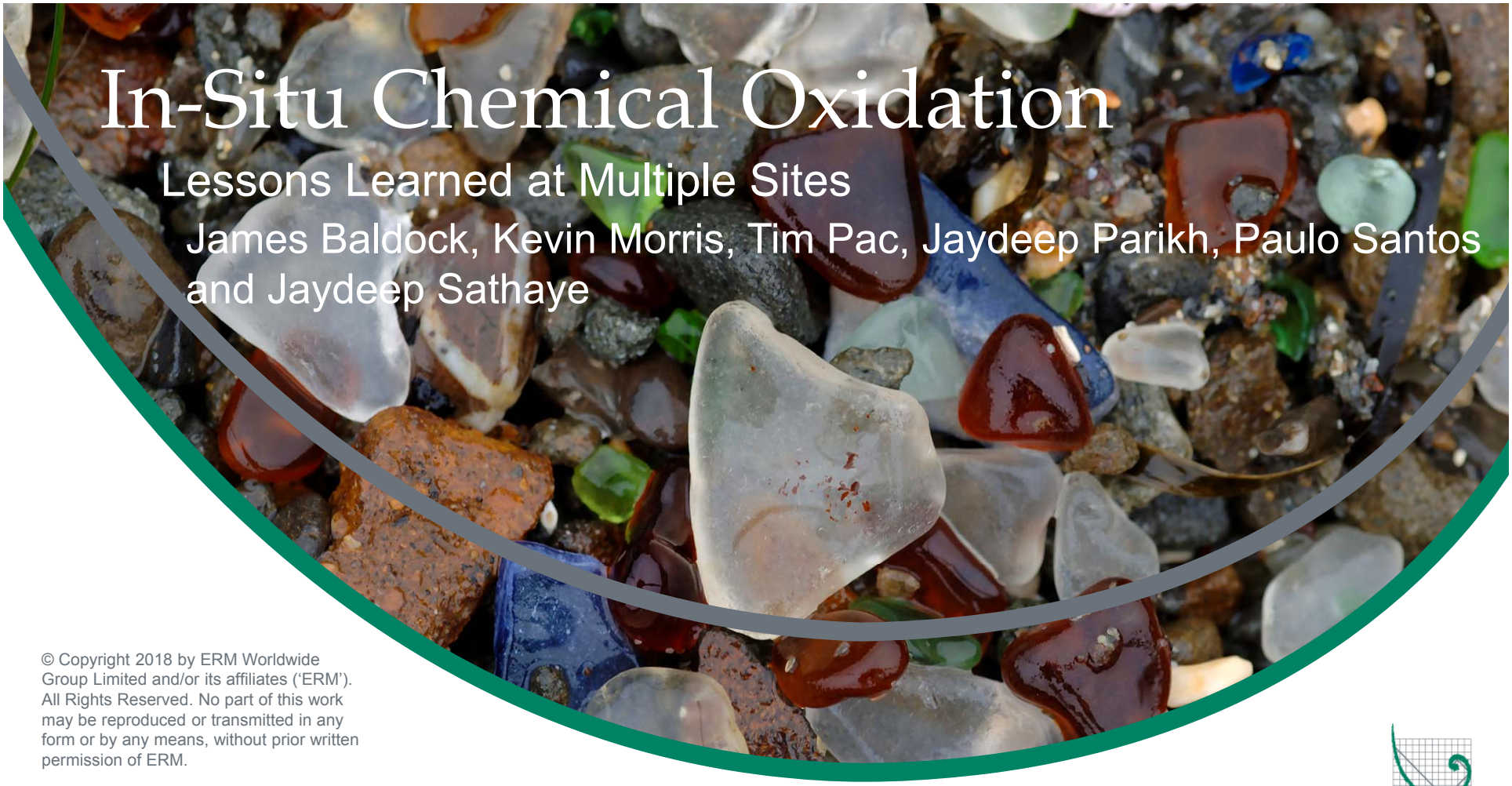


In-Situ Chemical Oxidation

Lessons Learned at Multiple Sites

James Baldock, Kevin Morris, Tim Pac, Jaydeep Parikh, Paulo Santos and Jaydeep Sathaye

