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Monitored Natural Attenuation and Enhanced Passive Remediation (MNA/EPR) for Chlorinated Solvents, DOE Alternative Project for Technology Acceleration Agenda

Date: September 23, 2003
Time: 9:00 am – 4:00 pm
Location: Washington State University CIC, 2770 University Drive, Richland, WA

Objectives:

1. To provide information about the project to regulators, stakeholders and end users.
2. To elicit feedback and gather input on a) the direction of the project, b) its usefulness, and c) applicability to the issues with which the respective sites, states and regions are dealing in relation to application of monitored natural attenuation of chlorinated solvent contamination.

Time	Topic	Lead
9:00 am	**Welcome** • Matt McCormick US DOE, Richland Operations Office • Bruce Ford Fluor Hanford • Rod Quinn, PNNL	Tyler Gilmore, PNNL
9:30 am	**Introductions and Review of Agenda**	Tyler Gilmore, PNNL
9:35 am	**Project Introduction** • Background on MNA/EPR for Chlorinated Solvents, DOE Alternative Project for Technology Acceleration (10 min.)	Claire Sink, DOE-EM
9:45 am	**Definition of MNA and History of MNA Protocols/Introduction of Project** • Overview of MNA Project (15 min.) – Why this project was funded – Purpose of project, product and desired outcome – Project structure – Project timeline – Snapshot of: - Areas identified for improvements to existing MNA approach - New way of expressing problem - Enhanced passive remediation and how it complements MNA - Strategy for long-term monitoring; transition from active to passive systems • Discussion (5 min.)	Karen Vangelas, SRTC

10:05 am	**Break**	
10:20 am	**Technical Presentation/Discussion** • Overview of technical working group development of technical targets for MNA/EPR project (30 min.) – Overview of ground rules and lines of inquiry – Natural Attenuation Capacity – Characterization/Monitoring Strategy – Bioassessment Tools – Results of Prioritization of Technical, Policy and Implementation Topics • General Discussion, Questions and Answers (15 min.)	Brian Looney, SRTC Tyler Gilmore, PNNL Participants
11:00 am	**Concurrent Breakout Discussion Groups**	Facilitated discussion
12:00 pm	**Lunch**	
1:30 pm	**Concurrent Breakout Discussion Groups (cont.)**	Facilitated discussion
2:15 pm	**Plenary Session on Breakout Group Results** • Summary of key issues and comments from each breakout group (15 min.) • Discussion (5 min.)	Breakout group spokespeople
2:35 pm	**Application to Hanford**	Mike Thompson, DOE-RL
2:45 pm	**Regulatory, Tribal and Stakeholder Perspectives** • EPA (10 min.) • Ecology (10 min.) • Confederated Tribes of the Umatilla Indian Reservation (10 min.) • Nez Perce Tribe (10 min.) • Wanapum Tribe (10 min.) • Yakama Indian Nation (10 min.) • State of Oregon (10 min.) • Other interested parties	
4:00 pm	**Action Items and Next Steps**	Facilitator
4:15 pm	**Adjourn**	

Monitored Natural Attenuation and Enhanced Passive Remediation MNA/EPR) for Chlorinated Solvents Technology Alternative Project

Tyler Gilmore (PNNL)
Brian B. Looney/Karen. M. Vangelas (SRTC)
Claire Sink (DOE)
September 23, 2003
Richland, Washington

Agenda

9:45 am - 10:05 am	Definition of MNA
	History of MNA Protocols
	Introduction of Project
10:05 am - 10:20 am	Break
10:20 am - 11:00 am	Technical Presentations
	General Discussion/Q&A
11:00 am - 12:00 pm	Breakout Sessions

Project Background

•Chlorinated solvents represent many of the largest and most challenging plumes at DOE sites across the country – including the Hanford Site, Savannah River Site, and the Oak Ridge Site.

•To facilitate implementation of MNA and EPR, the DOE Office of Environmental Management has sponsored an Alternative Project.

•The project narrowly focused, *provides the scientific and policy support to facilitate implementing appropriate passive cleanup and cost effective monitoring strategies leading to responsible completion of remediation activities at high risk DOE waste sites.*

•A technical working group with broad national representation was formed to strategically guide the project.

