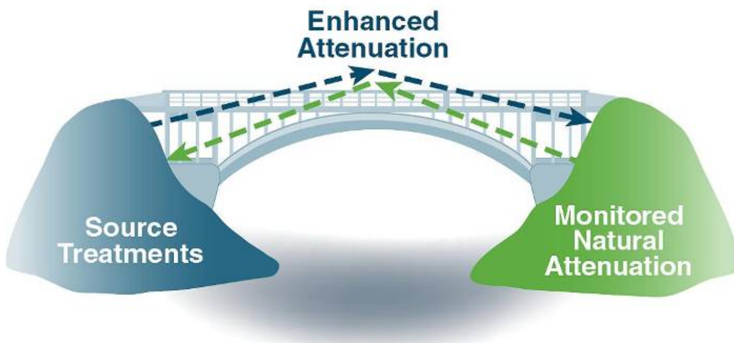
1

Welcome – Thanks for joining us.
ITRC's Internet-based Training Program



Technical & Regulatory Guidance for Enhanced Attenuation: Chlorinated Organics (EACO-1, 2008)

A Site Management Tool

Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: US EPA Clean Up Information Network (www.cluin.org)

Many sites with chlorinated organic contamination in groundwater have gone through extensive remedial evaluations and actions. After years of operating high energy processes, their effectiveness has begun to diminish without remedial objectives being met. Other effective remedial alternatives can be applied; however, there are difficulties transitioning these sites from these high energy systems to other low energy remedial alternatives and eventually to Monitored Natural Attenuation (MNA).

This training on the ITRC Technical and Regulatory Guidance for Enhanced Attenuation: Chlorinated Organics (EACO-1, 2008) describes the transition (the bridge) between aggressive remedial actions and MNA and vise versa. Enhanced attenuation (EA) is the application of technologies that minimize energy input and are sustainable in order to reduce contaminant loading and/or increase the attenuation capacity of a contaminated plume to progress sites towards established remedial objectives. Contaminant loading and attenuation capacity are fundamental to sound decisions for remediation of groundwater contamination. This training explains how a decision framework which, when followed, allows for a smooth transition between more aggressive remedial technologies to sustainable remedial alternatives and eventually to Monitored Natural Attenuation. This training will demonstrate how this decision framework allows regulators and practitioners to integrate Enhanced Attenuation into the remedial decision process.

As our experience and knowledge grows around the implementation of MNA, the EA process will be considered an important management tool for optimizing site remedies and moving sites to final completion. This approach is consistent with the current regulatory environment and can be accommodated within a broad range of regulatory programs such as CERCLA and State dry cleaner regulations. This new framework and decision process will accelerate the environmental clean-up progress on a national scale and reduce overall costs, while still providing protection to human health and the environment.

For reference during the training class, participants should download and print a copy of the decision flowchart, Figure 2-1 on page 10 of the "ITRC Technical and Regulatory Guidance for Enhanced Attenuation: Chlorinated Organics" (EACO-1, 2008) and available as a 1-page PDF at http://www.cluin.org/conf/itrc/eaco/ITRC-EACO-DecisionFlowchart.pdf

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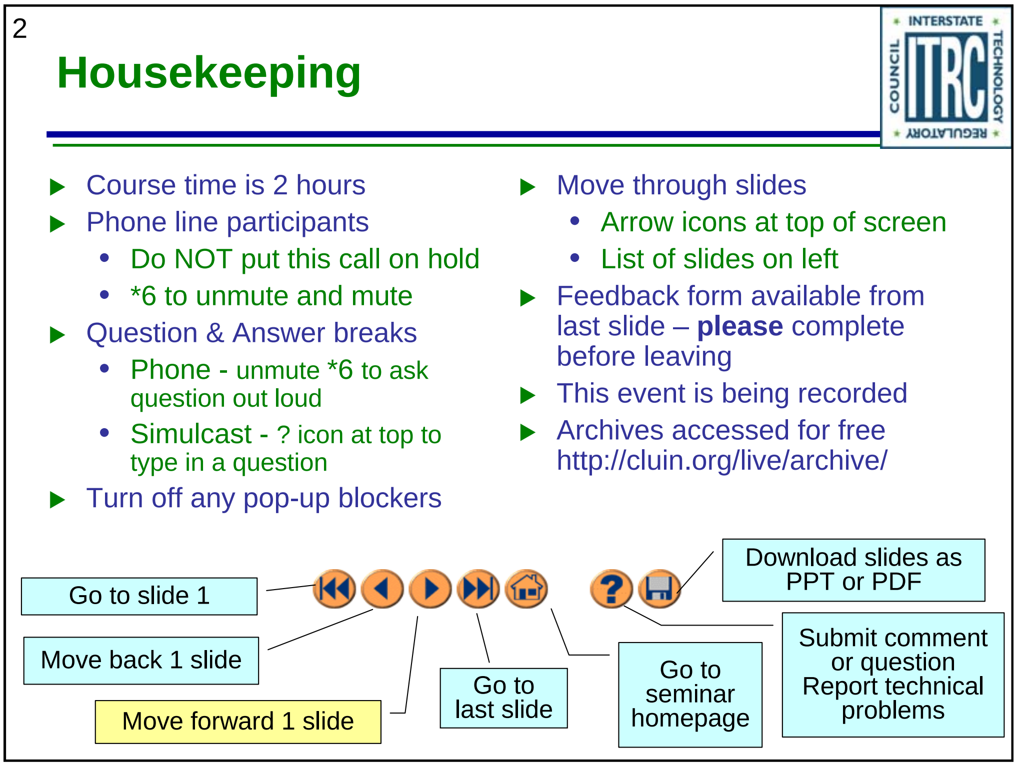
ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419



Although I'm sure that some of you are familiar with these rules from previous CLU-IN events, let's run through them quickly for our new participants.

We have started the seminar with all phone lines muted to prevent background noise. Please keep your phone lines muted during the seminar to minimize disruption and background noise. During the question and answer break, press *6 to unmute your lines to ask a question (note: *6 to mute again). Also, please do NOT put this call on hold as this may bring unwanted background music over the lines and interrupt the seminar.

You should note that throughout the seminar, we will ask for your feedback. You do not need to wait for Q&A breaks to ask questions or provide comments using the ? icon. To submit comments/questions and report technical problems, please use the ? icon at the top of your screen. You can move forward/backward in the slides by using the single arrow buttons (left moves back 1 slide, right moves advances 1 slide). The double arrowed buttons will take you to 1st and last slides respectively. You may also advance to any slide using the numbered links that appear on the left side of your screen. The button with a house icon will take you back to main seminar page which displays our presentation overview, instructor bios, links to the slides and additional resources. Lastly, the button with a computer disc can be used to download and save today's presentation slides.

3

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•We recommend you check with the local and state laws and experts.

•Although we discuss various technologies, processes, and vendor's products, we are not endorsing any of them.

•Finally, if you want to use ITRC information, you should ask our permission.

4

ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization (ECOS)
- Network
  - State regulators
    - All 50 states, PR, DC
  - Federal partners
    - DOE DOD EPA
  - ITRC Industry Affiliates Program (IAP)
  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
  - Sites
- Products
  - Technical and regulatory guidance documents
  - Internet-based and classroom training

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and Puerto Rico and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

5

ITRC Course Topics Planned for 2011 – More information at www.itrcweb.org

Popular courses from 2010

- Enhanced Attenuation of Chlorinated Organics: A Site Management Tool
- In Situ Bioremediation of Chlorinated Ethene - DNAPL Source Zones
- LNAPL 1: An Improved Understanding of LNAPL Behavior in the Subsurface
- LNAPL 2: LNAPL Characterization and Recoverability - Improved Analysis
- LNAPL 3: Evaluating LNAPL Remedial Technologies for Achieving Project Goals
- Mine Waste Treatment Technology Selection
- Phytotechnologies
- Quality Considerations for Munitions Response Projects
- Use and Measurement of Mass Flux and Mass Discharge
- Use of Risk Assessment in Management of Contaminated Sites

New in 2011

- Attenuation Processes for Metals and Radionuclides
- Biofuels: Release Prevention, Environmental Behavior, and Remediation
- Green & Sustainable Remediation
- Stabilization & Solidification
- Bioavailability Considerations for Contaminated Sediment Sites
- PRB: Technology Update
- Project Risk Management for Site Remediation

2-day Classroom Training:

- Vapor Intrusion Pathway
- LNAPLs (in development)

More details and schedules are available from www.itrcweb.org under “Internet-based Training” and “Classroom Training.”

6

Meet the ITRC Instructors

Kimberly Wilson
South Carolina Department of Health and Environmental Control
Columbia, South Carolina
803-896-4087
wilsonka@dhec.sc.gov

Richard Lewis
HSA Engineers and Scientists
Fort Myers, Florida
239-936-0789
rlewis@craworld.com

Guy Sewell
Professor of Environmental Health Science
East Central University
Ada, Oklahoma
580-559-5547
gsewell@ecok.edu

Kimberly Wilson is a Senior Hydrogeologist at the South Carolina Department of Health and Environmental Control (SC DHEC) in Columbia, South Carolina. Kimberly started working for SC DHEC in 1988. She currently oversees environmental remediation activities at nuclear waste disposal and post-closure RCRA sites. Previously, she oversaw environmental activities at the Department of Energy's Savannah River Site and in the Department's Underground Storage Tank Program. She has presented at conferences and has acted as an instructor for a past ITRC classroom training course. Kimberly has been active in ITRC since 2003. She is the co-Team Leader for the Enhanced Attenuation: Chlorinated Organics team and the PRB: Technology Update team. She earned her bachelor's degree in earth sciences from the University of North Carolina in Charlotte, North Carolina in 1981 and her master's in earth resources management from the University of South Carolina in Columbia, South Carolina in 1992. She is a registered Professional Geologist in South Carolina.

H. Eric Nuttall, Ph.D., is a professor emeritus of Chemical/Nuclear Engineering at the University of New Mexico (UNM) in Albuquerque . He has worked for UNM since 1973. He has over 200 publications/presentations and directs graduate student research on in situ bioremediation as well as teaches an annual course on bioremediation. At UNM, Eric developed and managed a very successful field site for in situ treatment of nitrate-contaminated groundwater. He has been an active member of ITRC since 1996 working with several different teams that create guidance documents and training related to in situ bioremediation, technology verification, chemical oxidation, enhanced attenuation: chlorinated organics, and perchlorate. He also has developed an in situ process to immobilized uranium and heavy metals which is being tested both by U.S. Department of Energy at an Uranium Mill Tailings Remedial Action (UMTRA) site and in Germany through WISMUT. Eric earned a bachelor's degree in chemical engineering from University of Utah in Salt Lake City in 1966, a master's degree in 1968 and a doctoral degree in 1971 both in chemical engineering from University of Arizona in Tucson.

Richard Lewis is a Principal Engineer at HSA Engineers & Scientists, a member of the CRA family of companies, in Fort Myers, Florida with corporate responsibilities for the Environmental Engineering Department. He has been with HSA since 1996 and is the largest individual shareholder and Secretary of the Board of Directors. Richard is or has acted as the Project Manager or lead Technical Advisor on HSA's contracts with the Department of Energy, City of Fort Myers, City of Tampa, NASA, Intel, and the Florida Department of Environmental Protection (FDEP), to name a few. He is a member of the Enhanced Attenuation Chlorinated Solvents (EACO) and Risk Assessment Resources teams of the Interstate Technology Regulatory Council (ITRC). Richard is an instructor on the ITRC EACO team's Internet-based training course, training regulators and others in the environmental community nationally. For the FDEP, he has acted as a peer reviewer for Chapter 62-785 FAC, which contained the original risk-based regulatory values for soil and groundwater. In addition, he served on the Methodology Focus Group of the Contaminated Soils Forum, which aided in the development of Global RBCA. He is a regular speaker at the Battelle Conferences, the Florida Remediation Conference, and the Theis Conference, which is an international invitation-only environmental conference. In addition, he recently invented a novel technique (Modified Active Gas Sampling) to assess volatile contaminants in soil, which in currently in use by the State of Florida for the Drycleaning Solvent Cleanup Program. He leads the Vapor Intrusion Group within HSA. Finally, he is the representative for both the Florida Engineering Society and the MIT Club of Southwest Florida for improving K-12 science and engineering education in Southwest Florida. Richard earned a bachelor's degree in physics from Centre College in Danville, Kentucky in 1988 and a bachelor's degree in environmental engineering from Vanderbilt University in Nashville, Tennessee in 1998 (3-2 Engineering Program). He earned master's degree in 1990 and doctorate in 1994 in environmental engineering from the Massachusetts Institute of Technology in Cambridge, Massachusetts. He is a registered Professional Engineer in Florida and he is board-certified in hazardous waste engineering by the American Academy of Environmental Engineers.

Dr. Guy W. Sewell holds the Robert S. Kerr Endowed Chair and the rank of professor of environmental health sciences at East Central University (ECU) in Ada, Oklahoma. In 2007, he was appointed as the Executive Director of the newly formed Institute for Environmental Science Education and Research (IESER). Prior to coming to ECU in 2002, he was a Research Microbiologist with the U.S. EPA at the Robert S. Kerr Environmental Research Center (1988-2002), where he served as principle investigator, Acting & Assistant Branch Chief, and as a research team leader. Guy is an internationally recognized expert in the areas of subsurface fate and transport, and the biotreatment of hazardous waste. He has published over 50 papers on topics such as water resources, ecology, environmental cleanup and bioprocesses, and has made scientific presentations at numerous national and international meetings. He has served on various environmental technical review panels for industry and government agencies such as U.S. EPA, DoD, DOE, USGS, NATO, and ITRC. Guy joined the ITRC Enhanced Attenuation: Chlorinated Organics (EACO) team in 2006. Guy earned a bachelor's degree in 1980 and a doctoral degree in 1987 in microbiology from Oklahoma State University in Stillwater, Oklahoma. He then accepted a Gas Research Institute postdoctoral fellowship in molecular biology at the University of Florida, focused on the genetic engineering of ethanol production in bacteria. He completed Environmental Economics Program at the John F. Kennedy School of Government, Harvard University in 2000, and in 2001 completed a sabbatical as a Visiting Researcher in bioinformatics at the University of Oklahoma.

