Pump-and-Treat Systems Are a Fact of Life (?)

How Do We Maximize Their Effectiveness?

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Parsons
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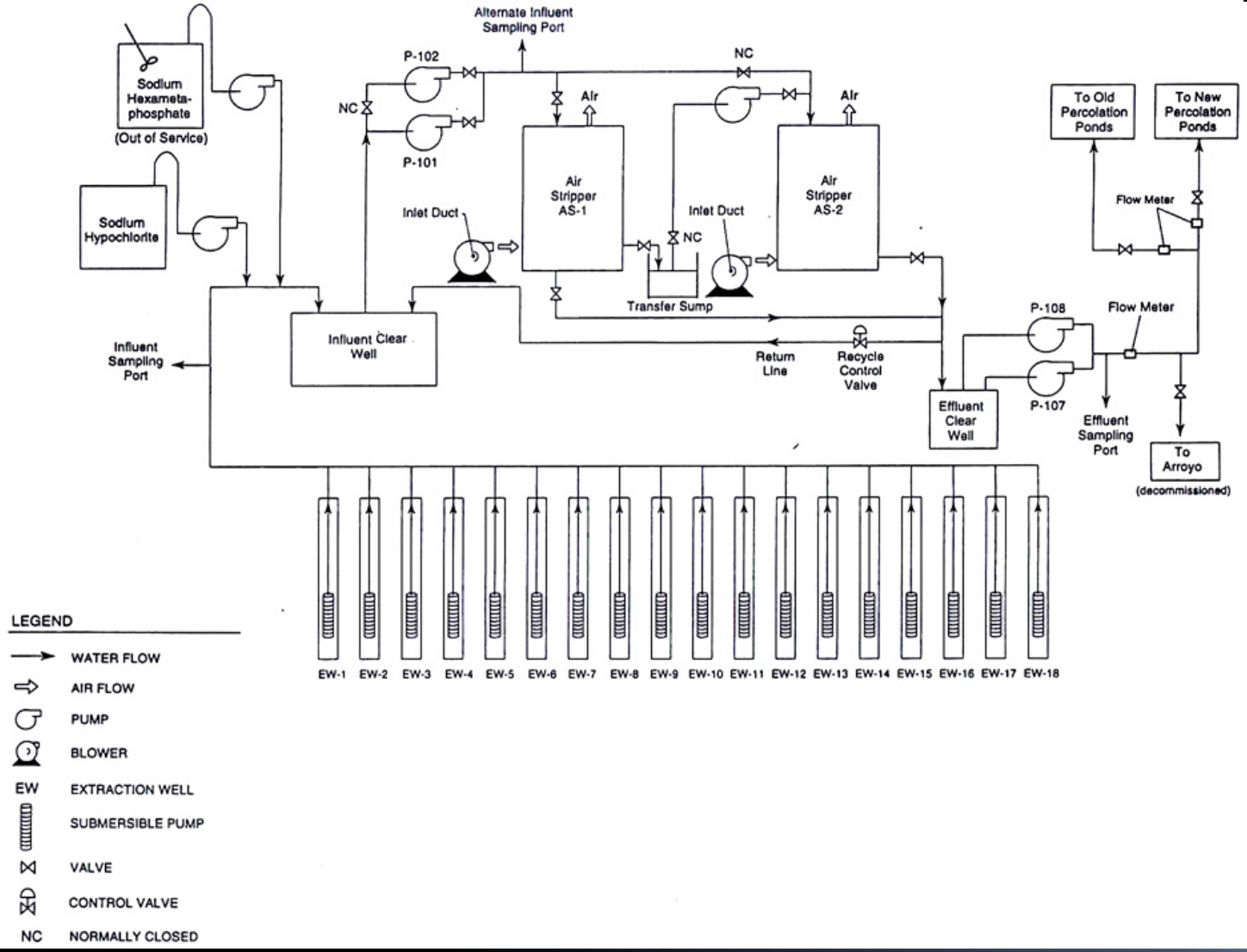
General Outline

- Introduction – Nature of the Problem
- Considerations and Approaches in Evaluating Groundwater Pump-and-Treat Systems
- Examples
- Conclusions

General Outline

- **Introduction – Nature of the Problem**
- **Considerations and Approaches in Evaluating Groundwater Pump-and-Treat Systems**
- **Examples**
- **Conclusions**

What is a Groundwater Pump-and-Treat System?



Components of Groundwater Pump-and-Treat System

- **Extraction Subsystem**
  - **Wells**
  - **Trenches**
  - **Drains**
- **Treatment Subsystem**
  - **Air stripping**
  - **Carbon adsorption**
  - **Floculation**
  - **Other**
- **Disposal Subsystem**
- **Monitoring Subsystem**
  - **System monitoring**
  - ~~**Characterization or long-term monitoring of contaminants**~~

Important Question

What is the Purpose of a Groundwater Pump-and-Treat System?

Possible Objectives of Groundwater Pump-and-Treat Systems

- Removing Contaminant Mass From Plume
- Reducing Concentrations of Contaminants
- Meeting Cleanup Objectives for Groundwater
- Preventing Migration to Potential Exposure Point
- Reducing the Size of Contaminant Plume
- Achieving Containment of Plume

Objectives of Groundwater Pump-and-Treat Systems

Mass-Removal Objective:

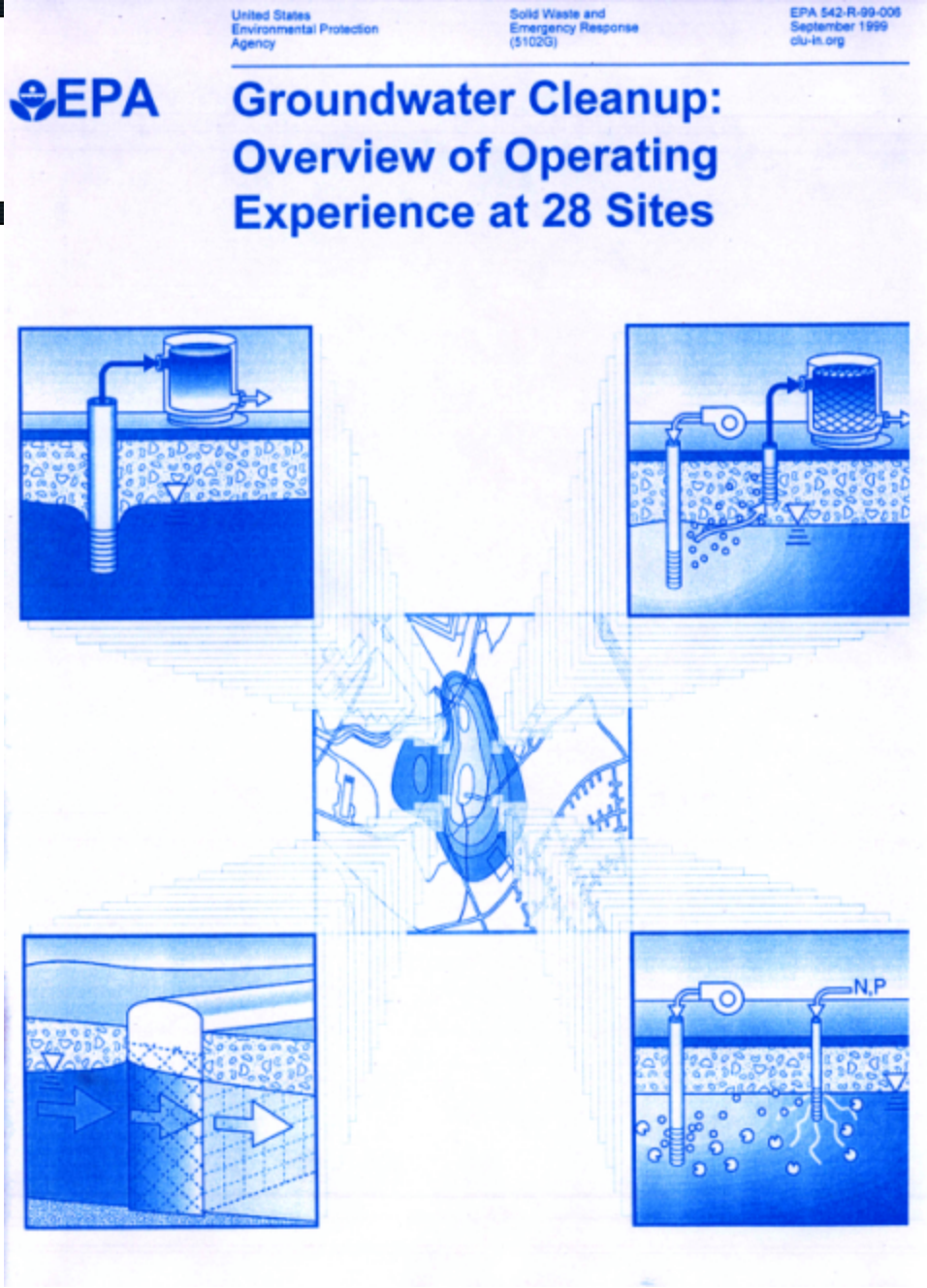
- Removing Contaminant Mass From Plume
- Reducing Concentrations of Contaminants
- Meeting Cleanup Objectives for Groundwater

Containment Objective:

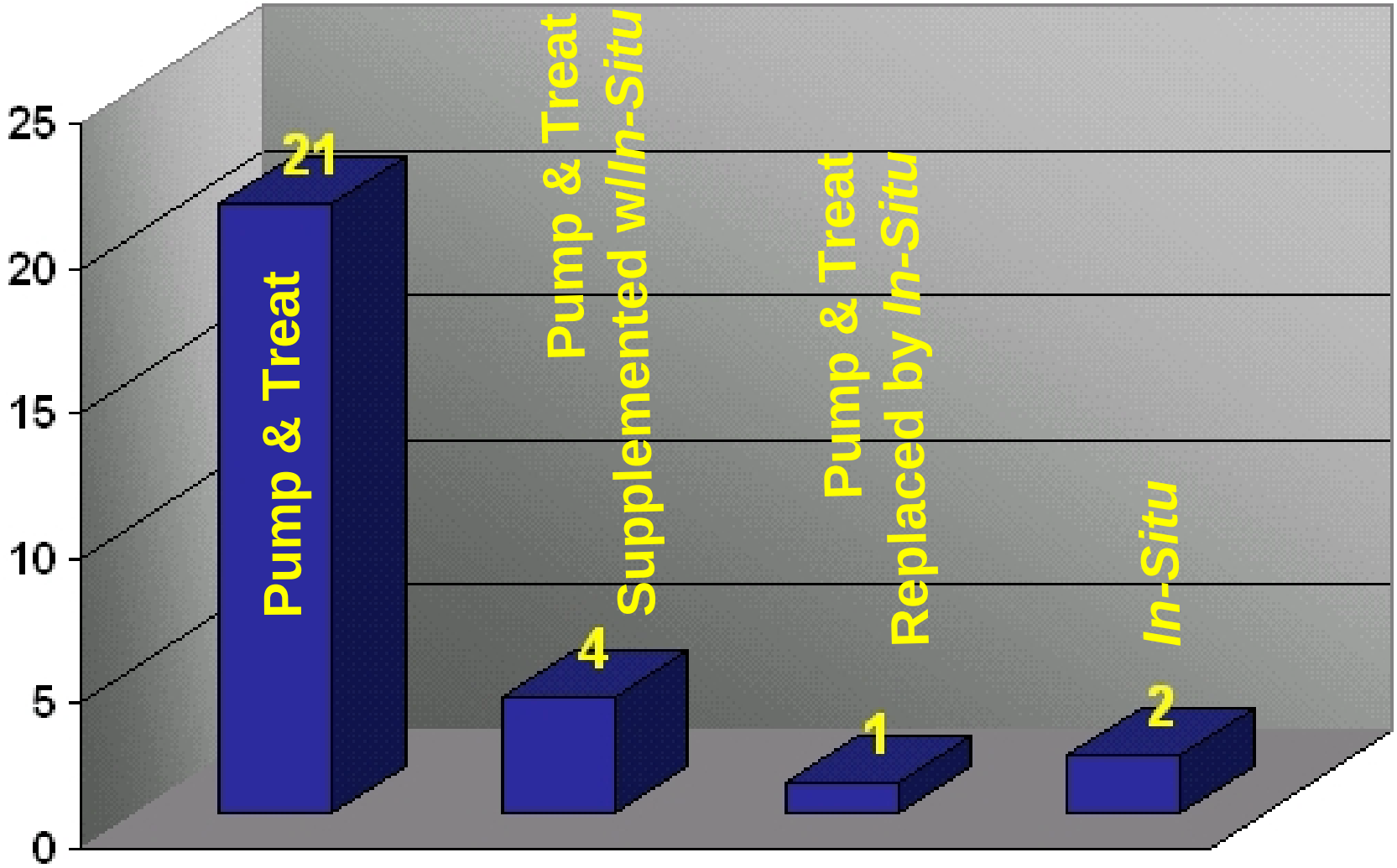
- Preventing Migration to Potential Exposure Point
- Reducing the Size of Contaminant Plume
- Achieving Containment of Plume

Synopsis of Some Pump & Treat Remedies:

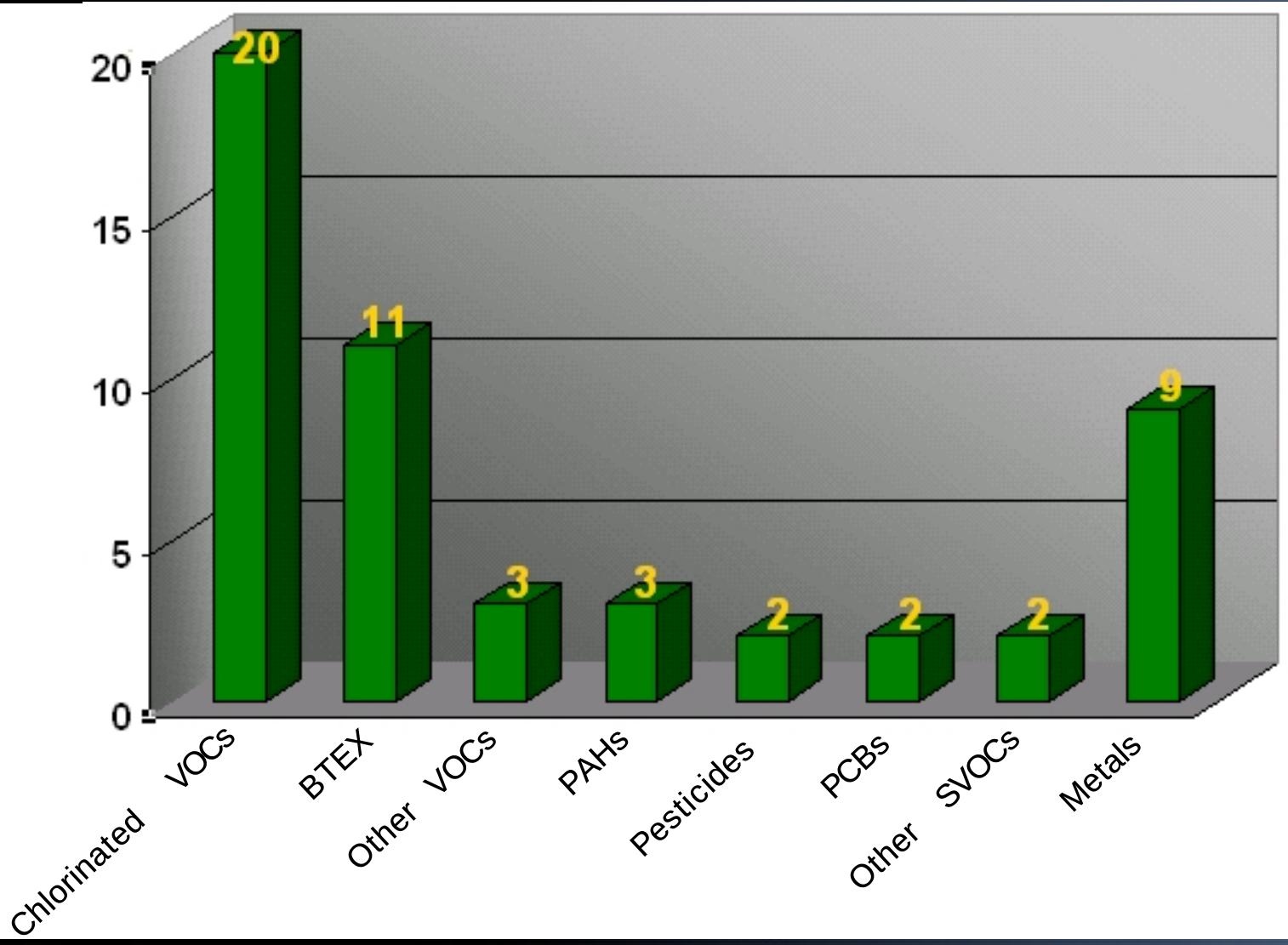
USEPA (1999)



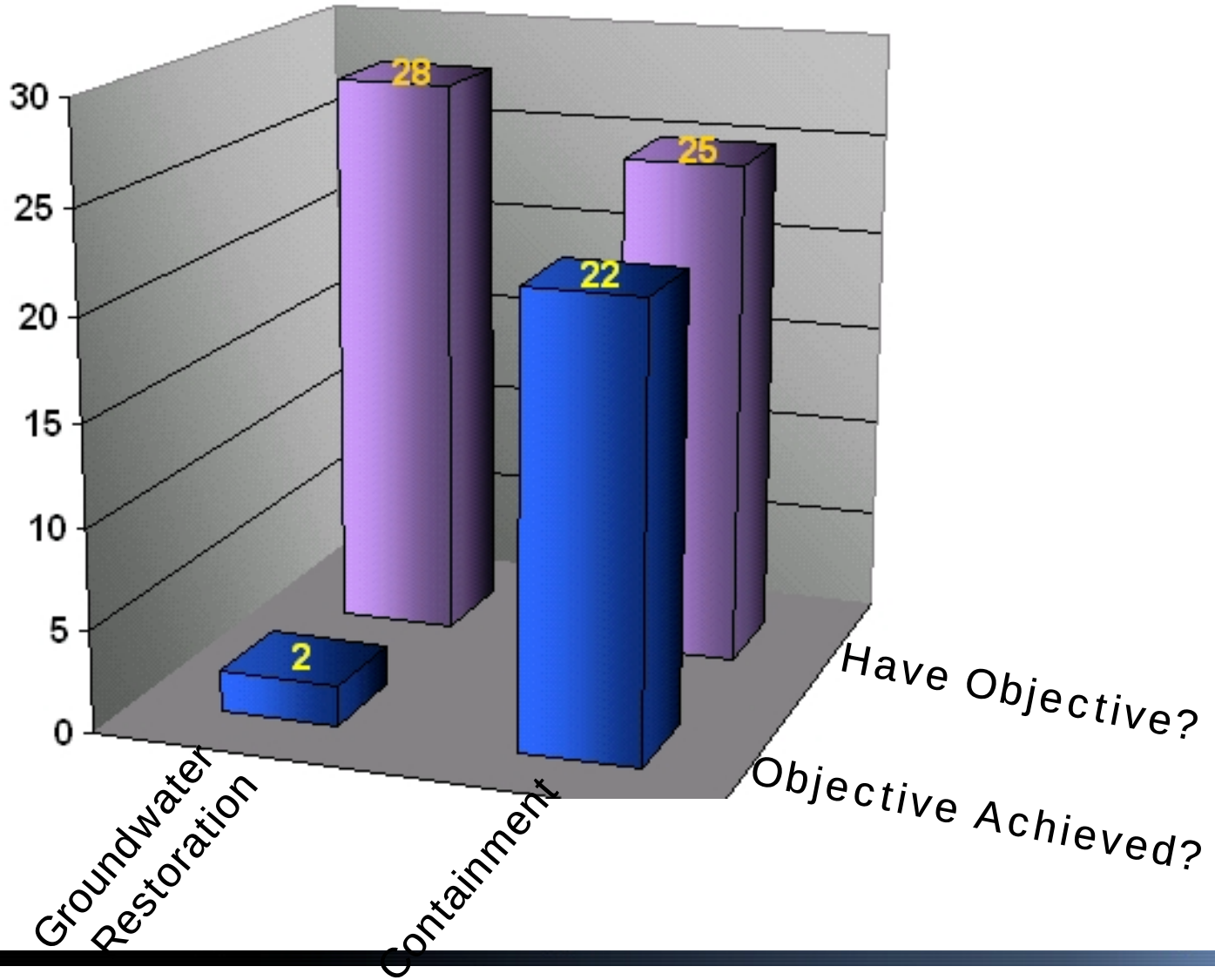
Typical Groundwater Treatment Systems



Types of Contaminants Treated



Achieving Remediation Objectives

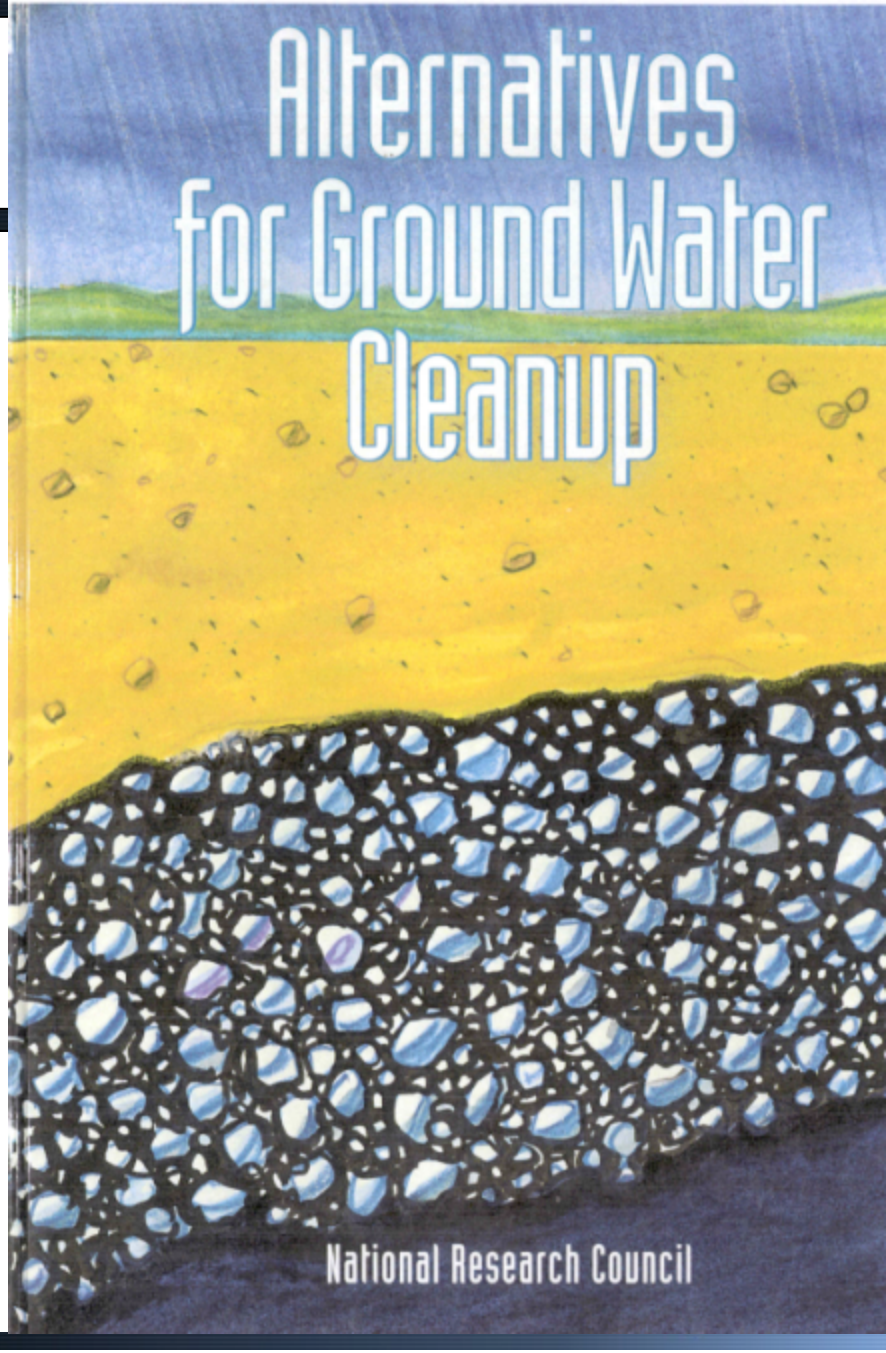


Cost Data for 26 Groundwater Pump-and-Treat Systems

	Low	High	Average
Capital Cost	$250 K	$15 M	$3.5 M
Annual O&M Cost	$91 K	$4.4 M	$670 K
Volume of Groundwater Treated per Year (gal)	1.7 M	550 M	63 M
Annual O&M Cost per Year ($/1,000 gal)	$0.21	$170	$31

Questions Regarding Effectiveness of Pump & Treat Remedies:

National Research Council (1994)



Hazardous-Waste Sites with Contaminated Groundwater

	USEPA (1993)	Russell *et al.* (1991)	OTA (1989)
CERCLA Sites	2,000	3,000	10,000
RCRA Sites	1,500 - 3,500	N/A	2,000 – 5,000
USTs	295,000	365,000	300,000 – 400,000
DOD Sites	7,300 (at 1,800 installations)	7,300	8,139
DOE Sites	4,000 (at 110 installations)	N/A	1,700
Other Federal Facilities	350	N/A	1,000
State Sites	20,000	30,000	40,000
Totals	330,150 – 332,150	N/A	363,000 – 466,000

NRC, 1994

- Groundwater restoration efforts began in early 1980s (Safe Drinking Water Act; RCRA; CERCLA; 1974 – 1984)
- Between 1982 – 1992, 73 percent of CERCLA Records of Decision (RODs) specified pump-and-treat systems for cleanup of contaminated groundwater
- Average cost of UST cleanup -- $100K
- Average cost of CERCLA cleanup -- $27M
- Total projected cleanup costs (1991 $$) -- $750B over 30 years

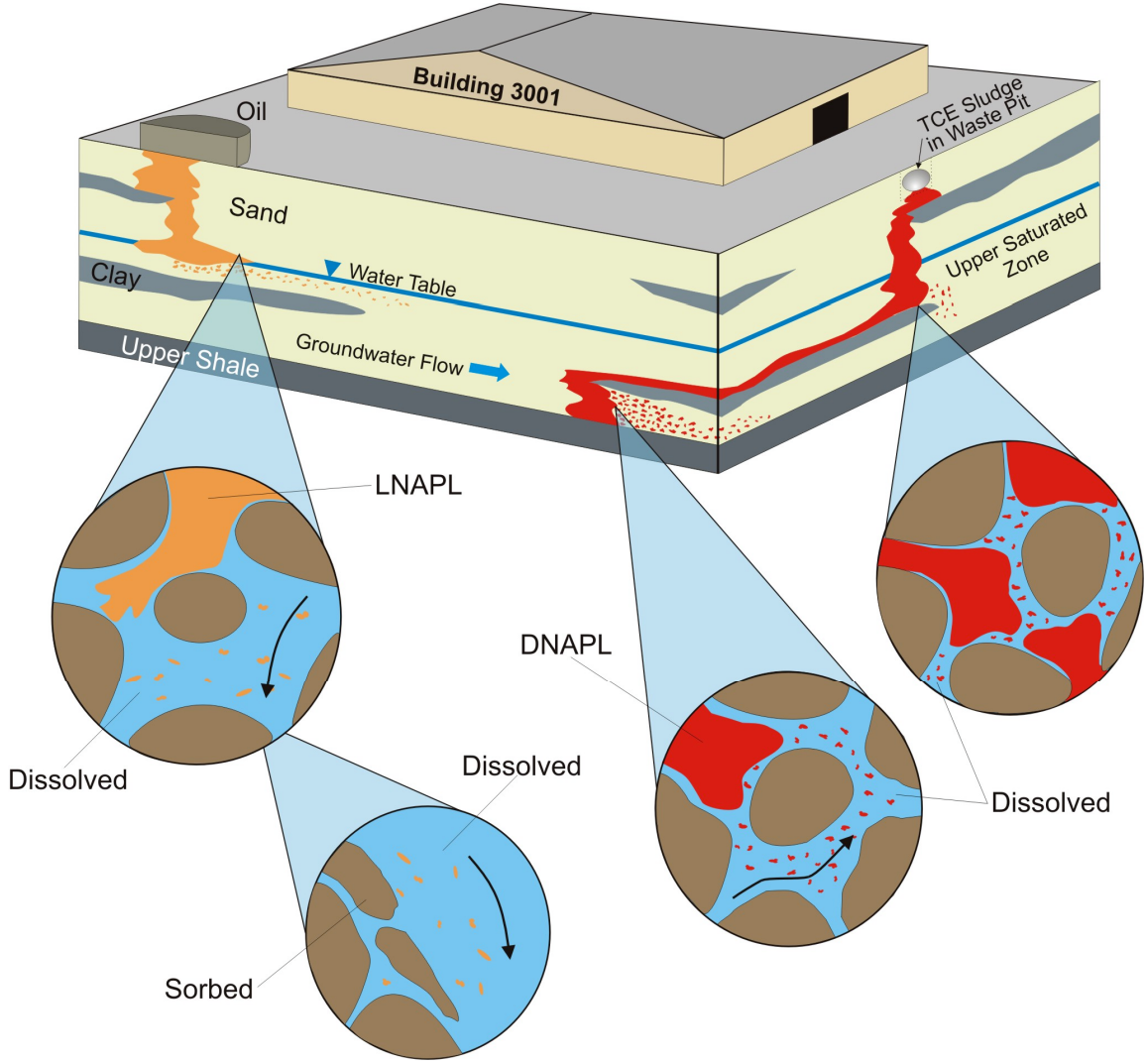
NRC, 1994 (continued)

- 77 groundwater pump-and-treat systems examined; 69 did not achieve cleanup goals
- Many systems appear (at first) to achieve cleanup goals; however, when system is taken off-line, contaminant concentrations may recover
- Capabilities of extractive remedies highly variable, depending upon site-specific factors

Factors Affecting Performance of Groundwater P&T Systems

- Presence of Non-Aqueous-Phase Liquids (NAPLs)
- Characteristics of Water-Bearing Unit(s)
  - More than One Water-Bearing Zone
  - Geologic Heterogeneities
  - Hydraulic Properties
  - Presence/Absence of Confining Unit(s)
- Contaminant Characteristics
  - Chemical Properties
  - Fate and Transport Properties
- Extent/Depth of Contaminants
- Remedial Objectives
- System Operational Factors

Conceptual Schematic of DNAPL and LNAPL Migration in a Porous Medium



Factors Affecting Performance of Groundwater P&T Systems

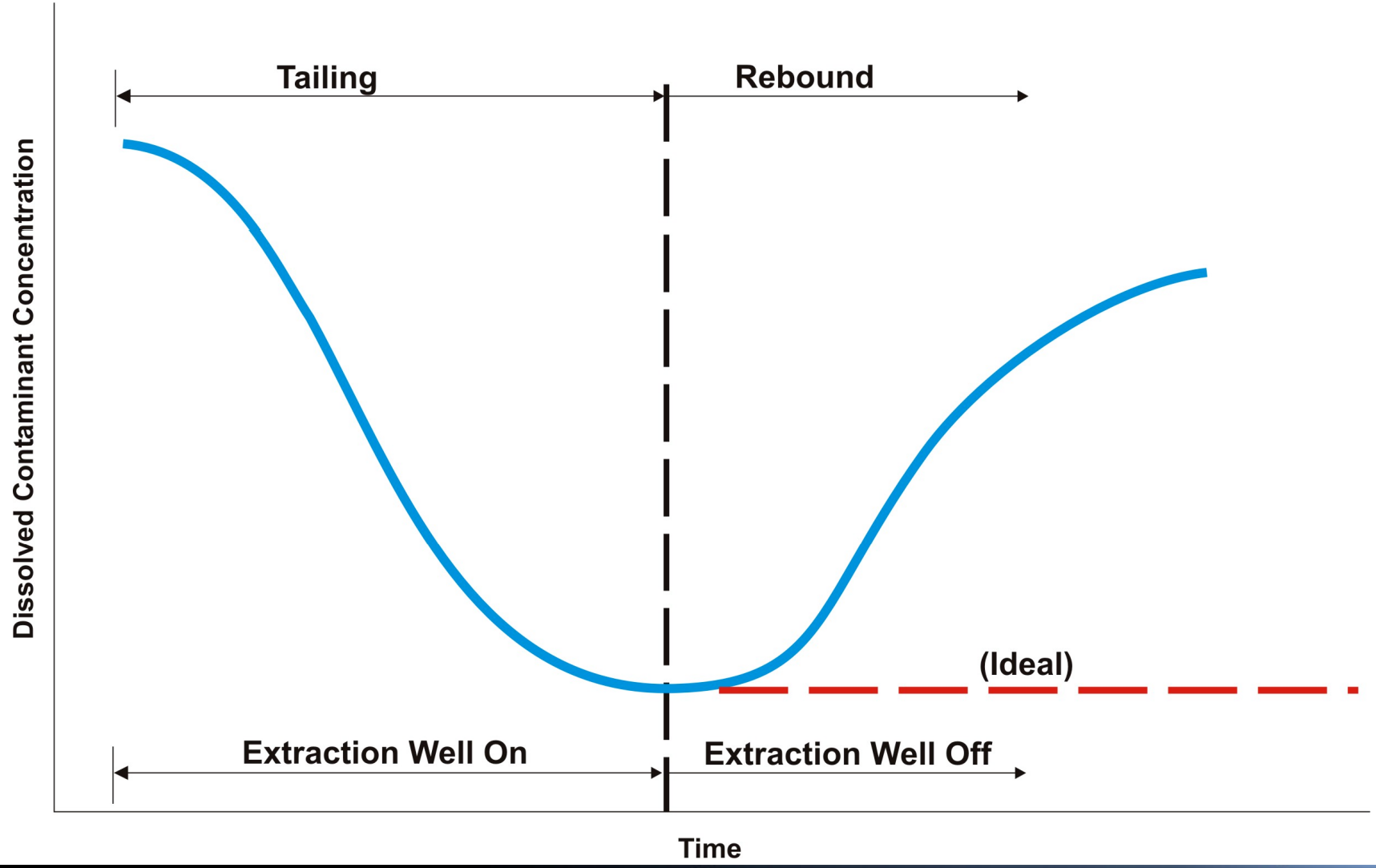
- Characteristics of Water-Bearing Unit(s)
- Contaminant Characteristics

In combination, have the following effects on contaminants in the subsurface:

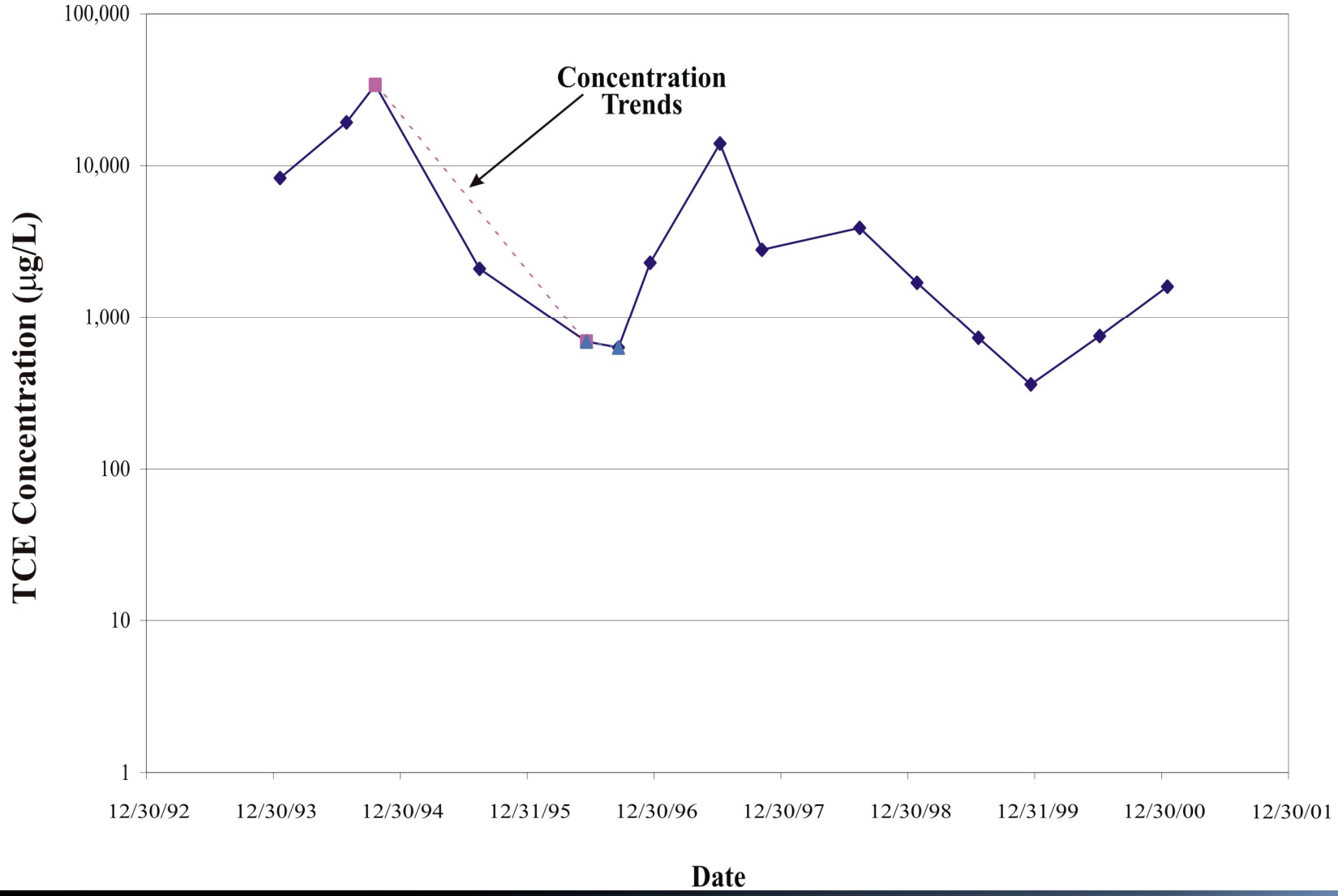
- Sorption of Contaminants to Matrix
- Diffusion of Contaminants into Matrix
- Heterogeneous Distribution of Contaminants
- Generally Low Rates of Dissolution (Pump & Treat Systems Address Dissolved-Phase Contaminants)

These lead to the phenomena known as *"Tailing"* and *"Rebound"*.

Contaminant Concentrations During "Tailing" and "Rebound"



Concentrations of TCE Though Time in Extraction-Well Effluent



Difficulties Presented by "Tailing" and "Rebound"

- **Longer Treatment Times**
  - **Without "tailing", contaminants could be removed by extracting a volume of groundwater equal to the volume of the contaminant plume.**
  - **Slow dissolution/desorption/diffusion maintains some level of contaminant concentrations in groundwater**
- **Residual Concentrations in Excess of Cleanup Standards**

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- Introduction – Nature of the Problem
- **Considerations and Approaches in Evaluating Groundwater Pump-and-Treat Systems**
- Examples
- Conclusions

Focus Topics

- Questions to Ask
- Relevance/Importance of Conceptual Site Model (CSM)
- Basis-of-Design for Groundwater Pump-and-Treat Systems
- Evaluation Techniques
- Optimization Strategies
- Negotiating Remedy Changes

Steps in Evaluating Groundwater Pump-and-Treat Remedies

- Identify and evaluate objectives of the system (Remedial Action Objectives, or RAOs)
- Assess whether system is achieving, or will be capable of achieving, RAOs
  - System must be evaluated within the context of current site conditions (i.e., CSM)
  - Examine current performance (in terms of CSM and RAOs)
  - Project future performance (in terms of CSM and RAOs)
- Identify and evaluate ways in which remedy performance (as measured by achievement of RAOs) can be improved

Important Question

What is the Purpose of a Groundwater Pump-and-Treat System?

Removal of Contaminant Mass

Restrict/Prevent Continued Contaminant Migration (Containment)

RAOs Usually Expressed in Terms of These Two General Goals

Remedy Screening Criteria

- **Protectiveness**
- **Effectiveness**
- **Cost-Effectiveness**
- **Preference for Treatment**
- **Permanence**

"Protectiveness" of Remedies for Groundwater

40 CFR §264.101:

"Potentially drinkable ground water would be cleaned up to levels safe for drinking throughout the contaminated plume, regardless of whether the water was in fact being consumed …"

Typical Remediation Objectives for Groundwater

Mass-Removal Objective:

- Drinking-Water Standards (MCLs)
  - TCE – 5 µg/L
  - 1,2-DCA – 2 µg/L
  - 2,3,7,8-TCDD (Dioxin) – 0.00003 µg/L
- Other Beneficial-Use Standard

Containment Objective:

- Preventing Migration, Achieving Containment
- Point-of-Compliance Issues

"Protectiveness" of Remedies for Groundwater

40 CFR §264.101:

"Potentially drinkable ground water would be cleaned up to levels safe for drinking throughout the contaminated plume, regardless of whether the water was in fact being consumed …"

"… Alternative levels protective of the environment and safe for other uses could be established for ground water that is not an actual or reasonably expected source of drinking water."

Important Question (RAOs)

Are Drinking-Water Standards Always Appropriate Cleanup Goals for Contaminants in Groundwater?

RAOs and "Effectiveness" of Groundwater Pump-and-Treat System

- Identify RAOs for the system
- System is "effective" if it achieves the stated objectives
- "Cost-effective" groundwater pump-and-treat system will achieve the stated objectives while minimizing incremental costs
  - Mass removal
  - Hydraulic containment

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Questions to Ask

- **Discuss (with O&M Contractor) progress towards meeting the RAOs and any changes to projected timeframe for completion**
  - **Is the contractor aware of RAOs?**
    - **Cleanup goals?**
    - **Preventing plume migration?**
  - **Is progress being measured?**
    - **Effectiveness of plume capture?**
    - **Timeframe?**
    - **Mass remaining?**

Questions to Ask

- **Does the CSM appear to be complete, comprehensive, and honor the available data? What unknowns remain?**
  - **Unknowns may include extent of NAPL or continuing source**

Purpose of CSM

- Provides the basis for understanding site conditions, including the occurrence, movement, and fate of contaminants
- Organizes geologic, hydrologic, and chemical information into a cohesive framework that can be used to:
  - Identify data gaps
  - Guide site investigations
  - Focus subsequent remedy selection and design

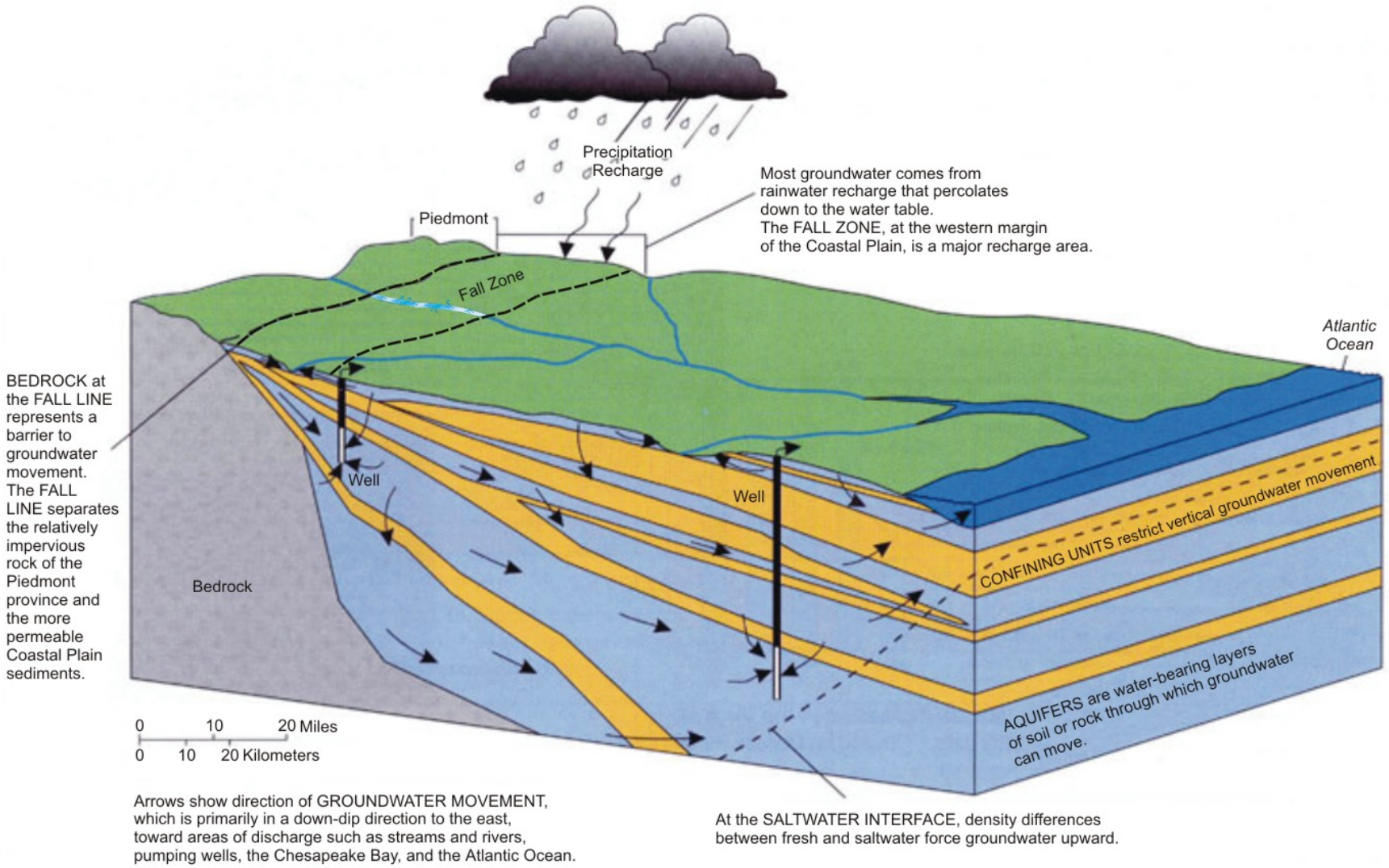
Elements of CSM

- Topography, cultural features, and climate
- Regional and local geology
- Principal hydrogeologic features
- Hydraulic properties of different hydrogeologic units
- Elevation and configuration of potentiometric surface(s)
- Surface drainage characteristics

Elements of CSM (continued)

- Surface water/groundwater interactions
- Identification of COCs
- Source(s) of contaminants
- Direction(s) and rate(s) of contaminant migration
- Fate of contaminants
- Location(s) of potential receptor(s)
- Potential exposure pathway(s)

Conceptual Representation of Some Elements of CSM



Questions to Ask

- **Is the system being properly maintained? What is the up-time for the system? What is the contractor doing to reduce their costs?**
  - **Proper Maintenance**
    - **Does the system look clean?**
    - **Preventive maintenance? System uptime?**
    - **Number of FTEs?**
  - **Cost Reduction**
    - **How are O&M costs changing over time?**
    - **What is payback period for proposed capital improvements?**

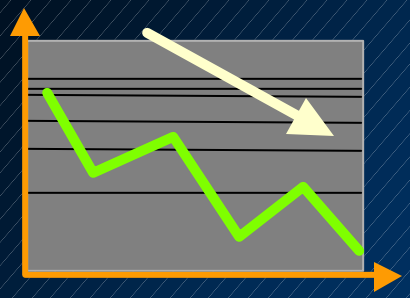
Questions to Ask

- How much contaminant mass has been removed, and how much mass remains? How much of the remaining mass is recoverable using the existing system?
- How has the cost per pound of contaminant removed changed over time?
  - Standard “Cost and Performance” comparison value
  - Allows qualitative evaluation of system effectiveness

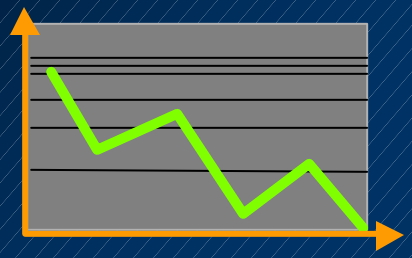
Examine Current Performance

- What is the likelihood that nature & extent of contaminants is not fully characterized?
- Is system addressing identified contaminants?
- Is mass removal occurring at an adequate rate?
- Has hydraulic containment been achieved?
- What were capital costs?
- What are current O&M costs?

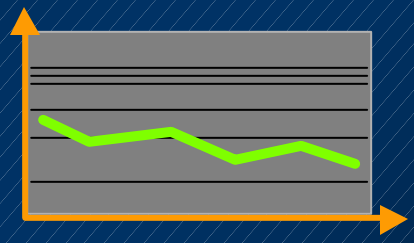
System Performance – Trends in Concentrations of COCs



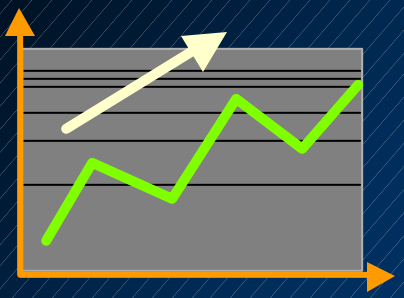
Decreasing Trend



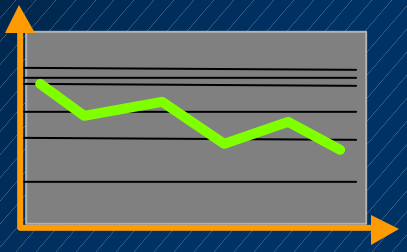
Strong Trend



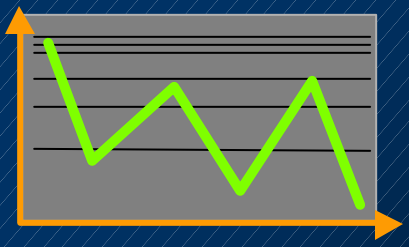
Stable Trend



Increasing Trend

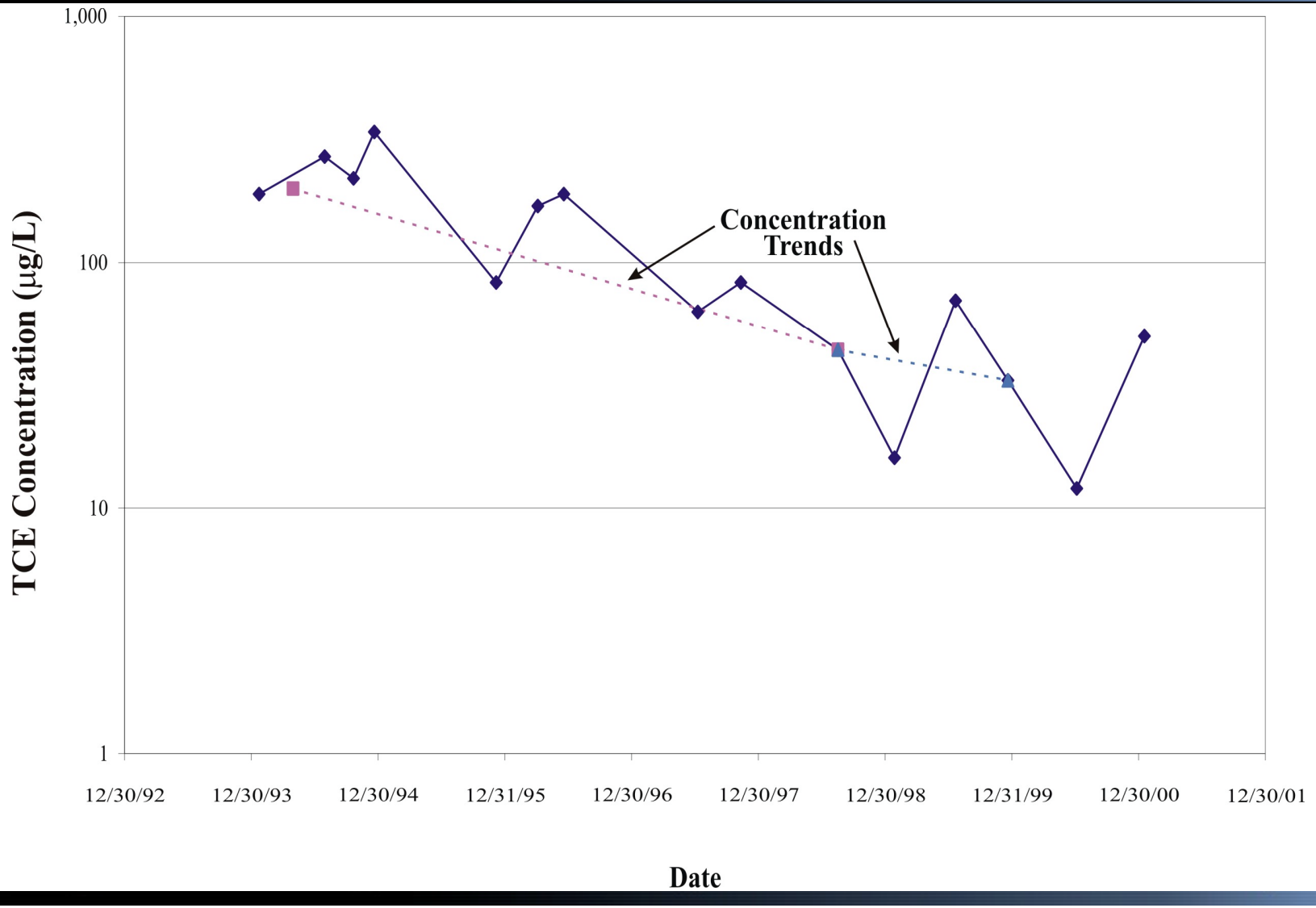


Weak Trend

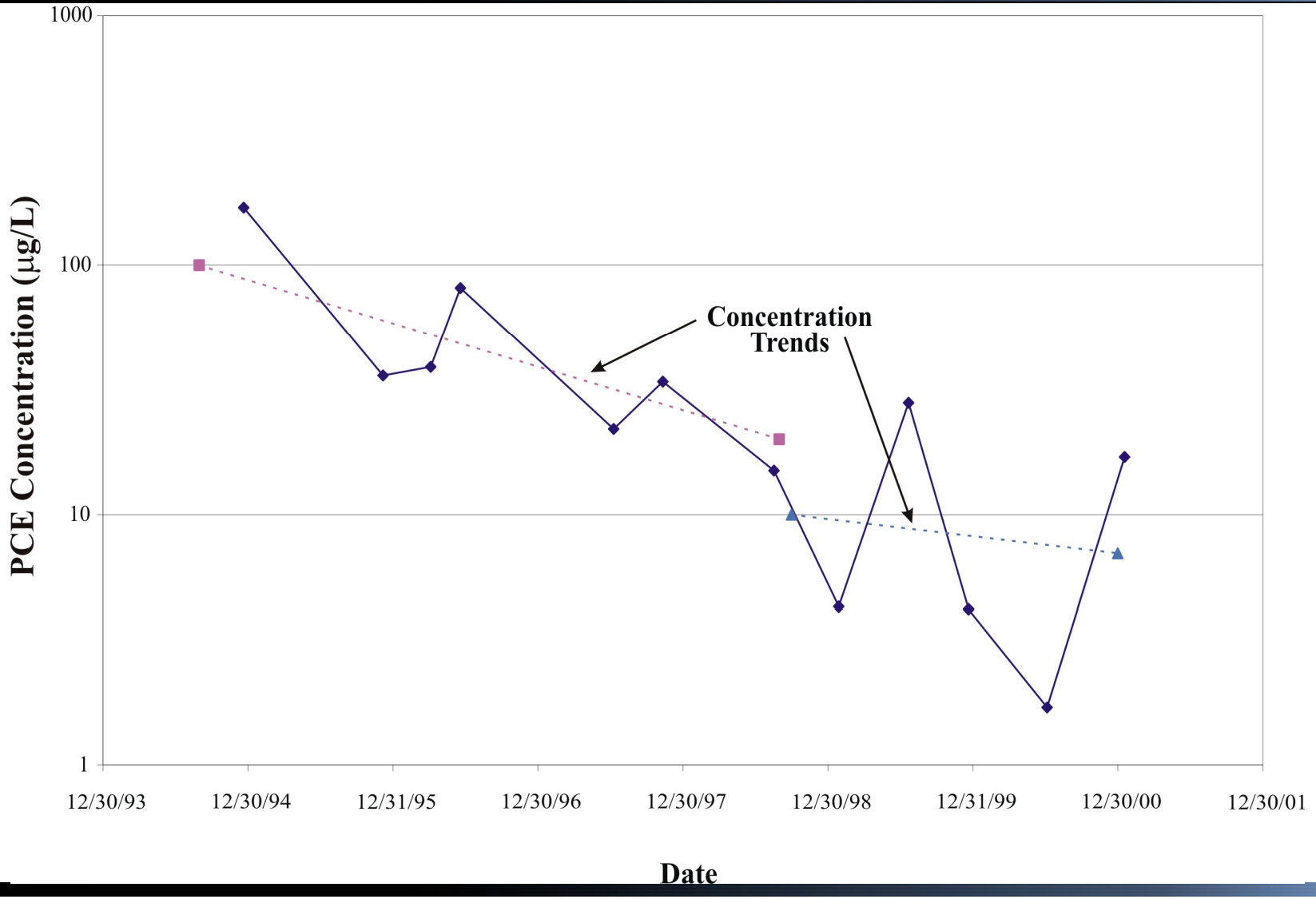


Fluctuating Trend

Concentrations of TCE Though Time in Extraction-Well Effluent



Concentrations of PCE Though Time in Extraction-Well Effluent



Questions to Ask During Initial Screening Evaluation

- **What masses of priority pollutants and greenhouse gases are being produced? How does this compare to the amount of contaminants removed?**
  - **McClellan AFB example**
    - **29 million gallons/month; 44 ppb VOCs influent**
    - **Removed 10 lbs VOCs/month (0.3 lbs/day)**
    - **Air stripper, liquid GAC, thermal oxidation of air**
    - **35 tons CO_2/month, plus NOx, dioxins, & furans**
    - **Recommended use liquid-phase GAC**

Project Future Performance

- Will system continue to address identified contaminants?
- Will mass removal proceed at a rate sufficient to achieve RAOs within a reasonable timeframe?
- Will hydraulic containment continue?
- What is likely range of future capital and O&M costs?

Questions to Ask

- **Is the contractor capable of providing recommendations regarding potential improvements to the existing system? Can the contractor implement those recommendations and track the results?**
- **Who is interested in optimizing the system?**
  - **Are appropriate parameters being tracked?**
  - **Is someone making decisions based on these data?**
  - **USEPA recommends that independent technical evaluations provide better opportunities for improving systems**

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Improvements in Remedy Performance

- Is groundwater pump-and-treat still a viable remedy for groundwater at this site?
- Can existing pump-and-treat remedy be improved?
  - Mass removal
  - Hydraulic containment
- What are some other alternatives?

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Case Histories

- **Defense Depot Ogden, Utah (DDOU)**
- **Defense Depot San Joaquin (DDJC) - Tracy**
- **Defense Supply Center Richmond, Virginia (DSCR)**

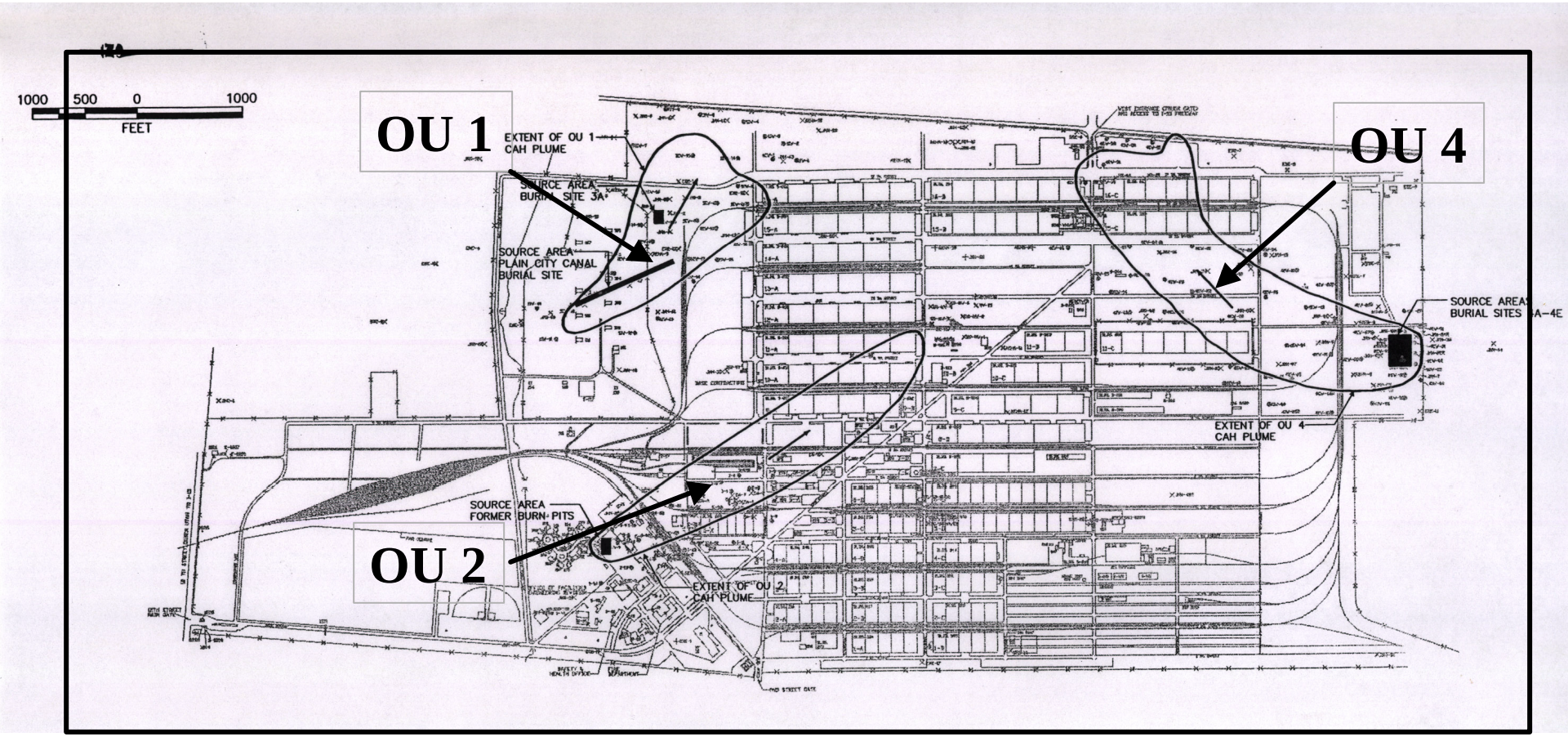
History of DDOU

- Activated in 1941
- Historic use as storage depot and equipment-repair facility
- Industrial activities used/generated organic chemicals, petroleum fuels, waste oils, spent solvents, solid wastes
- Disposal in waste pits/burn pits
- Listed on NPL in 1987; ROD signed 1992
- Decommissioned through BRAC process; transferred for non-military uses in December 2002

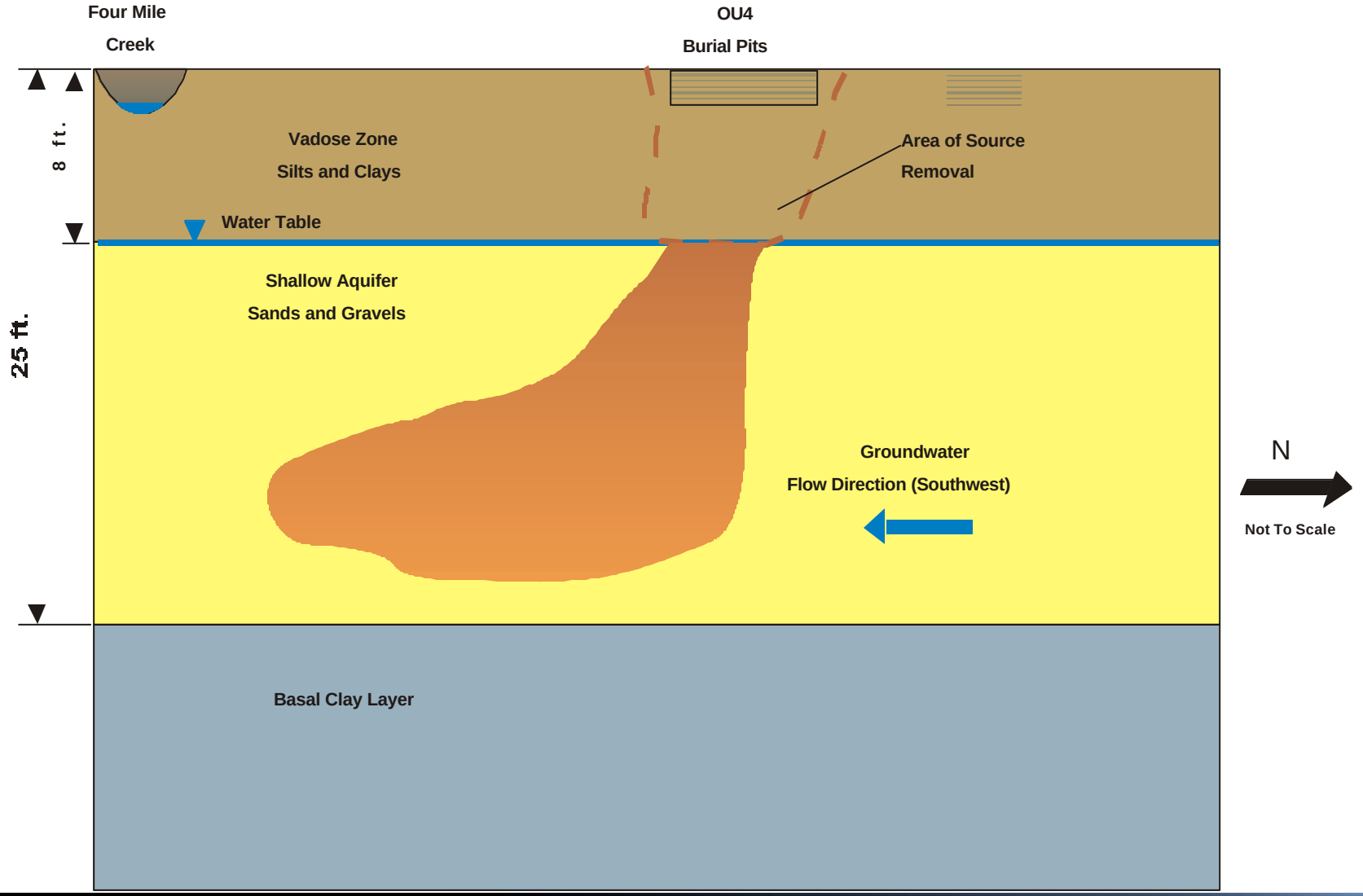
Operable Units at DDOU

- **OU-1 – Burial Sites 1, 3-B, 3-C;**
  Contaminated Groundwater Plume
- **OU-2 – Burn Pits;**
  Contaminated Groundwater Plume
- **OU-3 – Plain City Canal/Burial Site 3-A**
- **OU-4 – Burial Sites 4-A, 4-B, 4-C, 4-D, 4-E;**
  Contaminated Groundwater Plume

Operable Units – DDOU



Simplified CSM for DDOU



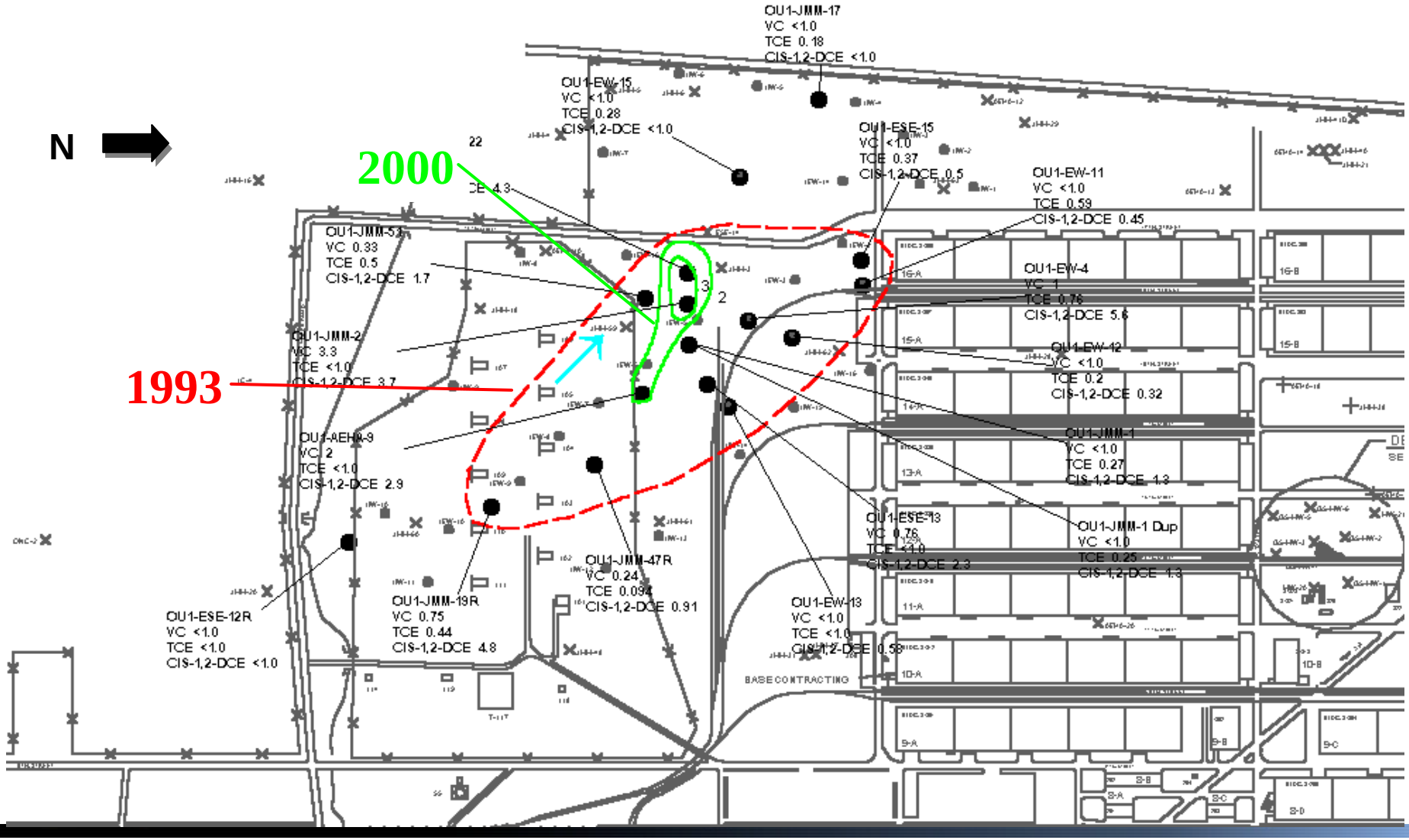
RAOs – DDOU

- Cleanup to MCLs
- Highest beneficial use of groundwater – drinking water
- Prevent off-depot migration

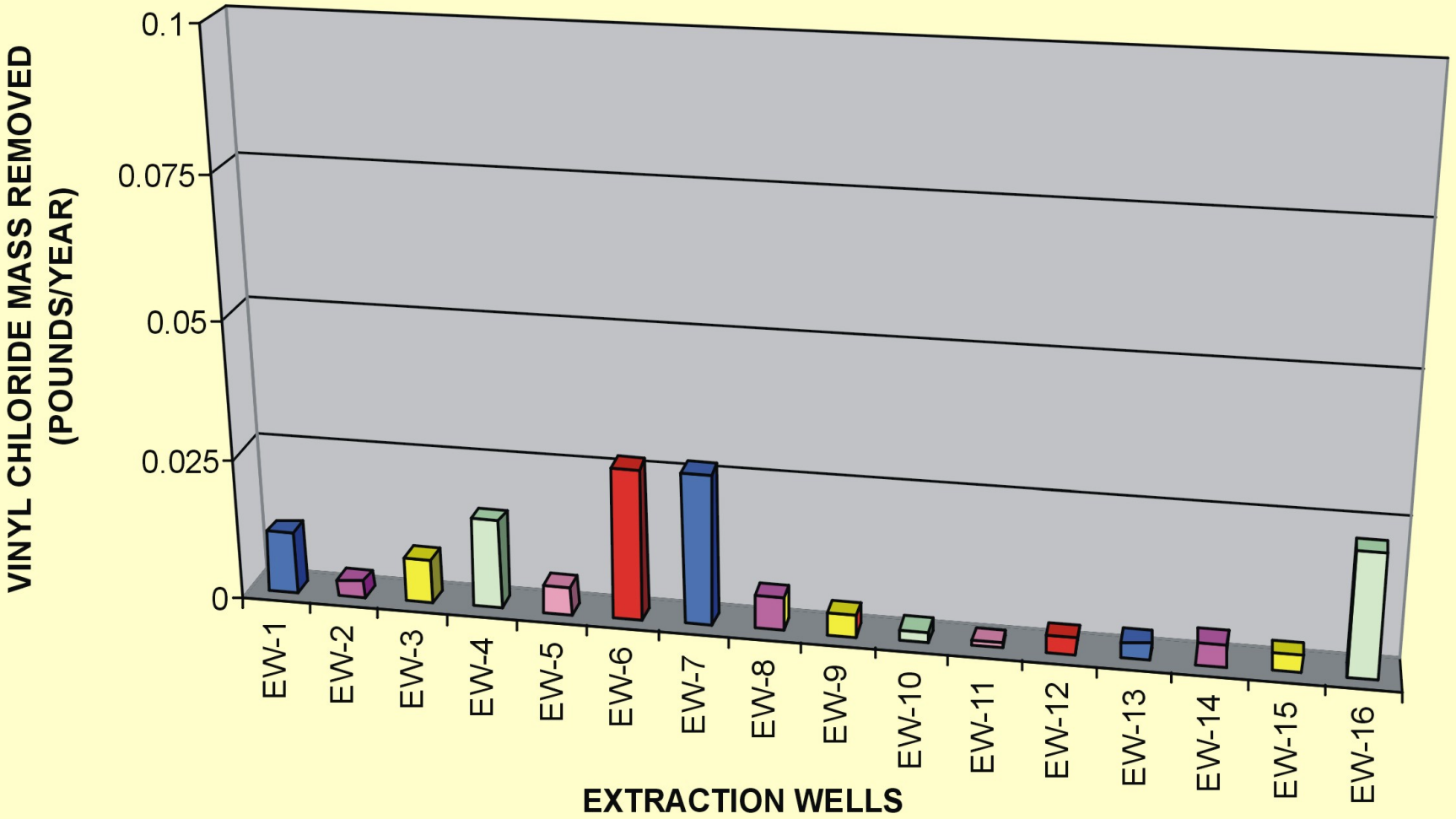
OU1 Groundwater ETI System

- ETI system operational since late 1994 (soil removal completed 8/94)
- Principal groundwater contaminants are *cis*-1,2-DCE and vinyl chloride (TCE daughter products)
- 16 groundwater extraction wells in system; design extraction rate ~100 gpm
- Groundwater treatment plant
  - Air stripper
  - Treated groundwater re-injected via 16 injection wells
- Approximately 15 monitoring wells
- OPS certification granted in November 2001

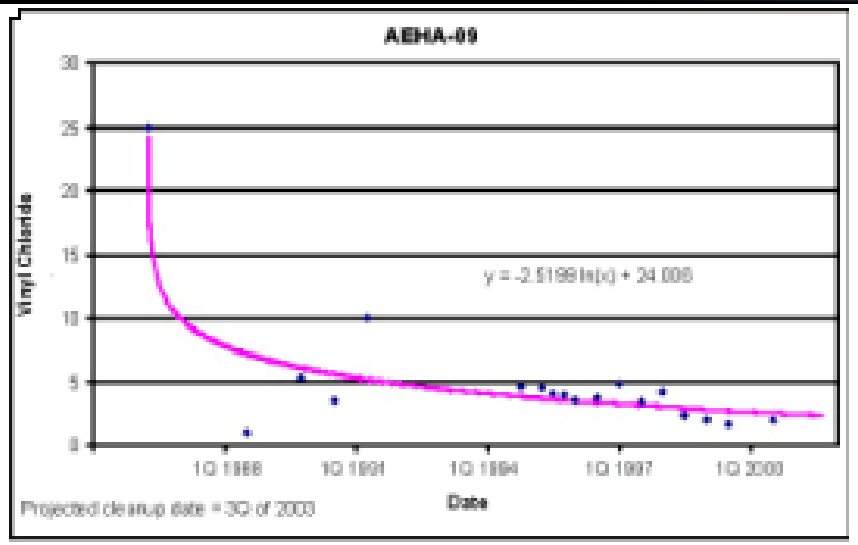
Comparison of Extent of Vinyl Chloride at OU1 – 1993 & 2000

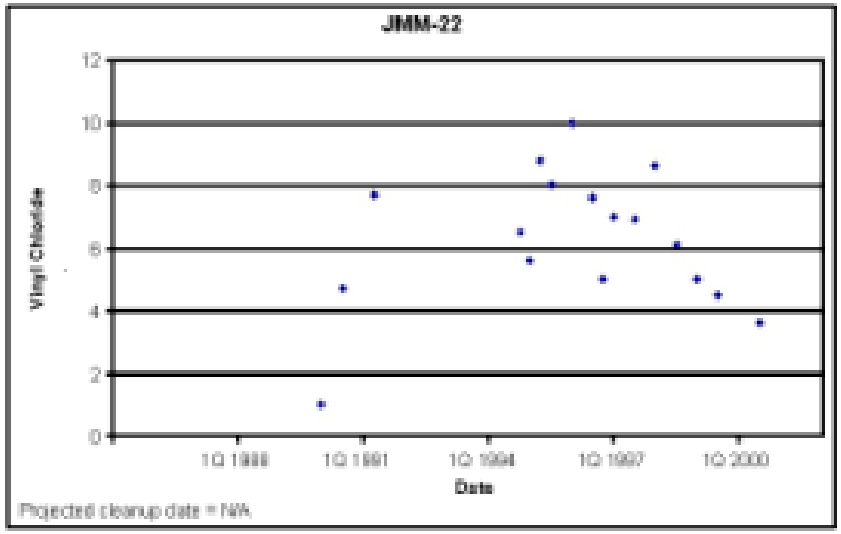


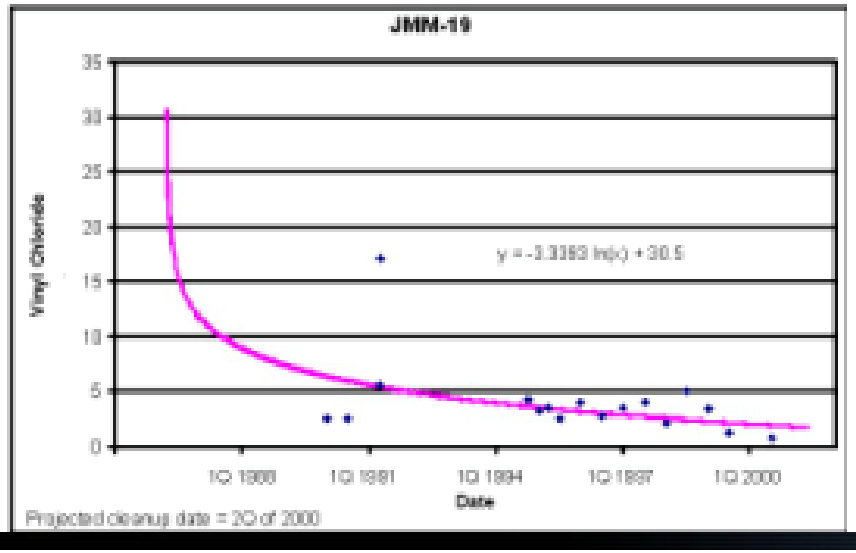
VC Mass Removal by Well During 2000 – OU1

