Do we have the tools we need?

Do we know how to use them?

What more can or should SERDP/ESTCP do to help?

Rob Hinchee, Panacea Environmental

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History of Forecasting Technology Advancement

Everything that can be invented has been invented

Charles H. Duell, Commissioner of US Patent Office, 1899 https://medium.com/swlh/everything-that-can-be-invented-has-been-invented-49c4376f548b

Radio has no future. Heavier-than-air flying machines are impossible. X-rays will prove to be a hoax Lord Kelvin, 1899 http://rinkworks.com/said/predictions.shtml

Nuclear-powered vacuum cleaners… a reality in ten years.

Alex Lewyt, president of Lewyt vacuum company, 1955 https://blogs.surrey.ac.uk/physics/2012/02/21/nuclear-powered-vacuum-cleaners-will-probably-be-a-reality-in-10-years/

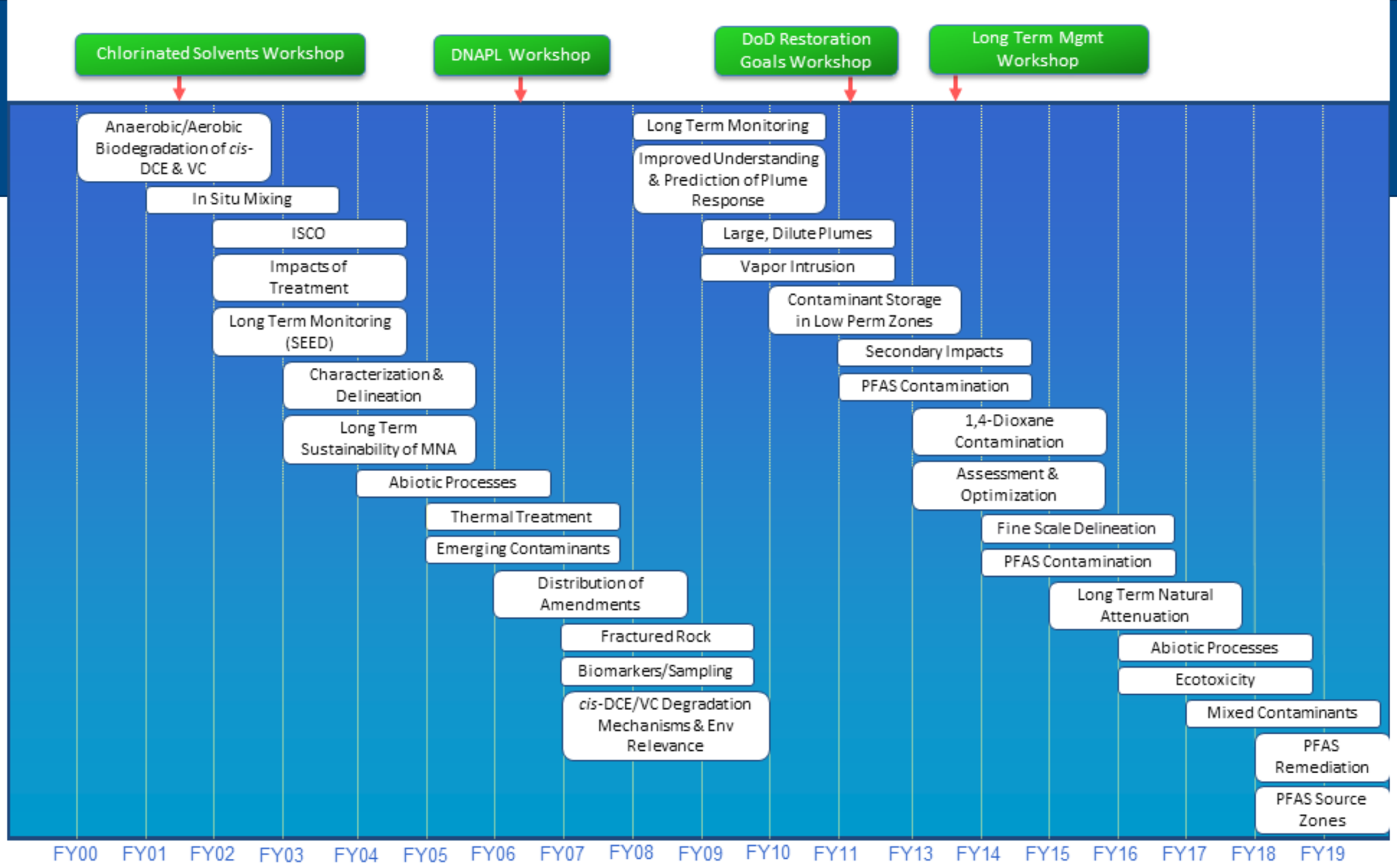
I think there is a world market for maybe five computers

