O&M for 2004 and Beyond: New EPA Fact Sheets

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NARPM Annual Training Conference
Miami Beach, FL
May 26, 2004

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Presentation Objective

- Introduce and present highlights from four new EPA fact sheets related to long-term O&M of P&T systems
  - Elements for Effective Management of Operating Pump and Treat Systems
    - OSWER 9355.4-27FS-A, EPA 542-R-02-009, December 2002
  - Cost-Effective Design of Pump and Treat Systems
    - OSWER 9283.1-20FS, EPA 542-R-04-004, Coming Soon!
  - Effective Contracting Strategies for O&M of Pump and Treat Systems
    - OSWER 9283.1-21FS, EPA 542-R-04-002, Coming Soon!
  - O&M Report Template for Ground Water Remedies with Emphasis on Pump and Treat Systems
    - OSWER 9283.1-22, EPA 542-R-04-003, Coming Soon!

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Background

- These four fact sheets were inspired by the results of a nationwide pilot to optimize operating Fund-lead P&T systems
  - 20 optimization evaluations (RSEs) were conducted
  - RSEs identified a number of useful practices
  - RSEs also identified over 200 opportunities for improvement
    - Over 60 related to improving or evaluating protectiveness
    - Over 60 related to cost reduction
  - Results suggested need for more specific information on O&M

Background

- From the first 20 RSEs…
  - Common themes regarding protectiveness included
    - Improve capture zone analysis and/or plume delineation
    - Conduct additional sampling of potential receptors
    - Improve data collection, interpretation, and/or reporting
  - Common themes regarding cost reduction included
    - Reduce groundwater and/or process monitoring
    - Replace existing treatment components with more efficient units or technologies
    - Simplify existing system and/or remove unnecessary treatment components
    - Consider alternate discharge options for treated groundwater
    - Reduce labor and/or project management costs

Background

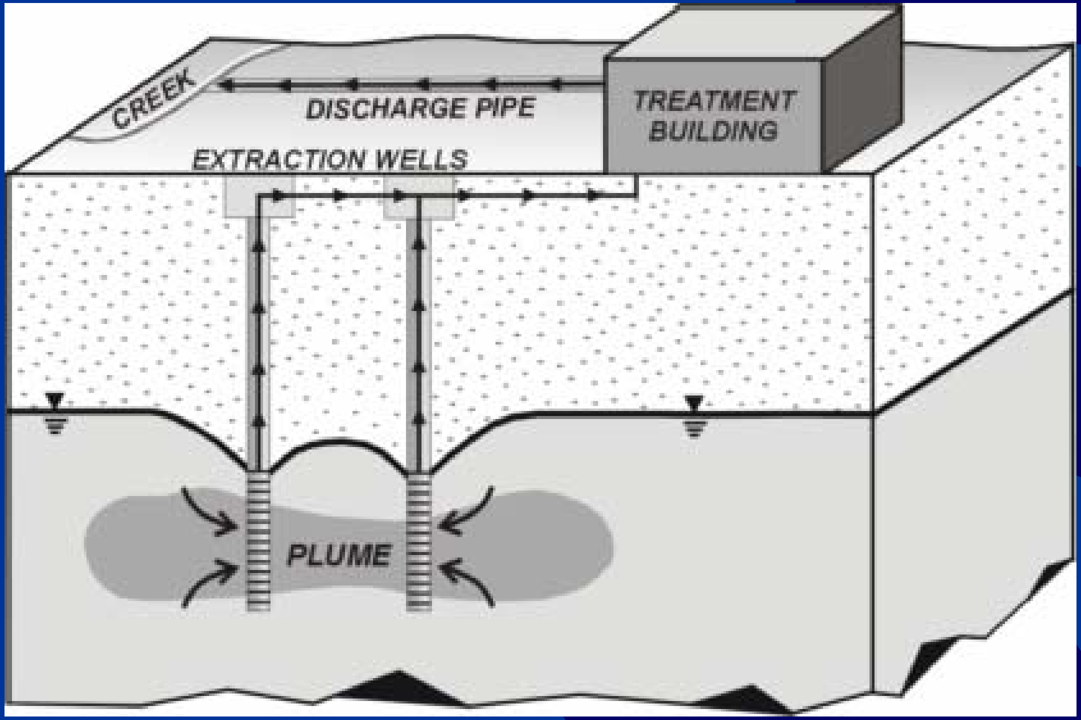
- These fact sheets are intended to
  - Demonstrate the need for active management during O&M
  - Outline primary responsibilities during O&M
  - Provide general information, tools, and "rules of thumb" for addressing those responsibilities
- They are NOT intended to
  - Replace hydrogeological or engineering expertise
  - Replace the need for external or independent optimization evaluations

Background

- Additional O&M-related documents will be developed
  - Funded and coming soon!
    - *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Sites* (led by ORD and Ground Water Forum)
    - *Groundwater Remediation Optimization: Benefits and Approaches*
  - Not yet funded
    - Options for discharging treated water
    - Cost-benefit analysis for evaluating alternative or supplemental technologies to an operating P&T system
    - Automation and remote telemetry for treatment plant operation
    - Exit strategy examples
- All documents will be available on

www.cluin.org/optimization & www.frtr.gov

Elements for Effective Management of Operating P&T Systems



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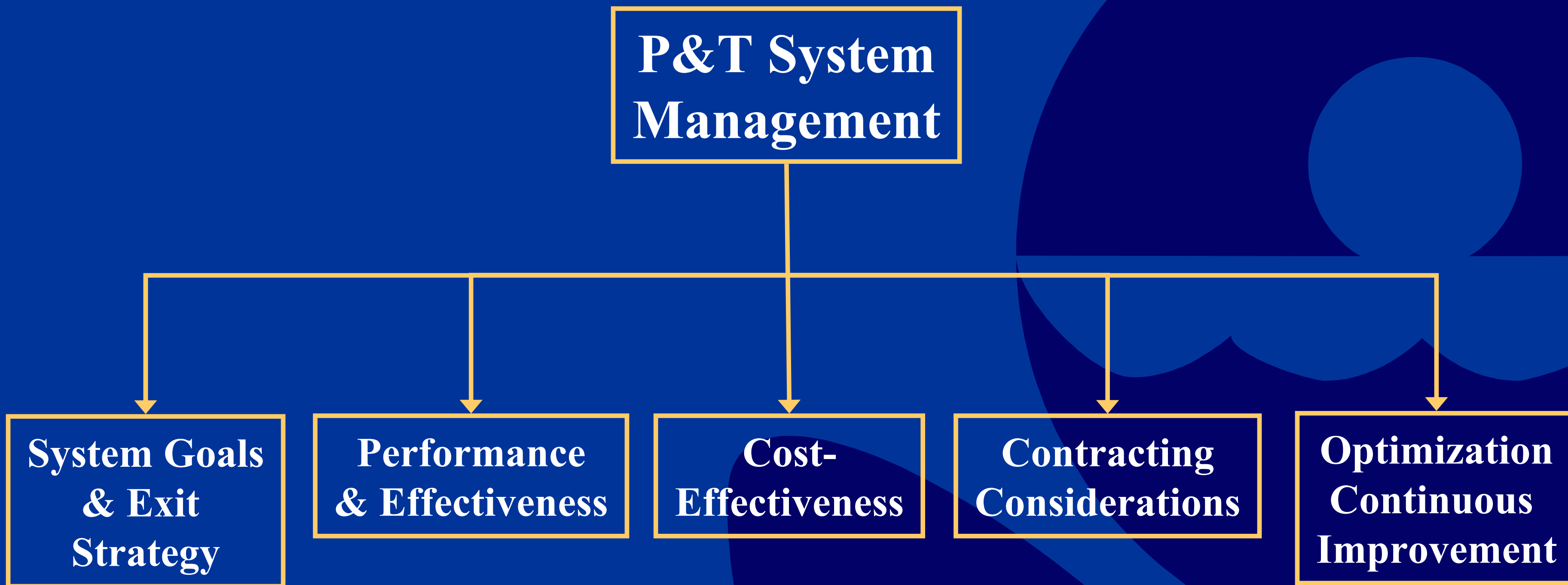
Elements



This fact sheet provides an overview of each of these topics. Other fact sheets that are under development provide additional detail.

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Relationship to Other Fact Sheets

"Elements…" Topic	Related Fact Sheet
System Goals & Exit Strategy	*Exit Strategy Examples*… not yet funded
Performance & Effectiveness	*O&M Report Template*…To be discussed *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Sites*…Coming Soon!
Cost-Effectiveness	*Cost-Effective Design*…To be discussed
Contracting Considerations	*Effective Contracting*…To be discussed
Optimization & Continuous Improvement	*Groundwater Remediation Optimization: Benefits and Approaches*… Coming soon!

