WHY DO SOME PASSIVE TREATMENT SYSTEMS FAIL WHILE OTHERS WORK?

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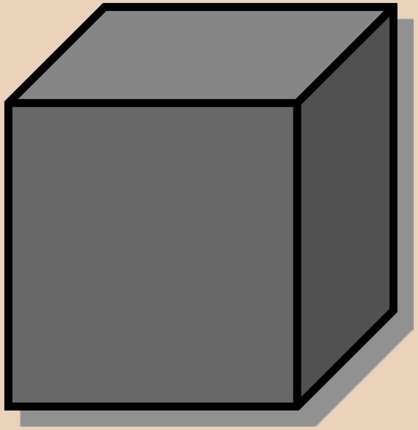
What is Passive Treatment?

Passive treatment ≠ 

If It's Not a BLACK BOX, What Is Passive Treatment?

- It's the:
  - **S**equential
  - **E**cological
  - e**X**traction

of metals in a man-made but naturalistic bio-system

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Passive System Requirements

- Utilize common geochemical reactions typically assisted by microbes or plants,
- No chemical reagents & power needed,
- No short term exchange of process media, and
- Must function without human intervention for long periods (decades).

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Passive Treatment
Metal Removal Mechanisms

- Sulfide and carbonate preciptn' via SRB
- Hydroxide and oxide preciptn' by *Thio-bacillus Ferro-oxidans* & other critters
- Filtering of suspended matl' and precips'

Major

- Metal uptake into live roots, stems and leaves
- Adsorption and exchange with plant, soil and other biological material

Minor

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Typical Wetland Ecosystem

Geochemical reactions are in competition in natural systems

Constructed systems emphasize one reaction zone per cell

Passive Treatment System Components

Biological Components

- Aerobic Cells or Rock Filters
- Anaerobic Cells
- Successive Alkalinity Producing Systems (SAPS)

Limestone Components

- Limestone Sand
- Anoxic Limestone Drains (ALD's)
- Alkaline Ponds
- Open Limestone Channels

Settling Ponds & Flow Equalization Ponds

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Design Parameters

NO COOKBOOK (YET)

- ARD Geochemistry (cell sequencing & cell type)
- Metal Loading = (concentration X flow rate)
- Surface Area is a function of loading
- Cell Depth is a function of loading

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So, Why Do Some Passive Systems Fail?

- No Design "Just build a swamp here, fill that pond over there with manure and call it good." (rarely encountered)

- Poor Design - undersized for load, applying wrong geochemical approach, phased design lacking, complex geochemistry, startup and operational procedures.

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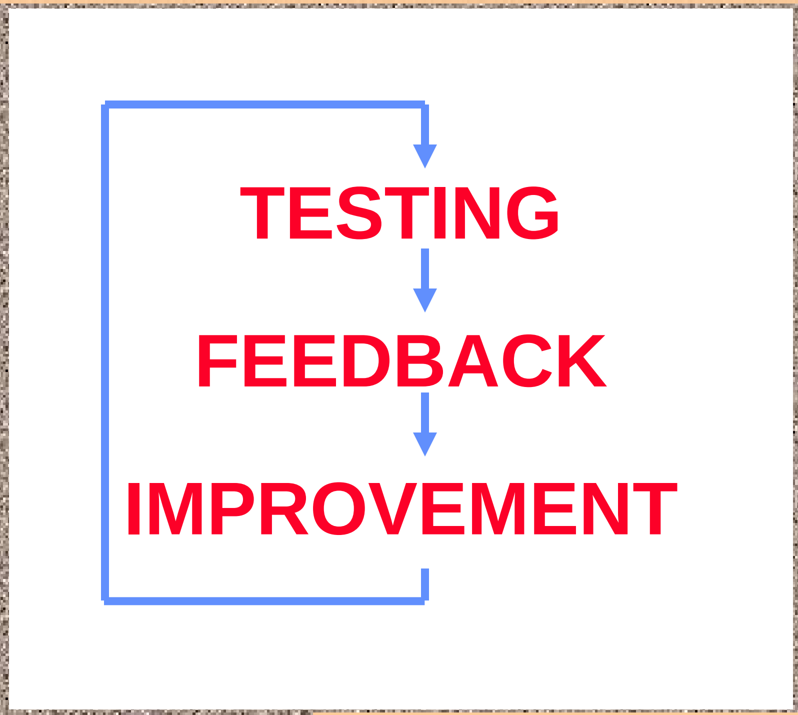
GOOD ENGINEERING PRODUCES GOOD RESULTS