Thomas Watson, president of IBM, 1943 http://rinkworks.com/said/predictions.shtml

What has been will be again, what has been done will be done again; there is nothing new under the sun Ecclesiastes 1:9, Kohelet, ~400 BC

Bioaugmentation will never work. Rob Hinchee, a long time ago

Warning! No guarantee of the accuracy of these quotes.


Chlorinated Solvents Workshop
DNAPL Workshop
DoD Restoration Goals Workshop
Long Term Mgmt Workshop
Anaerobic/Aerobic Biodegradation of *cis*-DCE & VC
In Situ Mixing
ISCO
Impacts of Treatment
Long Term Monitoring (SEED)
Characterization & Delineation
Long Term Sustainability of MNA
Abiotic Processes
Thermal Treatment
Emerging Contaminants
Distribution of Amendments
Fractured Rock
Biomarkers/Sampling
cis-DCE/VC Degradation Mechanisms & Env Relevance
Long Term Monitoring
Improved Understanding & Prediction of Plume Response
Large, Dilute Plumes
Vapor Intrusion
Contaminant Storage in Low Perm Zones
Secondary Impacts
PFAS Contamination
1,4-Dioxane Contamination
Assessment & Optimization
Fine Scale Delineation
PFAS Contamination
Long Term Natural Attenuation
Abiotic Processes
Ecotoxicity
Mixed Contaminants
PFAS Remediation
PFAS Source Zones
FY00
FY01
FY02
FY03
FY04
FY05
FY06
FY07
FY08
FY09
FY10
FY11
FY13
FY14
FY15
FY16
FY17
FY18
FY19

Many Tools and Technologies Supported Over the Past 20 Years

Type of Tool	Development	Demonstration	Guidance
Sensor or Monitoring	ER2419; ER200626; ER200518; ER2309; ER2312	ER2308; ER2420; ER201726; ER200717; ER200630; ER200114; ER200824	ER200704; ER200430;
Site Characterization	ER2419; ER1612; ER1613; ER2313	ER201732; ER201121; ER201118; ER201426	ER201567; ER201126
Remediation	ER201626; ER1740; ER1611; ER2310; ER2132	ER201733; ER201631; ER201629; ER201628; ER201627; ER201430; ER201427; ER201210; ER200715; ER200221; ER200218; ER200112; ER200008; ER199907; ER199808	ER201569; ER2011202; ER200623; ER200530; ER200424; ER200314;
Natural Attenuation	ER201730; ER201584	ER201129; ER201032; ER20084; ER200705	ER201572; ER201211
Long term O&M	ER2129; ER1738; ER2131;	ER201209	ER201566; ER200318

60+ Tools & Technologies

Chemical Reactivity Probes
High Resolution Samplers
Multiple Primary Substrate Cometabolic Biosparging
Mobile/Immobile Porosity Exchange Tool
Quantitative Framework for Evaluating Natural Attenuation
Molecular Biological Tools
Horizontal Reactive Media Well
Large Dilute Plumes using Cometabolic Approach
Zero Valent Zinc
Vertical Drains for Low Perm
EK-TAP
MNA MOOC
ER Wiki
Geophysics T2
Training System for Reductions in Cost and Complexity of Remediation & LTM
Environmental Fracturing
Bioaugmentation in Source Areas
Assessing Past Bioremediation Performance
Matrix Diffusion Modeling with REMChlor
MNA FAQs
Bioaugmentation in Fractured Rock Source Zones
LTM – Methods for Minimization and Management of Variability
BioPIC –Tool for selection of bioremediation approaches
Decision Support System for Matrix Diffusion Modeling
DyeLIF Tool – High res mapping of chlorinated solvents
Redox Based Groundwater Remediation Technologies
Contaminants in Low Permeability Zones
High Resolution Delineation in Saturated Subsurface Environments
Practical Cost-Optimization at DNAPL Sites
Secondary Impacts Remediation on Groundwater Quality
Rapidly Detection of Dehalococcoides and Dehalobacter