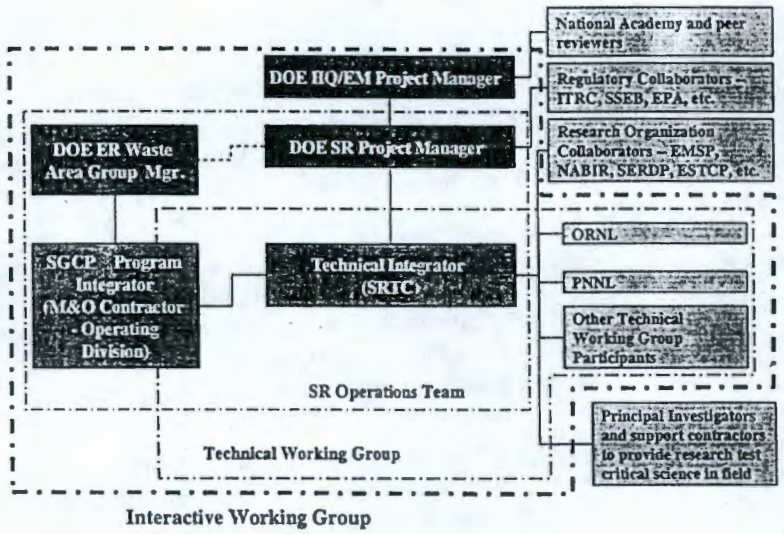
Project End Product and Desired Outcome

End Product: A technical guidance document that will provide additional information for implementing MNA.

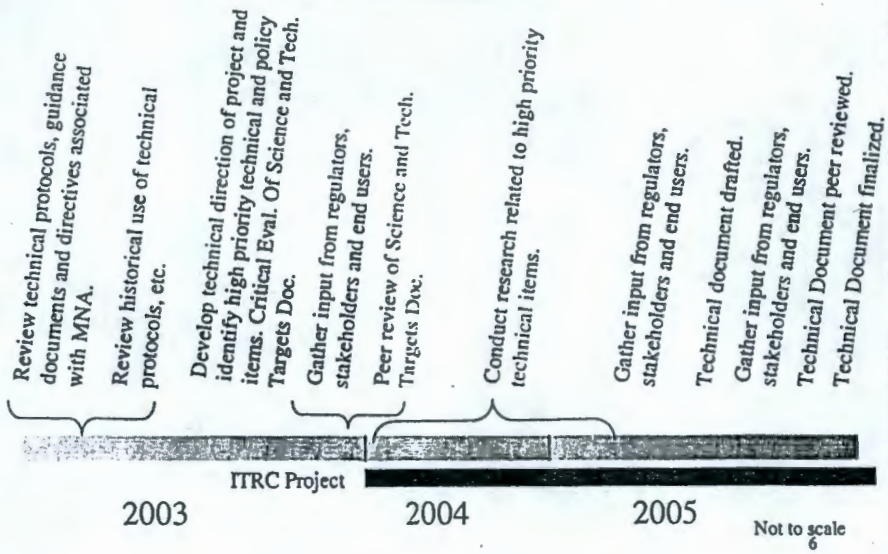
Desired Outcome: The end product of this project will provide value to and be used by the regulator and end user communities.

Strategy: In parallel with developing and implementing the technical strategy, we will gather and incorporate the issues, needs and concerns of the regulators, stakeholders and end users.

MNA Project Structure and Integration



Project Timeline

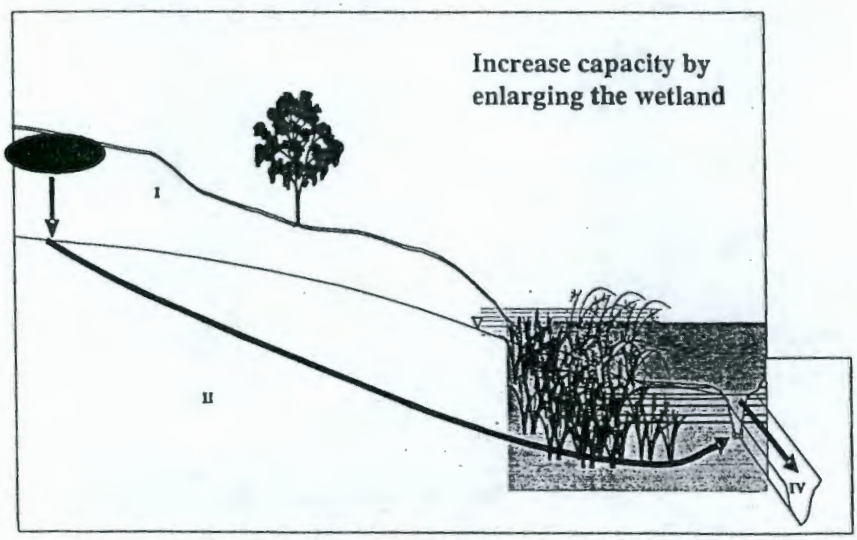


Definitions

MNA - Monitored Natural Attenuation - Managing all or part of a contaminant plume in soil and groundwater by utilizing the existing decontamination and attenuation mechanisms of the natural system and by documenting the resulting attenuation capacity. EPA definition states "no human intervention".