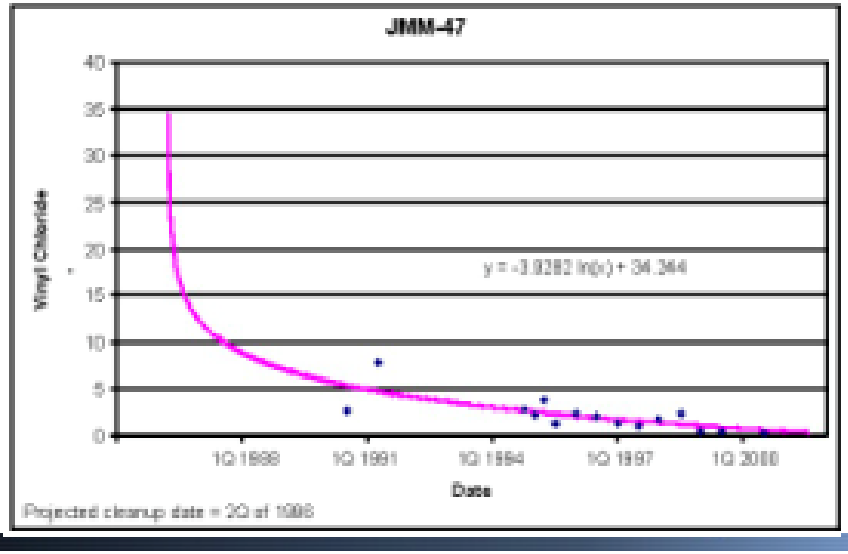


Temporal Trends and Cleanup Times for VC – OU1

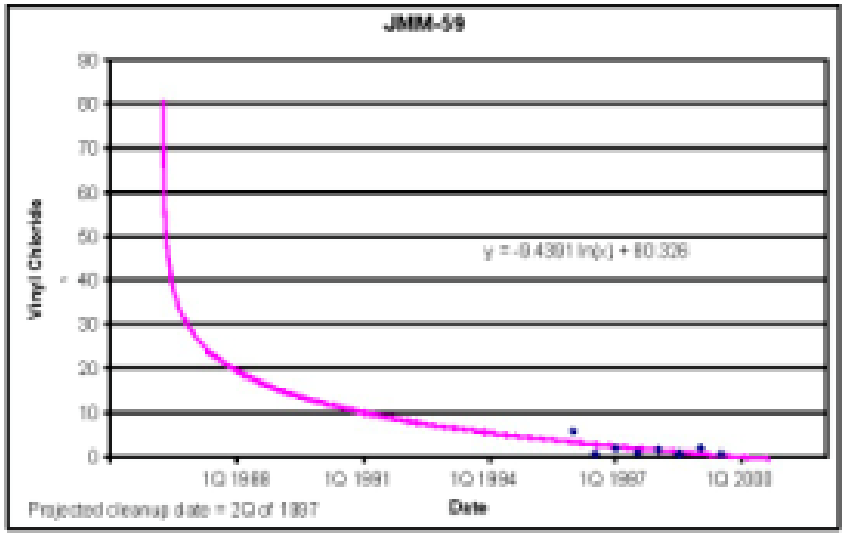


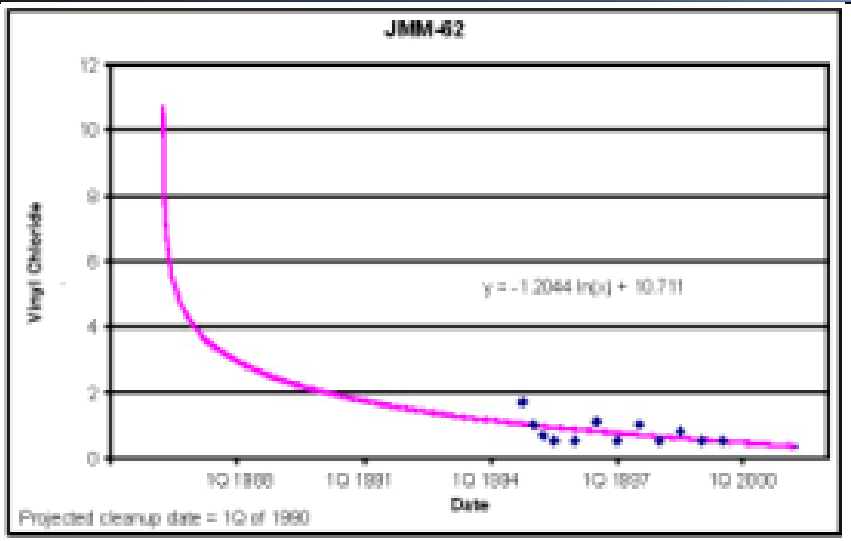


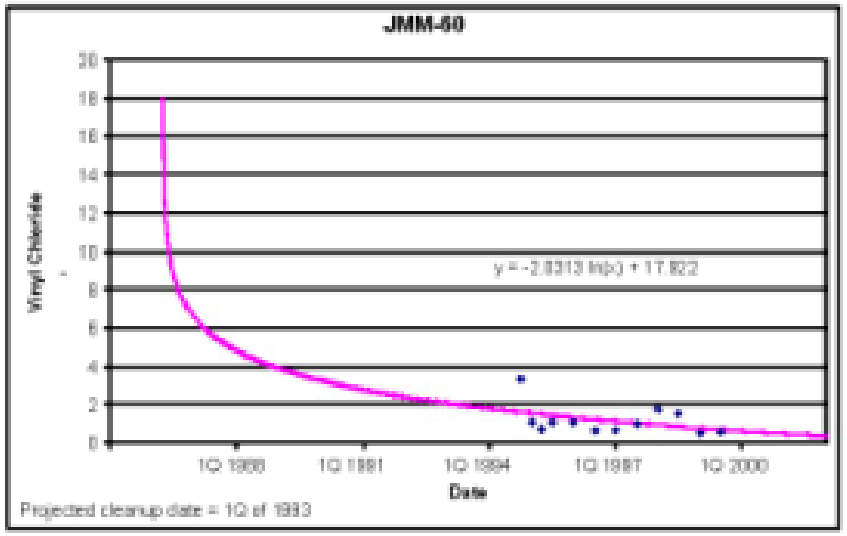




Temporal Trends and Cleanup Times for VC – OU1 (cont)







Summary of Capital and OM&M Costs

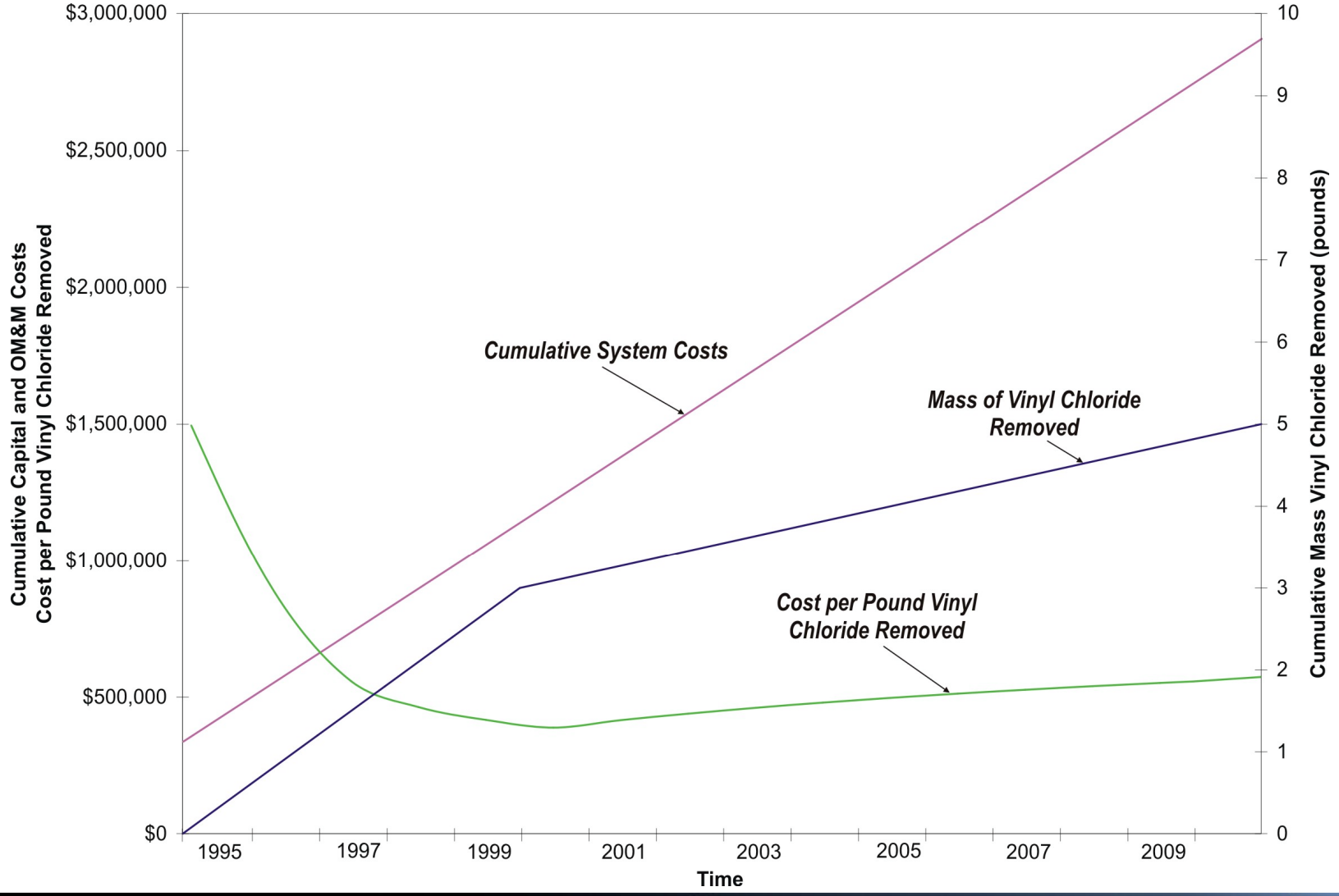
Operable Unit 1

Item	Costs
Capital Costs [a/]	$340,000
Annual OM&M Costs [b/]	$340,000
Total Cost to Date [b/]	$2,380,000

Cost Per Pound of Vinyl Chloride Removed	Costs
Mass of vinyl chloride removed to date (pounds)	~ 3
Cost per pound of vinyl chloride removed (to date) [b/]	$793,000
Current rate of vinyl chloride mass removal (pounds per year)	0.2
Mass of vinyl chloride removed (end of 2003) at current removal rate (pounds)	5.0
Cost per pound of vinyl chloride removed by end of year 2003 [b/]	$944,000

a/ - 1994 dollars b/ - 2000 dollars

Projected Cumulative Costs and VC Mass Removal for OU1 ETI System

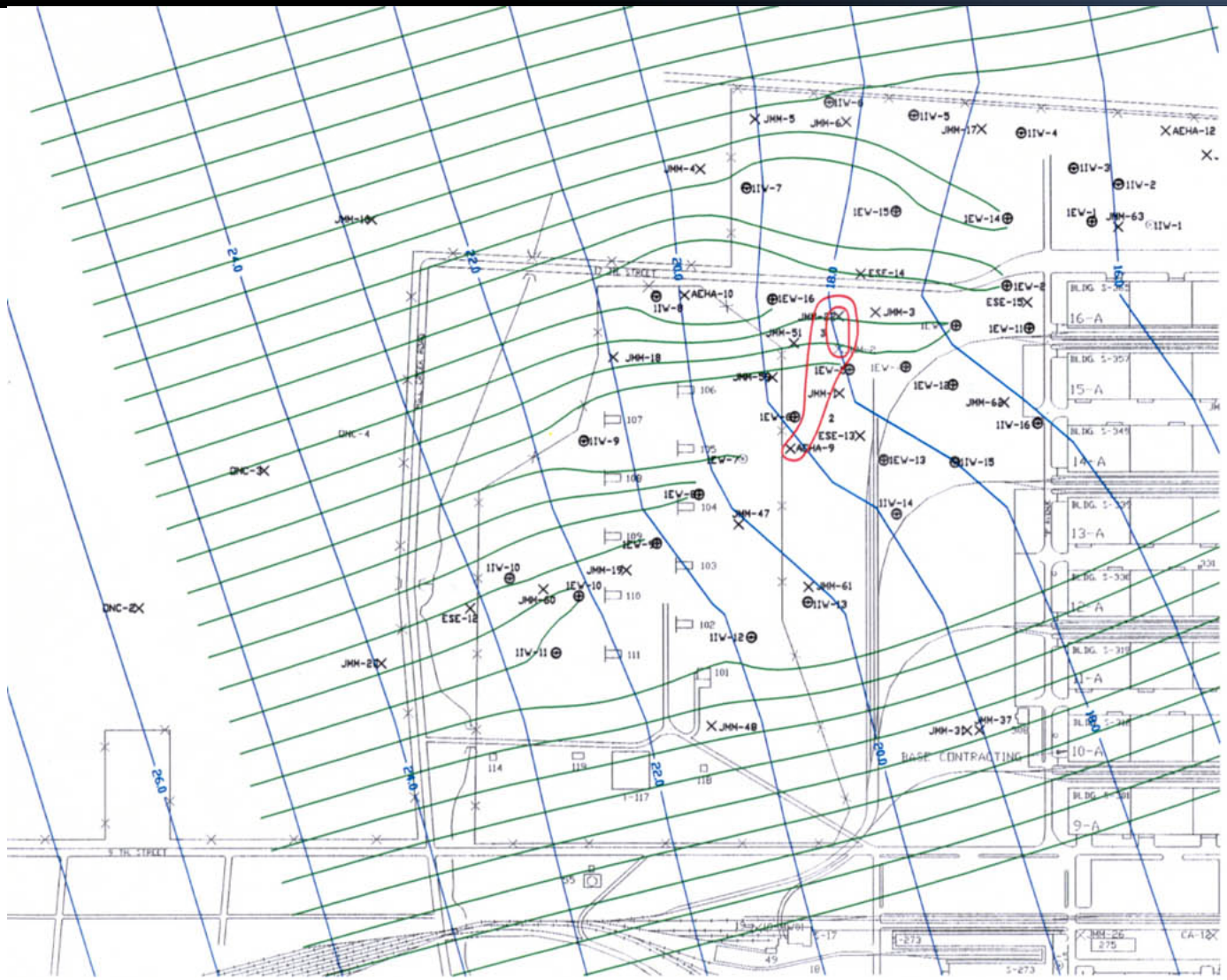


DDOU OU1
Effectiveness – Mass Removal

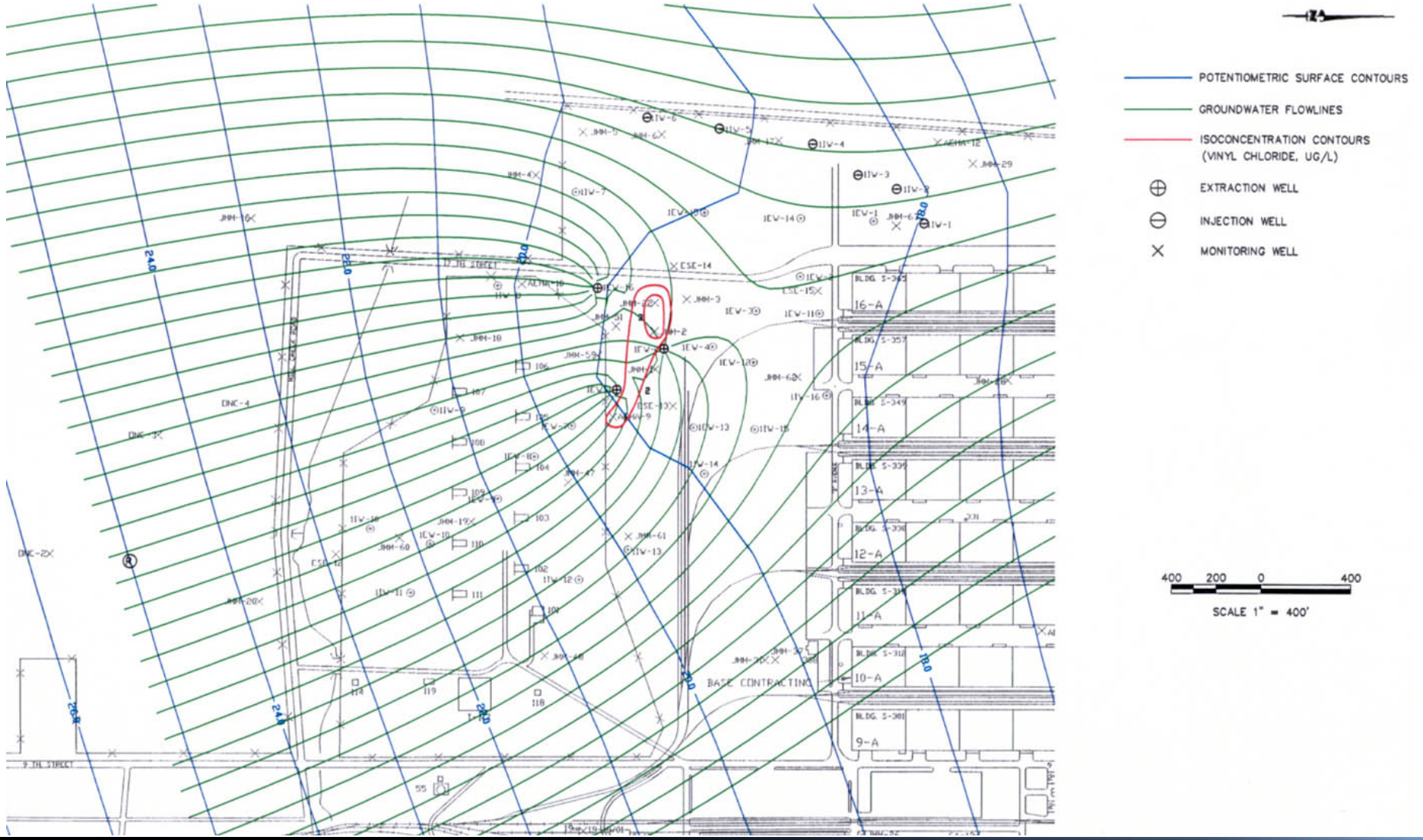
- **Nearly all mass is removed by 4 wells**
- **Total of 5 lbs of vinyl chloride removed during 7-year operational history**

Effective?

Containment of Contaminants OU1 Current System



Containment of Contaminants OU1 Optimized System



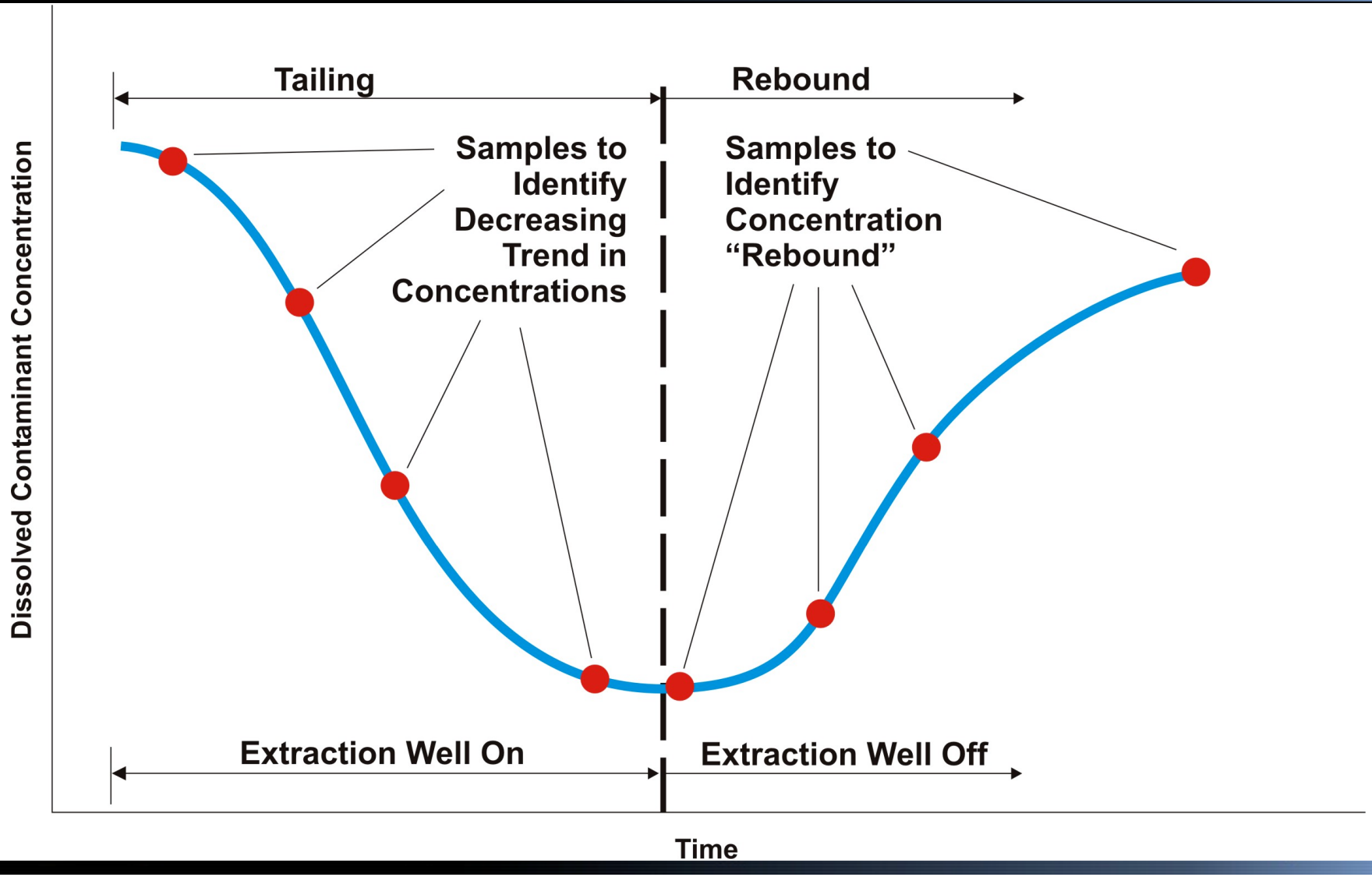
Results of Evaluation of Groundwater ETI System – OU1

- Mass removal virtually nil; containment could be achieved by reduced groundwater ETI system
  - Consider reducing number of extraction wells
- Migration may not occur (natural attenuation)
  - Consider conducting “rebound” test

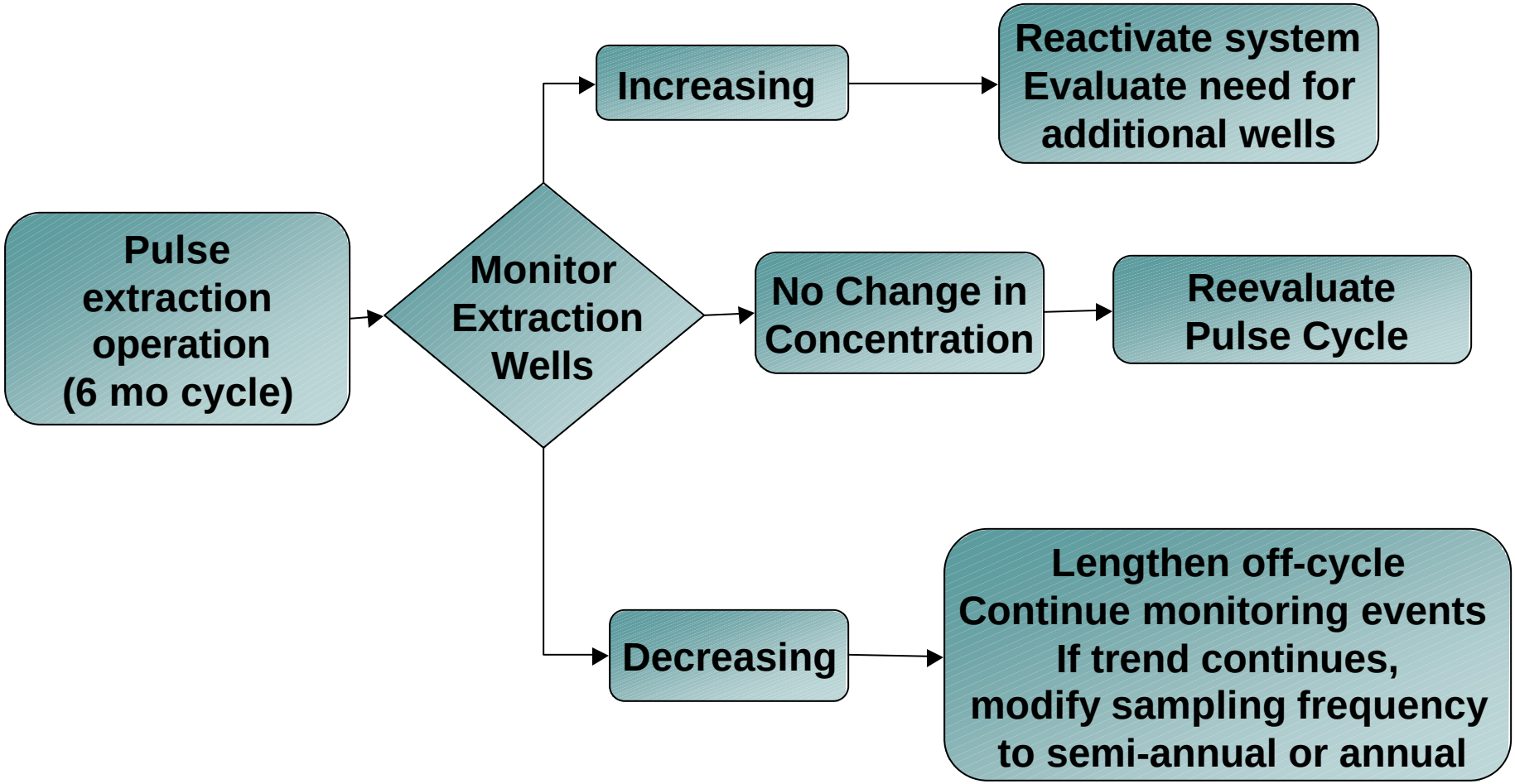
"Rebound" Test

- **Take groundwater extraction well(s) off-line temporarily**
- **Periodically monitor contaminant concentrations in out-of-service extraction well(s)**
- **Develop contingency(ies)**
- **If concentrations remain at acceptable levels, remove well(s) from service permanently**

Groundwater Sampling During "Rebound"



Example Decision Tree for "Rebound" Testing



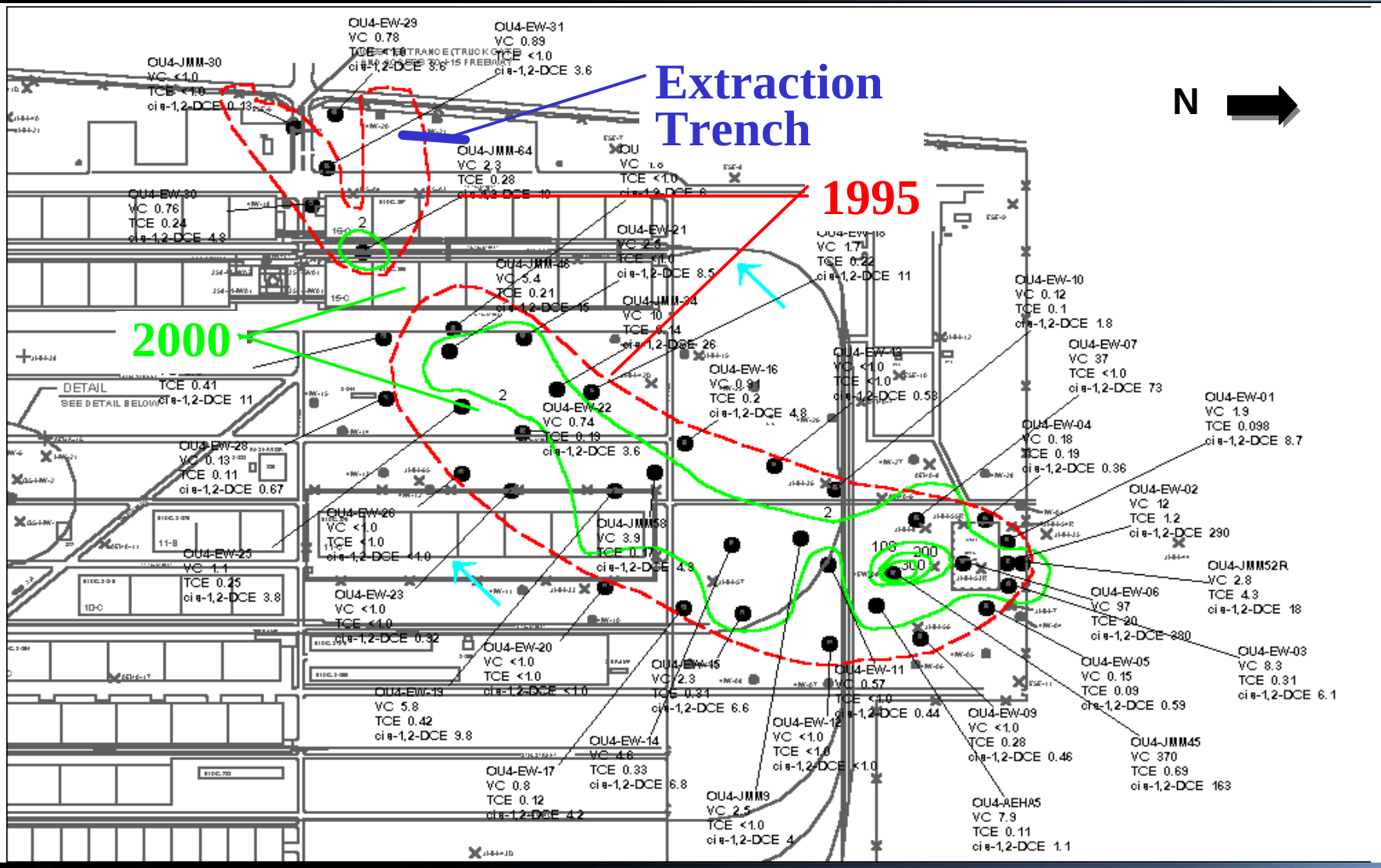
DDOU Optimization Opportunities

- **Operable Unit 1 (OU1)**
  - **7 groundwater extraction wells removed from active service (October 2001)**
  - **Current discharge rate ~ 55 gpm**
  - **“Rebound” testing to be conducted with extraction wells to remain off-line or be re-started in accordance with decision framework**

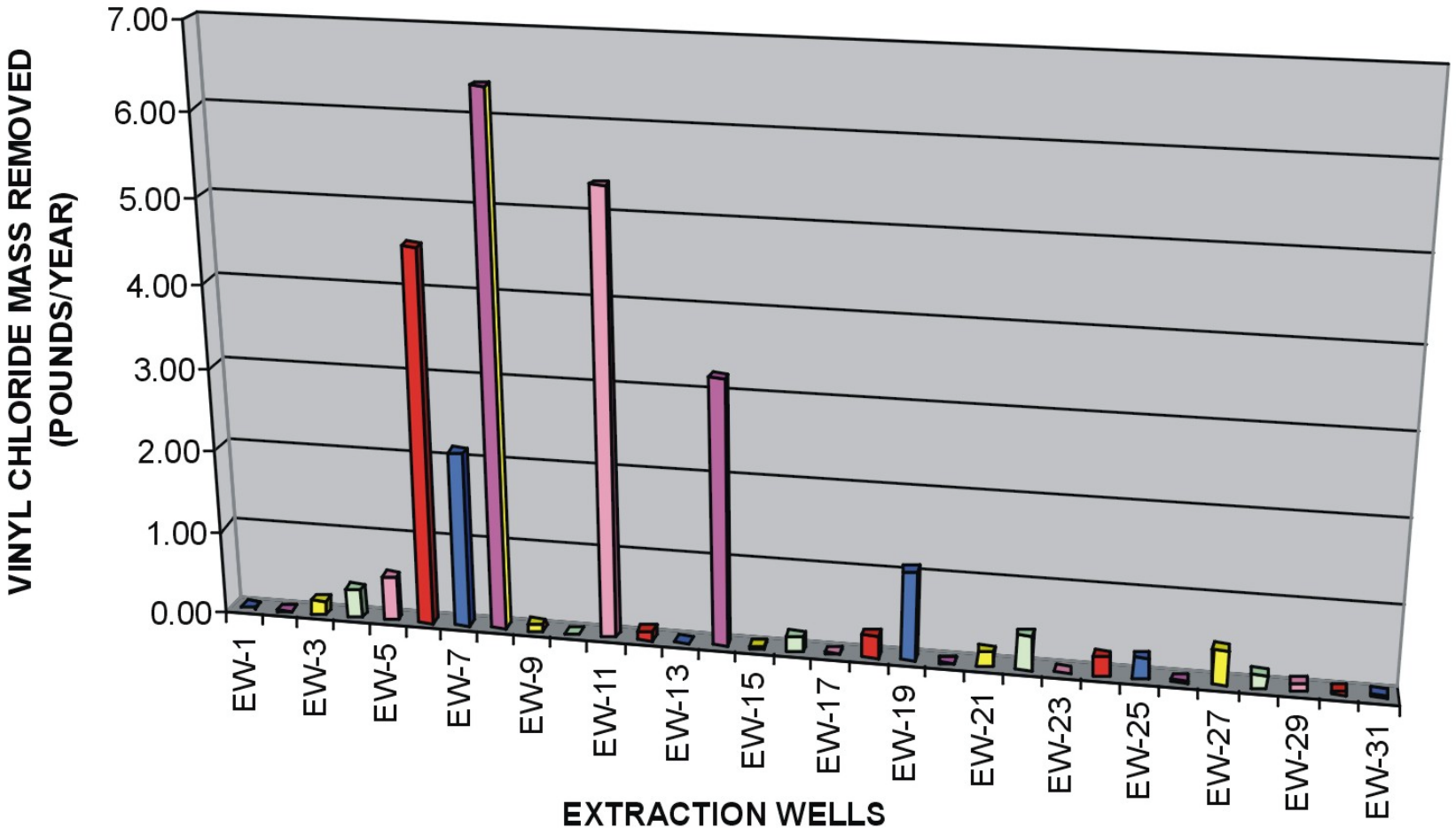
OU4 Groundwater ETI System

- Groundwater ETI system installed and operational since 1995 (source removal completed 1998)
- 31 groundwater extraction wells; design extraction rate ~120 gpm
- Groundwater treatment plant
  - Air stripper to remove VOCs
  - Treated groundwater re-injected via 25 injection wells
- Interceptor trench at “Hotspot” plume
- Ozone/hydrogen peroxide groundwater treatment plant; treated water discharged to sewer
- Approximately 20 groundwater monitoring wells
- OPS certification granted in August 2000

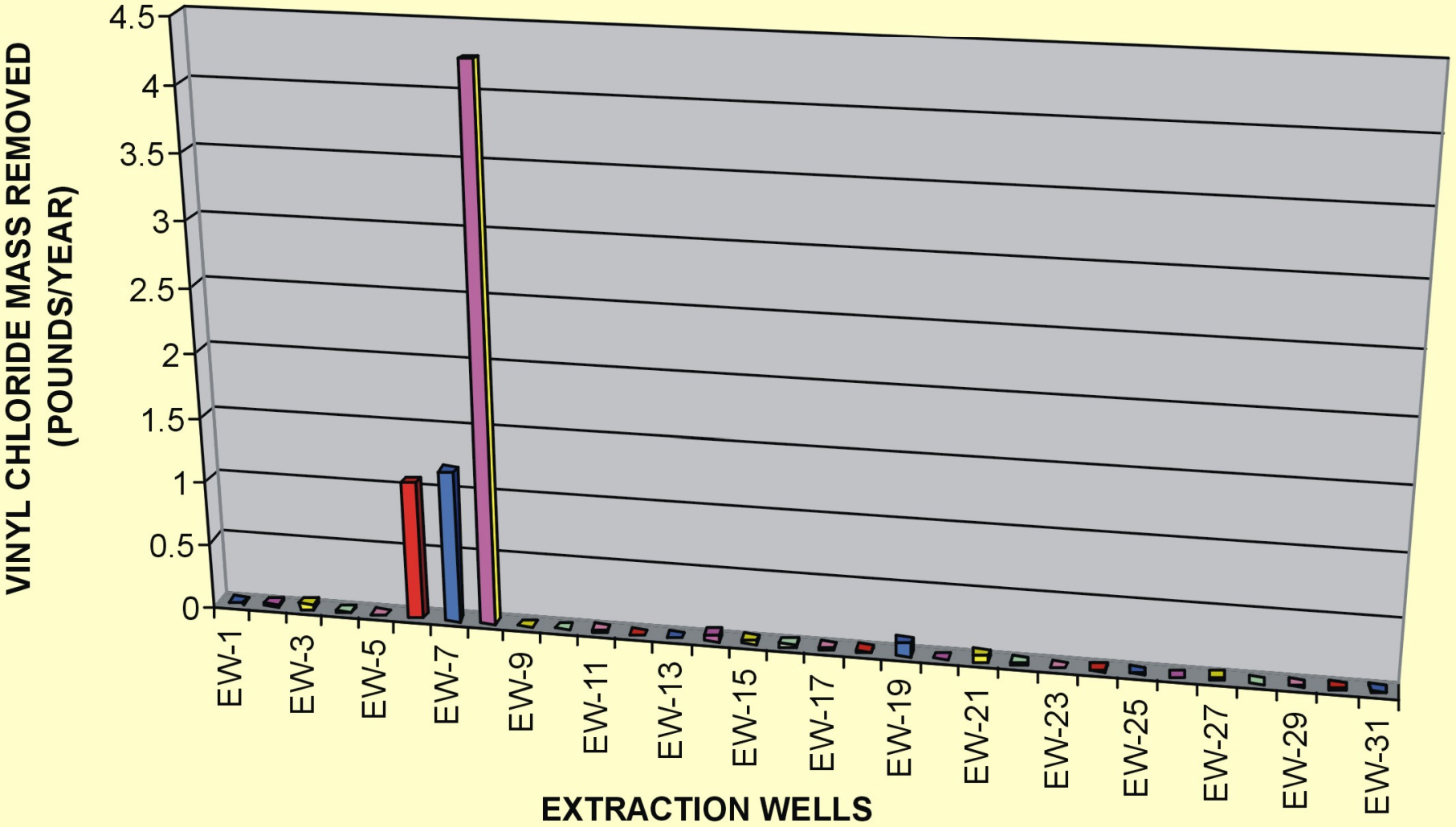
Comparison of Extent of Vinyl Chloride at OU4 – 1995 & 2000



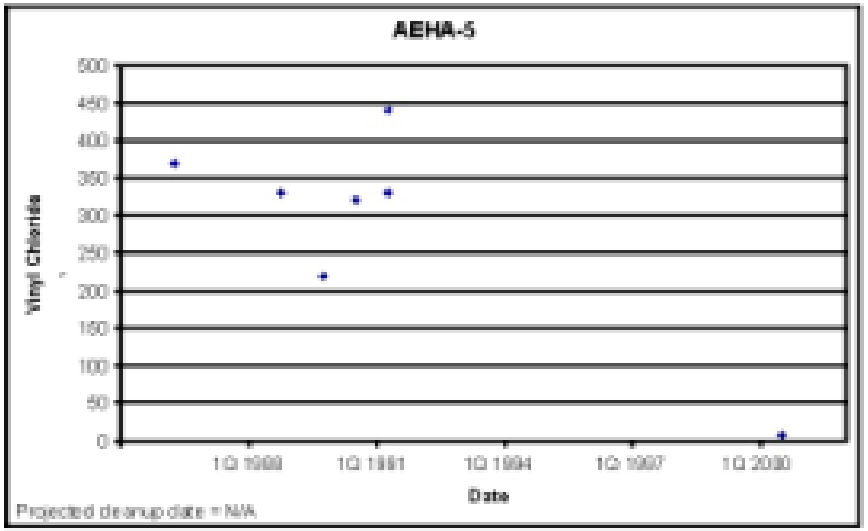
VC Mass Removal by Well During 1995 – OU4

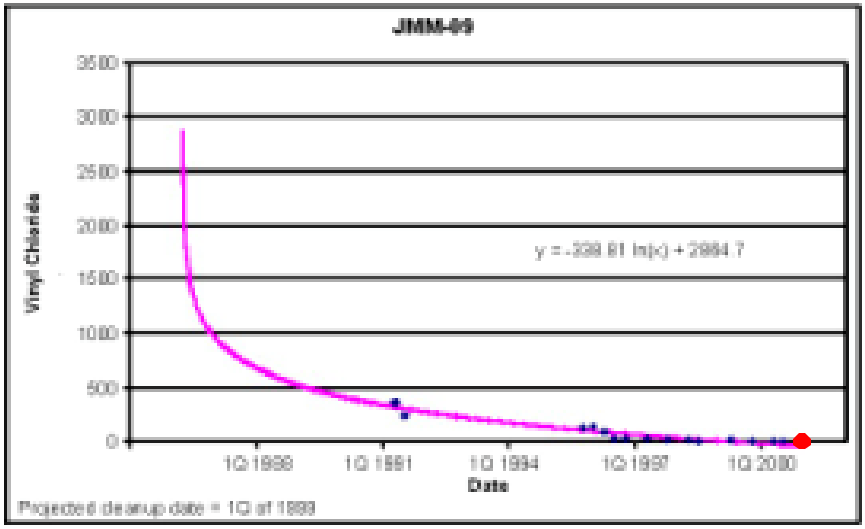


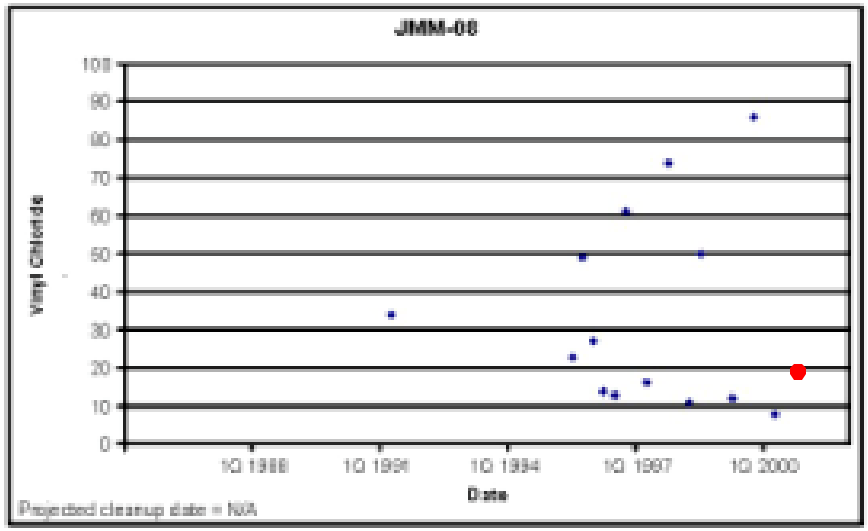
VC Mass Removal by Well During 2000 – OU4

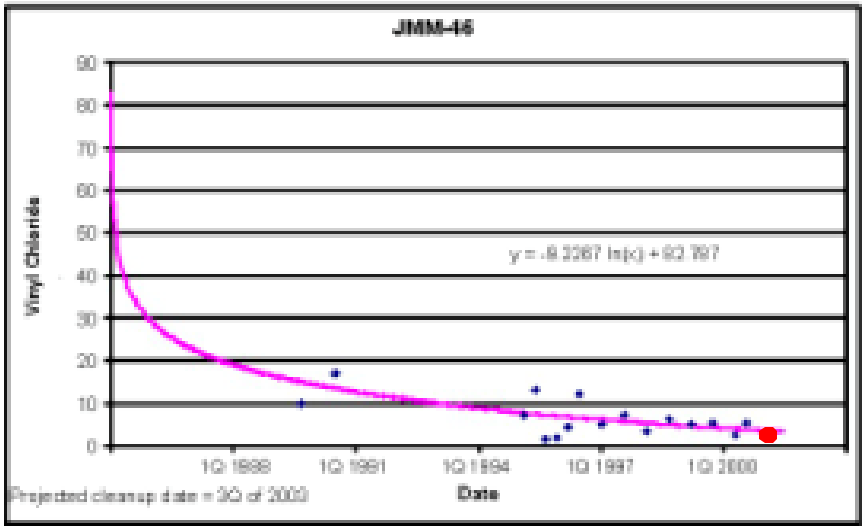


Temporal Trends and Cleanup Times for VC – OU4

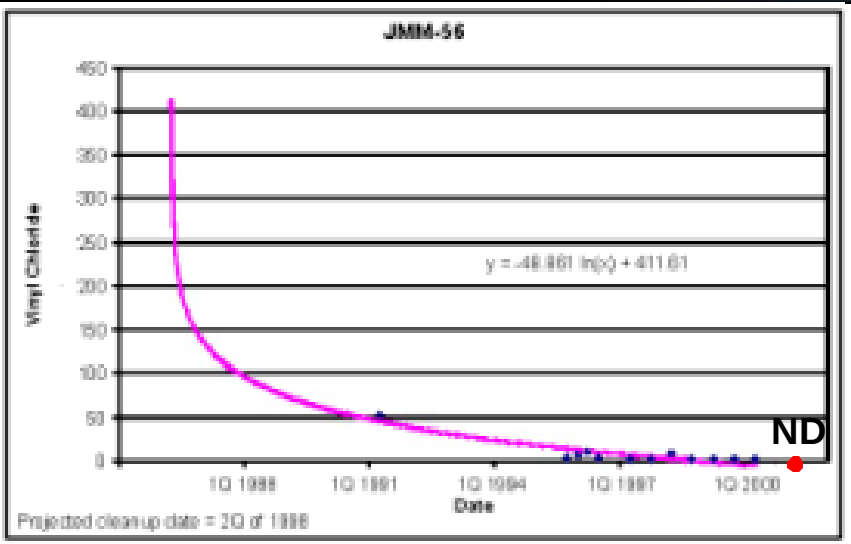


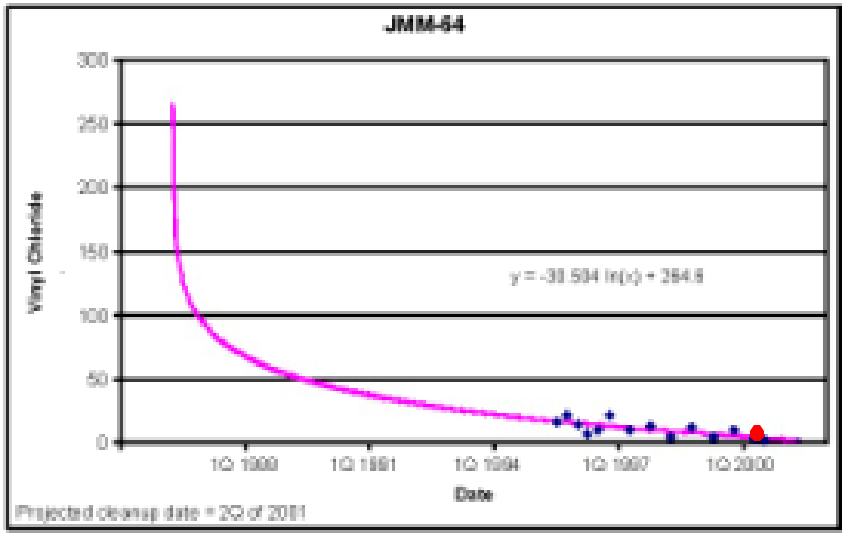


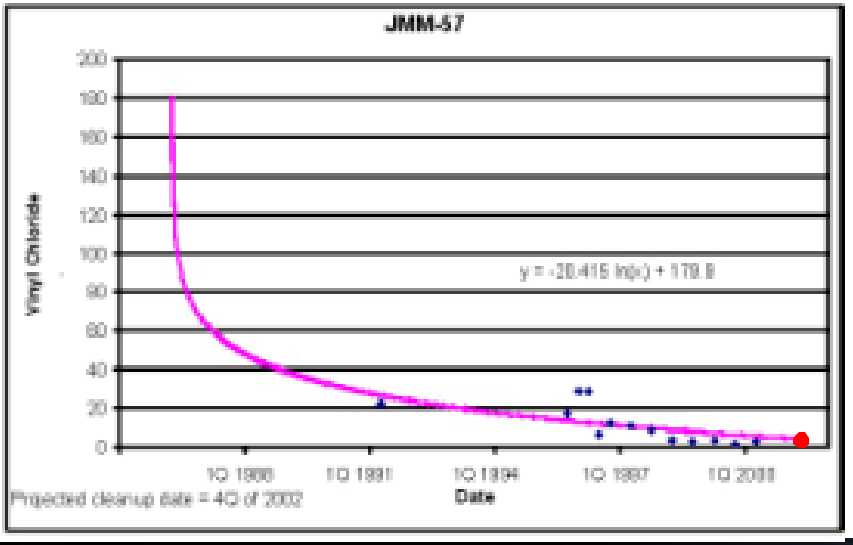




Temporal Trends and Cleanup Times for VC – OU4 (cont)







- **June 2001 Sampling Event**

Summary of Capital and OM&M Costs

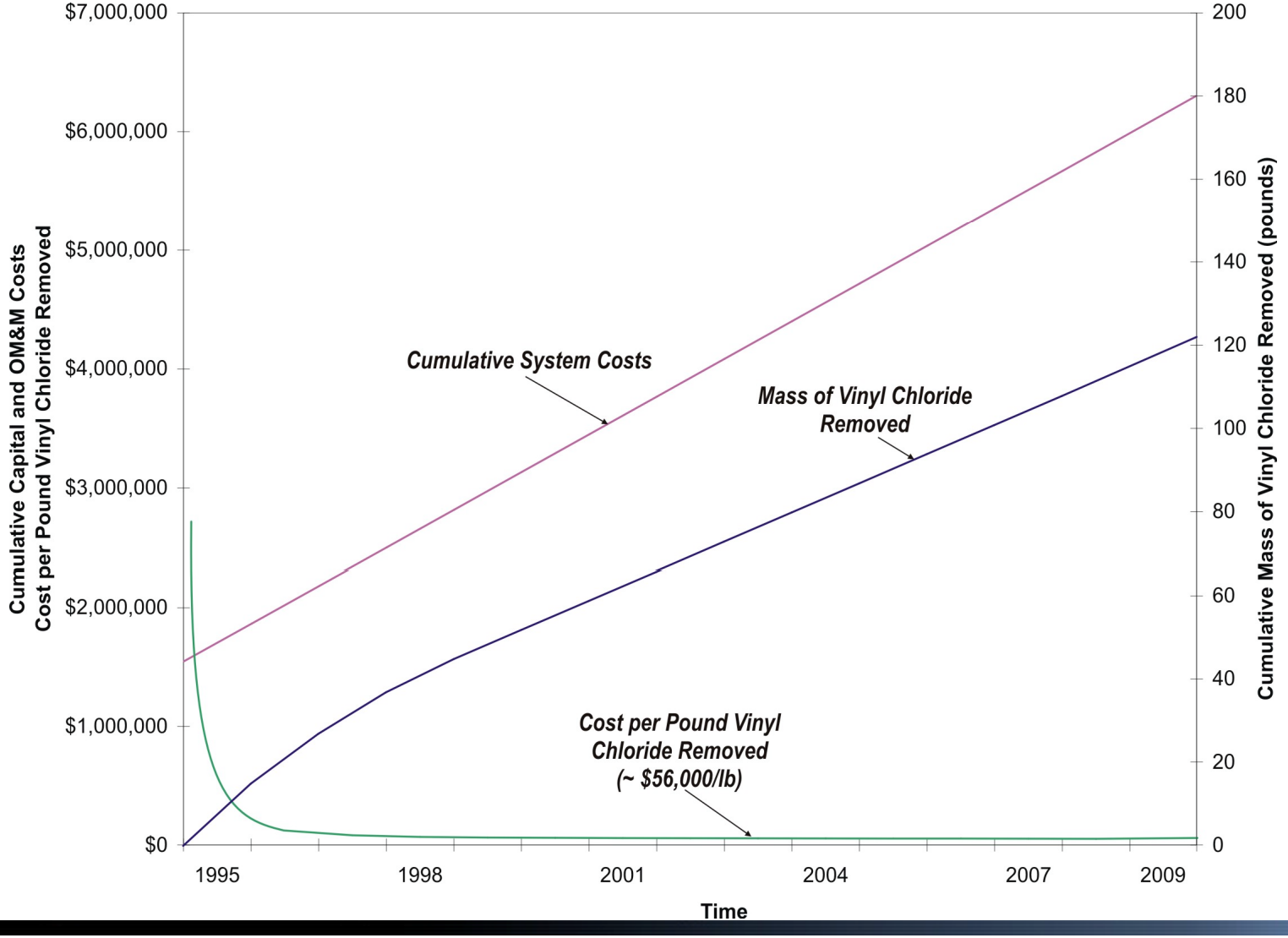
Operable Unit 4

Item	Costs
Capital Costs	
OU4 "Main Plume" System [a/]	$1,057,00
OU4 "Hot Spot" System [b/]	$507,000
Annual OM&M Costs [b/]	$614,000
Total Cost to Date [b/]	$4,634,000

Cost Per Pound of Vinyl Chloride Removed	Costs
Mass of vinyl chloride removed to date (pounds)	~ 57
Cost [b/] per pound of vinyl chloride removed (to date)	$81,300
Current rate of vinyl chloride mass removal (pounds per year)	7
Mass of vinyl chloride removed (end of 2003) (pounds)	78
Cost [b/] per pound of vinyl chloride removed by end of 2003	$83,000

a/ - 1995 dollars b/ - 2000 dollars

Projected Cumulative Costs and VC Mass Removal for OU4 ETI System



DDOU OU4
Effectiveness – Mass Removal

- Nearly all mass is removed by 3 wells
- Total of 57 lbs of vinyl chloride removed during 6-year operational history

Effective?

Results of Evaluation of Groundwater ETI System – OU4

- Rate of mass removal very low; containment could be achieved by reduced groundwater ETI system
  - Consider reducing number of extraction wells
- Migration may not occur (natural attenuation)
  - Consider conducting “rebound” test

DDOU Optimization Opportunities

- **Operable Unit 4 (OU4)**
  - **14 groundwater extraction wells removed from active service (January 2002)**
  - **Current discharge rate ~60 gpm**
  - **“Rebound” testing conducted with extraction wells to remain off-line or be re-started in accordance with decision framework**

Optimization Results – OU1 & OU4 Groundwater ETI Systems

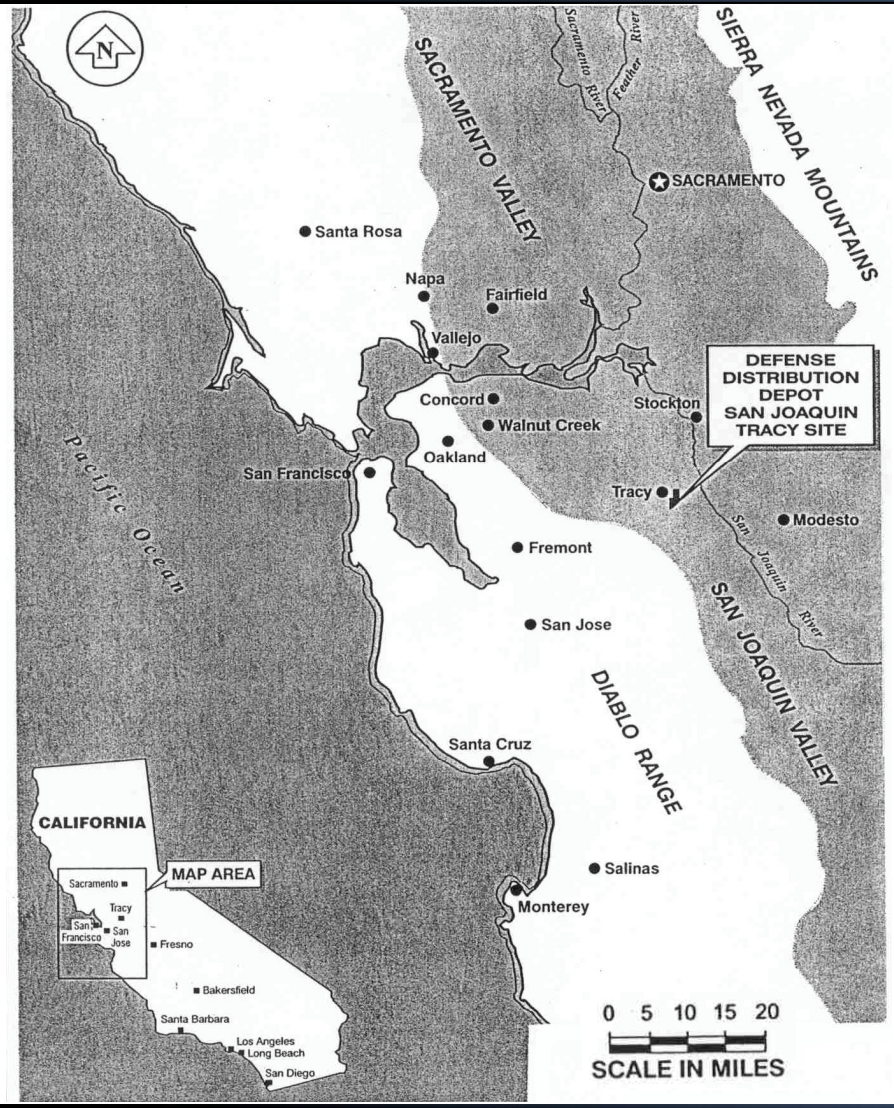
Outcome of Meeting with USEPA and Utah DEQ :

- Identify wells to be removed from service
- Identify injection wells to be re-located
- Propose monitoring and operational changes in a decision tree format
- Prepare implementation work plan and submit to regulatory agencies for approval
- Prepare delisting package
- Entire installation transferred in December 2002

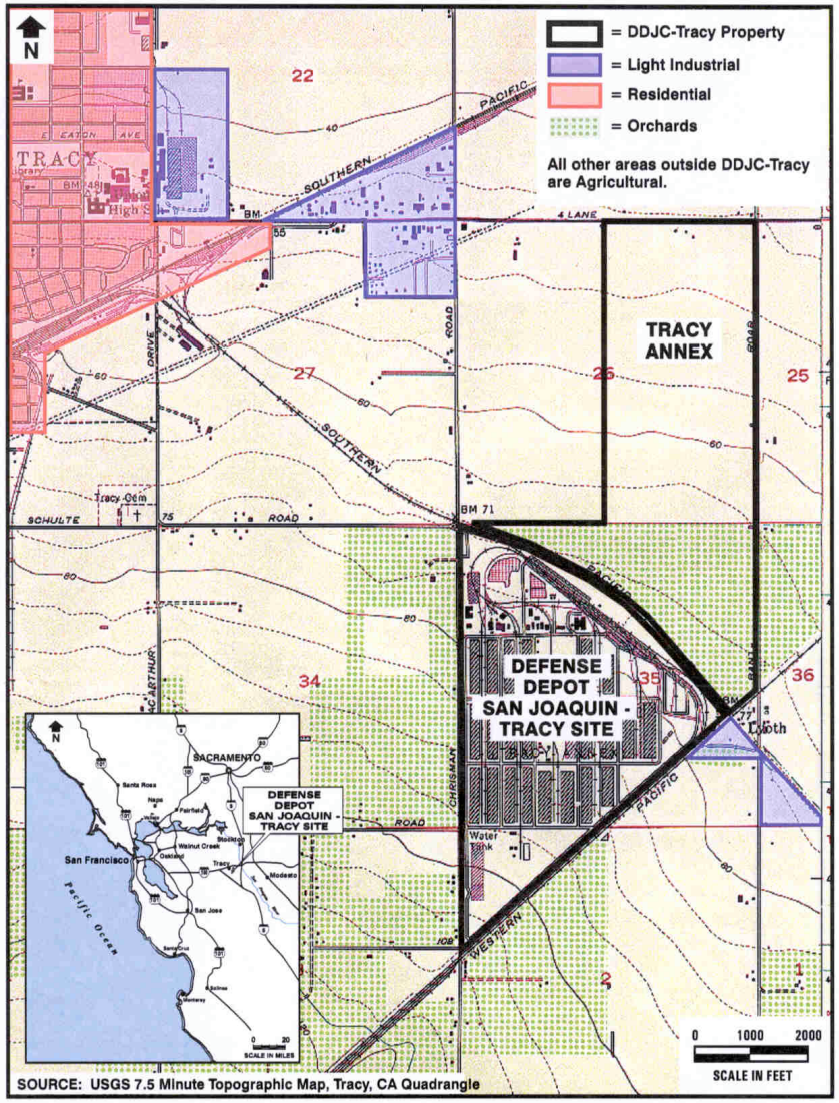
Case Histories

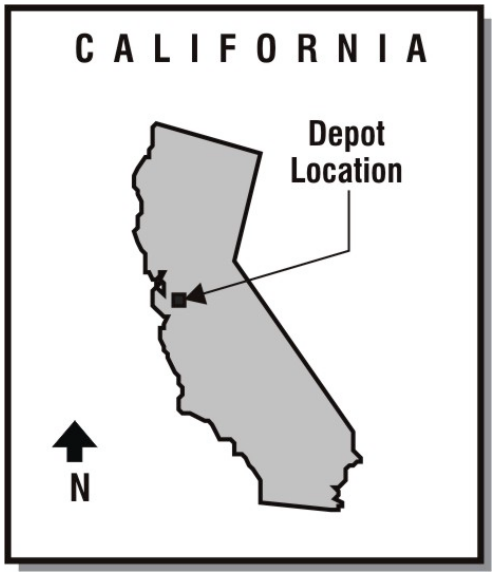
- Defense Depot Ogden, Utah (DDOU)
- **Defense Depot San Joaquin (DDJC) - Tracy**
- Defense Supply Center Richmond, Virginia (DSCR)

DDJC-Tracy -- Facility Location



Depot and Annex Layout



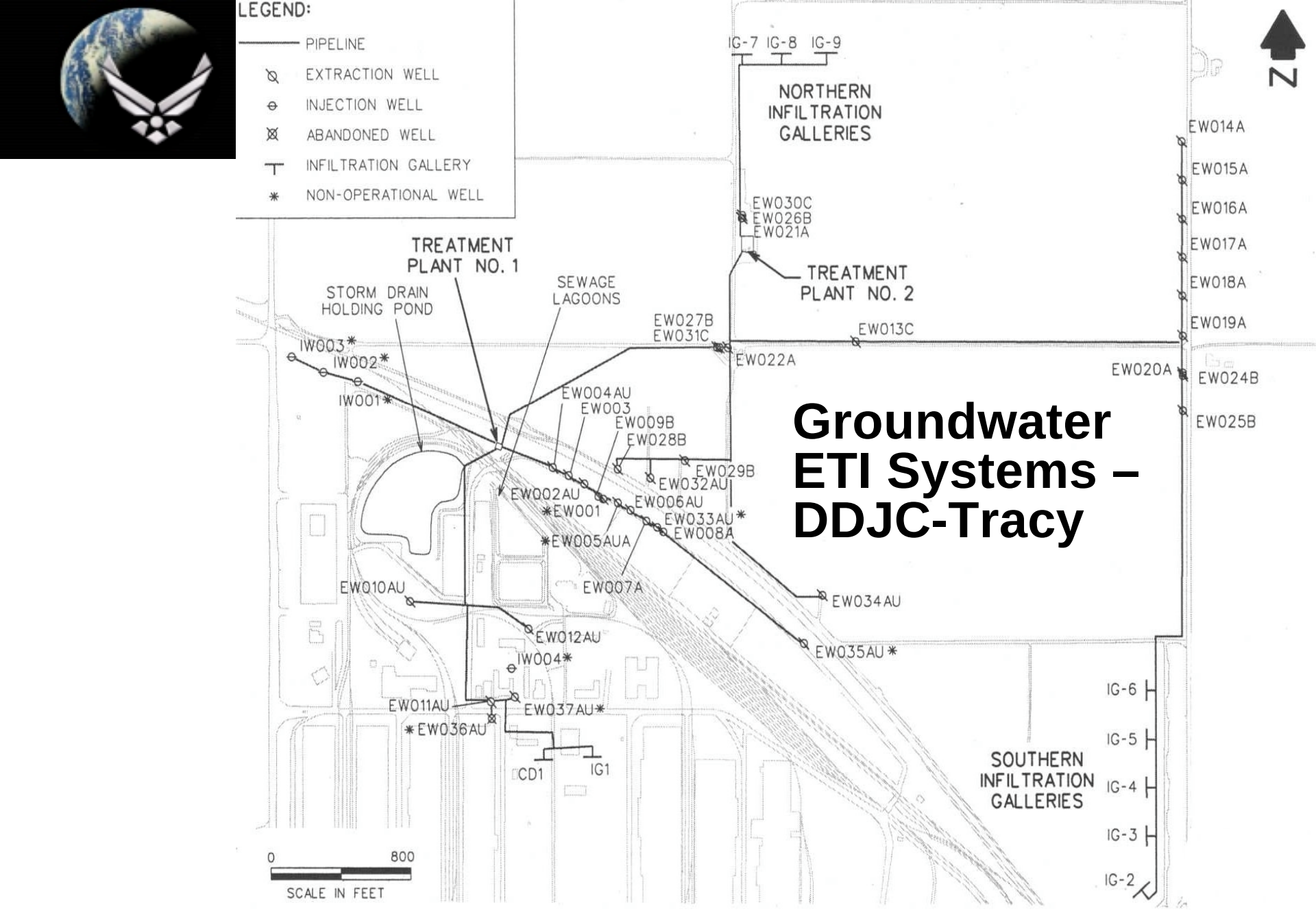


Then-Current Conditions – DDJC-Tracy

- Chlorinated solvents (TCE and PCE) and low concentrations of pesticides in groundwater
- Off-depot migration of COCs
- Extent of COCs in groundwater not fully characterized
- 2 groundwater pump-and-treat systems
- Significant operational issues (scaling, disposal)

Characteristics of Groundwater ETI Systems – DDJC-Tracy

- **Treatment Plant 1 (TP-1)**
  - 15 groundwater extraction wells
  - Total production rate – 100 – 400 gpm (wells often off-line)
  - Twin counterflow air-stripping towers
  - Some wellhead GAC units (pesticide treatment)
- **Treatment Plant 2 (TP-2)**
  - 20 groundwater extraction wells
  - Total production rate – 275 – 600 gpm (wells often off-line)
  - Twin counterflow air-stripping towers
- **Both Treatment Plants**
  - Treated water disposed in infiltration galleries
  - Scaling (calcium carbonate buildup) a constant problem



Groundwater ETI Systems – DDJC-Tracy

Current Costs of Groundwater ETI Systems – DDJC-Tracy

- TP-1 Capital Costs -- $9.5M
- TP-2 Capital Costs -- $3.3M
- Annual O&M Costs (Both Systems) -- $206K

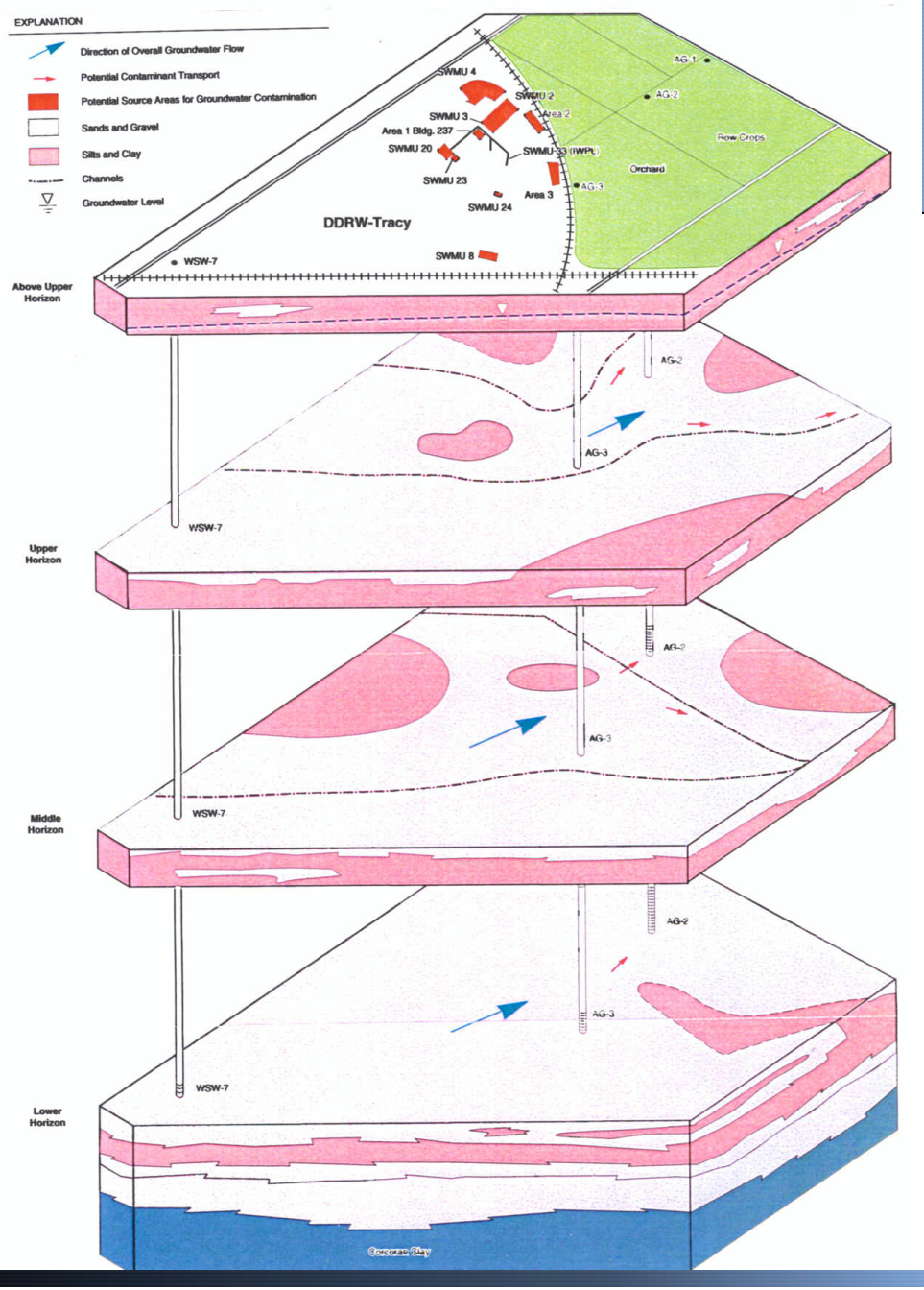
RAOs – DDJC-Tracy

- Cleanup to MCLs (groundwater is a receptor)
- Highest beneficial use of groundwater – drinking water
- On-site discharge of treated water to groundwater system a requirement of ROD

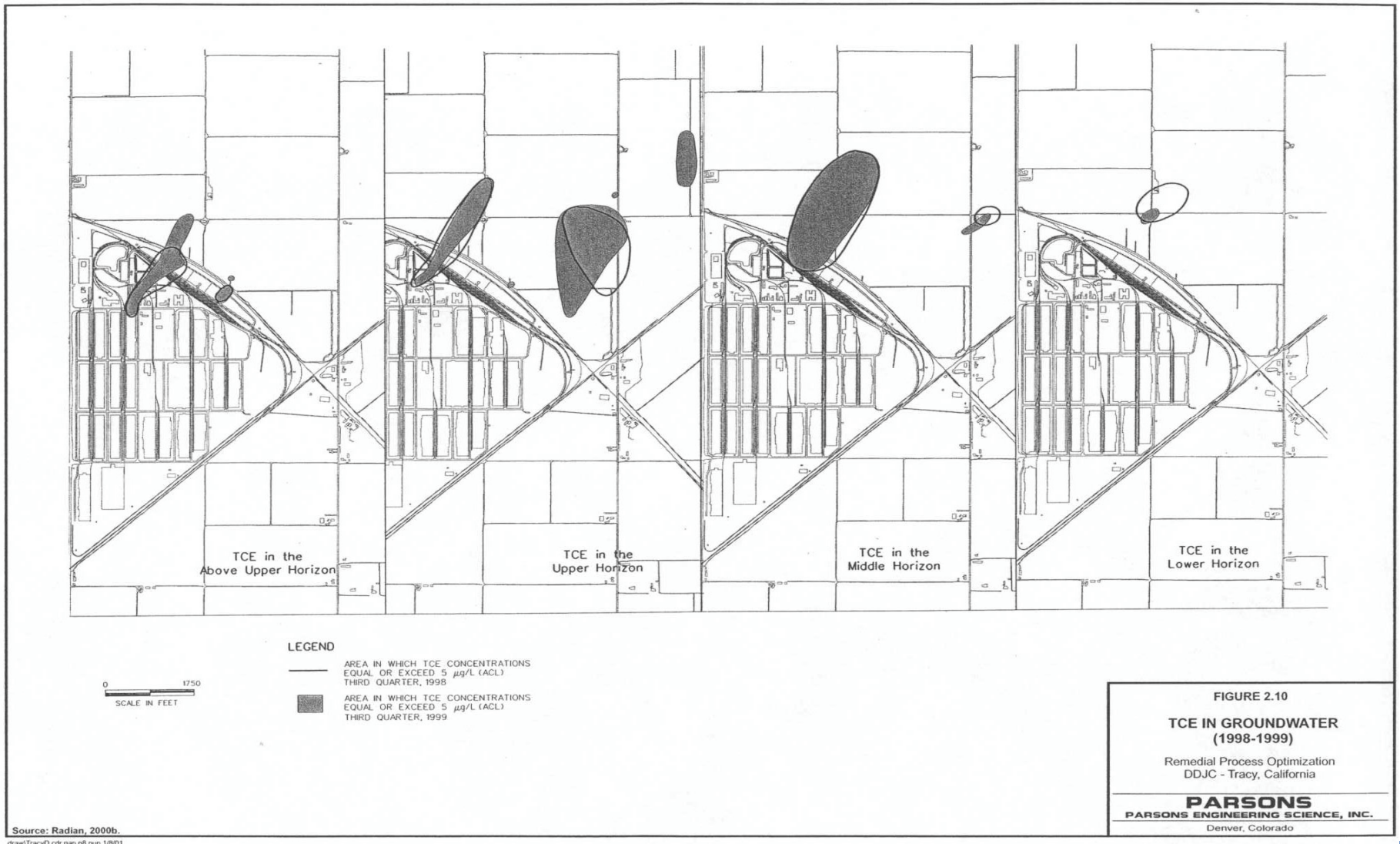
DDJC-Tracy – CSM Evaluation

- **Refine Conceptual Model**
  - **De-emphasize hydrostratigraphic units to clarify plume interpretations across horizons**
  - **Complete OU1 plume characterization**
  - **Incorporate natural attenuation study results**
  - **Revise groundwater data-presentation strategy to facilitate plume evaluation through time**

Historic Hydrogeologic CSM for DDJC-Tracy

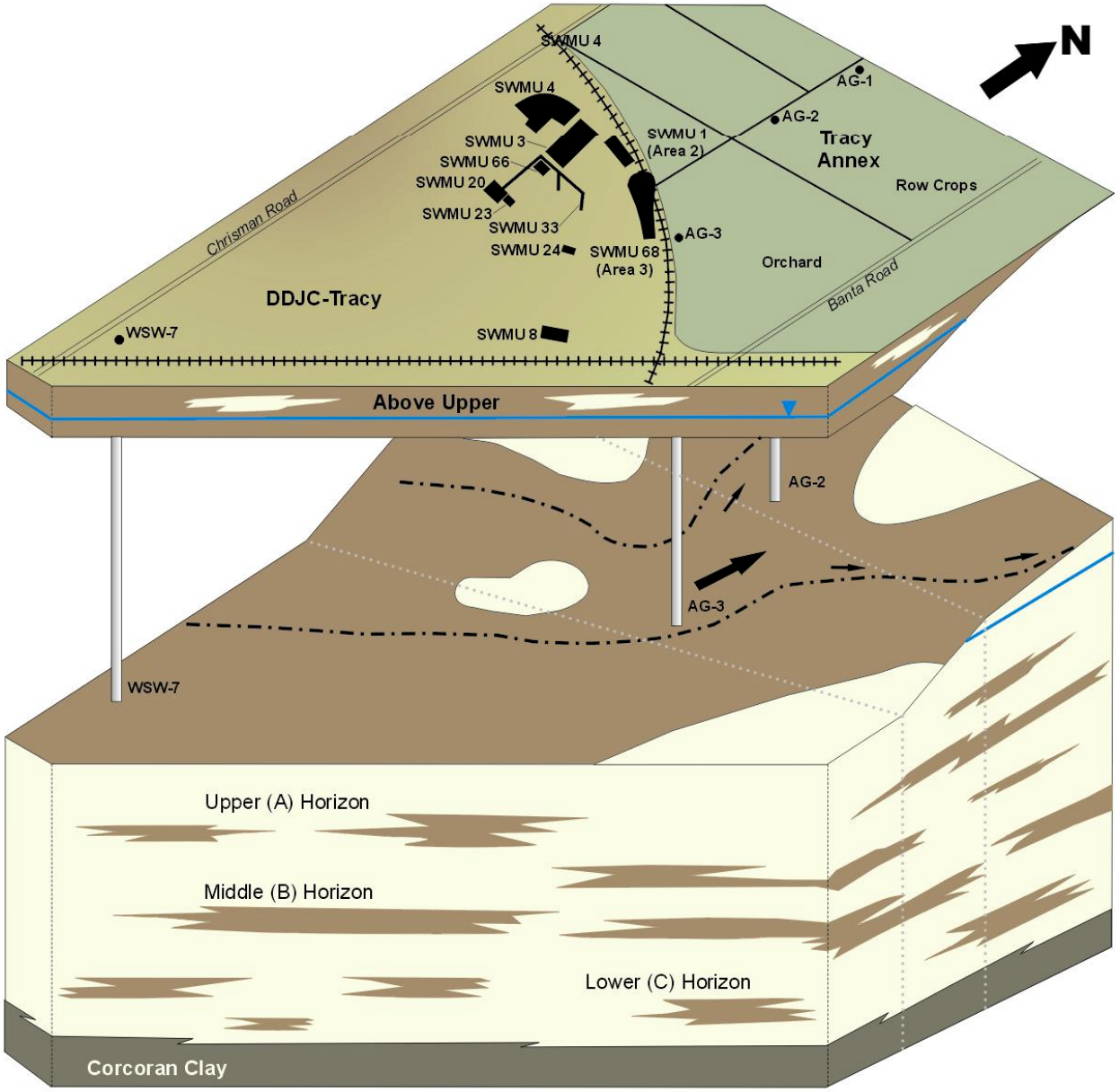


TCE Plume Interpretation (3Q98/3Q99) - DDJC-Tracy



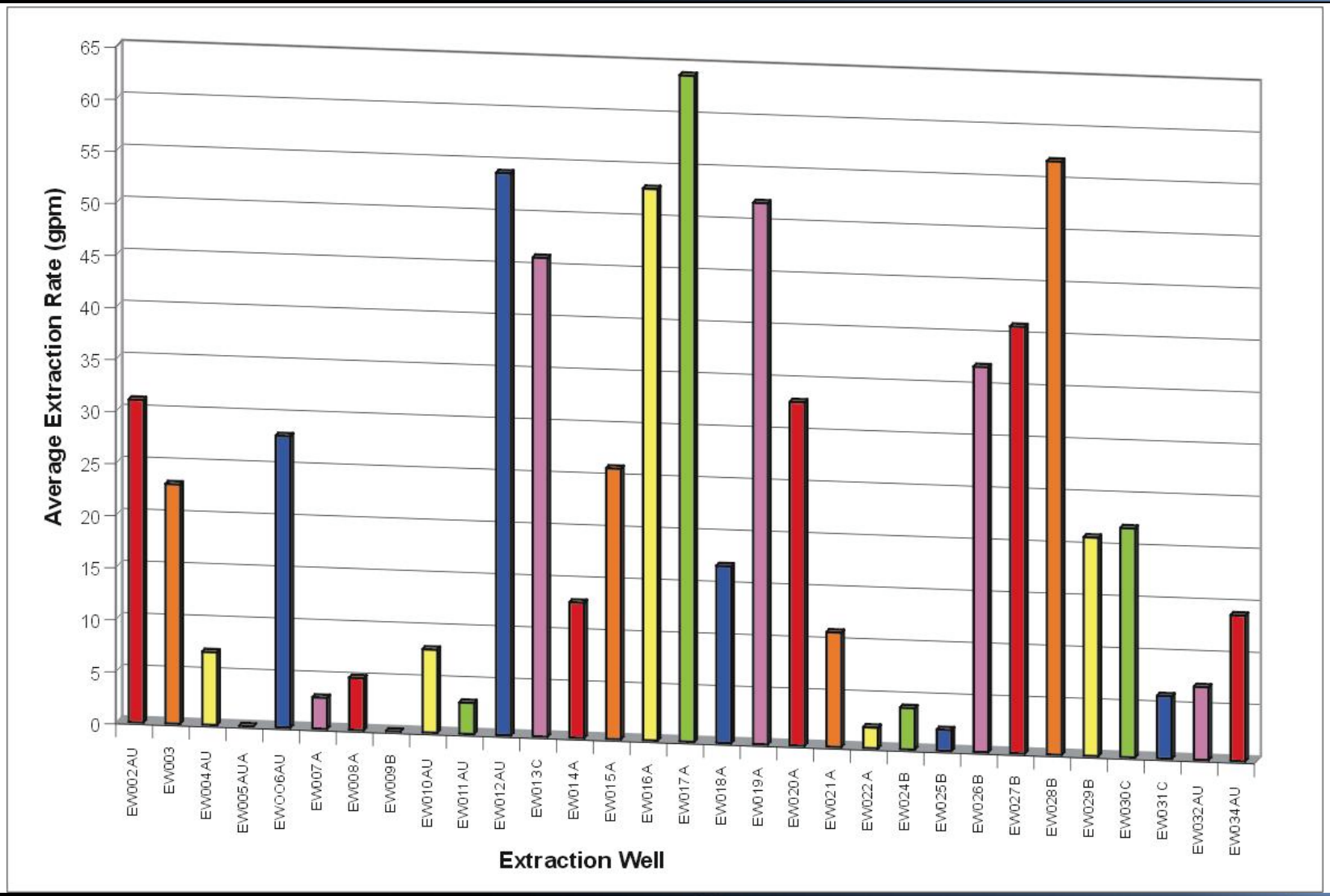
Source: Radian, 2000b.

Refined CSM for DDJC-Tracy

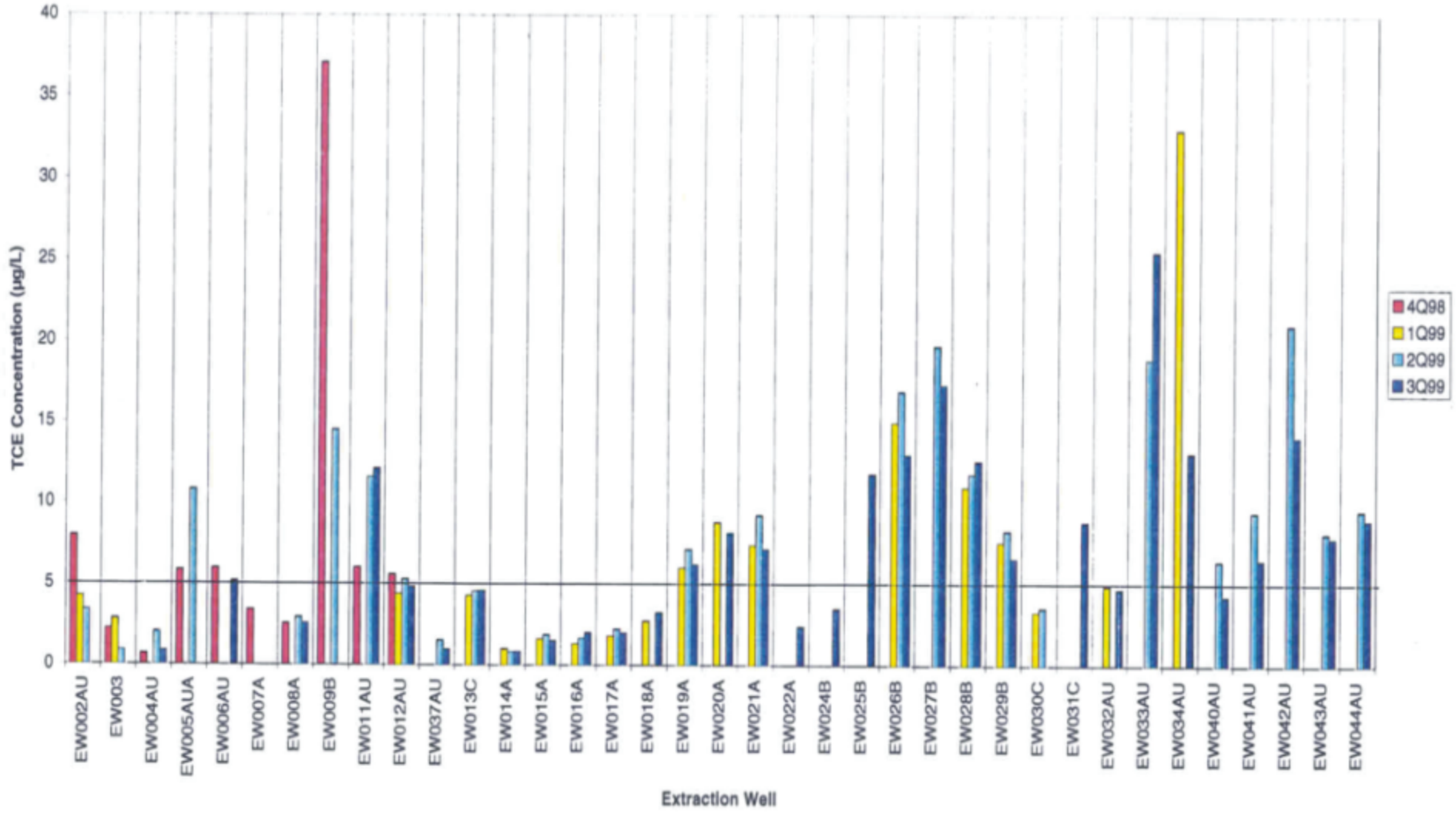


Refined Interpretation of Extent of TCE in Groundwater -- 2000

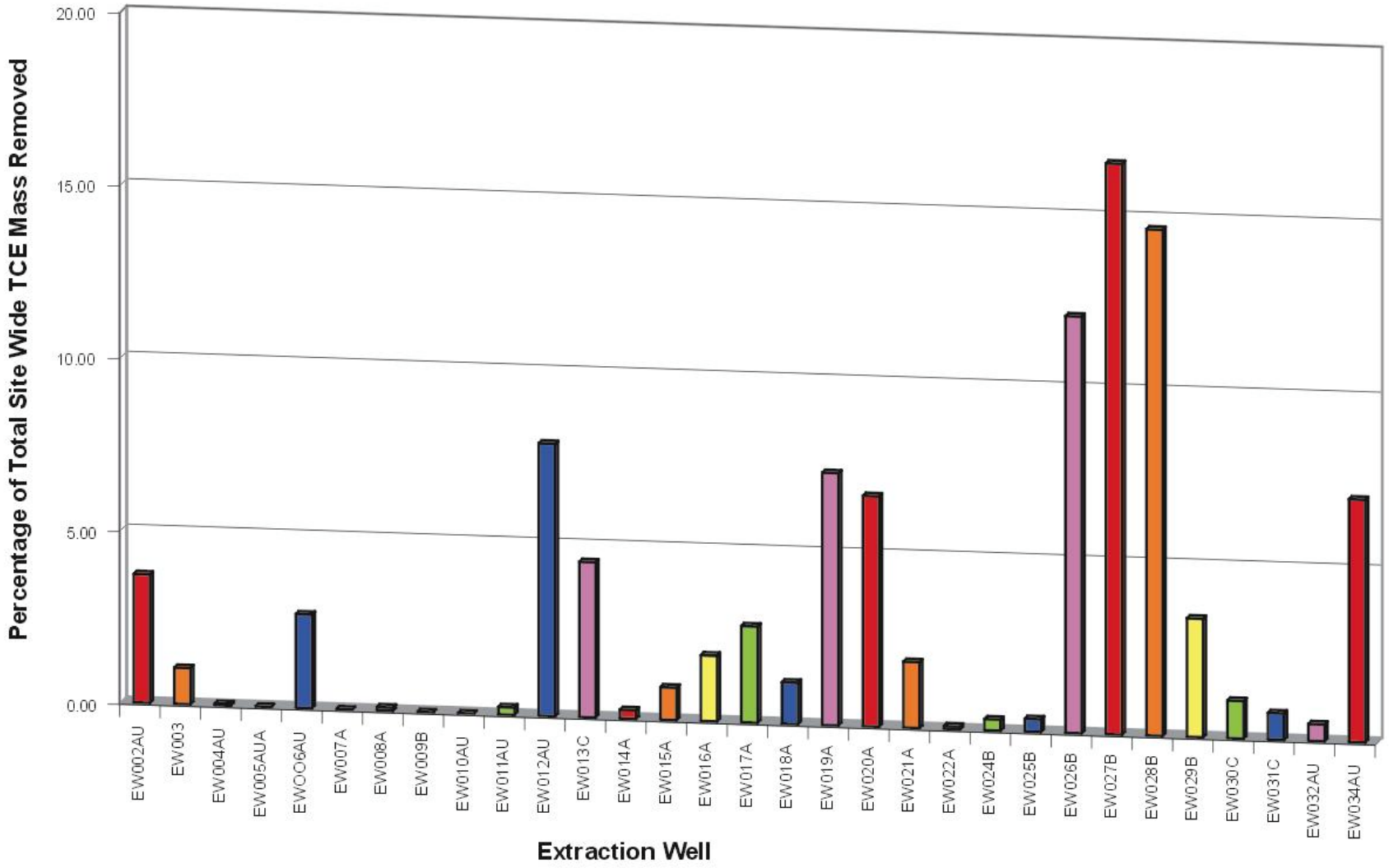
Average Extraction Rates by Well – DDJC-Tracy



TCE Concentrations by Well (4Q98-3Q99) – DDJC-Tracy



Relative TCE Mass Removal by Well – DDJC-Tracy



Observations – DDJC-Tracy

- No remedy in place for newly-identified COC "hot spot"
- Some wells are extracting groundwater that essentially is "clean"
- Some wells are not necessary to effect containment/capture
- Pesticides are "ND" at most wells; concentrations very low (< 0.2 µg/l) at remaining wells
- Concentrations of COCs influent to treatment plants are very low (< 10 µg/l)
- Off-site (or other) discharge of treated water could eliminate scaling and disposal problems in infiltration galleries

Groundwater ETI System Recommendations -- DDJC-Tracy

- **Groundwater Extraction Systems**
  - Install new extraction well(s) near SWMU 68 source area
  - Conduct rebound testing at 13 extraction wells
  - Based on rebound results, shut down wells with COC concentrations < MCLs
- **Groundwater Treatment Systems**
  - Replace air stripper at TP-1 with liquid-phase GAC
  - Route flow from all extraction wells in pesticide plume to TP-1; remove wellhead GAC units
  - Replace/supplement TP-2 recarbonation system with AQUA MAG
  - Ultimately direct all flow through TP-2 and shut down TP-1
- **Groundwater Disposal Systems**
  - Amend ROD to incorporate alternate disposal options

DDJC-Tracy Groundwater ETI System Optimization Summary

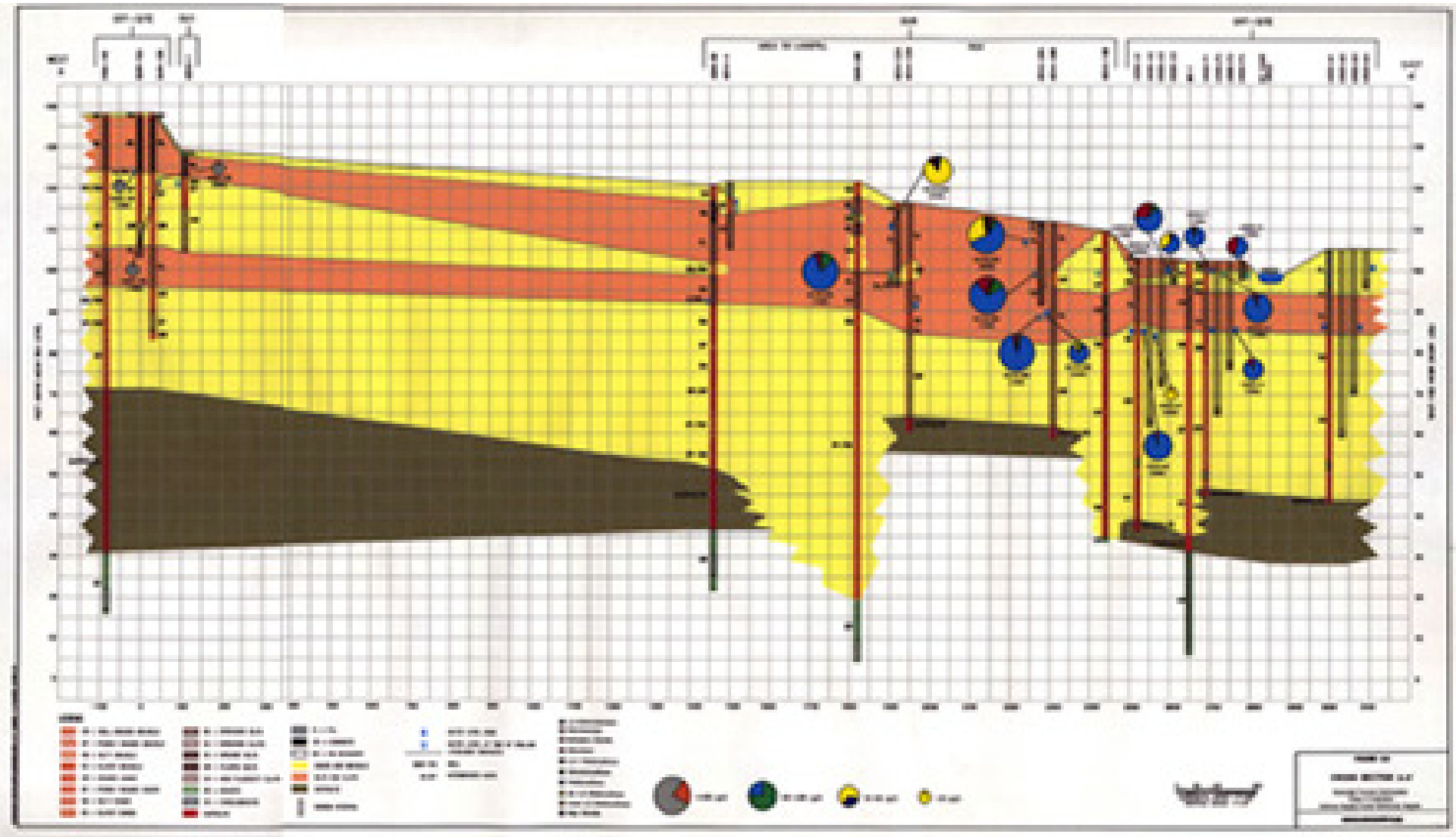
Operating Parameter	Integrated ETI System	
	FY99	Optimized
Operating Extraction Wells	29	17
Average Annual Pumping Rate	690 gpm	425 gpm
Annual Volume of Groundwater Extracted	362.6 million gallons	223.4 million gallons
Average Current Annual COC Mass Removal Rate	~29 lbs/yr	~24 lbs/yr
Estimated Current Cost per Pound of COC Mass Removed	$7,165/lb	$5,300/lb
Cumulative Mass of COCs Removed by Year 2028	~319 lbs	~310 lbs
Projected Cost per Pound of COC Mass Removed in Year 2028	$61,278/lb	$41,934/lb

Case Histories

- Defense Depot Ogden, Utah (DDOU)
- Defense Depot San Joaquin (DDJC) - Tracy
- **Defense Supply Center Richmond, Virginia (DSCR)**

Operable Units at DSCR

West-East Cross Section



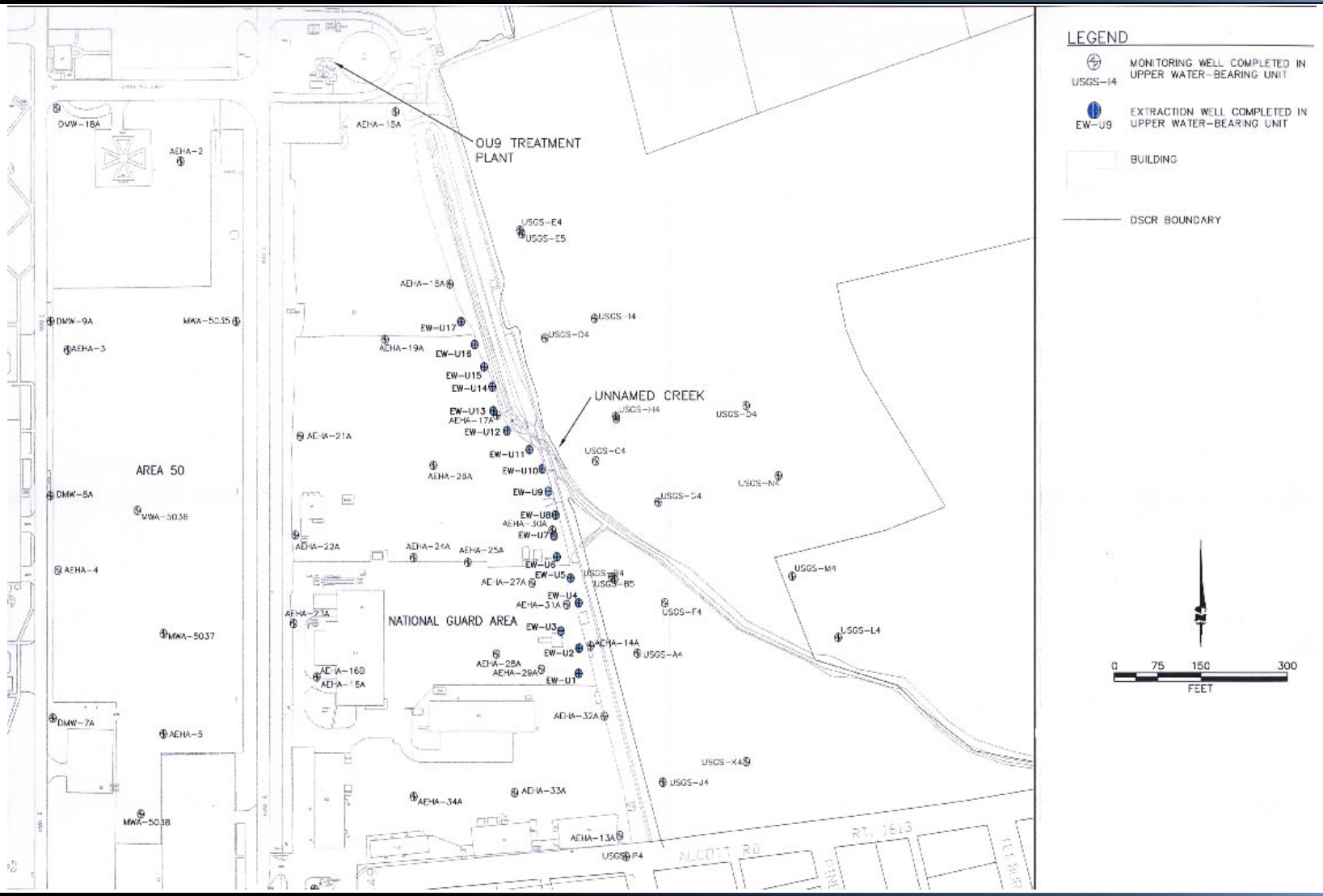
OU9 Groundwater Issues

- ETD system installed as interim remedy (1996)
- Principal groundwater contaminants are TCE and daughter products; also metals
- Concentrations of chlorinated-solvent constituents suggest presence of DNAPL
- Approximately 50 monitoring wells

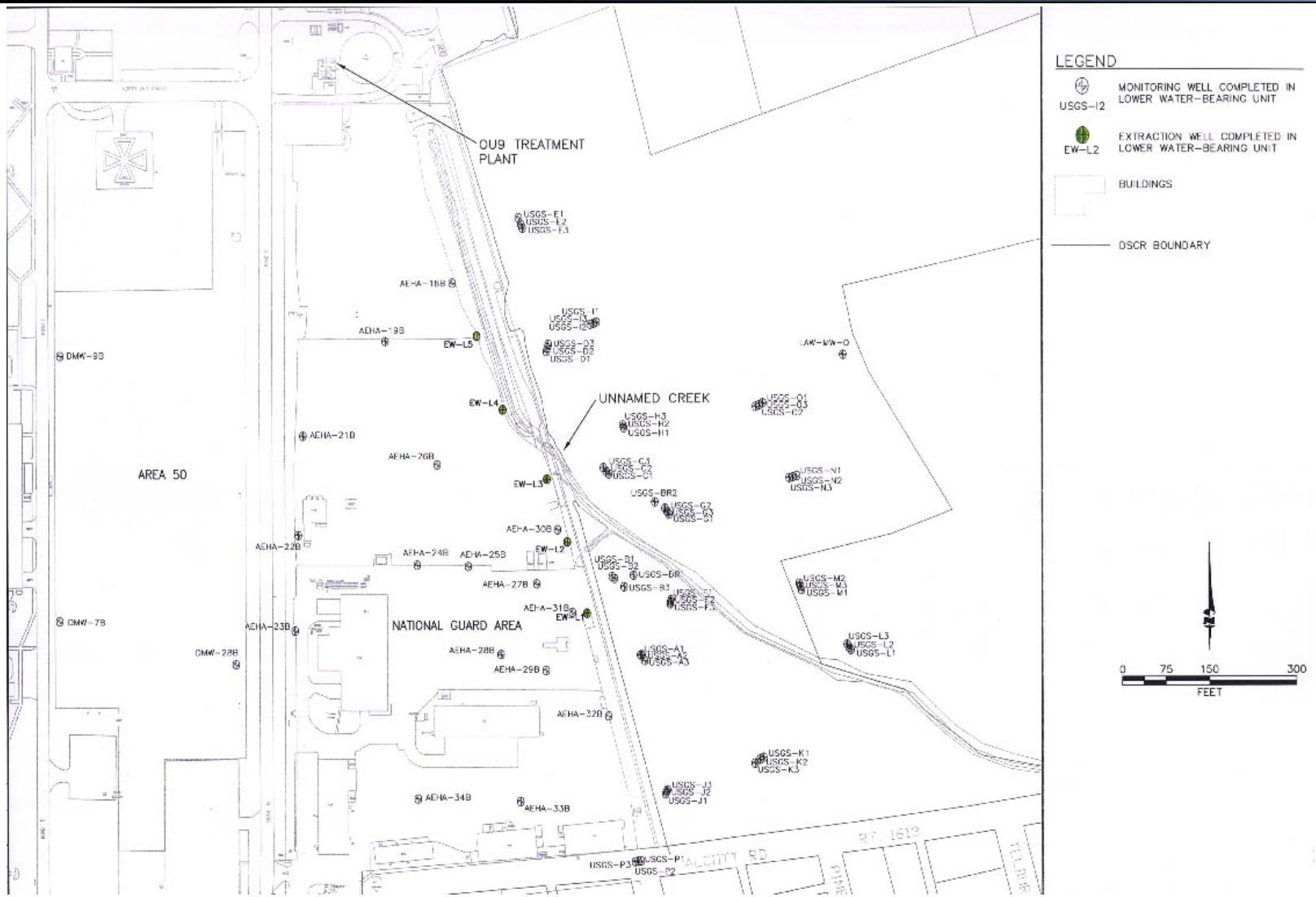
OU9 System – The Design

- 17 extraction wells in upper water-bearing unit – design extraction rate 1.5 gpm per well
- 5 extraction wells in lower water-bearing unit – design extraction rate 8 gpm per well
- Total design extraction rate – 65 gpm
- Air-stripping treatment system – design treatment rate 100 gpm
- Off-facility discharge to surface water (stream)
- In operation, scaling (iron fouling) a constant problem

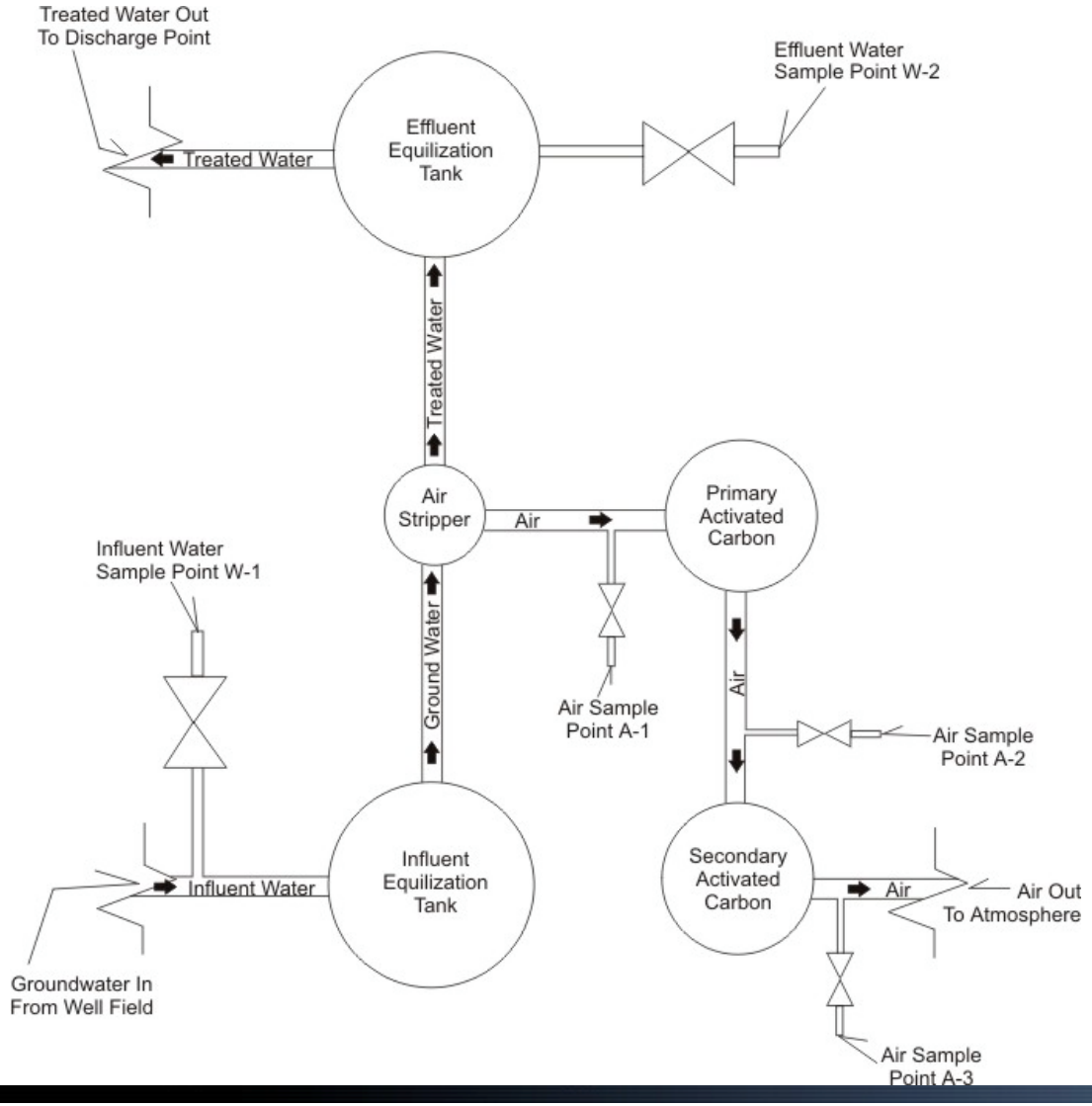
OU9 Extraction Wells in Upper Water-Bearing Unit



OU9 Extraction Wells in Lower Water-Bearing Unit



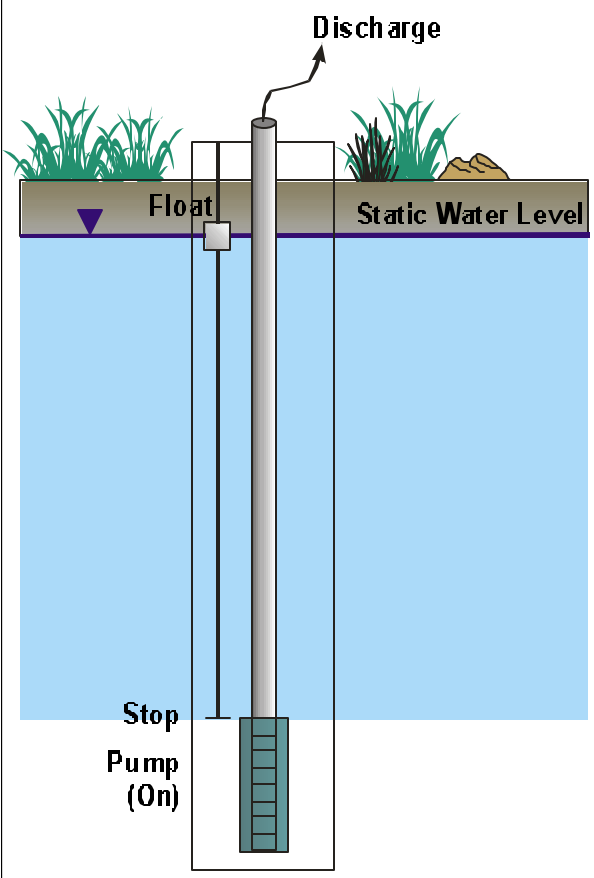
Schematic Diagram of OU9 Groundwater Treatment System

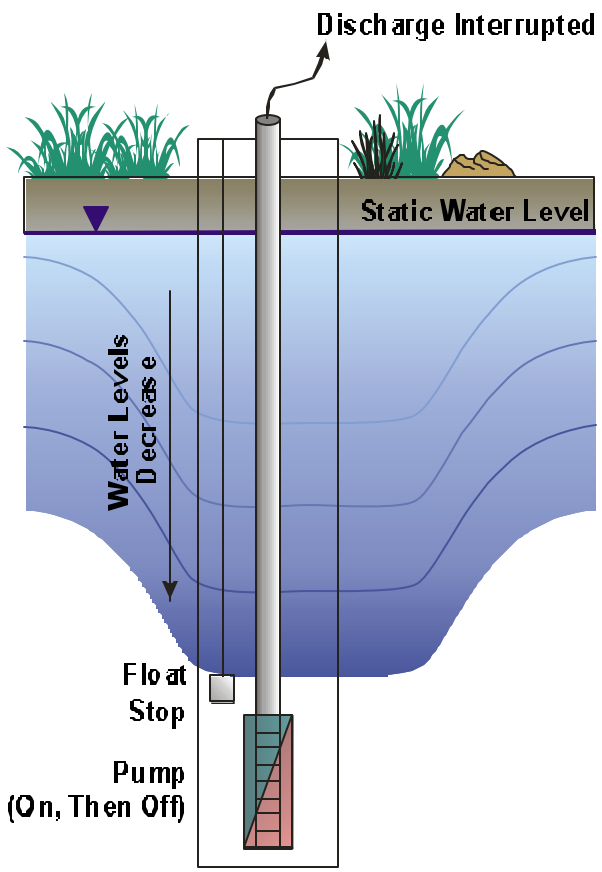


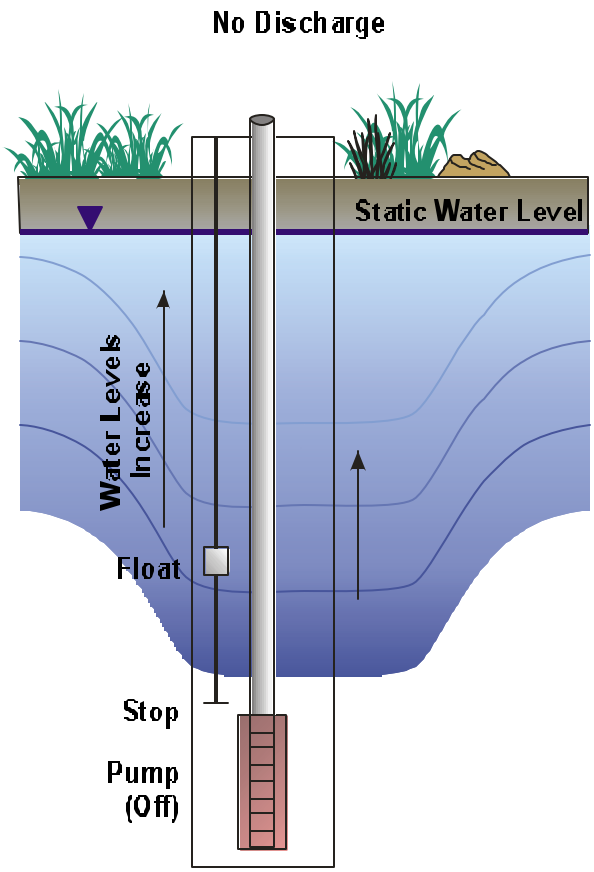
RAOs for OU9 System

- Reduce continued migration of VOCs in groundwater at OU6
- Reduce toxicity, mobility, concentrations, mass, and extent of contaminants in OU6 groundwater
- Collect information regarding response of aquifer and contaminants to pumping

Level-Controlled Cycling of Groundwater Extraction Wells

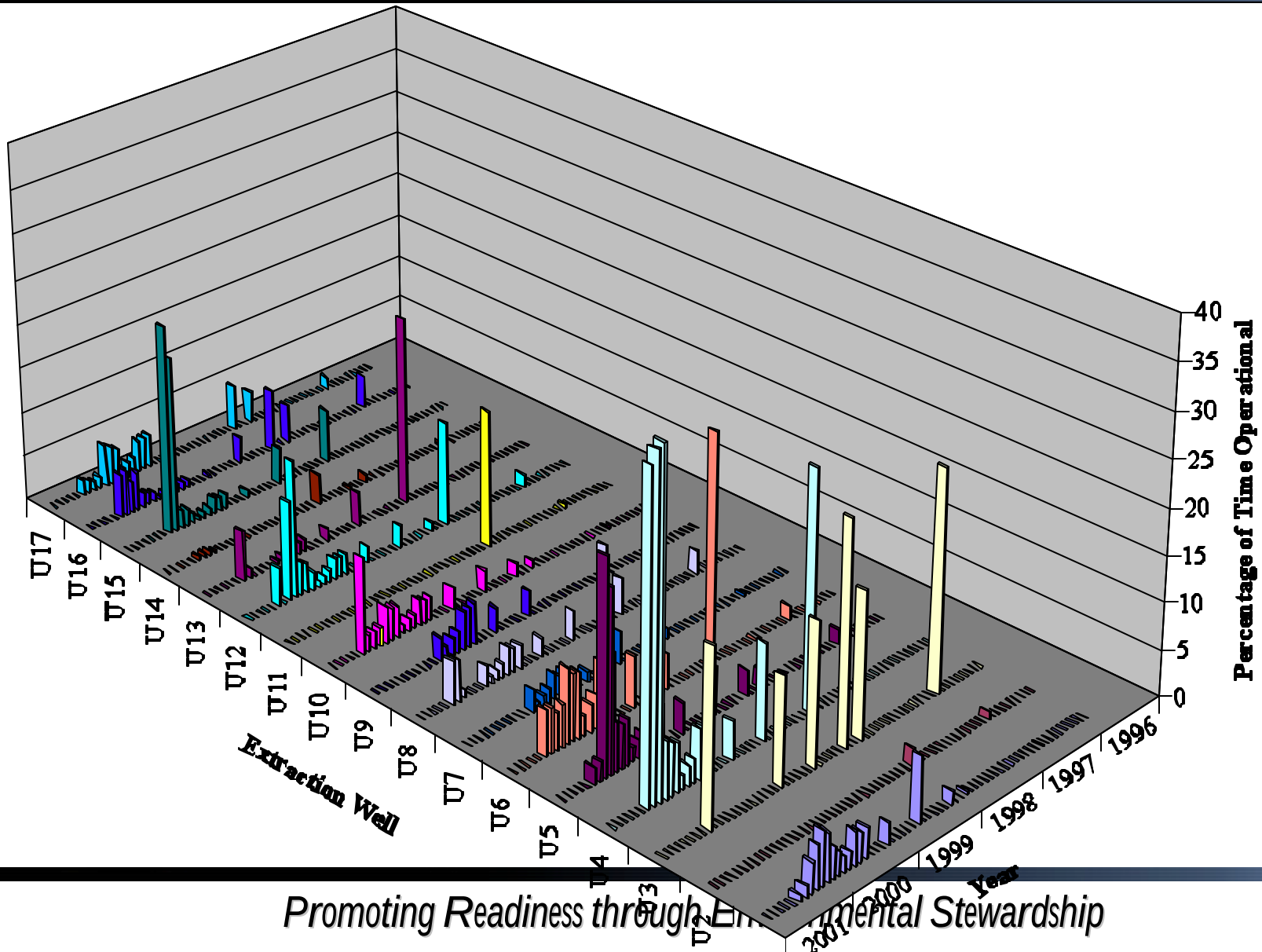




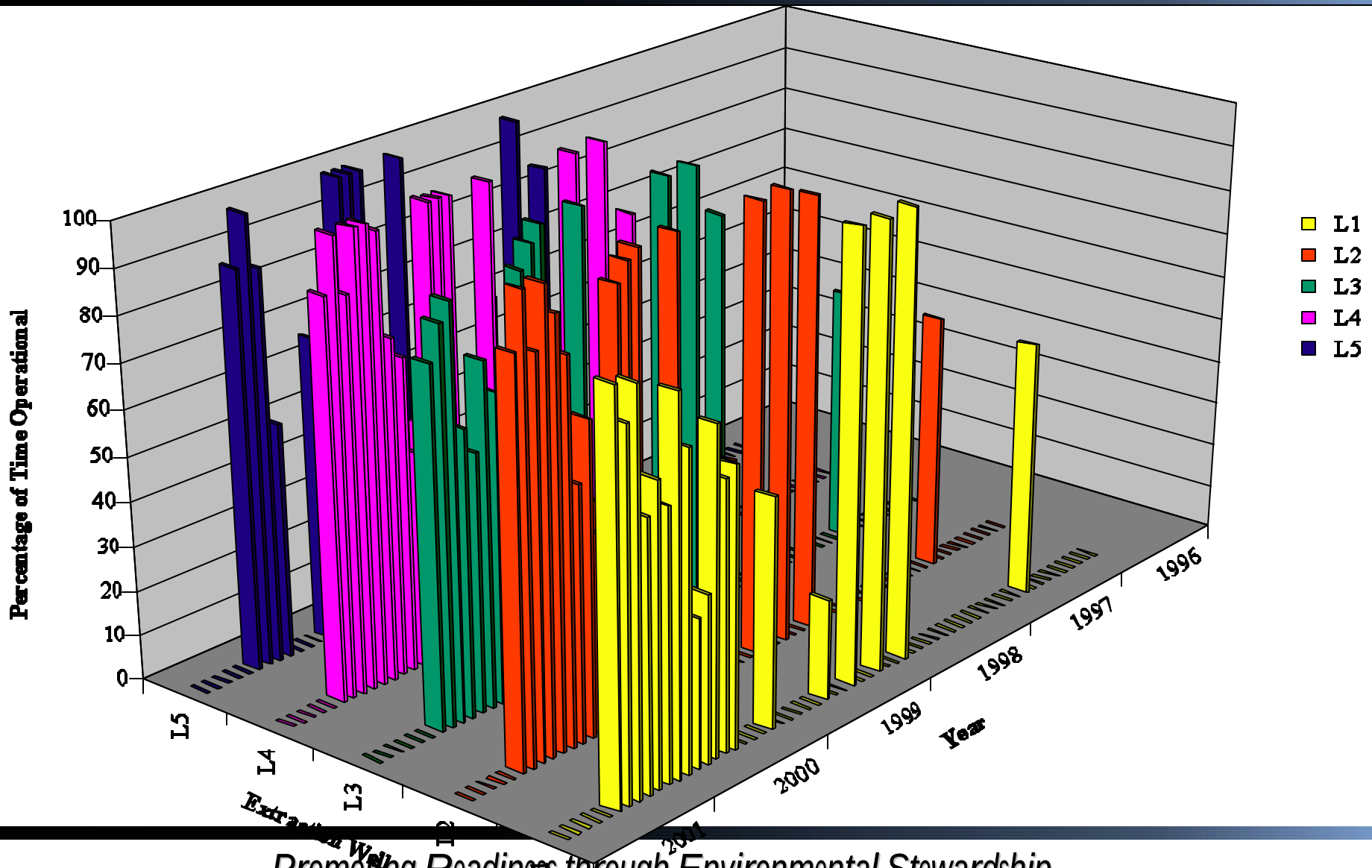


NOT TO SCALE

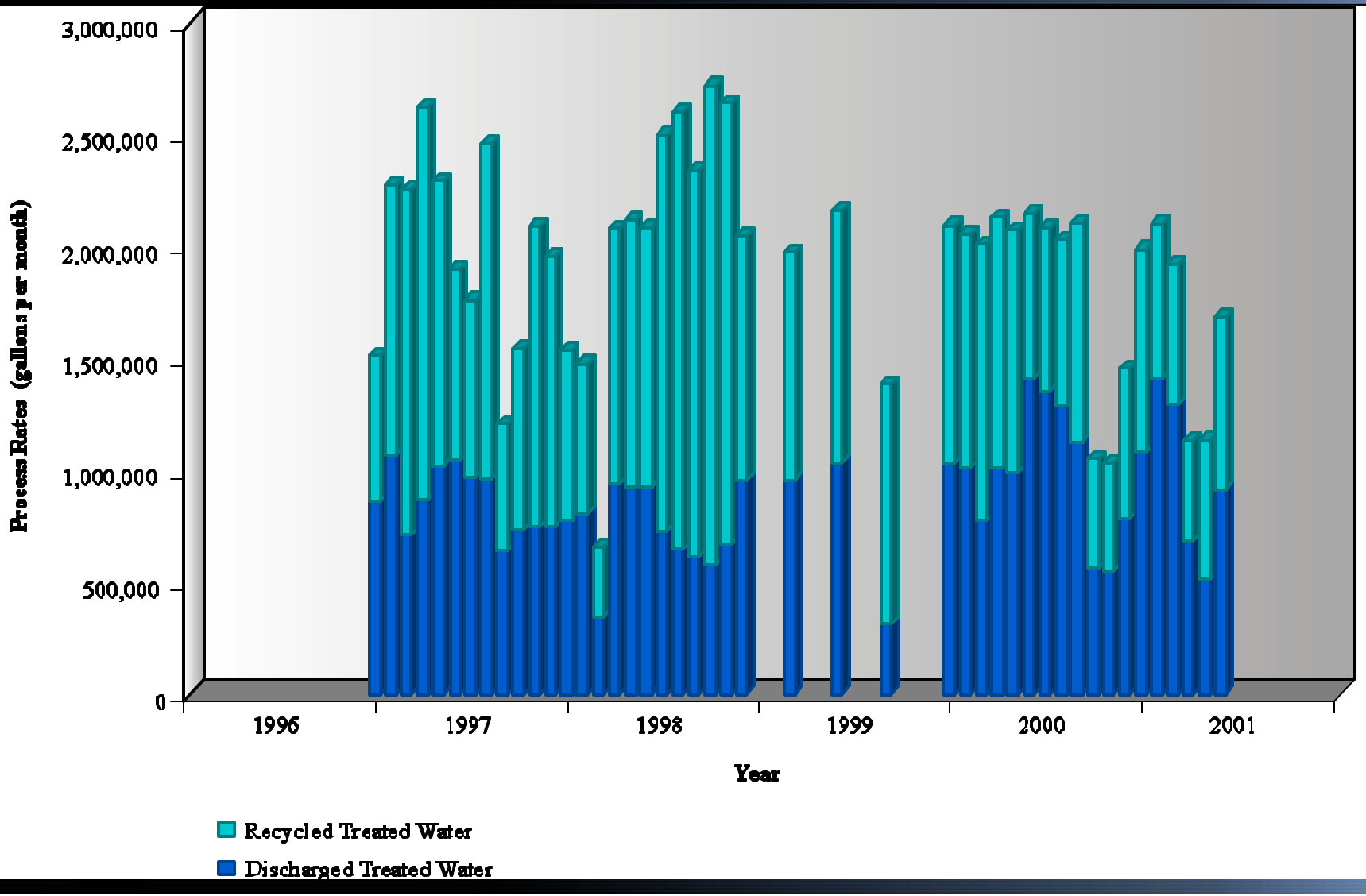
Percentage of Time (By Month) Upper-Unit Extraction Wells Operational



Percentage of Time (By Month) Lower-Unit Extraction Wells Operational



OU9 Treatment Plant Process Rates (By Month)



Results of OU9 System Evaluation

- Most wells in upper water-bearing unit in operation less than 5 percent of time
- Long-term extraction rates of wells in upper water-bearing unit ~0.01 – 0.1 gpm
- Radius of “capture zone” of typical well in upper water-bearing unit < 10 ft
- Most wells in lower water-bearing unit in operation less than 15 percent of time
- Long-term extraction rates of wells in lower water-bearing unit <4 gpm
- Radius of “capture zone” of typical well in lower water-bearing unit ~ 400 ft
- Total combined extraction rate for all wells ~16 gpm

Results of OU9 System Evaluation (continued)

- Air-stripping treatment for VOCs only (no metals treated)
- Makeup water is recycled through plant to sustain minimum operating capacity
- More than 60 percent of water-treatment stream consists of recycled water
- Approximately 165 lbs of VOCs removed from OU6 groundwater during 6-year operational history

Results of OU9 System Evaluation (continued)

- Extraction system is ineffective because most wells are completed in thin saturated zone of upper water-bearing unit; hydraulic characteristics do not allow sustained extraction at rates sufficient to achieve contaminant capture
- Rebound effects evident; suggestive of DNAPL
- Air stripper cannot treat non-VOC contaminants (i.e., metals)
- OU9 systems compromised by iron fouling due to high Fe^{+2} concentrations, redox/geochemical conditions
- Pump & treat technology is not suitable technical approach for OU6 groundwater

General Outline

- Introduction – Nature of the Problem
- Considerations and Approaches in Evaluating Groundwater Pump-and-Treat Systems
- Examples
- **Conclusions**

Optimization "Tiers"

- **Program Optimization**
  - **Remedy Optimization** ⟵
    - **System Optimization** ⟵

<u>Any</u> successful optimization effort must be conducted within the context of a defined and defensible *"Exit Strategy"*

Development of an Exit Strategy

- **Components of an Exit Strategy (Gordon *et al*., 2003)**
  - **Clear and concise statement of problem**
  - **Clear and concise statement of objectives**
  - **Identification of necessary information**
  - **Possible contingencies**

Components of an Exit Strategy

- **Clear and Concise Statement of Problem**
  - ***"Problem"*** **= a site condition posing an actual or perceived risk that requires a response**
  - **Specifies the condition(s) requiring action**
  - **Bounds likely response(s) appropriate for further consideration**
  - **Focuses identification and collection of additional data on that information necessary to reduce key uncertainties, thereby supporting selection and implementation of successful remedies**
  - **Define decision criteria to be used in identifying the problem, as well as in guiding and evaluating successful response actions**

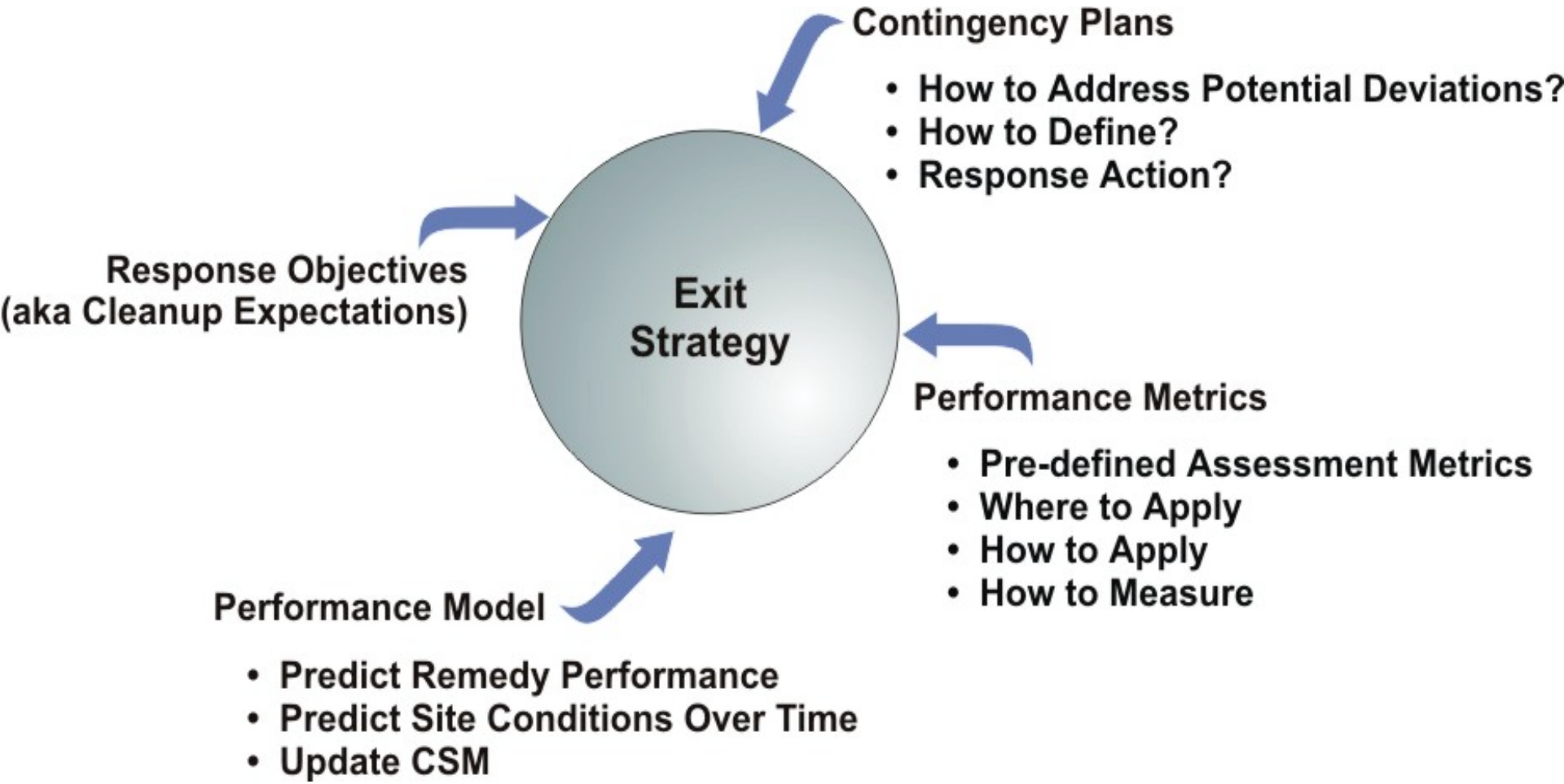
Components of an Exit Strategy (continued)

- **Clear and Concise Statement of Objectives**
  - **Specifies the problem(s) to be addressed**
  - **Identifies result(s) to be achieved**
  - **Establishes metrics for determining when result(s) has/have been achieved**

Components of an Exit Strategy (continued)

- **Identification of Necessary Information**
  - **Measures to demonstrate that desired remedy performance is being/has been achieved**
  - **Measures to demonstrate that response objectives are being/have been met**
  - **Measures to demonstrate that response activities can be terminated**

Defining an Exit Strategy



Exit Strategy Precautions

- **Inadequate Problem Definition Can Lead To:**
  - **Addressing the wrong problem(s) (e.g., dealing with a "symptom" rather than a "cause")**
  - **Difficulties in developing appropriate measures for addressing the problem**
  - **Addressing a problem in a manner that requires significantly greater time/expense than technically necessary**

Exit Strategies

- **Environmental Progress Performance Metrics**
  - **Process "milestones" (e.g., ROD issued, RD completed)**

vs

  - **Achieved results (e.g., progress toward cleanup objectives; environmental indicators of compliance)**

Exit Strategies (continued)

- **Environmental Progress Performance Metrics**
  - **Consistent with CERCLA and RCRA reforms**
  - **Ultimate objective is *completion of all required response actions***
  - **Remedy development and implementation must be consistent with overall exit strategy**
    - **Establish *performance-based* metrics during decision process**
    - **Incorporate evolving understanding of site and remedy characteristics into remedy development and review process**
    - **Encourage real progress toward *achievable* goals**

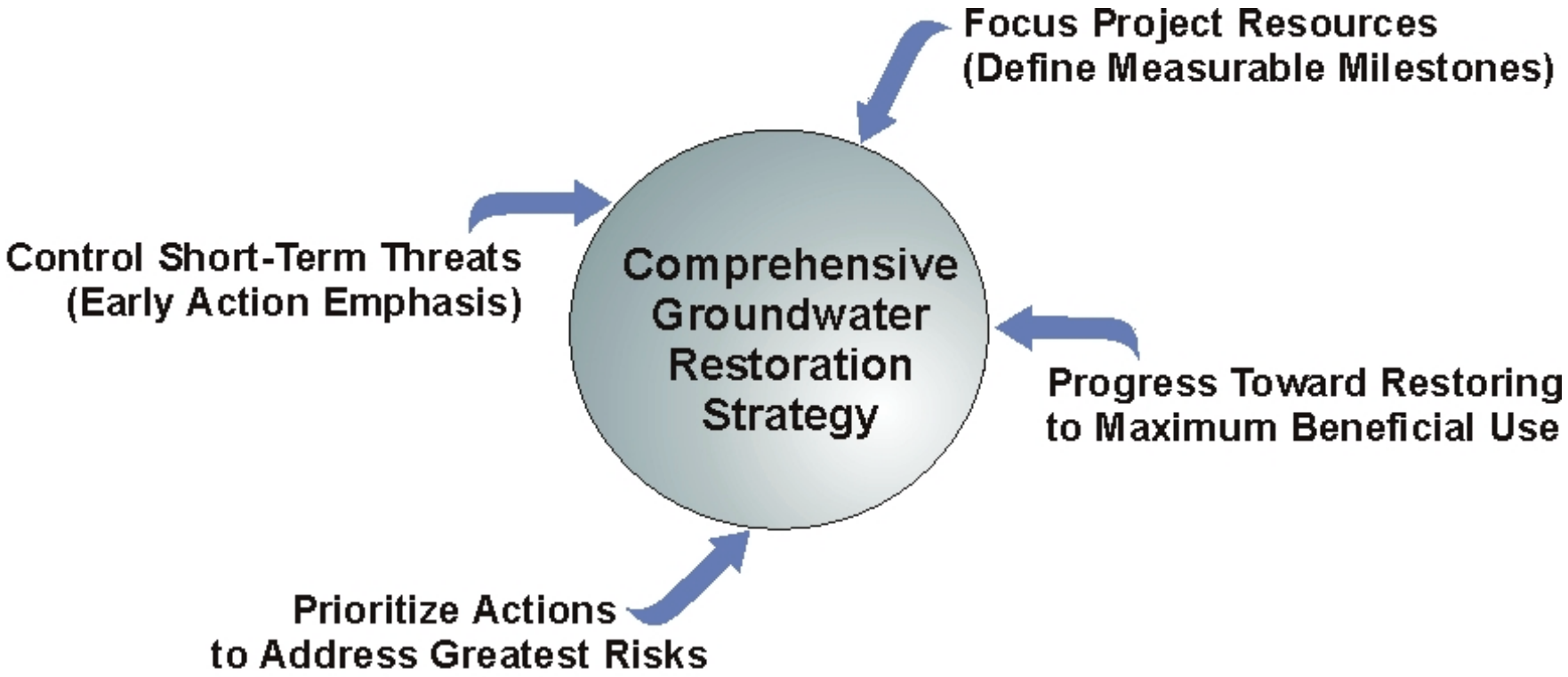
Exit Strategies (continued)

- **Questions for Strategy-Planning Discussions**
  - **Is there a problem requiring action?**
  - **What specifically is the problem requiring action?**
  - **What are the appropriate actions to consider?**
  - **What uncertainties must be reduced prior to selecting a remedy? (*Data Needs*)**
  - **What uncertainties can be managed during remedy implementation? (*Data Gaps*)**
  - **What information will be used to demonstrate that response objectives have been achieved?**
  - **What information will be used to trigger a contingency should the selected remedy fail?**

Considerations in Developing Exit Strategies for Groundwater

- Current and potential future beneficial uses of groundwater?
- Approximate timing of future need for groundwater
- Technically practicable within a “reasonable” timeframe?
- Range of remedial alternatives that can restore groundwater in “reasonable” time periods?
- What can be done to prevent exposure to contaminants and prevent further plume migration?

Policy Basis for Phased Groundwater Restoration Strategy



#1 - Protect Human Health

#2 - Restore Drinking Water Sources/ Groundwater Closely Hydraulically Connected to Surface Water

Based on USEPA, 2001

Take-Home Messages

- Exit strategy for a site must be developed and clearly articulated
- The role of a groundwater pump-and-treat system in an overall exit strategy for a site must be understood and well defined
- Establish RAOs for groundwater pump-and-treat systems that are ***achievable***
  - ~~Mass Removal~~
  - Hydraulic Containment
- Establish metrics for use in determining when response action is “complete” (i.e., “Are we done yet?”)

Take-Home Messages (continued)

- ***Routinely*** **collect data appropriate for use in assessing system performance**
- **Collect data appropriate for use in determining when RAOs have been achieved**
- ***Routinely*** **re-evaluate the role of the groundwater pump-and-treat system in the site exit strategy – Is groundwater pump-and-treat still an appropriate technology?**
- **Consider implementation of alternative remedies, including waiver of ARARs (TI Waiver)**

THANK YOU