Cost & Performance Database – Decision Support System
Fractured Rock Geophysical Toolkit
Source Attenuation History
MNA Sustainability Assessment
Geophysical Monitoring
Fractured Rock – Thermal Treatment
Natural Attenuation of Source Zones
PREMChlor
Snap Sampler
Design Tool for Aqueous Amendment Injection
ISCO Manual
Source Zone Protocol – Remedy Selection
Molecular Biological Tools
Mass Flux Toolkit
DNAPL Test Tool (Source Area Remediation Selection)
Diagnostic Tools
Thermal Treatment Evaluation
Edible Oil Barrier for Chlorinated Solvents
Bioremediation of Source Zones with Enhanced Mass Transfer
Passive Flux Meter
Electrically Induced Redox Barriers
Long Term Monitoring – Comparison of Direct Push vs Traditional Wells
Bioavailable Ferric Iron Assay & Dissolved Hydrogen Analyzer
Bioaugmentation
Permeable Reactive Barriers
Air Sparging
Protocol Development for Characterizing DNAPL Source Zone Architecture
Modeling of Post-Remediation Impacts of Bioremediation on Groundwater Quality
Performance Assessment and Optimization at DNAPL sites
Predicting Groundwater Quality following application of ISCO
Molecular Diagnostics to Assess, Monitor, and Predict Microbial Activities
Forecasting Early Remediation Performance
Contaminant Flux Reduction Barriers
Sorption in Low-Permeability Plume Longevity

Practitioners Canvased

rigorously unscientific survey

- Ross Miller, Parsons
- Kent Sorenson, CDM
- Fred Payne, Arcadis
- Matt Schnobrich, Arcadis
- Chuck Newell, GSI
- Dean Williamson, Jacobs
- Tom Simpkin, Jacobs
- Laurie Lapat-Polasko, Matrix New World Engineering
- Rula Deeb, Geosyntec
- Bo Stewart, Praxis
- Mark Loucks, Hill AFB
- Dave Becker, COE
- Michael Taraszki, Wood
- Bob Mutch, Mutch & Assoc.
- Scott Huling, EPA
- Ralph Baker, Terra Therm, Ret.
- Susanne Borchert, CH2M Hill

Big Picture Results 1

- 80+% believe we have most if not all the tools we need.
  - Some tweaking may help
    - A few ideas to follow
  - Many however expressed concern that SERDP/ESTCP remain open to truly new “breakthrough” ideas
- Most do not believe the tools we have are always being effectively used
  - Acceptance by site owners and or regulators a challenge
  - Effective use varies
  - Reasons for ineffective use varies
  - No clear agreement as to what SERDP/ESTCP can or should do about this
    - Tech Transfer, let the Marketplace sort it out, or do a better job of selecting consultants?

MBTs are a good example

- Many powerful new tools have been developed.
- A wide variety of tools are readily available commercially.

SiREM

- Gene-Trac Testing
- Determine if suitable microorganisms are present for MNA remedies.
- Predict the effectiveness of biostimulation before the addition of electron donor.
- Determine the need for bioaugmentation.
- Determine the impact of site amendments including, electron donors/acceptors.
- Predict if intermediates such as cDCE or vinyl chloride are likely to accumulate.
- Characterize microbial community spatial and temporal variability.
- Validate the performance of enhanced bioremediation projects.
- Make informed decisions to manage bioremediation and other microbial systems.
- ~40 tests identified on their website, ie Dhc, Dhb, Dsm, Dsb, Dhg, Chloroethene FGA, Polaromonas, etn, cfrA/dcrA, sMMO, PMO, SRB, ORM-2, Pepto-ben, abcA, & so on

PACE

- Compound Specific Isotope Analysis (CSIA)
- Next Generation Sequencing
- Quantitative PCR
- Remediation Test Panel including
  - Contaminant identification and concentrations
  - Degradation byproducts
  - Isotopic Carbon Ratios
  - BER DNA Array for up to 150 microbes known to degrade various contaminants
  - Interpretive reporting
  - The Remediation Test Panel may just provide the multiple lines of evidence needed to close your site.

