>				
	(mg/kg)			
Lead	2,950	255	100	100
Copper	11,000	880	>880	880
TPH as Diesel	6,200	80	>80	80
TOG	22,000	100	>100	100
<b>GROUNDWATER</b>				
	(mg/L)			Attempting MCLs.
TCE	8.8	-	-	
TCA	0.5	-	-	Future maybe
DCE	1.5	-	-	risk-based
DCA	0.5	-	-	cleanup criteria.

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## **RISK EXPOSURE/ASSESSMENT CASE STUDY**

### **CORRECTIVE ACTION IMPLEMENTATION**

#### **Soil**

Lead	}	700 cy
Copper		
TPH/TOC		7,900 cy
<b>TOTAL</b>		<b>8,600 cy</b>

#### **Groundwater**

**5-well extraction/treatment system operating**  
**Tentative MCL/health-risk-based cleanup goals**

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## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

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### **RISK MANAGEMENT ISSUES**

- Agency letter confirming all health risks are mitigated for residential soil
- Site cleanup order for G.W. remediation
- Deed notification for G.W. treatment system access/operations
- Contingency plan for future plume migration
- All records placed in the local city archives available for easy public access
- At time of building houses, an additional RA for G.W. volatilization to indoor air

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## ***RISK EXPOSURE/ASSESSMENT CASE STUDY***

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### **'Working Smart Vs. Working Hard'**

<b>Risk-Based Cleanup Approach</b>	<b>\$860,000</b>	<b>Time: 3 months</b>
<b>Cleanup to Background</b>	<b>\$1,600,000</b>	<b>Time: 12 months</b>

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## **RISK-BASED MANAGEMENT APPROACH TO CLEANUP OF CONTAMINATED SOIL**

**Authors: Mr. Ravi Arulanantham, Ph.D.  
Staff Toxicologist**

**"Mr. Arulanantham is the Staff Toxicologist for the Alameda County. Currently, he is serving as the Staff Toxicologist for the Regional Water Quality Control Board on an Inter Agency assignment. He is also an ASTM sanctioned National Trainer for the ASTM RBCA standard."**

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**"Mr. Eichstaedt has worked extensively in the hazardous/toxic materials field over the past 12 years performing remedial investigations, feasibility studies, remedial action plans, and construction management of hazardous waste cleanup projects. He is currently the Site Manager for two Superfund projects and a private site in which he has successfully used the cleanup strategy presented in this abstract for the cleanup of petroleum hydrocarbon contamination."**

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**Mr. Eddy P. So, M.Sc., P.E.  
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# **DESIGN OF ON-SITE WASTE CONTAINMENT SYSTEMS FOR RCRA CORRECTIVE ACTION**

*by*

**R. Jeffrey Dunn and Harold A. Tuchfeld**

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On-site waste containment systems have attracted increased interest among regulators and the private sector for potential management of on-site contaminant sources at sites regulated under RCRA, CERCLA, and state regulations. This interest has been heightened by the potential of on-site containment systems to be both environmentally protective and cost effective at certain sites, and by greater use of risk-based decisions for corrective action (especially for areas where there will be future industrial or open space use).

This presentation focuses on the design and construction of on-site systems for buried or excavated waste for use in RCRA interim stabilization measures and RCRA final corrective measures. Methods discussed include 1) in-situ containment of buried waste, such as capping and subsurface barriers (including slurry walls), and 2) development of new on-site containment cells for excavated solid and hazardous waste or impacted soil. The goal of the presentation is to provide private sector environmental managers and regulatory oversight managers with information that can be useful for deciding on the appropriateness of such on-site containment strategies for particular situations, and for the logistical planning, scheduling, cost estimating, and implementation of on-site containment methods.

An overview is provided of the various stages of a typical on-site containment project, including the regulatory approval process, design, procurement, construction, operation, and closure. Information is provided on the design of single-liner and double-liner systems, leachate collection systems, leak detection systems, final cover systems, and subsurface barriers. Leachate management is also discussed. In addition, the use of innovative materials and designs that have the potential for increased performance and cost savings are described. The reliability and longevity of modern engineered hazardous waste containment systems are also briefly discussed.

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## **OVERVIEW OF GEOSYNTEC CONSULTANTS**

GeoSyntec Consultants (GeoSyntec) is a geoenvironmental consulting and engineering design firm with 250 personnel in seven offices in the United States (including Walnut Creek and Huntington Beach California offices within EPA Region 9) and one office in France. GeoSyntec's technical staff includes engineers and scientists with specialties in a broad array of technical disciplines. The firm has an active process in the areas of RCRA corrective actions; RCRA TSD facility and closure design; CERCLA remedial investigations, feasibility studies, remedial design, and removal orders; landfill design and closure; subsurface fate and transport modeling for risk assessment and remedial design; investigation and remediation at agricultural chemical and manufacturing facilities, seismic design and evaluation of earth structures, geotechnical engineering, and construction management and construction quality assurance (CQA).

The firm is recognized nationally as the technological leader in the design, construction, and closure of hazardous and solid waste landfills, including application of subsurface barriers. GeoSyntec has completed over 500 landfill-related projects for private and public sector clients. GeoSyntec has also provided assistance to the EPA and state agencies throughout the country (including the California Integrated Waste Management Board and California Regional Water Quality Control Boards) in research, technical guidance document preparation, and training regarding landfill design and closure.

GeoSyntec has worked with the EPA in the evaluation of the performance of liner systems used at hazardous waste land disposal facilities, and on the development of technical regulatory guidelines for the design and construction of double liners and leak detection systems at these facilities. GeoSyntec recently performed research for the U.S. Navy on the use of subsurface barriers for containment source control at unlined Navy landfills.





## Outline of Presentation

- ◆ Functions of Systems
- ◆ Regulatory Drivers
- ◆ Factors Favoring Systems
- ◆ Components of Typical Systems
- ◆ Detailed Design
- ◆ Construction Quality Control/Assurance
- ◆ Contractor Procurement
- ◆ Typical Costs
- ◆ Opportunities/Cost Savings
- ◆ Case Studies

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## Functions of On-Site Disposal and In-Situ Containment Systems

- ◆ Provide for safe, environmentally protective on-site disposal and in-situ containment of wastes
- ◆ On-Site Disposal – Landfills
  - Industrial wastes (ash, sludge, manufacturing waste)
  - Hazardous wastes
  - Contaminated soils and sludges
  - Contaminated building debris
  - Construction/demolition debris
- ◆ In-Situ Containment – Source Control
  - Former disposal pits
  - Subgrade building debris
  - Contaminated soils and sludges
  - Marsh Sediment

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## Functions of On-Site Disposal and In-Situ Containment Systems (cont.)

- ◆ Disposal and containment systems are intended to protect the quality of human health and the environment by preventing contaminant migration across all major pathways, including
  - Ground water
  - Surface water
  - Air
- ◆ This goal is achieved through the use of engineered systems
  - Liquid and gas barrier layers
  - Liquid and gas collection systems

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## Factors Favoring On-Site Disposal and In-Situ Containment

- ◆ Source area contains wastes not amenable to treatment
  - Mercury containing plastic clay soils
  - PCBs containing co-contaminants (dioxins or lead)
  - Contaminated sludges containing MSW and C/D debris
- ◆ Source area contains RCRA hazardous waste
  - Remediation wastes become hazardous once removed from a CERCLA Operable Unit or RCRA CAMU
  - Off-site treatment and disposal cost for RCRA hazardous waste will typically be very high

**Note** Off-site treatment and disposal costs for RCRA hazardous waste consisting of soil, mixed sludge, and debris will depend on whether an LDR treatability variance can be obtained under 40 CFR § 268.44(a). USEPA is often predisposed to provide variances for these materials. 59 CFR 47986 states, "It has been the Agency's experience that contaminated soils are significantly different in their treatability characteristics from the wastes that have been evaluated in establishing the BDA T standards, and thus, will generally qualify for a treatability variance under 40 CFR 268.44(a)." 4

## Factors Favoring On-Site Disposal and In-Situ Containment (cont.)

- ◆ Source area contains nonhazardous waste requiring significant pretreatment prior to off-site disposal
  - Dewatering/filter press/drying beds
  - Ex-situ solidification
  - Unique material handling issues (debris, thixotropic material, tarry waste)
- ◆ Source area has waste identified by USEPA as being amenable to in-situ containment or not treatable with current technology
  - SACM Presumptive Remedies – in-situ containment for waste containing MSW and CDW
  - USEPA Technical Guidance – limitations on treatment technologies

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## Factors Favoring On-Site Disposal and In-Situ Containment (cont.)

- ◆ Source area contains waste that is difficult or dangerous to excavate
  - Source extends to significant depth
  - Source is in a high water table zone with loose, permeable soil
  - Source consists of sludges, muds, debris, etc., that are difficult to excavate
  - Source contains volatile components that create health and safety or air quality concerns if excavated
  - Source contains dangerous waste such as air-reactive material (phosphorus)
  - Short-term risks associated with excavation and transport exceed long-term management risk (requires risk assessment and demonstration)

Note On-Site disposal and in-situ containment do not result in a reduction in toxicity or volume of waste

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## Factors Favoring On-Site Disposal and In-Situ Containment (cont.)

- ◆ An analysis of the proposed remedy/corrective action demonstrates acceptable risk to human health and environment
  - Source performance modeling (ground water, surface water, air)
  - Risk assessment (human health, ecology)
  - Assessment of remedy reliability and permanence

Note Achievable performance levels are as follows

- (1) On-site disposal facilities can obtain leachate collection efficiencies of
  - 95 to 99.9% (RCRA Subtitle D landfill)
  - 99 to 99.99% (RCRA Subtitle C landfill)
- (2) In-situ containment systems can typically achieve reductions in source migration rates of 90 to 99%

## Factors Favoring On-Site Disposal and In-Situ Containment (cont.)

(ROM Construction Cost)

- |  |                                   |
|--|-----------------------------------|
| ◆ Institutional Controls                 | \$1 to \$5/yr <sup>3</sup>        |
| ◆ On-Site Disposal                       | \$20 to \$40/yr <sup>3</sup>      |
| ◆ In-Situ Containment                    | \$10 to \$250 /yr <sup>3</sup>    |
| ◆ Off-Site Disposal (Nonhazardous)       |                                   |
| – Without pretreatment                   | \$15 to \$50 /yr <sup>3</sup>     |
| – With pretreatment                      | \$25 to \$100 /yr <sup>3</sup>    |
| ◆ Off-Site Disposal (Subtitle C or TSCA) |                                   |
| – Pretreatment and disposal              | \$150 to \$200 /yr <sup>3</sup>   |
| – BDA1 treatment and disposal            | \$250 to \$1,000 /yr <sup>3</sup> |

Note On-site disposal or in-situ containment options may have significant O&M cost and long-term risk management implications. Passive in-situ containment options will typically be less costly than on-site disposal options

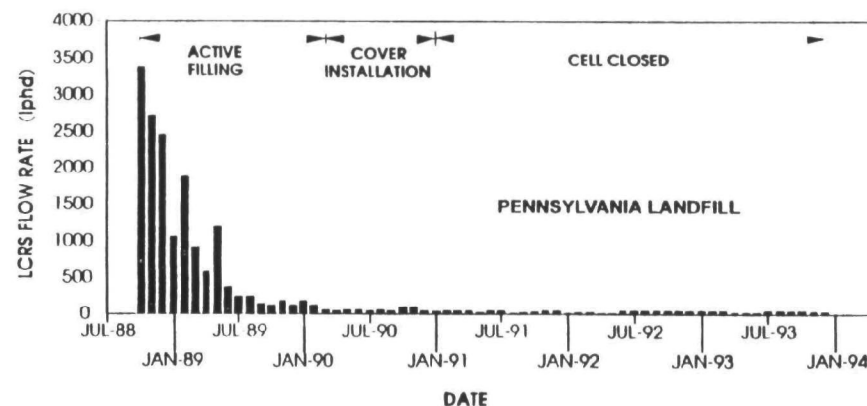
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## On-Site Disposal (Landfill) System Components

- ◆ Liner System
- ◆ Final Cover System
- ◆ Liquid/Gas Removal System

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DISPOSAL FACILITY LEACHATE GENERATION



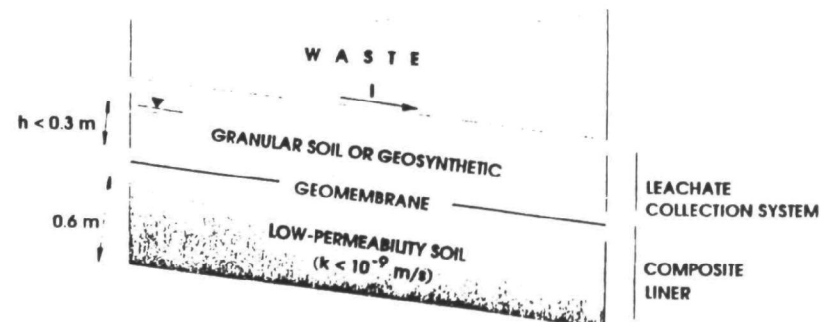
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## On-Site Disposal System Components: Liner System

- ◆ Combination of one or more drainage layers and low-permeability barrier layers (i.e., liners)
- ◆ Liners impede migration of liquid and gas out of the landfill
- ◆ Drainage layers control the build-up of hydraulic head on underlying liners and convey liquids to sumps

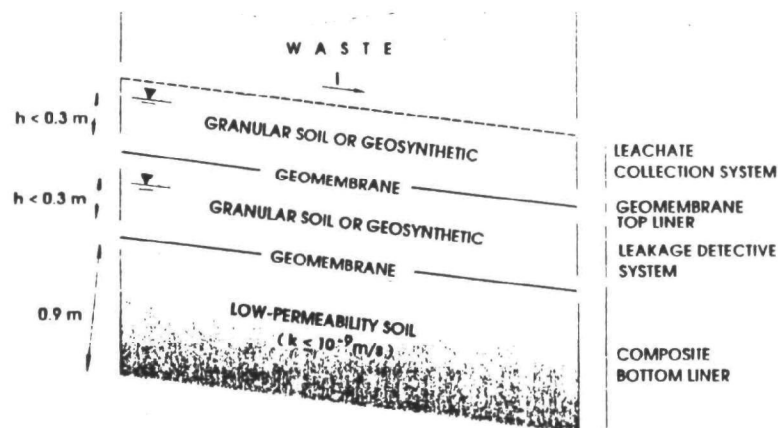
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LINER SYSTEM  
(RCRA SUBTITLE D)



12

LINER SYSTEM  
(RCRA SUBTITLE C)



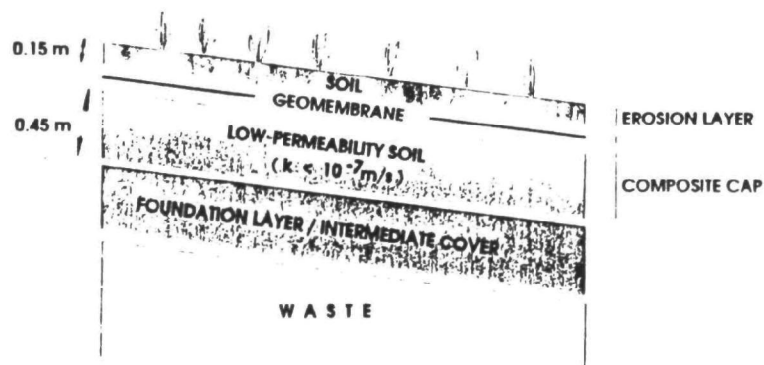
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## On-Site Disposal System Components: Final Cover System

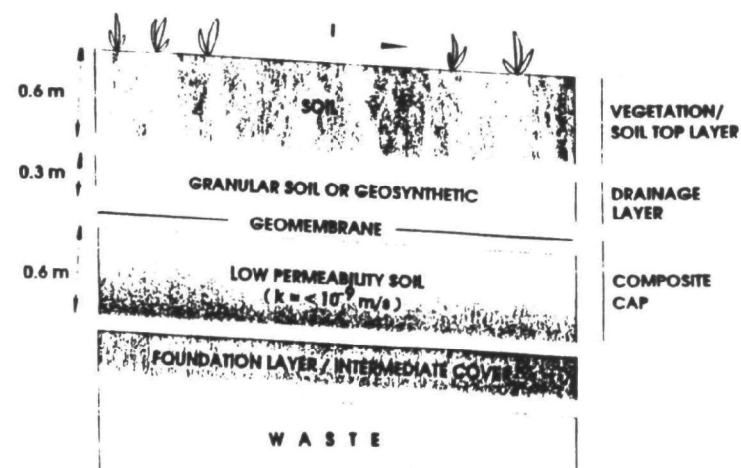
- ◆ Combination of one or more drainage layers and low-permeability barrier layers (i.e., caps)
- ◆ Caps prevent water infiltration into, and gas migration from, on-site disposal area
- ◆ Drainage layer above cap controls hydraulic head on cap and minimizes downslope seepage forces in the cover soil
- ◆ Grass and topsoil layer is usually the topmost layer; function is to limit erosion and promote surface-water runoff

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FINAL COVER SYSTEM  
(RCRA SUBTITLE D)



FINAL COVER SYSTEM  
(RCRA SUBTITLE C)



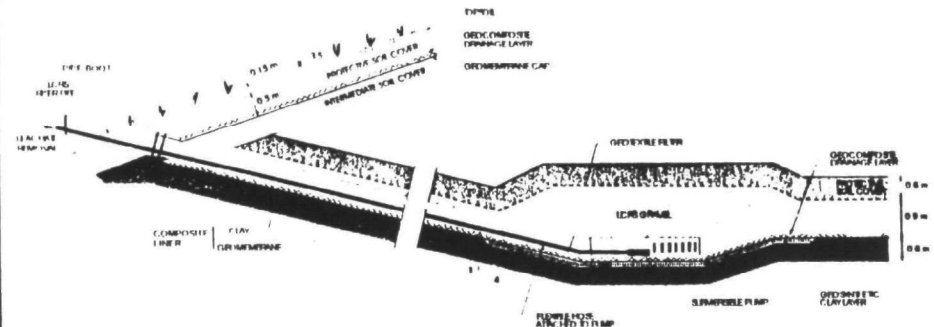
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## On-Site Disposal System Components: Liquid/Gas Removal Systems

- ◆ Liquid removal systems are used to remove collected leachate from landfills; leachate is discharged to a storage tank (for subsequent transport to an off-site treatment facility, near-site sewer line hookup, or on-site treatment facility)
- ◆ Gas extraction systems are used to remove gas from landfills; gas is either vented to atmosphere (usually with pretreatment), flared, or incinerated

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### LIQUID REMOVAL SYSTEM



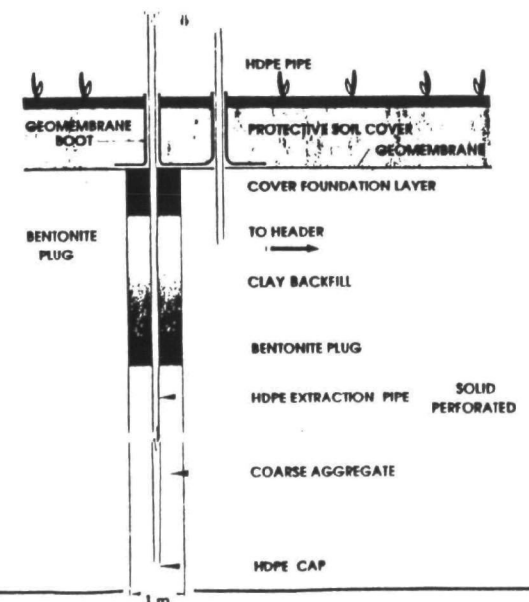
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## On-Site Disposal/In-Situ Containment Liquid Management Options

- ◆ Hard pipe to existing sanitary sewer line
  - Only occasionally acceptable to local sewer authority
  - Not an option for CERCLA/RCRA facilities
- ◆ Hard pipe to existing on-site wastewater treatment plant
  - Requires existing facility
  - Often requires facility upgrades
  - Often capacity constrained
- ◆ Construct new on-site leachate treatment plant
  - Cost range \$500,000 to \$2,000,000
- ◆ Truck to industrial wastewater treatment plant
  - Costs vary widely
  - Regional industrial facility – \$0.05 to \$0.25/gallon
  - RCRA TSDF – \$1.00/gallon

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### GAS RECOVERY SYSTEM



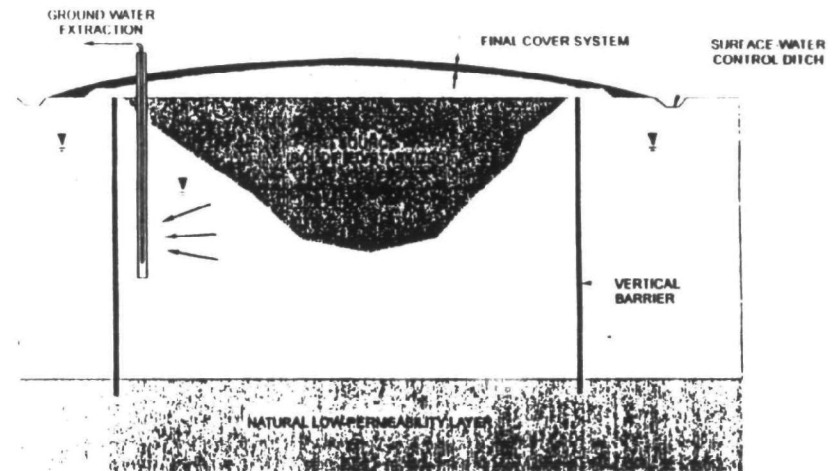
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## In-Situ Containment System Components

- ◆ Final Cover Systems
- ◆ Vertical Barriers
- ◆ Ground-Water Interceptor Trenches or Extraction Wells
- ◆ In-Situ Solidification/Stabilization

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## IN-SITU CONTAINMENT SYSTEM COMPONENTS



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7-8

## In-Situ Containment System Components: Final Cover System

- ◆ Combination of one or more drainage layers and low-permeability barrier layers (i.e., caps)
- ◆ Cap prevents water infiltration into surface or subsurface contaminant source area
- ◆ Drainage layer above cap controls hydraulic head on cap and minimizes downslope seepage forces in the cover soil
- ◆ Grass and topsoil layer is usually the topmost layer; function is to limit erosion and promote surface-water runoff

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## In-Situ Containment System Components: Vertical Barrier

- ◆ Low-permeability physical structure installed vertically into the ground to provide a barrier to:
  - Upgradient flow of ground water toward a subsurface source area or contaminant plane
  - Downgradient migration of contaminated ground water from a surface or subsurface source area
- ◆ Vertical barriers may be constructed of natural or synthetic materials and used alone or in combination with other in-situ containment components

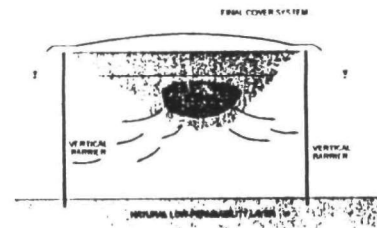
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## In-Situ Containment System Components: Vertical Barrier (cont.)

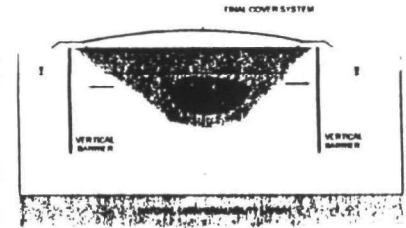
- ◆ Vertical barriers limit transport of ground water and/or specific chemical contaminants beyond a designated boundary due to:
  - Hydraulic gradient (advection)
  - Chemical gradient (diffusion)
  - Density gradient (density-driven migration)
- ◆ Barriers may be designed to provide:
  - Upgradient control
  - Downgradient control
  - Complete containment
- ◆ Barriers may be designed to be:
  - Fully penetrating
  - Partially penetrating

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FULLY-PENETRATING  
VERTICAL BARRIER

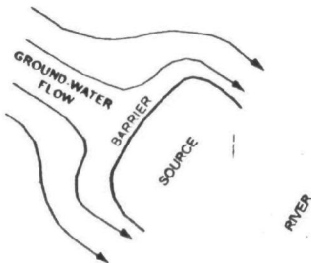


PARTIALLY-PENETRATING  
VERTICAL BARRIER

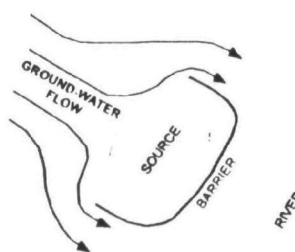


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UPGRADIENT VERTICAL BARRIER



DOWNGRADIENT VERTICAL BARRIER



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## Summary of Key Vertical Barrier Attributes

- ◆ Soil-Bentonite Cutoff Wall
  - Least expensive, reliable, versatile
  - Provides low to moderate permeability barrier
  - Potential issues related to air emissions and contaminated soil disposal
  - Requires horizontal ground and significant ROW
  - Potential negative ground stability impacts
- ◆ Polymeric Membrane Wall
  - Moderate cost
  - Essentially impermeable
  - Same limitations of soil-bentonite wall

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## Summary of Key Vertical Barrier Attributes (cont.)

### ◆ Vibrating Beam Wall

- Low to moderate cost and permeability
- Cannot penetrate stiff soils and bedrock
- Produces thin wall with potential for defects
- Does not require soil excavation, little ROW needed

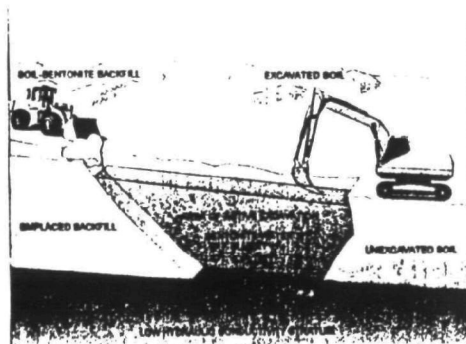
### ◆ Sheetpile Wall

- Moderate to high cost
- Very low permeability with special seals
- Can withstand hard driving
- Does not require soil excavation, little ROW needed
- Can improve foundation shear strength

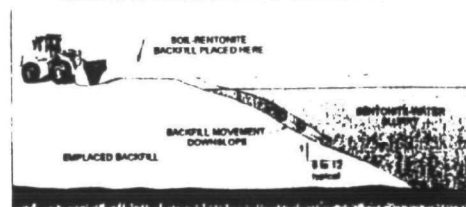
Note: Other barrier types include cement-bentonite slurry walls, deep soil mixing, jet grouting, and "enhanced" barrier systems.

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SOIL-BENTONITE WALL CONSTRUCTION



SOIL-BENTONITE WALL BACKFILLING



SCM RVC

VS 1991

## Summary of Soil-Bentonite Slurry Cutoff Wall Characteristics

Criteria	Relevant Characteristics
Effectiveness	Low hydraulic conductivity (typically $10^{-6}$ to $10^{-8}$ cm/s). Moderate retardation capacity due to inherent cation exchange capacity. Wall thickness easily controlled. Adaptable to most hydrogeologic settings.
Reliability	Relatively simple technology. Familiar construction techniques. Verifiable trench continuity and key to lower aquiclude. Significant wall thickness overcomes minor imperfections.
Durability	Very durable under permeation of low concentration aqueous phase liquids. NAPLs may cause significant local degradation. Deforms plastically and unlikely to crack. Wall thickness can be adjusted to handle most hydraulic gradients.
Implementability	Requires relatively level terrain for construction. Requires adequate space during construction to handle excavated material and mix backfill. Open trench length ten times depth required. Construction equipment readily available.
Environmental Impacts	Excavated material may be contaminated. Soil disturbance may release VOCs.
Construction-Related Impacts	Workers must handle potentially contaminated excavated material. Very messy construction site. Reduced trench stability prior to backfill. Imported backfill soil may be required.
Cost	\$5 to \$10 per vertical square foot of wall. Cost could escalate if off-site disposal of contaminated soil is required or wall is very deep.

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## Summary of Cement-Bentonite Slurry Cutoff Wall Characteristics

Criteria	Relevant Characteristics
Effectiveness	Moderate hydraulic conductivity (typically $10^{-5}$ to $10^{-6}$ cm/s). Wall thickness easily controlled. Adaptable to most hydrogeologic settings. Possibility of cracks makes control of breakthrough difficult.
Reliability	Relatively simple technology. Familiar construction techniques. Verifiable trench continuity and key to lower aquiclude. Significant wall thickness overcomes minor imperfections.
Durability	Durability same as or greater than soil-bentonite except when cracks develop. Moderate to high shear strength makes failure unlikely. Resistant to degradation under high hydraulic gradients in absence of cracks.
Implementability	Adaptable to sloping terrain. Requires space during construction to handle excavated material. Open trench length can be controlled. Construction equipment readily available.
Environmental Impacts	Excavated material may be contaminated. Soil disturbance may release VOCs.
Construction-Related Impacts	Workers must handle potentially contaminated excavated material. Excavated material mixed with small quantities of slurry must be handled. Bulk cement handling equipment required.
Cost	\$10 to \$25 per vertical square foot of wall. Cost could escalate if off-site disposal of contaminated material is required or wall is very deep.

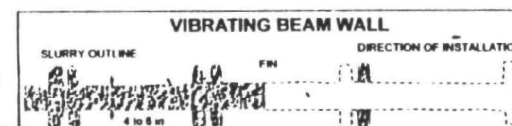
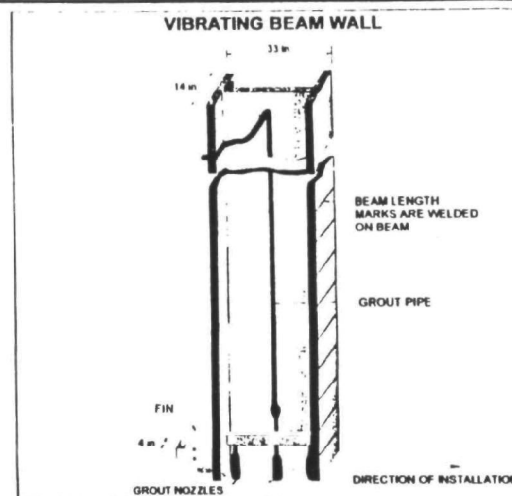
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## Summary of Vibrating Beam Cutoff Wall Characteristics

Criteria	Relevant Characteristics
Effectiveness	Low hydraulic conductivity (typically $10^{-4}$ to $10^{-6}$ cm/s). Use of specially designed backfill materials possible. Wall thickness not controllable. Not recommended for penetration of medium to stiff clays, glacial tills, or bedrock.
Reliability	Extensive experience and good results reported for seepage cutoff, but applicability for hazardous waste containment not conclusive. Defects in wall and key to aquiclude not easy to detect. Construction quality assurance difficult.
Durability	Could be very sensitive to hydraulic fracturing. Small wall thickness makes ability to withstand detrimental contaminant effects suspect. NAPLs may quickly degrade thin wall section.
Implementability	Easy to construct in loose granular soils. Cannot be constructed in firm soils or where cobbles or boulders are prevalent. Requires minimal space to construct. Applicable in restricted access situations in areas with sloping terrain.
Environmental Impacts	Lowest environmental impact because no contaminated soil is removed.
Construction-Related Impacts	Low potential for worker exposure.
Cost	\$7 to \$15 per vertical square foot of wall.

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SOURCE: AFTER LEONARDI ET AL. 1985

34

## Summary of Geomembrane Cutoff Wall Characteristics

Criteria	Relevant Characteristics
Effectiveness	Extremely low hydraulic conductivity (about $10^{-12}$ cm/s). Very thin wall thickness. Negligible attenuation capacity as compared to cutoff walls with soils. Adaptable to only a limited range of hydrogeologic settings.
Reliability	Newer technology with limited performance history. Barrier continuity is obtained with joints, and key into underlying aquiclude. Construction quality assurance of materials is excellent. Construction quality assurance of installation is difficult.
Durability	HDPE has excellent durability characteristics. Due to thinness, durability is a concern in the presence of NAPLs. Composite (HDPE and soil-bentonite) walls are possible.
Implementability	Has been installed in loose granular soils to moderate depths using pile driving frame. Can be installed in slurry trench to greater depths. Applicable to sloping terrain. Installed as continuous sheet for very shallow depths. Chemical compatibility testing between sealant and contaminant required before use.
Environmental Impacts	Dependent on installation method.
Construction-Related Impacts	Dependent on installation method.
Cost	\$8 to \$25 per vertical square foot of wall, not including off-site disposal of any contaminated soil.

35

## Summary of Mixed Soil Cutoff Wall Characteristics

Criteria	Relevant Characteristics
Effectiveness	Moderate hydraulic conductivity (typically $10^{-5}$ to $10^{-7}$ cm/s). Wall thickness somewhat controllable. Adaptable to most hydrogeologic settings except boulder zone.
Reliability	Based on familiar construction technique, although requires special sugars. Little available performance data. Defects in wall not easy to detect. Construction quality assurance difficult.
Durability	Quantities of bentonite in slurry limited. Durability dependent on slurry and soil type.
Implementability	Relatively clean process. Soil mixed in situ. Does not create open excavation. Requires clear overhead space. Applicable in restricted access situations and in areas with sloping terrain.
Environmental Impacts	Small volume of excess material may be contaminated.
Construction-Related Impacts	Low potential for worker exposure.
Cost	\$7 to \$15 per vertical square foot of wall. Cost could escalate if off-site disposal of contaminated soil is required.