7

Enhanced Attenuation: Course Map

Kimberly Wilson
South Carolina Department of Health and Environmental Control
Columbia, South Carolina
803-896-4087
wilsonka@dhec.sc.gov

- Background Information
- EA Concept
- Definitions and Application
- Benefits
- Decision Flowchart
- General Application
- Case Study

This is an overview of the presentation. As we move thru the presentation we discuss 7 basic information points.

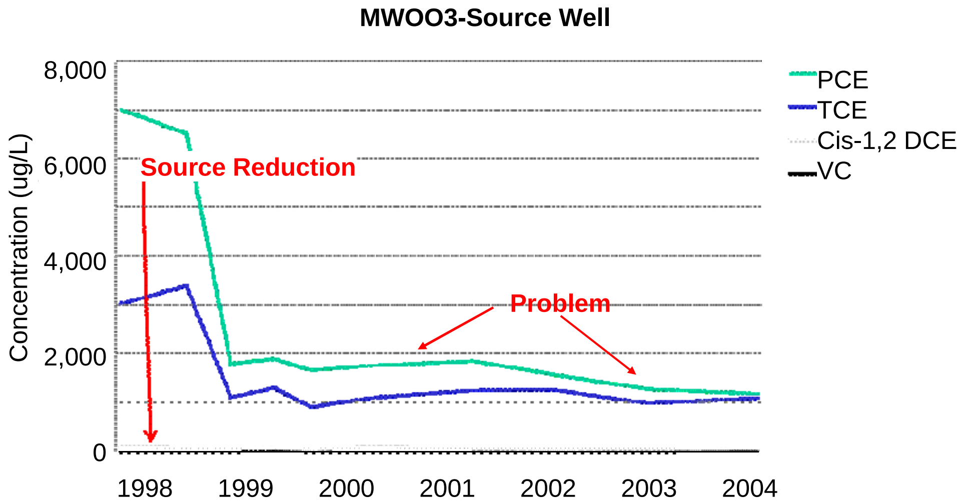
8

Source Reduction

Most people would agree that Source treatments/removal (mass reduction) is key to total site rehabilitation. This is a traditional **example** of a source removal at a drycleaning site in Florida. Other source reduction technologies for chlorinated solvents include soil vapor extraction, in-situ bioremediation, dual phase extraction, co-solvent flushing, etc.

9

Is This Your Site?



However, most of the time it doesn’t get us all the way to clean. This slide exemplifies the typical trend that we see at sites with chlorinated organic ground water contamination.

During the course of the rest of this presentation we will be providing information on how the EACO team evaluated this problem, the development of the EA concept, the Decision Flowchart, and the “technology toolbox”.

10

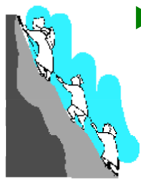
Why Enhanced Attenuation (EA)?

- Chlorinated organic contamination
  - Globally ubiquitous
- Little guidance available on when to transition from active remedies
- Development of applicable scientific protocol and decision tools
  - Encourages innovative approaches to site closure
  - Offers a more acceptable remediation in cost, time, and risk

Some of the reasons we developed this guidance are:

11

Challenges for Implementation of Monitored Natural Attenuation (MNA)



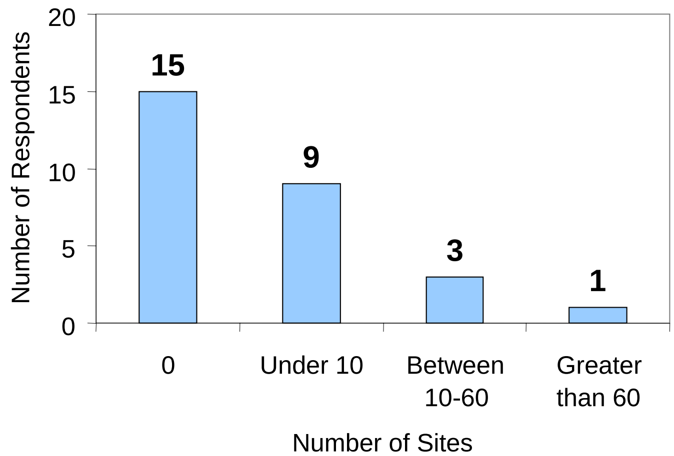
- Limited efforts to understand the balance between source loading and attenuation capacity, therefore longer remediation timeframes
- Limited understanding of site-specific natural attenuation processes
- Little guidance for when to transition
- Natural attenuation rates can be too slow

Some of the other issues noted with specific challenges associated with the implementation of MNA

12

General Experience with MNA (Chlorinated Organics) - Site Completion (Regulator Survey)

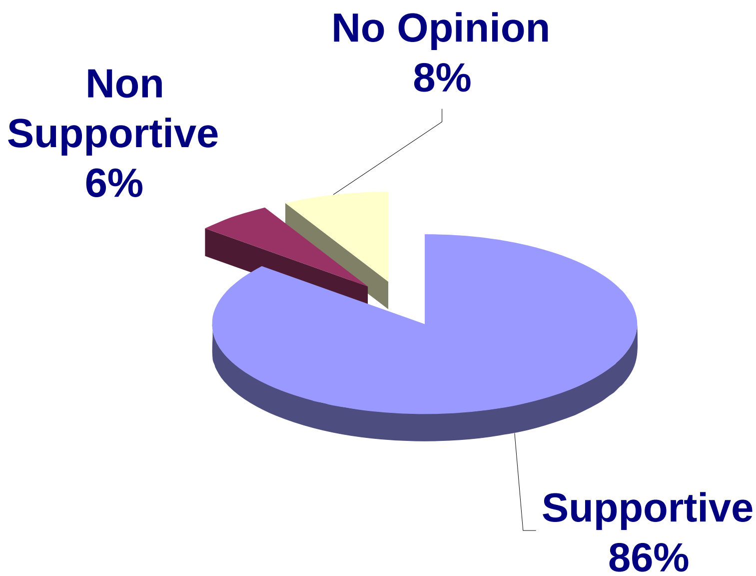
- 54% had no sites using MNA with chlorinated organics



One conclusion we were able to draw from the survey was that there was a general lack of experience by regulators with using MNA at these sites to bring them to completion. This conclusion is illustrated in this graph by indicating the number of regulators (noted along the vertical axis) vs. the general number of sites (noted along the horizontal axis) that had been brought to completion using MNA.

13

Develop Protocols to Encourage a Phased MNA/EA Decision Process



Another important piece of information gleaned from this survey was the acceptance of protocols that encourage a phased MNA/EA decision process. This graph is a representation of the support level for the development of these decision process protocols.

14

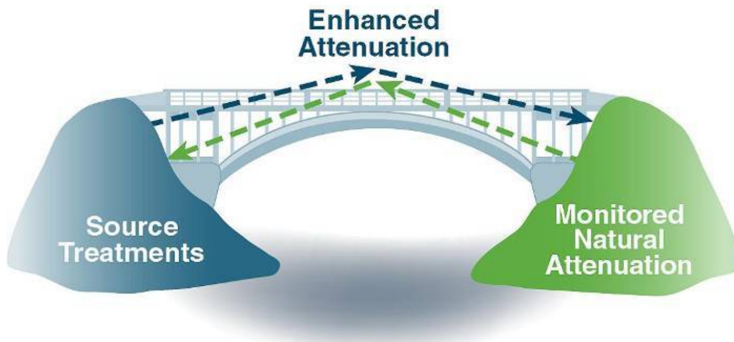
EA Is Consistent With MNA *and* Adds Additional Components

- Encourages comprehensive site characterization for
  - Accurate conceptual site model
  - Innovative remedial designs
- Relies on sustainability
- Encourages the use of mass flux evaluation to focus remediation strategy
- Allows the use of human intervention to boost natural attenuation processes
- Favorably manipulates the balance between mass loading and attenuation capacity in order to stabilize/shrink the plume.

The key phrase being human intervention as an action to boost the natural occurring processes.

15

EA Concept



- Mass balance evaluation
- Decision flowchart
- Technology toolbox

So these problem statements brought us to Enhanced Attenuation. Enhanced Attenuation is a plume remediation strategy or a protocol.

(Site Management Tool)

16

Key Concepts about EA

1. EA provides an organized, scientific, and structured approach to implement treatment technologies at appropriate sites and at appropriate times

2. Facilitates transition of contaminated sites through the complete remediation process

3. Develops the best solutions for the environment

4. Decision Process
   - Compliments MNA
   - Expands remediation opportunities

Note with regard to mass balance:

The mass balance efforts supported the general MNA conceptual developments of the 1990s and the idea that destruction processes are often dominant factors at sites with robust natural attenuation

– Any destruction process, not just reductive dechlorination can contribute

Key Concepts about EA (continued)

5. Encourages
   - Energy efficiency
   - Sustainability

6. Various EA technologies can be designed to reduce the source flux and/or increase the attenuation capacity/rate in the plume to assure the plume will stabilize and shrink

7. Technologies as described in the tech-reg guidance are not new -- what is new is a holistic design approach using a structured decision protocol.

No associated notes

Definitions and General Application

- Sustainable

  When the physical, chemical, and biological mechanisms or processes occurring within the contaminant source/plume continue over the lifespan of the remediation in a manner that the mass balance of the plume remediation favors source/plume reduction.

  (*Attenuation of contaminants continue over the course of the remediation until remedial objectives are attained*).

The word “sustainable” is used a lot in the political and environmental fields these days and the meaning varies depending on the context of its use.

As an example of sustainability:

In the case of reductive dechlorination, sustainability might be limited by the amount of electron donor which may be used up before remedial goals have

been reached.

19

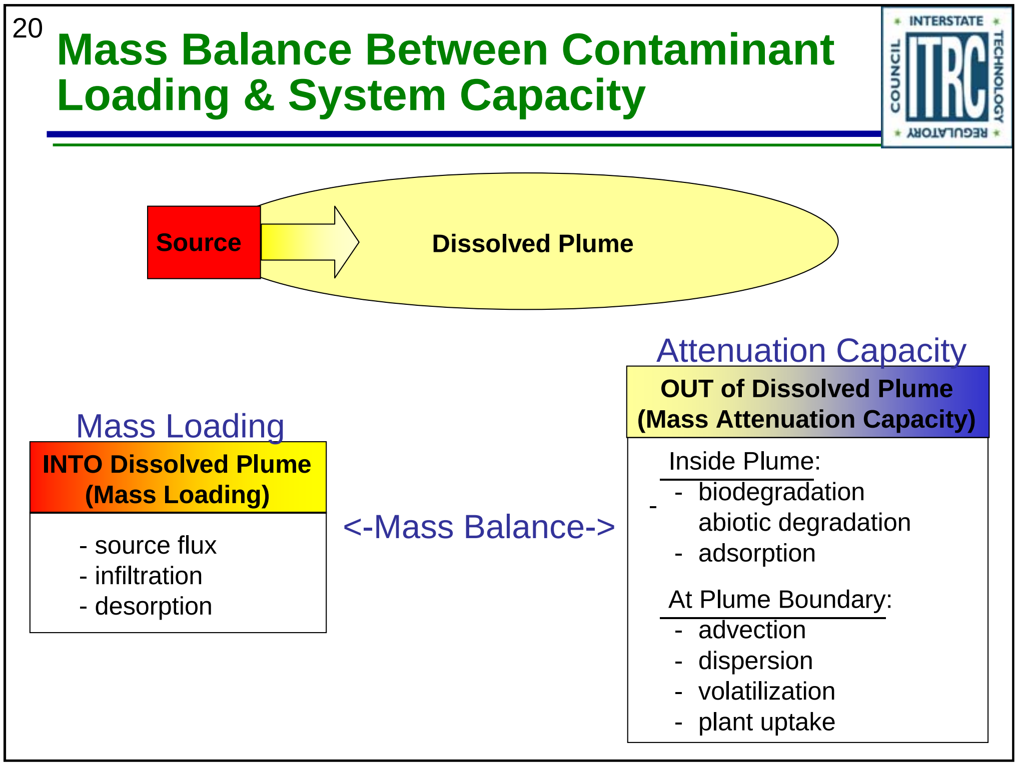
Definitions (continued)

- Mass loading
  The mass of material entering an area per unit time from the source zone and also from residual product that has been carried into the plume.
- Attenuation capacity
  The capacity of a groundwater system to lower contaminant concentrations along aquifer flow paths.
- Mass balance
  The quantitative estimate of the mass loading to the dissolved plume from various sources compared to the mass attenuation capacity for the dissolved plume.

Note with regard to mass balance:

The mass balance efforts supported the general MNA conceptual developments of the 1990s and the idea that destruction processes are often dominant factors at sites with robust natural attenuation

– Any destruction process, not just reductive dechlorination can contribute



On this slide we will discuss the definitions of: **Mass balance** which includes **Mass Loading** & Mass **Attenuation Capacity**

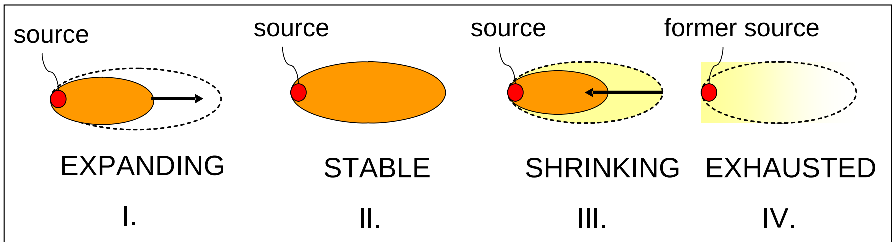
Mass Loading- is the mass of material entering an area per unit time from the source zone and also from residual product that has been carried into the plume.

Attenuation Capacity- The capacity of a groundwater system to lower contaminant concentrations along aquifer flow paths.

Mass Balance- quantitative estimate of the mass loading to the dissolved compared to its mass attenuation capacity.