MBTs are a good example

the good and bad news

- The good news:
  - Any entry level scientist or engineer can order these tools.
    - Easy to understand and follow guidance is available from the vendors.
  - ESTCP and SERDP guidance tends to help people understand the tools, what they mean, and how to apply them.
- The bad news:
  - Any entry level scientist or engineer can order these tools.
    - Easy to understand and follow guidance is available from the vendors.
  - It is not always clear how these tools should inform decision making.
- What can ESTCP/SERDP do to help?
  - Not clear, perhaps best left to the marketplace to sort out.

Bioaugmentation is another example

Oil Spill Treatment
- An example from a more mature business

The Science

(ASM, 2011, Microbes & Oil Spills – Frequently Asked Questions):

"Does adding bacteria to the contaminated environment speed the cleanup of an oil spill or improve the effectiveness of biodegradation?"

Response

"Because bacteria that can degrade oil constituents are ubiquitous, to date there is little convincing evidence that bioaugmentation (addition of more bacteria) significantly enhances either the rate or the extent of oil biodegradation in most environments."

Ron Atlas, Darrell Grimes, Terry Hazen, Jim Spain, Joseph Suflita, Ann Reid, Stanley Maloy, Carl Cerniglia, Gary King, Nancy Kinner, Joel Kostka, Kenneth Lee, Frank Loeffler, Roger Prince, Patty Sobecky, Robert Steffan, Andreas Teske, Benjamin Van Mooy, Al Venosa, Lawrence Wackett, Herb Ward, Lily Young, Gerben Zylstra https://www.asm.org/images/stories/documents/Microbes_and_Oil_Spills.pdf

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The Reality

Bioaugmentation is used as a part of oil spill remediation most of the time (more so internationally than in the US).

Soil Oil Spill Remediation Bacteria
https://www.alibaba.com/product-detail/Soil-Oil-Spill-remediation-bacteria_152537353.html

Enviro-safe organic bacteria will eat and absorb the oil naturally. Pour Safe! on oil or hydrocarbon chemical spills, add water and watch it eat the spill naturally!
http://www.comstarproducts.com/safe-bacteria-oil-spill-eater-10-pounds-593

Oil Gone Easy S-200 uses special nutrients to attract microbes to the spill, which then break the oil down into water. It takes about a week …preventing… evaporating… or seeping… into the ground.
http://www.utvweekly.com/2010/01/a-natural-way-to-remove-truck-oil-and-diesel-stains-from-driveways-concrete-and-soil/

Big Picture Results 2

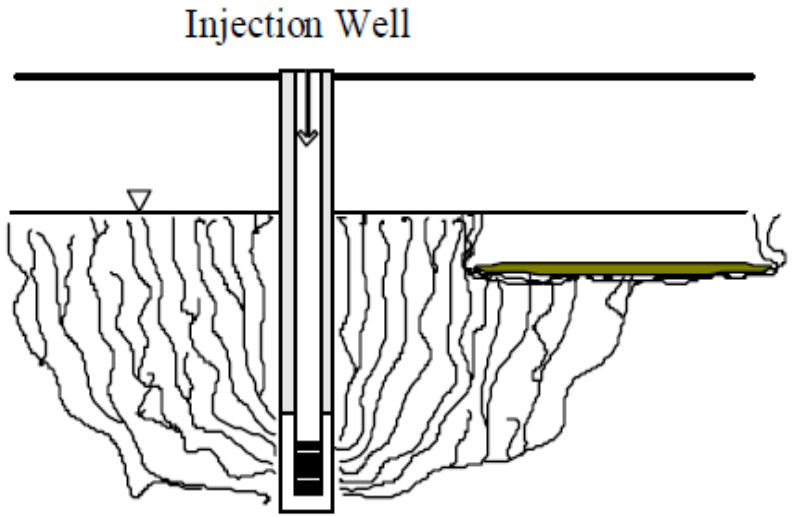
- ~50% Believed DoD will benefit from ongoing SERDP/ESTCP involvement
  - The majority of these believed that any ongoing SERDP/ESTCP role should be primarily tech transfer
- A significant minority believe the marketplace can sort out the existing tools, limited need for ongoing SERDP/ESTCP involvement
  - On reflection many of those who first stated they did not see a beneficial role for SERDP/ESTCP came up with some exceptions
    - New innovative ideas

Big Picture Results 3
If we have the tools we need why aren't we cleaning up more sites?