The business of sustainability

ERM

Agenda

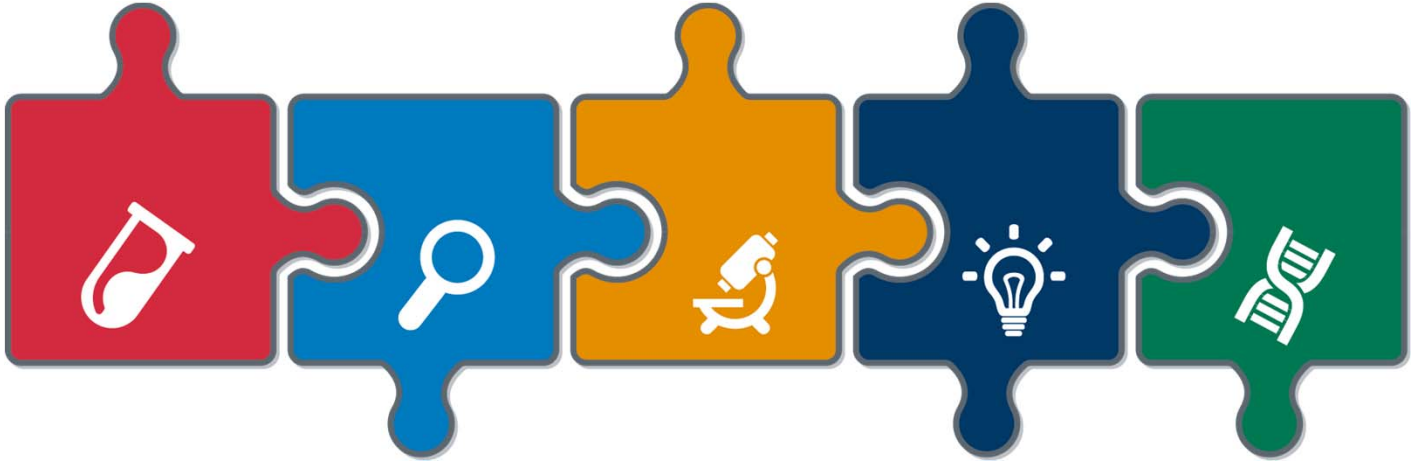
Introduction

Market Observations

Technical

Changes

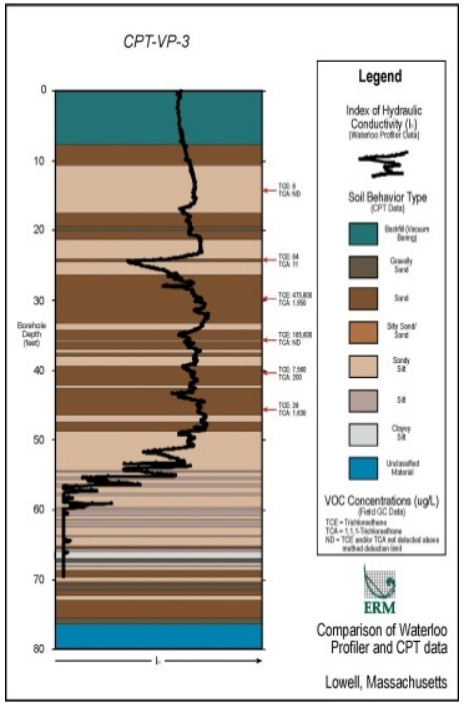
Future

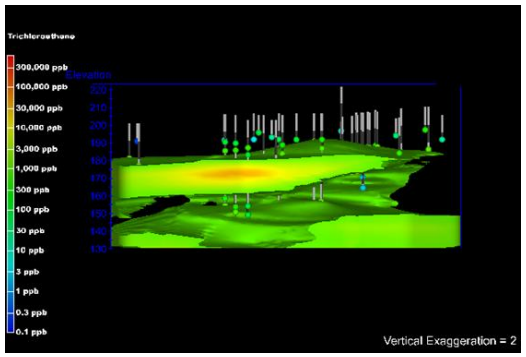


Introduction

State of the Practice

- Sites are increasingly complex
- Rapidly changing characterization tools
- Improved ISCO understanding
- Overpromised unrealistic expectations
  - *Multiple incidences of technology failures*
  - *No technology works everywhere*





Market Observations