EPR - Enhanced Passive Remediation - Managing all or part of a contaminant plume in soil and groundwater by initiating and/or augmenting natural and sustainable decontamination and attenuation mechanisms and by documenting the resulting attenuation capacity.

Attenuation Capacity - The sum of all physical, biological, and chemical processes serving to disperse, biodegrade, chemically transform, immobilize, or permanently sequester chlorinated ethenes in a ground-water system.



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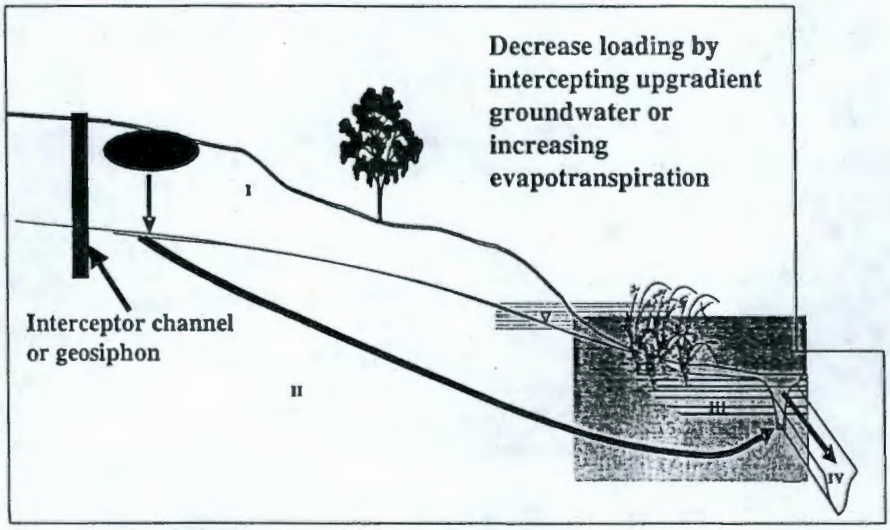

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Continuum of Individual Remediation Technologies

Source Removal

Excavation
In Situ Chemical Destruction
Thermal Methods

Interdiction

Pump and Treat
In Situ Bioremediation
Recirculating Wells
Permeable Treatment Systems

EPR - Enhanced Passive Remediation

Hydraulic Manipulation
Phytoremediation
Bioaugmentation
Fertilization
Passive Permeable Treatment Systems

Monitored Natural Attenuation

Dispersion
Advection
Sorption
Degradation
Volatilization
Plant Uptake

Source Near-Field Plume Far-Field Plume

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Key Objectives:

"To examine opportunities to incorporate recent science and expanded conceptual approaches to encourage appropriate use of MNA/EPR..."

- Develop the concept of enhanced passive remediation and all forms of sustainable passive natural remediation.
- Gain regulatory concurrence in the states and regions overseeing the Savannah River Site, Hanford, and Oak Ridge – work with interstate and national regulatory partners to contribute to national MNA efforts.
- Advance the science and broaden the understanding of natural attenuation and remediation systems.
- Establish and document new monitoring paradigms that provide high levels of performance for reduced costs.

Technical Working Group:

"This group is critical to the project success – they will specify and document the scientific approaches that will serve as the foundation of the project. As a result, a diverse group of recognized experts will participate."

Brian Looney, Savannah River Technology Center - Chairperson
Todd Wiedemeier, T. H. Wiedemeier and Associates
Tom Early, Oak Ridge National Laboratory
Frank Chapelle, U.S. Geological Survey
Jody Waugh, S. M. Stoller
David Major, GeoSyntec, Inc.
Tyler Gilmore, Pacific Northwest National Laboratory
Michael Heitkamp, Savannah River Technology Center
Gary Wein, WSRC-BSRI, Soils and Groundwater Engineering

Key Technical Resources and Project Team Members:
Ken Lovelace, US EPA, Office of Environmental and Remedial Response
Chuck Newell, Groundwater Services Inc.