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## Summary of Sheet Pile Cutoff Wall Characteristics

Criteria	Relevant Characteristics
Effectiveness	With sealed joints and good key to aquiclude, very low bulk hydraulic conductivity (about $10^{-8}$ to $10^{-9}$ cm/s) Adaptable to many hydrogeologic settings except rock and boulders
Reliability	No performance history Barrier continuity assured with sealed joint and key to aquiclude
Durability	Very high for most contaminants Joint material must be considered in presence of NAPLs
Implementability	Very familiar construction technology Applicable to sloping terrain Chemical compatibility testing between sealant and contaminants required before use
Environmental Impacts	Little environmental impact
Construction-Related Impacts	Low potential for worker exposure
Cost	\$25 to \$50 per vertical square foot

37

## Enhanced Vertical Barriers

- ◆ **Organically-modified clays (organoclays)** — bentonite cation substitution by organic molecules that reduce the hydrophilic nature of the bentonite and improve the ability of the bentonite to absorb specific organic molecules
  - Quarternary amines
  - Tetramethylammonium
  - Surfactant cations
- ◆ **Activated carbon** — granular activated carbon (2 percent by weight) is added to the soil-bentonite mixture to enhance the potential to retard specific organic molecules
- ◆ **Flyash** — flyash is added to the soil-bentonite mixture
- ◆ **Funnel and Gate** — combination of vertical barrier and permeable treatment wall

38

## In-Situ Containment System Components: Ground-Water Interceptor Trenches or Extraction Wells

- ◆ **Subsurface interceptors** (sand or gravel filled trenches or pumping wells) for the control and/or collection of.
  - Contaminated ground water migrating from a surface or subsurface source area
  - Upgradient ground water flowing toward a subsurface source area or contaminant plume
- ◆ **Extraction wells** for the lowering of ground-water wells within an area cutoff from surrounding ground water by a vertical barrier
- ◆ For in-situ containment applications, these components are typically used in conjunction with final cover systems and/or vertical barriers

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## In-Situ Containment System Components: In-Situ Solidification/Stabilization

- ◆ **Mixing, blending, or injection of physical/chemical additives to:**
  - Reduce contaminant mobility or solubility
  - Improve the handling, physical, and hydraulic characteristics of a waste
  - Decrease the exposed surface area across which transfer or loss of contaminants may occur
- ◆ **Solidification** refers to the process in which materials are added to a waste to produce a solid
- ◆ **Stabilization** refers to converting a waste to a more chemically stable form

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## In-Situ Solidification/Stabilization Construction Techniques

- ◆ Backhoe with shovels (< 15 ft)
  - Widely available equipment
  - Solidifying agent (cement, flyash placed dry or in grout/slurry form) must be applied separately
  - Typically used when only handling/strength improvements needed
- ◆ Backhoe with rotary tiller (< 15 ft)
  - Specialty equipment
  - Hydraulic system injects grout/slurry at tiller
  - Better mixing/blending than with shovel

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## In-Situ Solidification/Stabilization Construction Techniques (cont.)

- ◆ Crane with single flight auger (< 20 ft)
  - Widely available, conventional auger
  - Specialty auger has built-in hydraulic or pneumatic system
  - Auger can work under a removal hood
  - Large diameter auger (5 to 10 ft)
- ◆ Crane with multiple flight augers (< 50 ft)
  - Specialty equipment
  - Hydraulic or pneumatic system injects grout/slurry
  - Smaller diameter augers (2 to 3 ft)

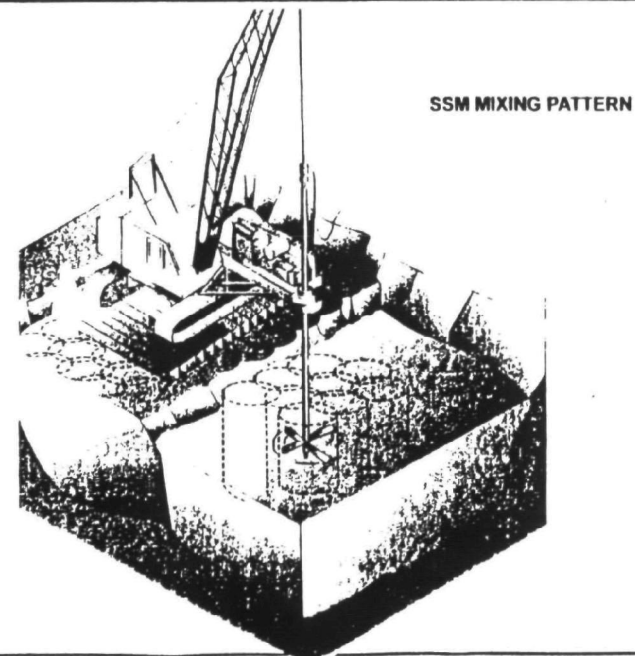
42

## In-Situ Solidification/Stabilization Construction Techniques (cont.)

- ◆ Jet grouting (>50 ft)
  - Greater depths possible
  - Effectiveness dependent on soil type
  - Good for solidifying isolated zones
  - Verification difficult

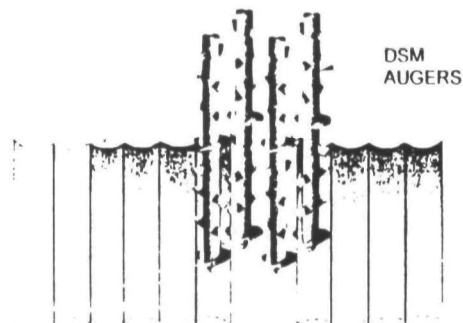
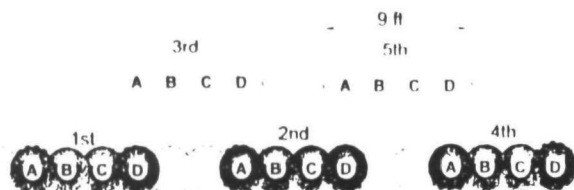
Note: All systems except backhoe and shovel require reagent delivery systems such as a grout plant or air compressor system.

43



44

# DEEP SOIL MIXING (DSM)



DSM AUGERS

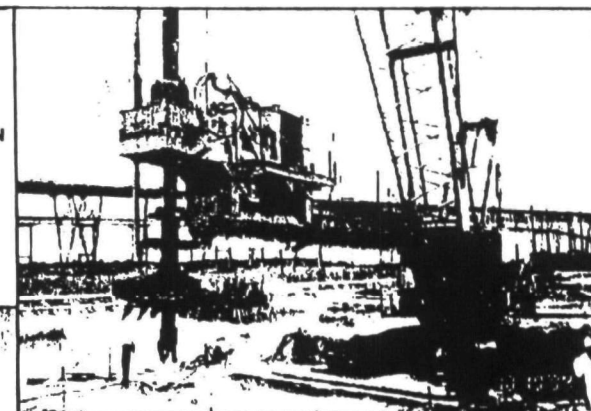
45

## IN-SITU SOLIDIFICATION / STABILIZATION

BATCHING / DELIVERY SYSTEM

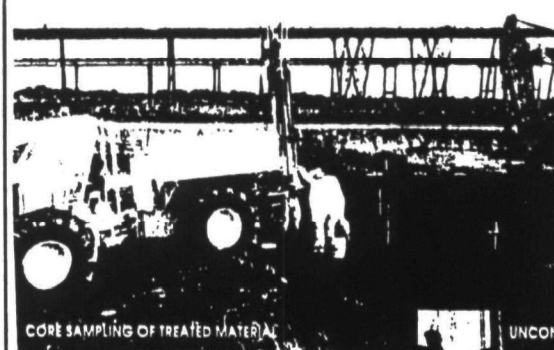


INJECTION / MIXING SYSTEM



46

## IN-SITU SOLIDIFICATION / STABILIZATION



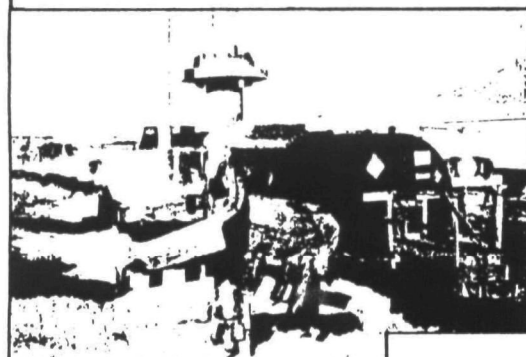
CORE SAMPLING OF TREATED MATERIAL

## IN-SITU SOLIDIFICATION / STABILIZATION

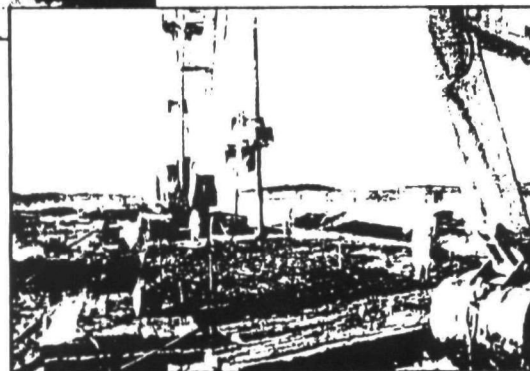


UNCONFINED COMPRESSIVE STRENGTH TESTING

48



FIVE FOOT DIAMETER AUGER



TREATMENT IN PROGRESS



- 1 ☐ **A SUCCESSFUL REMEDIATION OF METALS  
CONTAMINATED SOIL:  
A CASE STUDY**
  - Theodore R. Johnson, III**
  - Karen T. Baker**
  - Mohinder S. Sandhu**
  - Facility Permitting Branch**
  - Department of Toxic Substances Control**
- 2 ☐ **SUCCESSFUL REMEDIATION PROJECT OVERVIEW**
  - **Effective Coordination Among Remediation Team**
  - **Established Fee for Service Agreement between DTSC and Square D Company**
  - **Streamlined the Corrective Action Process**
  - **Reduced Costs**
  - **Protect Human Health and the Environment**
- 3 ☐ **BACKGROUND**
  - **Site Location: Square D Company Beaumont, California**
  - **Description of Site**
  - **Geology**
  - **Land Use**
- 4 ☐ **PROJECT OBJECTIVES**
  - **Remediate Square D Company Site in order to:**
  - **Protect Human Health and the Environment**
  - **Return Land Quickly to Beneficial Use**
  - **Reduce Costs to Save Time and Money**
- 5 ☐ **REMEDIATION TEAM**
  - **Members Consist of Square D Company, DTSC and the Public**
  - **Coordinate Work Schedule**
  - **Agree Upon Site Cleanup Goals**
  - **Provide Real Time Oversight**
  - **Streamline Report Approval Process**

6 ☐ **PROJECT SCHEDULE**

- 4/94: Fee for Service Agreement
- 5-7/94: RFI Phase I Completed
- 8-9/94: RFI Phase II/CMS Approval
- 9/94-1/95: Initial Risk Assessment
- 9/94-3/96: Public Participation
- 1/95-3/96: CMI Completed
- 3/96: Corrective Action Terminated

7 ☐ **CONSTITUENTS OF CONCERN**

- Antimony
- Arsenic
- Barium
- Beryllium
- Cadmium
- Total Chromium

8 ☐ **CONSTITUENTS OF CONCERN**

- Hexavalent Chromium
- Copper
- Lead
- Mercury
- Zinc

9 ☐ **HEALTH RISK-BASED CLEANUP LEVELS**

10 ☐ **RCRA FACILITY ASSESSMENT**

- 39 Solid Waste Management Units:
  - 1 Area of Concern (Main Plant Building)
- 9 Regulated Units in Post Closure Permit:
  - Surface Impoundments

- 11 ☐ **RCRA FACILITY INVESTIGATIONS (RFI)**
- RFIs Performed in 1990, 1992, 1993, 1994 and 1995
  - Identified 16 Areas of Concern
    - Parcels 1 and 2
  - Collected Baseline Data to Set Health Risk Based Cleanup Goals
  - Established Areas Require Corrective Measures
- 12 ☐ **CORRECTIVE MEASURES STUDY**
- Established Efficient Remedial Method
  - Reduced Costs and Labor
  - Streamlined Process
  - Combined RFI Phase II with Corrective Measures Study
- 13 ☐ **CORRECTIVE MEASURES STUDY**
- Record Deed Restriction
    - Parcel 1 only
  - Prepare Fact Sheet on Remediation
- 14 ☐ **PUBLIC PARTICIPATION ACTIVITIES**
- Prepared CEQA Initial Study and Negative Declaration
  - Sent Out Public Notice for Corrective Measures Study
  - Prepared Response to Public Comments
- 15 ☐ **CORRECTIVE MEASURES IMPLEMENTATION**
- Remedial Design Implemented 1/95
  - Used XRF to Screen Soil Samples
  - Verify Attainment of Cleanup Goals by Conventional Sampling and Analysis
  - Stored Remediation Wastes on Parcel 1
  - Stabilized Soil On-Site, If Necessary
  - Land Disposal of Wastes
  - Backfill and Cap Excavations



16 ☐ **CONCLUSIONS**

- **SQUARE D COMPANY SITE WAS SUCCESSFULLY REMEDIATED TO CLEANUP CONTAMINATED SOIL**
- **Effective Team Coordination**
- **Streamlined Corrective Action Process and Resport Approval**
- **Established Site Cleanup Goals Early**
- **Reduced Costs and Labor**

17 ☐ **RECOMMENDATIONS FOR FUTURE PROJECTS**

- **Established Site Cleanup Goals Early**
- **Use Appropriate Method for Onsite Screening**
- **Establish Team for More Efficient Coordination**
- **Combine Remediation Steps, If Feasible**

**RCRA CORRECTIVE ACTION:  
A CASE STUDY  
A SUCCESSFUL REMEDIATION OF METALS CONTAMINATED SOIL AT  
SQUARE D COMPANY, BEAUMONT, CALIFORNIA**

**By Theodore R. Johnson III, Karen Baker and Mohinder Sandhu  
Department of Toxic Substances Control**

**Presented at the U. S. EPA Region 9 RCRA Corrective Action Conference  
March 26-28, 1996**

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**Executive Summary**

The Square D Company ceased manufacturing operations at their Beaumont, California facility in 1989. Several phases of site characterization were undertaken to delineate the horizontal and vertical extent of heavy metals contamination at the facility. The facility elected to enter into the Fee For Service (FFS) program offered by the Department of Toxic Substances Control (DTSC) as a means of expediting remediation of the facility. Collaborative efforts were utilized to address issues dealing with scheduling, cleanup goals, regulatory requirements, field oversight, and site characterization. The success of this corrective action project hinged on the facility and DTSC acting as a team, working to achieve a mutual goal of returning the Square D Company's property to beneficial use in a timely and cost effective manner while protecting human health and the environment. This team approach accelerated the environmental cleanup process and resulted in an economically feasible and environmentally responsible remediation.

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**1.0 Corrective Action Program Objectives**

One of the key objectives of California's corrective action program is to accelerate environmental restoration by utilizing a streamlined and proactive team approach. The intent of the program is to identify releases or potential releases of hazardous waste or constituents requiring investigation. Once the release has been identified, the corrective action program provides guidance to evaluate the nature and extent of releases and identify, develop, and implement appropriate corrective measures to remediate the identified releases.

## **2.0 Introduction**

### **2.1 Site Background**

Square D Company, formerly Yates Industries, Inc., is located approximately 70 miles east of the City of Los Angeles, in Beaumont, California (Figure 1). The site consists of three contiguous parcels (designated as Parcels 1, 2 and 3) collectively comprising 42.6 acres. The facility is underlain by alluvial deposits composed of interbedded sands, clayey sands, silts, clayey silts and clays. The uppermost aquifer below the facility is at depths ranging from 160 to 223 feet below ground surface.

The facility operations involved manufactured copper foil sheets for the printed circuit board industry. The facility began operations in 1970 and ceased copper foil production in 1989 due to economic infeasibility.

Before entering into the FFS program, Square D Company conducted four site investigations on Parcels 1 and 2 between 1990 and 1994. The facility entered into the FFS program in April 1994. Corrective measures implementation began in January 1995 and concluded in March 1996.

### **2.2 Parcel 1**

Parcel 1 occupies nine acres and includes the former manufacturing and operational areas of the facility (Figure 2). The manufacturing process involved dissolving recycled and scrap copper metal in sulfuric acid and depositing the copper in thin sheets on drums in electroplating baths. The resulting copper sheets were used by the electronics industry for printed circuit board production.

Wastes generated by this process included spent solvents and plating solutions, waste machine oil, contaminated rinse waters, filters, and sludges containing heavy metals (antimony, arsenic, barium, cadmium, chromium, hexavalent chromium, copper, lead, mercury, nickel, and zinc). Various waste treatment operations were utilized including reverse osmosis, filtration, chemical precipitation, and evaporation process (surface impoundments) to concentrate liquid waste sludge and reclaim rinse water and metals. Early operations at the facility included on-site direct land application of process wastes.

Currently, there is one regulated unit on Parcel 1, designated as the North Post Closure Area (NPCA) (Figure 2). The NPCA was previously the site of the evaporation ponds (surface impoundments) and an area used for direct land disposal of wastes. The NPCA was certified as closed with waste in place in May 1988. The facility completed the Post Closure Permit Application in June 1995. DTSC is currently drafting the post closure permit.

### **2.3 Parcel 2**

Parcel 2 is an undeveloped 6.67-acre parcel east of Pennsylvania Avenue (Figure 2). No manufacturing activities occurred on Parcel 2, however the area was used for the storage of scrap copper and equipment. Surface impoundment sludges were found on Parcel 2 during site investigations conducted between 1992 and 1995. Additionally, during the period 1937 to 1947, disposal of refuse occurred in the Beaumont Channel, a dry wash bisecting the southern border of Parcel 2.

### **2.4 Parcel 3**

Parcel 3 is an undeveloped 27-acre open area adjacent to the facility located south of East 3rd Street (Figure 2). No known industrial activities have occurred on Parcel 3. This area was not a part of the proposed corrective measures; however, the site was utilized as a borrow site for the export of fill soil for Parcels 1 and 2 and is one of the areas where the background soil samples were collected.

## **3.0 Corrective Action Process**

### **3.1 Historical Site Investigation**

The U.S. EPA conducted a RCRA Facility Assessment (RFA) of Parcel 1 in 1987. The RFA identified 39 Solid Waste Management Units (SWMUs) and one Area of Concern (AOC). Subsequent site investigations conducted by the facility identified releases of wastes (generated by the facility) on Parcels 1 and 2. DTSC's review of the soil analytical data collected in the early investigations (1990 to 1994) indicated that lateral and vertical extent of contamination was not well delineated and several constituents of concern (COC), that are key health risk drivers, were not included in the investigations.

Based on the RFA results and subsequent site investigations, the 39 SWMUs and one AOC were screened down to 16 AOCs (15 on Parcel 1 and all of Parcel 2). A RCRA Facility Investigation (RFI) Phase I was conducted in order to determine the extent of soils contamination at Parcel 1 and Parcel 2. Based on the findings of the RFI Phase I, an additional soil investigation (RFI Phase II) and a health risk assessment were conducted to delineate the extent of the contamination present and assess the potential threat to human health and the environment. Site investigations revealed that the AOCs were contaminated with arsenic, antimony, copper, chromium, hexavalent chromium, lead, and zinc above background levels. On Parcel 2 and in the Beaumont Channel, site investigations conducted from 1992 to 1995 identified metals, including arsenic, cadmium, copper, chromium, lead and zinc at concentrations above background levels.

The Phase I and Phase II RFIs resulted in implementation of corrective measures for 15 AOCs on and adjacent to Parcel 1 and portions of Parcel 2.

### **3.2 Cleanup Goals**

The facility initially proposed to clean up the site to background levels for metals. Upon further study, the cost of cleanup to background levels was found to be excessive. Therefore, the facility subsequently proposed health risk-based cleanup goals derived from the California Preliminary Endangerment Assessment (PEA) guidance document. The PEA makes conservative assumptions for calculating the health risk-based cleanup levels. During the implementation of the health risk-based cleanup levels, it was determined that achieving these cleanup goals was also infeasible in that certain soil background concentrations (arsenic, beryllium, thallium and vanadium) were higher than the health risk-based cleanup goals. Thus, a combination of the two approaches of health risk-based and background levels was used to establish the cleanup goals for soil remediation.

In the last six months of the remediation, a site specific/constituent specific health based risk assessment was conducted to provide alternate cleanup goals for certain constituents (antimony, arsenic and hexavalent chromium) because the initial cleanup goals for these constituents were too conservative and, therefore, economically infeasible. The site specific/constituent specific cleanup levels provided the facility a means of completing the remediation in a cost effective and environmentally responsible manner.

Cleanup levels for Parcel 1 were established in consideration of the future land use to be industrial. A risk management goal of  $1 \times 10^{-6}$  for a typical industrial exposure scenario was used to set the cleanup levels for this parcel. However, for Parcel 2, an unrestricted land use scenario was used, thus assuming a residential use and a risk management goal of  $1 \times 10^{-6}$  was used to set the cleanup levels.

### **3.3 Proposed Corrective Measures**

The corrective measure selected for Parcel 1 and Parcel 2 was excavation and off-site disposal of impacted soil. Impacted soil was defined as soil with contaminant concentrations in excess of the health risk-based cleanup levels or contaminant levels that exceed naturally occurring background concentrations. Excavated soil from the remediation was stockpiled on Parcel 1, profiled for RCRA metals, stabilized on-site as required to meet Land Disposal Restrictions, and transported by rail to a permitted non-RCRA landfill in Utah. The cost savings for disposal to the Utah landfill versus disposal at the closest landfill in California was over \$7 million.

### **3.4 Public Participation Activities**

Interviews were held with community group leaders, legislative officials and local regulatory agencies to gather the community's concerns for the proposed project. In December 1994 and January 1995, DTSC issued public notices of the California Environmental Quality Act (CEQA) documents, the Corrective Measures Study and associated remedy selection. Comments received during the public comment period resulted in three additional off-site AOCs. After reviewing the soil sample analyses, one of the three additional AOCs required excavation.

Ten residential well owners responded during the public comment period with concerns regarding the effects of the facility's past practices on the groundwater pumped from their wells. DTSC met with the residential well owners and discussed the area hydrogeology. The residential wells are located hydraulically upgradient in relation to the facility and the water levels measured in the residential wells are approximately 150 feet vertically higher than the water levels measured at the facility. However, the facility, in a gesture of goodwill towards the community, tested all the residential wells. The results of the groundwater sampling analyses showed that the constituents present in the groundwater were at or below the levels which are considered background for the facility.

### **3.5 Corrective Measures Implementation**

Remediation work began at the facility in January 1995. Soil samples were collected for on-site metals screening by a portable X-Ray Fluorescence (XRF) instrument when excavated areas reached proposed depths. If the XRF analysis indicated residual soil contamination, additional excavation was performed. If the XRF analysis indicated that the soil concentrations of the COC were equal to or less than the cleanup goals, conventional confirmatory soil samples were collected. If confirmation sample analyses indicated residual soil contamination above the cleanup goals, the contaminated area was excavated until the cleanup goals were attained. Approximately 10 percent of the samples collected were duplicated for quality assurance/quality control (QA/QC) purposes. All confirmation and QA/QC samples were sent to an off-site laboratory certified by the Environmental Laboratory Accreditation Program.

## **4.0 General Issues Related to the Corrective Action Process**

### **4.1 Chronology of the site investigations:**

#### **4.1.1 Prior to DTSC oversight**

1987	U.S. EPA conducted a RCRA Facility Assessment
1990	Facility conducted Site Characterization on Parcel 1
1992	Facility conducted Site Characterization on Parcel 2
1993	Facility conducted Additional Site Characterization and Pilot Study on Parcel 2
1993 to 1994	DTSC reviewed previous site characterizations
1994	Facility conducted RFI Phase I (Parcels 1 and 2)
1994	DTSC compiled an additional list of AOCs and COC list

#### **4.1.2 Under DTSC oversight**

1994	Facility entered into FFS program, giving the corrective action project a priority status.
1994 to 1995	RFI Phase I Report (Parcels 1 and 2) and RFI Phase II (Parcels 1 and 2)

In April 1994, the facility proceeded with the RFI Phase I. However, the RFI Phase I Report on Parcel 1 did not include the additional AOCs and a complete list of COCs because the facility's investigation was completed prior to the compilation of DTSC's lists. The COC list was of particular concern to DTSC because the soil analyses to date excluded COC which were the main risk drivers for the health risk assessment, such as arsenic and hexavalent chromium. To investigate the additional AOCs and collect soil samples with the complete COC list, a RFI Phase II was initiated.

### **4.2 Combining corrective action steps**

In lieu of requiring the facility to complete a separate RFI Phase II for Parcels 1 and 2, DTSC suggested that the facility combine the RFI Phase II workplan with the Corrective Measures Study submittal and initiate the additional characterization concurrently with the corrective measures implementation. In effect, any additional areas requiring removal of soil could be combined with the existing areas scheduled for soil removal, thus eliminating duplication of cost for equipment and mobilization. Consolidation of these tasks reduced preparation and review time of workplans and reports resulting in a savings of over eight months of overall schedule time.

#### **4.3 Additional characterization versus excavation**

To avoid additional costs during the investigative stage of corrective action, the facility and DTSC concurred that characterization in the known contaminated areas was sufficient to initiate excavation, with the understanding that additional characterization, outside planned excavation areas on Parcel 1 and Parcel 2, would be undertaken concurrently.

Approximately ten (10) times the amount of soil was removed from Parcels 1 and 2 than originally estimated.

#### **4.4 Project coordination and oversight**

The facility and DTSC engaged in a series of meetings to discuss the protocol, processes, procedures and scheduling for the project. The agreement reached between DTSC and the facility ensured that workplans and reports were submitted and reviewed in a timely manner and that the concerns of all parties involved were addressed. This resulted in a savings of over six (6) months of overall schedule time.

The FFS process required scheduling and budgeting for the various phases of corrective action. The facility requested the corrective action process be accelerated to accommodate a schedule regarding a real estate transaction involving Parcel 1. DTSC assigned a project manager as the point of contact through whom all correspondence and transactions would be processed. The project manager was also responsible for the day-to-day oversight of field operations and accountable for project costs. This ensured efficient communication between the facility and DTSC; it also expedited decisions regarding excavations, stockpile management, regulatory requirements, and soil screening and confirmation sampling strategies.

Additionally, the presence of the DTSC project manager on-site facilitated rapid response to the community's concerns and created open communications between the community, DTSC and the facility.

#### **4.5 Regulatory issues**

##### **4.5.1 Land Disposal Restrictions (LDRs)**

The Corrective Action Implementation Workplans for Parcels 1 and 2 stated that the stockpiles would be placed on visqueen sheeting to prevent contamination of the underlying subgrade. The use of visqueen was not practicable because it was easily damaged by extensive heavy equipment traffic during stockpiling; and, therefore, was not used.



Heavy equipment used for stockpiling operations breached the asphalt/base layer adjacent to and below the stockpiles.

The loading of soil onto rail cars could not be accomplished from Parcel 2 as approved by DTSC in the CMI Workplan due to railroad regulation restrictions. Excavated soil from Parcel 2 was transported to Parcel 1 and placed in stockpiles in the parking area adjacent to and behind the Main Plant Building (Figure 2).

The placement of contaminated soil from Parcel 2 to Parcel 1 resulted in violation of the LDR regulations. To mitigate the spread of contamination from Parcel 2 to Parcel 1, in the areas where stockpiles were placed, DTSC requested that the asphalt, base material and underlying soil be excavated after removal of stockpiles and confirmation soil samples collected. DTSC determined that to stop the transfer of soil from Parcel 2 to Parcel 1 would result in costly delays in the remediation as well as create an impracticable situation for the disposal of soil off-site by train. DTSC requested the facility to remove the soil as soon as possible and to adhere to mitigating measures (visqueen-covered stockpiles and a covered route from Parcel 2 to Parcel 1) to prevent a release of contaminated soil excavated from Parcel 2.

#### **4.5.2 Deed Restriction**

Since the facility used industrial health risk-based cleanup levels for Parcel 1, a deed restriction was required to limit the future site use to industrial. In addition to a deed restriction, federal and state laws and regulations require future site owners and occupants to manage any hazardous materials that may be generated during excavations for modification of the buildings or the areas surrounding the buildings.

It was acknowledged by both DTSC and the facility during the early stages of the project that a deed restriction would be required. DTSC presented the standard deed restriction language (pursuant to DTSC Management Memo 87-14), to which the facility had several objections. The negotiation process took approximately three (3) months.

### **5.0 Observations and Recommendations**

Open and frequent communication between the facility and DTSC was paramount in the success of this corrective action project. Creating project schedules and goals prior to corrective action implementation established clear direction for the corrective action process. A combination of project management decisions enabled the facility and DTSC to complete this corrective action in an economically feasible, time effective and environmentally responsible manner.

**Some of these project management decisions were:**

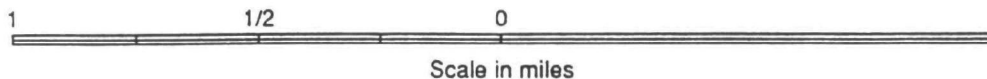
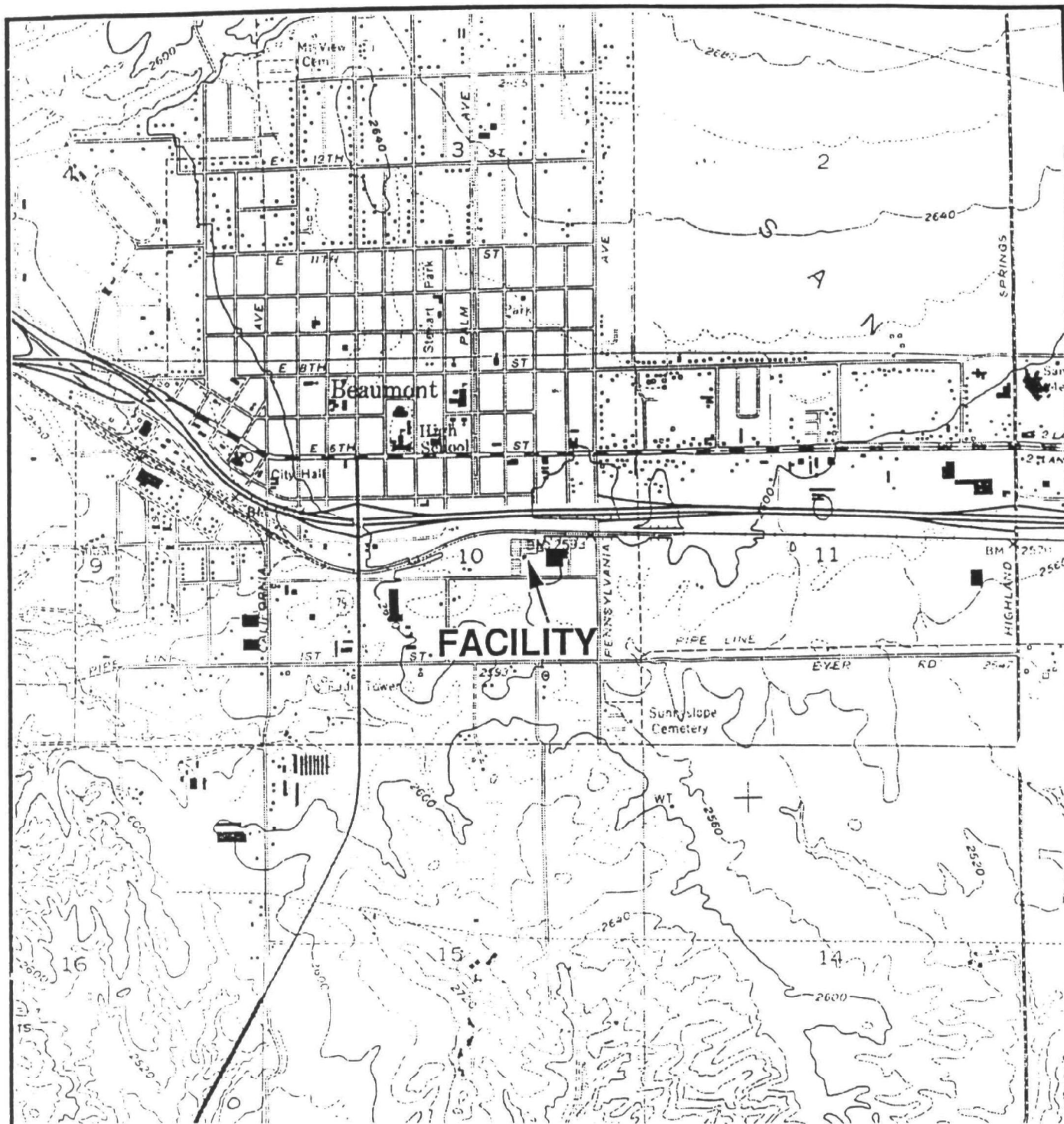
- 1. Combining corrective action steps such as RFI Phase II during excavation. This resulted in a savings of approximately eight months in overall schedule time.**
- 2. Utilizing meetings, including teleconference calls, to establish a mutual understanding of concepts, processes and problems.**
- 3. Streamlining report submittal and revision process. Draft reports were submitted and deficiencies were addressed through meetings and/or teleconference calls. Final reports incorporated the agreed upon changes resulting in reduced approval time for submitted reports.**
- 4. Providing frequent real time oversight in the field.**

**Some lessons that were learned during this project which may provide additional economic and time savings on future projects are as follows:**

- 1. Establish site specific cleanup goals early in the project. As soon as chemical compounds have been speciated, a Health Risk Assessment (HRA) should be completed. Also, a theoretical model of the various disposal scenarios should be developed. The modeling process coupled with the HRA can lead to the selection of the most feasible and economic alternative while detailed site characterization is in progress.**
- 2. If deed restrictions are anticipated, DTSC and the facility should start negotiating the documents mechanism and language early during the corrective action process.**
- 3. Acceptable on-site screening of soil can be cost effective and expedite site restoration.**
- 4. During the initial planning stages, the facility and the applicable regulating agencies should agree on the corrective measures implementation designs to mitigate any possible regulatory violations**

**The ultimate success of this project hinged on the regulated community (Square D Company) and the regulating agency (DTSC) working together to return the facility's property to a useful status while protecting human health and the environment**

**The duration of the corrective action project was two years (April 1994 to March 1996) The property will be ready for reuse in March 1996.**



## FACILITY LOCATION MAP

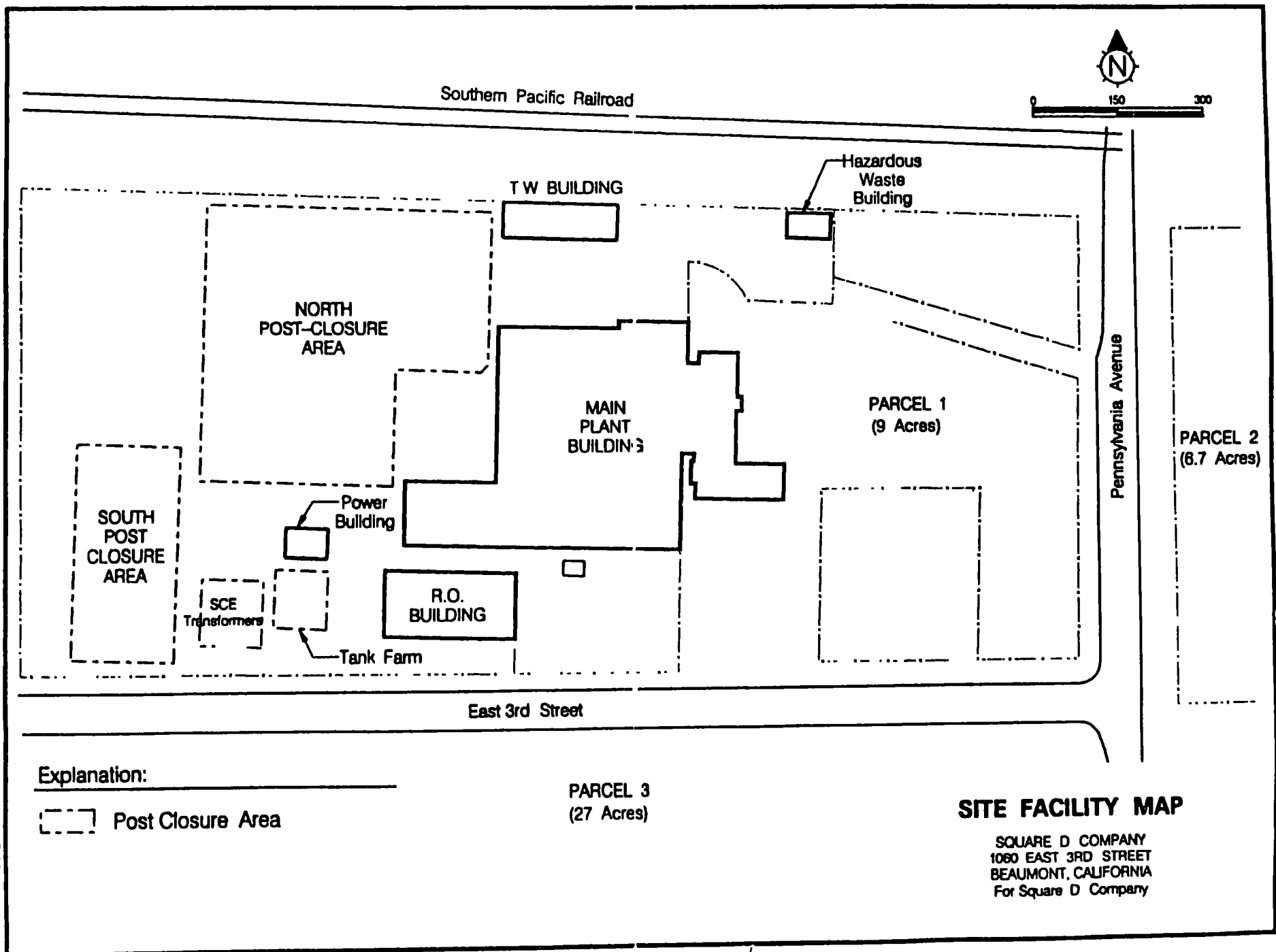
SQUARE D COMPANY  
1060 EAST 3RD STREET  
BEAUMONT, CALIFORNIA  
For Square D Company

**DRAFT**

REFERENCE: USGS 7.5 Minute Series Topographic Map, "Beaumont, Calif."  
Quadrangle, Photorevised 1988.