EACH SITE & SITUATION IS DIFFERENT PHYSICALLY & CHEMICALLY



KNOWLEDGEABLE

MAINTENANCE IS A MUST

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Passive Treatment Recommended Design Phases

- Lab (Proof of Principle) tests
- Bench tests
- Pilot tests
- Full scale implementation

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Passive Treatment
Lab - Proof of Principle Tests

Buckeye Landfill,
OH
POP Test Bottles

Brewer Gold Mine, SC
POP Test Bottles

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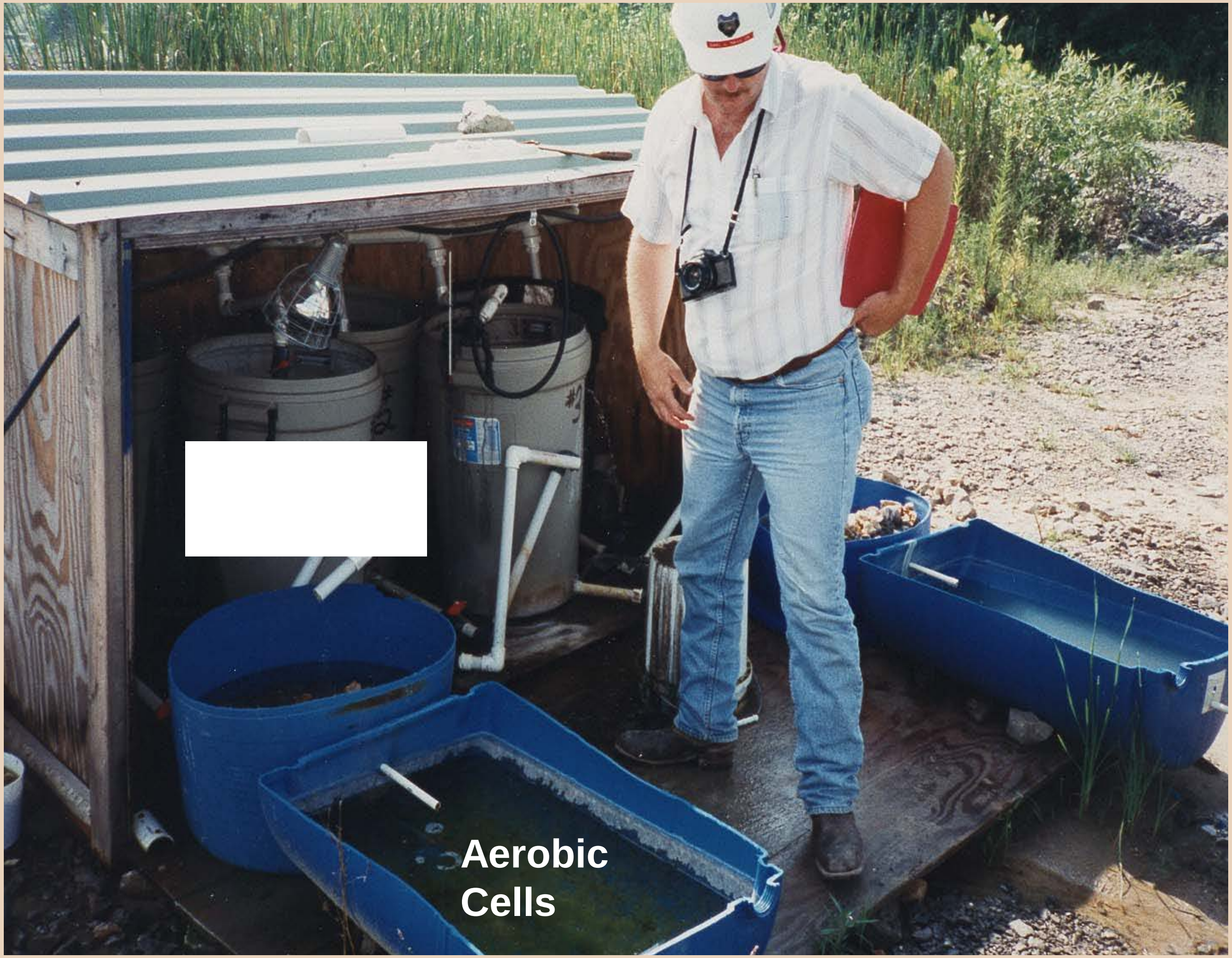
Bench Scale Tests