21

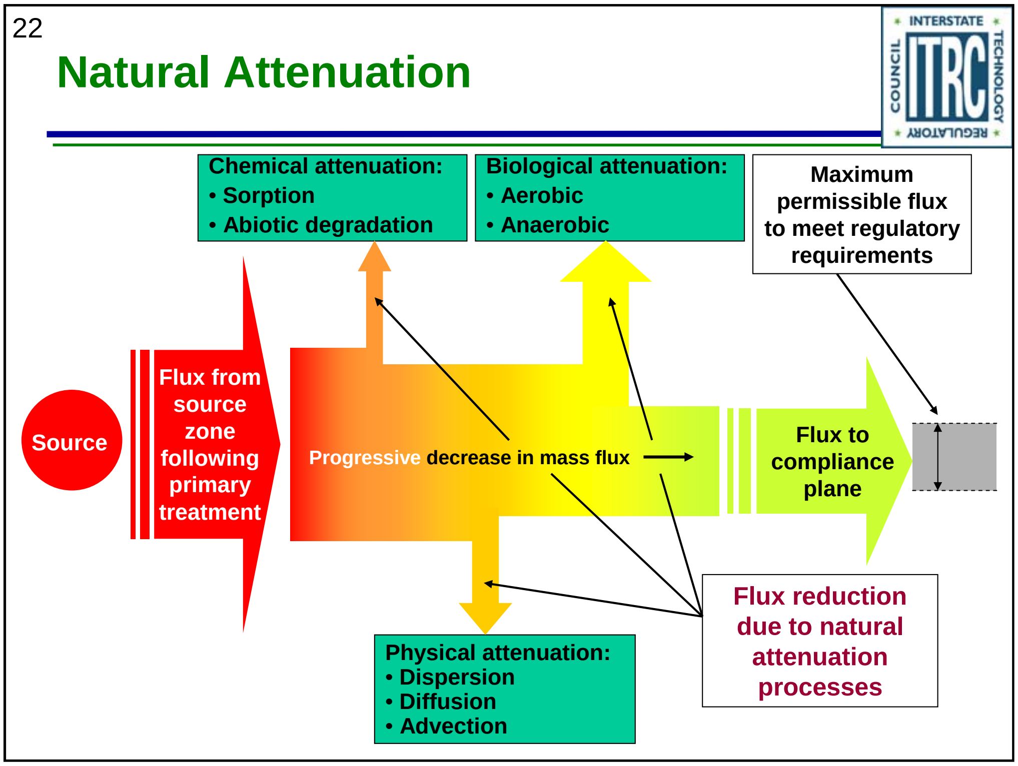
Plume Dynamics



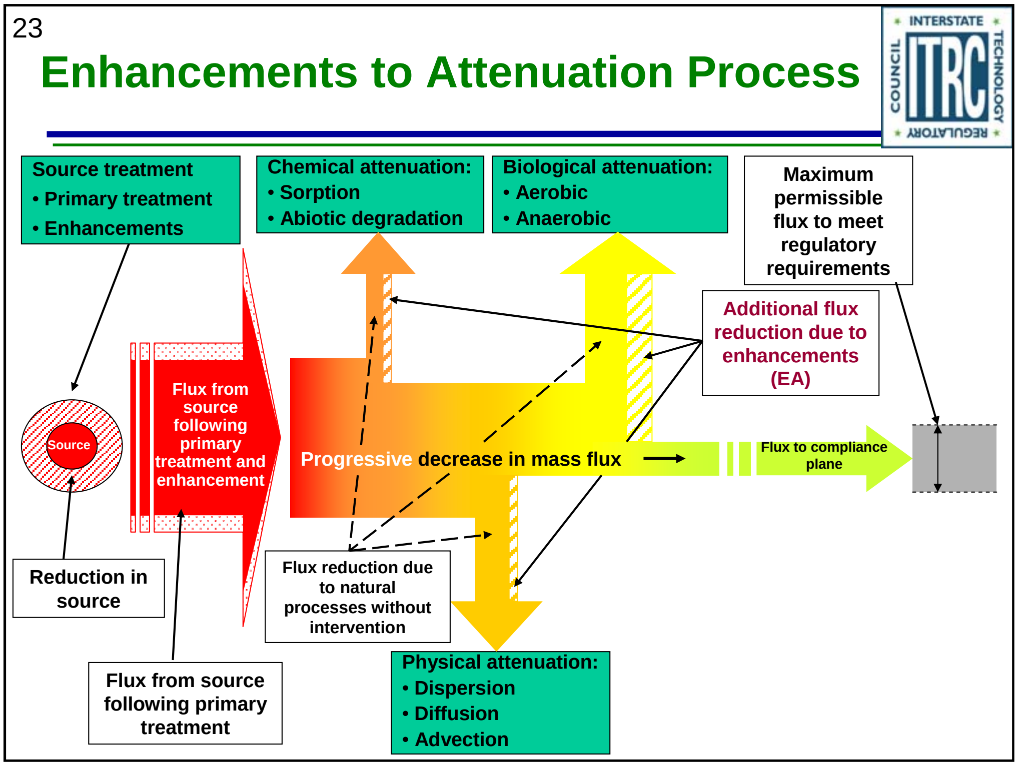
Time evolution of a plume if it undergoes attenuation

- Requirements for MNA
  - Plume poses minimal risk
  - Plume is stable or collapsing
  - Monitoring to assure environmental protection
  - Triggers to implement contingency plans as needed

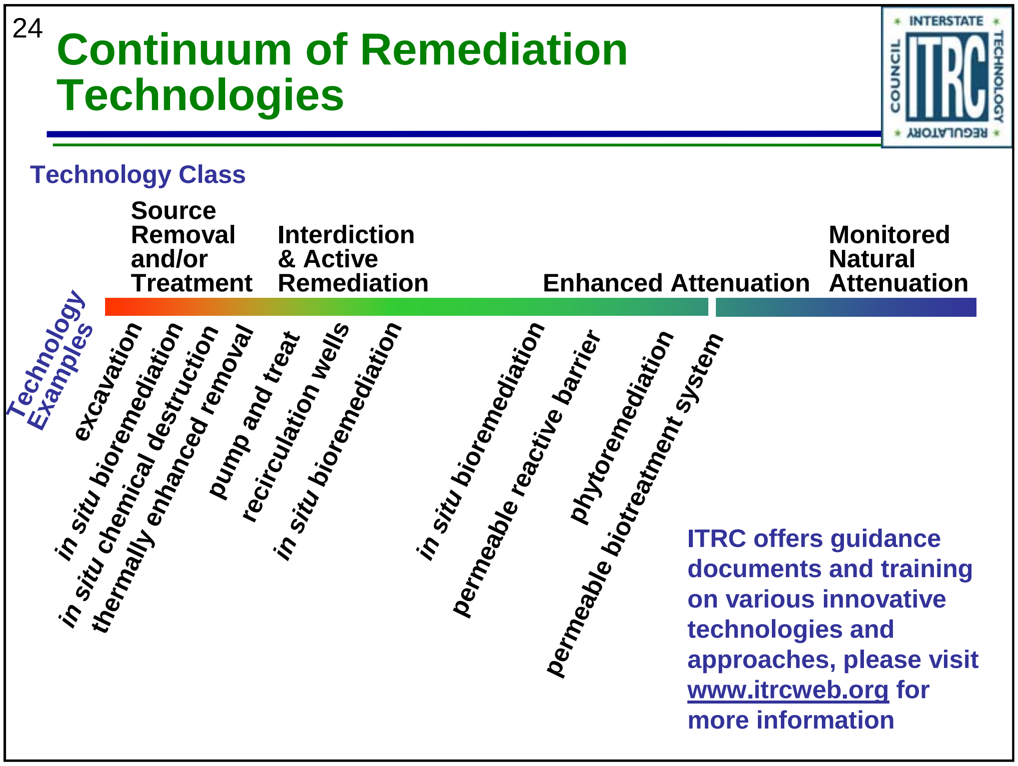
This slide simply provides an overview of the plume evolution, and the requirements for the use of MNA when the plume is stable and then shrinking.



This slide and the next one are good slides to further discuss Mass Flux. This diagram represents the Natural Attenuation process with a constant source. While this information is not new to you, it is important to review the concept, and then show you how “enhancements” can help to reduce the flux and concentrations along this flow line.



This figure illustrates how enhancements have an additive or supplemental effect on the natural attenuation processes operating on a plume to reduce the mass flux beyond that generated without intervention. The objective is for the cumulative impact of these enhancements to reduce the mass flux to a level that is less than the attenuation capacity within the aquifer.



The continuum of Remediation Technologies on this graphic includes “Enhanced Attenuation” Technologies before MNA.

25

Regulatory Considerations

- Permits
- Consideration of risk, time, and cost in the selection of EA remedy
  - Balancing Site Characterization with Cleanup
- Changes in geochemical conditions
- Contingency planning
- Mass flux measurements do not replace concentration-based measures
- Institutional controls

No associated notes

26

EA Benefits

- Facilitates transition of contaminated sites through the remediation process
- Provides scientific documentation for remedy change
- Complements MNA and expands remediation opportunities
  - Tailored intervention approach

This slide will provide the format to discuss benefits to regulators, industry, federal, stakeholder, consultants

27

EA Benefits (continued)

- Integrates source zone treatment and MNA
- Complies with existing environmental regulations
- Encourages a systematic approach to total site remediation
- Incorporates remedial efficiency by developing sustainable optimal solutions for each site

No associated notes

28

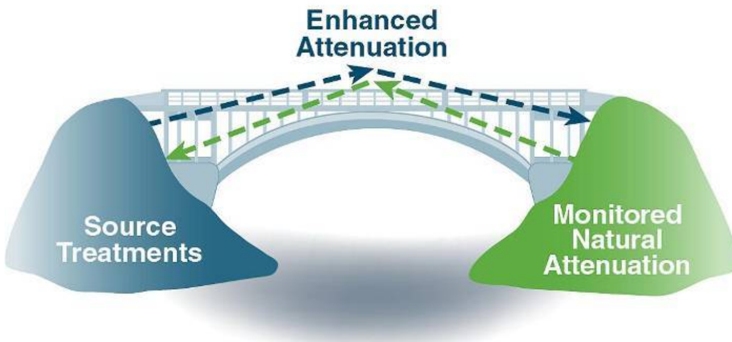
Summary

- Background information
- EA concept
- Definitions and general application
- Benefits

We have reviewed several major areas

29

Questions & Answers



No associated notes.

30

Enhanced Attenuation: Course Map

Richard Lewis
HSA Engineers and Scientists
Fort Myers, Florida
239-936-0789
rlewis@craworld.com

- Background Information
- EA Concept
- Definitions and Applications
- Benefits
- Decision Flowchart
- General Application
- Case Study

This is an overview of the presentation. As we move thru the presentation we discuss 7 basic information points.

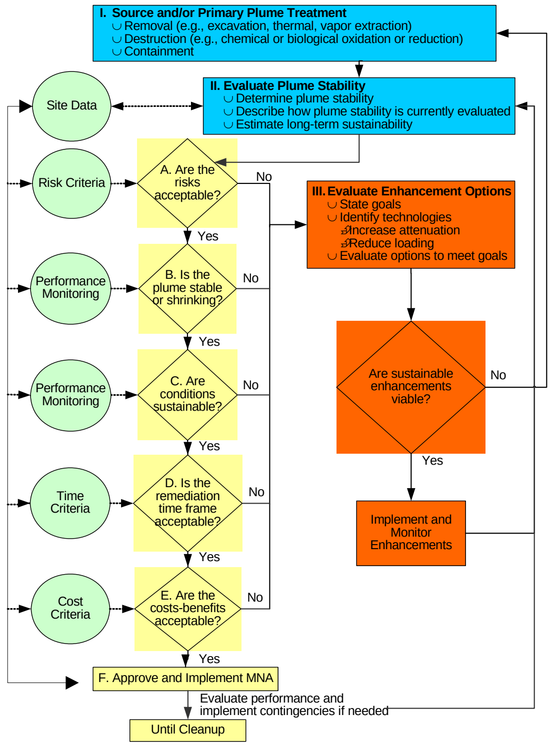
31

Goal of Flowchart

- Roadmap for decision making
- Framework for transitioning
  - From active remediation or MNA
  - From MNA to EA technology or back to active remediation
- Decision process for sustainable remedial alternatives
- Defensible protocol
  - Documentation for regulators
  - Flexibility to incorporate innovative solutions

Goals:

- decision-making framework for transition from active remediation to a sustainable solution.
- determine when to stop operation of the active remedy and transition to other appropriate EA/MNA remedies



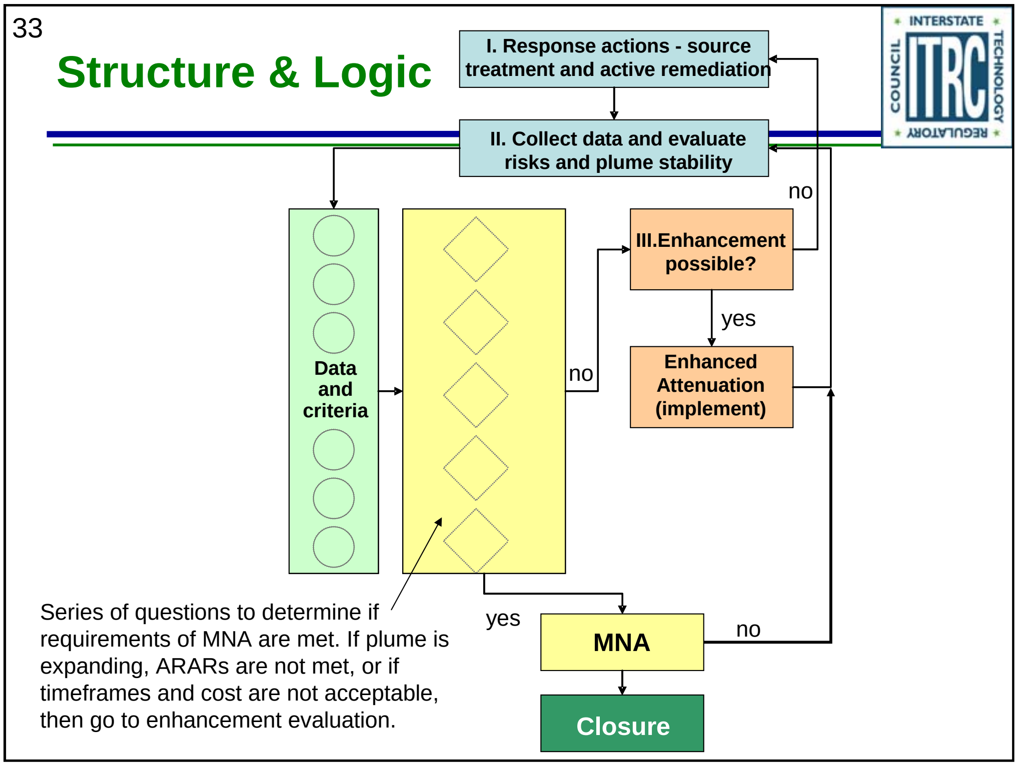
Decision Flowchart

Figure 2-1 of the ITRC Technical & Regulatory Guidance for Enhanced Attenuation of Chlorinated Organics