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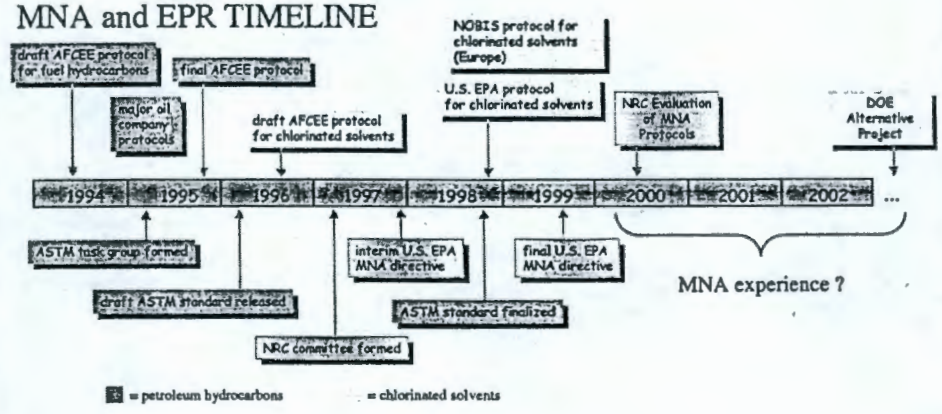
Recent Historical Development of MNA/EPR for Petroleum Hydrocarbons and Chlorinated Solvents (modified from Wiedemeier and Barden, 2002)



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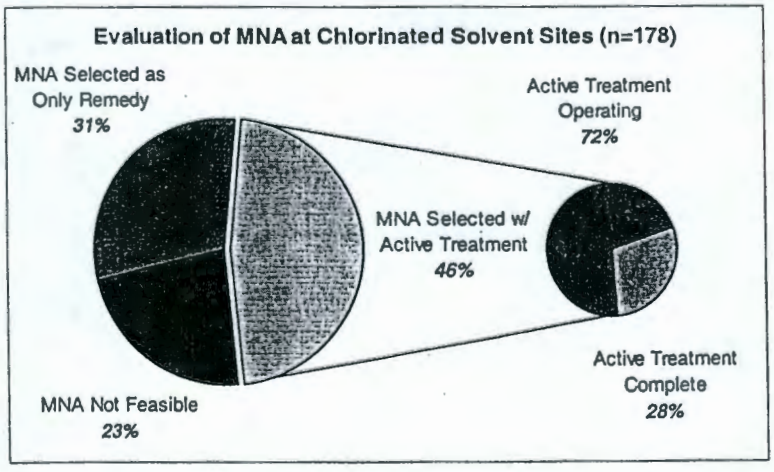

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Technical Organization:

"The project will critically examine opportunities for expanding MNA by following ground rules and directed lines of inquiry within the topics: Scientific Basis and Characterization/Monitoring"

Scientific Basis - Ground Rules

- Processes must be based on natural mechanisms.
- Processes must be sustainable and allow closure of the site from the perspective of active treatment.
- Develop the concept of EPR that allows enhancements and reconfiguration (as long as the resulting mechanisms are naturally sustainable) to increase the capacity of the naturally occurring processes.
- New approaches should build on and link to past MNA protocols.
- New approaches should focus on the basis for transitions from active to passive to MNA/EPR and defining a valid and environmentally protective exit strategy for active remediation.
- New approaches should emphasize the concept of working toward an "agreed" risk-based end state.

Characterization/Monitoring - Ground Rules

- Develop clear strategies for the distinct needs associated with MNA/EPR characterization and then long-term monitoring.
- Develop responsive characterization and monitoring approaches that beneficially use data to refine and improve decisions and interpretations.
- Emphasize integrating measures, such as flux, remote sensing and other averaging and volumetric methods.
- Refine the idea of "multiple lines of evidence" in current protocols and develop a defensible approach to define a "quorum of evidence" that will be acceptable (given natural variability and uncertainty).
- Emphasize large-scale design and monitoring concepts. Document performance and robustness using overall mass balances and MNA process/condition mapping to supplement or replace the traditional requirement of "plume stability".
- Emphasize system and ecosystem monitoring concepts.

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Summary Lines of Inquiry - Scientific Basis

- Natural Processes
- Natural Processes with Enhancements
  - •microbial
  - •phyto
  - •Interfaces
  - •Scenarios

Summary Lines of Inquiry – Characterization and Monitoring

- Strategy
- Multiple Lines of Evidence
- Enhancements to Characterization and Monitoring
  - Non-standard Monitoring Concepts
  - Modeling
  - Sensors
  - Configuration of Monitoring Systems
  - Advanced Bioassessment Tools

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Path Forward - A Three Month Window

- Peer Review of Science and Technology Targets document
- Conduct competitive process for selecting studies to support high ranked science and technology targets.
- Conduct briefings for end users, regulators and stakeholders associated with Savannah River, Hanford and Oak Ridge Sites.
- Initiate newly approved project with the Inter-State Technology Regulatory Council (ITRC).