- **Delivery, Delivery, Delivery!**
- Near 100% agreement **Delivery** is the biggest problem limiting effectiveness
  - Heterogeneity
  - Characterization
  - Getting reactions to occur where the contaminants are
- We know how to degrade, oxidize, reduce, or thermally treat, we just don't know always know where the contamination is or how to make the process work in situ.

Delivery has long been the problem

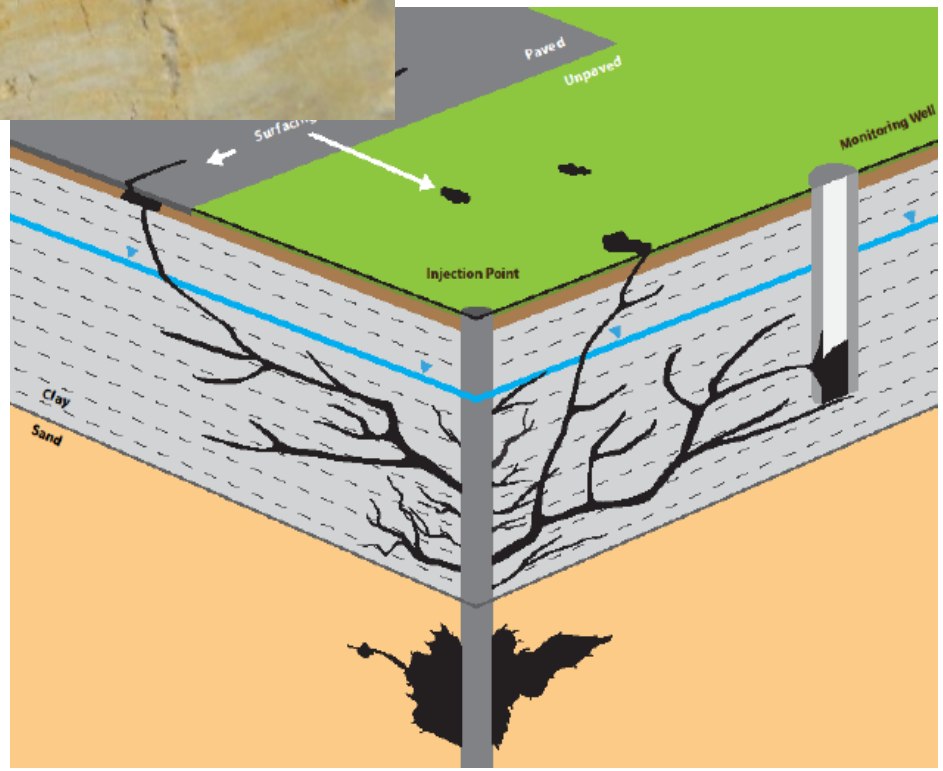
Examples



ER-199808

Fox 2015

http://neiwpcc.org/tanks2015old/tanks2015presentations/3-Tuesday/Carbon-Based%20Injections/fox.carbon_injection.tuesday.pdf



Our tools do not always perform as advertised.

Understanding why is important

Big Picture Results 4

If we have the tools we need why aren't we cleaning up more sites?

- The majority often saw poor performance, tools not effectively applied.
  - ~50% blamed DoD contracting practices
    - Most agreed need for tech transfer to DoD people writing RFPs and SOWs and evaluating proposals. General agreement that if DoD contracting leads consultants will follow.
  - Lack of understanding and acceptance of the tools we have.
    - Not just by RPMs and consultants, regulators are a part of this problem.
- A significant minority believed that these problems cannot be overcome and DoD should plan for lower cost LTM.