Also available on the Enhance Attenuation: Chlorinated Organics Team resource page at http://www.itrcweb.org/teamresources_50.asp (EACO-1)

The flowchart is available in Appendix A of the guidance. It’s also available online at the Enhance Attenuation: Chlorinated Organics Team resource page at http://www.itrcweb.org/teamresources_50.asp

The ITRC Technical & Regulatory Guidance for Enhanced Attenuation of Chlorinated Organics (EACO-1, 2008) is available from the ITRC website (www.itrcweb.org) under “Guidance Documents” and “Enhanced Attenuation of Chlorinated Organics”



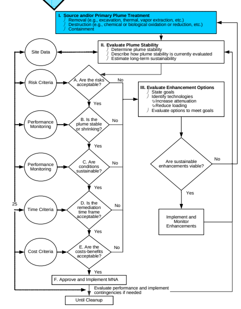
Simplified version of the flowchart

34

I. Source and/or Primary Plume Treatment

- Source generally requires treatment
- Two key issues in context of EA treatment
  1. Integration of the source remedy with current/ future EA/MNA remedy
  2. Consideration of the entire plume during development of source remedy

I. Source and/or Primary Plume Treatment
- Removal (e.g., excavation, thermal, vapor extraction)
- Destruction (e.g., chemical or biological oxidation or reduction)
- Containment

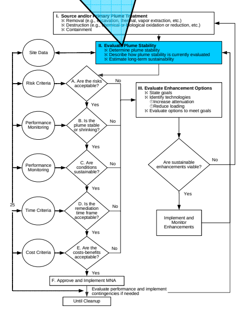


A new term **Subsurface Ecological Assessment** recognizes the interrelatedness of the living and geochemical components of the subsurface environment. A subsurface ecological assessment is an evaluation of the direct impact on subsurface conditions, or potential change in conditions, associated with a remedial technology, and how those conditions will directly impact biotic-biotic and biotic-abiotic interactions.

II. Evaluate Plume Stability

- Key factor in the regulatory decision process
  - Plume stability occurs when the perimeter of the plume attains sufficient size or location such that attenuation mechanisms equal or exceed the mass flux at that boundary.

II. Evaluate Plume Stability
- Determine plume stability
- Describe how plume stability is currently evaluated
- Estimate long-term sustainability



- mass flux from the source is less than or equal to the attenuation capacity of the aquifer
- system will not change in the future such that the balance is disrupted

Estimate Long-term Sustainability

INTO Dissolved Plume (Mass Loading)

- source flux
- infiltration
- desorption

OUT of Dissolved Plume (Mass Attenuation Capacity)

Inside Plume:
- biodegradation
- abiotic degradation
- adsorption

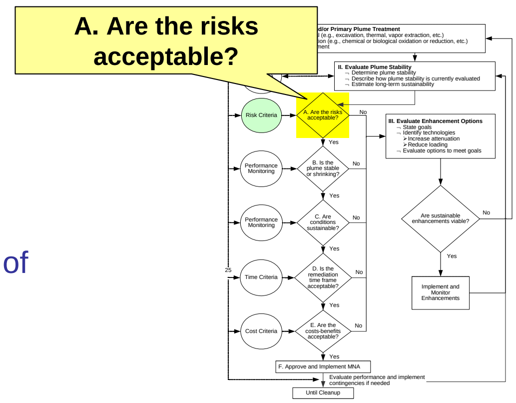
At Plume Boundary:
- advection
- dispersion
- volatilization
- plant uptake

- Traditionally
- Enhanced attenuation
- Mass balance evaluation

- balance is needed for the long-term stability

II A. Are the Risks Acceptable?

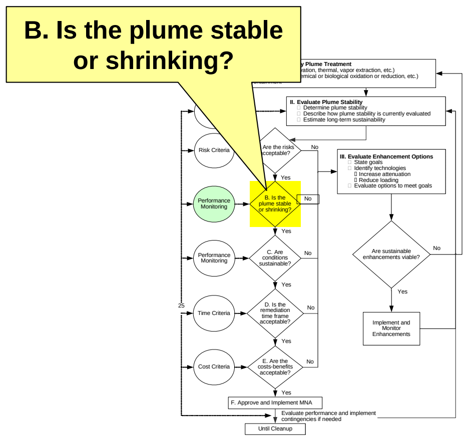
- Does the current risk to a receptor require some additional remediation before MNA can be implemented?
- Unacceptable risks precludes consideration of an EA / MNA / Closure remedy



- as part of this evaluation, go through each diamond and answer the questions.
- is there anything that would preclude the use of EA or MNA?

II B. Is the Plume Stable or Shrinking?

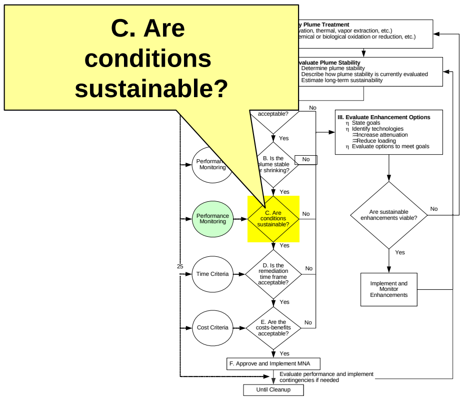
- Decision point is a yes/no response based on the evaluation of long-term plume stability
- Must obtain regulatory acceptance



- is the plume is stable or shrinking?

II C. Are Conditions Sustainable?

- Demonstrate sustainability of solutions
  - EA – technologies are sustainable and low energy
  - MNA – EA technologies not allowed

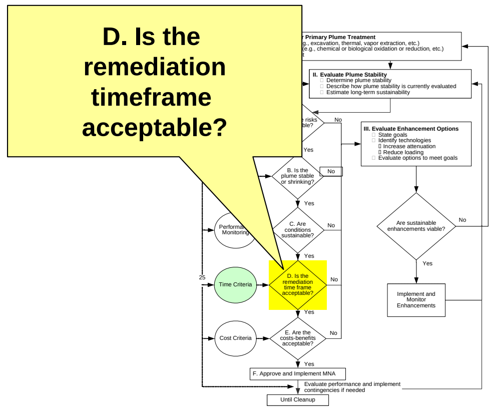


- is the system sustainable?
- will the current conditions that result in plume stability exist in the future?

40

II D. Is the Remediation Timeframe Acceptable?

- Consider input from
  - Responsible party(s)
  - Resource agencies
  - Local governments
  - Impacted community and public
  - Environmental groups and advocates



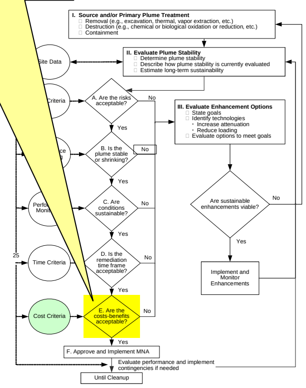
- is the timeframe for remediation acceptable to the stakeholders?

41

II E. Are the Cost / Benefits Acceptable?

- Interaction among the following
  - Remediation timeframe
  - Reliability
  - Achievement of regulatory standards
  - Performance goals
  - Cost effectiveness

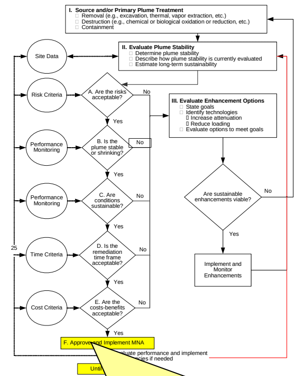
E. Are the cost/benefits acceptable?



- costs and benefits are weighed.

II F. Approve and Implement MNA

- If all FIVE decision steps resulted in YES,
  - MNA is the appropriate remedy
  - Contingency plans needed
- If any NO,
  - Go back into flowchart
  - EA or active remediation

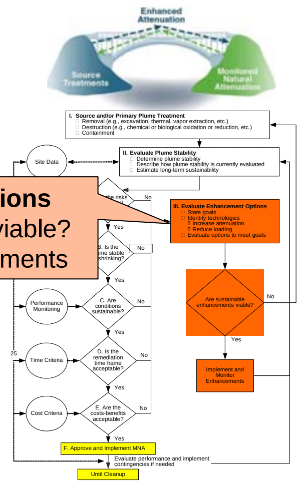


F. Approve and Implement MNA until site is cleaned up

- if all five questions were answered “yes”, then MNA is appropriate.
- the framework allows for movement back up the flowchart if conditions change or assumptions made in the process are found to be incorrect.

III. Enhanced Attenuation

- Provides a “bridge” between active remediation and MNA/Closure

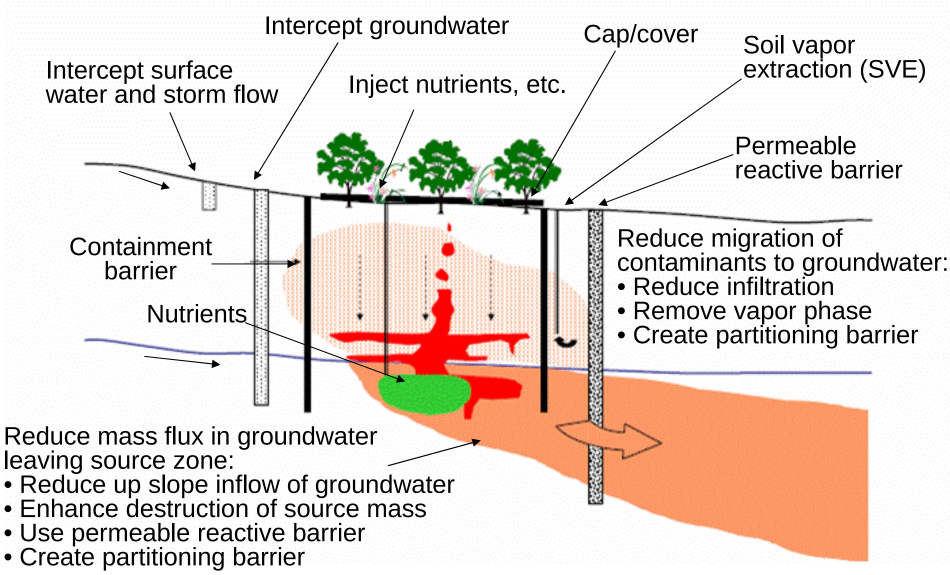


III. Evaluate Enhancement Options
Are sustainable enhancements viable?
Implement and monitor enhancements

- Sustainability
  - Decrease contaminant loading and/or
  - Increase attenuation capacity of aquifer

A “no” response was received in the previous box resulting in a recommendation to consider EA.

Enhancement – Source Zone

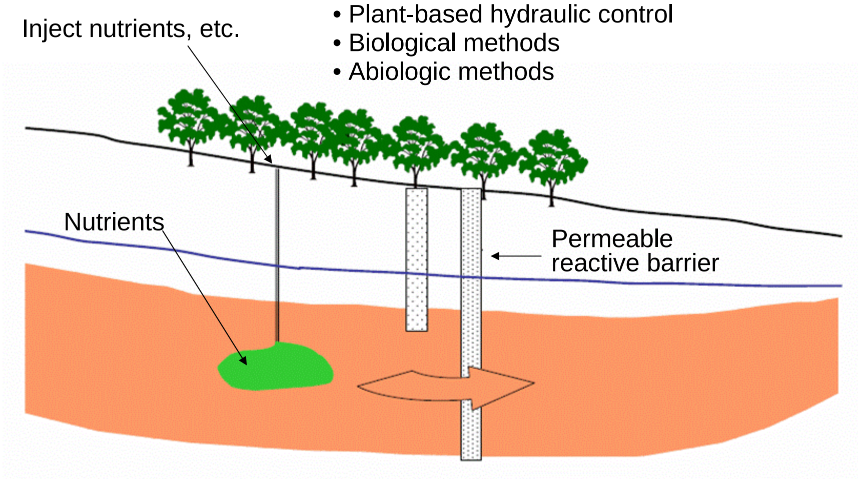


Enhancements can be used at different areas of the plume. Determining the optimal application of enhancements is an important element and is as important to the success of EA as identifying the enhancements themselves.

45

Enhancement – Primary Plume

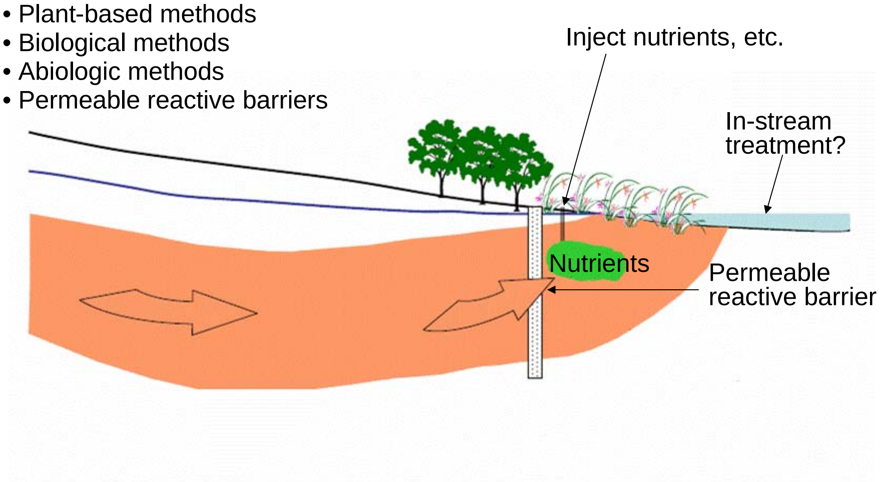
Reduce mass flux of contaminants in plume:
- Phytoextraction
- Plant-based hydraulic control
- Biological methods
- Abiologic methods



No associated notes.

