Headquarters U.S. Air Force

I n t e g r i t y - S e r v i c e - E x c e l l e n c e

Efficient Use of Technology

U.S. AIR FORCE

John K. Miller

Mitretek Systems

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Efficient Use of Technology Choices

Conventional Remedies

versus

Innovative Remedies

How Do I Chose?

Presentation Topics

- Selected conventional and innovative remedies
- Factors to consider and how to choose between competing remedies
  - Favorable conditions and advantages
  - Unfavorable conditions and disadvantages
  - Controversial issues
  - Rules of thumb
- Why not just use the conventional remedy?
- Why make sure the selected remedy is working?

Types of Technologies

Conventional Remedies

- Dig and haul off site
- RCRA landfill cap
- Soil vapor extraction (SVE)
- Groundwater pump and treat (P & T)

Innovative Remedies

- Monitored natural attenuation (MNA)
- Enhanced bioremediation
- Phytoremediation
- Innovative landfill caps
- Permeable reactive barriers (PRB)

Concepts to Consider

Sources

- **Control or containment**
- **Removal and remediation or "cleanup"**

Plumes

- **Remedy for each site versus a combined remedy**

Conventional Remedies

- **Quicker?**
- **Less data?**
- **Lower cost? — short-term versus long-term**

Factors to Consider

Implementation Issues

- Remedial objective: control or remediation
- Appropriateness: can the remedy achieve the goal?
- Time and cost
- Community and regulatory acceptance
- Long-term effectiveness
- Political science?
- Proactive *not* reactive
- There is no single solution ® *multiple combinations*

Conventional Remedies

Soils

- **Dig and haul off site**
- **RCRA landfill cap**
- **Soil vapor extraction**

Groundwater

- **Pump and treat**

Conventional Remedies: Dig and Haul Off Site

Favorable Conditions:

- **Small, well-defined, shallow source**
- **High-concentration "hot spot"**
- **Waste above groundwater table**
- **Nearby disposal site or treatment facility**
- **Easily accessible**

Advantages:

- **Good public acceptance**
- **No operating costs**
- **Minimal long-term groundwater monitoring?**
- **Potential for fast site closure**

Conventional Remedies: Dig and Haul Off Site (Continued)

Unfavorable Conditions:

- **Deep contamination or waste below the water table**
- **Irregular waste pattern or "waste pockets"**
- **Unstable or uncohesive soil**
- **Utilities/surface features**

Disadvantages:

- **High cost, no destruction of contaminants**
- **Land disposal restrictions/pretreatment required**
- **Long distance to disposal site**
- **Air emissions and dust problems**
- **Truck traffic in neighborhoods**

Conventional Remedies: Dig and Haul Off Site (Continued)

Controversial Issues:

- **Why dig if some waste will be left in place and will continue to impact groundwater e.g., dense non-aqueous phase liquids (DNAPL)?**
- **Confirmation sample frequency, parameters, and values**
- **Removed waste may create "new" source or liability at the disposal site**
- **Loss of control *but* retained liability for waste**
- **Public acceptance is good (NIMBY), but regulatory acceptance is poor to fair**

Conventional Remedies: Dig and Haul Off Site (Concluded)

Rules of Thumb

- Don't dig when waste is below water table
- Don't dig if boundaries are not well delineated
- Expect to remove more material than planned
- This is a quick, though costly solution
- There is a long-term liability risk; keep waste on site if possible
- This remedy is most effective when:
  - Source is high-concentration, small, well-defined, shallow, with little or no groundwater impact
  - There is an imminent risk to receptors and groundwater

Conventional Remedies: RCRA Landfill Cap

Favorable Conditions:

- Recent “unweathered” waste deposits
- Wet and cool climates, high infiltration rates
- Moderate to deep water table

Advantages:

- Quick installation
- Good acceptance by regulators, fair by public
- Minimizes direct contact and leaching to groundwater