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System Goals & Exit Strategy

- P&T system goals should…
  - Be clearly stated and prioritized with an estimated time frame
  - Be appropriate relative to the site-specific conceptual model
  - Include metrics for evaluating system performance
  - Clearly indicate when some or all of the P&T system can be discontinued
  - Be achievable and revised over time as appropriate

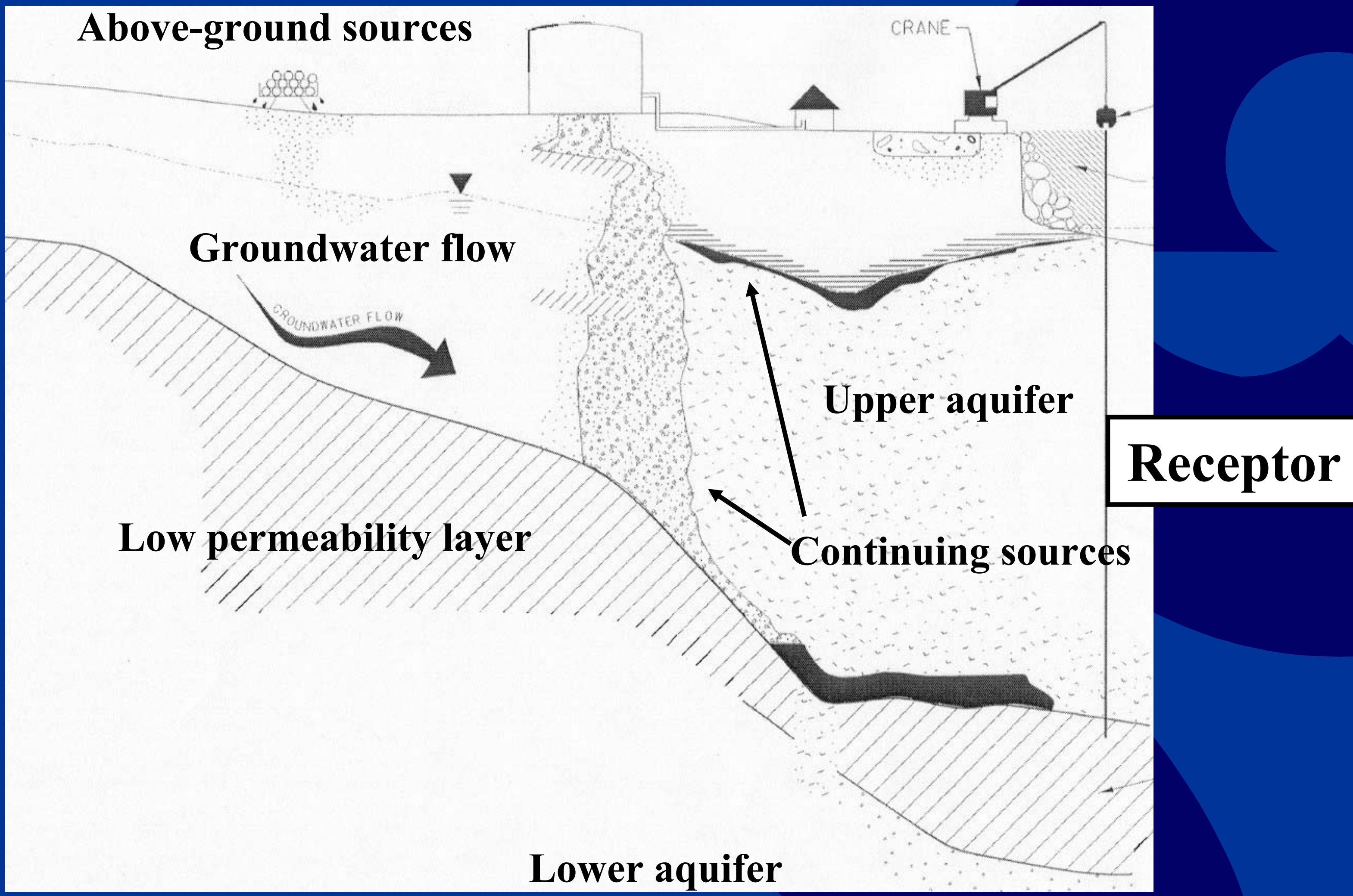
Know where the **EXIT** *is!*

System Goals & Exit Strategy

- A site-specific conceptual model should identify and/or explain the following…
  - Historical and continuing sources of ground water contamination, both above ground and below the surface
  - Historical growth and/or retreat of the ground water plume
  - Ground water flow velocity (horizontal and vertical) and other parameters controlling contaminant fate and transport
  - Potential human and ecological receptors
  - Anticipated results of remedial actions
- A site-specific conceptual model should also be updated regularly

System Goals & Exit Strategy

- Some elements of a site conceptual model



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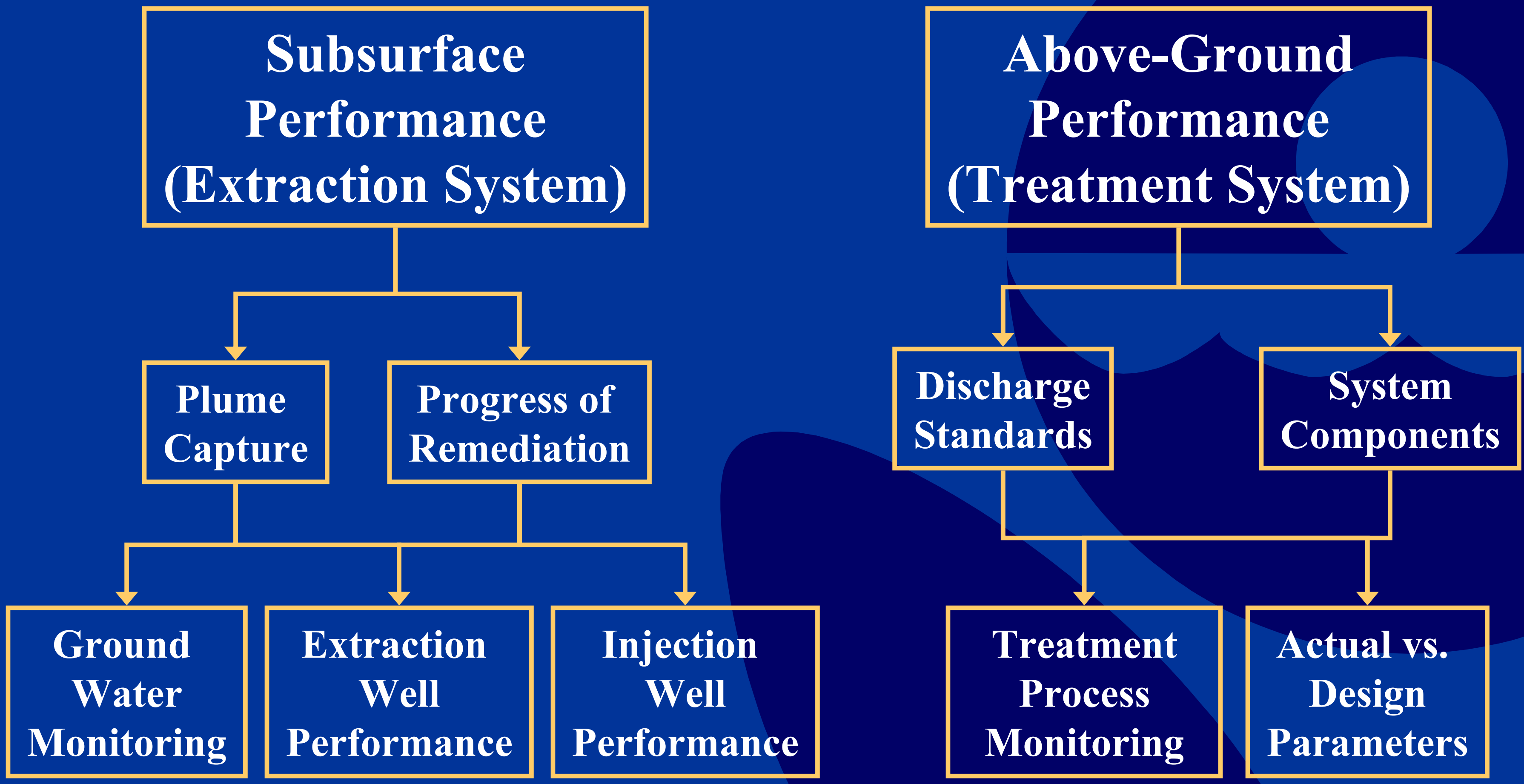
Performance & Effectiveness

- Actual O&M parameters may change over time and may differ from design parameters…
  - Extraction well yields
  - Influent concentrations
  - Site and regional conditions (including potential receptors)
  - Utility or consumable costs
  - Discharge costs or other discharge alternatives
  - Community influence
- In addition, the aquifer response to pumping may differ from that expected during design

A system may not remain protective and cost-effective if the necessary changes are not made.