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Different schools of thought

- You could get to Bangor
  - If only you knew the way

- You can never get to Bangor
  - Admit it and quit trying
  - Learn to be safe and happy
  - where you are

Two different schools of thought

- Existing tools consistently should achieve near MCLs at most sites.
  - Some people are consistently achieving this level of remediation
    - Others are not, primarily due to a lack of understanding
  - DoD needs to insure effective application of tools happens consistently.
  - Unattributed quote: "*Most people who believe our currently available tools don't work just lack the experience to understand*"

- Existing tools will never achieve near MCLs at complex sites
  - While beneficial mass removal is possible achieving near MCLs is not
  - DoD needs to accept this and manage its sites accordingly
    - More focus on Risk Management, MNA and LTM is needed
  - Unattributed quote: "*I am tired of seeing remediation efforts little better than half-baked hoping for success*"

What should ESTCP/SERDP do to help?
Tech transfer to sort out the Bangor problem

- Find out who is and isn't getting there
  - Independent 3rd party critical evaluation of select remediation successes and failures.
    - Good demonstrations have always been ESTCP's key contribution.
    - Documenting what really worked and what didn't.
      - Substantiated by data and,
      - A solid understanding of underlying mechanisms.
- Help stop folks from following the same old dead ends
  - Identify and document technologies that rarely if ever work, possibly:
    - In situ ozone oxidation and perhaps Fenton's
    - Groundwater circulation wells
    - Others?

What should ESTCP/SERDP do to help? continued

- Consider additional support for guidance carefully, the marketplace can be an efficient way of sorting things out.
- Provide tech transfer aimed at DoD RFP and SOW writers and proposal reviewers.
  - Help provide the tools to support good DoD management and decision making.
- DoD needs to more actively consider responses to regulators
  - Some believe DoD accepts requirements unchallenged more than industry.
  - Possible window of opportunity under the new administration.
- DoD needs better benchmarking, comparing as quantitively as possible, cost, application and regulatory requirements.
  - To other DoD sites
  - To industry
- Don’t preclude support for truly new ideas with significant potential.

SERDP/ESTCP DNAPL Workshops

2006

Research Needs

- Characterization and monitoring methods
- Plume response to source depletion
- Treatment and monitoring for flow-limited portions of DNAPL source zones
- Combined remedies
- Karst and complex sites
- Vapor from sources

Demonstration Needs

- Methods for reducing LTM/characterization costs
- Focused data mining
- Characterization & remediation guidelines
- Technology transfer

2018 ->

Research Needs

- Understanding & Quantification of Natural Attenuation Mechanisms in Plumes
- Quantitative Understanding of the Effect of Co-contaminants on CVOCs
- Integration of Information from Fine-Scale Delineation Tools for Improved Decision Making at Complex Sites
- Comprehensive Decision Framework for Remedy Selection
- Improved CSMs for Understanding the Factors Sustaining and Controlling Persistent Chlorinated Solvent Plume Behavior
- Fundamental Understanding of Processes Influencing the Effectiveness and Fate of Particulate Amendments
- Analysis of Performance Data from Pump-and-Treat Systems to Predict Decline in Mass Discharge over Time
- Methodologies to Determine Ability to Transition from Active Measures

Demonstration Needs

- Improved Understanding & Quantification of MNA Mechanisms in Plumes
- Evaluation of Techniques for Optimized Delivery and Distribution of Amendments in Heterogeneous Environments
- Improved Remedy Performance Monitoring and Process Control
- Best Management Practices for Back Diffusion and Plume Management Integration Of Information From Fine-Scale Delineation Tools For Decision Making At Complex Sites
- Development of Adaptive Site Management Tools
- Comprehensive Decision Framework for Remedy Selection
- Improved CSMs for Understanding the Factors Sustaining and Controlling Persistent Chlorinated Solvent Plume Behavior

Technology Transfer Needs

- Refinement Of Existing Technology Transfer Communication Strategies To Improve Outreach To Site Managers
- Access to Technical Expertise on Project Specific Technology Implementation Issues
- Adaptive Site Management Tools
- Technology “Myth-busting” to Avoid Preventable Mistakes
- Experienced Based Rational Design and Guided Optimization for In Situ Treatment of Chlorinated Solvents
- Improved CSMs for Understanding the Factors Sustaining and Controlling Persistent Chlorinated Solvent Plume Behavior
- Develop Effective, Immersive Training Tools

Summary

Do we have the tools we need?

- Yes, probably most of them; the fundamentals anyway.
- Refinements and improvements are always welcome.

Do we know how to use them?