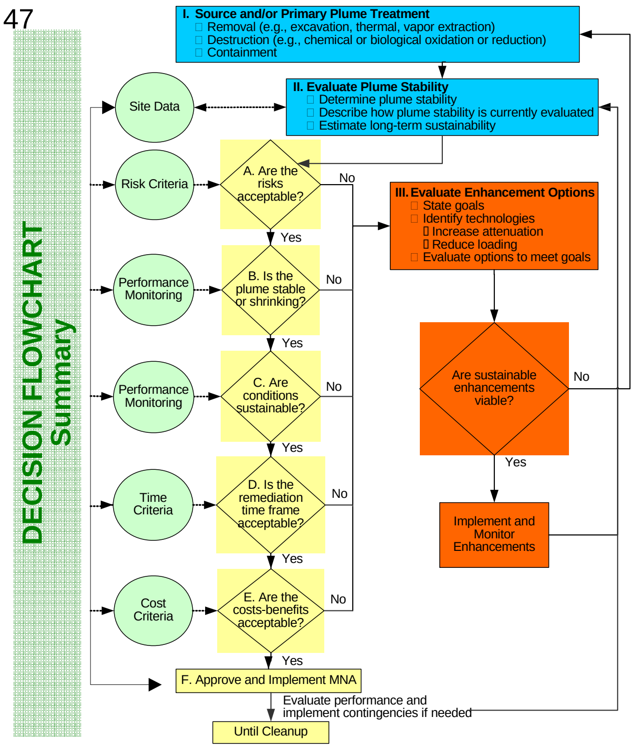
Enhancement – Near Discharge

Reduce mass flux of contaminants at groundwater / surface water interface:
- Plant-based methods
- Biological methods
- Abiologic methods
- Permeable reactive barriers



No associated notes.

47



Decision Flowchart

Figure 2-1 of the ITRC Technical & Regulatory Guidance for Enhanced Attenuation of Chlorinated Organics

Available on the Enhance Attenuation: Chlorinated Organics Team resource page at http://www.itrcweb.org/ teamresources_50.asp (EACO-1)

- From the orange shapes that consider EA, if the answer were "no", then you could move back up to top of the chart to consider active source or plume remediation (in blue rectangle I).
- On the other hand, a "yes" response indicates that enhancements should be implement and monitor.
- At the completion of EA, plume stability can again be examined and the process is repeated (in blue rectangle II).
- feedback loops are part of the process.

48

Enhanced Attenuation: Course Map

- Background information
- Key concepts
- Definitions
- Benefits
- Decision tree
- General application
- Case study

Guy Sewell
Professor of Environmental Health Science
East Central University
Ada, Oklahoma
580-559-5547
gsewell@ecok.edu

This is again, on slide 51, the overview of the presentation, and as we move thru the presentation we discuss 7 basic information points.

In this section we will discuss the last 2 points, general application of the flowchart and an applied case study.

Why Enhanced Attenuation?

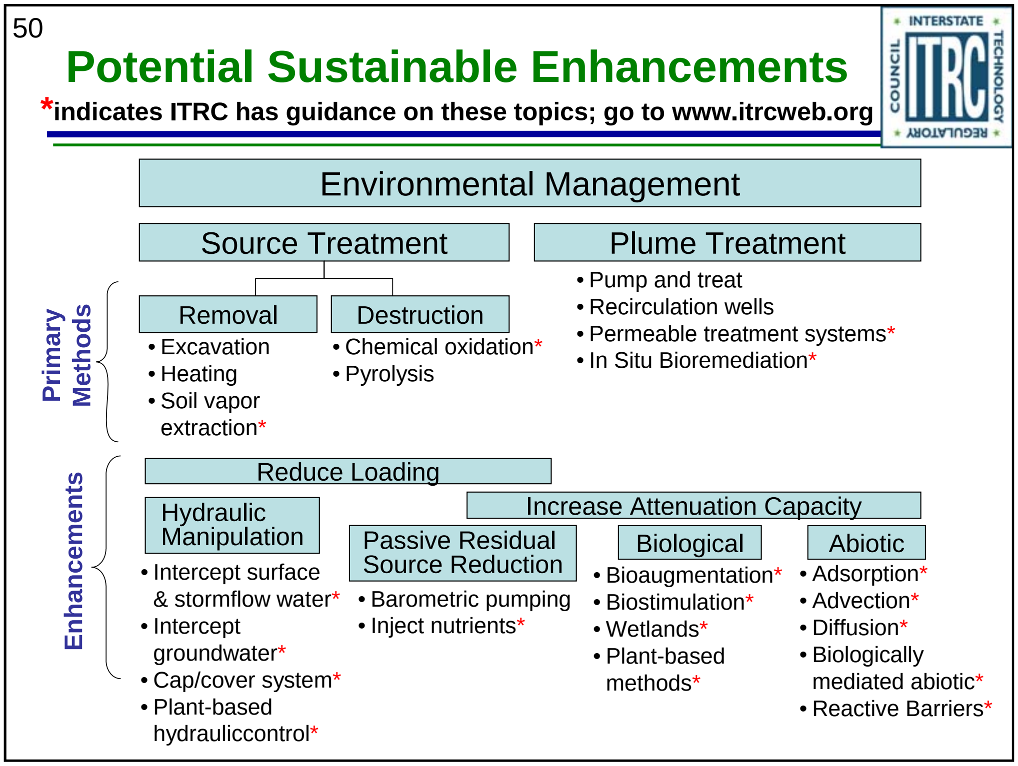
- **Integrates** source zone treatment and MNA
- Complies with existing environmental regulations
- Facilitates transition of contaminated sites through the remediation process
- Encourages a systematic approach to total site remediation
- Incorporates **remedial efficiency** by developing optimal solutions for each site

So at this point you may begin asking yourself why should I use the EA flowchart and what are the advantages.

We feel that the appropriate use of the EA flowchart:

- **Complements** both source zone treatment and MNA by integrating them
- helps to **expand the regulatory paradigm while complying with existing environmental regulations**
- Provides a defined **methodology for transitioning** of sites through regulatory process
- Provides a flowchart for the systematic evaluation of enhancement technologies and **combinations** of technologies (such as integrated phased approached) and allows us to ask “what if“ questions.
- Enhances **remedial efficiency** by developing optimal solutions **for each site** by tailoring to site-specific conditions and to site-specific remedial objectives.

Thus we feel the EA flowchart provides a flexible site management tool to respond to changes in performance, costs or risk reduction goals, and that the flowchart can be used both proactively and reactively.



Once again we need to be clear that the EA flowchart is site management **tool** and not a remedial technology. And indeed the flowchart can incorporate all existing technologies and even new remedial technologies that will be developed in the future.

So the EA flowchart allows for the incorporation of a wide variety of diverse, primary and secondary remedial options, that fit a site's regulatory, performance and cost goals.

And it allows us to address site management challenges, such as hot spots, variable exposure paths, and multiple future use scenarios .

You will note on the slide that the ITRC offers more detailed guidance on use of many of these enhancements, as designated by the red asterisks.

51

Implementation and Monitoring of Enhancements

Confirm and ensure

- Sustainability of the EA remedies
- Mass loading reductions
- Increased attenuation capacity of the aquifer
- Protection of human health and the environment through reduced risk
- Appropriateness of current remedial response
- Regulatory milestones have been achieved

But the EA flowchart does require that each option, or combination of options, be evaluated within the context of the on-going and planned remedial activities, and then, if acceptable, implemented and monitored in a manor consistent with the sites remedial goals, and consistent with the on-going site remedial evaluation in the EA flowchart.

So we ask the following questions as we implement and (to the extent possible) as we evaluate enhancements:

- Are the enhancements sustainable?
- Do we achieve mass loading reductions?
- Is the attenuation capacity increased?
- Are the enhancements protective of human health and the environment?
- Are the enhancements appropriate in the context of the current remedial response?
- Will regulatory milestones be achieved?

Example Implementation of the Flowchart

- Step 1: Baseline characterization
- Step 2: Source treatment
- Step 3: Use EA Decision Flowchart
- Step 4: Implement enhancements as necessary
- Step 5: Transition to MNA
- Step 6: Site closure 

This slide has an overview of the steps in the implementation of the EA flowchart.

Step 1: Baseline characterization including a mass balance assessment to characterize plume stability and to provide a baseline for evaluating remedial performance

Step 2: Aggressive source treatment using active remediation technologies and MNA for the down-gradient portion of the dissolved plume, if appropriate

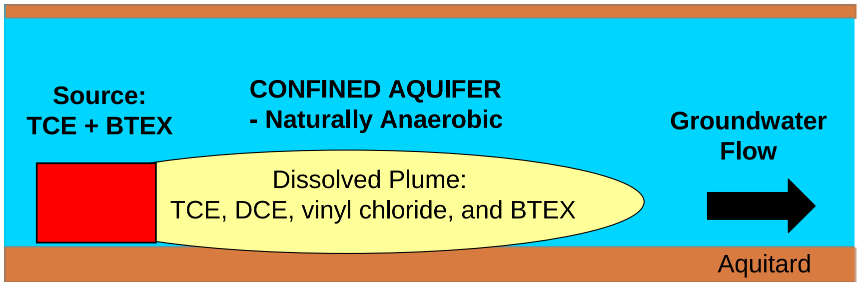
Step 3: Utilization of the EA Decision Flowchart to implement MNA for the down-gradient plume after the active treatment phase resulted in substantial reduction of contaminant loading from the source zone (skip to step 5) or evaluate enhancements as appropriate

Step 4: An enhancement is implemented to increase the rate of mass attenuation of the dissolved plume to accelerate the achievement of compliance with site clean-up criteria

Step 5: After the enhancement results in a sustained increase in mass attenuation rates for the dissolved plume, MNA is continued as the remedy for the dissolved plume

Step 6: Site closure is achieved

Scenario Description



- Recent spill of TCE and BTEX
- Natural TCE biodegradation
- Electron Donors: BTEX and native organic matter

Lets consider a hypothetical site:

Conditions

•Confined aquifer with interbedded lenses of finer materials;

•A high-concentration source of TCE and BTEX in the saturated zone with negligible contributions from the vadose zone

•A dissolved plume with TCE, DCE, vinyl chloride, and BTEX

•Naturally anaerobic groundwater conditions

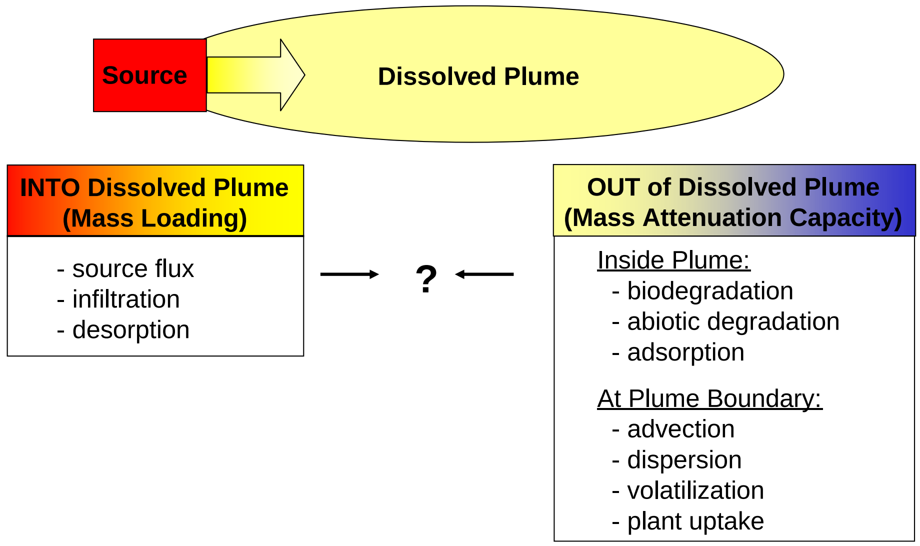
•Natural attenuation conditions due to the presence of both anthropogenic electron donors (i.e. BTEX), and native organic matter that also provided a source of electron donors for the biodegradation of the chlorinated organics (Wiedemeier et al, 1999)

•The plume is relatively young and insufficient time data were available to directly evaluate plume stability

•There were no potential receptors on the site, although there is public concern about the high concentrations of chlorinated organics leaving the site

54

Step 1 – Baseline Assessment



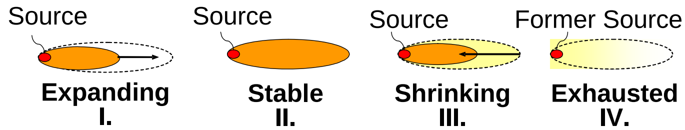
Step 1 baseline assessment

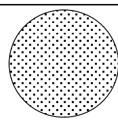
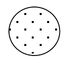
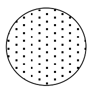
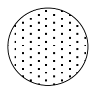
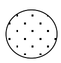
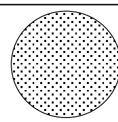
We need to evaluate loading and attenuation capacity, so lets look at our two boxes.

On the loading side we assess the source flux and evaluate the impact of infiltration and desorption if appropriate.

To determine the attenuation capacity we will assess biological and abiotic transformations, as well as adsorption. We also will evaluate the impact of advection, dispersion, volatilization and uptake, if appropriate.

Mass Loading vs. Attenuation Capacity



Mass Loading	Mass Attenuation Capacity	Plume Dynamics
		Expanding
		Stable
		Shrinking

Lets stop for moment and consider the potential dynamics between loading and attenuation we saw earlier.

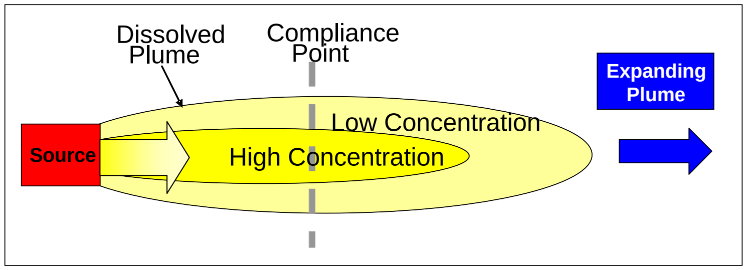
In the **first** example, loading exceeds the attenuation capacity, resulting in an expanding plume.

In the **second** example, mass loading and attenuation capacity are approximately equal resulting in a stable plume.

In the **third** example, attenuation capacity significantly exceeds the loading processes, resulting in a shrinking plume.