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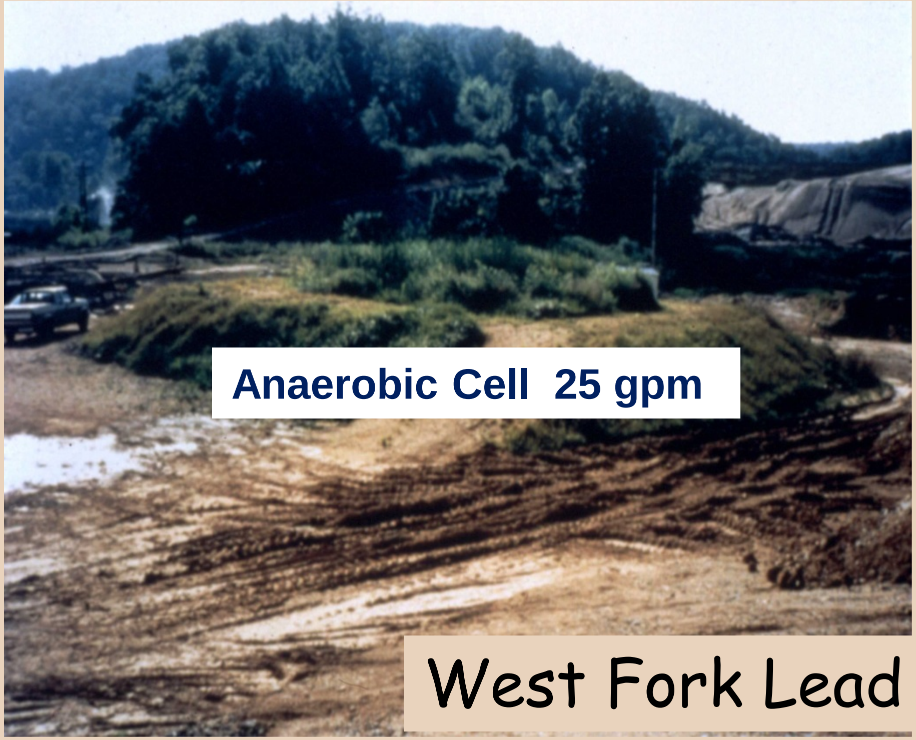
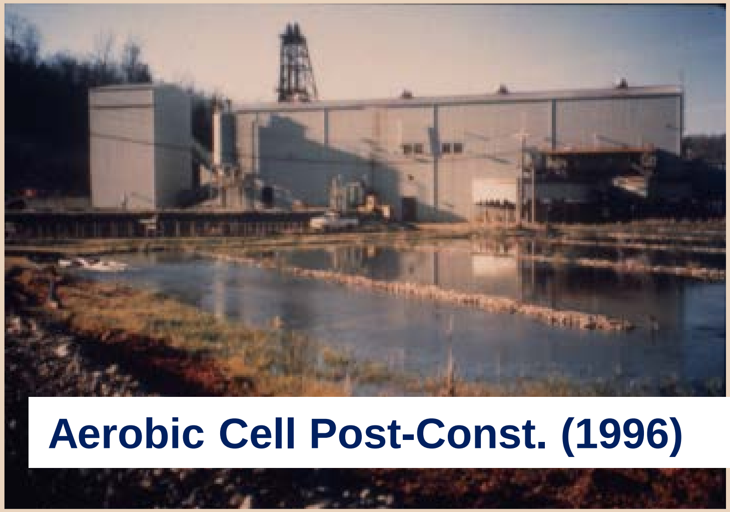
Pilot Scale Tests