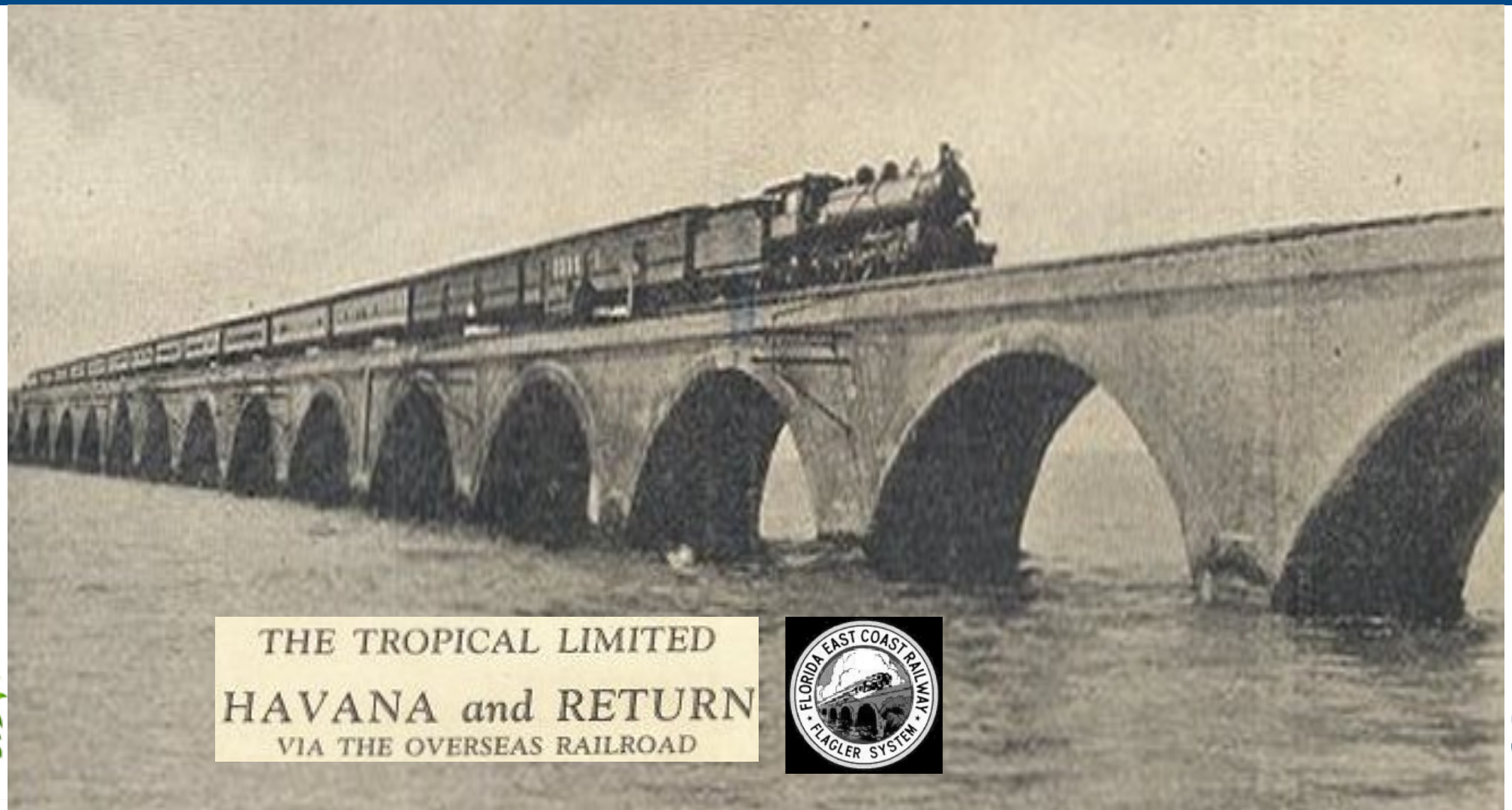
- Clearly not everyone does.
- Importantly there is no consensus as to how effective the tools are or can be.

What more can or should SERDP/ESTCP do to help?

- Provide credible **experience based** guidance.
- Provide effective Tech Transfer.
- Provide better Tech Transfer to key DoD decision makers.
- Keep an open mind to useful new ideas.

"DNAPL remediation is like building a bridge across a river but you can't see to the other side because it is too foggy. We are attempting to remediate DNAPLs anyway so that we can pass on a cleaner environment to the next generations. By the time our children are grown, they can continue building the DNAPL bridge to the other side of the river."

John Cherry 1998



Hinchee 2003

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