The final example is meant to represent a site where the source zone has been removed to the extent that any residual contamination loading to the dissolved phase is far exceeded by the resident attenuation processes.

Baseline Plume Conditions



Mass Loading (kg/year)	
Source:	10,000
Desorption:	+ 0
Total:	10,000

>

Mass Attenuation Capacity (kg/year)	
Biodegradation:	5,000
Adsorption:	+ 500
Total:	5,500

OK back to our hypothetical site. Lets say as we conduct our Baseline Assessment we get the following results.

Mobilization from the source results in 10,000 Kg of contamination a year entering the dissolved phase.

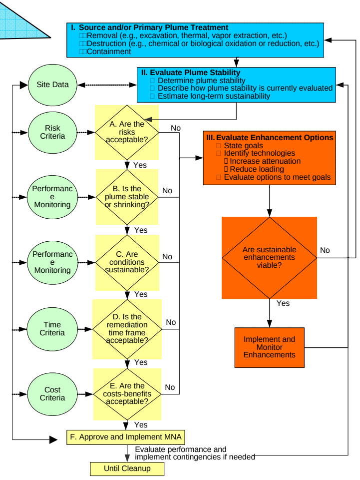
Attenuation mechanisms, primarily biodegradation and adsorption, remove 5,500 Kg/year from the dissolved phase.

So in this hypothetical example, loading exceeds attenuation capacity and we have an expanding plume.

Step 2 – Source Treatment

I. Source and or Primary Plume Treatment

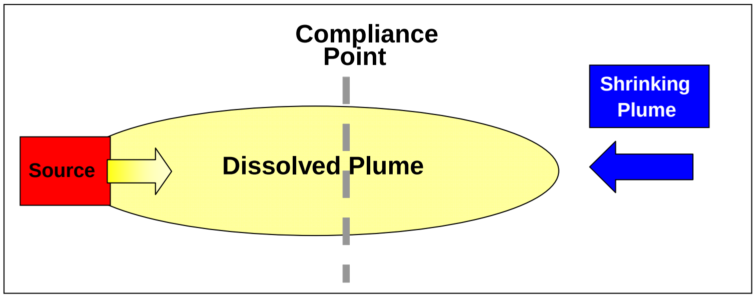
- **Removal (e.g., excavation, thermal, vapor extraction)**
- **Destruction (e.g., chemical or biological oxidation or reduction)**
- **Containment**



Remember our Step 1, baseline assessment yields the need for a Level 1 response: An untreated or expanding plume indicates that Source and/or Primary Plume Treatment is required.

So as per slide 55, at Step 2, as shown on this slide, Source treatment is conducted at our site.

Step 3 – Post Source Treatment – Use the EA flow chart- MNA?



Mass Loading (kg/year)	
Source:	100
Desorption:	+ 20
Total:	120

<

Mass Attenuation Capacity (kg/year)	
Biodegradation:	200
Adsorption:	+ 0
Total:	200

Post Source Treatment - Let us assume after Source and/or Primary Plume Treatment, attenuation capacity now exceeds loading and this results in a shrinking plume. Can we transition into MNA?

Maybe.

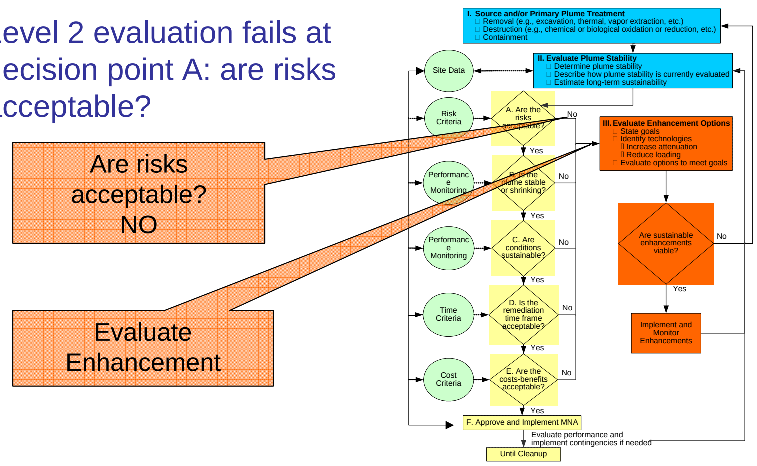
In Step #3 we use the EA flowchart and proceed to a level 2 evaluation of plume stability and sustainability.

Assume, in this example, that the compliance point represents a potential receptor or a property boundary.

Attenuation capacity exceeds loading and we achieve a shrinking plume.

Level 2 Evaluation of Plume Stability and Sustainability

- Level 2 evaluation fails at decision point A: are risks acceptable?



As we continue in Step 3 using the flowchart at the Level 2 evaluation of Plume stability and sustainability, and using the available site information (green circles).

In this case although we might pass through our level 2 evaluation at decision points B, C, D, and E, we fail at decision point A (Are the Risks Acceptable).

Risks from elevated concentrations at a receptor or to a down-path property owner are unacceptable. Following the flow chart, we are kicked to the right, and we would then consider enhancements and evaluate their potential to meet site specific management and performance goals.

Level III evaluation Enhancements for a Stable or Shrinking Plume that is Out of Compliance

- Increase attenuation capacity

or

- Reduce loading of the contaminant (flux)

Enhancements

Reduce Loading

Increase Attenuation Capacity

Hydraulic Manipulation	Passive Residual Source Reduction	Biological	Abiotic
• Intercept surface & stormflow water* • Intercept groundwater* • Cap/cover system* • Plant-based hydrauliccontrol*	• Barometric pumping • Inject nutrients*	• Bioaugmentation* • Biostimulation* • Wetlands* • Plant-based methods*	• Adsorption • Advection • Diffusion • Biologically mediated abiotic • Reactive Barriers*

***indicates ITRC has guidance on topic**

<u>We can now conduct a level III evaluation of enhancements and/or combinations of enhancements needed to meet our performance goals</u>

<u>But remember we must confirm and ensure</u> that these options meet the following criteria:

•The sustainability of the EA remedies

•Remedy must result in mass loading reductions and/or increased attenuation capacity of the aquifer

•Remedy must be protective of human health and the environment through reduced risk

•The remedy is appropriate and compatible with on-going and past remedial activities

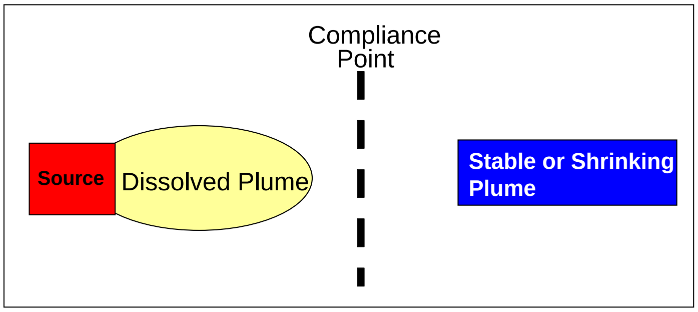
•Regulatory milestones and site specific conditions are addressed

• ITRC has guidance on topics listed on the slide

In Step 4, we select and implement (and continuously assess) our selected enhancement.

61

Step 4 – Post Enhancement, Plume Reaches New Stable or Shrinking Conditions after Enhancement



Mass Loading (kg/year)	
Source:	100
Desorption:	+ 0
Total:	100

=

Mass Attenuation Capacity (kg/year)	
Biodegradation:	100
Adsorption:	+ 0
Total:	100

Post Implementation of Enhancements (Step 4)

Let us assume after implementation of enhancements attenuation capacity is equivalent to loading and this results in a stable plume with acceptable concentrations at the compliance point. Can we transition into MNA?

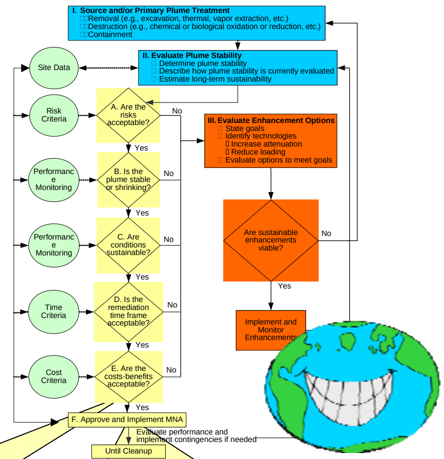
Maybe.

Proceed to another level 2 evaluation of plume stability and sustainability.

62

Steps 5&6: MNA Selection and Site Closure

- Level 2 evaluation of plume stability and sustainability
- Pass DP's A through E
- Continue to MNA
- Continue with MNA to site closure (if appropriate)



F. Approve and Implement MNA

Re-evaluate until full site closure

Following along the flowchart

In Step 3 we used the flowchart to evaluate site and select enhancements -> In Step 4 we implemented and monitored enhancements -> we then conducted another Level 2 evaluation of Plume stability and sustainability

In this case (based on the information in the previous slide), we pass through our level 2 evaluation at decision points A, B, C, D, and E. Risks are acceptable. The plume is stable or shrinking. The attenuation capacity appears to be sustainable (based on performance data). Time frame is acceptable. Cost benefits are acceptable. We can now proceed to Step 5 and select MNA (if needed) and continuously evaluate performance until remedial goals are met, and we can proceed to Step 6 and closure is achieved.

Remember, through the use of the EA flowchart with its continuous reevaluate of performance, we retain the option to change remedial processes if conditions, information or site management goals change in the future before closure.

63

Enhanced Attenuation: Course Map

- Background information
- Key concepts
- Definitions
- Benefits
- Decision tree
- General application
- Case study

Here again, the overview of the presentation.

And at this point we would like to provide an example site

64

Case Study: Florida Drycleaner

- Operated over 8 years
  - 1980's through mid-1990's
- Located in strip mall
- No current receptors
  - Although well field within one mile
- Assessment completed in 1998
  - DNAPL present to 20 feet (atop clay)
  - Plume over 100 feet
    - Emanating from under building

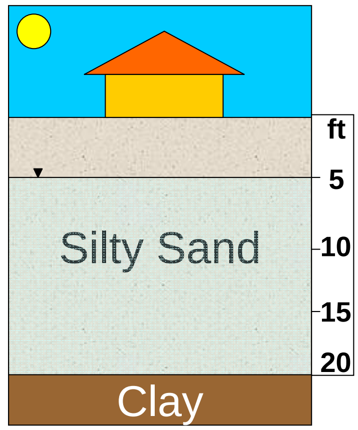
Lets consider the use of the flowchart at an actual site.

Florida Drycleaner……..(READ)

All thought this site was not managed with the EA flowchart, we can use it as an example. This example use also demonstrates the value of flowchart to existing sites. The flowchart is a valuable site management tool regardless of the lifecycle position or status of a site.

Hydrogeology

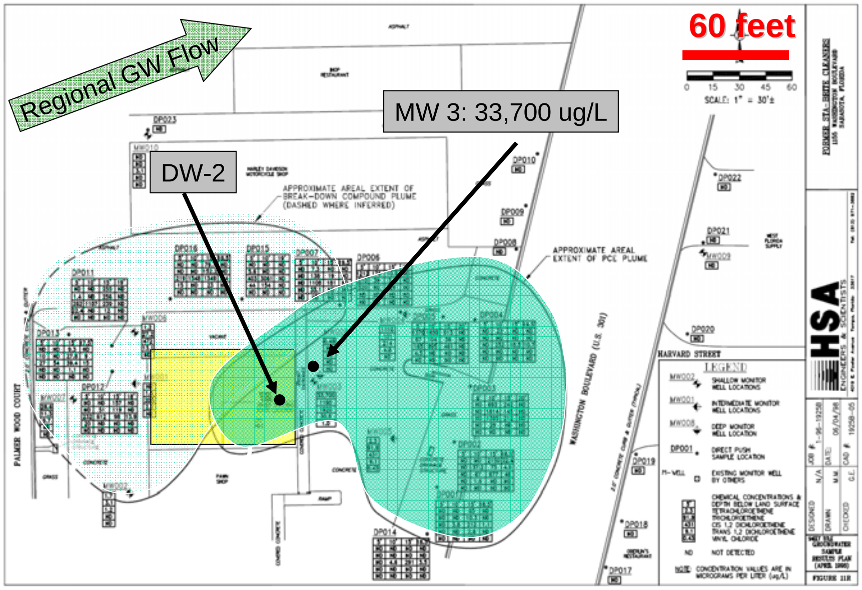
- Unsaturated zone: **5 feet**
- Silty sand to **20 feet bls** (below land surface)
  - Silt content increases with depth
- Clay layer **below 20 feet bls**
- No impacts below clay layer
- K was **10 ft/day**
- Gradient was **0.003 ft/ft**



As we look at the hydrogeology of the site we find

A surficial aquifer approximately 15 ft thick and 5 ft below land surface.
The aquifer matrix of silty sand fining down, with an underlying clay layer.
K was 10 ft/day and the gradient was relatively flat at 0.003.
No contamination was detected below the clay.

Step 1: Baseline Characterization PCE Assessment Results



Step 1: Baseline Assessment

Dry cleaner is defined by the yellow box
Light blue is a lower concentration plume and darker blue is a higher concentration area.
The regional flow is toward the north east

We see here the typical dual plume often found with drycleaners with multiple release points.

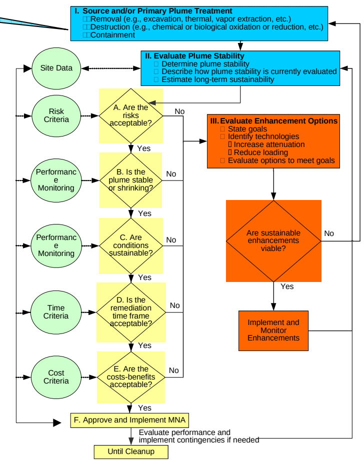
You can note that the plume was expanding and moving off site.