West Fork Lead Mine, Missouri

Full Scale System - 1,200 GPM

West Fork Lead Mine, Missouri
Constructed in 1996 for Asarco



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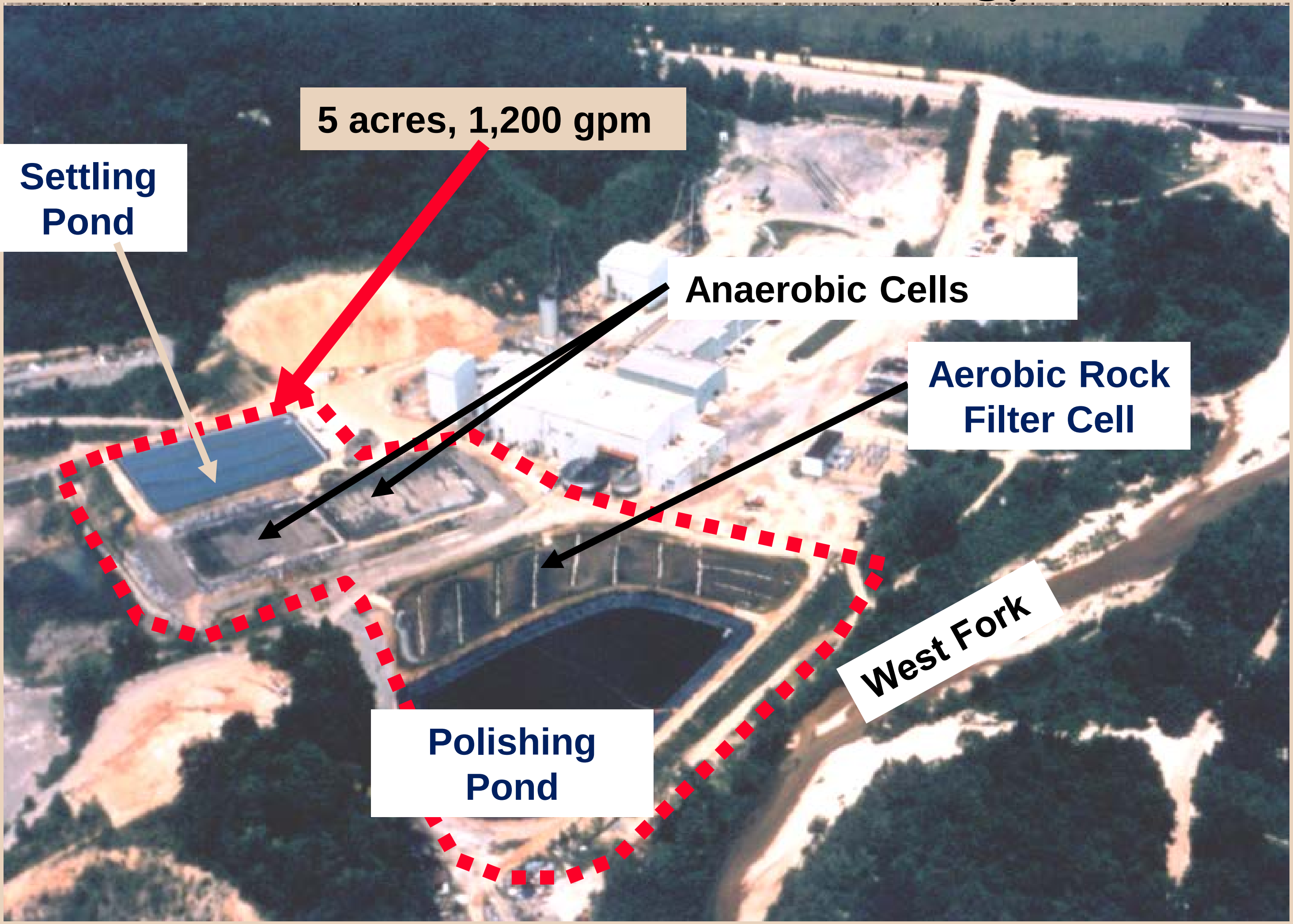
Full Scale Passive Treatment of Dissolved Lead at 1,200 gpm



50 m³/hr Treatment of Ni and Mn in Minas Gerais, Brazil

More Reasons That Some Passive Systems Fail

- Not enough maintenance (low maintenance does not mean "NO" maintenance).
- Last minute changes to construction specs can affect system performance - experience helps.

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Three Case Histories
What Lessons Were Learned?

- Burleigh Tunnel, Colorado
- Wheal Jane Mine, Cornwall, UK
- West Fork Mine, Missouri

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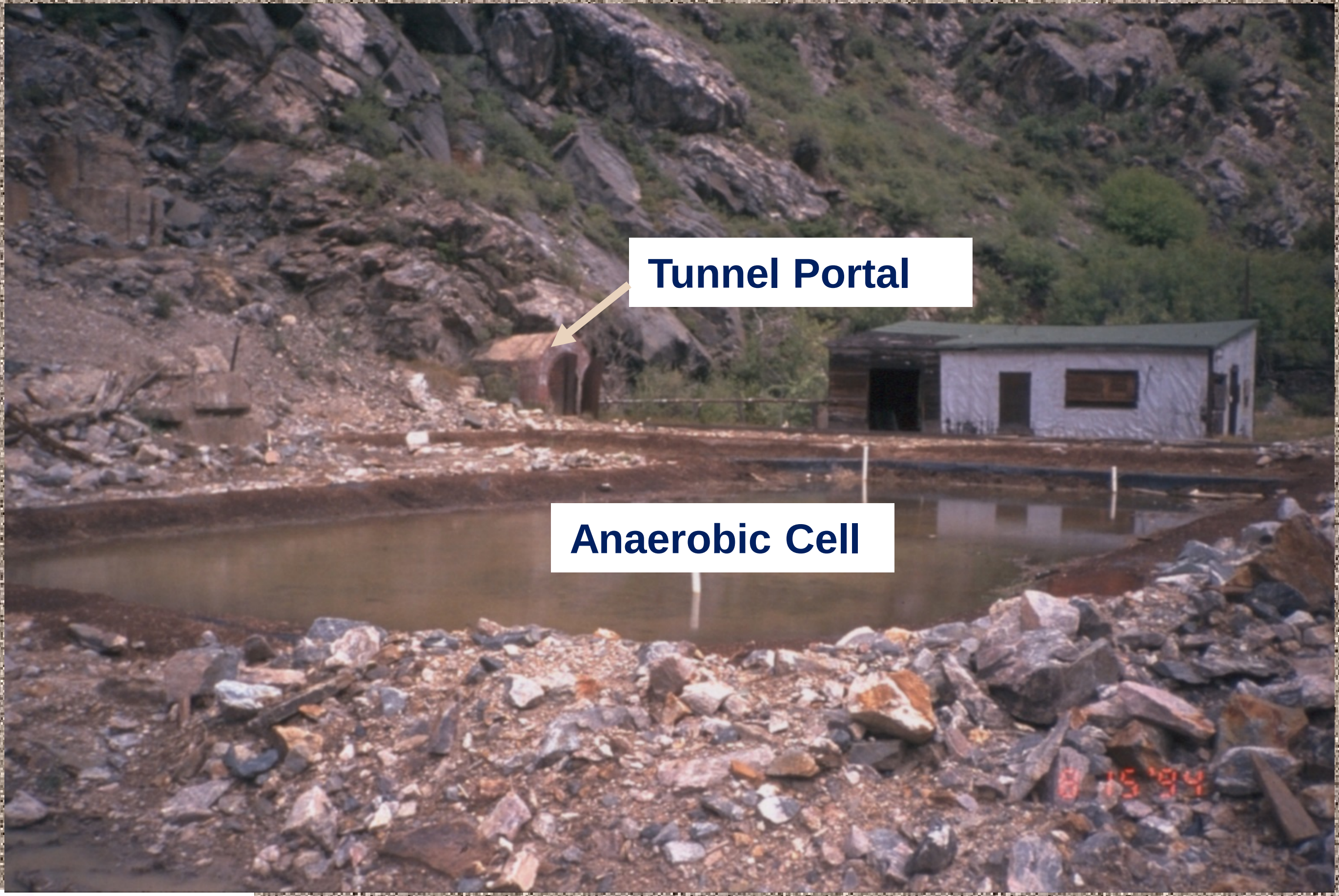
Burleigh Tunnel, Colorado (1994)