Dames & Moore  
FIGURE 1

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12/08 Ba/G2C dgm  
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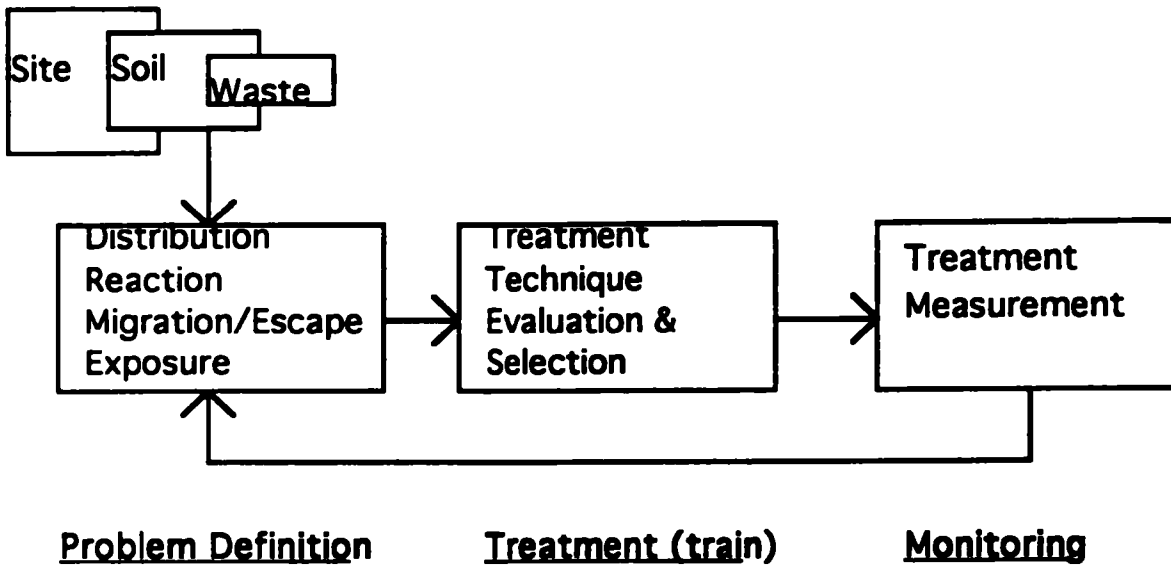
# **VADOSE ZONE CONTAMINANT TRANSPORT**

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- \* MISUNDERSTOOD WORLD OF  
UNSATURATED FLOW**
- \* STORAGE IN THE VADOSE ZONE**
- \* LIQUID FLOW IN THE VADOSE ZONE**
- \* CHEMICAL MOBILITY IN THE  
VADOSE ZONE**

# METHODOLOGY FOR INTEGRATING SITE CHARACTERIZATION WITH SUBSURFACE REMEDIATION

## Characterization





## VADOSE ZONE

Vadosus = shallow  
Vadere = walk or wade

Therefore:

slow movement at a shallow depth

"When water moves into relatively dry, unsaturated sediment, it is only slightly affected by gravitation."

*decreases with dryer soils,*  
Hydraulic conductivity in the unsaturated zone depends upon the amount of water residing at any one time in that material.

*If you control water content of soils can control leachability of landfills*

# EDITORIAL

## The Misunderstood World of Unsaturated Flow

by Jay H. Lehr

For decades, farmers made critical errors in the establishment of drainage systems to maintain proper soil-moisture levels in the root-zones of their crops. These errors were the result of misunderstanding flow in the unsaturated zone, by confusing it with saturated flow. Results were as radically out of phase as those experienced when people favorably compared the nature of surface water flow with ground water flow. In spite of widespread beliefs, we have few underground streams bubbling turbulently along as they do on the surface, and contrary to accepted physical precepts, highly permeable conduits will not normally conduct moisture rapidly through the unsaturated zone.

Perhaps for ground water scientists following in the erroneous paths of misguided soil physicists and agricultural engineers, the problem has been exacerbated by the ill-chosen but popular appellation, "vadose zone." True enough, the Latin roots "Vadosus" meaning shallow and "vadere" meaning to walk or wade infer slow movement at a shallow depth. But as Latin has fallen out of our common, intellectual framework, obvious terms "unsaturated zone" or even "zone of aeration" would create less confusion.

We all recognize that ground water flow—when governed by Darcy's century-old, physical law—allows precise description. Here, potential energy is efficiently utilized in overcoming frictional resistance and creating the kinetic energy of movement. Surface water flow, on the other hand, defies accurate prediction because of random energy loss produced by turbulence. Many of us still do not clearly understand the equally distinct variations that make Darcian flow dramatically different from unsaturated flow.

The variations occurring between surface and ground water flow result from dramatic velocity variations, while the differences between unsaturated and saturated flow result from very different variables that control permeability. Many of the articles in this issue, and countless others that have preceded them, offer ground water scientists and engineers insight into how we can monitor flow in the unsaturated or "vadose" zone, as well as a hint of what that data may mean in terms of the movement of

contaminants in and through that zone and ultimately to the water table below. But as I converse with colleagues across this country and abroad, I am amazed at how few truly understand the basic physics that make this intermediate zone of fluid movement so radically different from the familiar arena of saturated flow. If you are not among my misinformed, uninformed or apathetic friends in our rapidly expanding scientific community, you may find this editorial sophomoric, simplistic or even insulting. If you suspect that your intellectual acuity on this subject needs no additional stimulus, by all means skip ahead to the far more sophisticated contributions that follow. But if I have piqued your curiosity, follow me, we shrink ourselves to the size of water drops and imagine our way through the misunderstood world of unsaturated flow.

Let us first define our boundaries in accordance with the oft-forgotten father of ground water hydrology, Oscar E. Meinzer, whose classic 1923 USGS Water Supply Papers 489 and 494, divided the vadose zone into three belts. The uppermost belt "consists of soil and other materials that lie near enough to the surface to discharge water into the atmosphere in perceptible quantities by the action of plants or by soil evaporation and convection." The lowest belt, which we know as the capillary fringe, is "the belt immediately above the water table that contains water drawn up from the zone of saturation by capillary action." Meinzer then defined the primary target of this monologue as the intermediate belt, which simply "lies between the belt of soil water and the capillary fringe." For further simplicity in this discussion, we will assume that the porous solid is chemically and physically inert, that liquid flows through the pores of this zone isothermally, and that vapor and gas flow is inconsequential. While these assumptions are arguable, they will allow us to focus on the basic, flow-controlling factors that lead to errors of greater proportion than will ever result from the aforementioned assumptions. They may also allow us to recognize that many of the extremely complicated and costly technologies for computing flow in the zone of aeration, employed to account for all the measurable hydraulic characteristics of unsaturated

media, may not be necessary for many of our engineering purposes.

Movement in the unsaturated zone is primarily a function of negative forces built up by conditions found not to be in equilibrium. The negative or suction forces are collectively called capillary forces and include adhesion—the attraction of unlike molecules (i.e., water to rock particles) and cohesion—which is the attraction of like molecules such as water to water.

The strength of both cohesion and adhesion in water is due chiefly to hydrogen bonding as a result of the hydrogen and oxygen attachment unsymmetrically surrounded by electrons, so that there is a separation of charge or polar character. If other molecules with non-binding electrons are present, there is a tendency for hydrogen to increase the symmetry of its surroundings by approaching a pair of electrons in line with its chemical bond to oxygen.

When water moves into relatively dry, unsaturated rock or sediment, it is only slightly affected by gravitation and will move horizontally as well as downward. Adhesive and cohesive forces are responsible for this movement against the force of gravity. The pressure in the water is less than the pressure of the atmosphere, and the water is said to be under tension. As the sediment becomes wetter and wetter, however, gravity does play a stronger role and the volume of potential flow-paths increase thereby increasing hydraulic conductivity.

Water is held in small pores by large adhesive and cohesive forces as a result of greater surface area of sediment per cubic inch of earth material. These small pores are like those in blotting paper used to soak up ink or paper towels used to soak up whatever liquid you spilled. Larger pores cannot hold water at tensions that exist in smaller pores, so water does not move readily from fine to coarse material.

As finer material becomes very wet, water will eventually move from it to coarser material in contact with it much as coffee will leak from a soaked paper towel. Coarse material, layered below fine material in an unsaturated zone, will act like a check-valve, holding water back until the finer material above it becomes very wet, then allowing the excess flow to pass through.

The unsaturated zone may include portions that are, in fact, totally saturated as a result of being perched above an impermeable segment of rock or clay-like material which, in turn, may overlie an exceptionally dry area sheltered by the perching material.

Although fine sediment hinders downward movement of water, it does absorb water readily. Perched water tables are built up over fine materials not because of water's inability to enter them, but as a result of slow transmission through them. The extent to which downward flow is restricted and water storage is altered depends on the fineness of the pores and the thickness of the restricting layer.

Porous materials with very large pores in the unsaturated zone aid in water movement only under conditions where there is contact with free water or water under positive or atmospheric pressure. Where water in these

pores exists under tension, as is usually the case, such materials stop or materially retard water flow. Thus, efforts by farmers to drain unsaturated sediments by construction of coarse media drains have had the reverse effect; in fact, creating barriers to flow. Similarly, ground water scientists who can correctly predict the movement of contaminant plumes into more highly permeable members of underlying formations below the water table are rudely awakened when they attempt to interpolate similar scenarios in the unsaturated zones. Thus, we see the topsy-turvy world of this zone of aeration—this zone where, it seems, that night is day and small pores attract while large pores repel.

*"When water moves into relatively dry, unsaturated sediment, it is only slightly affected by gravitation."*

Let us not gloss over too quickly the possibility of larger pores being in contact with free water or atmospheric pressure. It does happen as a result of almost microscopic root-borings and fractures that produce what we call "finger-flow" instead of the predictable wetting front in homogenous, dry sediment. Many contaminants introduced at or near ground surface will flow through fine to narrow vertical paths as a result of their initial ability to maintain atmospheric pressure in these relatively open micro-pore channels. Continued flow along these paths is maintained by cohesive forces that draw water along the previously wetted channels much like water flows in rivulets over a pane of glass, never evenly wetting the entire pane. This phenomenon further exacerbates the unpredictable passage of contaminants through the unsaturated zone.

Trapped air can also play a significant role in the unsaturated zone. Initially an advancing front of leachate will be irregular and air will be expelled at various points. The energy required to force air out of the unsaturated zone will slow the rate of infiltration. As a saturating front advances, pockets of dry sediment will be left to form barriers to water movement. Continued movement of leachate, nevertheless, will dissolve some of the air. In this manner, effects of trapped air may reverse the response expected when fine sediment is encountered.

Eventually, as all good scientists do, we must try to quantify movement in the saturated zone which leads us to attempt the use of equations distantly related to Darcy's. In fact, many attempt this exercise by using Darcy's law recognizing that hydraulic conductivity is a far more elusive number than it is in the saturated zone. While conductivity is a virtual constant in the saturated zone where it is entirely dependent on the frictional resistance rendered by a formation's collective surface area and that same formation's cross-sectional area of void space through which flow may occur, conductivity is a moving target in the unsaturated zone where the slightest change

in moisture content alters both the restrictive adhesive and cohesive forces and the volume of pathways open for transport.

\* Hydraulic conductivity in the unsaturated zone is a function of both grain size and sorting of particulate materials just as it is in the saturated zone; additionally, it depends on the amount of water residing at any one time in that material. Water in the pores under negative pressure cannot move from small pores to large pores, thus contaminant movement takes place only through the continuous films of water that surround the rock particles. As the volume of water declines, there is less area left through which water can flow. Thus, as water or moisture content declines, so does the hydraulic conductivity in the unsaturated zone.

Theoretically, if one can properly characterize the physical nature of the structure of the unsaturated zone and maintain continuous readings of soil moisture (or soil tension) in a depth profile from neutron logs, porous blocks, or suction-lysimeters, one can use a Darcy equation to calculate flow. But, obviously, we are dealing with a dynamic system that changes continuously over time in a non-linear manner. At the lower end of the moisture scale, transport is overwhelmed by the capillary force capabilities to retard flow. In the mid-range of moisture content, a degree of linear improvement in conductive properties occur. As saturation approaches 70 percent of available pore space, flow begins to be Darcian in nature and hydraulic conductivity asymptotically approaches that which we recognize in the saturated zone.

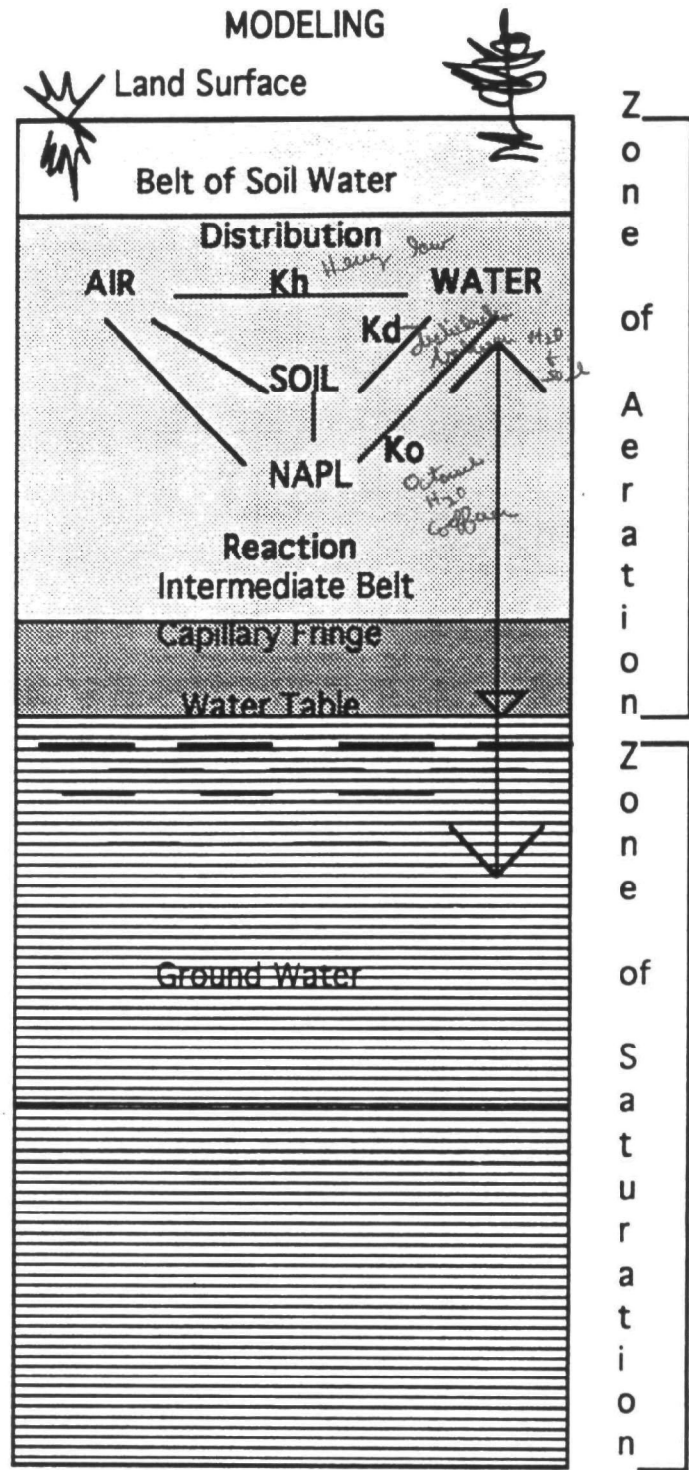
For a number of reasons, I have avoided delving into the capillary zone which is the next stop on the way to the water table. First, it is normally a thin zone, a few inches over coarse material and a few meters over fine material. Second, it acts both like the unsaturated zone by exhibiting tension and the saturated zone by allowing movement in the direction of the local ground water flow gradient. It is probably a subject for another editorial but, regardless, its ultimate impact on the timing and direction of contaminant transport into our ground water systems is of considerably less impact than that offered by the intermediate zone of aeration lying above it.

If I have piqued your interest, overwhelmed or confused you, and you are determined to get to the bottom of this misunderstood subterranean strata, you may be able to alleviate the misery by viewing an old but excellent film titled Water Movement in Soil made in 1960 by Dr. Walter Gardner and the Agronomy and Soils Department of Washington State University in Pullman, Washington. Gardner's film is a classic in educational simplicity, if not mathematical elegance. If you can't find it in your local university film library, you can find it in NWWA's.

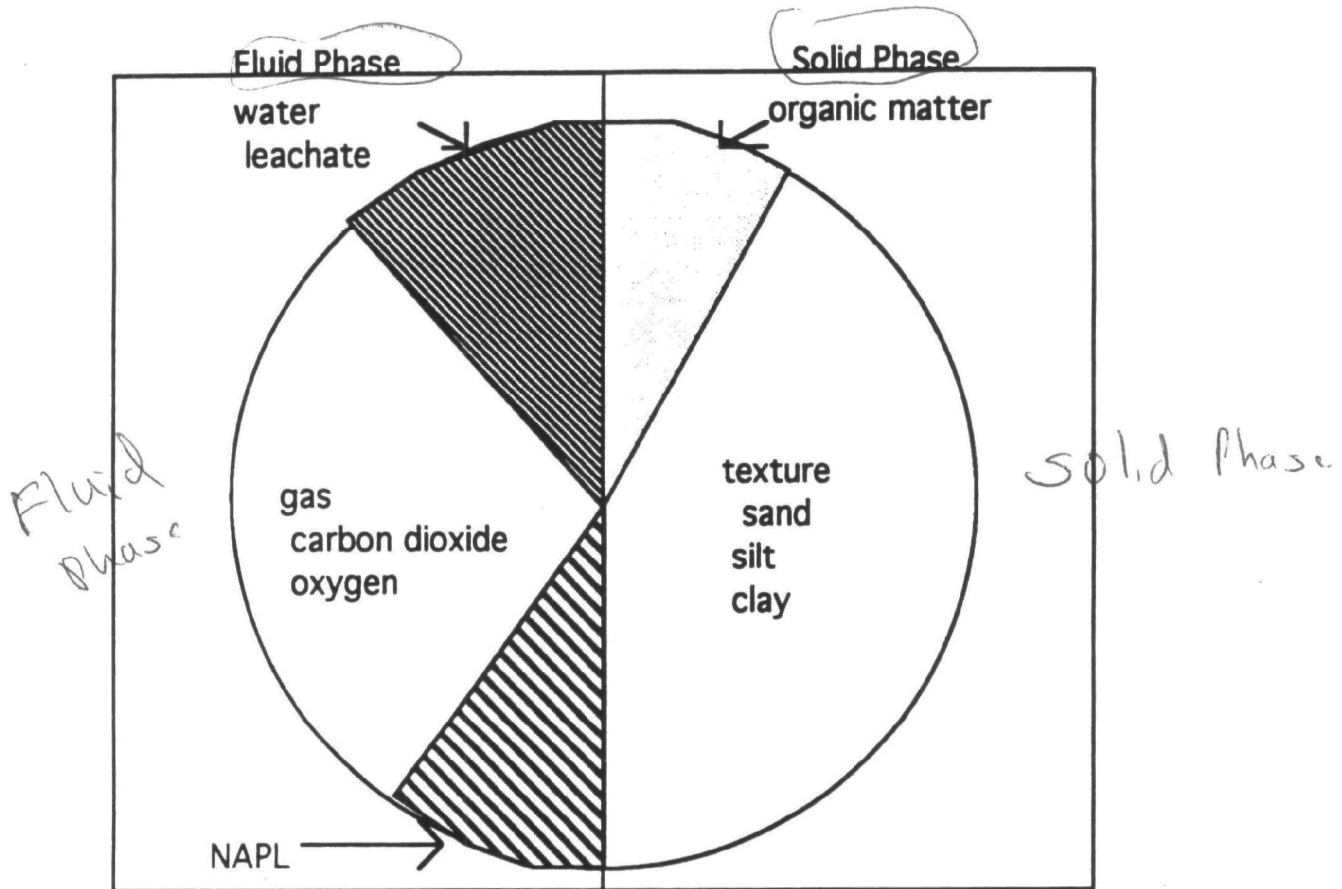
Let me conclude this monologue with a riddle that has served me well these past four decades in ground water science. If the answer isn't obvious, ask any teenager to fill in the blanks.

"Flow in the unsaturated zone is is is."

# MODELING



## CHEMICAL MASS BALANCE APPROACH FOR CONTAMINATED SOIL



Solid Phase contains solid components of soil/waste mixture

- (1) organic matter
- (2) texture, i.e., sand, silt, and clay components

Fluid Phase contains components that can flow

- (1) NAPL - Non-Aqueous Phase Liquid (e.g., oil)
- (2) gases, generally including carbon dioxide and oxygen
- (3) water or leachate

## SOIL MOISTURE EXAMPLE

### GIVEN:

60 cc MOIST SOIL

WEIGHT = 100 GRAMS (MOIST)

WEIGHT = 85 GRAMS (AIR-DRY)

WEIGHT = 80 GRAMS (OVEN-DRY)

### FIND:

$\Theta_m$

$\Theta_v$

BULK DENSITY ( $\rho_b$ ) *should be 1.1 to 2.6*

### SOLUTION:

$$\Theta_m = [100 \text{ gm} - 80 \text{ gm}] / 80 \text{ gm} = 25\%$$

$$\Theta_v = [100 \text{ gm} - 80 \text{ gm}] / 60 \text{ cc} = 33\%$$

$$\rho_b = 80 \text{ gm} / 60 \text{ cc} = 1.33 \text{ gm/cc}$$

**Field Capacity:**

**Amount of water held by soil against gravitational force. (0.3 atm for fine-textured soils, 0.1 atm for coarse-textured soils).**

**Wilting Point:**

**Soil moisture at which the ease of release of water to plant roots is just barely too small to balance the transpiration losses. (15 atm).**

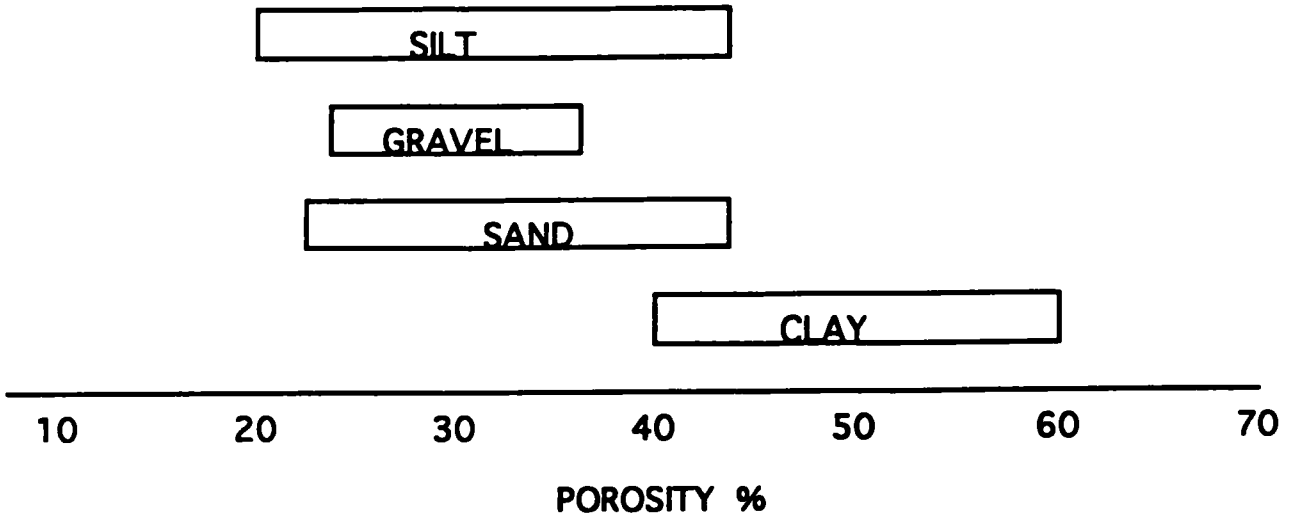
**Available Water:**

**Difference in soil water content at field capacity and wilting point.**



## POROSITY

$$\% \text{ POROSITY} = [1 - \text{BULK DENSITY/PARTICLE DENSITY}] \times 100$$

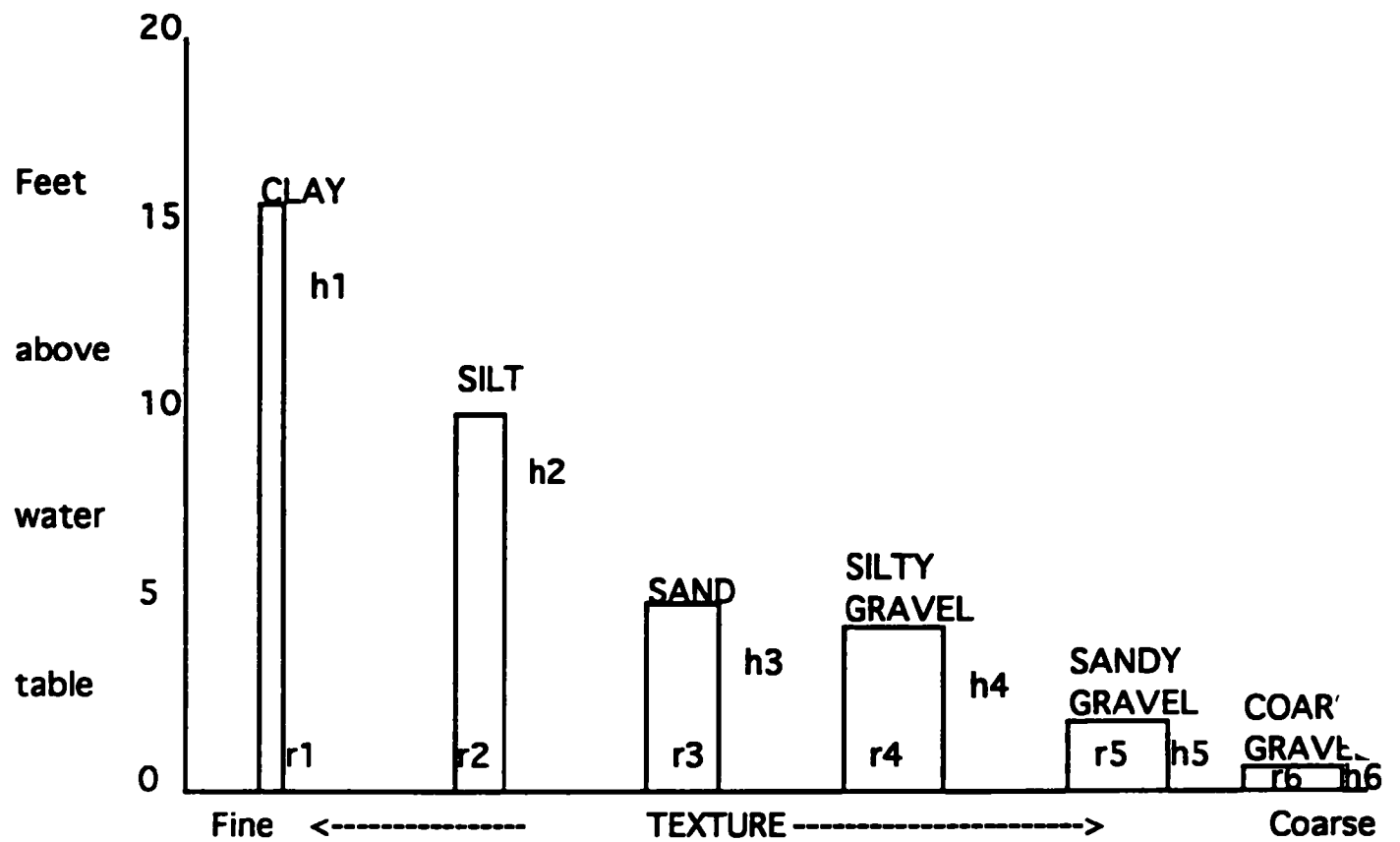


(REFERENCE: DRAGUN, 1988)

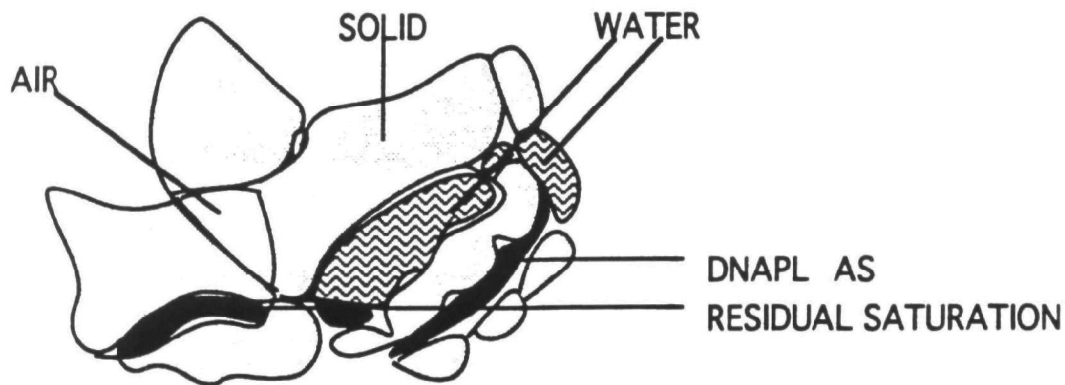
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### Discussion:

- \* Clay is more porous than sand, silt, & gravel, therefore can store more water;
- \* Clay is more porous than sand, silt, & gravel, therefore can store more water soluble contaminants;
- \* Clay represents smallest particle size, therefore offers greatest resistance to flow of fluids including water, air, NAPL.
- \* Clay texture has slowest diffusion and greatest sorption of chemicals, therefore old sites (>50 years) may have high contamination and new sites (< 1 year) may have low contamination in clay.



RELATIONSHIP BETWEEN PORE SIZE ( $r$ ) AND  
CAPILLARY RISE ( $h$ ) IN UNSATURATED SOIL



DNAPL CONTAMINATED UNSATURATED ZONE WITH FOUR PHASES: AIR, SOLID, WATER, AND NAPL. RESIDUAL SATURATION IS NAPL RETAINED BY CAPILLARY FORCES IN THE MEDIA. SOLUBILIZATION OF RESIDUAL SATURATION CAN OCCUR BY WATER PERCOLATION.