1. Combining technologies
   - Maintaining sweet spot vs. resistance to change
2. Increased pressures for project execution
   - Site “needs,” “wants” and cost balancing
3. Overselling capabilities
   - Unique and complex sites
   - Surprises are the norm

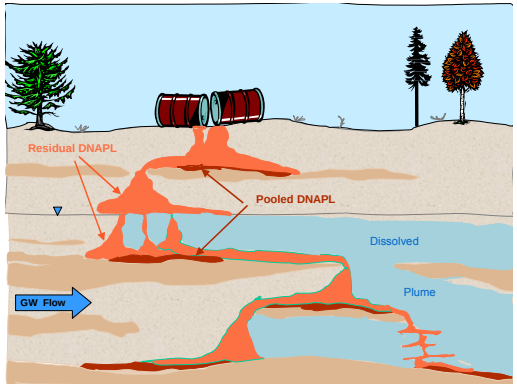
Technical Observations

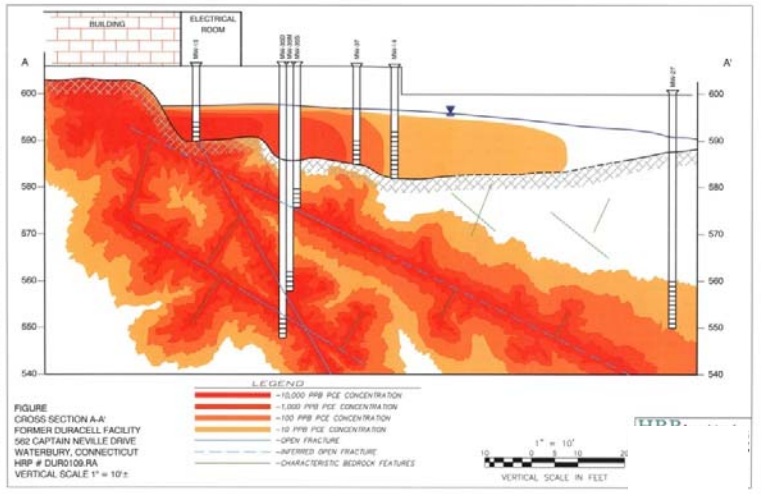
1. Visualization/conceptual models (CSM)
2. Design
3. Underutilization of existing data
4. Implementation
5. Post injection monitoring
6. Skilled personnel