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Burleigh Tunnel, Colorado (1994)

Designed For/Actually Happened

- **7 gpm** of neutral mine water, 45 to 65 mg/L zinc
- Received up to **20 gpm** of acidic? mine water for two weeks (pH ?; zinc @100 mg/L) and normal flow w/Zn @ 100 mg/L for 4 months in 1995
- Pilot cell system - active flow management
- Failure to reduce flow and re-incubate SRB after extraordinary loading event, 4 months of overloading

Plugging/deterioration of organic substrate caused flow restriction - substrate was designed on geochemical basis, not hydrologic basis due to inexperience

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Burleigh Tunnel, Colorado (1994)

Some Other Observations

Composting destroys substrate physical structure; manure is ok for inoculum but does not provide a good long term carbon source - there are better materials available and they're typically cheaper!

Toxicity of zinc on SRB has not been demonstrated; excessive area loading rates are partially responsible for SRB mortality

Substrate alkalinity enhancement with limestone could have provided protection from overloading

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Wheal Jane Mine, Cornwall, UK (1995)

Wheal Jane Mine - Lime Free Pilot Cell, Cornwall England (1995)

- 7 gpm of acidic mine water; pH 3.2, Fe 250 mg/L, As 1 mg/L, Zn 250 mg/L, Mn 20 mg/L
- Proof of Principle test results were favorable
- Political pressure to "do something" necessitated **skipping bench scale study** - many design assumptions required, several were wrong...
  - SRB could be sole source of alkalinity (no limestone added to anaerobic cell substrate)
  - Rainfall events (dilution) would not affect metals loading on anaerobic cells
  - Manure used in P.O.P. tests not available in bulk… "diluted" manure "slurry" used in pilot

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Wheal Jane Lessons Learned

- Make sure materials used in P.O.P tests are available in large quantities
- Avoid skipping bench test phase
- Anaerobic substrate needs "insurance" alkalinity source to protect SRB from water quality excursions

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West Fork Unit, Missouri

West Fork Unit

Designed For/Actually Happened

- Pilot cell operation was based on a monolithic substrate layer 6 feet thick.
- The full scale design required intermediate layer flow controls to enable “throttling” of the system during the summer when SRB activity was high; layers of geotextile and pipes were added in the design but were not modeled in the pilot.
- Substrate recipe called for hay/alfalfa
- Last minute field substitution of moldy alfalfa pellets adversely changed the saturated hydraulic conductivity of the substrate mix.

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West Fork Unit

Some Other Observations

Doe Run Company excavated both anaerobic cells and removed geotextile; apparent hydraulic conductivity improved, but not as much as pilot cell performance (likely due to alfalfa pellets).

Doe Run excavated both anaerobic cells again to add limestone rock which improved hydraulic conductivity to design estimates.

Lesson learned: test **ALL** design features on a pilot scale.

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Summary

- Passive treatment systems can handle a wide variety of flows, water, chemistry and site conditions (low to high: pH, metal concentration, flow and temperature) provided:
- The systems are properly sized, designed, constructed and protected from overloading conditions

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In Water Treatment, if you're not a part of the **Solution**, you're part of the **Precipitate**.

Thank You

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