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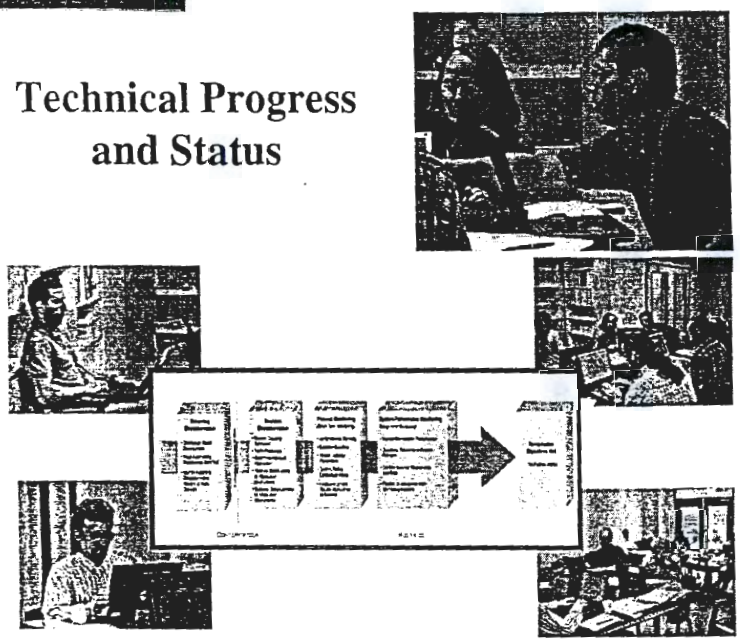
Technical Progress and Status



Scientific Basis Ground Rules

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Characterization and Monitoring - Ground Rules

- Develop clear strategies for the distinct needs associated with MNA/EPR characterization and then long-term monitoring.
- Develop responsive characterization and monitoring approaches that beneficially use data to refine and improve decisions and interpretations.
- Emphasize direct measures of processes rather than indirect where possible.
- Emphasize integrating measures, such as flux, remote sensing and other averaging and volumetric methods.
- Refine the idea of "multiple lines of evidence" in current protocols and develop a defensible approach to define a "quorum of evidence" that will be acceptable (given natural variability and uncertainty).
- Emphasize large-scale design and monitoring concepts. Document performance and robustness using overall mass balances and MNA process/condition mapping to supplement or replace the traditional requirement of "plume stability".
- Emphasize system and ecosystem monitoring concepts.

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Summary Lines of Inquiry - Scientific Basis

- Historical and Retrospective Evaluation
- Natural Processes
- Natural Processes with Enhancements
  - •microbial
  - •phyto
  - •Interfaces
  - •Scenarios

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Summary Lines of Inquiry - Characterization and Monitoring

- Strategy
- Multiple Lines of Evidence
- Enhancements to Characterization and Monitoring
  - •Non-standard Monitoring Concepts
  - •Modeling
  - •Sensors
  - •Configuration of Monitoring Systems
  - •Advanced Bioassessment Tools

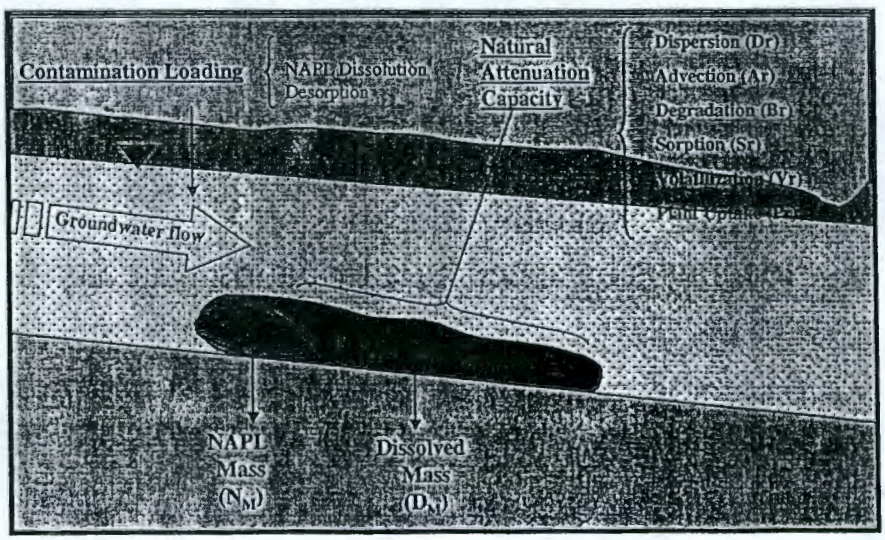
Existing MNA Protocols

- do a good job of identifying what needs to be measured at a site.
- do a poor job of explaining ***why*** those measurements should be made.

How can we improve use/acceptance of MNA?

- Do a better job of explaining why, when, and how certain measurements are useful.
- One way to do this is to focus the MNA paradigm to one of contaminant loading versus attenuation capacity.

MNA as a balance between contaminant loading and natural attenuation capacity



Plume Stability

- $D_m = D_r + A_r + B_r + S_r + V_r + P_r$
- contaminant loading is equal to the sum of the removal mechanisms
- This is a central concept and product of the technical work to date

A Mass Balance Paradigm

- Assess Contaminant Loading
- Assess Natural attenuation capacity
- Efficiency of MNA depends on how loading is balanced by attenuation capacity.

The Mass Balance Approach is conceptually simple and easy to understand

- It is an excellent organizing principle.
- Why then, is assessing MNA, and obtaining regulatory acceptance so difficult?

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Consider biodegradation …

- Reductive dechlorination
- Anaerobic oxidation
- Aerobic oxidation
- Fermentation
- Co-metabolism

These processes are difficult to measure directly. Rather a series of indirect measurements are used to deduce their presence/absence/rates.

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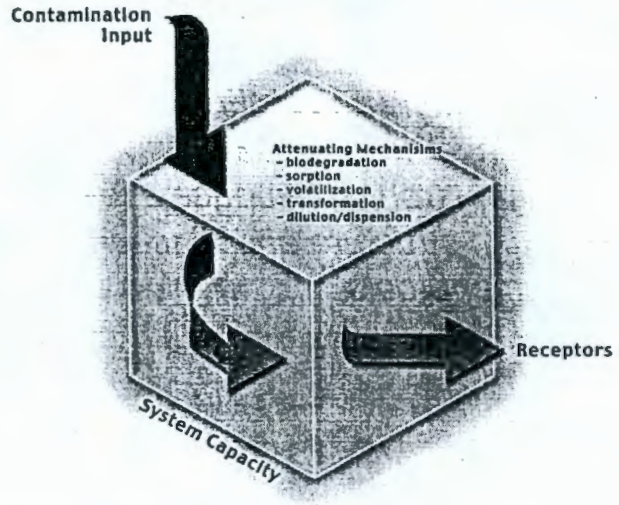
A shadow of its former self …

- *The different components of natural attenuation capacity contributing to the mass balance of a given site cannot be directly measured.*
- Actual evaluations of natural attenuation must rely on indirect measurements and indicators for each component of the mass balance problem.

Characterization and Monitoring Strategy for MNA and EPR

System Capacity



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Characterization and Monitoring Objectives

MNA is viable if the sum of the various mechanisms are sufficient to attenuate the contaminants and protect potential receptors.

- **Characterization** provides evidence that the attenuation capacity in the system is sufficient and sustainable
- **Monitoring** verifies the attenuation capacity is maintained over time and as conditions vary until remediation objectives are met.

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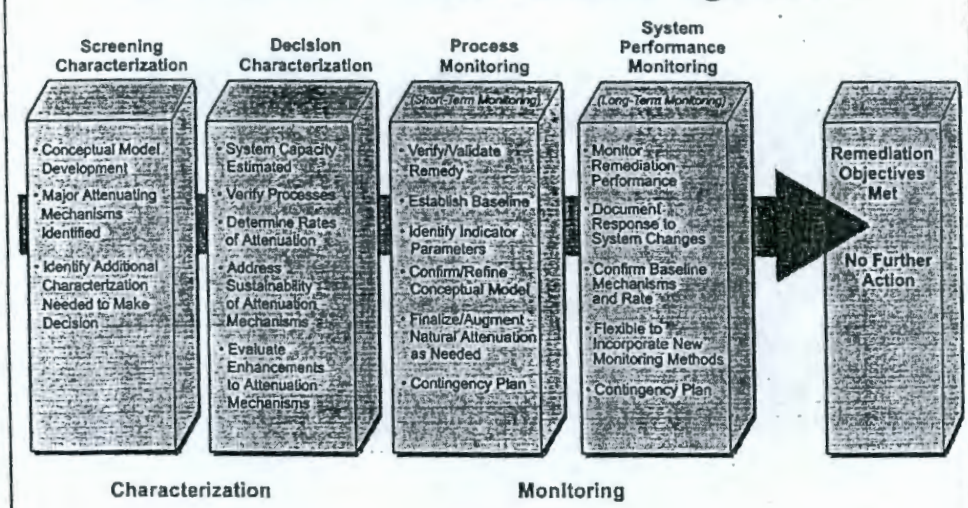
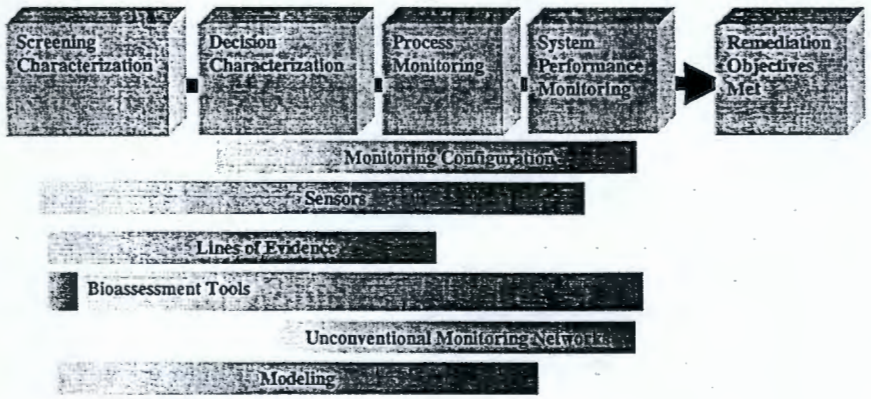
Incorporate Latest Research