(Reference: Huling and Weaver, 1991)

### NON-AQUEOUS PHASE LIQUIDS (NAPLS)

#### o Light Non-Aqueous Phase Liquids (LNAPLS)

Oil

Pentachlorophenol in oil

*Also is DNAPL*

#### o Dense Non-Aqueous Phase Liquids (DNAPLS)

Creosote

Methylene Chloride

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### Discussion:

- o Can have free phase flow
- o Can have residual saturation
- o Chemicals within the NAPL can contaminate air, water, and soil through distribution among compartments in the subsurface

## **Photograph of Residual Saturation in the Subsurface**

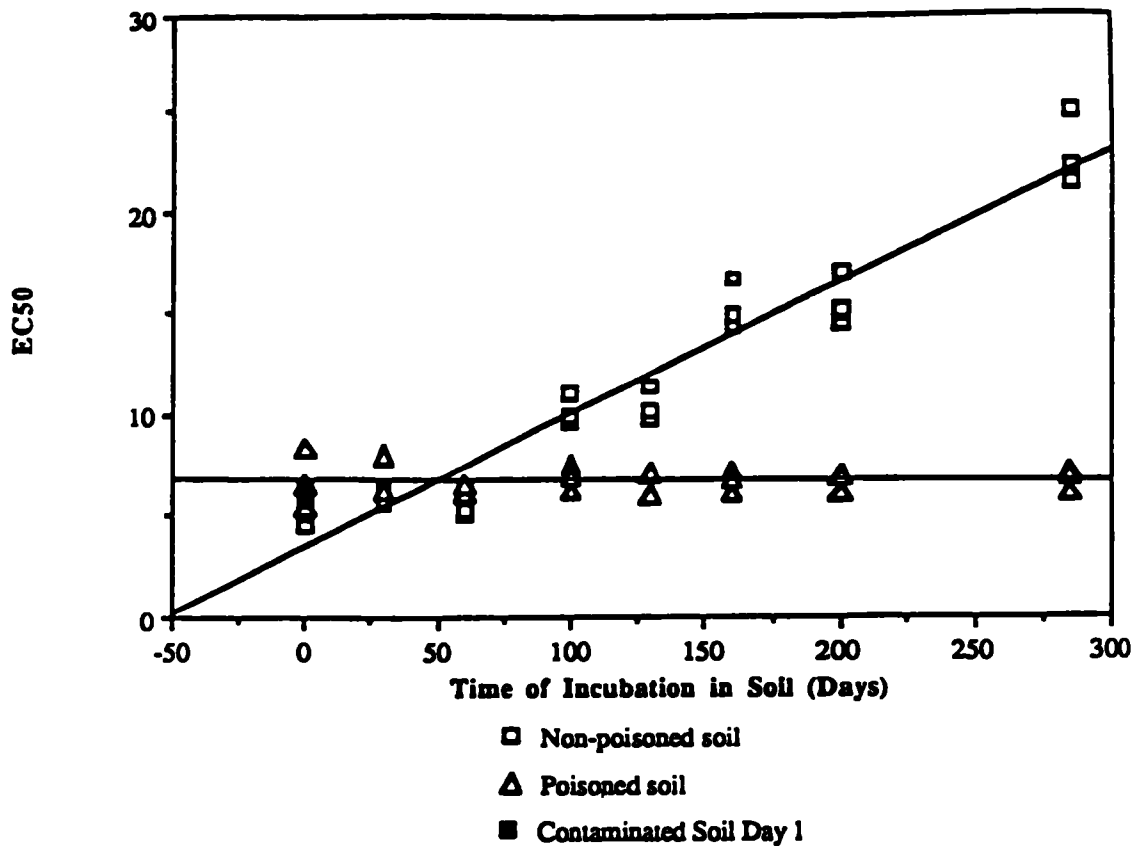
- o Another source of contamination
  - o Chemicals originate from "residual saturation" and distribute in air, water, and soil phases in unsaturated zone
  - o Chemicals distribute in water and soil phase in saturated zone
  - o Chemicals can be transported from "residual saturation" in the unsaturated zone into the saturated zone by percolating water
- 

### **Discussion:**

- o Distribution among phases depends upon "tendency" or "preference" of each chemical to be in a particular phase(es)
- o Knowing something about the "tendency" of each chemical to be associated with one or more phases provides information that can be used to formulate the "problem" at the site
- o Challenges to bioremediation of residual saturation include toxicity and "bioavailability" of chemicals within the "residual saturation"

**PCP and PAH concentrations in water fractions from non-poisoned soil in  $\mu\text{g/mL}$ .**

<b>Time (days)</b>	<b>0</b>	<b>30</b>	<b>60</b>	<b>100</b>	<b>130</b>	<b>160</b>	<b>200</b>	<b>285</b>
<b>PCP</b>	<b>7.53</b>	<b>2.63</b>	<b>2.67</b>	<b>2.28</b>	<b>1.38</b>	<b>1.35</b>	<b>0.50</b>	<b>1.13</b>
<b>Naphthalene</b>	<b>6.90</b>	<b>5.17</b>	<b>5.02</b>	<b>4.98</b>	<b>4.59</b>	<b>3.24</b>	<b>2.93</b>	<b>2.82</b>
<b>Acenaphthylene</b>	<b>5.70</b>	<b>5.21</b>	<b>4.90</b>	<b>4.44</b>	<b>4.91</b>	<b>4.68</b>	<b>4.00</b>	<b>4.19</b>
<b>Acenaphthene</b>	<b>2.86</b>	<b>2.34</b>	<b>2.17</b>	<b>2.00</b>	<b>2.05</b>	<b>2.06</b>	<b>1.33</b>	<b>1.42</b>
<b>Fluorene</b>	<b>0.39</b>	<b>0.22</b>	<b>0.20</b>	<b>0.16</b>	<b>0.09</b>	<b>0.02</b>	<b>0.04</b>	<b>0.04</b>



Microtox™ EC 50 for B(a)P Spiked Creosote Contaminated McLauren Soil.

### Distribution Coefficients

- o  $C_s/C_w = K_d$  Concentration in Soil / Concentration in Water
- o  $C_o/C_w = K_o$  Concentration in NAPL / Concentration in Water
- o  $C_a/C_w = K_h$  Concentration in Air / Concentration in Water

### Discussion:

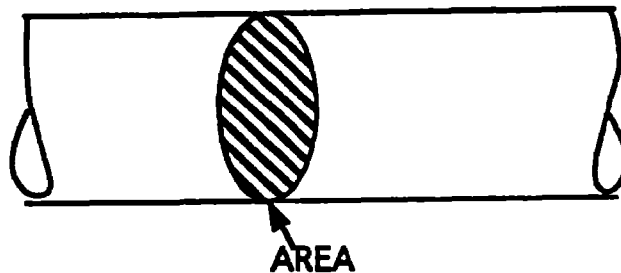
- o Tendency or preference of a chemical for a compartment or phase can be quantified
- o Useful in characterizing a site with regard to specific chemicals that may be associated with specific subsurface compartments
- o Useful for formulating the problem (transport and exposure) at a site with regard to treatment requirements (which chemicals in which compartment need treatment)
- o Useful for evaluating treatment approaches at a site with regard to specific chemicals that are appropriate for treatment by specific technologies

# FLUX

## EXAMPLE:

Velocity

----->



$$\text{Flux} = \frac{\text{Volume}}{\text{Time} \cdot \text{Area}} = \frac{\text{gal}}{\text{day} \cdot \text{ft}^2}$$

$$J = -\int_0^z \frac{\partial \theta}{\partial t} dz$$

$$J = -\int_0^{135} \frac{0.015}{16 \text{ hr}} (135 \text{ cm})$$

$$\underline{J} \equiv \underline{-0.125 \text{ cm/hr}}$$

## VELOCITY

### EXAMPLE:

$$V = J/\Theta$$

$$V = \frac{0.125 \text{ cm/hr}}{0.23}$$

$$\underline{V} \equiv \underline{0.54 \text{ cm/hr}}$$

$U =$  *interstitial through pore space*

## MOBILITY OF CHEMICALS IN SOIL

$$R = V_w/V_p$$

$$R = 1 + \rho_b K_d/\Theta$$

**R = Water velocity relative to pollutant velocity (Retardation)**

**$V_w$  = Velocity of water**

**$V_p$  = Velocity of pollutant**

**$\rho_b$  = Soil bulk density**

**$K_d$  = Soil partition coefficient**

**= Conc. in soil/conc. in water**

$$= \frac{C_c \text{ (ug/gm)}}{C_w \text{ (ug/ml)}} = \frac{\text{ml}}{\text{gm}}$$

**$\Theta$  = Soil moisture content**

$$R = 1 + \frac{[\text{gm/cc}] [\text{ml/gm}]}{[\text{cc/cc}]}$$

$$= 1 + \frac{[\text{ml/cc}]}{[\text{cc/cc}]} \text{ and since ml=cc}$$

$$= 1 + \frac{[\text{cc/cc}]}{[\text{cc/cc}]}$$

$$R = \text{UNITLESS}$$



### **Discussion:**

- o Useful for characterizing the behavior of a chemical at a site (takes into account site characteristics ( $\rho$ ,  $\theta$ ) and chemical-site interaction ( $K_d$ ))
- o Useful for formulating the problem at a site with regard to transport
- o Useful for devising treatment approaches - may be possible to "manage" the magnitude of  $R$  by controlling  $\theta$  or  $K_d$
- o Useful for designing monitoring strategies for specific chemicals - rank chemicals in terms of tendency to be immobilized at a site

### **RETARDATION EXAMPLE**

#### **Assume:**

$$\begin{aligned}\rho_b &= 1.4 \text{ gm/cc} \\ \Theta_v &= 0.2 \text{ cc/cc} \\ K_d &= 2 \text{ ml/gm}\end{aligned}$$

#### **Then: using**

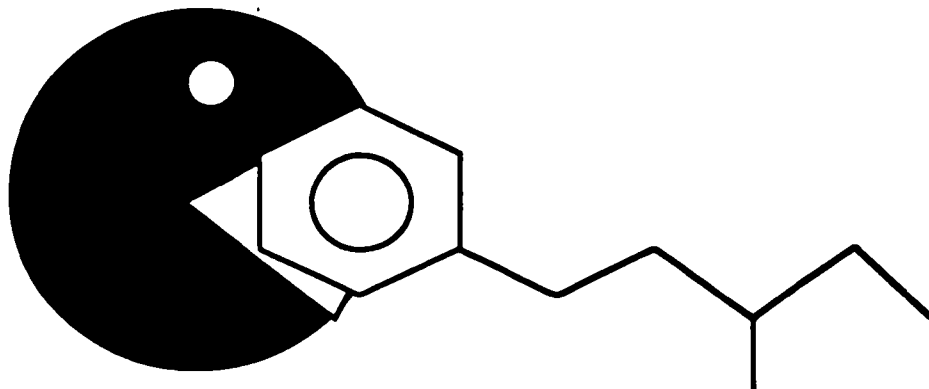
$$R = 1 + \rho_b K_d / \Theta$$

#### **Results in:**

$$\begin{aligned}R &= 1 + [1.4] [2] / [0.2] \\ R &= 1 + [2.8] / [0.2] \\ R &= 1 + 14 = 15\end{aligned}$$

**Interpretation:** The pollutant will move 15 times more slowly than the water through the soil.

## BIOREMEDIATION



**Illustration of "Pac-Bug"**

- o Biodegradation
- 

### **Discussion:**

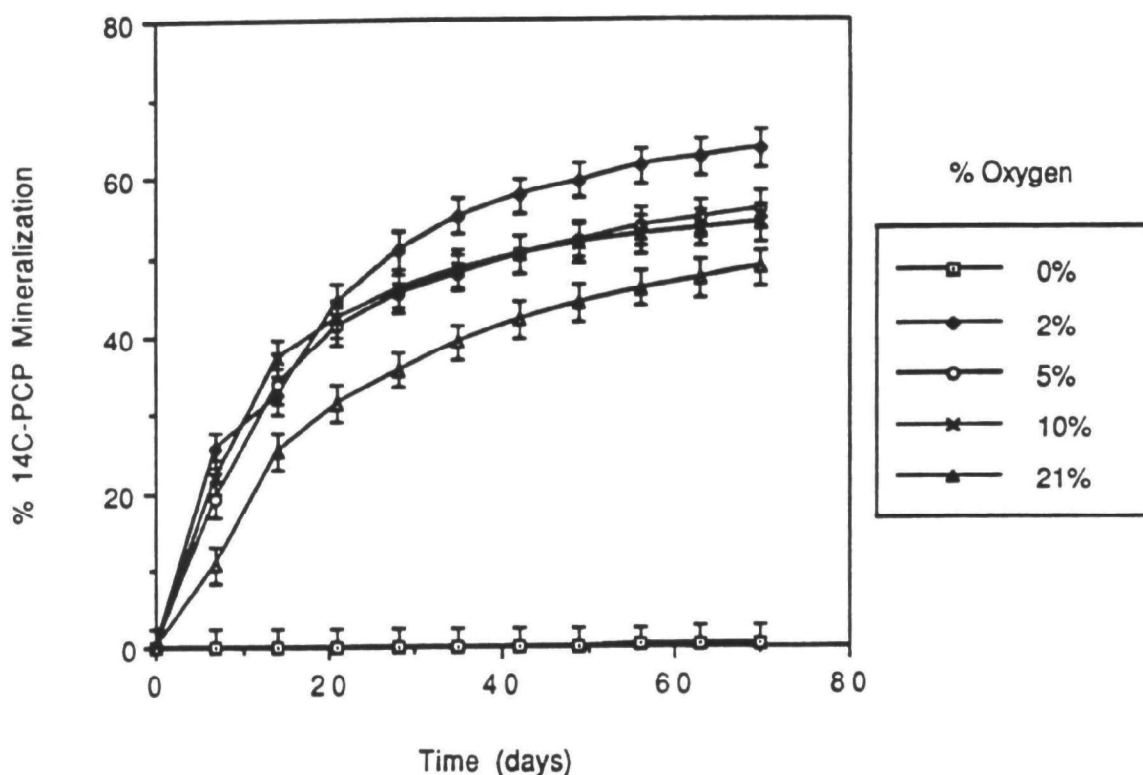
- o Often mis-interpreted for volatilization, leaching, sorption
- o Implies many things to many people: a) mineralization to carbon dioxide and water; b) destruction of toxicity; c) transformation to a chemical that is not the parent compound
- o Can result in the production of "metabolites" or chemicals that represent "what left" of the parent chemical - these can be more or less toxic than the parent compound (e.g., trichloroethylene [TCE] to vinyl chloride [VC])

## **Degradation of Contaminant in Soil**

- o  **$dC/dt = -kC^1$**
  - o  **$t_{1/2} = 0.693/k$  [a first order equation]**
  - o  **$t_{1/2}$  = half-life of the chemical**
  - o **0.693 = a constant (natural logarithm of 2)**
  - o  **$k$  = slope of first order plot of  $\ln$  Concentration versus time**
- 

### **Discussion:**

- o **The first order equation for half-life is commonly used by scientists and engineers to quantify biodegradation in soil and ground-water**
- o **Many half-life values are in the literature**
- o **Ask what mechanisms the half-life value includes for a chemical, i.e., does it include volatilization, leaching, abiotic degradation?**



Mineralization of <sup>14</sup>C-PCP in non-poisoned soil microcosms as a function of oxygen concentration. Error bars represent the least significant difference of 4.27. Values plotted are the means for triplicate reactors.

Average distribution of <sup>14</sup>C in non-poisoned microcosms spiked with <sup>14</sup>C-PCP ± standard deviation.

Oxygen Concen tration	Mineralized		Volatilized		Soil Extractable		Soil Bound		<sup>14</sup> C Recovered	
0 %	0.5±	0.64	0.11±	0.15	85.8±	2.82	3.8±	0.45	90.2±	2.93
2 %	63.5±	0.51	0.01±	0.01	15.0±	1.18	14.5±	0.91	93.0±	1.57
5 %	55.8±	0.15	0.03±	0.02	15.3±	2.69	14.3±	1.43	85.3±	3.05
10 %	54.1±	3.17	0.05±	0.04	12.0±	4.76	16.4±	0.79	82.6±	5.77
21 %	48.4±	0.60	0.02±	0.01	17.9±	1.01	15.3±	0.52	81.6±	1.29

## SOIL-BASED CHARACTERIZATION

Chemical Properties	Chemical Class	Chemical Reactivity	Soil Degradation Parameters
Specific Gravity Water Solubility Molecular Weight Melting Point	Acid Base Polar Neutral Nonpolar Neutral Inorganic	Oxidation Reduction Hydrolysis Polymerization Precipitation Photodegradation	Half-life, ( $t_{1/2}$ ) Rate Constant Loss of Parent Compound Mineralization Intermediates Biotic/Abiotic

## SOIL-BASED CHARACTERIZATION

Volatilization Parameters	Soil Sorption Parameters	Soil Contamination Parameters
Air:Water ( $K_h$ ) Vapor Pressure	Soil:Water ( $K_d$ ) Soil Organic Carbon ( $K_{oc}$ ) Octanol:Water ( $K_{ow}$ )	Concentration in Soil Soil Horizonation Depth of Contamination Physcial Phases (oil,water,air)

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**WASTE BURIAL IN ARID ENVIRONMENTS—  
APPLICATION OF INFORMATION FROM A FIELD LABORATORY IN THE MOJAVE DESERT**

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**ABSTRACT**

As arid sites in the western United States are increasingly sought for disposal of the Nation's hazardous wastes and as volumes of locally generated municipal and industrial wastes continue to increase, concern about the potential effect of contaminants on environmental quality in the region is being raised. A prevalent assumption is that percolation will be negligible at an arid site. However, few data have been available to test assumptions about the natural soil-water flow systems at arid sites, and even less is known about how the natural processes are altered by construction of a waste facility.

In 1976, the U S Geological Survey began a series of studies at a site in the Mojave Desert, near Beatty, Nev , to evaluate mechanisms that can affect waste isolation. Precipitation at the site averages 108 mm/yr and depth to ground water is 110 m. Chloride concentrations in the unsaturated zone beneath an undisturbed, vegetated area indicate that deep percolation of water was limited to the upper 10 m during the past 16,000 to 30,000 years. Long-term field monitoring confirms the effectiveness of the natural soil-plant system in limiting the potential for deep percolation: stratified soils impede deep percolation and accumulated water is rapidly depleted by vegetation. Under waste-burial conditions, however, infiltrated water accumulates and continues to move downward in liquid and vapor form. Rates of trench-cover subsidence are positively correlated with the long-term accumulation of infiltrated water and erosion rates are inversely related to near-surface rock-fragment content.

Continued long-term monitoring at the Mojave Desert site is critical to documenting how mechanisms controlling waste isolation may change with time. Because of the complexity of liquid- and vapor-flow processes, we also need to take the next step and combine existing laboratory and field data with numerical simulations to quantitatively evaluate the importance of these potential contaminant-release pathways.



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# Waste Burial in Arid Environments— Application of Information From a Field Laboratory in the Mojave Desert, Southern Nevada



U.S. Department of the Interior—U.S. Geological Survey

Accumulation and management of waste is a pressing problem facing the United States today. Improper disposal of hazardous wastes poses a threat to public health and environmental quality. As arid sites increasingly are being sought for disposal of the Nation's radioactive and other hazardous wastes, concern about the potential effect of contaminants on water resources in the arid western United States is being raised. In addition, volumes of locally generated municipal and industrial wastes are increasing because of rapid population growth and industrialization of the region.

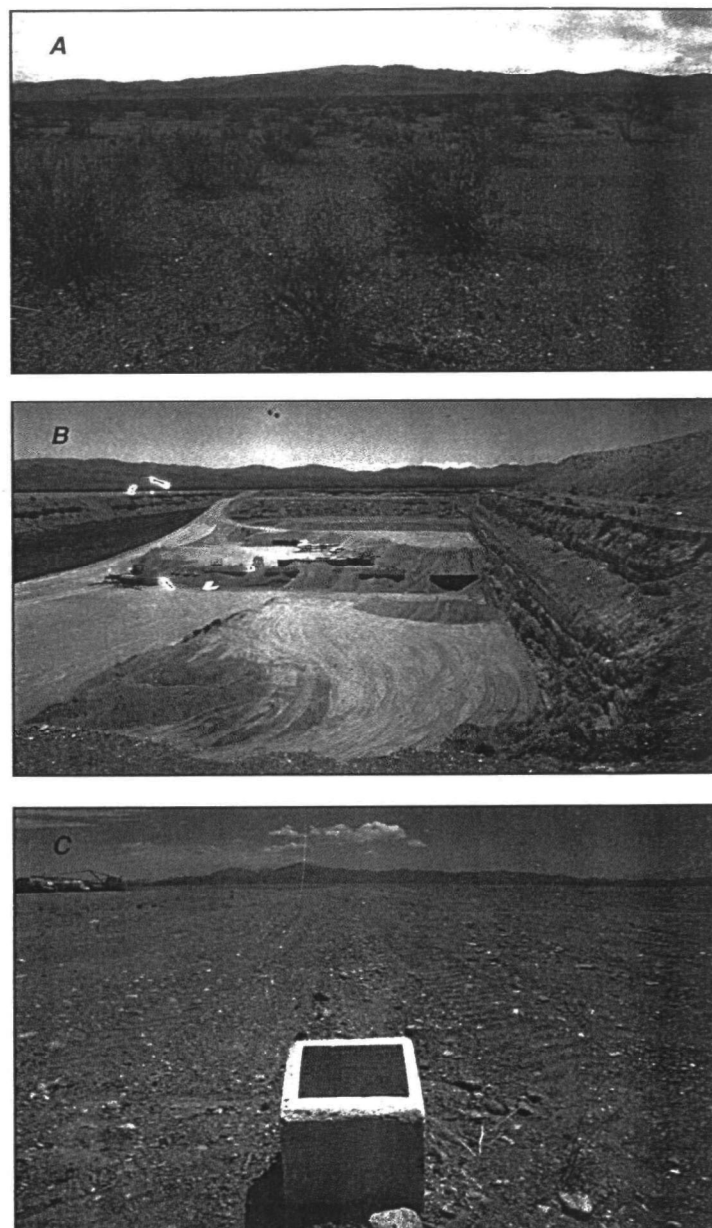
The suitability of a waste-burial site or landfill is a function of the hydrologic processes that control the near-surface water balance. Precipitation that infiltrates into the surface of a burial trench and does not return to the atmosphere by evapotranspiration from the soil and plants can percolate downward and come in contact with buried waste. Water that contacts the waste can enhance the release of contaminants for subsequent transport by liquid water, water vapor, or other gases.

The prevalent assumption is that little or no precipitation will percolate to buried wastes at an arid site. Thick unsaturated zones, which are common to arid regions, also are thought to slow water movement and minimize the risk of waste migration to the underlying water table. On the basis of these assumptions, reliance is commonly placed on the natural system to isolate contaminants at waste-burial sites in the arid West.

Few data have been available to test the validity of assumptions about the natural soil-water flow systems at arid sites, and even less is known about how the construction of a waste-burial facility alters the natural environment of the site. The lack of data is the result of (1) technical complexity of hydraulic characterization of the dry, stony soils and (2) insufficient field



**Figure 1.** Location of waste-burial site, Death Valley, and Mojave Desert of southwestern United States.



**Figure 2.** Undisturbed, vegetated area near waste-burial site, October 1991 (A); low-level radioactive waste burial trench (B); and nonvegetated surface of backfilled waste-burial trench with identifying monument, June 1988 (C).

studies that account for the extreme temporal and spatial variations in precipitation, vegetation, and soils in arid regions. In 1976, the U.S. Geological Survey (USGS) began a long-term study at a waste-burial site in the Mojave Desert near Beatty, Nev., to collect the necessary data and evaluate untested assumptions. This fact sheet summarizes the findings of investigations at the site and discusses how this information is important to issues of waste burial in an arid environment.

## Mojave Desert Waste-Burial Site

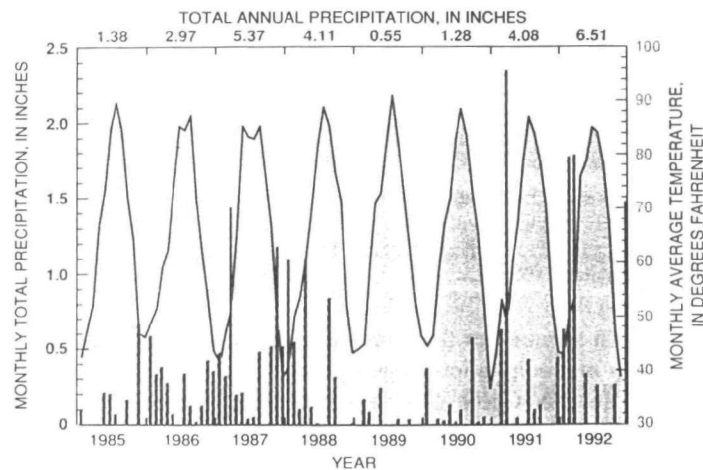
The waste-burial site, 30 miles east of Death Valley National Park, is in one of the most arid parts of the United States (fig. 1). Precipitation in the area averages about 4 inches per year. The water table is about 360 feet below land surface. Vegetation in the area is sparse (fig. 2A). Burial trenches at the site have been used for disposal of low-level radioactive waste (1962-92) and hazardous-chemical waste (1970-present). Burial-trench construction includes excavation of native soil, emplacement of waste, and backfilling with previously stock-piled soil (fig. 2B). The surfaces of completed burial trenches and perimeter areas are kept free of vegetation (fig. 2C). Regulations governing burial of low-level radioactive waste do not require that trenches be lined with impervious materials. Prior to 1988, linings were not required for chemical-waste trenches. As a result, only the most recent chemical-waste trench at the site is lined.

## Field Laboratory Established

Recognizing the need for long-term data collection, the USGS established a study area adjacent to the waste-burial site through agreements with the Bureau of Land Management and the State of Nevada. This 40-acre area serves as a field laboratory for long-term data collection and the study of hydrologic processes under natural-site and waste-burial conditions.

## Lessons Learned to Date

Early (1962) evaluation of the general hydrologic conditions at and near the waste-burial site suggested that low average annual precipitation and high average annual evapotranspiration would prevent water from percolating downward more than 1 or 2 feet below land surface. This assumption, however, did not consider the extreme annual and seasonal variations in a desert climate. During 1985-92, annual precipitation measured at the USGS study site ranged from 0.55 to 6.51 inches and monthly precipitation ranged from 0 to 2.34 inches. Monthly average temperature ranged from 38 to 92 degrees Fahrenheit. Most of the precipitation falls during the cool

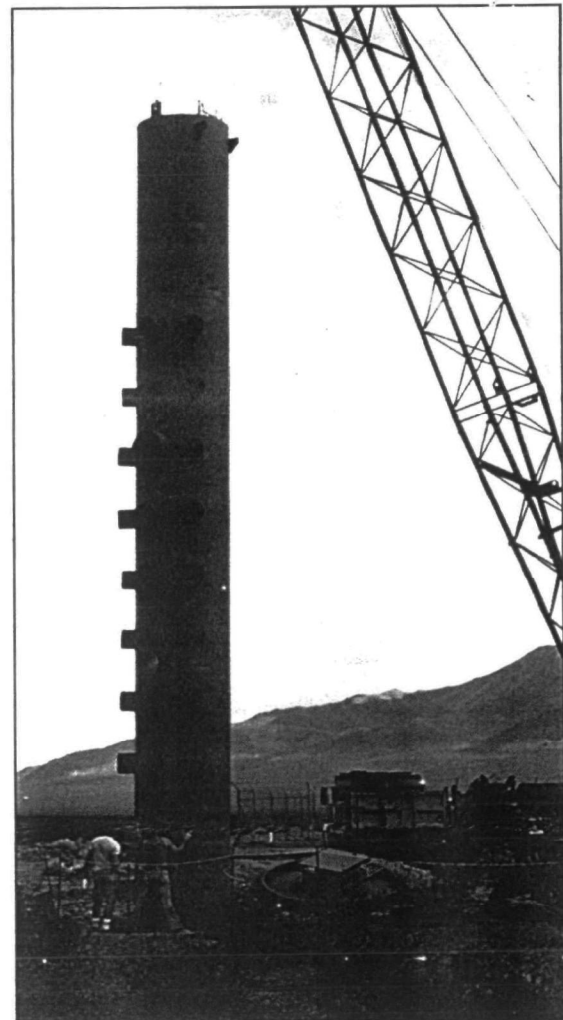


**Figure 3.** Annual and monthly total precipitation and monthly average temperature measured at U.S. Geological Survey field laboratory during 1985-92.

winter months when evaporative demands are low (fig. 3). Initial water-balance modeling by the USGS demonstrated that, under particular climate and soil-moisture conditions, the potential for deep percolation does exist, in spite of high annual evaporative demands (Nichols, 1987).

Field investigations to define the rates and directions of water movement through the deep unsaturated zone beneath an undisturbed, vegetated area began in the early 1980's and continue today. A study of chloride concentrations in the unsaturated zone indicates that deep percolation of water was limited to the upper 30 feet during the past 16,000 to 33,000 years (Prudic, 1994a). To monitor present-day flow processes, an instrument shaft was installed that allows access for operation of electronic devices to a depth of 45 feet (fig. 4; Fischer, 1992). Additional instrumentation has been installed to study flow processes throughout the unsaturated zone (Prudic, in press). Meteorological data are collected by an automated weather station (Wood and Andraski, 1995).

Water movement in the unsaturated zone is complex. Several variables—water content, water potential, humidity, and temperature—must be monitored to define rates and



**Figure 4.** Installation of vertical shaft used for soil-moisture monitoring in upper 45 feet of unsaturated zone beneath undisturbed, vegetated area. Photograph by David S. Morgan, U.S. Geological Survey, August 1983.

directions of water movement. Water content indicates how much water is held in the soil. Water potential indicates how easily the water is held by the soil matrix. Water moves through soil in liquid and vapor form, and the two forms can move simultaneously as a consequence of water-potential, humidity, and temperature gradients in the soil.

Ongoing investigations at the undisturbed, vegetated site indicate that the natural soil-plant-water system effectively limits the potential for deep percolation. During more than 5 years of monitoring, downward percolation was limited to the upper 3 feet of soil (Fischer, 1992; Andraski, 1994). Between the depths of 40 and 160 feet, water movement, as liquid and as vapor, is consistently upward. Preliminary evidence indicates that upward flow of water vapor through the thick unsaturated zone may potentially serve as a contaminant-release pathway (Prudic, 1994b; Prudic and Striegl, 1994).

Little is known about how, or to what degree, features of the natural system may be altered by installation of a disposal facility. Investigations to determine the effects of disturbance on soil properties and the long-term soil-water balance began in 1987. Two nonvegetated test trenches and an area of bare soil are monitored (fig. 5; Andraski, 1990). The effects of disturbance are evaluated in terms of observed differences between data collected at the undisturbed, vegetated site and data collected at the disturbed sites.

Accurate characterization of hydraulic properties is critical for calculations of water movement through soil. Characterization data normally are measured to a minimum water-potential value referred to as the permanent wilting point for crops. Below this value, water is held so tightly by the soil matrix that a crop plant cannot extract the water and will wilt and die. Data collected by the USGS at the Mojave Desert site, however,

show that this lower limit is not adequate for nonirrigated, desert soils and plants, nor is it appropriate for the extremely dry backfill material produced by trench construction. Thus, characterization of hydraulic properties at the site has been extended to include data measured over a soil-moisture range that is representative of seldom-studied arid conditions (Andraski, in press).

Backfilling with very dry material will, at least initially, increase the importance of vapor flow as a potential transport mechanism in the trench fill (Andraski, in press). These initial dry conditions can change substantially, however, in response to subsequent precipitation and a lack of vegetation. On an annual basis, no water accumulates in the vegetated soil because water is removed by the plants (fig. 6). In contrast, even under conditions of extreme aridity, water accumulates in the nonvegetated soil and test trenches. Water that has accumulated at the three disturbed sites is continuing to percolate downward (Andraski, 1994). Thus, the construction of waste-burial trenches and removal of native vegetation markedly alters the natural site environment and may increase the potential for release of contaminants (Gee and others, 1994). Surprisingly, such changes typically are not considered in the evaluation of a proposed waste site and may not be considered in management of existing sites.

## Well-Informed Decisions Needed

Regulations governing the licensing of solid-waste landfills and hazardous-waste sites require an assessment of the potential for deep percolation of water through buried waste before disposal operations can begin. Numerical models commonly are relied on for this assessment. For a proposed low-level radioactive waste site, 1 year of preoperational monitoring of site conditions also is required. Thus, data used in numerical

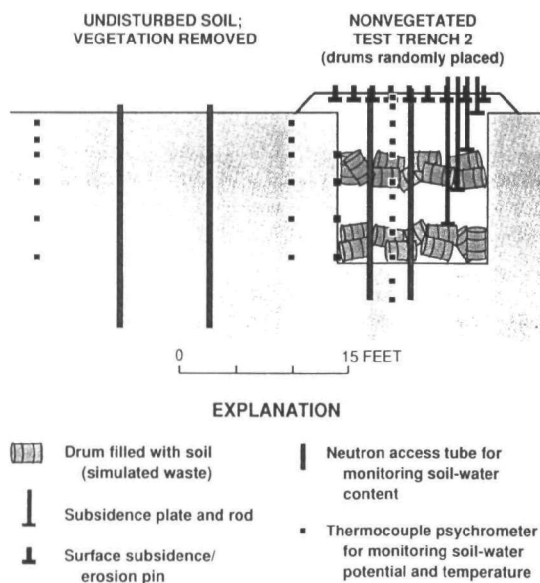


Figure 5. Schematic diagram of instrumentation used to determine effects of vegetation removal and trench construction on water movement through unsaturated zone. Subsidence and erosion are monitored to determine changes in structural integrity of test trenches. In second test trench (not shown), soil-filled drums are stacked in orderly fashion.

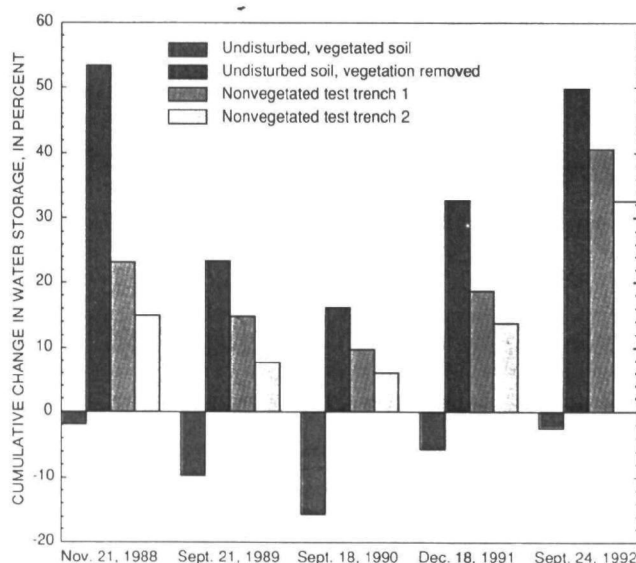


Figure 6. Cumulative changes in quantity of water being held in uppermost 4 feet at four monitoring sites: undisturbed, vegetated soil; undisturbed soil where native vegetation was removed; and two nonvegetated test trenches. Values are based on measurements during first 5 years following vegetation removal and trench construction at disturbed study site in October 1987.



analysis of a proposed waste-burial site may be based solely on hydraulic information available in the literature, or the data may include some site-specific information, which typically is limited to natural conditions and a short period of time. This approach is of particular concern for waste sites in arid regions because, compared with the amount of information available for more humid sites, the amount of hydraulic-property data and long-term field data for arid sites is negligible. In addition, although significant advances have been made in the development of soil-water flow models, the lack of long-term field data has resulted in these models remaining largely untested as to how well they represent flow systems at arid sites.

## Long-Term Benchmark Information

Ongoing work by the USGS at the Mojave Desert field laboratory continues to provide long-term, quantitative "benchmark" information about the hydraulic characteristics, water movement, and the potential for release of contaminants through the unsaturated zone in an arid environment. Monitoring methods developed and tested at the Mojave Desert site have helped others in their study and evaluation of waste-isolation processes at the Nevada Test Site, and at proposed waste sites in Texas and California. The U.S. Nuclear Regulatory Commission and Pacific Northwest Laboratory have chosen the Mojave Desert waste site for use in numerical modeling of infiltration because it is representative of burial operations in an arid environment. Data collected at the USGS field laboratory are being provided for this effort. The National Academy of Sciences also has used information from the site in the evaluation of issues related to waste disposal in an arid environment.

Because of the potentially harmful effect of improper waste disposal on water resources in the arid West, comprehensive laboratory and field studies are critical to identifying likely contaminant-release pathways and the potential for waste migration at arid sites. However, the quandary for those charged with assessment of the suitability of potential disposal sites is that site characterization and evaluation must be accomplished in a relatively short period of time—only 1 to 2 years.