67

Step 2: Source Treatment Active Remedial Solution

I. Source and or Primary Plume Treatment

- Dual Phase Extraction (DPE) **"box design"** was used to dewater within the facility
- Air is more efficient carrier than water
  - Many more pore volumes can be extracted
- DPE removed over **250 lbs of PCE**



Step 2

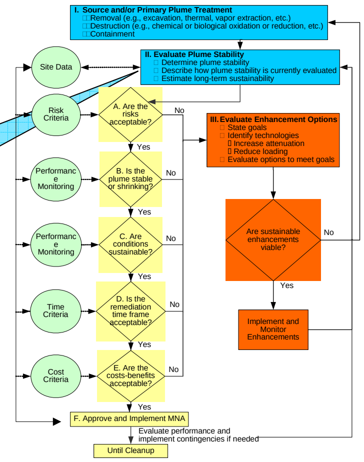
An untreated or expanding plume indicates that Source and/or Primary Plume Treatment (a Level 1 response) is required.

A Dual Phase Extraction (DPE) "box design" was used to dewater, mobilize and extract contamination at the site

68

Step 3a: Use EA Decision Flowchart Evaluate Plume Post Treatment

- Asymptotic conditions reached
- Performance Evaluated



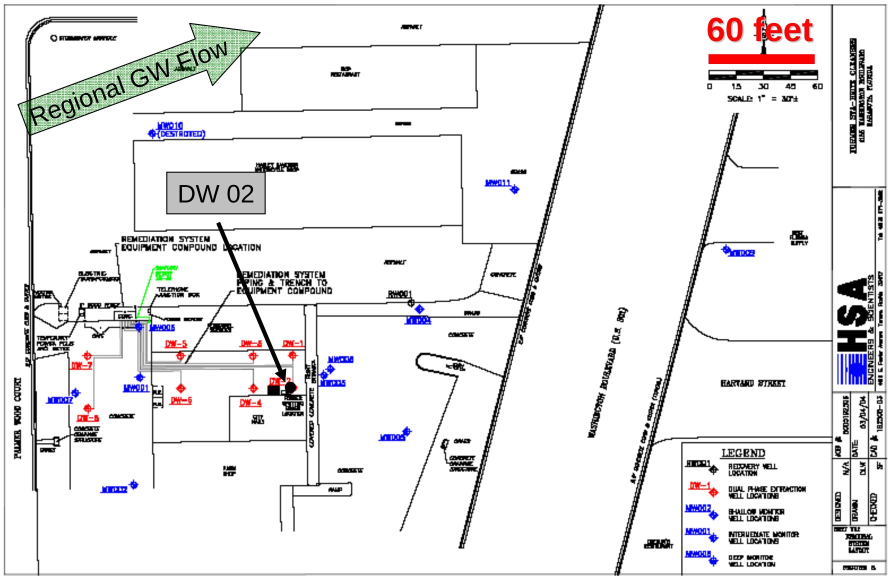
II. Evaluate Plume Stability
Determine plume stability and estimate long-term sustainability

After source treatment a level 2 evaluation of plume stability and sustainability is conducted.

So a this point we need to assess decision points A, B, C, D, and E.

So lets consider some performance monitoring data.

DW 2, Source Area Well

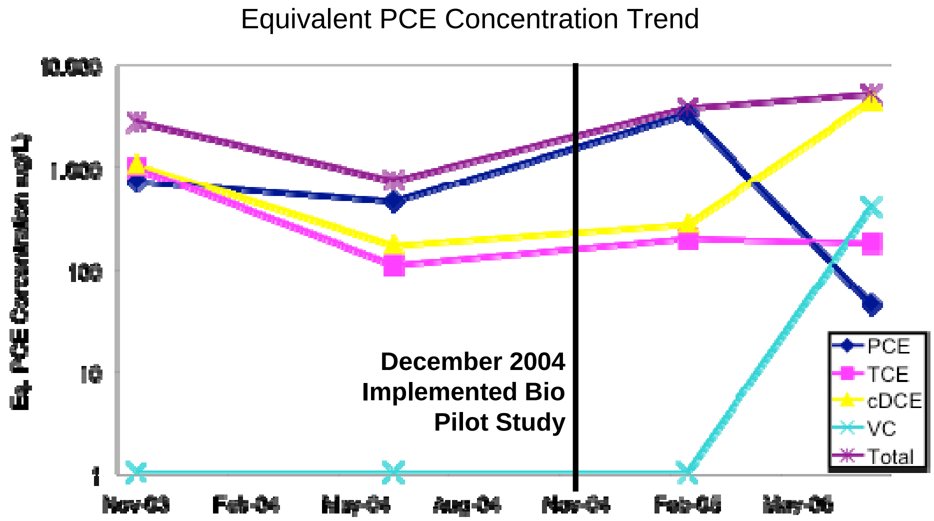


Note the location of Source Area Monitoring Well DW-02

Soil (core) concentrations from this area were high

70

Source Area Well DW02



Evaluating concentrations in DW02 post source treatment we see that The loading to the mobile phase appears to be relatively stable but at unacceptable levels

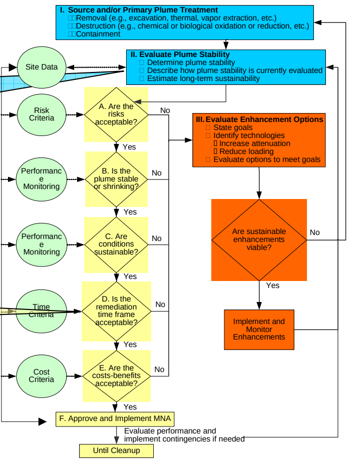
71

Step 3a: Use EA Decision Flowchart Evaluate Plume Post Treatment

II. Evaluate Plume Stability

Determine plume stability and estimate long-term sustainability

Decision Point D. Are remedial timeframes acceptable? No



So, still in Step3, we are conducting our Level 2 evaluation: Plume stability and sustainability

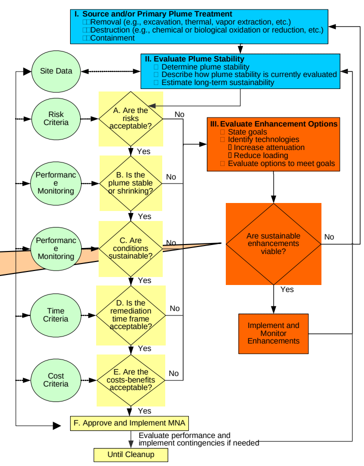
In this case although we might pass through our level 2 evaluation at decision points A (risk), B (stability), C (sustainable), and E (cost/benefits), we fail at decision point D (time to closure). Remedial timeframes are unacceptable.

Following the flow chart to the right, we consider enhancements and their potential to meet site management and performance goals.

Step 3b: Use EA Decision Flowchart - Evaluate Enhancement Options

- Evaluate potential options based on previous activities, site conditions and performance goals

III. Evaluate Enhancement Options
Are sustainable enhancements viable?
Implement and Monitor Enhancements



<u>So continuing in Step 3, We evaluate enhancement and combinations of enhancements needed to meet our performance goals</u>

<u>But remember we must confirm and ensure</u> these options meet the following criteria:

•The sustainability of the EA remedies

•Remedy must result in mass loading reductions and/or increased attenuation capacity of the aquifer

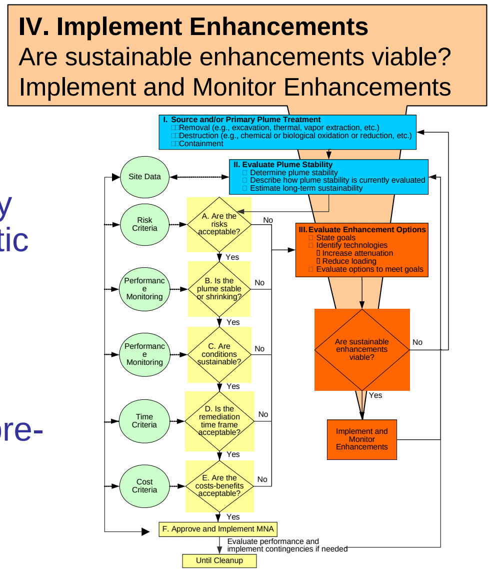
•Remedy must be protective of human health and the environment through reduced risk

•The remedy is appropriate and compatible with on-going and past remedial activities (DPE)

•Regulatory milestones and site specific conditions are addressed

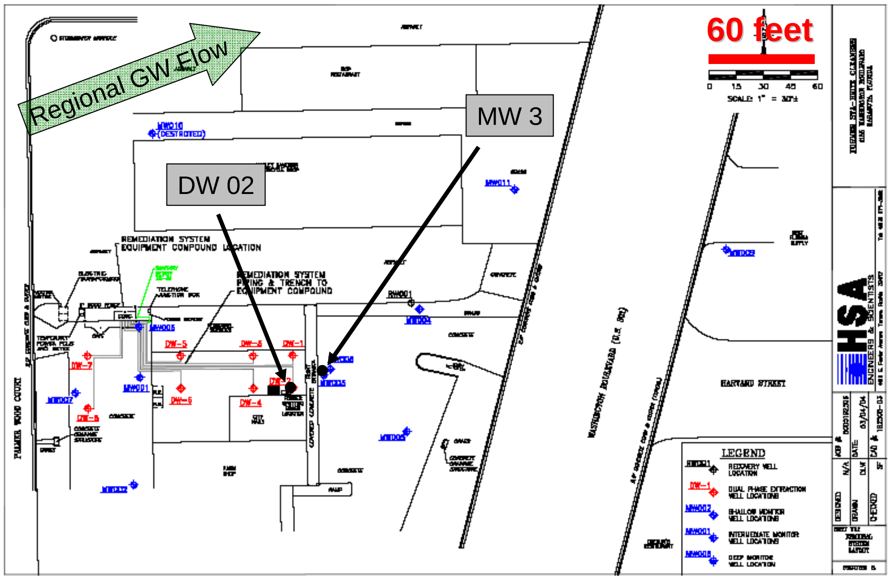
Step 4a: Implement Enhancements

- Remedial action assessment was done to consider all options
- Bioremediation pilot study conducted after asymptotic conditions reached
- Pilot: **Lactate, nutrients, micronutrients,** and ***Dehalococcoides ethenogenes*** added to pre-conditioned aquifer
  - Biostimulation and bioaugmentation



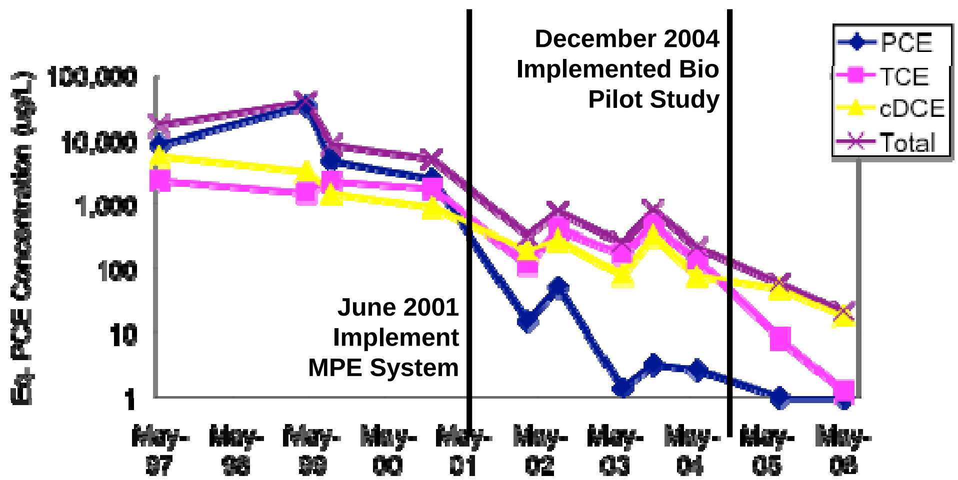
After evaluation an enhancement is selected. At this site a biostimulation-bioaugmentation enhancement was chosen, implemented and monitored.

DW 2, Source Area Well



Before consider some performance data, Note location of DW-2 we discussed before and a down gradient well MW-3

Immediately Down-gradient MW 3



Attenuation capacity appears to be significantly enhanced.

Note: new loading-attenuation equilibrium post DPE and increase in attenuation capacity post bio.

Note: Log scale, maroon/magenta Xs

Newest MW 3 Data

Date Sampled	Depth (ft bls)	PCE (µg/L)	TCE (µg/L)	cDCE (µg/L)	tDCE (µg/L)	VC (µg/L)
5/2/1997	4.5-11.5	8,500	1,870	3,370	130	BDL
4/23/1999	4.5-11.5	33,700	1,180	1,920	30.6	1.0
8/12/1999	4.5-11.5	4,790	1,830	852	21.9	3.2
12/20/2000	4.5-11.5	2,500	1,400	520	17	BDL
3/8/2002	4.5-11.5	15	93	110	2.7	BDL
8/29/2002	4.5-11.5	52.2	335	164	4.2	BDL
6/24/2003	4.5-11.5	1.4	136	47.3	1.5	BDL
11/26/2003	4.5-11.5	3.3	370	191	2.6	BDL
6/28/2004	4.5-11.5	2.7	109	45	<1	<1
7/27/2005	4.5-11.5	<1	6.6	29.1	<1	<1
5/4/2006	4.5-11.5	<1	<1	11	<1	<1

Concentration data table supports mass removal.

DPE 6/2001
Bio 12/2004

Note RED lines

Simple Flux Estimates – Dimension

width	60 ft	18.288 m
depth	15 ft	4.572 m
velocity	0.15 ft/day	0.04572 m/day

Flux planes defined by DW2 and MW3 at their center

So lets do some very simple flux estimates.