Relevant scientific and technical advances have been made on diverse topics ranging from subsurface access, to ecosystem structure and function, to bioassessment tools

Characterization and Monitoring Phases





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Screening Characterization

- Conceptual model development
- Major attenuating mechanisms identified
- Identify additional characterization needed to make a decision

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Decision Characterization

- System Capacity Estimated
- Verify Processes
- Determine Rates of Attenuation
- Address Sustainability
- Evaluate Enhancements (EPR)

Considerations for Selecting Modeling Approach Based on Site Properties

KEY: ◎ better ○ <----------> ● worse

	Sites with supportive geochemical/hydrologic conditions		Sites with hydrologic &/or geochemical complexity/challenges		
Modeling Approach[1]	Simple site with stable or shrinking plume	Plume stability & geochemical footprints uncertain	Documented plume growth or outcrop -- may be stable in the future	Geochemical conditions uncertain and/or complex hydrologic conditions	Attenuation process enhancement evaluation
Conceptual Model - Identify contributing processes and the active zones within a plume	◎	○	● [3]	● [3]	● [3]
Conceptual Model plus Analytical Model or Mass Balance Calculation	○	◎	○	○	○
Conceptual Model, possible analytical model and numerical model	● [2]	○	◎	◎	◎

Process Monitoring

- Verify/validate remedy
- Establish baseline
- Identify indicator parameters
- Confirm/refine conceptual model
- Augment attenuation as needed

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System Performance Monitoring

- Monitor remediation performance
- Document response to system changes
- Confirm baseline mechanisms and rate
- Flexible to incorporate new monitoring methods
- Contingency Plans in Place

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- **Technical defensibility**
- **Cost savings through efficient characterization and monitoring**

Costs

Characterization and monitoring are the primary costs of MNA

- If traditional monitoring techniques are used the costs of MNA may be too high
- Efficient long-term monitoring is where most cost-savings will be realized

Attributes of Long-term Monitoring

- Passive
- Robust
- Flexible
- Utilize leading (failure) indicators
- Measure change from baseline
- Utilize indicator parameters
- Low maintenance
- Low cost
- Measures volume or flux
- Measures of ecological health

Adherence to these attributes should promote non-traditional monitoring configuration

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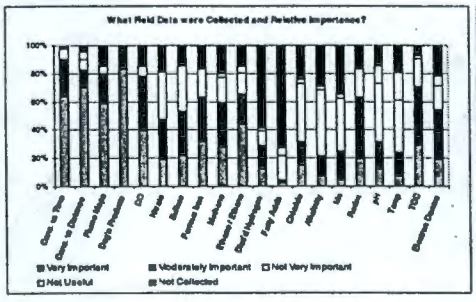