Data collection at the Mojave Desert field laboratory provides the needed long-term benchmark against which short-term data from proposed arid sites can be compared. The data base and monitoring facilities developed at the field laboratory also provide an excellent foundation upon which to build collaborative efforts with universities and local, State, and other Federal agencies to further the study and understanding of hydrologic processes in an arid environment.

—*B.J. Andraski, David E. Prudic, and William D. Nichols*

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# **ACCELERATED SITE CHARACTERIZATION**

## **(A CASE STUDY)**

*by*

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**RCRA Corrective Action Conference  
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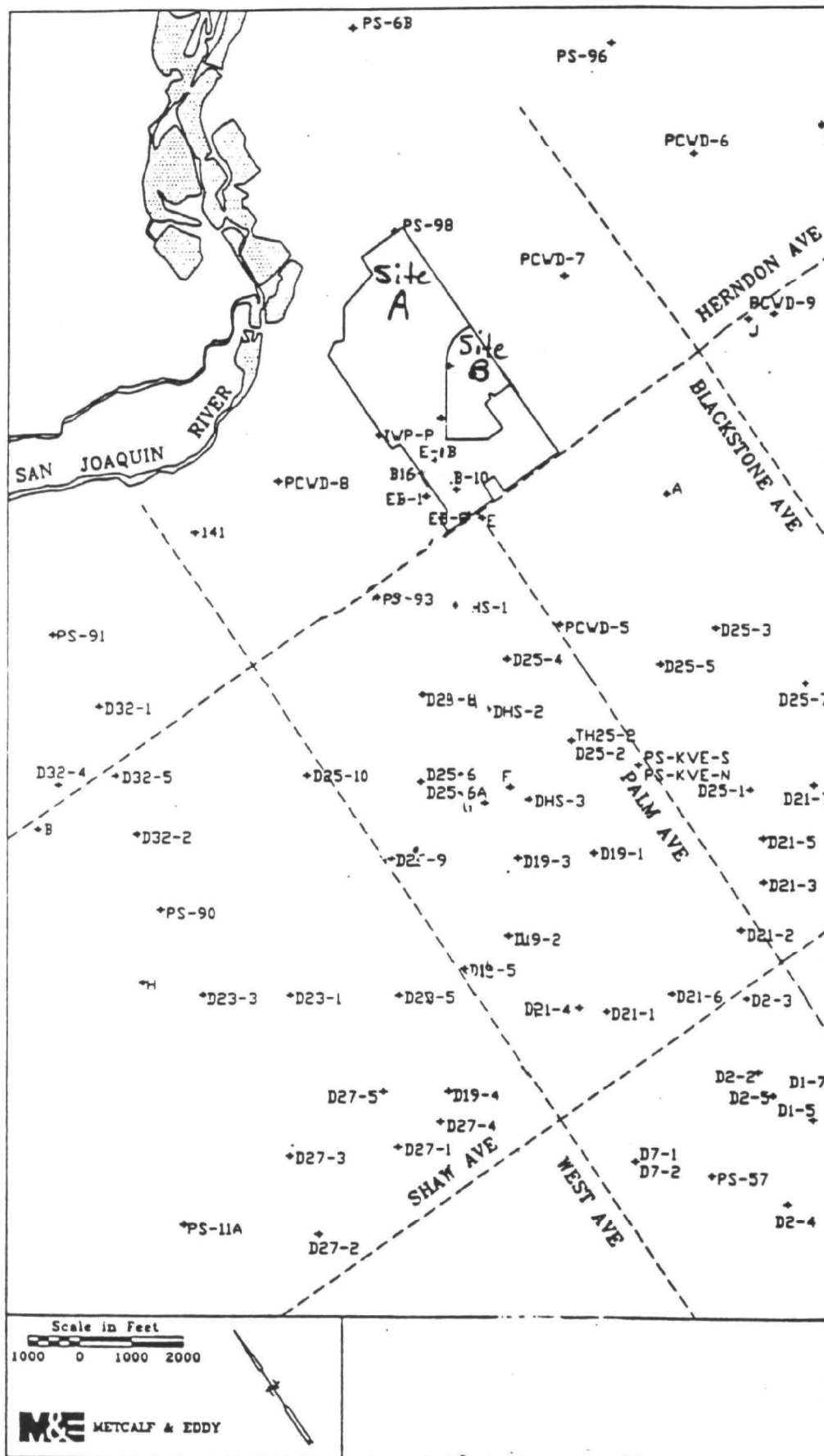
**March 26-28, 1996**

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## **ABSTRACT**

**The "iterative" process being used to characterize volatile contaminants at many hazardous waste release sites is taking years to complete and is very costly for both industry and government. A change from using this commonly applied process is needed. Investigations should address the entire extent of contamination using "rapid field characterization" and the least number of phases as possible; usually, no more than two or three phases of field investigation should be necessary. This approach should utilize an on-site laboratory to collect real-time data from soil gas, soil, or ground water samples. Rapid field characterization provides for collecting accurate and precise contaminant data that define pathways. If collected early during projects, these data should reduce the overall site cleanup time by ninety percent and overall site cleanup costs by one-half. Rapid field characterization techniques should be used by both RCRA Corrective Action and Site Mitigation CERCLA investigations.**









FEET

POUNDER  
CANAL

LANDFILL

FOUNDATION  
SLAB  
STEEL STRUCTURES  
COMPANY

FIRE  
PROTECTION  
POD

Site A

Site B

Site C

BIRCH AVE

SPRUCE AVE

LOVELL AVE

SEMPER  
TRUCKING  
COMPANY

MAINTENANCE  
SHOP

PICT'S  
BOYS

WATER  
TOWER  
ROGER'S  
AUTOMATIC  
LAUNDRY AND  
DRY CLEANING  
EQUIPMENT

VALLEY DECORATING  
COMPANY

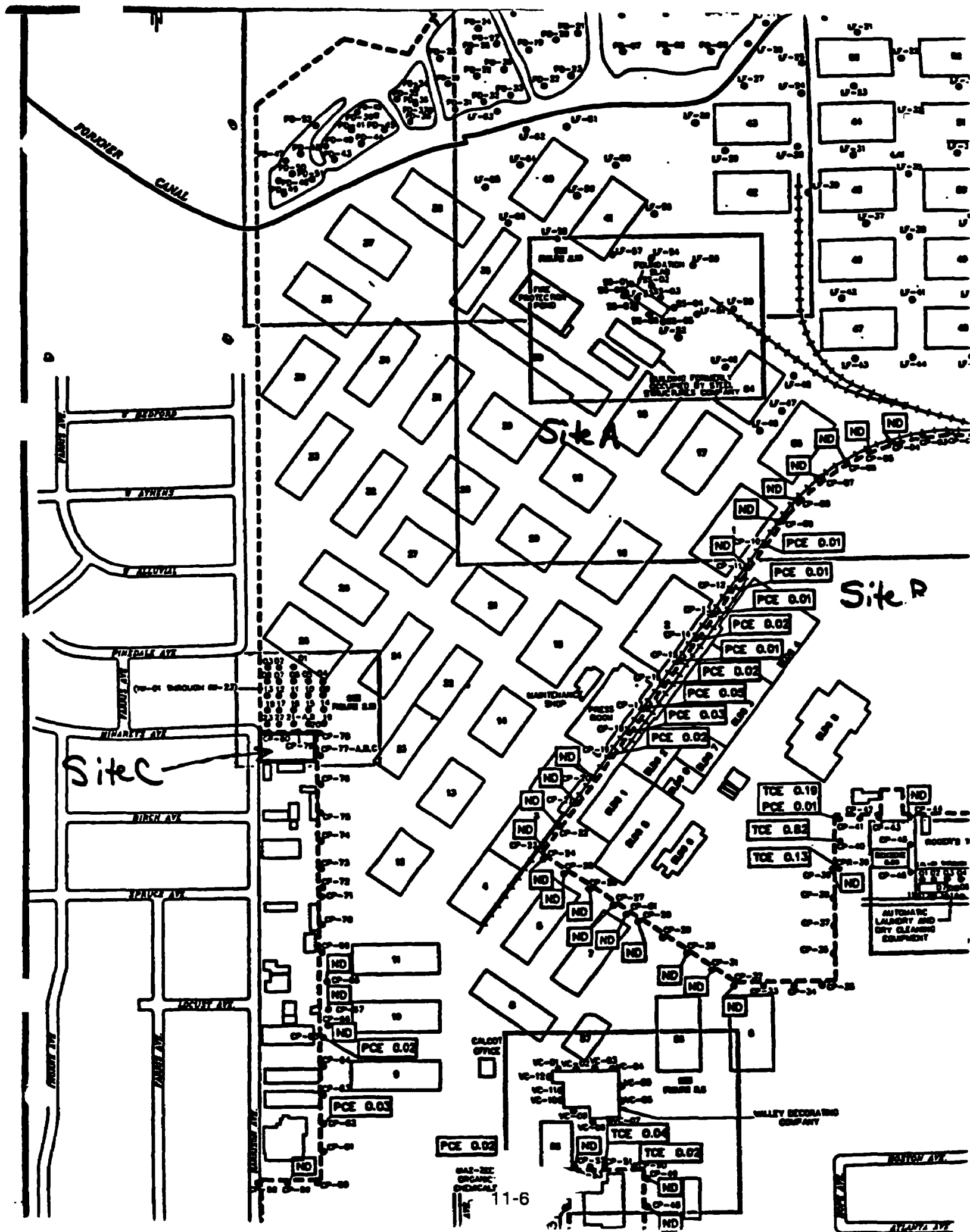
MAZ-ZEE  
ORGANIC  
CHEMICALS

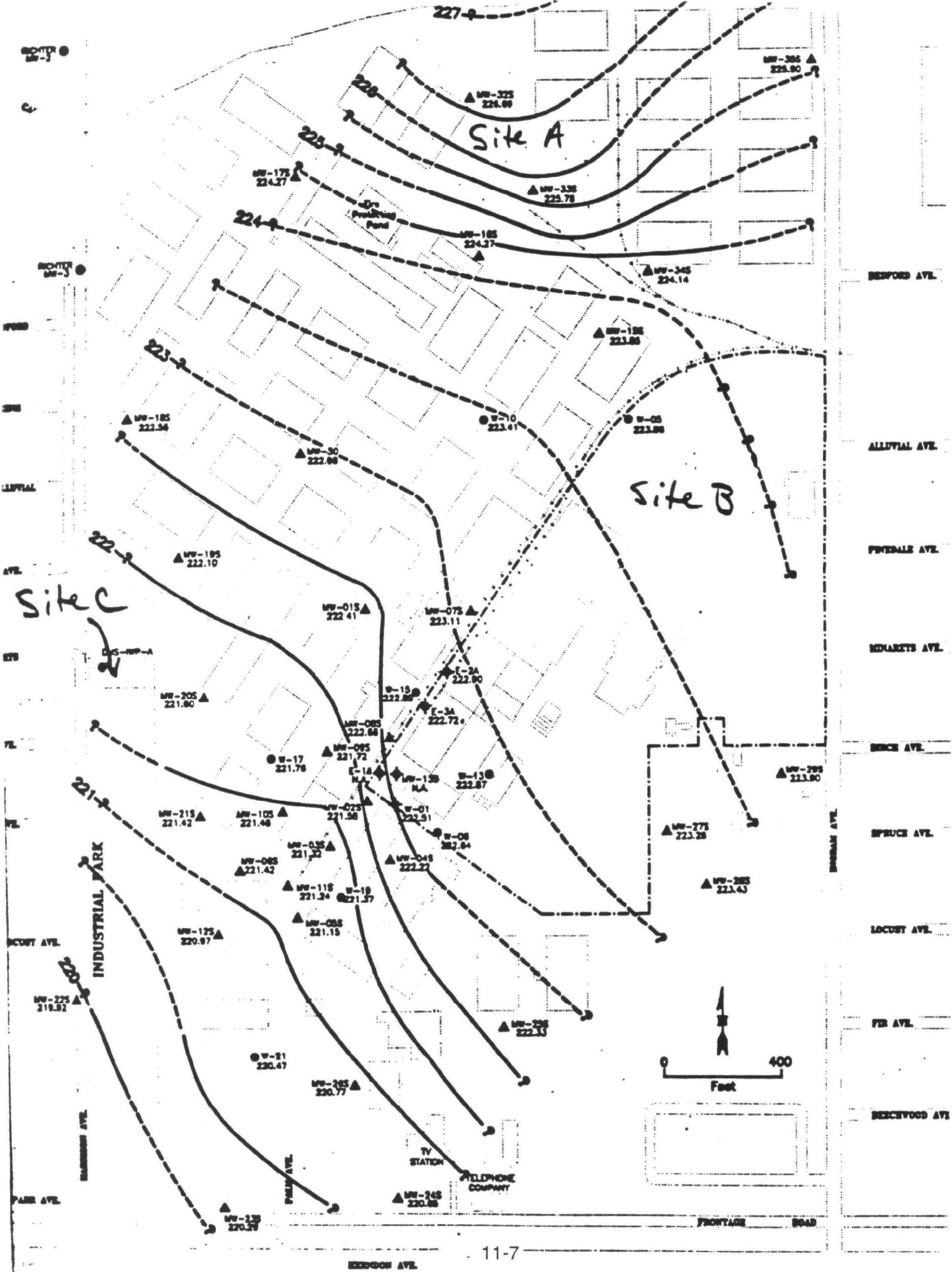
PACIFIC BELL TELEPHONE

11-5

23RD AVE

24TH AVE





**CW**



Fire  
Protection  
Fund

Site B

Site C

INDUSTRIAL PARK

**Foot**

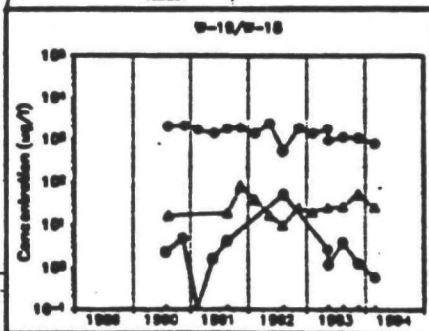
400

Well in which elevation of water surface was measured. Upper number is well designation, lower number is the elevation of the

▲ MW-2120

ing well location





Measuring point elevation for extraction well survey which is considered accurate to  $\pm 0$  extraction well E-18 was not pumping bet-



### EXPLANATION OF WELL SYMBOLS

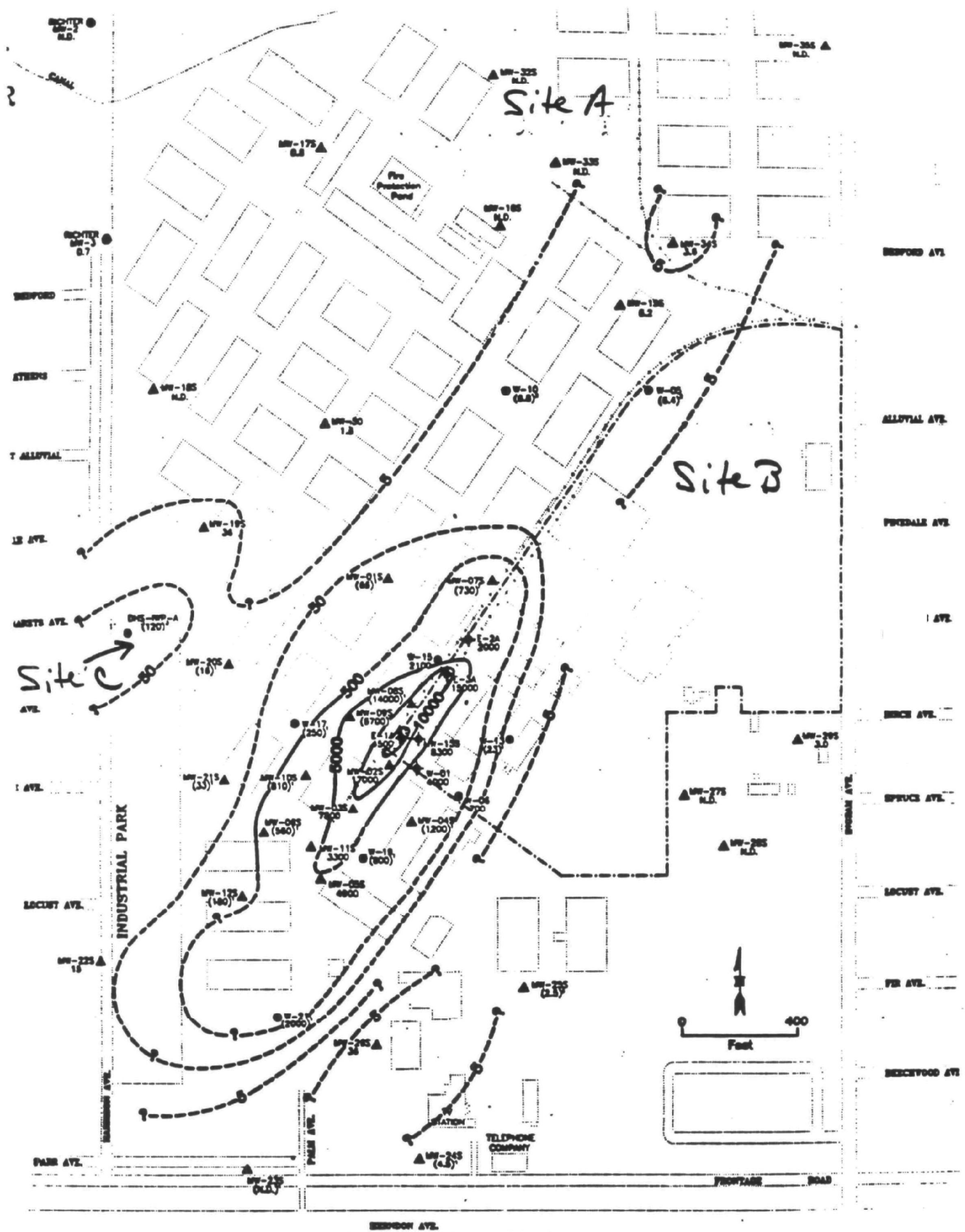
● W-19	A-zone monitoring well
○ W-18	B-zone monitoring well
◆ E-2A	A-zone extraction well
◆ E-1B	B-zone extraction well

### **EXPLANATION OF INSETS**

 A-zone TCE  
 A-zone chromium  
 B-zone 11-9  
 B-zone 11-9

**NOTE**

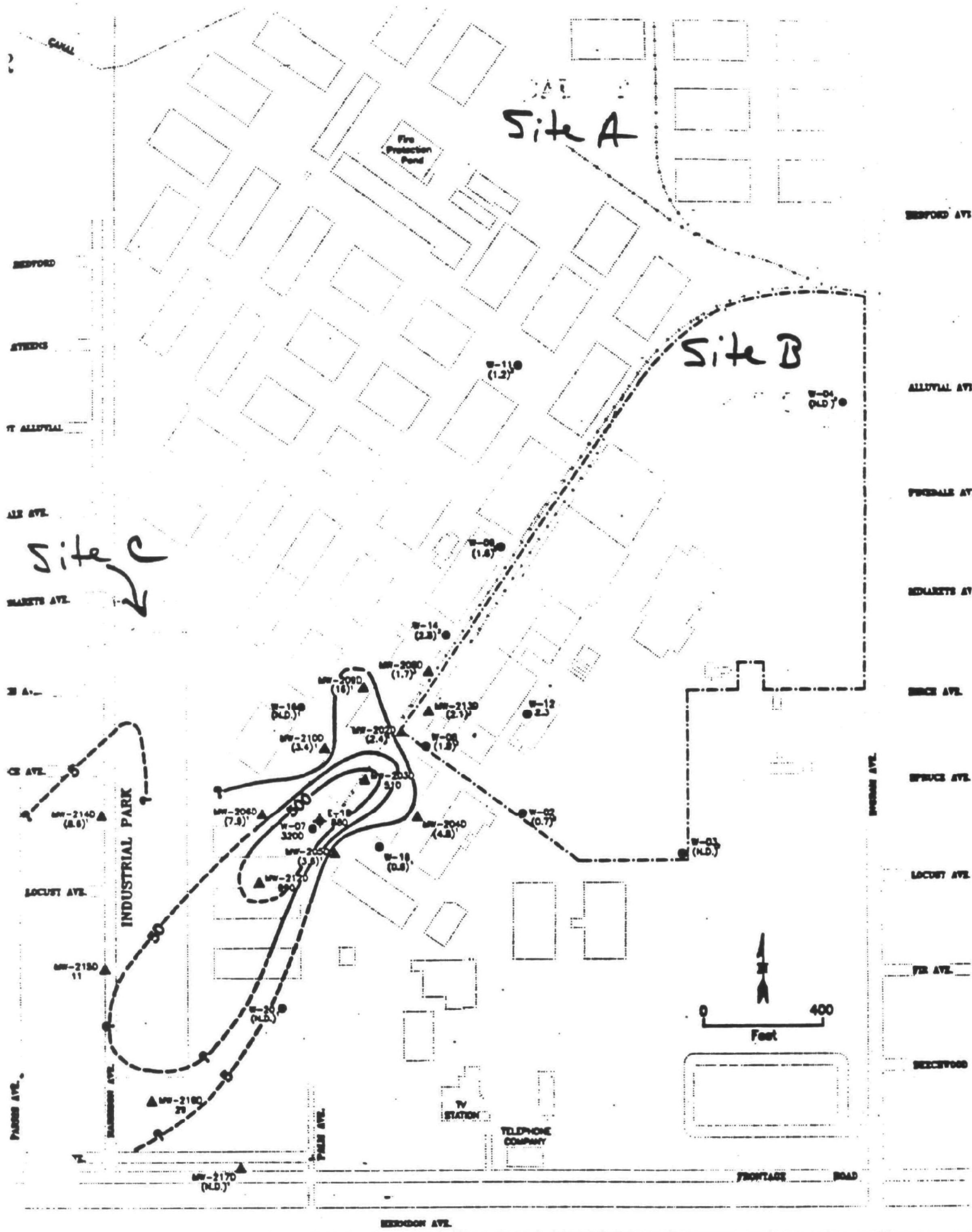
TCE or chromium which was not detected at or above the minimum detection level is plotted as a value of  $10^{-1}$ .



Site A

Site B

Site C



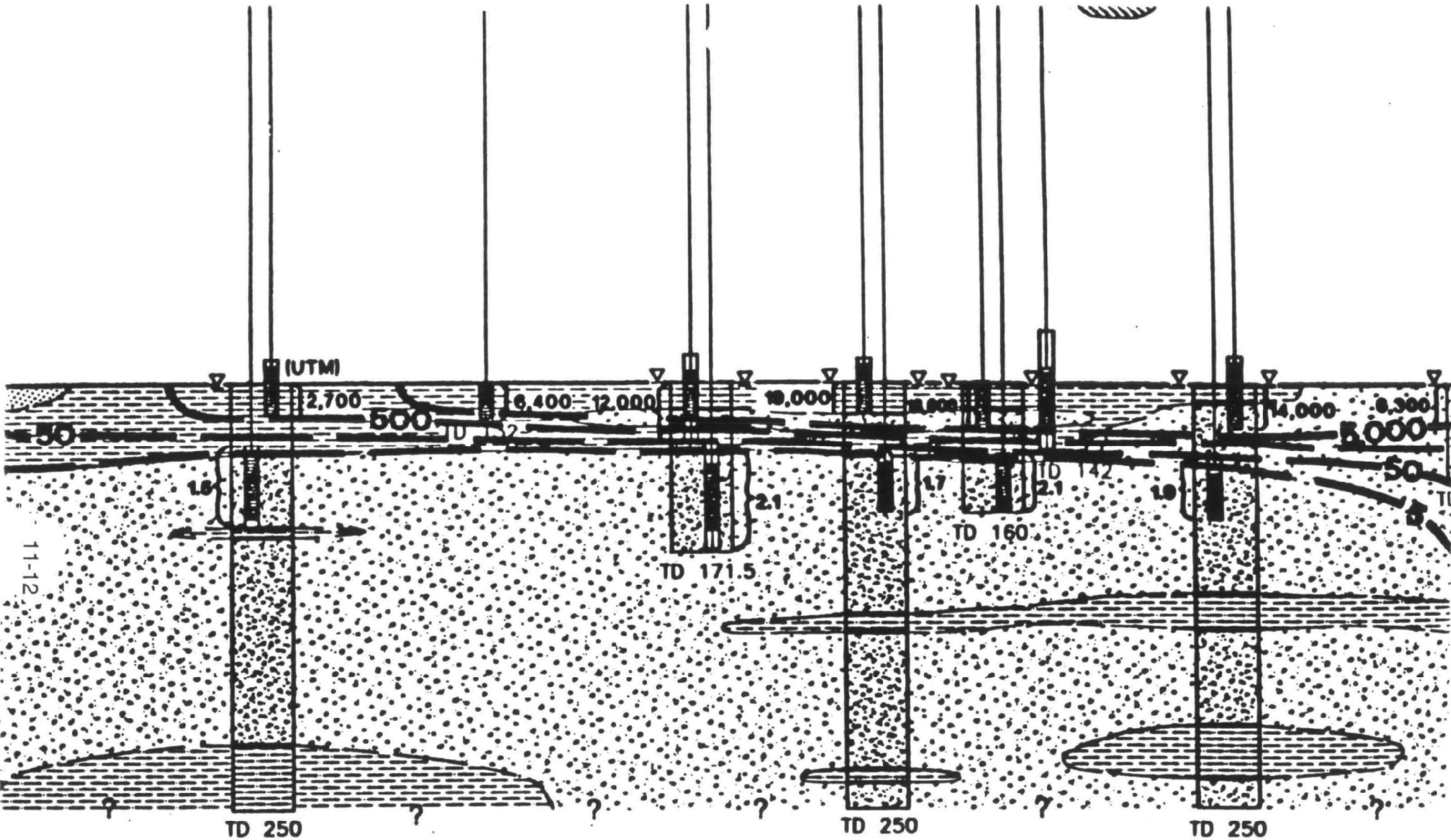
which groundwater was  
 1 during May 1994  
 number is well designation.

- W-18
- ▲ W-14

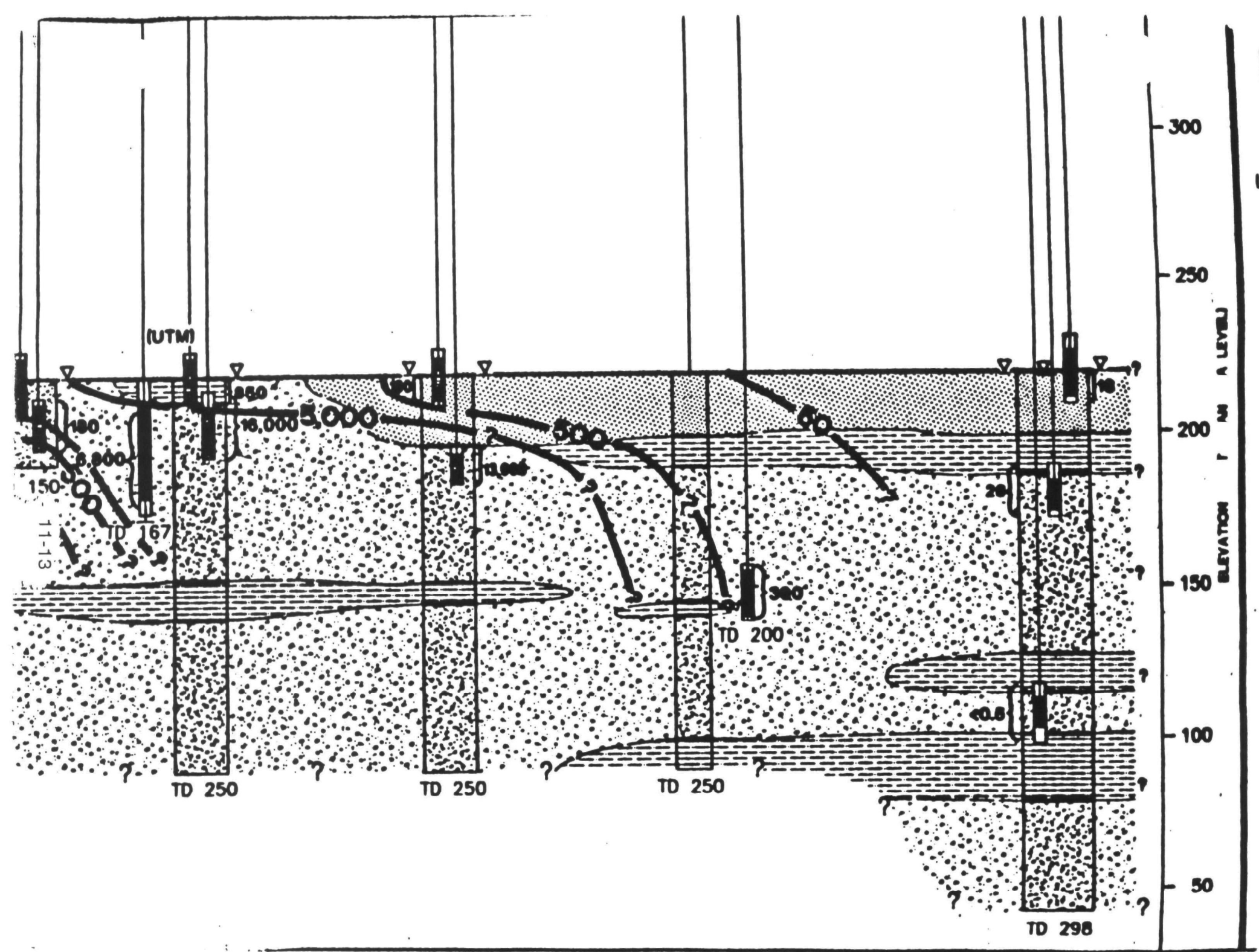
version B-zone moni  
 11-11

**NOTES:**  
 E-18 is a groundwater extraction well.  
 5 ug/l contour is based on the "Maximum Contaminant Level" (MCL) of  
 for TCE in drinking water, per Title 22, California Code of Regulations.









**BORING NO. B-16a**

**65 Feet Southwest of Bldg. 8 on Calcol Property**

**SHEET 10 OF 13**

11-14**Figure No.**

**GROUNDWATER SITE  
California**

**BORING NO. B-16a**

**BORING LOCATION**

**65 Feet Southwest of Bldg. 8 on . Property**

**SHEET 9 OF 13**

DEPTH (feet)	Recovery	Sample No.	Blows/ 6-in.	PID	Lithology	DESCRIPTION	Completion Detail	REMARKS
197						SAND (SP): reddish gray (SVR 5/2), mostly med. gr. sand, fair-to-bd f. gr. sand, sil. few clay. lenses 3-in. thick con. layer @ 194.5-ft.		
199		BAT Y-375 Y-376				SAND (SP): color grades to grayish brown (SVR 5/2), mostly med.-gr. gr. sand, f. - few sil. oxidized laminae		BAT sample @ 200-ft.
201								
203								
205						becoming f. gr., mostly f.-med. gr. sand (SP) from 204 to 204.5-ft.		reddish brown oxidized layers throughout 1 to 3-in. thick layers, about 1 to 6-in. apart
207			7					
209		BAT Y-377 Y-378	10					BAT sample @ 210-ft.
211								
213								
215						SAND (SP): light yellowish brown (SVR 6/4), mostly med. gr. sand, f. - few sil. f. gr. sand; loose-med. dense		
217			7					attempted BAT sample @ 220-ft. no sample obtained
219								
Project No. 91017 B6					- 11-15			Figure No.

**GROUNDWATER SITE  
California**

**BORING NO. B-16a**

**BORING LOCATION:**

**65 Feet Southwest of Bldg. 9 on Property.**

**SHEET 8 OF 13**

DEPTH (feet)	Recovery	Sample No.	Blows/ 8-in.	PID	Lithology	DESCRIPTION	Completion Details	REMARKS
172						GRAVEL (SP/6 1/2 variegated, med. granitic & mafic, up to 1-in. dia., mtx: silty sand, mostly f.-med. gr. sand, few silt & clay		Drill rig chatter from 171 to 172.5-ft.
174		BAT -373	7 8 9 11 12 14			SAND (SP) yellowish brown (GYR 5/4), mostly med. gr. sand, tr.-few silt, tr. occ. f. gravel gr.; base-med. dense		
176						thin gravel layer @ 175-ft.		BAT sample @ 176-ft.
178								drilling mud visc.=60 sec. wt=10 lbs/gal disorder on
180								
182						SILTY SAND w/ Clay (SP): brown (GYR 5/3), mostly s. f.-f. gr. sand, some silt, few clay, dense, sand content incr. @ base		
184						SILTY SAND w/ Clay (SP/SC): reddish brown (GYR 4/3), mostly f. gr. sand, some silt, few-fine clay, dense		
186								drilling mud: visc.=63 sec. wt=9.8 lbs/gal
188						SAND/SILTY SAND (SP/SC): reddish brown (GYR 5/3), mostly med. gr. sand, few-fine silt & clay, tr. org. gr. sand, variable silt & clay content; med. dense		
190								
192		BAT W-374						BAT sample @ 192-ft.
194								
Project No. 91017 B6								Figure No.

GROUNDWATER SITE  
California

BORING NO. B-16a

LOCATION

55 Feet Southwest of Bldg. 8 on

Property

SHEET 7 OF 13

DEPTH (feet)	RECOVERY	SAMPLE NO.	BLDG./ G-11	PID	LITHOLOGY	DESCRIPTION	Completion Detail	REMARKS
147						SILTY SAND (SP) yellowish brown (SP) S&S, mostly f. gr. sand, few silt cl. tr. clay, granitic sand, 1 to 2-in. thick layers of dark orange brown mottling, coarse		
149						SAND w/ SIL & Clay (SP) S&S, mostly med. gr. sand, little-silt f. gr. sand, few silt & clay, med. coarse		
151						SAND (SP), pale brown (SP) S&S, mostly med. gr. sand, few silt & f. gr. sand, tr. silt-clay, loose-med. coarse		
153						med. SAND (SP), occ. (to 4-in. thick layers of silt-cl. silt. sand		
155								
157								
159						gravel layer, 1 to 2-in. thick (T) @ 159-ft.		
161								
163		BAT H-372				SAND (SP), pale brown-brown, mostly med. gr. sand, tr. gravel; to 1/2-in. med. coarse. 2-in. thick gravel layer @ 162.5-ft.		BAT sample @ 163-ft.
						Gravel layer (T) @ 164-ft.		drill rig chatter @ 164-ft.
165								
167								
169						gravel layer @ 169-ft., up to 1.5-in. dia. med. lithic frag., mostly mafic, few granitic.		
Project No. 91017 B6								Figure No.

# GEO-HYDRO-DATA

INCORPORATED

## ELECTRIC WELL LOG

COMPANY :  
WELL : B-16A  
LOCATION/FIELD : PALM & HERNDON -  
COUNTY :  
STATE : CALIFORNIA  
SECTION : -

COMPANY

OTHER SERVICES:

INV 8000

MUD 8000

TOWNSHIP : -

RANGE : -

DATE : 08/10/93  
DEPTH DRILLER : 303  
LOG BOTTOM : 304.00  
LOG TOP : 1.00

PERMANENT DATUM : G.L.  
ELEV. PERM. DATUM : -  
LOG MEASURED FROM: G.L.  
DRL MEASURED FROM: G.L.

ELEVATIONS

KB : -

DF : -

GL : -

CASING DRILLER : -  
CASING TYPE : -  
CASING THICKNESS: -

LOGGING UNIT : 7  
FIELD OFFICE : SAN JOSE  
RECORDED BY : C. HERON

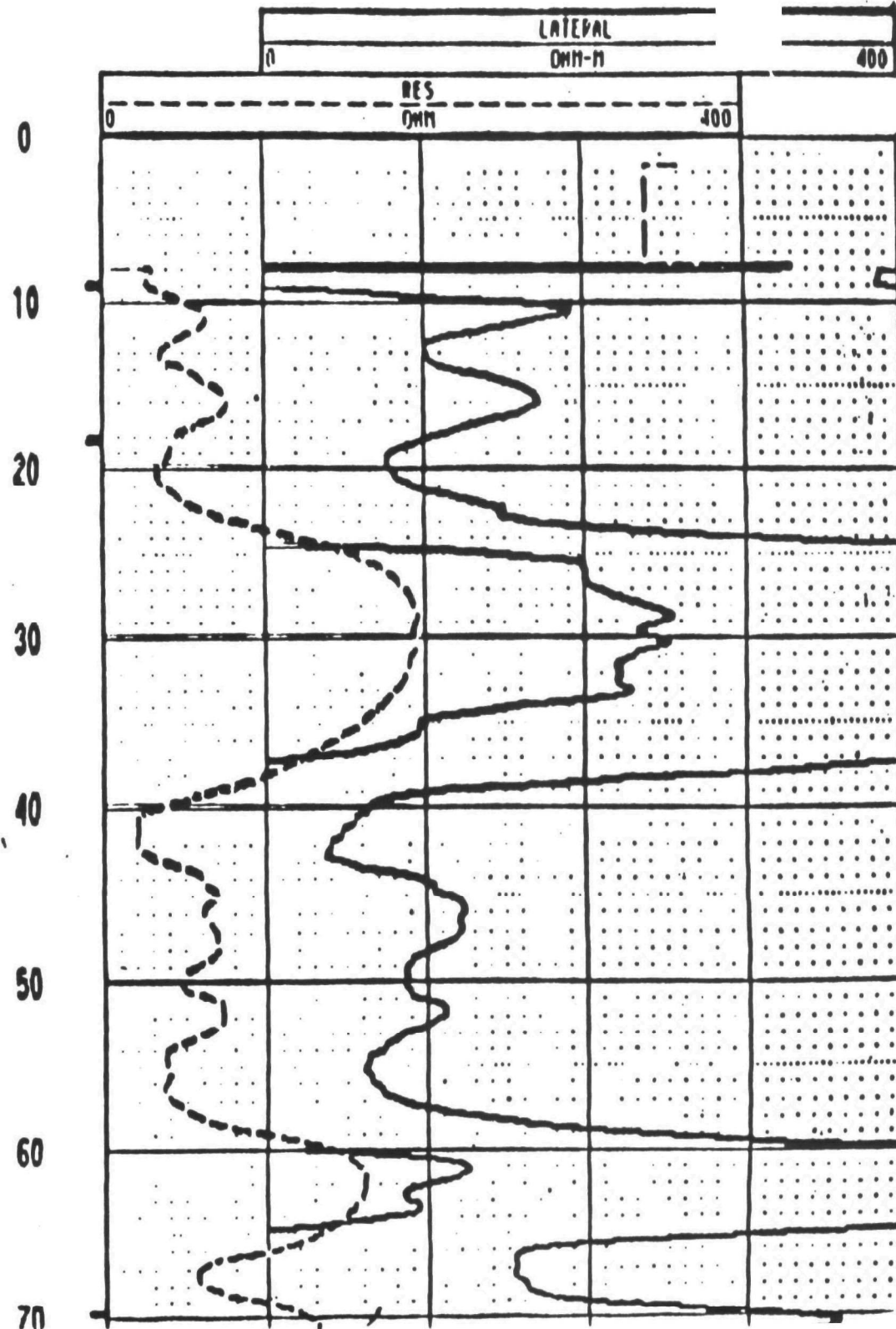
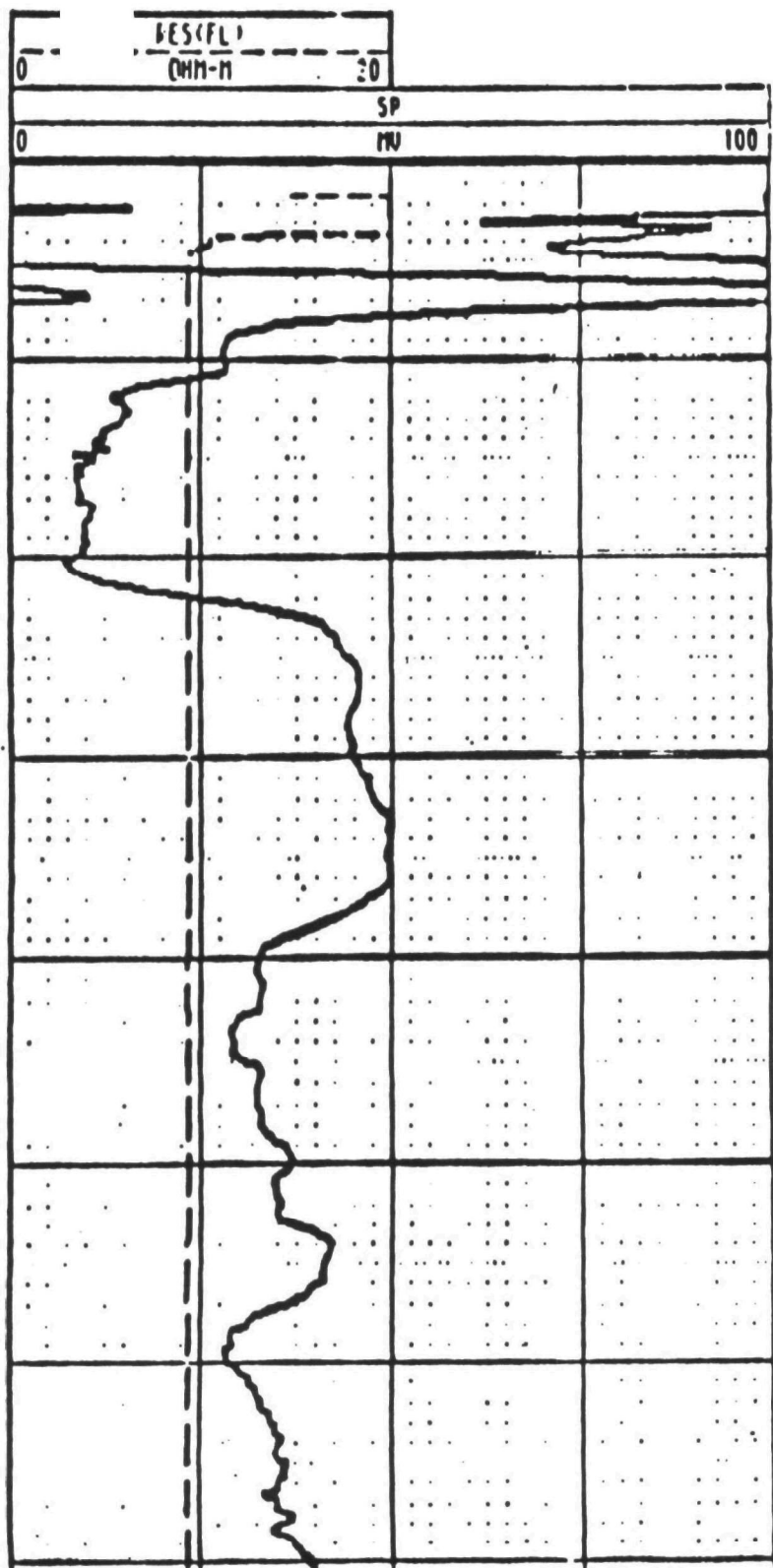
BIT SIZE : 5  
MAGNETIC DECL. : -  
MATRIX DENSITY : -  
FLUID DENSITY : -  
NEUTRON MATRIX : -  
REMARKS :

BOREHOLE FLUID : CLAY-GEL  
RM : -  
RM TEMPERATURE : -  
MATRIX DELTA T : -  
FLUID DELTA T : -

FILE : PROCESSED  
TYPE : 9041A  
LOG : 5  
PLOT : 1 0  
THRESH: 1000

DRILLED BY: ALL TERRAIN DRILLING - PLEASANT HILL, CA  
CONSULTANT: CA

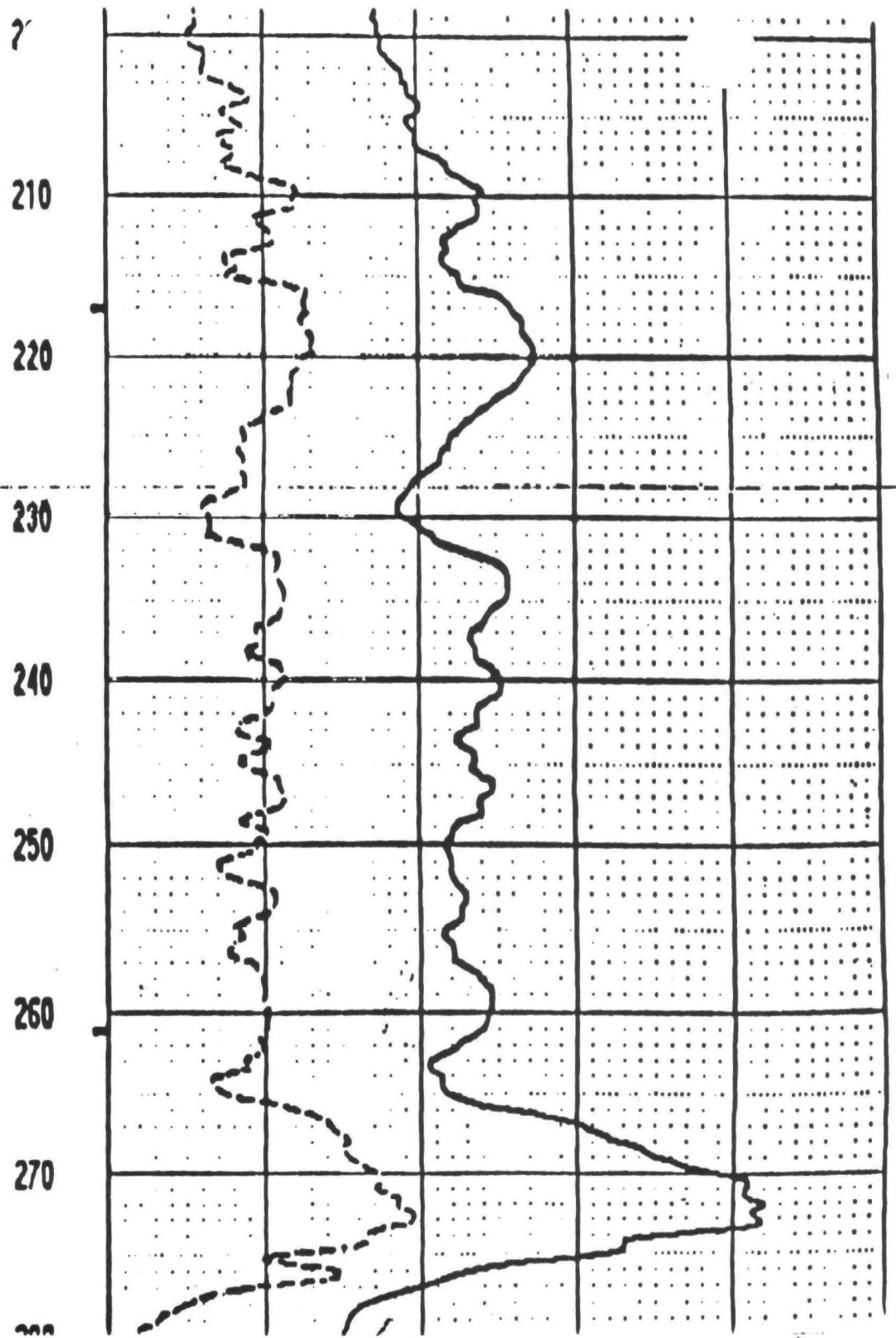
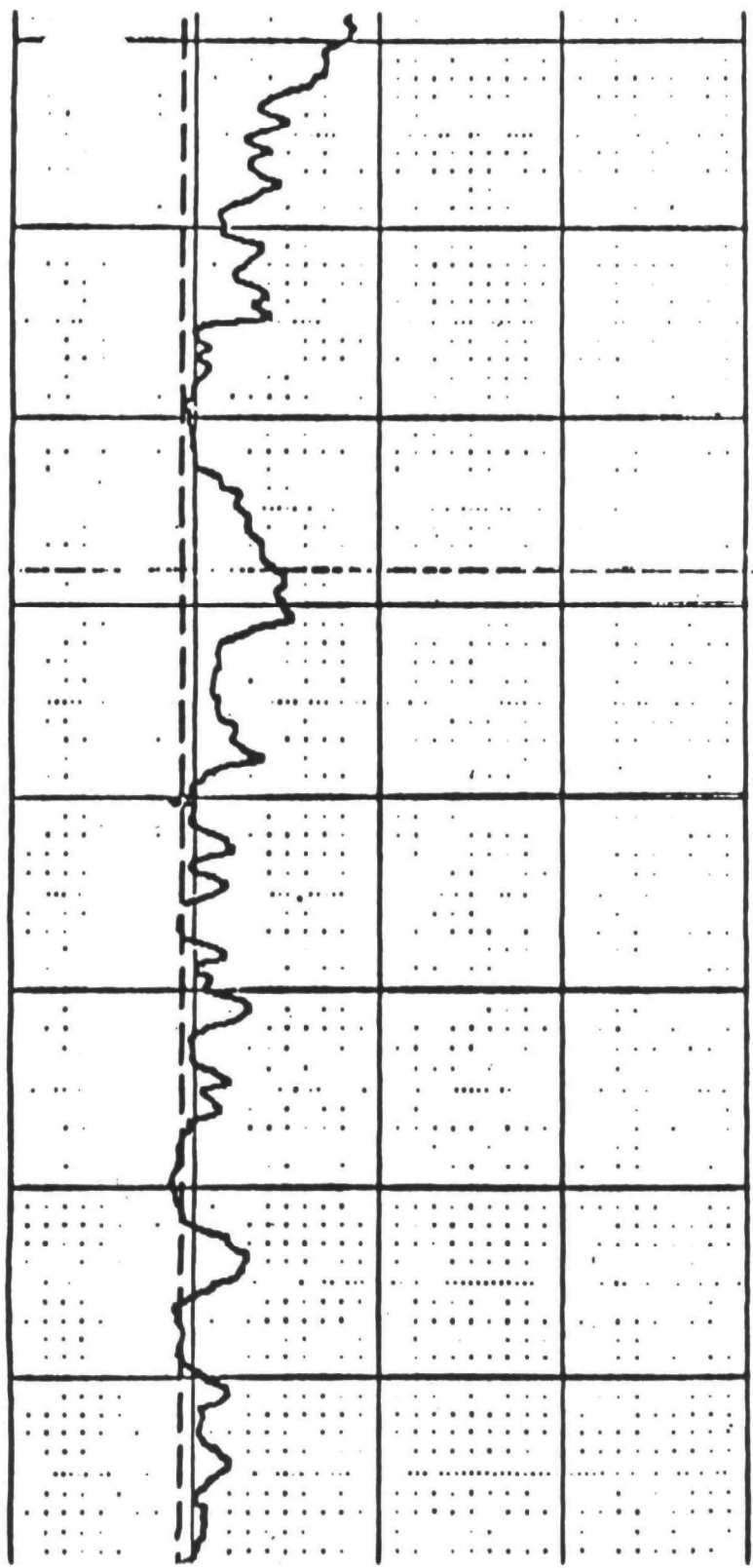
ALL SERVICES PROVIDED SUBJECT TO STANDARD TERMS AND CONDITIONS







11-21



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**12**

# Stable Isotope Methods

## Hydrogeologic Modeling and Monitoring of Contaminated Sites

A method for assessing the sources and movement of waters and pollution by measuring stable isotopic data

### Statement of Problem

Analysis of the oxygen isotope ( $^{18}\text{O}/^{16}\text{O}$ ) and hydrogen isotope (D/H) ratios of waters is a popular tool in hydrogeologic assessment. Applications of the technique, however, have been limited to studies of uncontaminated watersheds at much larger scales than are required for meaningful environmental characterization. Moreover, because environmental site characterization activities typically incorporate only those analytical methods required under environmental law, characterization efforts at contaminated sites

normally lack stable isotopic data.

Stable isotopic techniques enable a comprehensive understanding of the hydrogeology at scales appropriate for the rational development of monitoring and remediation

### methodology for developing rational monitoring and remediation strategies

strategies. Isotopic data provide a baseline for the assessment of water and pollutant sources and movements, and for the implementation of strategies for environmental protection, determination of ecological impacts, and assessments of environmental risk.

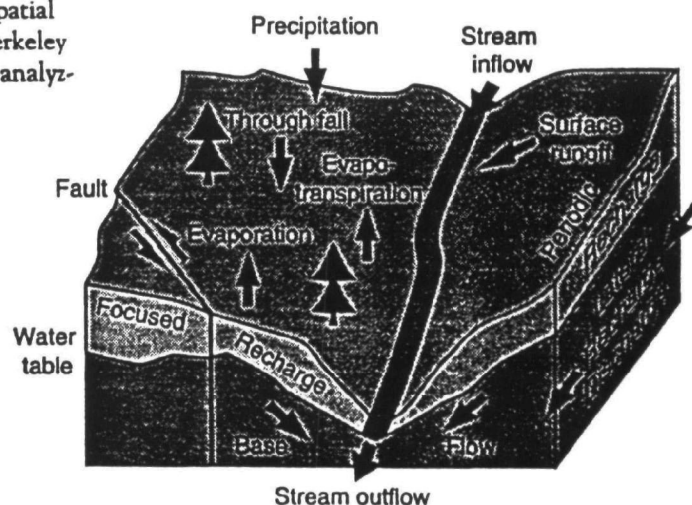
### Laboratory Capabilities

Our work has focused on determining the spatial and temporal isotopic variations of water at Berkeley Lab and other DOE sites. For example, we are analyzing

the components (biotic and abiotic) of the water cycle within Berkeley Lab's Strawberry Canyon area to establish flow rates and directions. The isotopic contrasts between rainfall, groundwater, and municipal water at Berkeley Lab have been used to develop mass balance equations to calculate stream flow, and to demonstrate that groundwater is a major component of runoff and stream flow—even in the rainy season.

Groundwater isotopic data also have helped identify areas of contrasting infiltration velocities (and thus differing risks for contamination) and areas where municipal water leaks have occurred. Vadose zone isotopic data highlight the importance of fog water inputs, processes such as plant water uptake and transpiration, and organic matter decomposition in determining water budgets and water isotopic characteristics in the unsaturated zone.

We also use isotopic ratios in plant biomass and plant fluids to investigate variations in plant water sources in space and time. This information will help in planning vegetation cover for regulating water infiltration and transpiration rates, for immobilizing pollutants, and for minimizing exposures to humans and organisms in the food chain.



### Contact

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Fax: 510/486-4776  
Mail stop: 75B-101

Hydrogeologic modeling requires oxygen isotopes.

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## **SOIL VOC METHANOL PRESERVATION**

**Kurt Zeppetello**  
**Arizona Department of Environmental Quality**  
**KJZ@EV.STATE.AZ.US**  
**(602)-207-4410**  
**(602)-207-4236 (fax)**

### **Abstract**

This paper presents different field sampling techniques that the Arizona Department of Environmental Quality (ADEQ) recommends emphasizing the methanol preservation method. This procedure is used when samples will not be extracted at the mobile or fixed laboratory within 2 hours. Using pre-weighed vials (40 or 60 ml vials), add 15 gms of soil to the 40 ml vial or 25 gms of soil to 60 ml vial. After adding the sample to the vial, quickly add a pre-measured amount of methanol to the vial and close it. Other methods for adding methanol may be acceptable. This method is the most recommended method for when samples cannot be extracted by a laboratory within 2 hours. Results from case studies performed in Arizona indicate that VOC concentrations may be significantly under reported using conventional sampling techniques.

### **Introduction**

Volatile organic compounds VOCs, halogenated and aromatic, are widely used throughout society and as such are commonly the most prevalent contaminants at remediation sites. Since site assessment decisions and remedial actions are based on sampling results for these compounds, it is essential that accurate data is collected. Frequently, laboratory results show no detectable volatile organic compounds (VOCs) in soil samples collected from sites that have significant ground water contamination (Koroghlanian et al., 1995). This indicates that there may be a problem with the conventional soil collection procedure of containerizing the sample in a Teflon capped glass jar or sealing it in a brass sleeve, refrigerating it at 4° C, and then transporting it to a laboratory.

Although there other explanations for not detecting VOCs in soils where the ground water is contaminated, such as collecting a soil sample which composed of a non-sorbing material like sand or not collecting the sample in the correct zone, field research from the last six years has suggested that the procedures associated with conventional soil collection may lead to substantial errors when sampling for VOCs. Preliminary studies on the problems with conventional soil sampling has been conducted by Siegrist and Jensen (1990), Jackson et al. (1991), Lewis et al. (1991), King (1993), and Hewitt (1993). The ADEQ has been involved with alterative VOC sampling since discovering soil vapor results were more indicative of VOC contamination than soil results (Heywood et al., 1992).

Conventional methods for soil sampling are subject to errors which can under report VOC concentrations by as much as 100% (Koroghlanian et al., 1995). These errors result from: volatilization of VOCs during removal from the soil profile and transfer of the soil from the sampling device to the sample container; volatilization of VOCs from the sample container during pre-analytical holding; and volatilization of VOCs during the subsampling by the laboratory prior to analysis (Siegrist, 1992). Of these, sample transfer is the most crucial step in collection process (Koroghlanian et al., 1995).

#### **ADEQ Recommendations**

In August 1995, the Draft ADEQ Quality Assurance Project Plan (QAPP) was submitted to the Environmental Protection Agency (EPA). The QAPP contains ADEQ's recommended methods for VOC sample collection, handling, and storage. The methods are modifications of those described EPA document by Lewis et al. (1991), American Society for Testing and Materials (ASTM, 1991), and other publications.

#### **The following are the ADEQ recommended VOC sampling methods:**

1. Collect samples in brass, stainless Steel, Teflon or acetate sleeves:
  - a. Submit to a mobile lab or a fixed lab for extraction within 2 hours. Completely filled sleeves should immediately sealed by: 1) covering ends with a Teflon patch; 2) covering the Teflon patch with foil; 3) covering patches with tight fitting plastic caps; and 4) sealing the caps by wrapping custody seals or a non-contaminating tape around the sleeve, overlapping the lower edge of the cap.  
  
or immediately upon collection;
  - b. Use a sub-coring device to obtain and transfer samples to a vial. The sample can then be processed in four ways (in order of preference): 1) immerse sample in methanol; 2) use a sub-coring sampler that can be demonstrated to prevent loss of VOCs for an adequate period of time to get to a laboratory (for example EnCore samplers or equivalent proven to hold VOCs for 48 hours); 3) use specially designed purge-and-trap adaptor cap for direct connection to a laboratory equipment; or 4) other proven methods approved by the appropriate ADEQ program.
2. For soils collected from split-spoon (or similar devices) used without liners, or any drilling method which produces a soil core, samples should be obtained by either pushing a sleeve into the core immediately after the core is brought to



the surface, or sub-coring and processing the sample using one of the four methods listed above.

3. Collect soil vapor samples when the cobble and gravel content of soils result in low, or no sample recovery by any of the above methods.

After sample collection the sample should be immediately labeled, placed in a cooler on ice. "Blue ice" should not be used unless required for shipping purposes. Field measurements and the lithologic description should be conducted with the remainder of the recovered sample. Figure 1 shows a diagrammatic sketch of the procedure.

### **Methanol Preservation**

The methanol-immersion procedure calls for the transfer of the sample into a glass jar containing a known volume of laboratory grade methanol (ideally, 1:1 weight-to-volume ratio of soil to methanol). Currently, ADEQ uses the methanol-immersion procedure described in the 1995 draft Environmental Laboratory Advisory Committee (ELAC) technical guidance document. The ELAC appointed a technical sub-committee made up of representatives from Arizona laboratories to develop a suggested guidance document for the procedure.

#### **Highlights from suggested soil sampling guidance for methanol field preservation is as follows:**

- Soil samples should be collected in either a 40 ml vial or a 60 ml vial. Ideally, 15 gms of soil are needed for the 40 ml vial and 25 gms of soil are needed for the 60 ml vial.
- If the amount soil added to the vial is less than 10 or more than 20 gms for the 40 ml vial, or less than 20 or more than 35 gms for the 60 ml vial, then the samples may not be analyzed by the laboratory.

#### **Weight Estimation in the Field**

##### **60 ml vial:**

- a. Measure a volume of soil equivalent to 15 - 20 mls with a soil syringe, non-coring type sampler, or other sampling method that is appropriate.
- b. Add 15 - 20 mls of liquid (equivalent to soil) in a test vial and put a mark on a vial. Fill the sample vials to approximately the same level.

##### **40 ml vial:**

- a. Same as for the 60 ml vial except measure between 7 - 11 mls of soil.

- b. Same as for the 60 ml vial except measure between 7 - 11 mls of liquid.

Both:

- c. Measure the soils at the site using a pocket scale to train the eye and estimate the amount of soil to add.

**Addition of Methanol**

- a. Using pre-measured vials (20 mls) provided by the laboratory, quickly open the soil vial and pour the methanol in the sample vial immediately and close it.
- b. Using a syringe, transfer methanol from a pre-measured septa vial provided by the laboratory to the sample vial. To avoid cross contamination, a clean syringe will be needed for each new vial.
- c. Using a Teflon re-pipetor that attaches to a bottle of methanol and delivers 20 mls, quickly open the soil vial and depress the pump to deliver the methanol.

Methanol preservation must be performed within 2 hours of sample collection. Samples should be returned to an iced cooler immediately after preservation. A reference mark should be placed on the vial showing the top of the methanol to indicate that no methanol has leaked. Sample labels should be placed on ziploc bags and not sample vials.

**Loss of Methanol Due to Evaporation**

Concern has been expressed that the high temperatures common to Arizona may cause significant methanol losses during the time the jar is opened to add the soil sample. Significant losses of methanol would tend to over-estimate the amount of VOC in the sample. In order to explore the magnitude of the loss, ADEQ performed an experiment using wide and narrow mouth jars containing methanol at approximately 4°C and room temperature. The jars were opened and placed in the shade and periodically weighed. The air temperature ranged from 107 - 109°F during the experiment, the humidity ranged from 23 - 25% and a light wind was present most of the time.

The results of the experiment (figure 2) indicate that methanol losses are not significant during the time reasonably needed to add a soil sample to the jar (Koroghlanian et al., 1995).

**Sample Preparation at the Laboratory**

- 1. The sample vials must be pre-weighed by the laboratory (label vials before weighing). A separate vial containing

either 10 or 20 mls of methanol is included for each sample at least one extra for the methanol blank.

2. After samples are received by the laboratory, the vials are weighed to determine the weight of soil added.
3. Add more methanol to the vials in order to maintain a 1:1 ratio of grams of soil to milliliters of methanol.
4. Laboratories should extract the VOCs from soils by sonication in a bath, vortex mixing, shaking, or other approved method.

#### **Case Studies**

1. Table 1: Field methanol preservation vs. conventional sampling methods.
2. Table 2 and 3: Field methanol preservation vs. sealed metal sampler.

#### **Conclusions**

Several laboratory and field investigations have documenting VOC losses inherent with conventional soil sampling methods since 1990. Alternative methods to conventional VOC sample collection methods have been incorporated into the 1995 ADEQ QAPP. The method described in the QAPP represents a combination of EPA and ASTM publications along with current articles from scientific journals.

Preparation is necessary prior to sampling. If samples are not going to be extracted at a fixed or mobile laboratory within 2 hours, then conventional field VOC sampling is no longer recommended in Arizona. The methanol preservation method represents ADEQ's most recommended alternative for VOC sampling when a mobile lab is not used. Additional case studies are needed in order to add to the validity of this method and refine the technique.

## FIGURES

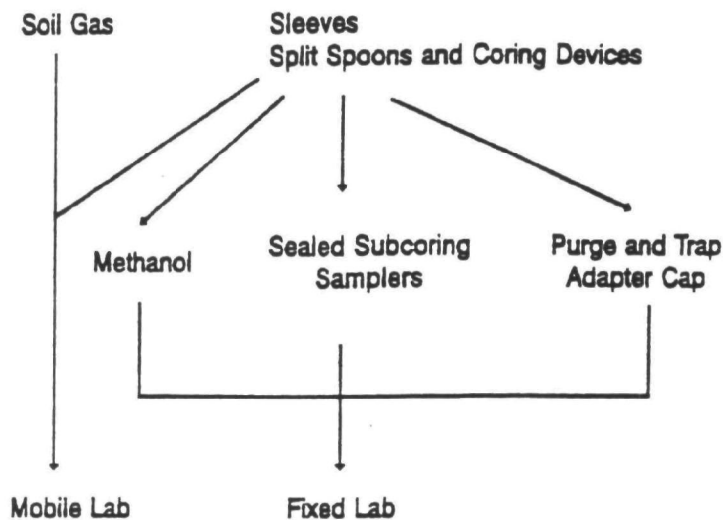


Figure 1: ADEQ's Recommended VOC Soil Collection and Handling Methods

(from Koroghlanian et al., 1995)

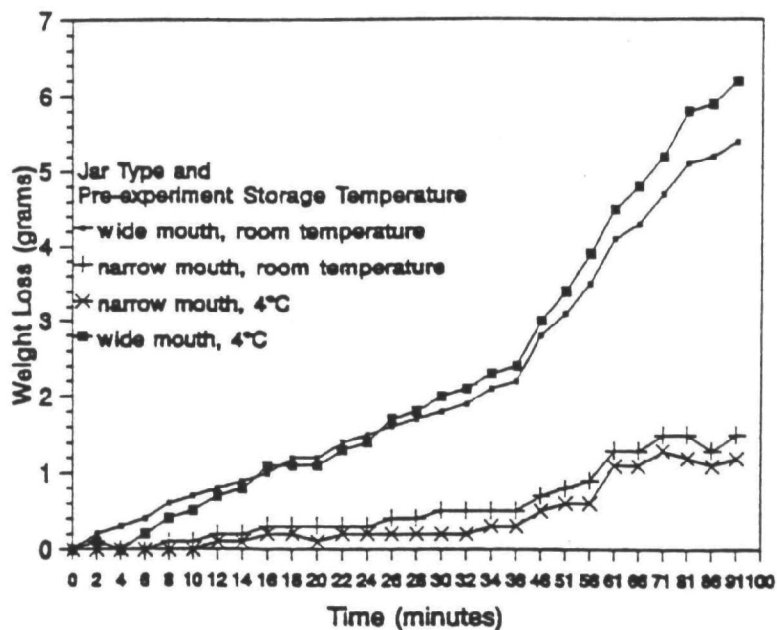


Figure 2: Methanol Weight Loss Over Time

(from Koroghlanian et al., 1995)

## TABLES

**Table 1**

Location	PID (ppm)	Soil Gas (ug/L in air)	Methanol Immersion (ug/kg)	Extracted W/in 2 hrs. (ug/kg)	Extracted W/in 24 hrs. (ug/kg)
A	1,000	200	<50	NC	<100
B	<2,500	1,300	13,000	NC	<100
C	75	48	270	<50	<100
D	<2,500	23	310	<50	<100
E	68	0.21	<50	<50	<100
Field Blank	NC	NC	<50	NC	NC

NC = No sample collected

PCE Results for a Soil Investigation at a Dry Clear in Phoenix

(Modified from Koroghlanian et al., 1995)

**Table 2**

Location	Methanol Spatula (ug/kg)	Sealed Metal Sampler (ug/kg)	Methanol Syringe (ug/kg)
B-1-5	1,100	640	NC
B-1-14	670	190	NC
B-1-15	170	<50	NC
B-2-3	170	<50	88
B-2-10.5	110	<50	NC

NC = No sample collected

PCE Results for a Soil Investigation at a Dry Cleaner

in Flagstaff (Modified from Koroghlanian et al., 1995)

**Table 3**

Location	Methanol Spatula (ug/kg)	Sealed Metal Sampler (ug/kg)
BH-10	360	60

PCE Results for a Soil Investigation at an AFB in Phoenix

## **References**

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Siegrist R.L. and Jennsen P.D. 1990. Evaluation of Sampling Method Effects on Volatile Organic Compound Measurements in Contaminated Soils. Environmental Science and Technology 24, no. 9: 1387-1392.



## Bacterial Degradation of Chlorinated Solvents

Ned Black, Ph.D.  
United States Environmental Protection Agency  
Hazardous Waste Management Division

### I. Background information

- a. PCE and TCE degradation products: TCA, the DCEs, VC, ethene, ethane, organic acids
- b. *In situ* vs *ex situ* activity
- c. Intrinsic vs amended remediation

### II. Microbiology

- a. In general
- b. Comatabolism
- c. Aerobic vs anaerobic growth

anaerobic activity  
fermentation, denitrification  
sulfate reduction, methanogenic

### III. Aerobic bacterial dechlorination of chlorinated solvents

- a. Expected rates and degradation products
- b. Methods to augment intrinsic activity

### IV. Anaerobic bacterial dechlorination of chlorinated solvents

- a. Potential rates and degradation products
- b. Methods to augment intrinsic activity

### V. Conclusions



A summary of mechanisms of bacterial degradation of TCE and PCE.  
(With an emphasis on work done in the Dept. of Civil Engineering  
at Stanford University.)

Natural attenuation of chlorinated solvents (e.g., PCE, TCE and carbon tetrachloride) by microbial action can take place both aerobically and anaerobically. The bacteria which are capable of dechlorination can be found in all habitats, including deep aquifers. However, the conditions necessary to allow the bacteria to degrade chlorinated solvents at a particular site may not exist.