Performance & Effectiveness



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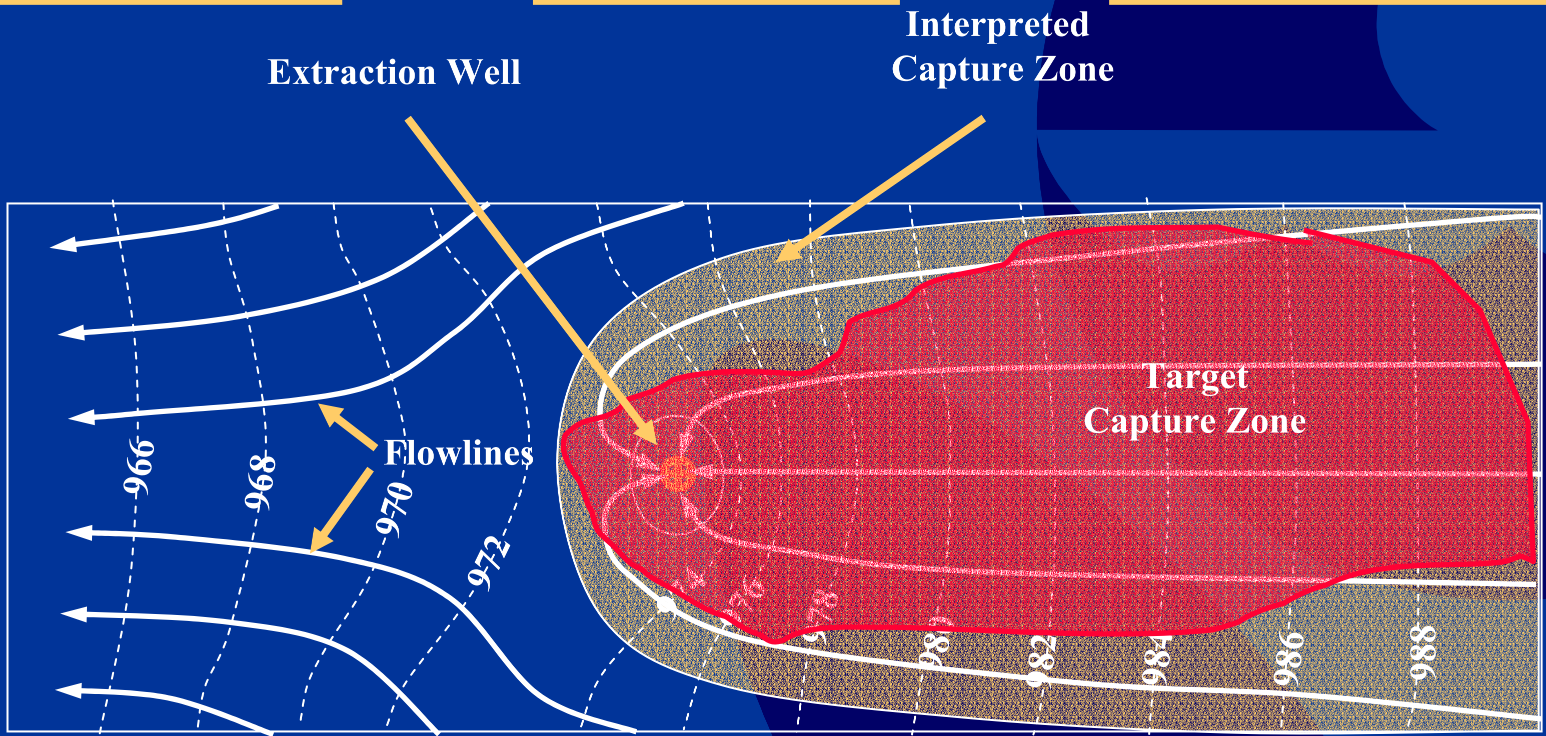
Subsurface Performance

Evaluating Plume Capture

Determine Target Capture Zone → Interpret Actual Capture Zone → Compare Actual and Target Capture Zones



Look for "A Systematic Approach to Evaluation of Capture Zones at Pump and Treat Sites", which is currently under development.

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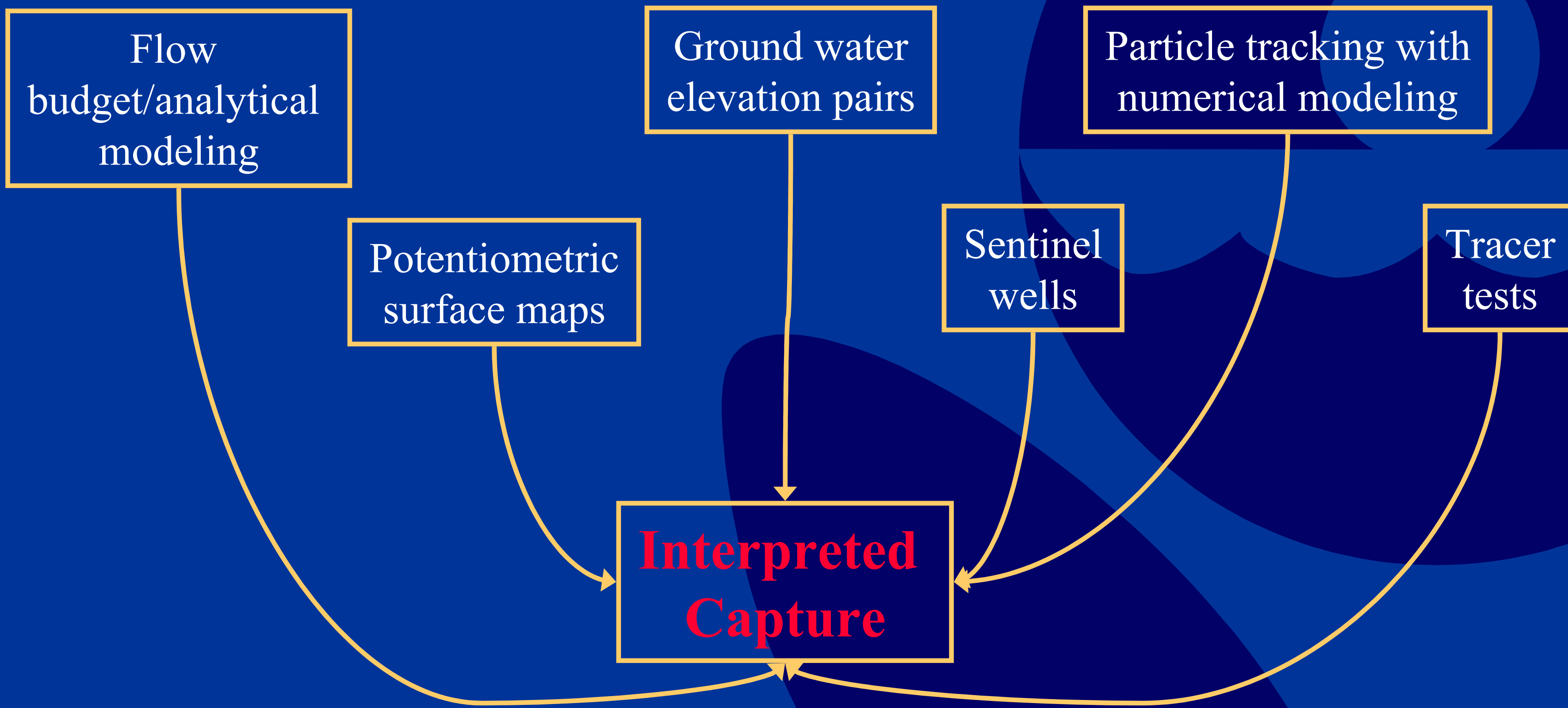
Subsurface Performance

- Interpret actual capture zone with converging lines of evidence (all of the following lines of evidence are NOT required at each site)



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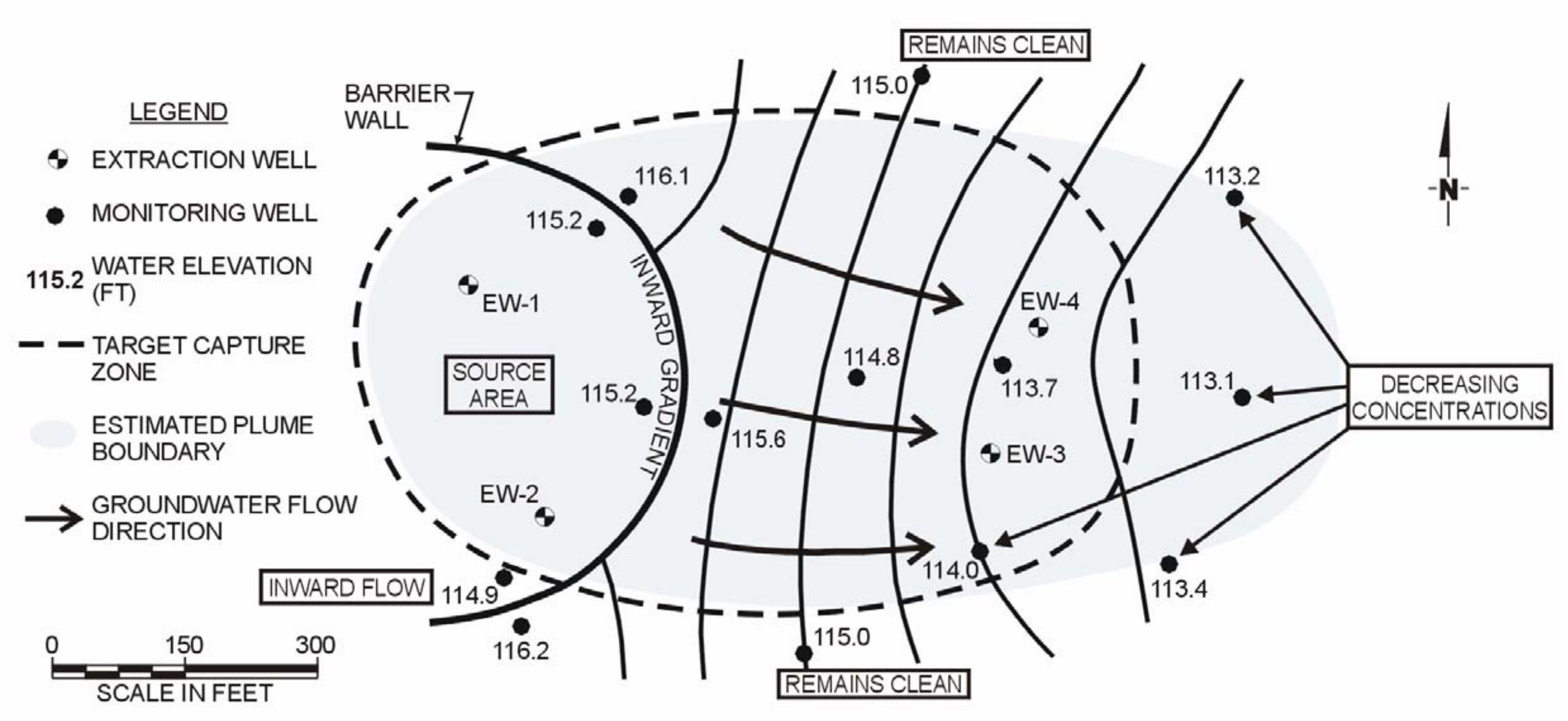
Subsurface Performance

- Example of a simplistic capture zone evaluation



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Subsurface Performance

- Example of a simplistic capture zone evaluation
  - Simplistic water budget analysis
    - Assumptions
      - Single layer with uniform thickness
      - Homogeneous, isotropic aquifer
      - No recharge
    - $Q = W \times C \times B \times K \times I$

Parameter	Value in Example
Q = required extraction rate	3.7 gpm
W = target width	600 ft
C = conversion factor	0.00518 gpm-day/ft^3-min
B = saturated thickness	20 ft
K = hydraulic conductivity	10 ft/day
i = hydraulic gradient	0.006 ft/foot

Result: 3.7 gpm is flowing through target capture zone, and EW-3 and EW-4 extract 8 gpm combined

Conclusion: This line of evidence supports capture.

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Subsurface Performance

- Example of a simplistic capture zone evaluation (cont.)
  - Water level pairs demonstrate inward flow across barrier wall
  - Potentiometric surface demonstrates flow toward EW-3 and EW-4 but resolution is insufficient to confirm capture
  - Downgradient wells show decreasing concentrations

Conclusion: For this example, there are multiple lines of evidence that suggest capture and no lines of evidence that reject capture.

  - Other issues
    - Consider seasonal variation
    - Evaluate vertical capture
  - Other potential lines of evidence (optional)
    - Additional piezometers near extraction wells to provide more resolution
    - Ground water modeling with particle tracking

Look for "A Systematic Approach to Evaluation of Capture Zones at Pump and Treat Sites", which is currently under development.

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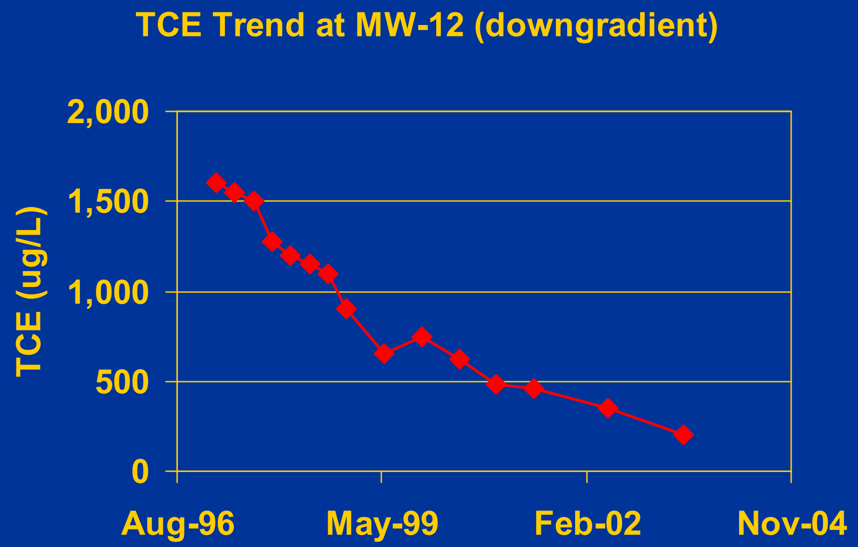
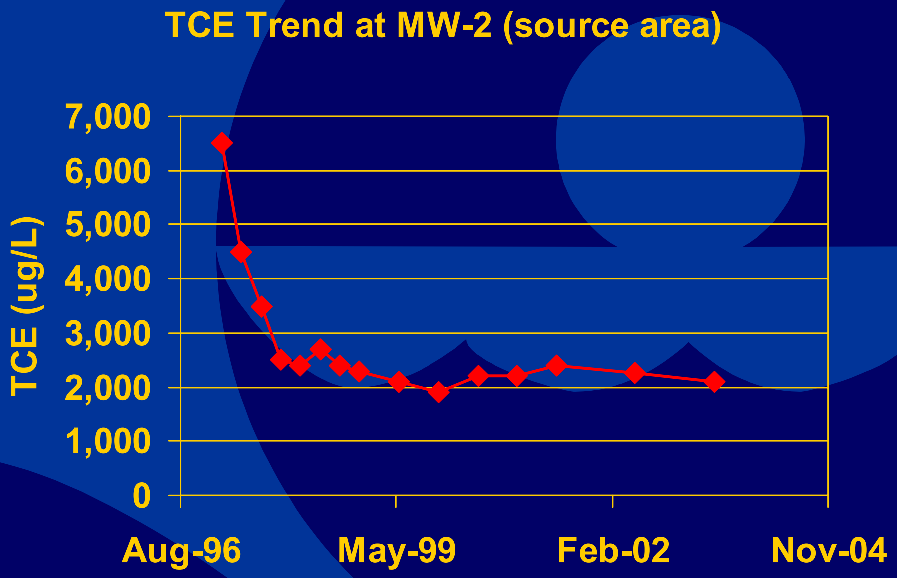
Subsurface Performance

- Evaluate progress toward remediation goals

<u>Downgradient</u>

- Where did you expect to be by 6/2003?
- Is the remedy effective downgradient?
- How do these results compare with the conceptual model?





<u>Source Area</u>

- What concentrations do we need to reach to shut off the P&T system?
- Will P&T meet those concentrations?
- What alternatives can we consider?

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Subsurface Performance

- Other topics in the document include…
  - Perform and interpret groundwater monitoring,
    - Considerations for measuring water levels
    - Considerations for monitoring water quality
    - Trend analyses
  - Evaluate extraction well performance and injection system performance
    - Discussion regarding specific capacity
    - Reference to USACE well maintenance guidance

Above-ground Performance

- Perform and interpret process monitoring, for example…
  - Calculate mass loading/removal rate in influent water

$$\text{influent concentration} \times \text{flow rate} \times \text{conversion factors} = \frac{\text{lbs}}{\text{day}}$$

$$\frac{1{,}000\ \text{ug}}{\text{L}} \times \frac{250\ \text{gal.}}{\text{min.}} \times \frac{3.785\ \text{L}}{\text{gal.}} \times \frac{2.2\ \text{lbs.}}{1 \times 10^{9}\ \text{ug}} \times \frac{1{,}440\ \text{min.}}{\text{day}} = \frac{3.0\ \text{lbs.}}{\text{day}}$$

  - Calculate mass loading/removal rate for air (not valid for ppm)

$$\text{influent concentration} \times \text{flow rate} \times \text{conversion factors} = \frac{\text{lbs}}{\text{day}}$$

$$\frac{200\ \text{mg}}{\text{m}^3} \times \frac{170\ \text{ft}^3}{\text{min.}} \times \frac{0.0283\ \text{m}^3}{\text{ft}^3} \times \frac{2.2\ \text{lbs.}}{1 \times 10^{6}\ \text{mg}} \times \frac{1{,}440\ \text{min.}}{\text{day}} = \frac{3.0\ \text{lbs.}}{\text{day}}$$

- Compare results to design specifications for system and system components

Cost-Effectiveness

- Identify significant cost items
- Maintain and clean equipment as appropriate
- Modify inefficient system components
- Remove redundant of unnecessary components
- Consider alternate discharge/disposal options
- Eliminate excess monitoring

Cost-Effectiveness

Annual O&M Costs for a Hypothetical P&T System

Cost Category	Annual Cost	% of Total Annual Cost
Labor ● PM & reporting ● O&M operator ● Sampling labor	 $30,000 $49,200 $28,800	43%
Utilities ● Electricity, gas, sewer, etc.	 $54,000	22%
Materials ● GAC ● Chemicals	 $12,000 $15,000	11%
Chemical Analysis	$36,000	14%
Disposal costs	$24,000	10%
Total	**$249,000**	**100%**

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Cost-Effectiveness

- Savings from downsizing motors, etc.
  - Assuming 75% motor efficiency, 1 HP = 1 kW
  - 1 kW operating for 1 day = 24 kWh
  - Electricity rates generally range from \$0.05 to \$0.15 per kWh
  - Reasonable to assume 1 HP → \$70/month
- Example: Replacing a 50 HP blower with a 15 HP blower

50 HP × \$70/month/HP	\$3,500/month	\$42,000/year
15 HP × \$70/month/HP	\$1,050/month	\$12,600/year
Savings	**\$2,450/month**	**\$29,400/year**

Payoff time: Less than one year, assuming a capital cost of \$25,000 to replace the blower.

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Cost-Effectiveness

- Example: Evaluating over-design of air stripper offgas treatment
  - Operational parameters
    - 36 lbs of VOCs per day in plant influent (0 lbs per day in effluent)
    - 36 lbs of VOCs per day in air stripper offgas
  - Offgas treatment (thermal oxidizer) parameters
    - Designed for 160 lbs of VOCs per hour
    - Requires $22,000/month for natural gas and $3,000/month for electricity
  - Solution – Replace thermal oxidizer with on-site GAC regeneration
    - Designed for 50 lbs of VOCs per day
    - Capital costs for implementation: $370,000
    - Utility costs of $2,000 per month
    - Estimated annual cost savings: $276,000
  - GAC with off-site regeneration would also be more cost effective, than the thermal oxidizer and may be preferable depending on GAC usage and expected influent concentration trends

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Contracting Considerations

- Topics include
  - Clearly establishing the responsibilities of the contractor for key items such as
    - Maintenance of site records
    - Data collection, reporting, and analysis
  - Comparing lump-sum vs. cost-reimbursable contracts
  - Planning for reductions in scope as site conditions change

These topics, and others, are covered in more detail in the contracting fact sheet that we will discuss in a few slides.

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Optimization and Continuous Improvement

- It is beneficial to periodically evaluate goals, performance, and cost-effectiveness
- Value of third-party (or independent) reviews
  - An unbiased, external review of the system and operating costs
  - Expertise in hydrogeology and engineering
  - Specific knowledge and experience with alternative technologies
  - Experience gained from designing, operating, and evaluating other P&T systems
  - A fresh perspective on problems the site team has been addressing

Look for a new EPA fact sheet titled "Groundwater Remediation Optimization: Benefits and Approaches", which is coming soon!

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Discussion

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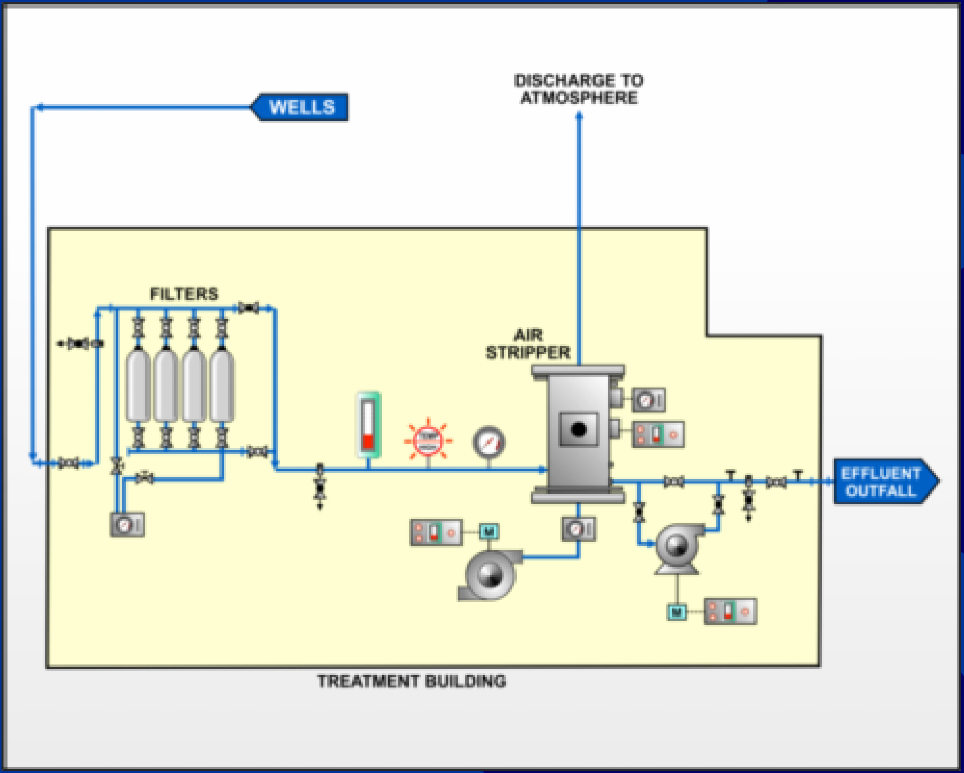
Cost-Effective Design of Pump and Treat Systems



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Topics

- Remedy Goals and Performance Monitoring
- System Design Parameters
- The Extraction System
- Selecting the Appropriate Treatment Technology
- Discharge Options
- Controls/Redundancy/Failsafes
- Additional illustrative examples are provided as an appendix

General Themes

- Use the appropriate design parameters
- Avoid redundant treatment components and treatment trains
- Avoid costly items (consider both capital and O&M costs) and plan for the long-term
- Weigh all of your options
  - Treatment components
  - Discharge options
  - Etc.

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System Design Parameters

- Flow rate
  - Design extraction rate – base it on pumping data and perhaps modeling
  - Hydraulic capacity – design extraction rate × a factor of safety
- Design concentration
  - Determine for each constituent
  - Base it on samples collected during sustained pumping
  - Do NOT base it on maximum concentration from RI
- Design mass removal rate
  - Design extraction rate × design concentration (see slide #23)
- Maximum influent concentration
  - Design influent concentration × a factor of safety (e.g., 2)
- NAPLs
  - LNAPL, DNAPL, etc.
  - Is it recoverable?

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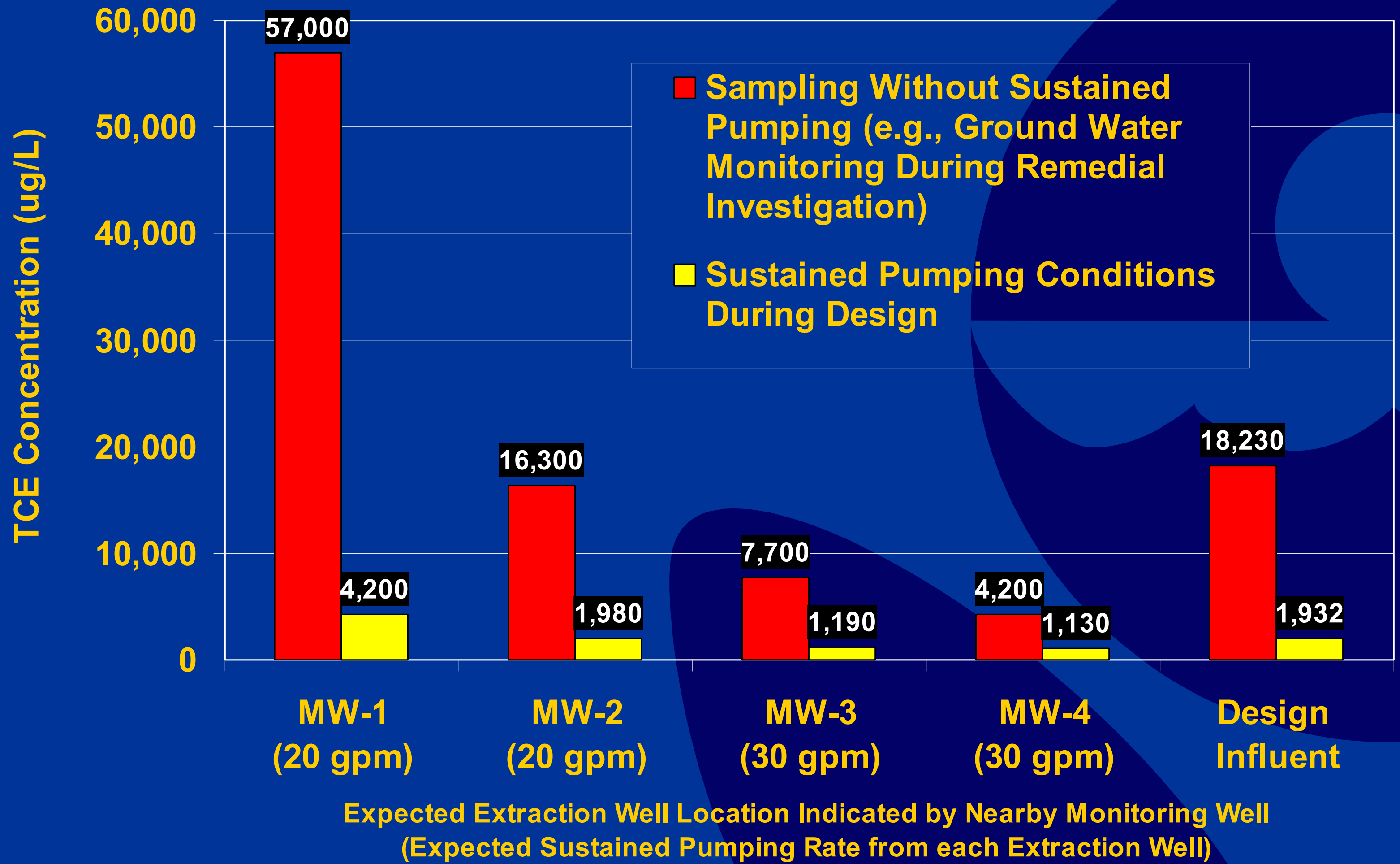
System Design Parameters



Do NOT use the maximum RI concentration for design concentration!!!

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Treatment Technologies

Technology	Example Comments
For removing NAPL	
● Phase separators	● Easy to maintain, do not remove emulsified product
● Oleophilic filters	● Remove emulsified product, costly for large volumes
● Dissolved air flotation	● Removes neutral NAPL, costly to operate
Treating organic compounds	
● Air stripping	● Good for most VOCs, low operator requirements
● GAC	● Good for many organics, low operator requirements
● Polymeric resin	● Effective for high concentrations, compound specific
● Biological treatment	● Useful for ketones, requires more operator attention
● UV oxidation	● Destroys most organics, high energy costs
Treating inorganic compounds	
● Filtration	● Low operator requirements, removal may not be sufficient
● Settling and/or metals precip.	● Effective and reliable, operator and material intensive
● Ion exchange	● Low operator requirements, compound specific

These and other provided comments are general "rules of thumb".