Technical Observations

1. Visualization/Conceptual Models

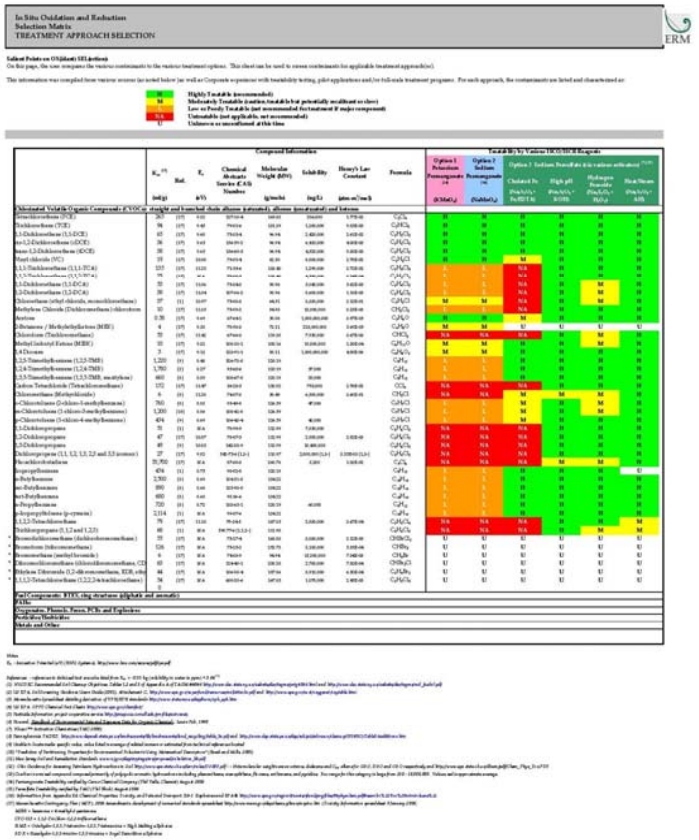
- Increased toolbox to characterize Sites holistically
  - *Tool box capabilities and interpretation in real time*
  - *Heterogeneity is the norm not the exception (variability on all scales)*
  - *Representativeness?*





Technical Observations

2. Design
   - A. Oversimplification
   - B. Amendment and Dose
   - C. Pore volume
   - D. Flexibility

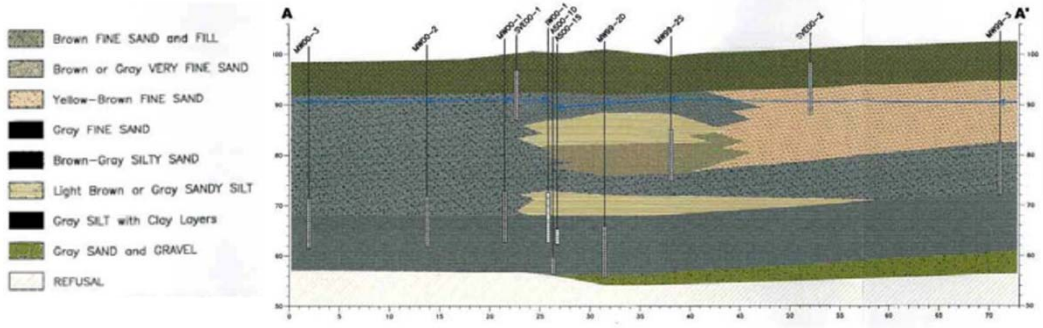

In Situ Oxidation and Reduction
Reduction Matrix
TREATMENT APPROACH SELECTION

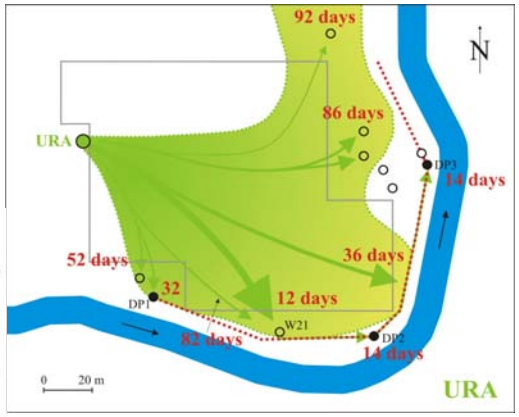
Technical Observations

2. Design (*continued*)

A. Oversimplification

- Simplification is required to conceptualize difficult or incompletely understood systems; simplification however results in,
  - *Elimination of accuracy*
  - *Incomplete understanding of source to terminus*
  - *Overreliance on existing data*



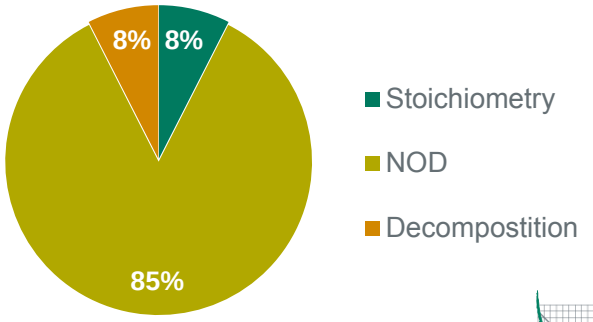


Technical Observations

2. Design (*continued*)

B. Amendment and dose – no ISCO silver bullet chemical

- Under dosing - failure to account for all demands
  - *SOD/TOD*
  - *Decomposition losses*
  - *Unintended or unknown reactions, other unknown compounds*
- Overdosing – more than necessary
  - *Cost and time*
- *Oxidant persistence*
- Improper dosing
  - *Wrong amendment – No ISCO agent treats everything*



Technical Observations

2. Design (*continued*)

B. Amendment and dose – no ISCO silver bullet chemical (*continued*)

- *Improper dosing*
  - *Wrong amendment – No ISCO agent treats everything (DCA)*

Technical Observations

2. Design (*continued*)

C. Pore volume – injection volume relative to pore volume (PV)

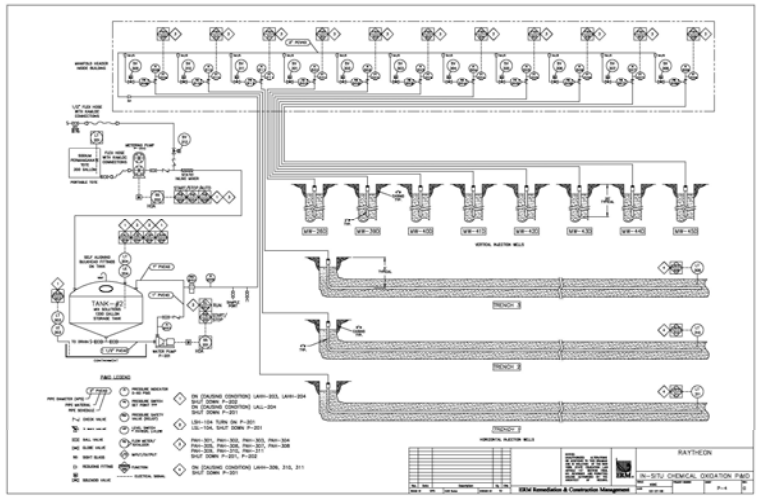
- *Volume = f (amendment, concentration, time, cost)*
- *Injectate volume vs PV varies widely by program: < 0.1X to > 5X*
- *Volume of amendment (saturation versus surgical):*
  - *Too much– long duration, high cost, breakout, water table rise, Site disturbance*
  - *Too little– stripping in advective zones only, variable performance, rebound*

Technical Observations

2. Design (*continued*)

D. Flexibility

- *Incorporate flexibility into design – static designs difficult to change*
- *Restrictive operational criteria – drinking water closure goal, uptime*
- *Differing Site conditions*



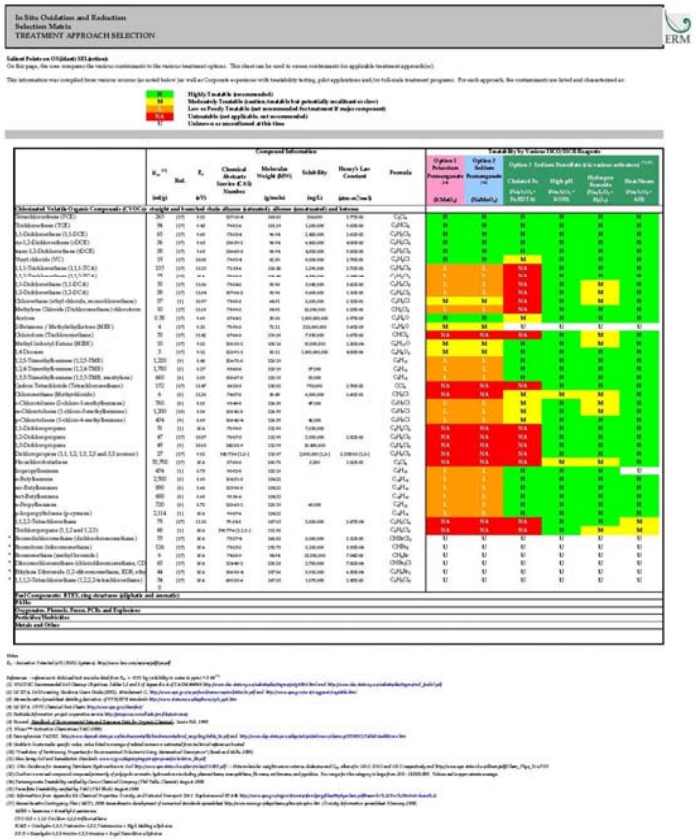
Technical Observations

3. Underutilization of existing data

- Simple tests can yield valuable information – *water infiltration, grain size, air permeability*
- Available information - *utility plans / subsurface clearance / as-built's*
- Observational data – *drill logs, historical records, Site knowledge*
- Soil/cutting examination and logging – *discontinuities, breaks, voids*

Technical Observations

4. Implementation
   - A. Delivery and Distribution
   - B. Hydraulics
   - C. Pressure



Technical Observations

4. Implementation (*continued*)

   A. Delivery and Distribution

   - *Mass focused treatment is the norm*
   - *Uneven or incomplete amendment placement*
   - *Difficult geologies*
   - *Use of improperly designed wells*

Technical Observations

4. Implementation (*continued*)

B. Hydraulics

- *Inhomogeneity is the norm - radial flow does not occur, is the distribution being measured and confirmed?*
- *Presence of oxidant does not mean that no contaminants are present*
- *Injectate properties*
  - *Density – injectate specific gravity*
  - *Viscosity – injectate viscosity*

Technical Observations

4. Implementation (*continued*)

C. Pressure - Injectate preferentially follows higher conductive zones – "the water doesn't care"

- *Overpressure fractures – start up pressures, over pressurization*
- *Friction loss and breakout – vertical fracture*
- *Risk and impact of spill increases exponentially with increasing pressure*

Technical Observations

5. Post injection monitoring

- Verification QA to evaluate performance vs. objectives
- Quantification vs. Speculation
  - *Distribution – versus plan and versus target mass*
  - *Persistence – activity, longevity*
  - *Performance – target declines*

- Presence of oxidant does not mean there are no detectable contaminants

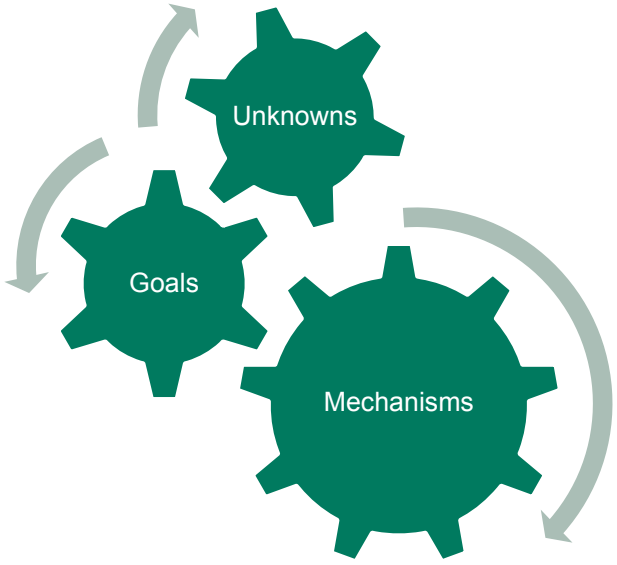
Technical Observations

6. Skilled personnel – *"been there, done that"*

- Operational knowledge of project and process
- Expectations for chemical behavior and markers for outliers
- Response action and tools
- Knowledgeable and experienced field teams
- Contingency and communication plans in place
- Total team approach to execution

Changes in ISCO Remedies

1. Recognition of multiple mechanisms of treatment
2. Imposition of impractical closure goals
3. Site Unknowns



Changes in ISCO Remedies

1. Recognition of multiple mechanisms of treatment

- Technology coupling – ISCO/bio, thermal/bio, hi/low temperature thermal
- Multi component amendments – persulfate/permanganate
- Effect of natural or added surfactants
- Quantification of contributions
  - Which technology does the “work”
  - Quantification?

Changes in ISCO Remedies

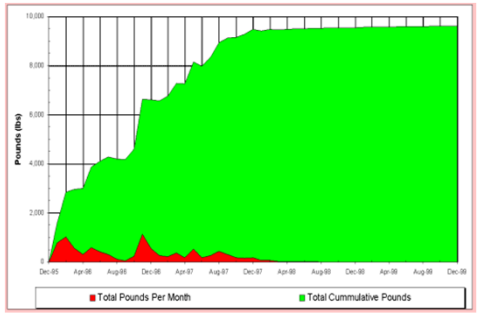
2. Imposition of impractical closure goals

- Typically non-degradation standards
- Closure defined as drinking water standards – vs. RIBC's
- Closure defined at specific compliance point(s) – e.g., property boundary
- Flux based remediation – focus on mobile materials, just because mass is there does not mean it has to be treated

Changes in ISCO Remedies

3. Project unknowns

- Project re-openers
  - *New and emerging contaminants – 1,4-D, PFAS/PFOA, ED's, next?*
  - *Decreased closure goals – TCE, VI issues*
- What is "clean enough" – impact of risk assessment
- Flexibility in Plans – elimination of static approvals
- Use of mass based approaches
- Revisit of "pay for performance" and "guaranteed outcomes"?



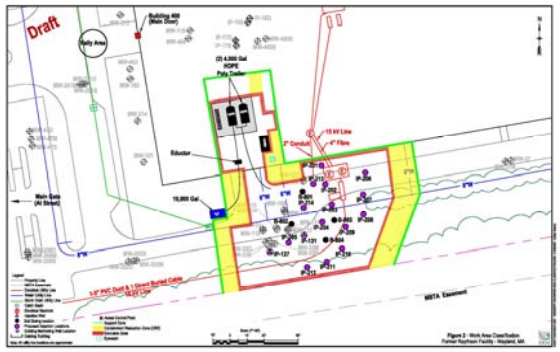
Future

1. Setting reasonably attainable expectations
2. Incorporation of mass balance approach
3. Team-vested approach for remediation

Future

1. **Setting reasonably attainable** expectations

- Time, cost and performance
- Coupling of characterization and delivery
- Recognition of oxidant persistence – proper SOPs
- Plan for remediation
  - Tasks
  - Expectations
  - Measurement



Future

1. **Setting reasonably attainable** expectations (*continued*)

- Recognition of alternative remedial approaches
  - *Fixed – vertical, inclined, horizontal wells, trenches*
  - *Temporary – direct targeted injection, fracturing*
  - *Automation – "continuous" low flow processes*
  - *Recirculation – "closed loop" horizontal or vertical*
  - *Soil mixing*
  - *Slow-release options*

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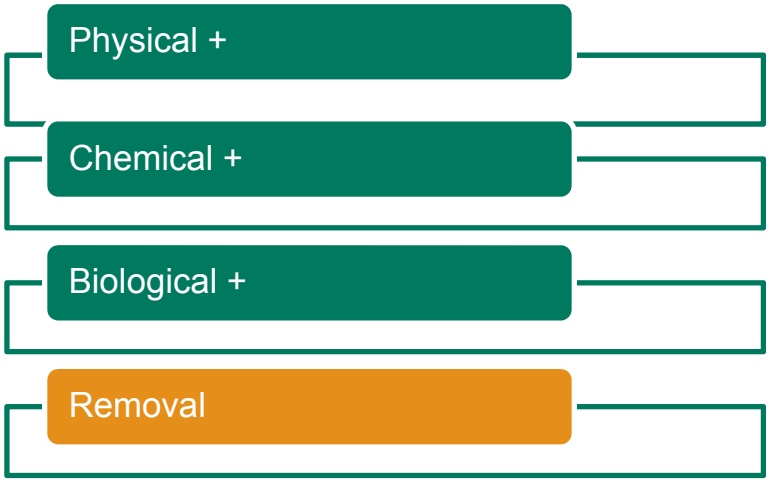
Future

2. Incorporation of mass balance approach

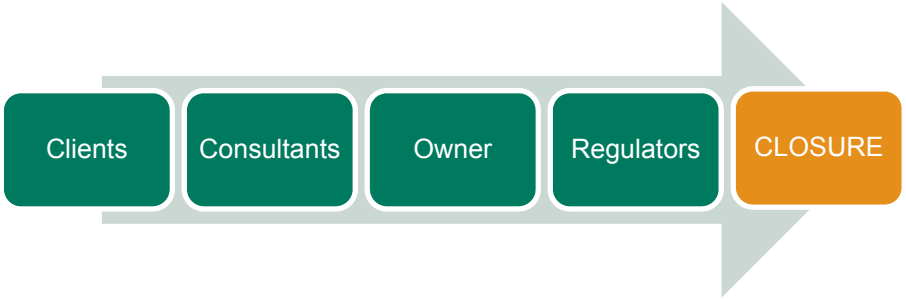
- Pre-remedial conditions - accurate baseline understanding
- Recognition (and measurement of) multiple means of treatment
- Use the best of each method – technology coupling



Future

3. **Team-vested approach** for remediation

- Clients – corporate, regional, local, plant
- Consultant(s) and engineer(s)
  - *Management*
  - *Field team*
  - *Contractors*
- Site owner/operator
- Regulators



Active Leadership
Training and Competency
Emphasizing Positive Safety
Risk Management
Maintaining Balance

Contact Info

James Baldock
Technical Director
ERM
James.Baldock@ERM.com

Kevin Morris
Technical Director
ERM
Kevin.Morris@ERM.com

Tim Pac
Technical Director
ERM
Tim.Pac@ERM.com

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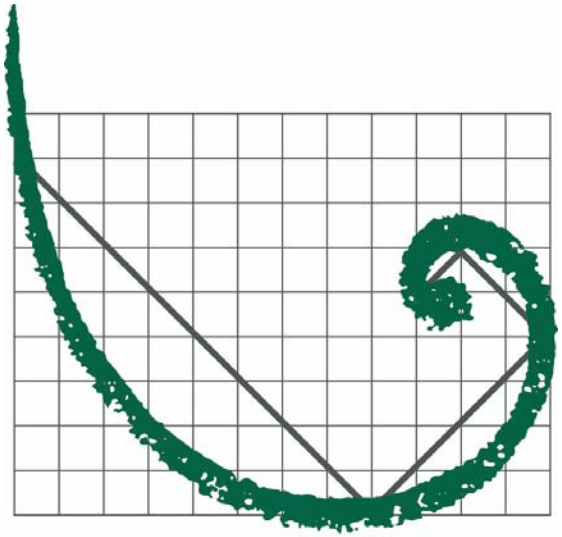
Jaydeep Parikh
Partner
ERM
Jaydeep.Parikh@ERM.com

Paulo Santos
Partner
ERM
Paulo.Santos@ERM.com

Jaydeep Sathaye
Partner
ERM
Jaydeep.Saythaye@ERM.com



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