### Aerobic mechanisms

The aerobic (oxygen-utilizing) mechanisms involve single enzymes (and so single bacterial strains) for the entire dechlorination. TCE is completely dechlorinated via cometabolism by oxygenase enzymes intended to act on such growth substrates as ammonia, propane, isoprene, toluene, phenol, and methane. Due to the specific enzymatic mechanism, vinyl chloride does not accumulate and is actively dechlorinated by these organisms. Fully chlorinated compounds, such as PCE and carbon tetrachloride are NOT dechlorinated by these enzymes. Thus, in a field situation, PCE will not be biodegraded when oxygen is present.

Most of the early lab and field work concentrated on methanotrophic transformation of TCE. (Methanotrophs are bacteria which eat methane.) Unfortunately, methanotrophs produce two different forms of methane oxygenase. When copper is present, as is the case in almost all groundwater environments, the methane oxygenase with the lower capacity to transform TCE is produced. Groundwater field experiments conducted at the Moffett Field Station by Stanford University showed only 20-30% TCE removal. In addition, methanotrophs require large amounts of oxygen to grow or degrade chlorinated compounds.

Many researchers have also studied cometabolism by oxidase enzymes for aromatic compounds (e.g., toluene and phenol) both in the lab and at groundwater field sites. Again, TCE and other partially chlorinated solvents are transformed, but PCE is not. Vinyl chloride does not accumulate. The organisms are able to grow and cometabolize TCE using less oxygen than methanotrophs, so TCE removal is higher. Stanford University researchers have induced TCE transformation at the Moffett Field Station by injecting phenol into the groundwater.

For methanotrophs, trans-DCE is dechlorinated faster than cis-DCE, and 1,1'-DCE is toxic. For the bacteria which consume aromatics, cis-DCE is dechlorinated more readily than trans-DCE.

Most of the aerobic mechanisms in groundwater require addition of some substrates (nutrients), so they should be described as *in situ* bioremediation, not natural attenuation.

### Anaerobic mechanisms

TCE, PCE and carbon tetrachloride are dechlorinated by anaerobic cometabolism (where no oxygen is present). This is also referred to as reductive dechlorination. Largely because anaerobes are harder to culture, there is less detail known about the mechanism for this activity. It is likely that consortia (i.e., two or more bacterial strains working together) are responsible for this activity. Vinyl chloride is produced and does accumulate in some lab and field experiments. However, in many field situations, transformation to ethene, ethane, and methane is complete. This activity occurs with no human intervention, and so can be described as natural attenuation or intrinsic remediation. The process can be promoted by addition of substrates such as benzoate or sulfate.

In unamended groundwater, reductive dechlorination will only occur where oxygen has been depleted and where there is sufficient organic matter to support a microbial community. Thus, aerobic aquifers with low organic carbon, typical of the arid southwest, do not support natural attenuation by this mechanism. Reductive dechlorination is commonly observed in aquifers with higher natural levels of organic carbon, such as those in eastern North America, and at sites in the West where contaminant mixtures provide readily degradable organic matter to support the microbial community and lead to oxygen depletion. This is occurring in the groundwater at the Aerojet Propulsion plant in Rancho Cordova, CA.

Reductive dechlorination of TCE and PCE is observed under fermentative, sulfate-reducing and methanogenic conditions; carbon tetrachloride reduction has been observed under denitrifying conditions.

There is laboratory evidence that cis-DCE is toxic to some anaerobes at concentrations above 10 mg/L.

Some useful references for the above and further information:

Hinchee, R.E., A. Leeson, L. Semprini, and S.K. Ong. 1994. Bioremediation of Chlorinated and Polycyclic Aromatic Hydrocarbon Compounds. Lewis Publishers, Boca Raton, FL. 525 pp.

Hopkins, G.D., L. Semprini, and P.L. McCarty. 1993. Microcosm and In Situ Field Studies of Trichloroethylene by Phenol-Utilizing Microorganisms. Applied and Environmental Microbiology 59:2277-2285. (Also released as EPA600/J-93/295.)

Weaver, J.W., J.T. Wilson, D.H. Kampbell, and M.E. Randolph. 1995. Natural bioattenuation of trichloroethene at the St. Joseph, Michigan, Superfund site. US EPA. EPA/600/SV-95/001.

## aerobic Dechlorination - General

- constitutive
- complete
- TCE + DCE are dechlorinated; PCE and carbon tet are not
- Carried out by oxidase enzymes for ammonia, methanol, simple aromatics, broad substrate specificity
- Intrinsic activity may not occur, but amended has not been demonstrated

## aerobic Dechlorination

- Usually constitutive, but primary metabolism probably occurs
- PCE, TCE, and carbon tet readily dechlorinated under fermentative, sulfate-reducing and methanogenic conditions; 1,1,1-TCA degradation only observed under denitrifying conditions
- Can result in transient accumulation of vinyl chloride



# Recommendations To Improve the Cleanup Process for California's Leaking Underground Fuel Tanks (LUFTs)

## Authors

David W. Rice  
Brendon P. Dooher\*  
Stephen J. Cullen\*\*  
Lorne G. Everett\*\*  
William E. Kastenberg\*\*\*  
Randolph D. Grose\*\*\*\*  
Miguel A. Marino\*\*\*\*

Submitted to the California State Water Resources Control Board and the  
Senate Bill 1764 Leaking Underground Fuel Tank Advisory Committee

October 16, 1995

\*University of California, Los Angeles  
\*\*University of California, Santa Barbara  
\*\*\*University of California, Berkeley  
\*\*\*\*University of California, Davis



Environmental Protection Department  
Environmental Restoration Division

## UC LUFT Team



Principal Investigator/Contract Manager  
David W. Rice, LLNL

Risk Analysis/Decision-Making Approaches:  
William Kastenberg, Ph.D., UC Berkeley  
Brendan Dooher, UC Los Angeles

Vadose Transport:  
Lorne Everett, Ph.D., UC Santa Barbara  
Stephen Cullen, Ph.D., UC Santa Barbara

Saturated Transport:  
Miguel Marino, Ph.D., UC Davis  
Randolph Grose, UC Davis



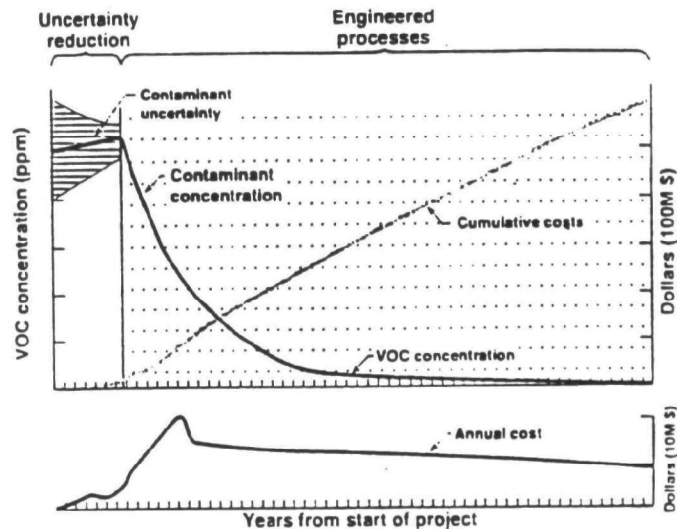
- California Underground Storage Tanks (USTs) are regulated through a framework of laws, regulations, and state, regional, and local policies
- The California Water Code is the law from which regulations and policies are derived
- State Water Resources Control Board (SWRCB) resolutions are policies used to implement the Water Code
- SWRCB resolutions are prepared through a public hearing process and consideration of the current state of knowledge and experience

## Hypothetical Cost vs Cleanup Curves



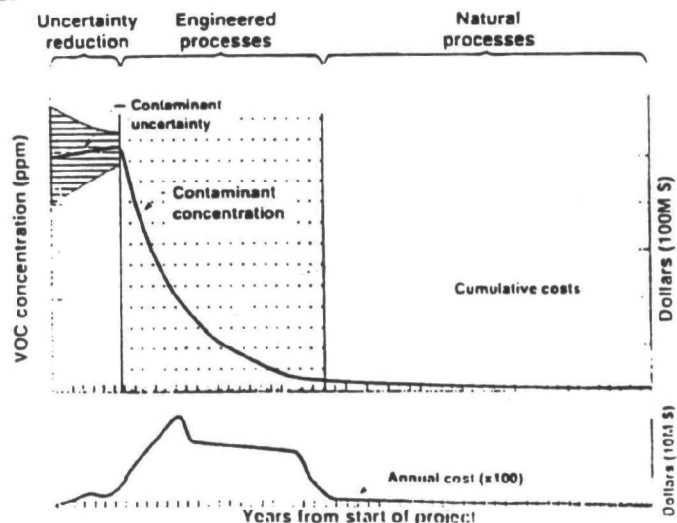
### Base Case

- Total pumping time: 50 years
- Stop pumping at 5 ppb



### Alternative Approach

- Total pumping time: 17 years
- Stop pumping at 200 ppb



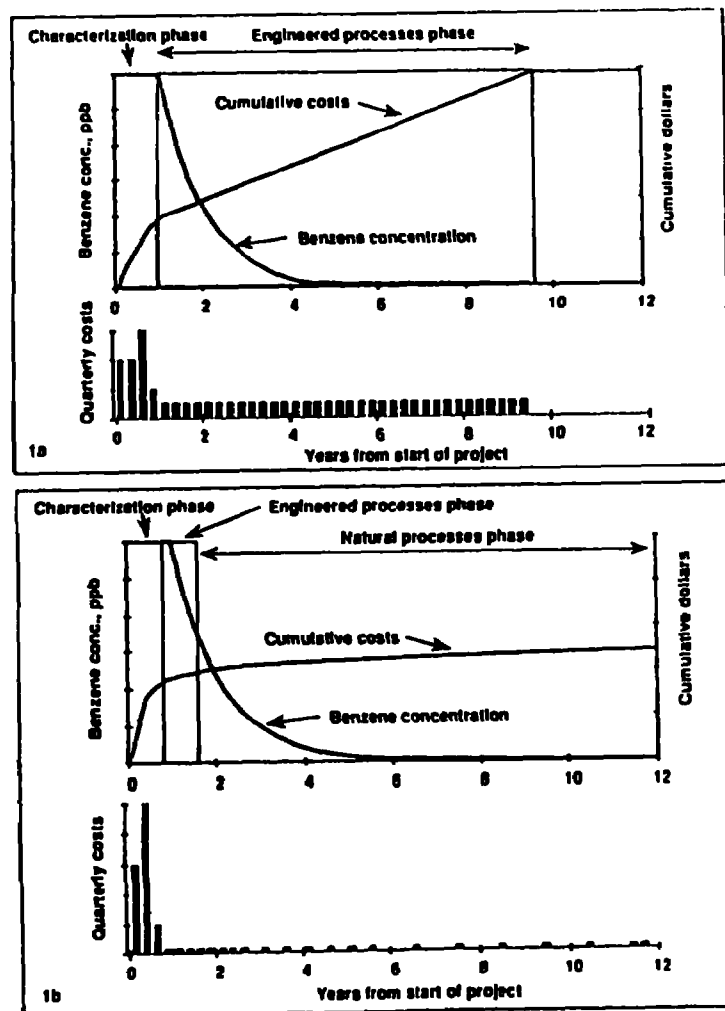


Figure 1. Hypothetical cost versus cleanup curves for typical LUFT case

a. **Base case:** Pump and treat remediation with a total cleanup time of 9.5 years, stopping at 1ppb

b. **Alternative approach:** Over excavation of source and establishment of plume management zone while allowing intrinsic bioremediation to clean ground water to 1ppb over 12 years.

## Revised LUFT Decision-Making Approach



Broad, consistent decision-making approach that can be adopted at State level, but still retain element of local control

- Overcome inconsistencies of old LUFT implementation
- Facilitates water management planning
  - local beneficial use determination
- Streamlines the clean-up process
- Considers cost/risk benefit as a component in the decision-making process
- Addresses issue of highest beneficial uses (Water quality standards goals) versus risk-based prioritization



### **Relies on continuous access and utilization of data for decision-making**

- **Provides increased regional/area hydrogeologic representativeness**
  - **Regional/area specific target screening levels established**
- **Decision-making approach is evergreen**
  - **Action levels periodically re-evaluated**
  - **Knowledge of one site transferred to another**

## **Conclusions**

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- **Drinking water impacts from leaking underground fuel tank (LUFT) fuel hydrocarbons (FHCs) have been low in California**
- **The cost of cleaning up LUFT FHCs is often inappropriate when compared to the magnitude of the impact on California's groundwater resources**
- **LUFT groundwater cleanup requirements are derived from policies that are inconsistent with the current state of knowledge and experience**
- **Current understanding of passive bioremediation processes in the subsurface environment is not reflected in the present LUFT cleanup process**



## **Conclusions**

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- **A risk-based corrective action (RBCA) framework would provide a common decision-making process to systematically address LUFT cleanup**
- **Modifications would be necessary for the American Society for Testing and Materials (ASTM) RBCA framework to be used in California**
- **After removal of a FHC source, there are few LUFT cleanup situations where pump and treat should be attempted**

## **LUFT Recommendations**

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**Once the fuel leak (tank and contaminated soil) source is removed:**

- **Utilize passive bioremediation as a remediation alternative whenever possible**
  - **Minimize actively engineered LUFT remediation processes**
  - **Once passive bioremediation is demonstrated and unless there is a compelling reason otherwise, close cases after source removal to the point of residual FHC saturation**
  - **In general, do not use the UST Cleanup Fund to implement pump and treat remediation unless its effectiveness can be demonstrated**
  - **Support passive bioremediation with a monitoring program**

## **Recommendations — Risk Management Process**



- **Immediately modify and implement the ASTM RBCA framework to allow streamlined closure criteria that:**
  - **Encompass a majority of LUFT cases;**
  - **Facilitate and encourage the use of natural bioremediation;**
  - **Position low-risk LUFT sites for rapid closure if risk-based groundwater cleanup goals are allowed.**

## **Recommendations — Process Validation**



- **Identify a series of LUFT demonstration sites to:**
  - **Test recommended sampling and monitoring procedures and technologies to use natural bioremediation**
  - **Confirm cost effectiveness of the ASTM RBCA process**
  - **Act as training grounds for the implementation of a modified ASTM RBCA process**
  - **Facilitate the implementation of a revised LUFT decision-making process**



# **Practicalities of the Technical Impracticability Guidance**



## **What is TI?**

- waiver of ARARs in a specific area because of
  - DNAPL
  - hydrogeologic complexity
  - cost
  - ineffectiveness of selected remedy

## **What is TI? (cont.)**

- establishment of "alternate remedial strategies"
  - exposure control
    - deed restrictions on supply well construction
  - source control
  - aqueous phase remediation

## **How is TI determined?**

- the TI Guidance
  - finalized in Sept. 1993
  - clarifies how, when, and where to waive ARARs for reasons of TI
  - establishes alternate remedial objectives

## **Who determines TI?**

- TI team makes recommendation to DD
  - RPM, HQ, ORC, hydro(s) make up ad-hoc team
  - state involvement encouraged
    - Rich Freitas is point of contact in Superfund (744-2315)
    - Steve Linder is point of contact in RCRA (744-2036)
    - Peter Feldman is point of contact in HQ (703) 603-8768

## **When can EPA consider TI?**

- petitions may be submitted for review
  - at the time of the ROD
  - post-ROD

## **Requirements for a TI evaluation**

- identification of ARARs to be waived
- identification of zone (area and depth) in which ARARs are to be waived
- thorough site characterization
- conceptual model
- evaluation of restoration potential
  - analysis of why efforts have not achieved ARARs
  - timeframes
  - applicability of other technologies
  - cost

## **Recent impetus for TI**

- July 31, 1995 memo from AA Laws
  - "OSWER expects TI waivers will be generally appropriate for DNAPL sites"
- October 1995 Superfund Administrative Reforms
  - suggests update of remedies at sites where we now know DNAPL to exist
    - "current policy is to isolate and contain DNAPL, removing the source only to the degree practicable"

## **The rush for TI**

- **What rush?**
  - one petition submitted so far under 9/93 guidance

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# Containment Zones

*"A Regulatory Policy and  
Process in Development...."*

Presentation to  
US EPA Region 9's  
1996 Corrective Action Conference

by  
Steve Morse  
San Francisco Bay Regional Water Quality Control Board  
March 27, 1996

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## Introduction

### Topics to be covered

- Background
- CZ rationale
- Comparison with US EPA's Policies
- SWRCB's new proposed requirements
- Experiences implementing
  - ▶ Case Studies
  - ▶ Possible uses
- Challenges and Opportunities

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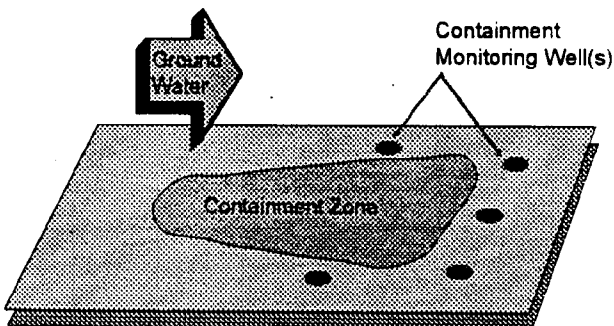
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## What is a Containment Zone (CZ)?



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*Management strategy, not  
closure strategy*

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## Why Containment Zones?

- 20,000 LUFT sites in California for cleanup
- 6,000 LUFT in San Francisco Bay Area for cleanup
- 1,000 solvent site cleanups in San Francisco Bay Area
- "Lessons Learned" from fifteen years experience cleanup of ground water contamination:  
Solvents:  
*cleanup to background or even MCLs is often technically impracticable or economically infeasible*  
Fuels:  
*fuel hydrocarbon leaks have had limited impacts and risk to human health, the environment, or groundwater resources and can be regulated less stringently*
- National – "Alternatives for Ground Water Cleanup", NRC (June 1994) and EPA studies
- Some sites inherently pose limited risk to health, environment, and water quality (present and future)
- Reality check

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## Why Containment Zones (cont.)?

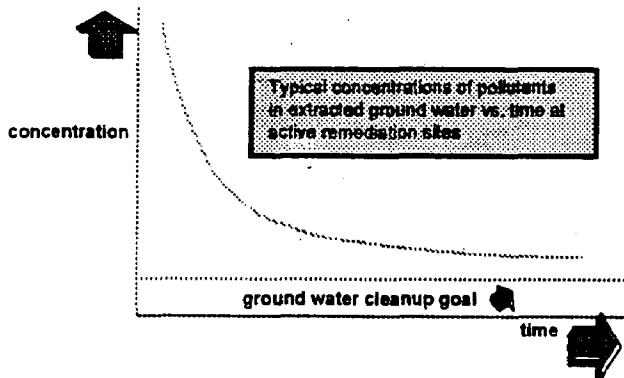
Relative Ease of Cleaning Up of Contaminated Aquifers  
as a Function of Contaminant Chemistry and Hydrogeology

Hydrogeology	Contaminant Chemistry					
	Mobile, Dissolved (degrades/volatilizes)	Mobile, Dissolved	Strongly Sorbed (degrades/volatilizes)	Strongly Sorbed, Dissolved	Separate Phase LNAPL	Separate Phase DNAPL
Homogeneous, single layer	1*	1-2	2	2-3	2-3	3
Homogeneous, multiple layers	1	1-2	2	2-3	2-3	3
Heterogeneous, single layer	2	2	3	3	3	4
Heterogeneous, multiple layers	2	2	3	3	3	4
Fractured Rock	3	3	3	3	4	4

\* Relative ease of cleanup, where 1 is easiest and 4 is most difficult.  
From: Alternatives for Ground Water Cleanup, NRC, June 1994

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## Why Containment Zones (cont.)?



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## Why Containment Zones (cont.)?

- "Lessons Learned" – Fuel Leaks  
& Lawrence Livermore recommendations
  - ▶ Different characteristics than VOC, especially chlorinated
    - Light NAPL (LNAPL - fuels) vs. Dense NAPL (VOC chlorinated)
    - Can biodegrade readily and easily
    - Limited plume length
  - ▶ Remediation Costs vs. Value Gained
  - ▶ Limited historical impacts

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## Why Containment Zones (cont.)?

- Regulatory Reform – Desired Changes and Purpose
  - ▶ A regulatory strategy for the reasonable protection of beneficial uses
    - ◆ Would
      - Provide stronger consideration of costs
      - Recognize technical limits
      - Recognize probable risks
    - ◆ Would Not
      - Let water be further contaminated
      - Let those responsible escape
  - ▶ State and Regional Water Boards
    - ◆ Non-Attainment Area (now Containment Zone)
      - Higher risk sites – solvents, metals, etc
    - ◆ Low-risk fuel leak sites – bioremediation
      - State law & regulations will change

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## Comparison with US EPA's Policies

- US EPA's "Technical Impracticability" Policy
  - ▶ Similarities:
    - Recognizes difficulties of ground water cleanups
    - Must be protective of human health and environment
    - Data requirements similar – site characterization
  - ▶ Differences:
    - Covers all ground water pollution
    - Allows establishment of CZ prior to full implementation of remedy
    - Use of "mitigation"
    - Management of risk following establishment
- EPA recommending implementation of risk-based cleanups for LUFTs
- EPA considering intrinsic bioremediation for cleanup

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**Highlights of Proposed Containment Zone  
Amendments to SWRCB Res 92-49**

(from SWRCB's September 14, 1995, proposed amendments)

- **Renamed Non-Attainment Zone to Containment Zone (CZ)**
- **Draft Program Environmental Functional Equivalent Document**
- **Recognized non-attainment as remediation strategy, if...**
  - Determined that objectives cannot "reasonably be achieved"
  - Considering what is technologically or economically feasible, accounting for
    - reasonable period
    - environmental characteristics of the hydrogeologic unit
    - degree of residual risk
  - Technological feasibility
    - Assessing available technologies effective in similar hydrogeologic conditions
  - Economic feasibility
    - Objective balancing of the incremental benefit of attaining further reductions in concentrations and mass vs incremental costs

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**Highlights of Proposed Containment Zone  
Amendments to SWRCB Res 92-49 (cont.)**

(from SWRCB's September 14, 1995, proposed amendments)

- **Source removed (containment/storage vessels, floating free product, etc.)**
- **Plan submitted**
  - a. Agree to do work
  - b. Residual risk management plan
    - Includes land use controls
  - c. Mitigation Plan -- must provide reasonable mitigation measures for any significant adverse environmental impacts in the CZ.
- **g**
  - Alternative water supplies and/or costs
  - Regional groundwater monitoring programs
  - Contributing groundwater basin cleanup or management programs
    - Off-site, another person, SEP, SWRCB's CAA
    - Financing off-site adequate with improvement to water quality

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**Highlights of Proposed Containment Zone  
Amendments to SWRCB Res 92-49 (cont.)**

(from SWRCB's September 14, 1995, proposed amendments)

- **Defined three types of Containment Zones**
  - Sites with an approved cleanup program
    - fully implemented, groundwater asymptotic
    - generally VOC solvents, etc
  - "Low risk sites"
    - stable plume
    - classes of sites possible
    - generally fuels, areas
  - Difficult sites
    - strong sorption, DNAPLs, complex geology
- **Must be limited in extent**
- **Not cause a substantial decline in overall yield of basin**
- **"No further action" when implemented**

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**Highlights of Proposed Containment Zone Amendments to SWRCB Res 92-49 (cont.)**

(from SWRCB's September 14, 1995, proposed amendments)

- Water quality objectives are attained and maintained at and beyond the containment monitoring points
- Containment Zone's Containment Points
  - Close as possible
  - CZ no larger than necessary
- Must not adversely affect human or other biological receptors

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**Highlights of Proposed Containment Zone Amendments to SWRCB Res 92-49 (cont.)**

(from SWRCB's September 14, 1995, proposed amendments)

- Comply with local ground water management plan (AB 3030)
- CZ not permitted in some areas
  - Critical recharge areas
- Local agencies may implement
  - Petroleum products only
- Utilize a TAC before designation

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**Highlights of Proposed Containment Zone Amendments to SWRCB Res 92-49 (cont.)**

(from SWRCB's September 14 1995 proposed amendments)

- SWRCB/RWQCB Review Committee
  - will review for consistency first 2 years and prepare specific guidance as necessary
- Must be designated by Cleanup Abatement Order (i.e. SCR)
  - RWQCB — not Executive Officer
  - CEQA and public participation issues to be addressed
    - SWRCB's Program environmental document
    - Minimum requires RWQCB agenda notice
    - LUFT program (RWQCB coordination?)

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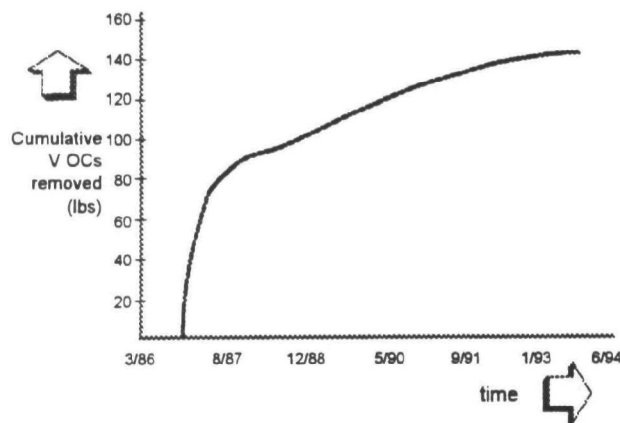
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## Case Study #1 -- Higher Risk Site

- Site is 30 acres; formerly used for manufacture of computer disk drives; pollution in soils and ground waters on-site
- Predominant VOCs in shallow ground water are TCE, Freon-113, 1,2-DCE, and vinyl chloride; some pollution in deeper ground waters
- Classified as "potential" drinking water by SWRCB Res 88-63
- Ground water extraction and treatment system installed in August 1986; operated continuously to early 1994:
  - ▶ 84 million gallons water; 152 pounds VOCs; asymptotic
- SF Bay RWQCB adopted CZ December 1993
  - ▶ Ground water extraction no longer efficient; could be improved, but not cost-effective and still would not meet MCLs on-site
  - ▶ Ground water above MCL must be contained on-site
  - ▶ Residual risk management and contingency plan to be implemented

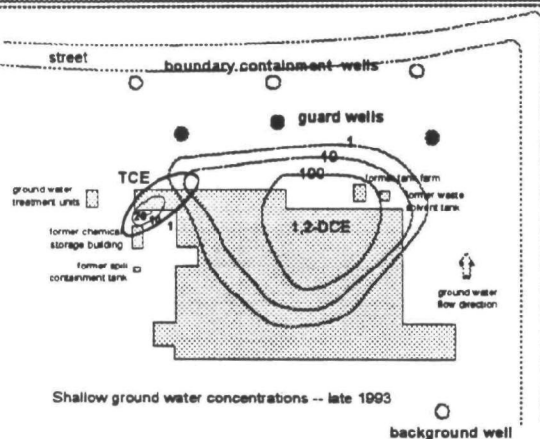
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## Case Study #1 - Cumulative Pounds of VOCs Removed



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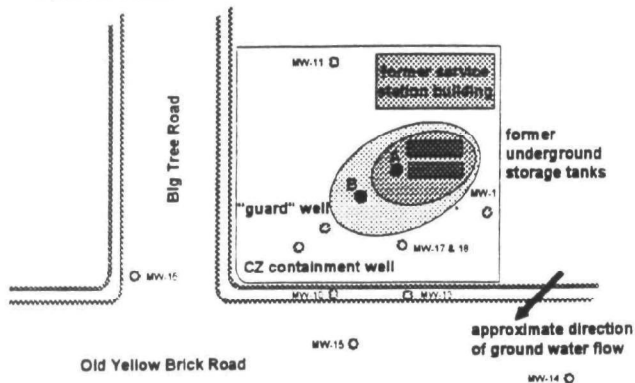
## Case Study #1 - Contaminant Isocontours of TCE and 1,2-DCE



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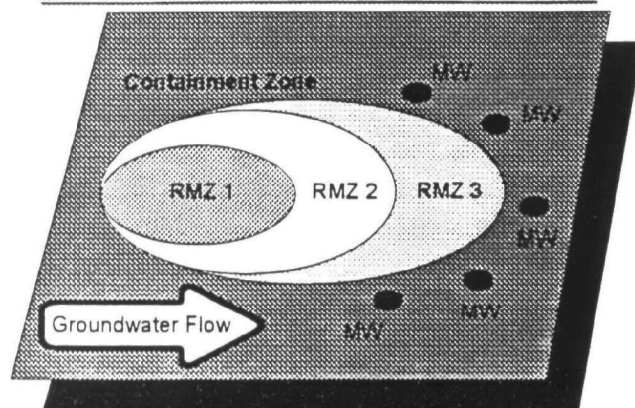
### Case Study #2 – "Low Risk" CZ Site

(cleanup at a former gasoline service station)



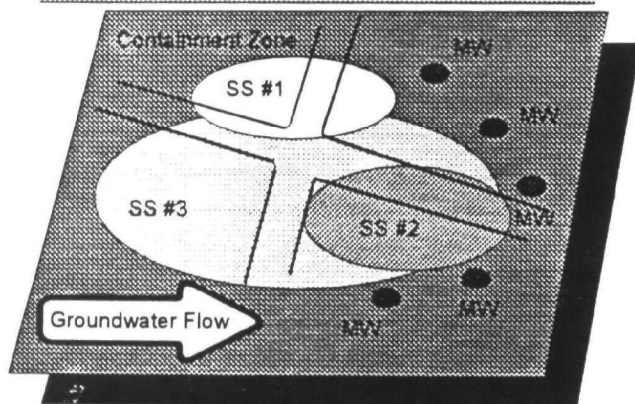
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### Application of CZ to Larger, Complex Sites



MW = Monitoring Well RMZ = Remediation Management Zone 20

### Application of CZ to Commingled Plumes



MW = Monitoring Well

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### **"Ideal" CZ Sites**

- Residual risks are acceptable and low
- Contaminant concentration at asymptotic levels and/or close to State water quality objectives
- Fine-grained soils
- Benign biodegradation taking place
- Pollutant plume contained on-site
- Non-potable water uses under the site
- "Institutionals" remain stable and constant
  - ▶ Few owners/operators involved
  - ▶ Continuity of operator, regulator, contact person, lab
  - ▶ "Standard" deed restrictions
- Industrial and/or commercial land uses on-site and adjacent

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### **Disadvantages of CZ?**

- 1 "Closure" mechanism is not yet formulated for CZ
- 2 Establishment of a CZ will require some risk assessment
- 3 Lack of technical training for risk evaluation at RWQCBs and LOPs may create reluctance of approval
- 4 It may create cumbersome management requirements at "clean" sites where CZ should not even be deemed necessary
- 5 Potential for misapplication in situations where water quality does not warrant consideration

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### **Advantages of CZ?**

- 1 De-emphasizes "closure" at sites where closure is impractical
- 2 Allows long-term monitoring only vs aggressive technological application
- 3 Allows long-term, predictable cost-planning for approved site management plan
- 4 Could be ideal for operational facilities where plumes are stable and source cannot be removed
- 5 Would be recognized remedial alternative within SWRCB Resolution 92-49 and therefore is not subject to further enforcement action
- 6 Use of risk assessment process provides increased insight and understanding of the problem and optimizes protection of health, environment, and water quality
- 7 Assumes that the beneficial use as potable water is not immediate and therefore allows time to remediate the pollution

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### **Opportunities to Improve Implementation of CZ**

1. Simplify and streamline all procedures for low-risk sites to match threat
2. Consider cleanups on the basis of "risk-management" alone, eg low-risk fuel sites
3. CZ leading to "closure" must be developed
4. Integration into upcoming SB1764 process / regulations
5. "Reasonable", etc. to be defined through examples and case studies and education
6. Real estate and financial institutions must be satisfied
7. UST Cleanup Fund decision-making should be integrated into CZ
8. Partial CZ, e.g. off-site vs. on-site CZ
9. Commingled plumes using an "area" approach
10. Guidance for project mitigation requirements

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### **Summary**

- Containment Zones could provide for:
  - ▶ Recognition of the technical and financial infeasibility to reasonably achieve ground water quality objectives;
  - ▶ Rational management of site cleanups;
  - ▶ Protection and conservation of significant amounts of ground water
  - ▶ Protection of public health and the environment;
  - ▶ Potentially the most "cost-effective" to the public and private sector.

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### **SF Bay RWQCB Comments & Recommendations on SWRCB's Proposed 92-49 Amendments (Containment Zone)**

- Compliments pursuing Containment Zone amendments and Program Functional Equivalent Document (FED)
- Requested SWRCB consider following changes
  - ▶ Amend finding to commit to change to reflect fuel leak cleanups as special category (ref LLNL report)
    - Consider use of risk management for fuel cleanups
  - ▶ Revise to not unnecessarily restrict RWQCBs
    - CAOs by RWQCBs only
    - "One size fits all" administrative requirements
  - ▶ Clarify intent and use of certain sections (and FED)
    - Which local agency to implement
    - tank removal practicality
    - Use of FED
      - Significant adverse impacts
      - Mitigation
- Adopt and move on

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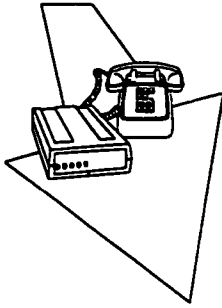
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**BBS / Internet**



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## THE IMPORTANCE OF FIELD OVERSIGHT FOR GROUNDWATER SAMPLING

Brian Lewis (HQ-24)  
Department of Toxic Substances Control  
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### ABSTRACT:

Groundwater sampling, including collection, handling, preservation, and transportation, is carried out by a wide variety of personnel. Some samplers have little training, whereas other samplers may have had extensive training. A few Owner/Operators and environmental companies offer internal training to ensure competency as well as consistency. This presentation provides an overview of some of the common errors observed in the field. DTSC has found that with oversight and coaching of the sampling done for Owner/Operators, sampling collection methods have improved over time. However, more work (e.g., training, detailed sampling and analysis plans, etc.) is needed to insure that representative samples are obtained. Additionally, DTSC encourages Owner/Operators, consultants, and regulators to routinely audit samplers.

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## **Guidelines for the Preparation of Water Quality Sampling and Analysis Plans (WQSAPs)**

The Department of Toxic Substances Control's (Department's) Permitting and Enforcement Geological Services Unit (PEGSU) has developed guidelines for use in the review of WQSAPs by Department staff. As the Department implements Senate Bill 1082 (Calderon), these guidelines may change to incorporate comments from the State Water Resources Control Board and/or the Regional Water Quality Control Boards. PEGSU may also revise these guidelines to incorporate concepts and guidelines from the Department's Regulatory Structure Update (RSU).

The WQSAP is the document that completely describes the water quality monitoring program for a regulated unit at a RCRA facility. It identifies the regulated unit, describe pertinent details about the construction of the unit and the historical use of the property, and describe waste management activities at the unit. The WQSAP describes the hydrogeology of the area and contain specifications for the water quality monitoring systems (ground water, surface water and unsaturated zone) in use at the facility. The WQSAP describes any contamination that has been identified and state whether the regulated unit will be in detection, evaluation or corrective action monitoring.

The WQSAP should also include the following

- the constituents of concern (CoCs) and monitoring parameters and documentation to support the lists,
- the sampling frequency and the number and kinds of samples to be collected during each sampling event,
- documentation (hydrographs) indicating the seasonal maximum and minimum water levels expected (by month),
- a discussion of the need to monitor for wellhead gases and immiscible layers,
- the rationale for deciding if samples for metals will be filtered or not. The decision must include a consideration of the purpose of sampling (i.e., detection monitoring, evaluation of a release or risk assessment),
- information used to establish background values for all CoCs and all monitoring parameters, and provides a detailed description of the statistical methods to be used to evaluate analytical data,



- the Quality Assurance Project Program (QAPP) or reference to the QAPP. The QAPP describes the data quality objectives (in terms of accuracy and precision), acceptance criteria for analytical data, and the format for reporting the results of the Quality Assurance/Quality Control (QA/QC) program. (*Note: Proposed detection limits must be low enough to fulfill the data needs of the monitoring program*),
- the statement that actual laboratory values between the detection limit (DL) and the practical quantitation limit (PQL) will be reported (and maintained in the data base) with the numerical value determined by the laboratory and a flag to indicate that these values are below the PQL. In such cases the value of the PQL must also be reported and maintained in the data base. The practice of artificially censoring data that is reported below the calculated PQL can lead to the use of less powerful statistical methods. It is important to preserve the actual uncensored values for all concentrations above the DL for possible use in future statistical analysis, and
- a detailed description of the content and submittal dates for periodic reports (including the submittal of quarterly determinations of groundwater flow rate and direction). The name, address, and telephone number of the person at DTSC to whom reports and notifications of significant findings are to be addressed and the name, address and telephone number of the facility representative to contact for questions regarding the report should also be included.

The following items may also be needed in WQSAPs.

- For a detection monitoring program, a specification of the maximum amount of time needed after each monitoring episode to perform statistical analysis and make a determination of whether or not there is statistically significant evidence of a release from the regulated units.
- A description of well redevelopment and routine well maintenance. For permitted facilities, it is wise to include a section on well decommissioning and replacement so that those procedures can be implemented without a permit modification.
- To evaluate the accuracy of the analytical data, provisions for initially and periodically characterizing the major cations and anions and testing the results by determining the charge balances. This could probably be most easily

performed during the initial sampling to establish background values for CoCs and during the periodic testing of CoCs in downgradient wells.

- For a detection monitoring program, a statement that DTSC will be notified by certified mail within 7 days of determining statistically significant evidence of a release for any monitoring parameter or CoC at any monitoring point (Section 66264.98(j)). The WQSAP should describe the exact procedures for performing verification sampling, specify the maximum amount of time before the results of the verification sampling are reported to DTSC and state that, if the significant evidence of a release is confirmed, the facility will comply with the requirements of Section 66264.98(k) Title 22 California Code of Regulations (CCR) for responding to significant evidence of a release (e.g., immediately collect samples for Appendix IX constituents and for all CoCs, etc.).

Finally, the WQSAP should contain detailed information describing the physical process of sampling. This portion of the WQSAP is generally written as a stand-alone document that is appropriate for use by field personnel and is usually referred to as the sampling and analysis plan (SAP). Attached is a checklist of items to be included in a SAP. Also included are two checklists indicating what the Department reviewers look for in quarterly monitoring reports and annual reports generated after the sampling takes place.

## **Sampling and Analysis Plan Checklist**

This sampling and analysis plan (SAP) checklist was developed to address the physical process of obtaining field information, measurements, and water quality samples. The SAP should be written as an enforceable document. Deviations from the procedures described in the current SAP for a facility are subject to enforcement by the Department. It should be written to unambiguously describe exactly what steps will be taken to ensure that representative samples are collected. The SAP must contain sufficient detail for a sampler with limited experience to understand and follow and to ensure that sampling will be conducted in the same manner by different samplers. The following items should be included in the SAP.

- 1) A copy of the document each member of the field team signs stating that he/she has read and understands the current version of the SAP. A signed copy of this document should be submitted to the Department with the report of analytical results.
- 2) A description of the equipment to be used and procedures to be followed for the measurement of the depth to water. The SAP should specifically state that water levels will be measured in all wells and piezometers at least quarterly for the calculation of ground water flow rate and direction, that all water levels will be measured in the shortest possible time, and that water levels in all wells will be measured before any well is purged.
- 3) A statement that water levels for the calculation of ground water flow rate and direction will be measured during times of expected seasonal maximum and minimum water levels.
- 4) A statement that the depth to water will be measured with reference to a marked point that has been surveyed by a licensed surveyor. The water level probe should be capable of obtaining reliable measurements to  $\pm 0.01$  foot. The SAP should specify the method for decontamination of the water level probe between use at each well.
- 5) The order in which wells will be visited for water level monitoring, sampling, and maintenance. The rationale for the order in terms of minimizing the possibility of cross-contaminating the wells and/or samples should be presented.

- 6) Calibration procedures, frequency, and recordkeeping for water level probes.
- 7) Procedures, frequency, and recordkeeping for measuring the depth of the well casing.
- 8) Calibration procedures, frequency, and recordkeeping for the well depth sounding instrument.
- 9) Copies of sample field data sheets.
- 10) A statement that well-head conditions (condition of well casing, well lock, markings, standing water at surface) and any suggested maintenance will be recorded in the field notes. The SAP should describe procedures for performing necessary well maintenance in a timely manner.
- 11) Equipment and procedures for testing wellhead gases and for testing the water surface for immiscible layers (if required per the WQSAP).
- 12) Procedure for calculation of well casing volumes. Where references are made to total well depth, it should be clear that the total well depth is the well depth as measured from the permanent mark on the well casing. (Total well depth is also commonly recorded as depth below ground surface.)
- 13) The maximum purge rate for each well. Whenever possible, purge rates should not exceed recharge rates. (Note: For wells completed at the water table, maximum purge rates may be a function of the water level in the well. The objective is to avoid purging a well to dryness whenever possible.)
- 14) A statement that, unless wells are purged to dryness, a minimum of three casing volumes will be removed during well purging.
- 15) A statement that, unless wells are purged to dryness, wells will be purged until field parameters stabilize. DTSC currently believes that stability of field parameters is the best indication that the water being sampled is representative of the ground water in the aquifer. All measurements of field parameters are to be recorded in the field log.

The final, stable value for each field parameter must be recorded and graphed through time for each well.

- 16) For wells purged to dryness, procedures for removing as much water as possible from the well, monitoring recharge, collecting samples as soon as the well has recharged sufficiently, and documenting the sampling events. For wells that are bailed, the SAP must state that a well will only be considered to have been purged until "dry" if less than 10% of the original volume of water remains in the well after purging. (Note: The objective is to minimize the amount of water that remains in the well after the well has been purged "dry", because that water is expected to mix with the recharging water so that the sample will be a combination of "stagnant" and "fresh" groundwater. It is important to optimize the percentage of "fresh" water.) The SAP must specify the frequency for measuring recharge and the criteria for initiating sampling. Sampling must proceed as soon as possible after the recharge criteria have been satisfied. Samples for volatile organics must be collected no more than two hours after purging.
- 17) For wells not purged to dryness, a statement that sampling will be conducted as soon as possible after purging is completed. The SAP should specify, based on measured recharge rates, the approximate time period after purging that sampling will occur; or, the SAP should describe the procedures for measuring and recording water levels after purging and before sampling and specify the criteria for recharge.
- 18) A description of equipment and procedures for measuring field indicator parameters during purging. The SAP should specify the criteria for determining that field parameters have stabilized before sampling (e.g., pH  $\pm$  .1 pH unit, temperature  $\pm$  1 degree Celsius, conductivity  $\pm$  10%, turbidity  $\pm$  10%) and must state the minimum purge volume between tests to determine if field parameters have stabilized (e.g., one-half casing volume). The SAP should specifically state that turbidity will be measured with a turbidity meter. Visual estimates are not sufficient.
- 19) Calibration procedures, frequency and recordkeeping for all meters used during sampling. The SAP should state that the expiration dates of standard solutions used for calibration will be recorded in the field log. Any deviations noted during the day (e.g. meter drift) should

also be recorded. If meter drift requires an adjustment to any final values for field parameters, the results should be flagged in the data base.

- 20) Procedures for recording flow rates and volumes of water purged and for disposing of purged water. Field notes should include the appearance of the purged water including its color and odor.
- 21) A description of the equipment and procedures for collecting samples. Sampling equipment should be constructed of inert materials. Dedicated equipment should be used whenever possible. If equipment must be used at more than one well, the SAP should describe in detail the procedures to decontaminate the equipment and procedures for the collection of equipment blanks.
- 22) A statement that clean, powderless, surgical gloves (or another approved type of glove) shall be worn by sampling personnel and shall be changed often.
- 23) A description of the sample containers (size and materials) for each type of analysis.
- 24) A description of the labeling of the sample containers.
- 25) A description of the preservation techniques necessary for each type of sample.
- 26) Procedures for determining the amount of preservative necessary to achieve the required chemical stability (e.g., amount of acid necessary to ensure  $\text{pH} < 2$  for metals analysis).
- 27) Procedures for checking and documenting the results of preservation (e.g., checking whether metals samples have been acidified to a pH of less than 2 and that temperatures are maintained at 4 degrees Celsius during shipping and storage). The SAP must state that problems will be reported to the Department. (We have had some trouble with laboratories documenting problems but not reporting them.)
- 28) A description of the equipment and procedures for taking each type of sample. Sampling procedures should be designed to minimize

disturbance of the sample that could result in changes in water chemistry.

- 29) If filtering is required, a description of the equipment (including filter size) and procedures for filtering samples. The use of in-line filters is preferred. If in-line filtration is not possible, filtering should be done as quickly as possible (immediately) using positive pressure filtering equipment. The SAP should specify the discard volume (the volume of groundwater to be used to flush the filter before sampling) for the type of filter to be used. If manufacturer's guidelines are not available, the SAP should specify that two times the capacity of the filtering device will be passed through the filter and discarded before samples are collected.
- 30) A statement that bottles that have been prepared with preservatives will not be overfilled.
- 31) A description of the equipment and procedures for storing samples for transport.
- 32) Forms and procedures for sample transport and chain of custody control. The SAP should specify the procedures to be followed to assure that strict custody of samples is maintained during sample collection, storage and transport (i.e., samples are not left unattended or samples are secured in storage areas with limited access). Sample copies of chain-of-custody and sample analysis request forms should be included.
- 33) A description of equipment, procedures, and recordkeeping for decontamination of all sampling equipment and protective gear. Equipment shall not be used if visual signs, such as discoloration indicate that decontamination was insufficient.
- 34) The analytical method to be performed for each sample.
- 35) A copy of a document each member of the field team signs following each sampling event, detailing any deviations from the SAP that were necessitated by field conditions (e.g, equipment failure, wells that could not be sampled, etc.) and stating that, with the exceptions noted above, all field measurements and samples were collected in accordance with the procedures described in the SAP. A signed copy

of this document must be submitted with the report of analytical results.



## **Checklist for Quarterly Monitoring Reports**

Within 60 (or 90) days following each quarterly sampling event, the facility is required to submit a quarterly monitoring report to the Department. The following items apply to each quarterly monitoring report:

- The report should be presented in a professional report format with a table of contents and numbered pages.
- Since the quarterly monitoring report must contain interpretations of hydrogeologic and geochemical data, each report should be signed by a Geologist, registered in the state of California who takes responsibility for the technical content of the report. This is required by California state law - Business and Professions Code, Geologists and Geophysicists Act. Reports should indicate the license number of the geologist.
- Each report should reference the current sampling and analysis plan (SAP) and state that, with only the exceptions listed in the report, all sampling and analysis was conducted in accordance with the current plan.
- Each report should contain a detailed description of any deviations from the current SAP, an explanation of the conditions that necessitated those deviations and a description of any corrective measures being taken to avoid future deviations from the SAP.
- When appropriate, each report should describe recent changes to the monitoring program that are allowed by the conditions of the current SAP. (For example, minor changes in sampling or analytical equipment or protocol, addition of new or replacement wells to the monitoring system, and the use of updated concentration limits.)
- Each report should contain a summary of the sampling event that identifies the type of monitoring program for each regulated unit (detection, evaluation, and/or corrective action) and describe significant findings.
- Each report should contain a narrative report summarizing and interpreting the results of the monitoring event, including, but not limited to:

- \* Analysis of water level data and potentiometric maps, including a determination of groundwater flow rate and direction in each hydrologic zone monitored at the facility;
  - \* A report on the results of quality assurance / quality control (QA/QC) sampling and analysis. The report must state whether or not data quality objectives of accuracy, precision and completeness have been met. If objectives were not met (e.g., target detection limits were exceeded), this section must discuss corrective measures (e.g., resampling) that are being taken by the facility and/or the laboratory.
  - \* Summary of the results of statistical analyses on water chemistry data;
  - \* Interpretation of soil moisture data; and
  - \* Summary of the results of facility maintenance inspections of the monitored units and their monitoring systems.
- Each report should contain a current set of potentiometric maps for the facility.
  - Each report should include summary tables of current water level data, analytical data, and the results of the statistical analysis.
  - Each report should contain supporting documentation related to the sampling event, including, but not limited to: copies of field logs and activity sheets; depth to water data; well head data; immiscible layer data; field parameter results; purge volume data; on-scene observations; chain-of-custody forms; and laboratory data sheets (analytical reports). Internal laboratory calibration and QA/QC data need not be submitted to the Department, but should be available at the facility or laboratory if needed.
  - Each report should contain an evaluation of the effectiveness of the leachate monitoring and control facilities and of the run-off/run-on control facilities.
  - For active units, each report should describe the quantity and types of waste discharged and the locations in the facility where waste has been placed since the submittal of the last such report.
  - Each report should include a section that tracks outstanding issues and/or follow-up work that needs to be performed (e.g., verification sampling of

apparently significant evidence of a release, repair or replacement of wells or equipment). Any item included in this section must be addressed in every subsequent quarterly report until the outstanding issue is resolved.

Note: The documentation requirements for quarterly monitoring reports are not a substitute for the notification requirements in section 66264.98 (j)(1) and 66264.98(l). As required by those sections, anytime the facility determines that there is statistically significant evidence of a release from the regulated unit, the facility must notify the Department by certified mail within seven days of making that determination.

## **Checklist for Annual Monitoring Reports**

By March 1 of each year (unless the facility permit states otherwise), the facility must submit an annual report that covers the activities of the previous year. The annual report may be combined with the quarterly report for the fourth quarter provided it is submitted within 90 days of the fourth quarter sampling event and all items required for each report are included in the annual report.

The following items apply to each annual monitoring report:

- The report should be presented in a professional report format including a table of contents and numbered pages.
- Since the annual monitoring report must contain interpretations of hydrogeologic and geochemical data, each report should be signed by a Geologist, registered in the state of California who takes responsibility for the technical content of the report. This is required by California state law - Business and Professions Code, Geologists and Geophysicists Act. Reports should indicate the license number of the geologist.
- Each report should contain an executive summary of previous year's sampling events that identifies the type of monitoring program for each regulated unit (detection, evaluation, and/or corrective action) and describe significant findings.
- Each report should contain a narrative report summarizing and interpreting the results of the water quality monitoring program to date, including, but not limited to:
  - \* An analysis of water level data and potentiometric maps. Water level data, including hydrographs and potentiometric maps, must be evaluated to determine if the water quality monitoring system is in compliance with the requirements of Section 66264.97(b)(1) (i.e., the system satisfies the data needs for the current monitoring program: detection, evaluation or corrective action.) If the system is not adequate, the report must specify the steps that will be taken by the facility to achieve compliance with those requirements.
  - \* Interpretation of the results of statistical analysis on water chemistry data; and

- \* Interpretation of soil moisture data.
- Unless otherwise stated in the permit or sampling and analysis plan, each report should contain comprehensive summary tables of all historical analytical data related to water quality monitoring (groundwater, surface water, and soil-pore liquid) at each regulated unit.
- Each report should contain time series plots of water level, laboratory analytical data, and the final, stable value of field parameters. Unless otherwise stated in the permit or WQSAP, graphs should be presented in the following format:
  - \* Every monitoring parameter or CoC should be shown on a separate graph with the data from as many wells as can be legibly displayed. As much historic data as possible should be included on each graph so that long-term and/or recurring trends can be distinguished.
  - \* When a concentration is reported as below the detection limit (DL), it should be displayed on the graph in such a way that the reviewer can clearly tell that the analyte was not detected. The value of the DL must be evident. If the DL has remained constant, it is sufficient to simply state what that limit is and to plot the data at a constant value (i.e., the value of the DL). If the DL has varied through time the facility should devise a way to depict that information on the graph.
  - \* When a concentration is reported below the reporting limit (or practical quantitation limit [PQL]), but above the DL (such data is frequently referred to as "censored" or "trace" data) it should be displayed on the graph at the estimated concentration reported by the laboratory, but in such a way that the reviewer can clearly tell that the concentration was estimated to be below the reporting limit (or PQL). The values of the reporting limit (or PQL) and the DL should be evident. Methods in use by other facilities include: substituting the letters TR (trace) for the well symbol on the graph, altering the well symbol in some standard way (e.g. circling the well symbol, using alternate colors), and plotting detection limits on overlays.
  - \* The spread of the y axis should be selected to best display the variability of the data and must be no more than three times the range of the data.

- \* When plotting concentration data for multiple wells, it is expected that much of the data will overplot for values near the mean of the data set. This still provides useful information and should not be a problem as long as the graphs are submitted at an appropriate scale and well symbols are clearly legible in areas where the concentration deviates from normal.
- \* If more than one graph is needed for each parameter then:
  - a) to facilitate comparison between upgradient and downgradient data, each graph shall show data from the background monitoring points (Note: This can also be accomplished by printing graphs on transparencies and overlaying the graphs.);
  - b) downgradient wells shall be grouped by location or by other significant characteristics; and
  - c) all graphs for a parameter shall be at the same scale.

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# **SPEAKER BIOGRAPHIES**

**APPENDIX A**



**SPEAKER BIOGRAPHIES**  
**1996 EPA REGION 9 CORRECTIVE ACTION CONFERENCE**

**BRIAN J. ANDRASKI**  
**U.S. Geological Survey**

**Brian Andraski**, Research Hydrologist, U.S. Geological Survey, has 10 years of experience in the study of soil physical and hydrological problems related to waste disposal in arid environments. His present work emphasizes the evaluation of soil-plant-water interactions and the testing and evaluation of methods for characterizing and monitoring water movement in desert soils. Previous work, done as a Senior Research Specialist at the University of Wisconsin Soil Sciences Department, included studies to characterize water movement in a coal fly-ash landfill.

**KAREN T. BAKER**  
**California EPA Department of Toxic Substances Control**

**Karen T. Baker** has been with the California Department of Toxic Substances Control (DTSC) for eight years. She received a M.S. in Geological Sciences from the University of California, Riverside in 1985. She is a California Registered Geologist, Certified Hydrogeologist and Certified Engineering Geologist. She is currently the supervisor of the Geological Support Unit. The unit provides geological consultation to both the RCRA and CERCLA Programs within DTSC.

**NED BLACK**  
**U.S. Environmental Protection Agency, Region 9**

**Ned Black, Ph.D.**, has been with the United States Environmental Protection Agency as a Superfund Project Manager and Ecologist for two years. Prior to that, he worked as a post-doctoral fellow and acting assistant professor in the Department of Civil Engineering at Stanford University, where he studied bacterial degradation of PAH's and chlorinated solvents. Dr. Black has a doctorate in Engineering Sciences from Harvard University. His doctoral research dealt with aquatic microbial ecology and metal geochemistry.

**R. JEFFREY DUNN**  
**GeoSyntec Consultants**

**R. Jeffrey Dunn, Ph.D., P.E., G.E.,** Manager of GeoSyntec's Walnut Creek Office, has more than 19 years experience in the permitting, design, construction, operations, and closure of municipal, industrial, and hazardous waste landfills. Dr. Dunn is a licensed Geotechnical Engineer and has a wide variety of experience in many different projects and is nationally recognized for his expertise in design and construction of geosynthetic and clay liners and covers. He has worked on projects for both private and public sector clients. Specific projects Dr. Dunn has managed include the closure design for the City of Fresno CERCLA Landfill, ISRT NPL remediation in Woburn, Massachusetts, as well as the expansion designs and construction quality assurance for the Sonoma, Vasco Road, and Keller Canyon sanitary landfills. He has worked with a number of clients and regulatory agencies in the development stages of state and local regulations and guidelines for closure and post-closure landuse at landfills. Recently he managed a two year state-of-the-art study of "Performance Criteria for Landfill Covers" for the California Integrated Waste Management Board (CIWMB).

**MATTHEW HAGEMANN**  
**U.S. Environmental Protection Agency, Region 9**

**Matthew Hagemann** has been with the U.S. EPA for seven years. He has worked as a hydrogeologist in the RCRA, Safe Drinking Water and Superfund Programs. Matthew earned a B.A. in geology from Humboldt State and an M.S. from Cal State L.A. In the twelve years he has practiced geology, Matthew has worked for a consulting firm, the U.S. Forest Service, and has taught at the secondary, community college and university levels. Currently, he teaches part-time at San Francisco State University.

**VALERIE HEUSINKVELD**  
**California EPA Department of Toxic Substances Control**

**Valerie Heusinkveld** has been with the California Department of Toxic Substances Control, Berkeley Regional Office, for seven years. She has a Bachelor's degree in chemistry from UC San Diego and a Master of Public Policy degree from UC Berkeley. Before coming to DTSC, she worked as a research chemist in industry.

**THEODORE R. JOHNSON**  
**California EPA Department of Toxic Substances Control**

**Theodore R. Johnson III** has over fifteen years experience as a geologist. He received a B.S. in Geological Sciences from the University of Southern California in 1981. He is a California Registered Geologist. He has been working for the last three years for the Department of Toxic Substances Control in the Hazardous Waste Management Program. His current projects include soil and groundwater characterization and remediation of contaminated sites. He specializes in environmental and engineering geology and project management, exploration and high resolution geophysics.

**DENNY A. LARSON**  
**Communities for a Better Environment**

**Denny Larson** has over 15 years experience with community organizing and outreach activities. He has a Bachelor of Science in Communications from the University of Texas at Austin.

Mr. Larson has worked closely with communities located near oil refinery and chemical plants to address concerns regarding chemical spills and air pollution problems. In the Bay Area, he helped found the West County Toxics Coalition in Richmond, California, and helped negotiate Good Neighbor Agreements with Shell, Chevron, Tosco, Pacific and Unocal refineries in Contra Costa County. The Good Neighbor Agreements reduced millions of pounds of toxic pollution, improved air monitoring, and gave neighbors inspection and oversight rights.

In 1994, Mr. Larson began a national effort to link oil refinery neighbors, workers and shareholders together to achieve "cleaner and safer refining." In recognition of Larson's work, U.S. EPA Administrator Carol Browner named Larson to a Federal panel charged with reinventing regulatory approaches to the oil industry.

**BRIAN LEWIS**  
**California EPA Department of Toxic Substances Control**

**Brian Lewis, CEG, CHG**, Chief of Permitting and Enforcement Geological Services Unit, California Department of Toxic Substances Control, has more than 16 years experience in the groundwater field, including 11 years with hazardous waste. For two years, he was on loan to the U.S. Environmental Protection Agency, Headquarters, as a member of the National Groundwater Task Force. This task force evaluated compliance with the Resource Conservation Recovery Act, Subpart F requirements at sixty facilities nationwide. Within California, he established a state task force based on the federal model. Currently he is a member of the Regulatory Structure Update (RSU) team that is focused on implementing the corrective action program in California.

**RICHARD McJUNKIN**  
**California EPA Department of Toxic Substances Control**

**Richard McJunkin, RG, CEG**, supervises the Geologic Services Unit in the Site Mitigation Program of the Department of Toxic Substances Control. He has a B.S. and M.S. in geology and is a Registered Geologist and Certified Engineering Geologist with over 10 years experience in characterizing and remediating hazardous waste release sites. He also teaches ground water classes as a part-time faculty member for the Environmental Hazard Management Program of U.C. Davis Extension.

**SARAH PICKER**  
**California EPA Department of Toxic Substances Control**

**Sarah Picker, P.E.**, senior hazardous substances engineer with the California Department of Toxic Substances Control has more than 10 years of technical expertise in hazardous waste management. She has a Bachelor of Science degree from California State University, Chico. She has worked extensively in the area of sanitary and landfill design, landfill closure and post-closure plan regulatory review and approval, implementation of the California Environmental Quality Act and hazardous waste incineration.

**DAVID W. RICE, JR.**  
**Lawrence Livermore National Laboratory**

**David Rice** is an expert on the fate and transport of contaminants in subsurface soils, ground water, and the marine environment. He is presently the lead scientist and Project Director in a team of University of California collaborators assisting the State of California in re-evaluating the leaking underground fuel tank cleanup decision-making process.

Mr. Rice is an expert in the fate and transport of energy-related contaminants in marine and terrestrial ecosystems. He has participated in the management of the Lawrence Livermore National Laboratory (LLNL) Superfund sites. His current research focus is on the technologies and information management systems to support time-critical environmental restoration decisions involving cost/benefit analysis and multiple stakeholders.

Mr. Rice has authored/co-authored over 50 publications.

**MOHINDER S. SANDHU**  
**California EPA Department of Toxic Substances Control**

**Mohinder S. Sandhu, P.E.**, has over sixteen years experience in the hazardous waste management field. He received his M.S. in Civil Engineering from the University of California, Berkeley in 1977. He is a registered Professional Civil Engineer. He is currently Chief of the Facility Permitting Branch of the California Department of Toxic Substances Control Region 4 Office in Long Beach, California. His responsibilities include a wide spectrum of technical and managerial assignments in the permitting, surveillance and enforcement and site mitigation programs.

**RONALD C. SIMS**  
**Utah State University**

**Ronald C. Sims, Ph.D.**, Professor and Head of the Division of Environmental Engineering at Utah State University, has more than 20 years of technical experience in vadose zone characterization, treatment, and monitoring. Dr. Sims has a Ph.D. in Biological and Agricultural Engineering from North Carolina State University. He has worked for the University of North Carolina at Chapel Hill, Mobay Chemical Corporation, SC, and Research Triangle Institute, NC, and was a visiting engineer at the U.S. EPA NRMRL, Robert S. Kerr Laboratory, Ada, Oklahoma, 1989-1990.

**BRIAN M. SMITH**  
**Lawrence Berkeley Laboratory**

**Brian M. Smith, Ph.D.**, has been using stable isotopes to understand natural processes for nearly 20 years, first as an exploration research geochemist for Unocal Corporation and more recently as a Staff Scientist and Environment, Health and Safety Specialist at the Lawrence Berkeley Laboratory. Dr. Smith has a Ph.D. in geology from Brown University, where he studied the geochemical consequences of interactions between waters and rocks in high temperature geothermal systems. Dr. Smith's current interests are to stimulate the use of stable isotopes in low temperature hydrogeologic systems, where they can be particularly useful in site characterization and monitoring programs and environmental management efforts.

**DANIEL STRALKA**  
**U.S. Environmental Protection Agency, Region 9**

Dan received his Ph.D. in biochemistry at the University of Texas at Houston in 1984 and then served on active duty with the Army Medical Research and Development Command for 6 years. He has been with the Superfund Technical Support Section in Region 9 since 1991 as a Regional Toxicologist. He has worked on review and oversight of Federal facilities and closing bases throughout the region.

**HAROLD A. TUCHFELD**  
**GeoSyntec Consultants**

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Patrick Wilson, Ph.D., M.P.H., is a Regional Toxicologist assigned to the Corrective Action Section of the Hazardous Waste Management Division at the United States Environmental Protection Agency, Region IX office in San Francisco, California. Dr. Wilson has a Ph.D. in Environmental Toxicology with a minor in Pathology from the UCLA School of Medicine. His Ph.D. research was conducted in the laboratory of Dr. John Froines, and focused on the molecular pharmacokinetics and biological monitoring of chemical carcinogens (aromatic nitro and amine compounds and toluene diisocyanate) found in the industrial and occupational environment.

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**Jeffrey J. Wong, Ph.D.**, is currently responsible for the development of the scientific basis and rationale for risk assessment, risk management and risk reduction strategies within the California Environmental Protection Agency's Department of Toxic Substances Control. He has more than 14 years of experience in (1) the assessment of public health and environmental effects associated with chemical exposures, (2) the development and formulation of risk management and reduction strategies and (3) analysis of policy implications of risk control options. Dr. Wong has a Ph.D. in Pharmacology and Toxicology and a Masters of Science degree in Food Science and Technology from the University of California, Davis.

Upon nomination by the US National Academy of Sciences, President William J. Clinton appointed Dr. Wong to the United States Nuclear Waste Technical Review Board. The US NWTRB is an independent establishment within the executive branch, which evaluates the scientific and technical validity of US Department of Energy activities in the spent fuel and high-level waste management program and reports its findings, conclusions, and recommendations to the Congress and the Secretary of Energy.

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Kola Olatunbosun	Cal EPA / RWQCB Region 7
Mike Cruz	Guam EPA
Conchita Taitario	Guam EPA
Paul Kalaiwaa	Hawaii Dept. of Health
Helen Hillman	NOAA Hazmat
Jeff Denison	Nevada Dept. of Environmental Protection
Devender Narala	Nevada Dept. of Environmental Protection
Mary Blevins	US EPA Region 9
Susan Chiu	US EPA Region 9
Joe Eidelberg	US EPA Region 9
Kenneth J. Erickson P.E.	US EPA Region 9
Karen Goldberg	US EPA Region 9
Lily Herskovits	US EPA Region 9
Dave Hodges	US EPA Region 9
Sean Hogan	US EPA Region 9
Jeff Inglis	US EPA Region 9
Mitch Kaplan	US EPA Region 9
Tom Kelly	US EPA Region 9
Mark Klairman	US EPA Region 9
Vicky Lang	US EPA Region 9
Steve Linder	US EPA Region 9
Mike Mahoney	US EPA Region 9
Nicole Moutoux	US EPA Region 9
Elaine Ngo	US EPA Region 9
Wayne Praskins	US EPA Region 9
Dante Rodriguez	US EPA Region 9
Roseanne Sakamoto	US EPA Region 9
Carmen Santos-Prior	US EPA Region 9
Vicky Semones	US EPA Region 9
Kathy Setian	US EPA Region 9
Wendi Shafir	US EPA Region 9
Barbara Smith	US EPA Region 9
Carl Warren	US EPA Region 9
Danita Yocum	US EPA Region 9
Nahid Zouestiagh	US EPA Region 9
Mark Peterson	US EPA Region 9 (P-3-2)
Mike Gill	US EPA Region 9, H-9-2
Nancy Alvarez	University of Nevada, Reno

**1996 Corrective Action Conference  
Facility / Industry Attendees**

Name	Organization
Gary Colbert	Allwaste, Inc.
Michael Dunbavan	BHP Hawaii Inc.
Tony Shan	BHP Hawaii Inc.
Marlene Bennett	BHP Melbourne Laboratory
C. Chow Lee	C. Chow Lee & Associates
Rick Wilson	Camp Dresser & McKee
Patricia Wagner	Chevron USA
Mary Esper	Dames & Moore
Zuyi Shen	Dames & Moore
Elizabeth Jacobson	Desert Research Institute
Sally Bilodeau	EMCON
Shri Nandan	ESE Inc.
Harry Takach	Environmental Science and Engineering 1
Mark Haney	Environmental Science and Engineering 5
James Breitlow	Env't. Management & Compliance Services
William Cutler	FMC Corporation
Craig O'Rourke	Geraghty & Miller, Inc.
Anthony Ward	Geraghty & Miller, Inc.
Julie Menack	Groundwater Technology
John Blasco	Harding Lawson Associates
Marilyn Blume	Harding Lawson Associates
Brian Waggle	Hargis & Associates
Iryna Kwasny	Heller, Ehrman
Eric Diethelm	IT Corporation
Gary Locke	IT Corporation
Douglas Waltermire	IT Corporation
Ed Leach	Kleinfelder, Inc.
Sue Vedantham	Laidlaw Environmental Services
Iraj Javandel	Lawrence Berkeley National Laboratory
Chao Shan	Lawrence Berkeley National Laboratory
Pablo McCloud	Levine-Fricke, Inc.
Susan Prentice	Morrison and Foerster
Dixie Hambrick	Ogden Environmental
Jay Jones	Ogden Environmental
Richard Gaitley	PACNAV-Facilities Engineering
Craig Fletcher	PG & E
Stephen Fok	PG & E
Ed Vigil	Phibro-Tech, Inc.
Peter Day	Phillips Petroleum Co.
Cindy Smith	Phillips Petroleum Co.
Timothy Bodkin	Radian International
Randy Ueshiro	Rockwell International
Amil Dharmapal	Roy F. Weston, Inc
Richard Burzinski	Rust Environment & Infrastructure
Elena Espada	Rust Environment & Infrastructure
Helen Lucas	Rust Environment & Infrastructure
Michelle Mason	Rust Environment & Infrastructure
Susan Peterson	Rust Environment & Infrastructure
Julie Small	Rust Environment & Infrastructure
Whit Smith	Rust Environment & Infrastructure
Charlie Wittman	Rust Environment & Infrastructure
William Knight	Rust Environmental & Infrastructure
Susan Corbaley	SAIC
Naomi Feger	SAIC
J Mark Inglis	SECOR International
Glenn Anderson	Texaco

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Facility / Industry Attendees**

Name	Organization
Rose Coughlin	Texaco Refining and Marketing, Inc.
Max Boone	Tosco Refining Company
Kati Neidig	Turner / MacLane
Mana Morales	U.C. Berkeley
Anthony Hoover	U.S. Naval Activities, N534
Tony Roberson	U.S. Navy Public Works Center
Ken Eichstaedt	URS Consultants
Justin Bradley	United Defense LP
John Tang	United Defense LP
Peter Wan	United Defense LP
Zahra Zahiraleslamzadeh	United Defense LP
Don Osterhold	United Technologies
Bill Pratt	United Technologies Corp.
Nancy Emerson	Unocal
Brad Esslinger	Woodward-Clyde Consultants
James Strandberg	Woodward-Clyde Consultants