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Treatment Technologies

- Preliminary design estimates for GAC
  - Determine influent concentration
  - Determine mass loading rate (see slide #23)
  - Determine ratio (R) for pounds of contaminants to pounds of GAC

$$R = \frac{1}{1{,}000} \times K \times C^{1/N}$$

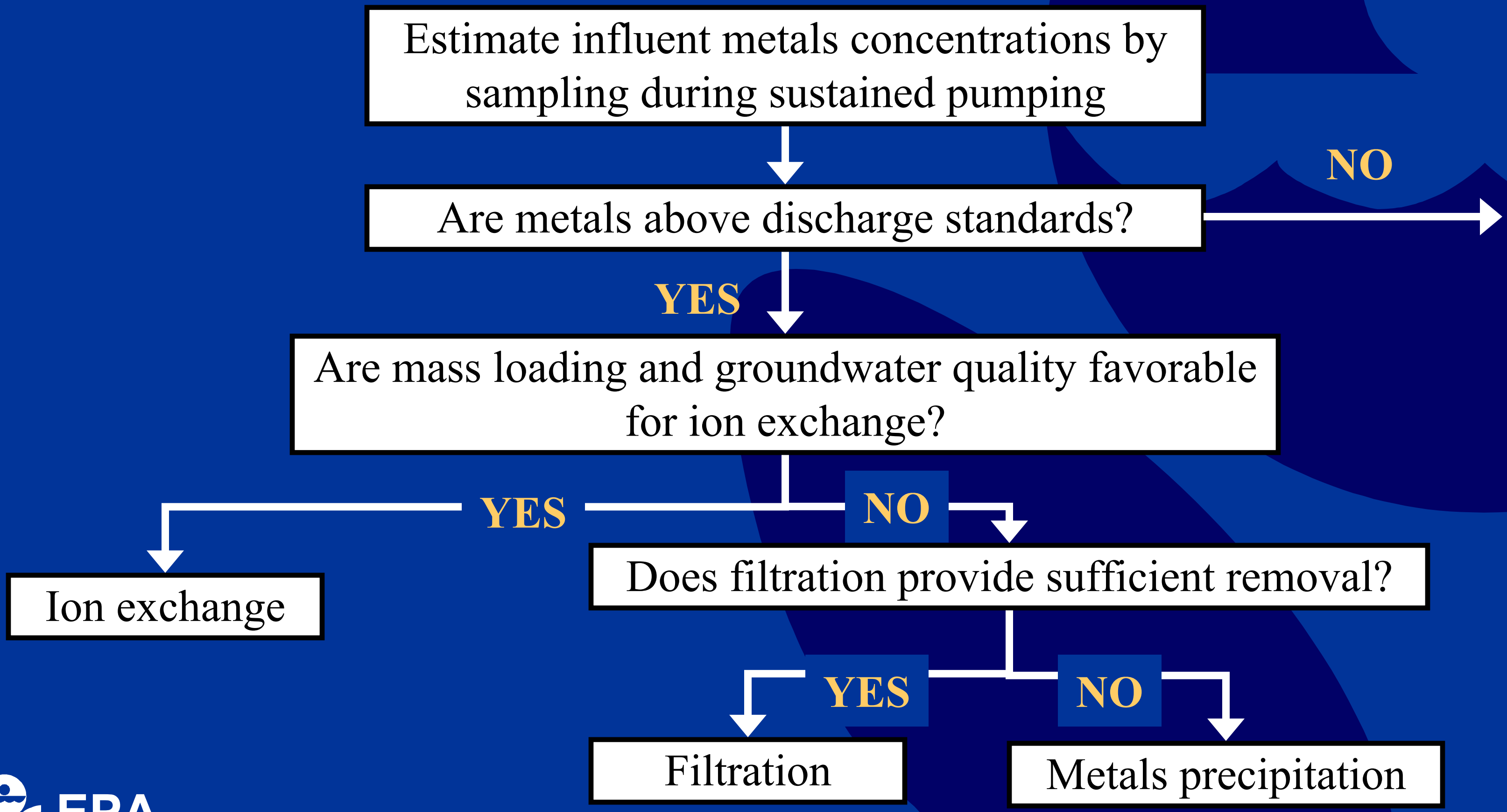
C is concentration in mg/L

Compound	PCE	TCE
K $(mg/kg)(L/mg)^{1/N}$	51	28
1/N	0.56	0.62

  - Calculate GAC usage (mass loading rate / R) and associated cost per year
  - Calculate vessel size based on usage and empty bed contact time

Treatment Technologies

- Consider ALL of your options before selecting a remedy, particularly if the presumptive remedy is known to be costly. Consider the following example decision tree for addressing metals in extracted groundwater



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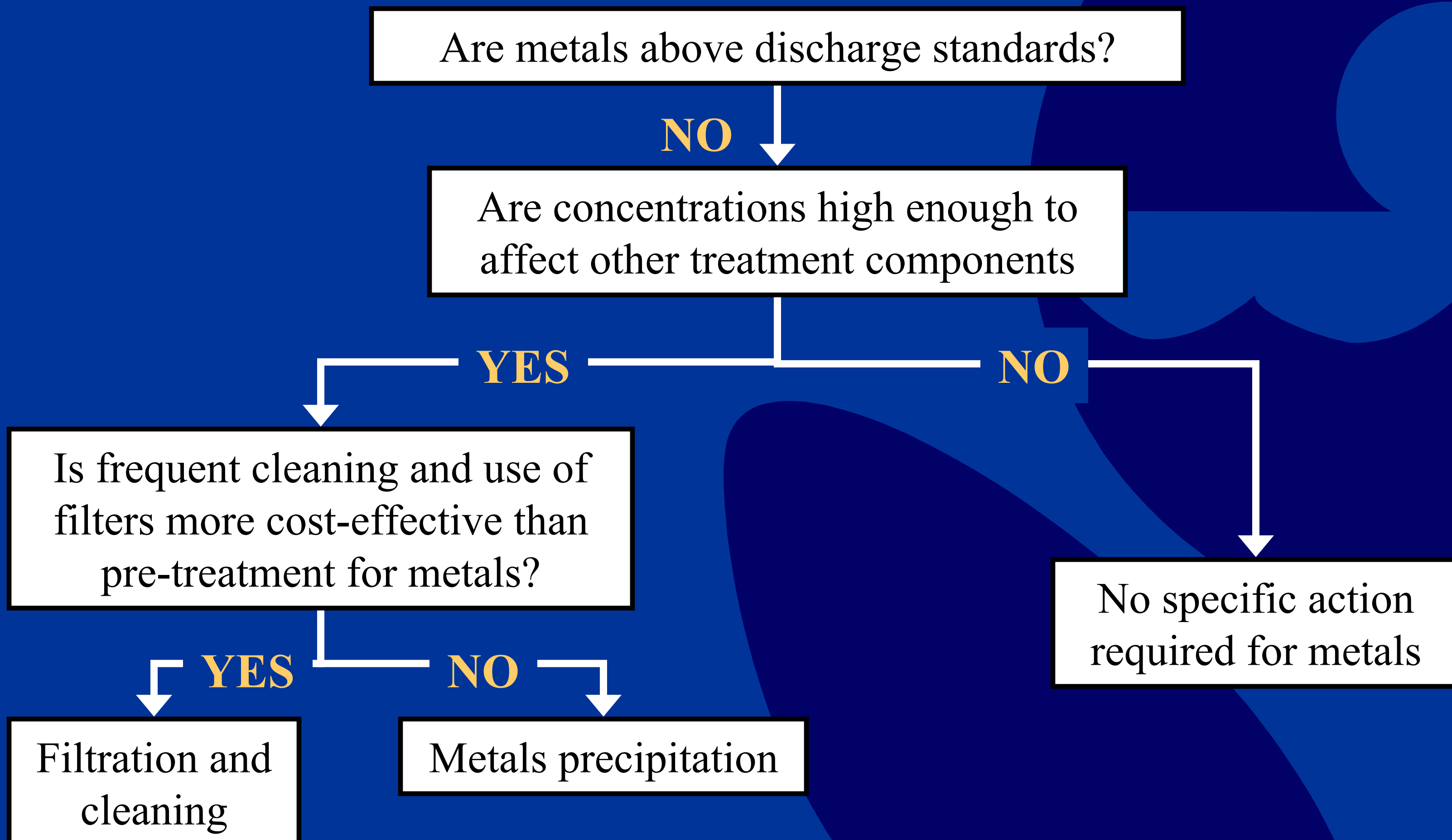
Treatment Technologies

Continued



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Discharge Options

Pros		Cons
Often take ketones, may have relaxed limits (TTO)	POTW	Pay by volume, may have limit on flow rate
Low cost, easy conduit to surface water	Storm Sewer	May have strict limits, require extensive sampling
Low cost, may allow high flow rates	Surface Water	Distance from site, strict discharge criteria, aesthetics/public perception
Resource conservation, plume control	Reinjection	Capital cost, maintenance (fouling), potential to spread plume

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Controls, Failsafes, and Automation

- General guidelines for labor typically required at various types of treatment plants

Treatment Train	Estimated Labor
Air stripping Vapor phase GAC for offgas treatment	• Weekly checks by local operator (8-12 hrs/wk) • Quarterly checks by engineer
GAC	• Weekly checks by local operator (8-12 hrs/wk) • Quarterly checks by engineer
Filtration UV/Oxidation GAC	• Weekly or semi-weekly checks by local operator (8-16 hrs/wk) • Quarterly checks by engineer
Metals removal Filtration (perhaps including air stripping, GAC, biotreatment, or UV/Oxidation)	• One operator full time with potential for part time assistance (40 - 60 hours/wk)

Discussion

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Effective Contracting Approaches for Operating Pump and Treat Systems

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Topics

- Essential contract components
- Options for contract type
- Considerations specific to contracts for operating P&T systems
- Optimization

General Themes

- A contract governs the relationship between the customer and the contractor
- A good contract…
  – Is beneficial to both parties
  – Clearly outlines roles and responsibilities
  – Allows for flexibility and modifications to account for changes in site conditions and system requirements

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Contract Components

- Scope of work
- Schedule and deliverables
- Level of effort and/or pricing
- Period of performance
- Terms and conditions
- Points of contact
- Procedures for contract changes
- Special clauses
- Others…

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Contract Types

- Fixed-price – contractor must complete scope, regardless of cost
  - Firm-fixed price
  - Fixed-price with economic price adjustment
  - Fixed-price incentive
- Cost-reimbursable
  - Cost plus fixed fee
  - Cost plus incentive fee
  - Cost plus award fee
- Time and materials
  - May be open-ended or may include a “not to exceed” clause

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Contract Types

Consideration	Fixed-Price	Cost-Reimbursable or T&M
Risk to contractor	Higher risk	Lower risk
Definition of tasks	Appropriate for tasks with predictable components	Appropriate for tasks with unpredictable components
Contractor incentive	Encourages contractor to work efficiently	No incentive within contract for contractor to work efficiently
Invoice information	Fewer details to review	More details to review
Risk to customer	Lower risk	Higher risk

Considerations for Operating P&T Systems

- Operating P&T systems have the following characteristics
  - They are long-term activities
  - Actual O&M is generally routine, but P&T systems are often associated with complex sites with non-routine activities
  - Site conditions change over time. Some items remain predictable while others are unpredictable

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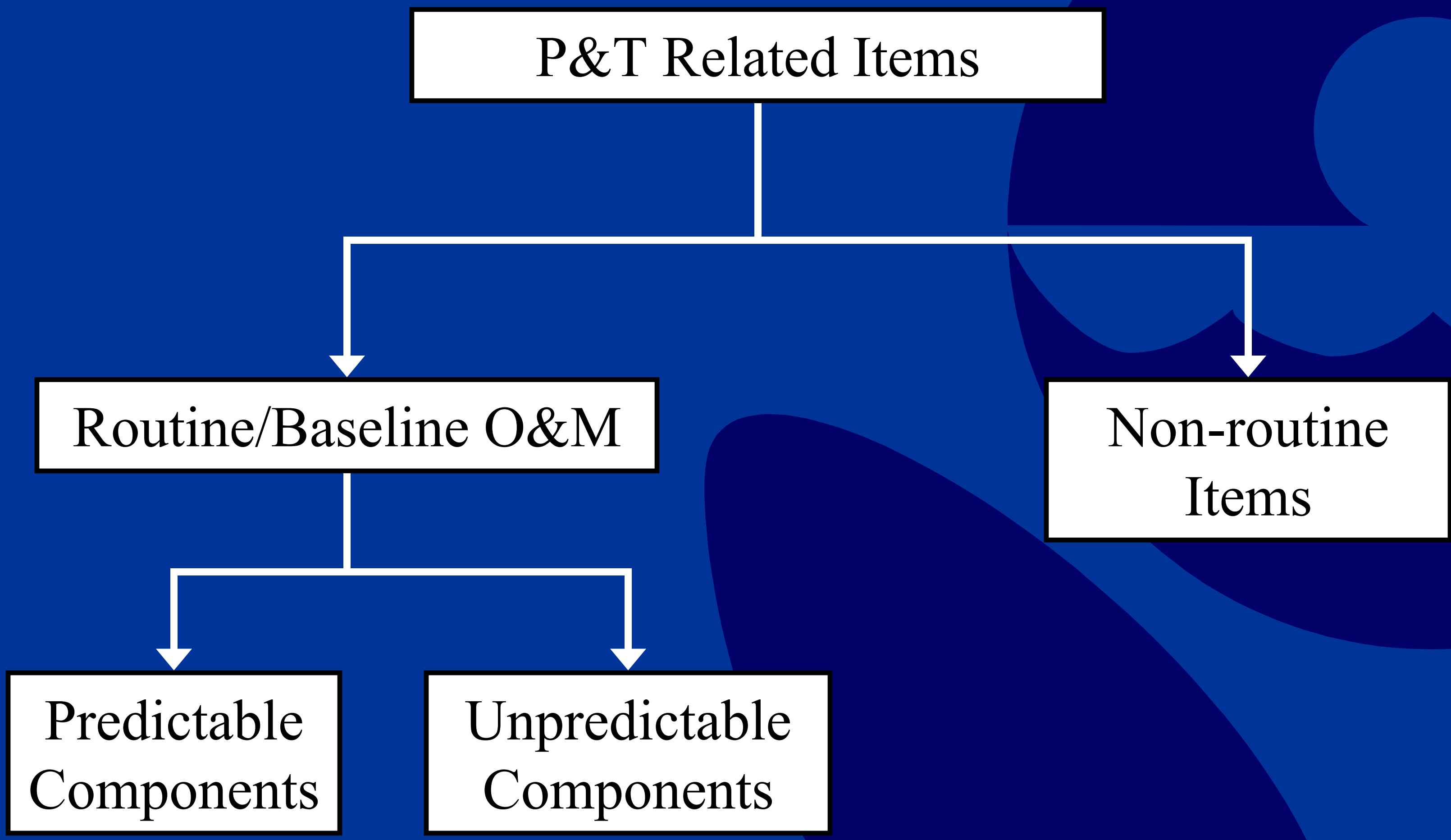
Considerations for Operating P&T Systems



Considerations for Operating P&T Systems

- Routine vs. non-routine
  - Non-routine items might include
    - Non-routine maintenance
    - Community relations
    - Evaluations (e.g., receptor evaluations, 5-year Reviews)
    - Source area investigations
    - Etc.
- Consider the scenario on the following slide to see why non-routine items should be tracked separately from routine items

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Considerations for Operating P&T Systems

Year	General Tasks	Approach 1 (Recommended)	Approach 2
1	• Baseline O&M • Non-routine tasks	$125,000 $100,000	$225,000
2	• Baseline O&M • Non-routine tasks	$150,000 $70,000	$220,000
3	• Baseline O&M • Non-routine tasks	$175,000 $50,000	$225,000
4	• Baseline O&M • Non-routine tasks	$205,000 $20,000	$225,000

With Approach 2, a customer may not see the cost increase for baseline O&M, which may signal contractor inefficiency or changes in O&M costs that need to be addressed

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Considerations for Operating P&T Systems

- Predictable vs. unpredictable

Lump Sum	Cost-Reimbursable or T&M
• Project management • Reporting/data analysis • Process monitoring/analysis* • Groundwater monitoring/analysis* • O&M labor and routine maintenance	• Non-routine maintenance and plant upgrades • Utilities • Consumables • Disposal

Fixed prices per unit item allow for reductions or increases depending on site conditions.

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Optimization

- As part of providing quality service, the contractor should continually work to optimize the system, but…
  - Contractors may be hesitant to recommend changes that reduce their level of effort
  - This consistent effort should not necessarily require an additional optimization line item
- A contract could outline incentives or awards to foster contractor-based optimization
- Contractors should receive awards for optimization, NOT simple reductions in scope
- More comprehensive optimization should be provided by an independent party that does gain or lose from changes in the O&M level of effort

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Optimization

- Examples of optimization include
  - Using a new oxidant that will increase efficiency of a metals removal system
  - Replacing a thermal oxidizer with GAC to treat air stripper or SVE offgas
  - Improving automation
- Examples of scope reductions include
  - Reducing groundwater monitoring due to established trends
  - Reducing process monitoring locations due to demonstrated system effectiveness
  - Reducing operator labor because the system operates continually without incident
  - Discontinuing a treatment process because the plant influent already meets effluent criteria

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Other Reminders

- Eliminate services no longer required after construction completion (e.g., trailers)
- Utilize technical assistance resources to scope work properly prior to O&M contract
- Each level of subcontracting costs money with no direct return
- Beware of O&M bids based on worst-case data from remedial investigation
- Use the contract to establish the O&M reporting requirements

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Discussion

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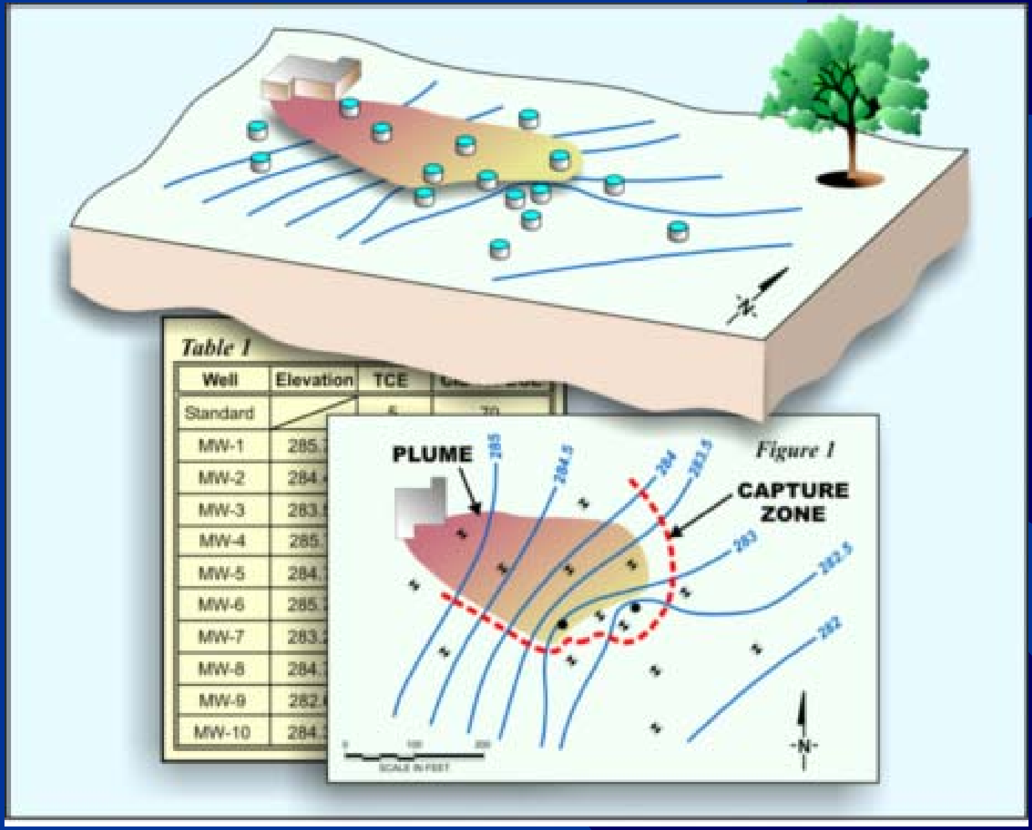
O&M Template Report for Ground Water Remedies
(with Emphasis on Pump and Treat Systems)



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O&M Reports

- Reasons for having quality, comprehensive O&M reports
  - Facilitate oversight by both site representative and regulator
  - Maintain a written, updated record of site data
  - Facilitate information transfer for switching O&M contractors or conducting independent optimization reviews

- This presentation discusses the following sections of an O&M report, including example figures and tables
  - Executive Summary
  - Introduction
  - Operations Summary
  - Subsurface Performance Summary
  - Suggested Modifications

Executive Summary

- The intended audience of an O&M report may only read the Executive Summary. Include statements regarding the following:
  - Extent of downtime and if any was non-routine
  - Exceedances of discharge criteria
  - Significant operational problems
  - Noteworthy changes to the system
  - Goals of system
  - Consistency of collected data relative to expectations
  - Whether or not short-term goals are being met
  - Whether or not long-term goals are likely to be met
  - New inconsistencies or identified gaps in the site conceptual model
  - Brief description of any recommendations, including potential costs and/or cost savings

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Introduction

- An introduction should likely include the following:
  - Site name and location (refer to a figure)
  - Purpose of report and reporting period
  - Summary and/or highlights of the updated site conceptual model
  - Statement of short- and long-term goals
  - Items being measured to evaluate those goals
  - Exit strategy for system

Operations Summary

- Include the following:
  - System downtime (routine vs. non-routine)
  - Process monitoring schedule and data
  - Extraction well data (flow rates, concentrations, specific capacities)
  - Current data presented alongside historic data and design parameters
  - Efficiency of primary treatment components
  - Utilities, consumables, and waste handling/disposal
  - Problems encountered (extraction and treatment system)
  - Maintenance (routine vs. non-routine)
  - And other items…

Operations Summary

Month	Flow Rate (gpm)	Influent VOC Conc. (ug/L)	Mass Loading this Month (lbs)	Cumulative Mass Loading (lbs)
Design Values	**100**	**2,000**	**71.9**	**N/A**
1/98	62.2	1,194	26.7	26.7
2/98	65.1	844	19.8	46.5
3/98	64.2	871	20.1	66.6
…	…	…	…	…
…	…	…	…	…

Note that parameters are compared to design values.

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Operations Summary

Month	Influent Conc.			Effluent Conc.			Benzene Stripper – GAC (ug/L)	Stripper Efficiency (%)***
	Benzene (ug/L)	Nickel (ug/L)	Lead (ug/L)	Benzene (ug/L)*	Nickel (ug/L)	Lead (ug/L)		
Discharge Limit	**5**	**200**	**50**	**5**	**200**	**50**	**5**	**200**
1/98	1,194	29.6	25.2	ND (1)	20.8	13.1	19.2	98.39%
2/98	844	16.8	23.8	ND (1)	15.6	9.2	-	-
3/98	871	41.4	28.7	ND (1)	25.0	16.2	-	-
4/98	1,008	41.9	25.2	**9.4****	29.2	19.4	15.4	98.47%

*** ND (1) indicates analyte was not detected above detection limit of 1 ug/L**

**** Exceedance of discharge criteria due to fouled GAC. GAC has been replaced.**

***** If sample between stripper and GAC is ND, the air stripper efficiency is calculated using half the detection limit**

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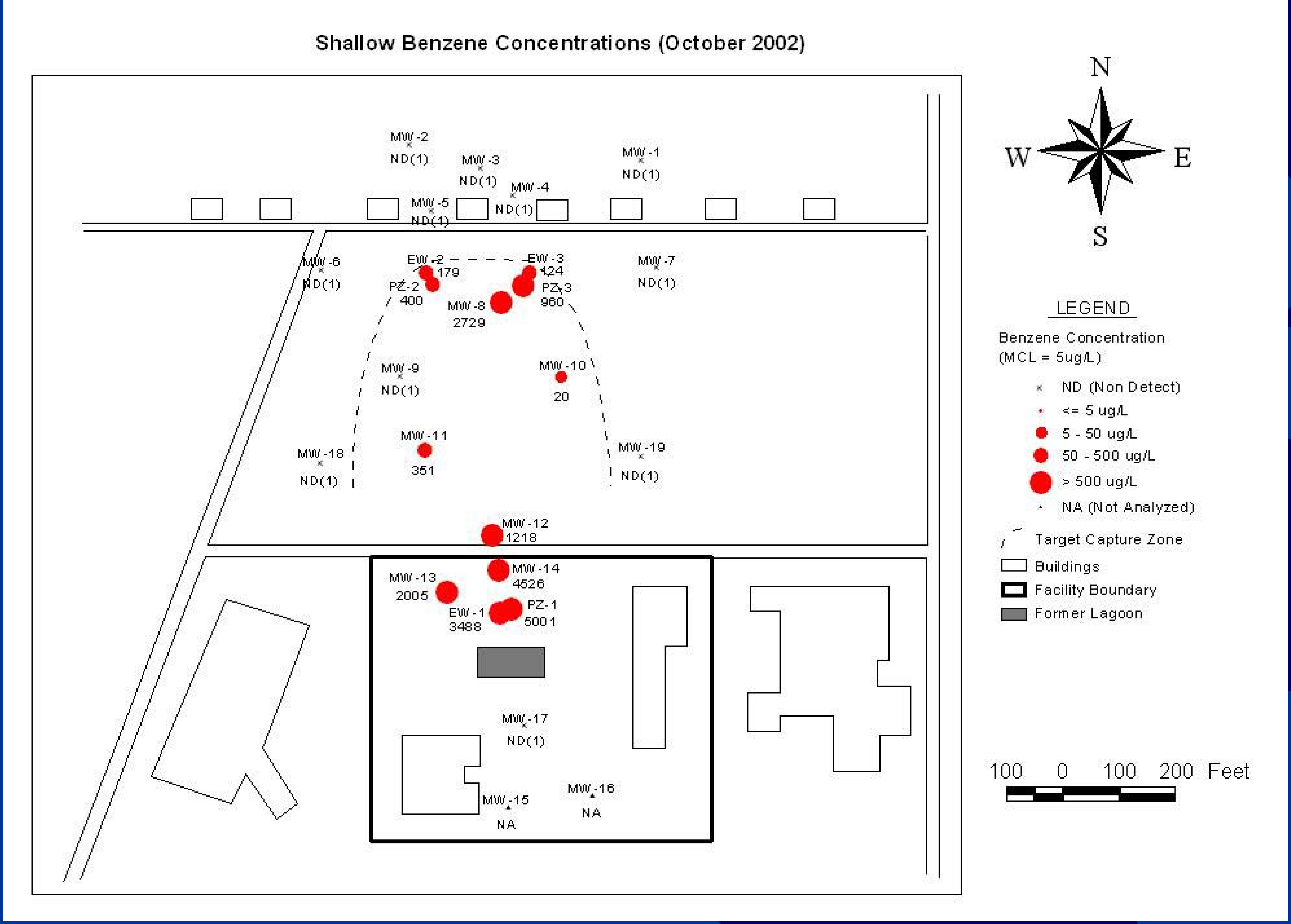
Subsurface Performance Summary

- Include the following:
  - Sampling events performed during the reporting period
  - Water level data
  - Concentration data
  - Other monitoring results (surface water, supply wells, etc.)
  - Interpretation of progress toward goals
    - Progress with respect to short-term goals (e.g., capture)
    - Progress with respect to long-term goals (e.g., aquifer restoration)
    - Gaps or inconsistencies in site conceptual model

This section might include capture zone analyses to evaluate plume capture and/or trend analyses to evaluate aquifer restoration.

Subsurface Performance Summary



Suggested Modifications

- Modifications may be suggested with respect to…
  - Groundwater extraction (locations and rates)
  - Adding, removing, replacing or otherwise modifying above-ground treatment processes
  - Disposal of treated water
  - Long-term groundwater monitoring
- Suggested modifications should include estimated potential costs and/or cost savings from implementing the modification

Concluding Remarks

- Remember… all of these documents and the others mentioned will be available at the following web sites

www.cluin.org/optimization

www.frtr.gov

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Question and Answer Session

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