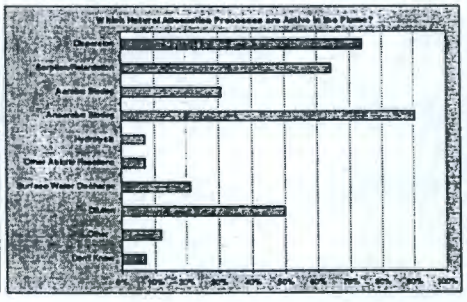

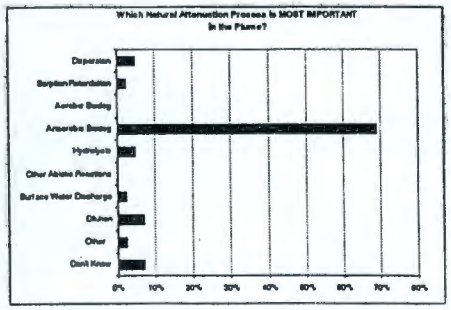

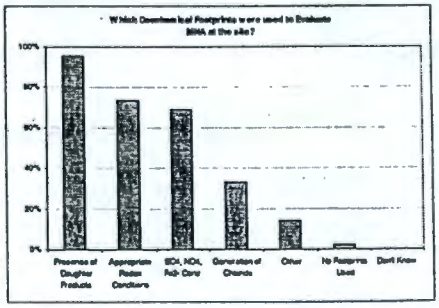

High Priority Technical and Implementation Targets

CHARACTERIZATION AND MONITORING

- Advanced bioassessment tools for determining ongoing microbial processes…
- Develop correlations between species, functional genes and degradation rate and potential.
- Further research on bioassessment oxidative and reductive processes.
- Scenarios based framework to support characterization monitoring and modeling decision making.
- Develop/apply measures and indicators for abiotic attenuation mechanisms.
- Develop specific alternative monitoring configurations to collect data at substantial cost savings during system performance monitoring stage.
- Develop threshold and binary monitoring devices and strategies for long-term monitoring.
- Remote sensing of parameters that can be related to contamination or system impact.
- Develop/apply optical spectroscopy techniques to measure critical MNA parameters.
- Flux measurements.
- Develop integrating or profiling sensors and indicators.

High Priority Technical and Implementation Targets Cont.

MODELING TARGETS

- Improve integration of modeling into MNA evaluation and implementation process.
- Improve reaction forms and include variable equilibrium partitioning coefficients within analytical models.

PROCESS AND ENHANCED PROCESS TARGETS

- Microbiology - Bioaugmentation
- Modifying Large-scale Hydrology

High Priority Policy Targets

- Develop decision process (based on science) to transition from active to more passive treatment.
- Develop concurrence with the stages of characterization and monitoring.
- Develop acceptance of central concept defining MNA/EPR - Balancing attenuation capacity and loading.
- Acceptance of framework for selecting the analytes and interpreting the results.

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Advanced Biomonitoring Tools

Role of Biomonitoring Tools

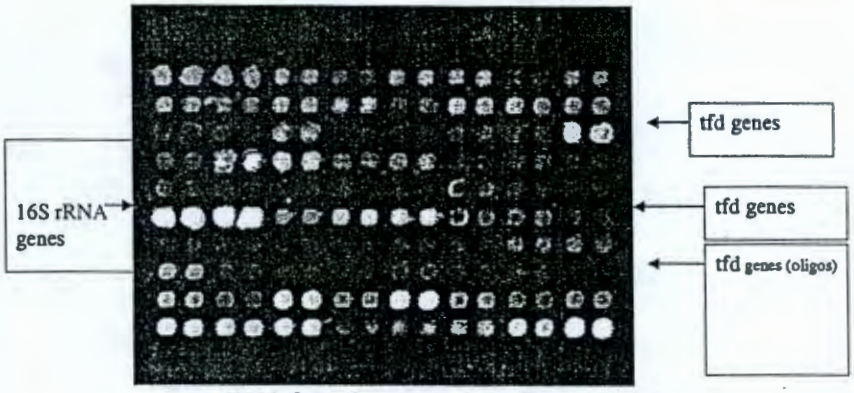
- **Support MNA decisions**
  - Verify key processes (part of tiered approach)
  - The "third-line" of evidence
- **Assessment of Capacity**
  - How fast, how much
- **Replace other parameters?**
  - i.e., becomes a direct measurement not a third-line of evidence

Molecular Tools

- **DNA Microarrays**
  - 1000's of "functional" genes from species or whole communities are placed on a chip
  - Samples extracted and chips exposed
  - Correlate which genes "light up" and their intensity to identify and quantify the metabolic processes that are occurring
    - How fast and where is TCE being dechlorinated?
    - How is an electron donor being metabolized?
    - Identify new or assess metabolic processes that are not as well characterized

Prototype DNA Microarray

64 Genes, mixed & pure cultures, over time



mRNA from Succinate fed cells ----Cy-3 (green)
mRNA from 2,4D-induced cells ----Cy-5 (red)

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Summary

Provide an overview of the MNA/EPR for Chlorinated Solvents Project

Introduce concepts developed by the TWG to further the appropriate use of MNA.

Initiate a dialog to elicit feedback from stakeholders, regulators and end users to provide input to the project's technical team.

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