Conventional Remedies: RCRA Landfill Cap (Continued)

Unfavorable conditions:

- **Part of waste at or below seasonal water table**
- **UXO present and waste consolidation required**

Disadvantages:

- **High cost**
- **No destruction of contaminants, entombment**
- **Construction may cause air emissions or dust**
- **Long-term monitoring of cap and groundwater, leachate treatment required**
- **Institutional controls to protect cap; loss of land use**

Conventional Remedies: RCRA Landfill Cap (Continued)

Controversial Issues:

- **Community view: a cap does little because waste remains in place and is not treated**
- **Regulatory view: a cap is "standard practice" even if it results in little change in risk or in potential releases to groundwater**
- **Does a 20+ year old landfill need a RCRA cap?**
- **Does a landfill need a RCRA cap if there is a low current and future risk?**

Conventional Remedies: RCRA Landfill Cap (Concluded)

Rules of Thumb

- **Determine the actual need for a cap**
- **Don't apply a RCRA cap just because it's a standard accepted practice**
- **Consider less costly caps that provide equivalent protection**
- **A RCRA cap may be a costly solution that provides little risk reduction — *Political Science*?**
- **About 12% of closed Air Force landfills were closed as no further action — without a cap.**

Conventional Remedies: SVE

Favorable Conditions:

- **Porous soils, deep water table**
- **Volatile organic compounds (VOCs)**

Advantages:

- **Good acceptance by regulators and the public**
- **In-situ approach with a good track record**
- **Relatively short treatment times (1-30 months)**
- **Low cost**
- **Can "draw" VOCs from under structures**
- **Increases oxygen levels in soil and this may stimulate SVOC degradation**

Conventional Remedies: SVE (Continued)

Unfavorable Conditions:

- **Shallow water table**
- **Large mass of NAPL in soil or groundwater**
- **Organic-rich soils that sorb VOCs**
- **Soils with a high moisture content**
- **Clay-rich soils with limited air flow**
- **Karst or fractured bedrock**

Disadvantages:

- **Treats only VOCs**
- **Can only treat material above the water table**

Conventional Remedies: SVE (Continued)

Controversial Issues:

- **Soil remediation goals are for soil, not soil gas — soil samples vs. soil-gas measurements**
- **Defining achievable goals for an SVE system**
- **Deciding when to shut down an SVE system**
- **Pulsing an SVE system versus continuous operation**
- **VOC "rebound" after SVE shut down**
- **Establishing criteria to decide if an SVE system is operating properly and successfully**
- **Capture of VOCs from adjacent sites**

Conventional Remedies: SVE (Concluded)

Rules of Thumb

- **Establish an exit strategy or remediation goals upfront**
- **Expect to remove more mass than estimated**
- **Negotiate and convert soil remediation goals to equivalent soil-gas concentrations using suitable equations**
- **Soil-gas samples are more likely to represent a larger area than soil samples, but only for VOCs**
- **Soil samples are more likely to be subject to larger field and lab variations than soil-gas samples**

Conventional Remedies: Groundwater P & T

Favorable Conditions:

- **Shallow to moderate water table**
- **Low aquifer heterogeneity**
- **Aquifer is current source of potable water**
- **Contaminants are readily soluble, no NAPLs**
- **Source is controlled or removed**

Advantages:

- **Good acceptance by regulators and the public**
- **May be used to control or contain a source**

Conventional Remedies: Groundwater P & T (Continued)

Unfavorable Conditions:

- **Aquifer heterogeneity, silts/clays, fractured/karst**
- **NAPLs present**
- **Logistics: buildings, roads: ® horizontal wells?**
- **Pretreatment may be necessary**
- **Disposal of treated water and possibly sludges**

Disadvantages:

- **High long-term costs, prohibitive for large plumes**
- **Not appropriate for insoluble or immobile contaminants (e.g., DNAPLs)**
- **Poor track record for achieving remediation**

Conventional Remedies: Groundwater P & T (Continued)

Controversial Issues:

- **Is P & T a containment or a remediation strategy?**
- **Well head treatment versus P & T**
- **P & T shut down criteria**
- **What is the *practical* remediation goal? MCLs?**
- **Exit strategy if remediation goals cannot be achieved in a reasonable timeframe**

Conventional Remedies: Groundwater P & T (Concluded)

Rules of Thumb

- Remove or control source quickly
- P & T is *not* a remedy for NAPL
- P & T can be a control measure for NAPL
- It is a "quick solution" but has high long-term costs
- Best used in high-concentration zones
- Don't apply to low-concentration plumes
- Don't remove NAPL by dissolving it in water and pumping!

Innovative Technologies: Options to Conventional Remedies

Soil or Groundwater

- Monitored natural attenuation (MNA)
- Enhanced bioremediation
- Phytoremediation
- Innovative landfill caps

Groundwater

- Permeable reactive barriers (PRB)

Innovative Technologies: MNA

Favorable Conditions:

- **No receptors at risk**
- **Limited contaminant mass or low concentrations**
- **Plume is stabile or shrinking**
- **No NAPL, or NAPL removed/controlled**

Advantages:

- **Potentially suitable for a wide range of contaminants**
- **Suitable for most alluvial geologic conditions**
- **Low cost, no waste generated or transferred**
- **Minimal disturbance**

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Innovative Technologies: MNA (Continued)

Unfavorable Conditions:

- **Receptors at risk — short-term or long-term**
- **Expanding plume with potential impact to receptors**
- **NAPLs or plumes with high concentrations**

Disadvantages:

- **Poor acceptance — public views as "no action"**
- **Longer time to achieve remedial goal**
- **"Non-traditional" data collection and modeling**
- **May produce more toxic intermediate products (e.g., vinyl chloride) or degradation may be incomplete**
- **Institutional controls may be required for a long time**

Innovative Technologies: MNA (Continued)

Controversial Issues:

- **Community views MNA as a "do nothing" approach**
- **Application to chlorinated solvents, MTBE, etc.**
- **Remediation timeframe may be longer**
- **Property transfer may be delayed**

Innovative Technologies: MNA (Concluded)

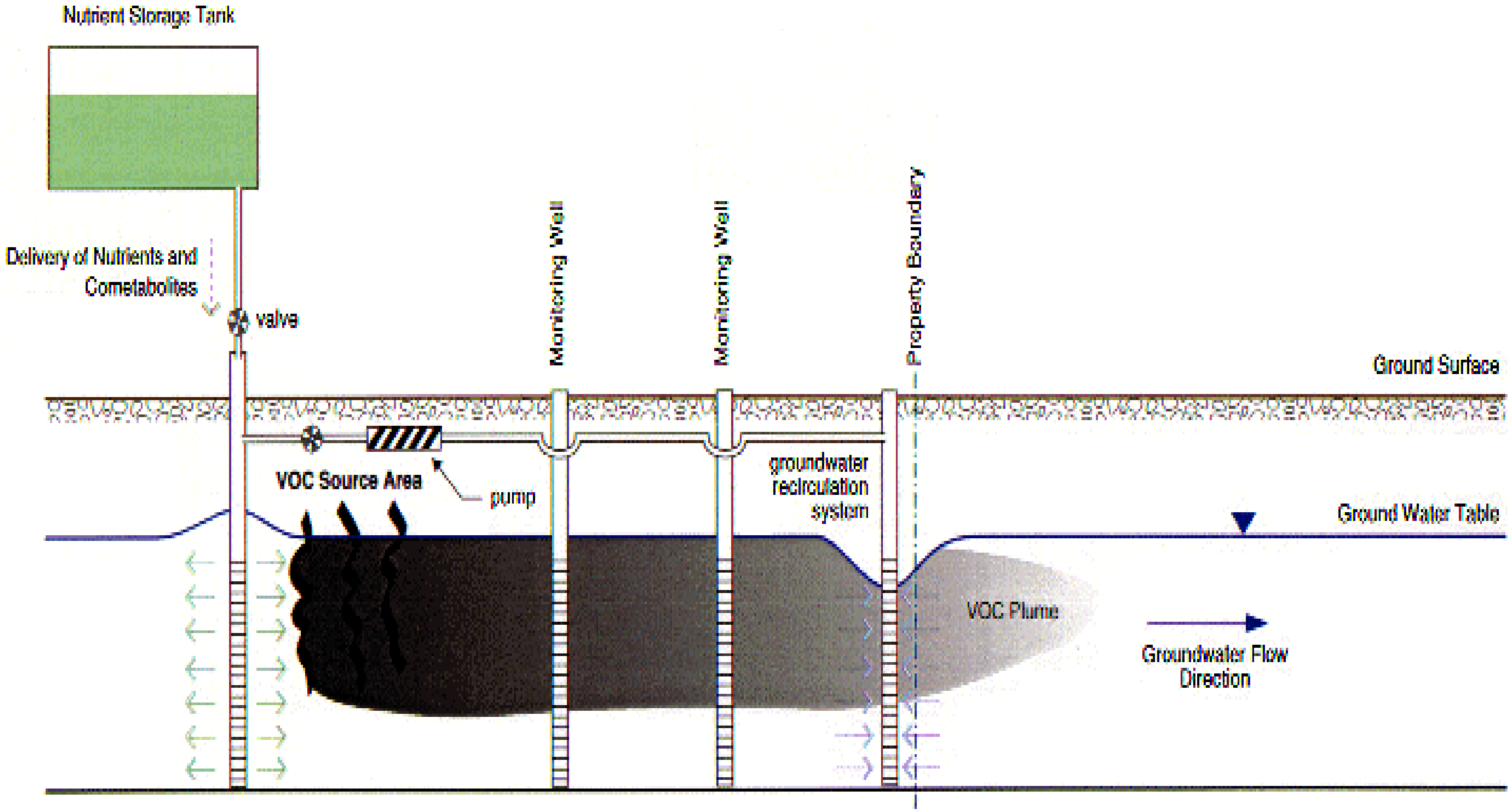
Rules of Thumb

- **MNA should be part of most remedies**
- **Generally, MNA should not be the only remedy**
- **Consider applying MNA to low-concentration plumes**

Innovative Technologies: Enhanced Bioremediation

- Moving or adding amendments to soil and/or groundwater to stimulate or control biological activity
- Substances added to enhance biological processes or directly influence metabolic rate or the type of metabolism (e.g., aerobic vs. anaerobic)
- Oxygen Release Compound (ORC) — aerobic
- Hydrogen Release Compound (HRC) — anaerobic
- Can be viewed as "accelerated" MNA
- Can be applied in-situ or ex-situ

In-Situ Bioremediation



http://www.oceta.on.ca/profiles/beak/probiorm/probiorm.html

Innovative Technologies:
Enhanced Bioremediation (Continued)

Favorable Conditions:

- **Small to moderate size sources or plumes**
- **VOC and/or SVOC organics**
- **Low to moderate contaminant concentrations**

Advantages:

- **Good acceptance by regulators and public**
- **Minimal waste generation**
- **Relatively low cost**

Innovative Technologies:
Enhanced Bioremediation (Continued)

Unfavorable Conditions:

- NAPLs or high values may be toxic to microbes
- A high degree of heterogeneity in the subsurface
- Low temperatures that may slow microbe activity
- Developed areas with limited injection locations or land area suitable for treating material ex-situ

Disadvantages:

- Can't treat recalcitrant substances (e.g., metals, PCBs)
- Possible biofouling of injection points
- Regulatory/safety issues of some materials (e.g., H_2O_2)

Innovative Technologies: Phytoremediation

Favorable Conditions:

- **Shallow depths**
  - **<10 feet to groundwater**
  - **<3 feet for soils**
- **Low to moderate concentrations, final "polishing"**
- **Shallow, slow-moving groundwater**

Advantages:

- **Low cost relative to P & T**
- **Non-invasive, passive system**
- **Potential application to many contaminants**
- **Aesthetically pleasing, a natural system**

Innovative Technologies: Phytoremediation (Concluded)

Unfavorable Conditions:

- **High concentrations may be toxic to plants**
- **Seasonal impacts — plants dormant in winter**
- **Requires land area to plant over plume or source**

Disadvantages:

- **Unfamiliar to regulators and public**
- **Still in demonstration stage**
- **Requires a suitable plant species**
- **May take a long time to establish plants (e.g., trees)**
- **Plants may need to be harvested and destroyed**
- **Requires "non-traditional" expertise**

Innovative Technologies
Innovative Landfill Caps

Evapotranspiration (ET) or Vegetative Cap

Favorable Conditions:

- **Locations where evapotranspiration exceeds precipitation**
- **Older landfills**

Advantages:

- **Low cost compared to RCRA Subtitle C cap**
- **Low maintenance cost, less prone to failure**
- **Natural self-renewing system**

Innovative Technologies
Innovative Landfill Caps (Concluded)

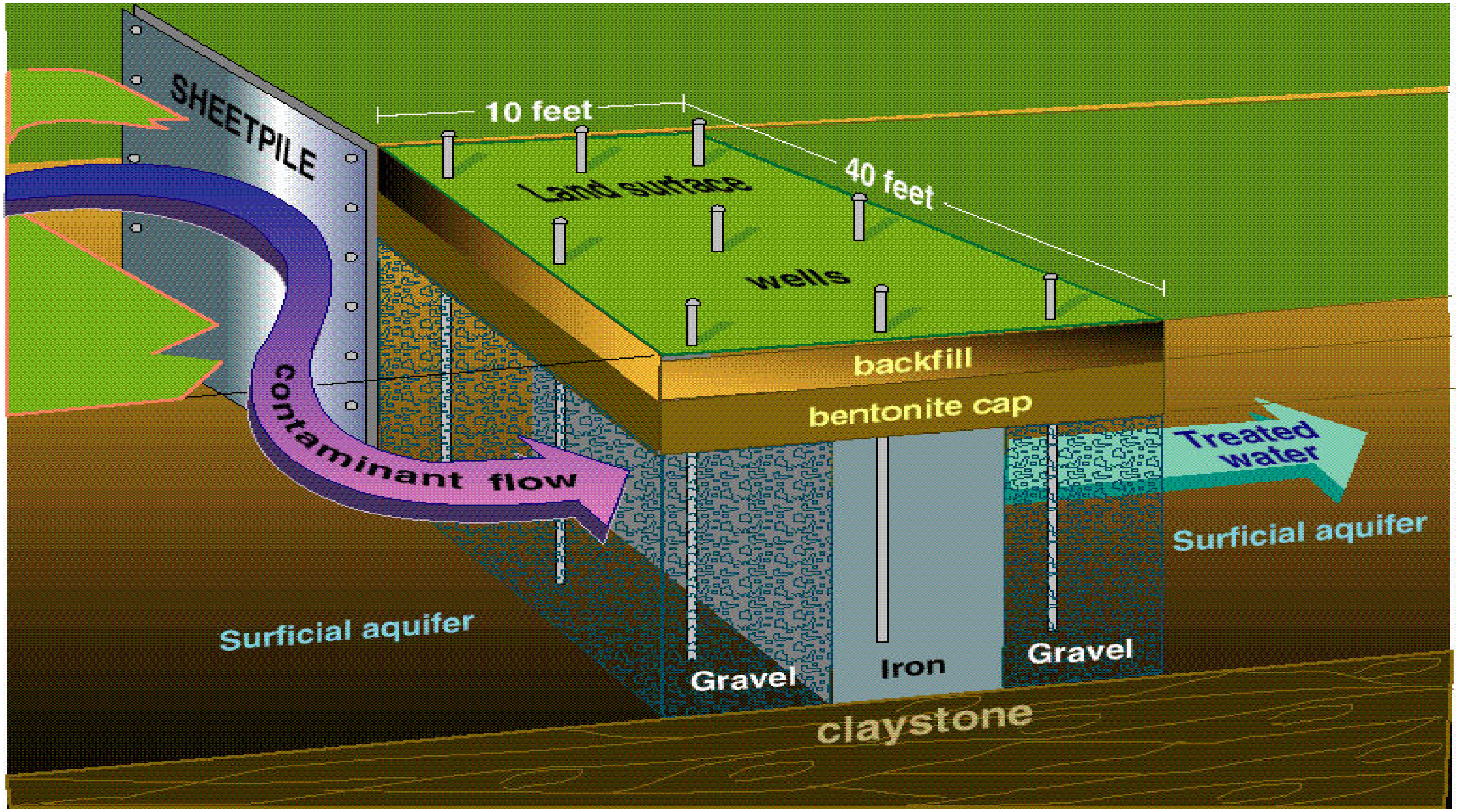
Unfavorable Conditions:

- **Geographic limitations, not appropriate for areas with high infiltration and low evaporation**
- **Requires a nearby source of high water-holding capacity soil for the cap**

Disadvantages:

- **Poor regulatory acceptance—this is changing**
- **No standards, must be customized**
- **Requires "new" expertise, such as agricultural engineers, soil and plant scientists, etc.**

Innovative Technologies: Permeable Reactive Barriers



http://www.oceta.on.ca/profiles/beak/probiorm/probiorm.html

Innovative Technologies:
PRBs (Continued)

Favorable Conditions:

- **Shallow groundwater depths**
- **Must have aquitard at base of shallow aquifer**
- **Area free of buildings and utilities for trenching**

Advantages:

- **Wide range of contaminants and concentrations**
- **Good initial acceptance**
- **Passive, limited invasive technology**
- **Installation costs are similar to full scale P & T, but are dropping**
- **No operating costs, but monitoring costs remain**

Innovative Technologies:
PRBs (Continued)

Unfavorable Conditions:

- **Deep groundwater contamination**
- **No aquitard at base of contaminated aquifer**
- **Buildings and utilities in installation area**
- **Locations with very slow natural groundwater flow or highly variable flow directions**

Disadvantages:

- **Relatively high initial cost**
- **The long-term effectiveness of PRBs is unknown**

Innovative Technologies:
PRBs (Concluded)

Controversial Issues:

- **Long-term effectiveness of PRBs**
  - **PRBs may "plug" with precipitates over time**
  - **Reactive capacity may decrease over time**
  - **PRBs may alter groundwater chemistry and add or release other substances to groundwater as a result of changes in groundwater pH and redox**

Efficient Use of Technology: Summary

- Keep a well-developed conceptual site model
- Determine the purpose of the selected technology, is it for containment or remediation
- Define clear remediation goals and exit strategy
- Be proactive NOT reactive; maintain leadership
- Don't ask: "What do you want us to do?"
- One size does not fit all; use multiple remedy combinations —
  - Source area
  - High-concentration plume
  - Low-concentration plume

Efficient Use of Technology: Summary (Concluded)

- **Remedy Selection Criteria**
  - **Appropriateness**
  - **Time and cost**
  - **Community and regulatory acceptance**
  - **Long-term effectiveness**
  - ***Political Science?***
- **Collect data to demonstrate successful operation, track progress, and optimize your remedial systems**

Remedial Technology Selected References

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Remedial Technologies ® http://www.epareachit.org

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