Define the site conditions

Define the flux planes

Simple Flux Estimates – Calculations

- Flow

width (m)	x	depth (m)	x	velocity (m/day)	x	porosity	x	1000 (L/m^3)	=	flow (L/day)
18.288	x	4.572	x	0.04572	x	0.20	x	1000	=	764.5 L/day
									=	279,000 L/year

- Mass flux

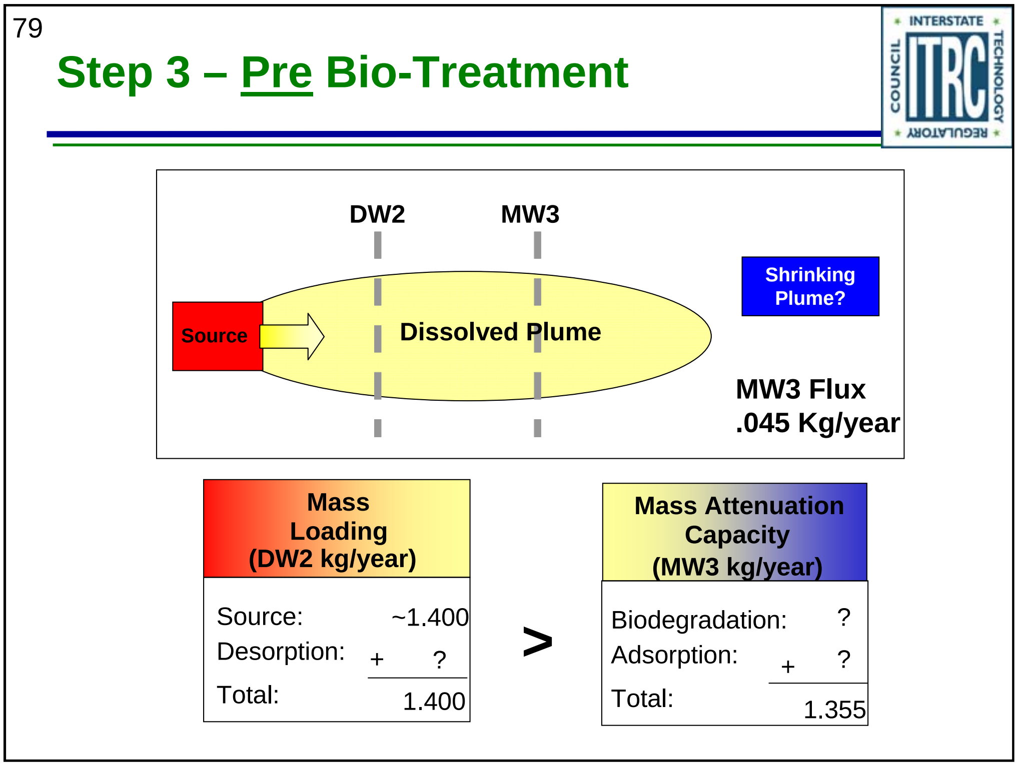
$$\frac{\text{cross-sectional flow (L/year)} \times \text{total conc. chloroethenes (mg/L)}}{1{,}000{,}000\ \text{(mg/kg)}} = \text{Flux (kg/year)}$$

- DW2: (279,000 x 5) / 10^6= 1.400 Kg/year
- MW3 pre Bio: (279,000 x 0.16) / 10^6= 0.045 Kg/year
- MW3 post Bio: (279,000 x 0.035) / 10^6= 0.010 Kg/year

DW2 plane

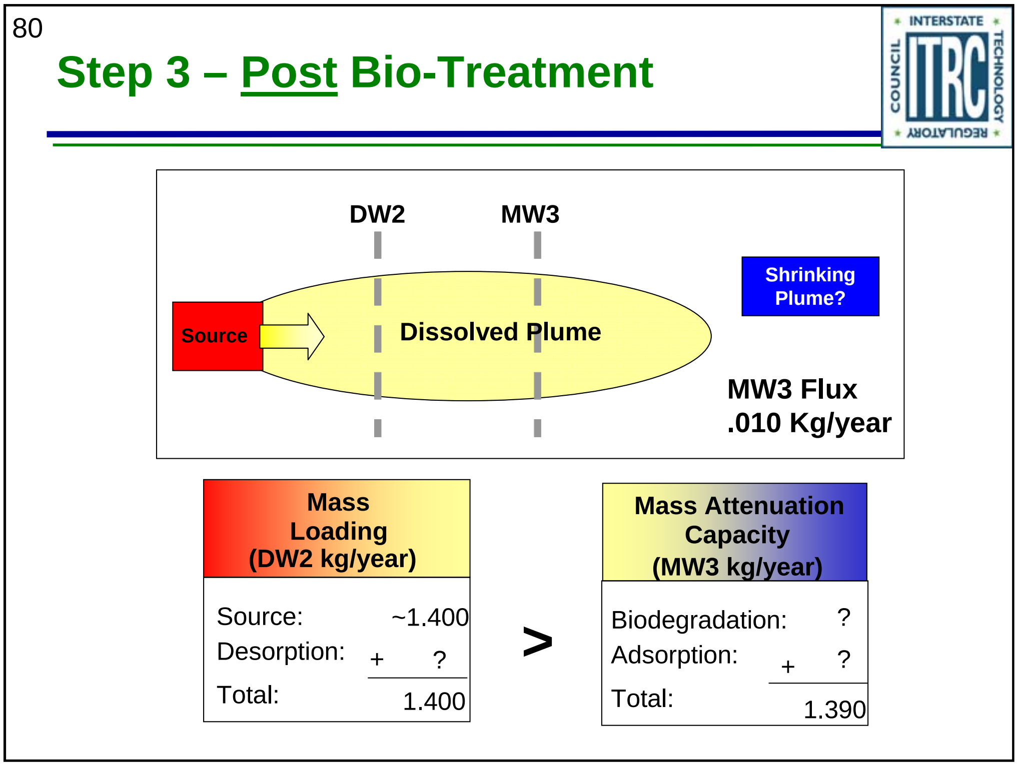
Vs

MW3 plane (pre and post bio)



Lets apply our flux calculations to our site conceptual model.

Loading from our DW2 plane (1.400) and attenuation from the difference of the DW2 and MW3 planes (1.400-.045 or 1.355).(pre bio in this example)



Post bio we see an increase in attenuation capacity from 1.355 to 1.390 kg/year

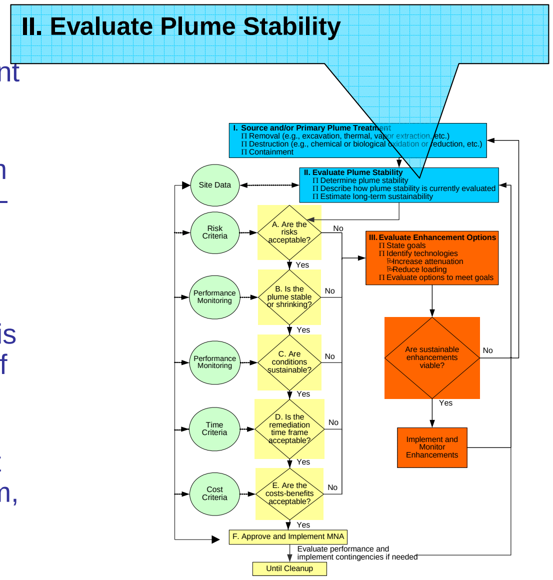
Remember this is the simplest form of flux measurement: 2 planes defined by one point each, and applying the concentration across the entire plane.

The value of additional site characterization is shown strongly here. More planes should yield lower mass flux, additional planes allow us to assess additional attenuation.

81

Step 4b: Use EA Decision Flowchart Evaluate Enhancement Performance

- **Increase in assimilative capacity** of aquifer (equivalent mass decreased down-gradient)
- Equivalent flux over time from the source did not decrease – DNAPL
- Additional lactate added (elements of EA)
- Need to confirm added DHE is present and required levels of carbon/ORP can be maintained over time
- Currently, contemplating shift to **emulsified oil** as long-term, sustainable **[EA]** bioremedial solution



We again use a level 2 evaluation of plume stability and sustainability after the enhancements

In this case, we are currently conducting our level 2 evaluation at decision points A, B, C, D, and E for risks, stability, sustainability, and performance. We may select MNA and continuously evaluate performance until remedial goals are meet and closure is achieved.

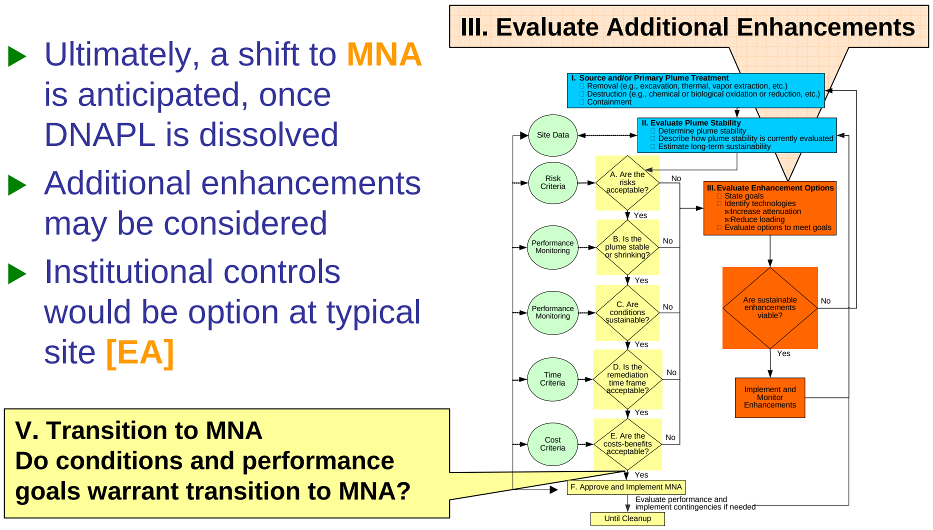
However if MW3 plane is the compliance point then A (risk) and B (stability) are both questionable.

And we would be considering additional enhancements or additional performance data.

When additional enhancement is selected we reevaluate, and through the use of the EA flowchart with its continuous reevaluate of performance, we retain the option to change remedial processes if conditions, information or site management goals change in the future before closure.

Step 5: The Future, Transition to MNA

- Ultimately, a shift to MNA is anticipated, once DNAPL is dissolved
- Additional enhancements may be considered
- Institutional controls would be option at typical site [EA]



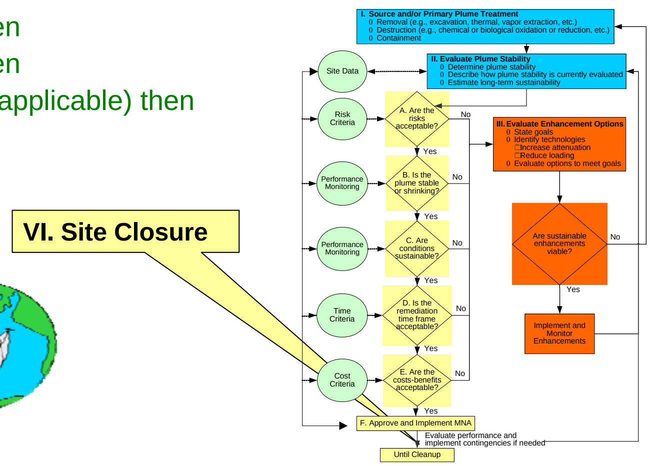
The future.

If the performance and/or conditions are not acceptable then we go again to a level 3 evaluation of additional enhancements. If the performance and/or conditions are acceptable then we may transition to MNA.

Through the use of the EA flowchart with its continuous reevaluate of performance, we retain the option to change remedial processes if conditions, information or site management goals change.

Step 6: Site Closure

- Back to
  - Step 3 then
  - Step 4 then
  - Step 5 (if applicable) then
  - Step 6



Regardless of the choice we will use the EA flowchart to continuous reevaluate of performance until closure.

84

In Review

Kimberly Wilson
South Carolina Department of Health and Environmental Control
Columbia, South Carolina
803-896-4087
wilsonka@dhec.sc.gov

- Today's training roadmap
  - Background Information
  - EA Concepts
  - Definitions and Application
  - Benefits
  - Decision Flowchart
  - General Application
  - Case Study

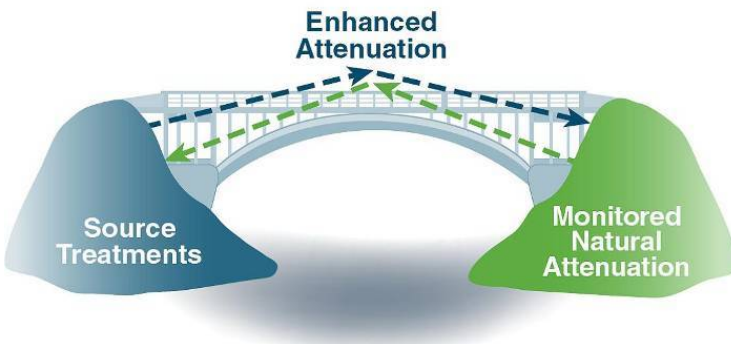
- **Enhanced Attenuation (EA)** is a plume remediation strategy to achieve groundwater restoration goals by providing a "bridge" between source zone treatment and MNA and/or between MNA and slightly more aggressive methods.
- EA provides an organized, scientific, and structured approach to implement treatment technologies at appropriate sites and at appropriate times.
- Various EA technologies can be designed to reduce the source flux and/or increase the attenuation capacity/rate in the plume to assure the plume will stabilize and shrink.

No associated notes.

85

Key Concepts of EA to Remember

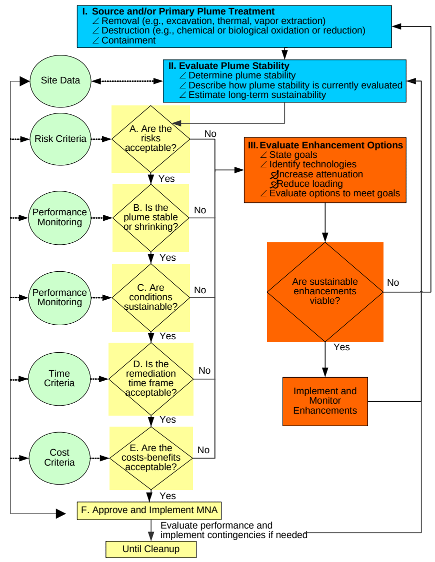
- Facilitates transition of contaminated sites through the complete remediation process
- Complements MNA and expands remediation opportunities
- Encourages energy efficiency and develops the best solutions for the environment



During real life site management discussions, EA helps determine amount of source treatment

Enhanced Attenuation

- Enhanced Attenuation is not what you do, it's how and when you decide what to do
- The Decision Flowchart and Enhanced Attenuation integrates well within existing regulatory framework



No associated notes.

Thank You for Participating

- 2nd question and answer break
- Links to additional resources
  - http://www.clu-in.org/conf/itrc/eaco/resource.cfm
- Feedback form – *please* complete
  - http://www.clu-in.org/conf/itrc/eaco/feedback.cfm

Need confirmation of your participation today?

Fill out the feedback form and check box for confirmation email.

Links to additional resources:
http://www.clu-in.org/conf/itrc/eaco/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/eaco/feedback.cfm

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects