Welcome to the CLU-IN Internet Seminar

Mining-Influenced Water: Treatment Technologies

Sponsored by: EPA Technology Innovation and Field Services Division (TIFSD)

Delivered: **February 6, 2013, 12:00-2:00PM EST**

Instructors:

J. Brady Gutta (West Virginia Water Research Institute)

Jim Gusek (Golder Associates)

Kevin Mayer (EPA Region 9)

Moderator: **Michele Mahoney (EPA TIFSD)**

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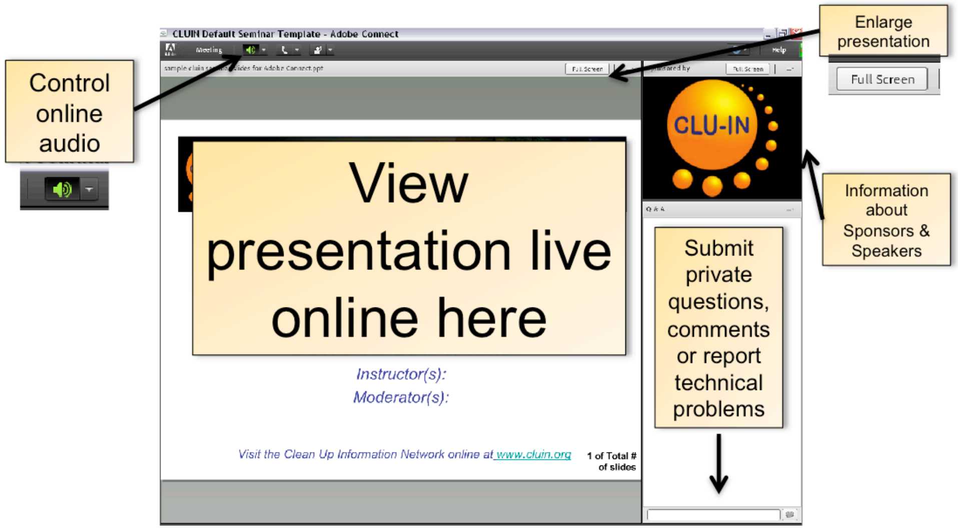
Although I'm sure that some of you have these rules memorized from previous CLU-IN events, let's run through them quickly for our new participants.

You should note that throughout the seminar, we will ask for your questions and feedback. You do not need to wait for Q&A breaks to ask questions or provide comments. To submit comments/questions and report technical problems, please use the Q&A pod in the bottom right of your AC room.

The presenters will be moving their slides during their presentation. The presentations are available for download at the main seminar page. The main seminar page also displays our agenda, speaker information, links to the slides and additional resources.

New online broadcast screenshot



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Overview

- Today's webinar: Mining-Influenced Water Treatment Technologies
  - MIW Treatment Technology Study – Michele Mahoney
  - Overview of Acid Mine Drainage Chemistry & Passive Treatment at the Lambert Run Watershed – Brady Gutta
  - Passive Treatment 101: Overview of the Technologies – Jim Gusek
  - Mining-Influenced Water Treatment at the Leviathan Mine Superfund Site, California – Kevin Mayer

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Today's seminar is the third in the webinar series launched by Technology Innovation and Field Services Division in June 2012 as part of its CLU-IN Mining Sites Focus Area. The webinars are intended to serve as a source of relevant and current information on the environmental issues associated with active, closed, and abandoned mining sites, as well as the technologies available for treatment.

Our webinar today will focus on the treatment of mining-influenced water. This is the second webinar of the series on this topic. The previous webinar, held on September 19, 2012, included presentations on PCBs at mining sites, a tool available to help estimate cost of abatement for water pollution caused by acid mine drainage, and a case study on acid rock drainage remediation at the Berkeley Pitlake site in Montana. This webinar is available through our CLU-IN archives at http://cluin.org/live/archive. Today's webinar will provide an overview of passive treatment technologies and will feature several case studies in both eastern and western United States. We will begin with a brief presentation by me [Michele Mahoney] on what EPA is doing to identify and evaluate mining-influenced water treatment technologies being employed at both active and abandoned mining sites. Brady Gutta will then give general overview of acid mine drainage and discuss the implementation of five passive treatment installations at the Lambert Run Watershed in West Virginia. His presentation will be followed by Jim Gusek, who will compare the advantages and disadvantages of various passive treatment components and provide an introduction to the wide range of remediation design options available to practitioners of passive treatment. Finally, Kevin Mayer will wrap up our webinar today with a presentation on the three different treatment systems currently operating at the Leviathan Mine Superfund Site on the eastern slope of the Sierra Nevada mountain range in California.

With that, let's move to the next slide and begin our webinar.

Mine Influenced Water Treatment Technology Study

Michele Mahoney
EPA Office of Superfund Remediation & Technology Innovation
mahoney.michele@epa.gov

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EPA

Goals

- Identify and evaluate MIW treatment technologies
- Develop written materials to support selection of appropriate and cost-effective treatment technologies
- Further inform decision makers about the diverse technologies available for MIW

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Key Information

- Types of technologies
- Contaminants treated
- System operations
- Engineering constraints
- Initial and long-term costs
- Treatment effectiveness
- Example sites
- Additional research needs

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Snapshot of Summary Table

Technology	Technology Description	Treated Constituents	Scale	Example Sites	Operations	Long-term Maintenance	Engineering Constraints	Costs	Effectiveness
Anoxic Limestone Drains (ALD)[5,33,21]	A limestone drain is a simple treatment method which involves the burial of limestone in air-tight trenches that intercept acidic discharge water. Keeping carbon dioxide within the drain can enhance limestone dissolution and alkalinity production. Furthermore, keeping oxygen out of contact with the discharge water minimizes the potential for oxidation of dissolved iron and the consequent precipitation of solid iron hydroxide [Fe(OH)3], which could armor the limestone and clog the drains.	Al, Fe, acidity	Full-scale	Fabius Coal Preparation Plant, AL Copper Basin Mining Site, TN Hartshorne/Whidock-Jones: Hartshorne, OK Ohio Abandoned Bituminous Coal, SE OH Tecumseh - AML Site 262, IN Tennessee Valley Authority, AL Valzinco Mine, VA	The construction of an ALD consists of a trench containing limestone (typically 90% calcium carbonate equivalent minimum) encapsulated in a plastic liner and covered with clay or compacted soil to maintain anoxic conditions, as well as to prevent water infiltration and to keep CO2 from escaping. The width and length of the trench are based on the levels of dissolved metals present in the mine drainage, the retention time needed to raise the pH, as well as the amount of area that is available for construction. The ALD may be capped with topsoil and vegetation to control erosion. The dimensions of the drain depend upon individual on-site conditions, including topography, geology, and available area and, equipment. However, the two factors that must be considered when sizing an anoxic limestone drain are the accommodation of the maximum probable flow and the desired longevity of the drain.	Routine maintenance is typically limited to inspection of the surface for evidence of leakage in the anoxic cover material, and periodic cleaning of the discharge point to remove accumulated iron oxides. The systems are generally designed for limestone replenishment every 15–25 years, depending on the characteristic of the drainage flow. Maintenance costs for ALD's are not expected to be significant. Apart from monitoring costs which might be required to ensure the effectiveness of downstream systems, costs should be limited to periodic inspection of the site and maintenance of the vegetation cover.	ALDs are suitable to treat MIW that has low concentrations of ferric iron, dissolved oxygen and aluminum. When any of these three parameters are elevated, armoring of limestone can occur and slow the dissolution rate of limestone. When the dissolution rate slows, these is a higher buildup of ferric iron and aluminum on the limestone, which eventually clogs the open pore spaces, resulting in abnormal flow paths that can reduce both the retention time of MIW within the ALD and the reactive surface area of the limestone. With only a few exceptions, passive systems cannot handle Acidity Loads in excess of 100-150 kg of CaCO3 per day. Metal removal must occur elsewhere to prevent clogging of the bed and system failure. ALD's must be kept anoxic to prevent the oxidization of soluble ferrous iron to the insoluble ferric species. Field tests show that relatively high rates of limestone dissolution occur within the initial 15 hours of contact with mine water. After that period, the rate of dissolution is much slower. For this season, ALD's are sized to have a 15-hr retention time at the end of its design life (25-30yrs). Although ALDs are documented to have success in raising pH, the differing chemical characteristics of the influent mine water can cause variations in alkalinity generation and retention of metals. Most ALD systems exhibit reduced effectiveness over time and eventually require maintenance or replacement. To meet effluent compliance limits, (Tennessee Valley Authority) TVA advocates the use of ALDs only as a staged portion of aerobic acid drainage wetlands systems, and does not recommend their use as stand-alone systems, or as a stage of an anaerobic wetlands system.	Passive treatment systems can provide low cost solutions unless they are used for inappropriate applications, which have resulted in many being far more costly (per ton of acid neutralized) than conventional active treatment plants The cost of installing ALDs can vary from site to site, depending largely on location and chemical makeup of the MIW. Operators of the Tennessee Valley Authority abandoned mine site in Alabama reported that their capital cost was approximately $0.25/1000 gal of water and their operation and maintenance costs were approximately $0.10/1000 gal of treated water. Passive treatment systems provide low cost solutions with low to medium capital costs (AU$5,000 -200,000) and generally very low operating costs (<AU$1,000 / year). A 'typical' ALD constructed at most locations in Canada is expected to cost in the range of $4,000 to $25,000 depending on chosen dimensions and design flow. This estimation would not apply to more remote sites, or sites where establishment of an ALD would require extensive excavation or blasting.	Alkalinity concentrations in the effluent ranged 80–320 mg/L as CaCO3 with near maximum levels being reached after approximately 15 hours of detention in the ALD. Where influent mine water contained less than 1 mg/L of both ferric iron and aluminum, the ALDs produced consistent concentrations of alkalinity for over 10 years. An ALD receiving influent mine water containing 21 mg/L of aluminum experienced rapid failure due to permeability reduction within 8 months. Although long term data is not available, the research conducted to date suggests that ALD's can be expected to be effective for 20 to 80 years (Brodie et al. 1992) and perhaps even longer (>100 years), if influent quality is within the required criteria and the system is properly designed and constructed.

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Anticipated Outcomes

- Supplement and complement existing materials
- Identify promising technologies and best practices
- Share information
- Implement pilot projects

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Watershed Restoration Through the Implementation of Passive Treatment Technology in the Lambert Run Watershed, Harrison County, West Virginia

J. Brady Gutta
West Virginia Water Research Institute

WestVirginiaUniversity   West Virginia Water Research Institute

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So what is AMD?
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Acid mine drainage (AMD) occurs when sulfide minerals in rocks are exposed to oxidizing conditions
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The 4 AMD Equations

- $FeS_2 + 7/2\ O_2 + H_20 = Fe^{+2} + 2SO_4^{-2} + 2H^+$
- $Fe^{+2} + ¼O_2 + H^+ = Fe^{+3} + ½H_2O$
- $Fe^{+3} + 3H_2O = Fe(OH)_3 + 3H^+$
- $FeS_2 + 14Fe^{+3} + 8H_2O = 15Fe^{+2} + 2SO_4^{-2} + 16H^+$


So how do we treat AMD?
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Treatment of AMD consists of:
In-Situ Treatment
Active Treatment
Passive Treatment
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In-Situ Treatment

- Is used to treat AMD in the mine before it daylights.
- Consists of injecting alkaline material into mines.
- Alkaline material can consist of limestone, fly ash, sodium hydroxide, etc…
- Also used in areas where subsidence is common.

Active Treatment

- Occurs on sites that have been permitted after 1977 and abandoned (WVDEP Special Rec)
- Also on active mine sites
- Active treatment requires operations and maintenance funds (for chemical costs and sludge management)

Passive Treatment

- Is a one time system designed to treat a discharge for a certain amount of years (usually 20)
- Theoretically does not require any additional operations and maintenance after installation
- Uses alkaline material to raise pH, and precipitate metals.

Lambert Run entering West Fork at Rt. 19, Spelter bridge

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Lambert Run - Background

- 8 sq. mile subwatershed of the West Fork River
- Harrison County, WV
- Nearby communities:
  - Hepzibah, Meadowbrook, Spelter
  - 4 miles from Clarksburg city limits
- Low population density
- Land uses:
  - Hayfields, pasture, woodlots, low density residential, natural gas development

Project Partners

- Guardians of the West Fork (GOWF)
  - Local stakeholder group, assisted with project implementation
- West Virginia Water Research Institute (WVWRI)
  - Conceptual design, project management
- West Virginia Department of Environmental Protection (WVDEP)
  - Funding partner, assisted with project management
- Office of Surface Mining and Reclamation (OSMRE)
  - Funding partner

Early Collaboration

- GOWF and the WVDEP established a monitoring program through the 319 program in 2003.
- The first project funds were applied for in 2004
- The funding partners consisted of EPA Section 319 and OSM Cooperative Agreement Funds.
- Landowner agreements were key to project implementations
- All 5 of the projects installed in this watershed were implemented using these funding programs

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Lambert Run Mining History

- Pittsburgh seam
- Mining consisted mostly of deep mining as well as some surface
- Water chemistries vary from acidic mine drainage to alkaline mine drainage
- First successfully submitted watershed based plan to EPA

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LR-6, Twin portals

LR-4, Moore seep

Mainstem Lambert Run

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Lambert Run Treatment

- In 2004, a partnership between the WVDEP – DWWM, OSM, WVU – NMLRC, and the Guardians Group started working towards restoration of multiple sites by installing passive treatment systems

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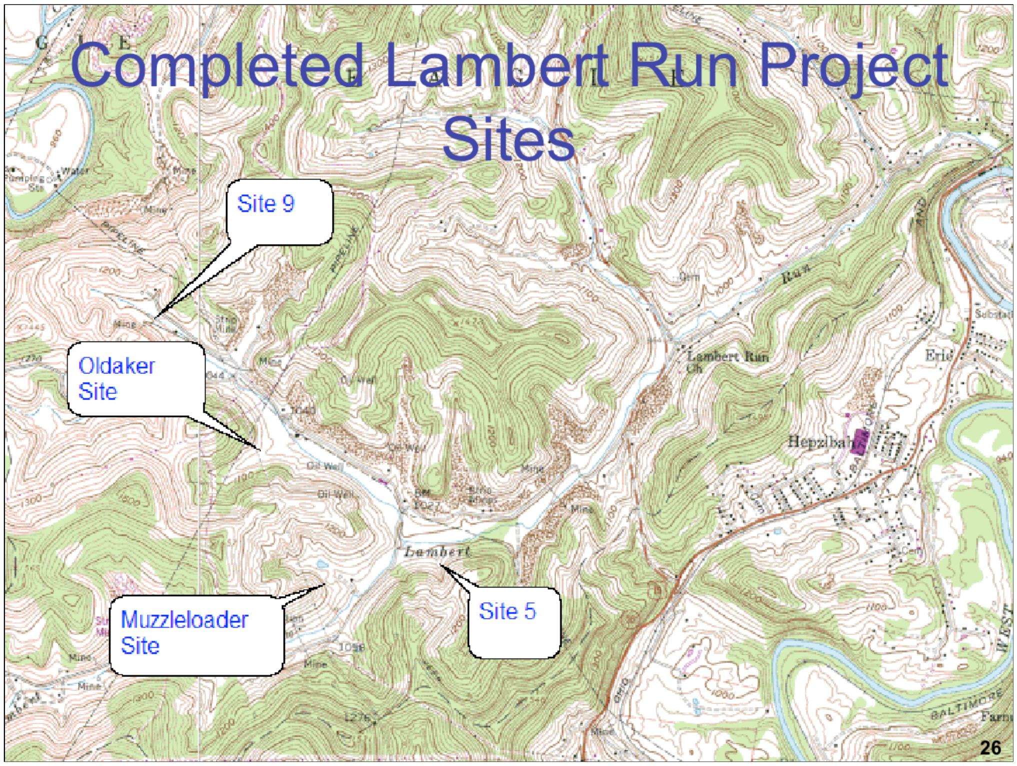
Completed Lambert Run Project Sites




Muzzleloader Club Project Site
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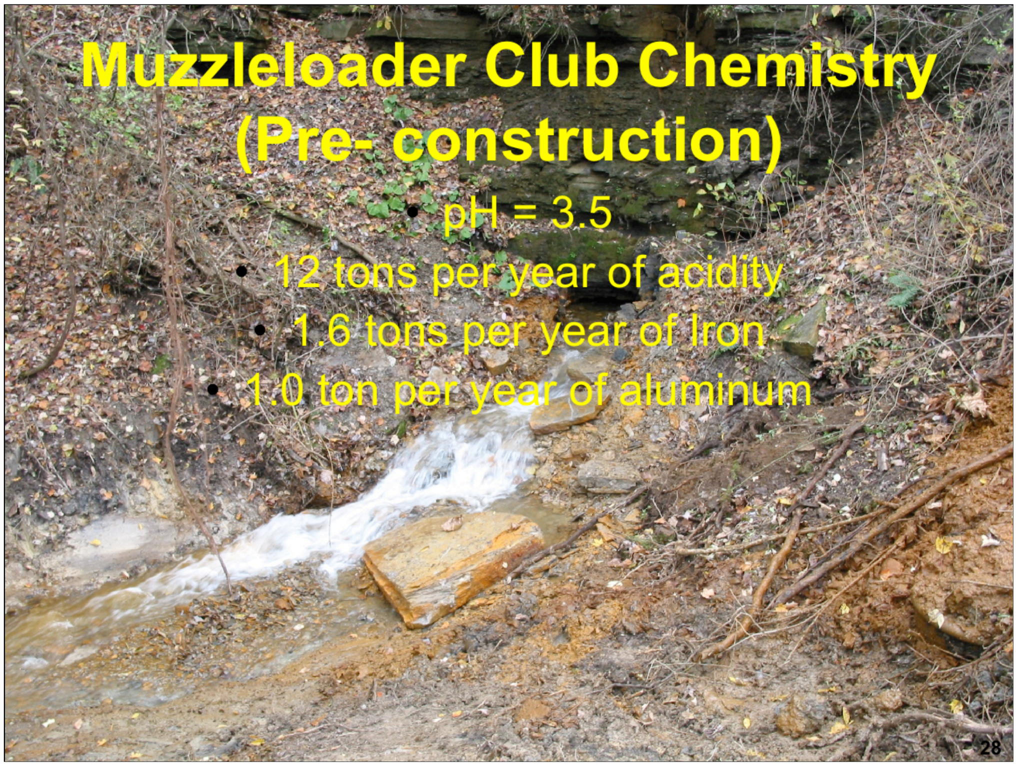
Muzzleloader Club Chemistry (Pre- construction)
• pH = 3.5
• 12 tons per year of acidity
• 1.6 tons per year of Iron
• 1.0 ton per year of aluminum
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Muzzleloader System Design

- Wet Sealed Portal
- Open Limestone Channels
- Steel Slag Leach Bed
- Two Treatment Wetlands

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Muzzleloader Steel Slag Bed
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Post-Construction Results
• pH = 8
• Acid Load = - 5 tons/year acidity
• Iron Load = 0.05 tons/year
• Aluminum Load = 0.14 tons/year
• There are fish living in the bottom wetland as well as downstream of the project site.
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Oldaker Project
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Oldaker Chemistry
(Pre-Construction)
• pH = 6.1
• -0.8 Tons per year acidity
• 17 tons per year of Iron
• 1.0 ton per year of aluminum
33


Oldaker System Design
• Since water is alkaline, no neutralization required, only oxidation
• redirected drainage from one portal north of the site to the southern portal
• Enhanced one wetland while creating a second wetland
• Implemented Agricultural BMP's as part of mitigation required by USACOE
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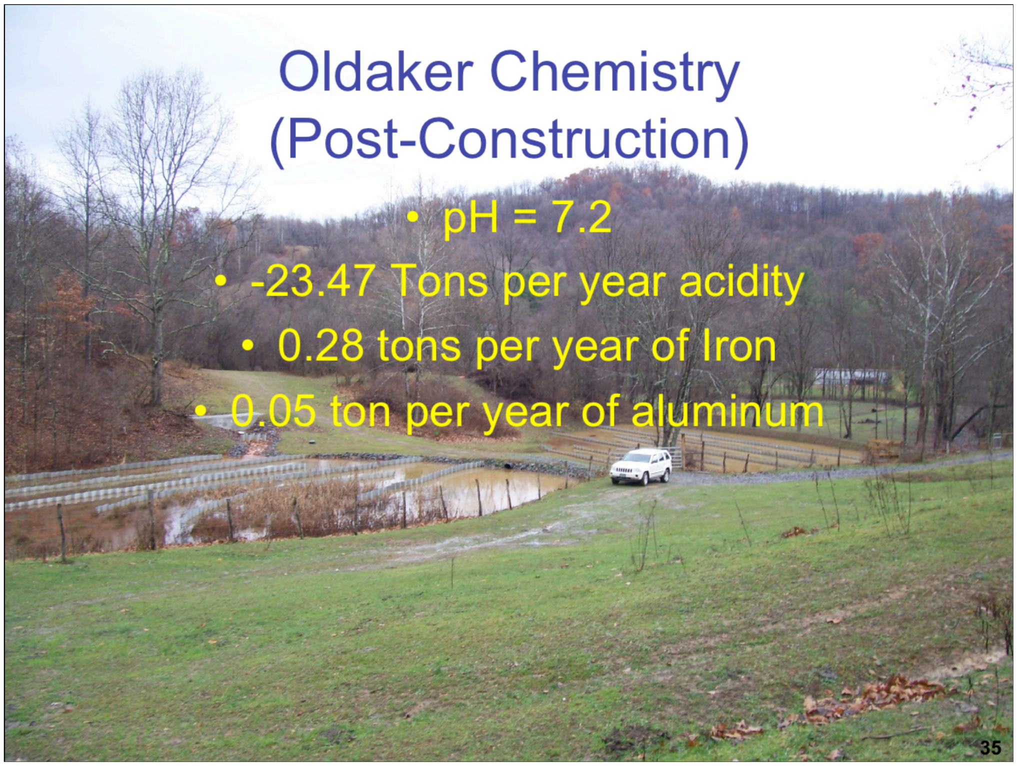
Oldaker Chemistry
(Post-Construction)
• pH = 7.2
• -23.47 Tons per year acidity
• 0.28 tons per year of Iron
• 0.05 ton per year of aluminum
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Site 5 – Allen Meadows Project
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Allen Meadows chemistry
(Pre-Construction)
• pH = 6.4
• Acid load: 26.4 tons/year
• Fe load: 5.6 tons/year
• Al load: 0.76 tons/year
2006 2 16
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Site 5 System Design
• Open Limestone Channel designed to enhance air/water interactions
• Settling Ponds
• 2 Wetlands
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Site 5 (Post-Construction)
• pH = 7.3
• - 111 Tons per year acidity
• .73 tons per year of Iron
• 0.03 tons per year of aluminum
39


Site 9 Cox/Kyle Project
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Site 9 Chemistry
(Pre-Construction)
• pH = 4.8
• 123 tons per year acidity
• 34 tons per year of iron
• 9 tons per year of aluminum
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Site 9 – System Design
• System consists of a primary settling pond (due to fluctuating pH's)
• One large Vertical Flow Reactor
• Series of downstream wetlands
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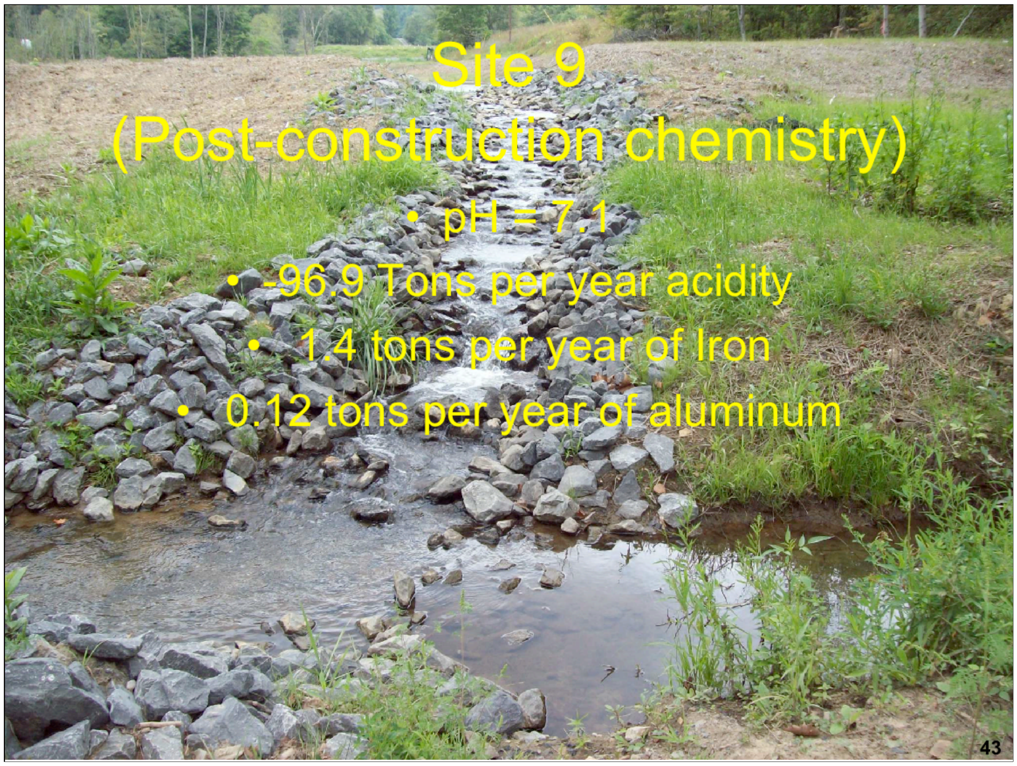
Site 9
(Post-construction chemistry)
• pH = 7.1
• -96.9 Tons per year acidity
• 1.4 tons per year of Iron
• 0.12 tons per year of aluminum
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Site 6 – Guinn Property
Pre-Construction
• pH = 6.7
• Acidity = 17.2 tons/year
• Iron = 6.4 tons/year
• Aluminum = .35 tons/year
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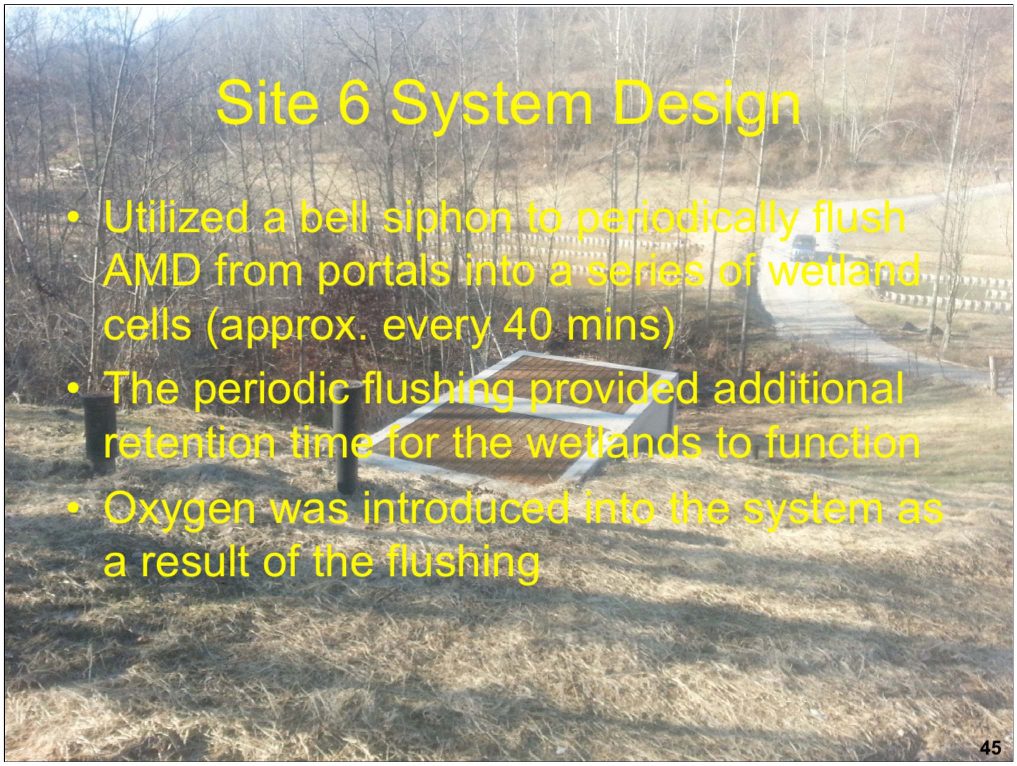
Site 6 System Design
• Utilized a bell siphon to periodically flush AMD from portals into a series of wetland cells (approx. every 40 mins)
• The periodic flushing provided additional retention time for the wetlands to function
• Oxygen was introduced into the system as a result of the flushing
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Site 6 – Post Construction
• Awaiting initial sampling results
• Visual inspection of project outfall shows no iron and or/aluminum staining
• Field pH of 7.4
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Results

Biological Lift

- April 2008, WVSCI = 26.2 (Extremely poor)
- September 2009, WVSCI = 57.8 (Moderate)
- Anticipated spring 2013 sampling to happen in March


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Conclusions

- The installation of the five passive treatment systems in the Lambert Run headwaters has neutralized the 160 tons per year of acidity these sites produced and are now contributing approximately 236 tons per year of alkalinity to Lambert Run
- The collaboration between stakeholders, state and federal agencies, academia, and private industry can work together to accomplish watershed restoration.
- Passive treatment installations in small watersheds can yield dramatic results

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Questions?
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Passive Treatment of Mining Influenced Water 101: An Overview of the Technology

By Jim Gusek, P.E. Golder Associates Inc.

- Chemistry and Microbiology of Passive Treatment
- Examples of PT Components
- Design Process
- Case Studies
- Key Treatment Issues

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Acknowledgements

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Mine Water Treatment Options

- Active (Treatment by **"Brute Force"** using chemicals, energy, labor, & infrastructure to produce clean water in the shortest time & smallest possible footprint)

- Passive (Treatment capitalizes on the low-energy dynamics that **Mother Nature** employs at ambient temperatures)

- Combination active/passive (hybrids)

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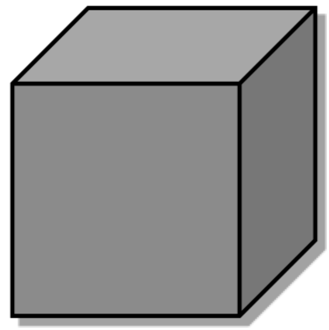
What Is Passive Treatment?

Passive treatment ≠ 

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What Is the Passive Treatment Process?

Passive Treatment of MIW involves the:

***S**equential*

***E**cological*

*e**X**traction*

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

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Definition of Passive Treatment

Ocean Wave Tunnel (circa 1904) Volunteer PTS

P.T. Metal Removal Mechanisms

Major

- Sulfide and carbonate precipitation via sulfate reducing bacteria, et al.
- Hydroxide and oxide precipitation by *thiobacillus ferro-oxidans* bacteria, et al.
- Filtering of suspended materials and precips
- Carbonate dissolution/replacement

Minor

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

?

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Passive Treatment Chemistry 101

REDUCING/ ANAEROBIC CONDITIONS

$$SO_4^{-2} + 2\ CH_2O \rightarrow HS^- + 2HCO_3^- + H^+$$

(Sulfate reduction and neutralization by bacteria)

$$Zn^{+2} + HS^- \rightarrow ZnS\ (s) + H^+$$

(Sulfide precipitation)

OXIDIZING CONDITIONS

$$Fe^{+3} + 3\ H_2O \rightarrow Fe(OH)_3\ (s) + 3\ H^+$$

(Hydroxide precipitation)

ALL CONDITIONS

$$H^+ + CaCO_3 \rightarrow Ca^{+2} + HCO_3^-$$

(Limestone dissolution)

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Aluminum Precipitation

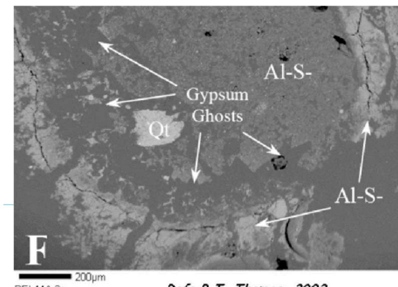
Al^{3+} + $3H_2O$ => $Al(OH)_3$ (Gibbsite) + $3H^+$

(problematic due to sludge buildup)

Conditions within BCRs are favorable for aluminum hydroxysulfate precipitation:

$3Al^{3+} + K^+ + 6H_2O + 2SO_4^{2-}$ => $KAl_3(OH)_6(SO_4)_2$ (Alunite) + $6H^+$

$6Ca^{2+} + 2Al^{3+} + 38H_2O + 3SO_4^{2-}$ => $Ca_6Al_2(SO_4)_3(OH)_{12}:26H_2O$ (Ettringite) + $12H^+$



Ref: B.T. Thomas, 2002

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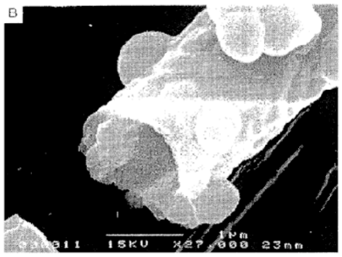
Arsenic Removal

Thiobacillus type microbes w/ arsenic rich sheaths



LeBlanc, et al., 1996

ANAEROBIC

Removal as a sulfide either as *Arsenopyrite(FeAsS)* or *ORPIMENT* (As_2S_3) or *REALGAR* (As_2S_2)

AEROBIC

Removal by sorption onto $Fe(OH)_3$

Possible formation of *SCORODITE* ($FeAsO_4$)

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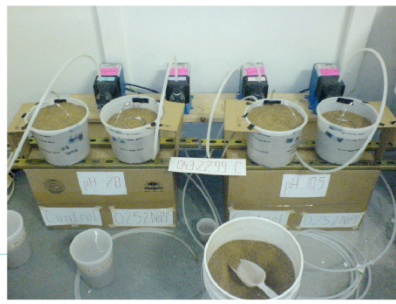
Arsenic Removal # 2

Zero Valent Iron (ZVI) can remove arsenic (anecdotal evidence from Bangladesh)

Farrell (E.S.&T., May 15, 2001) and others

In a clean lab system, it appears that As(V) is not reduced but involves surface complexation with iron oxy-hydroxides.



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Selenium Removal Reactions

Reduction / Precipitation

Se^{6+} and Fe^{2+} => Se^{4+} and Fe^{3+} (or other reductant)

$3Se^{4+} + 2Fe(OH)_2 + 8H_20 + ½O_2 \Rightarrow Fe_2(SeO_3)_3 \bullet 4H_20 + 12H^+$
(amorphous ferric selenite)

Se^{6+} + bacteria (*P. stutzeri*) + nutrients => Se_0 (elemental selenium)

Adsorption

Effective for Se^{4+} on to ferrihydrite (αFeOOH), activated alumina, peat (This is EPA's BDAT, but need to pre-reduce Se^{6+})

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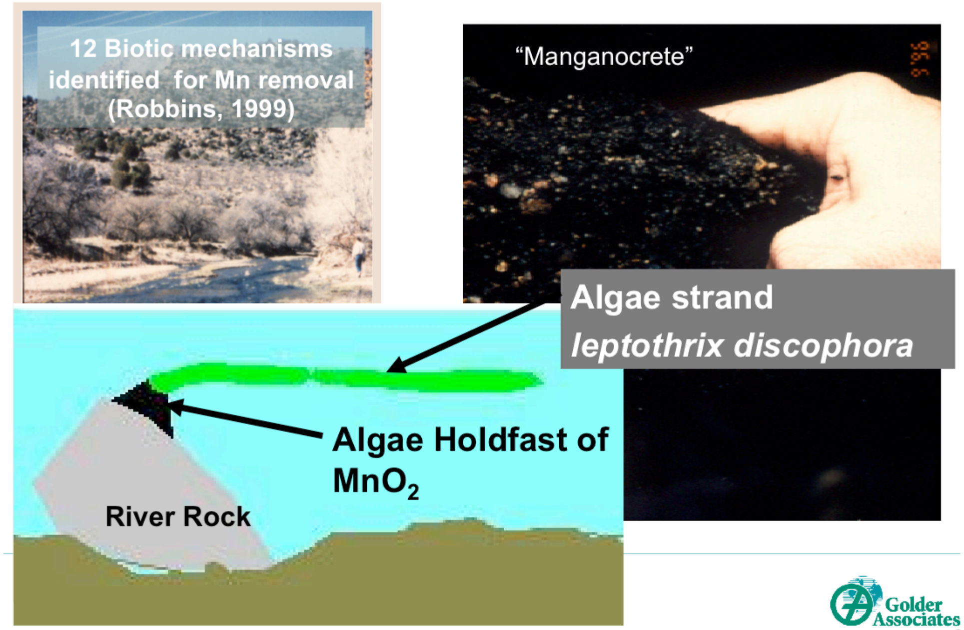
Manganese Oxidation at Neutral pH



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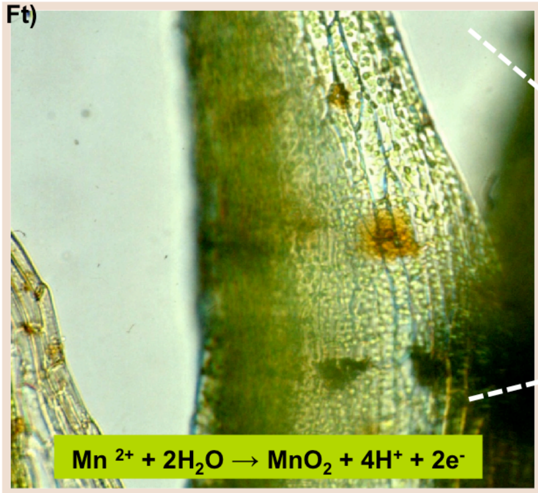
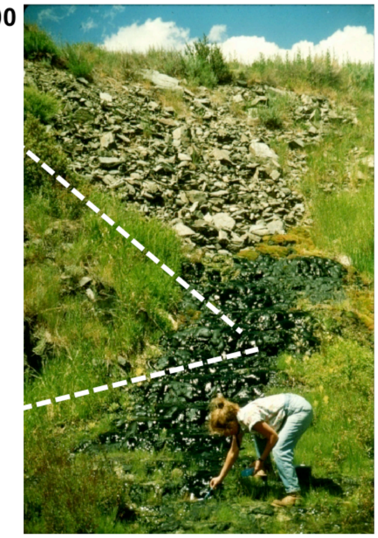
Iron & Manganese Oxidation on Moss

Atlantic City Iron Mine in Wyoming (Elev. 8,000 Ft)





Moss has 39% Mn and 13% Zn by Dry Wt!

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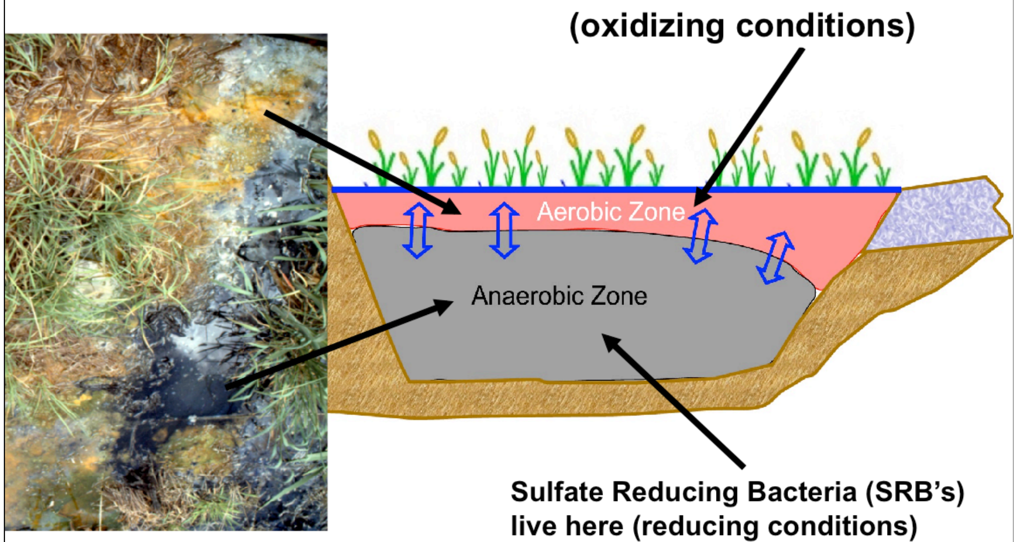
Typical Wetland Ecosystem



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Passive Treatment System Components

Biological Components

- Anaerobic Biochemical Reactors (BCRs)
- Aerobic Cells or Rock Filters
- 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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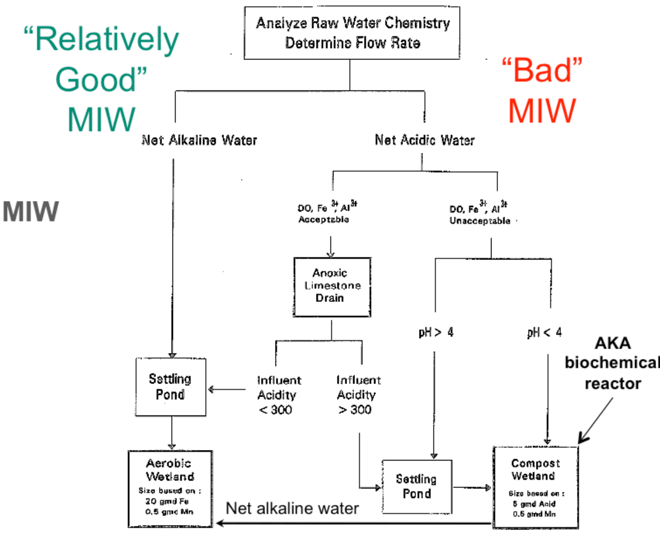
PT Decision Tree 1994

- FOCUSED ON COAL MIW
  - Iron
  - Aluminum
  - Manganese
  - Acidity



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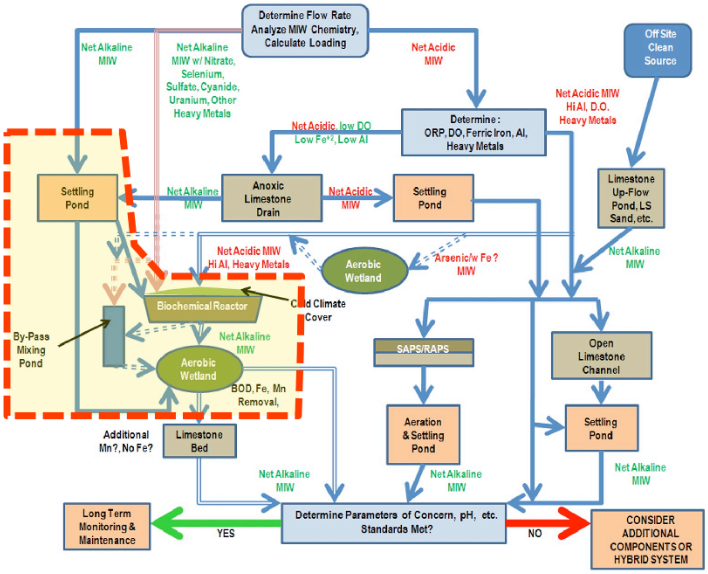
Passive Treatment Decision Tree 2013

Typical Golder Design



Ref: Gusek, 2008

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Periodic Table of Passive Treatment

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H																	He
Li	4 Be											B	6 C	7 N	8 O	9 F	Ne
11 Na	12 Mg											13 Al	Si	15 P	16 S	17 Cl	Ar
19 K	20 Ca	Sc	Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	Ga	Ge	33 As	34 Se	Br	Kr
Rb	Sr	Y	Zr	Nb	42 Mo	Tc	Ru	Rh	Pd	47 Ag	48 Cd	In	Sn	51 Sb	Te	I	Xe
Cs	56 Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	79 Au	80 Hg	81 Tl	82 Pb	Bi	Po	At	Rn
Fr	88 Ra	Ac~	Rf	Db	Sg	Bh	Hs	Mt	---	---	---		---		---		---

Actinide Series: 92 U

LEGEND

- Red- passive untreatable
- Blue – anaerobic **(BCR)**
- Orange – oxidizing **(Aerobic Cell)**
- Green - beneficial
- Uncertain - untreatable?
- Orange + Blue } Anaerobic and oxidizing

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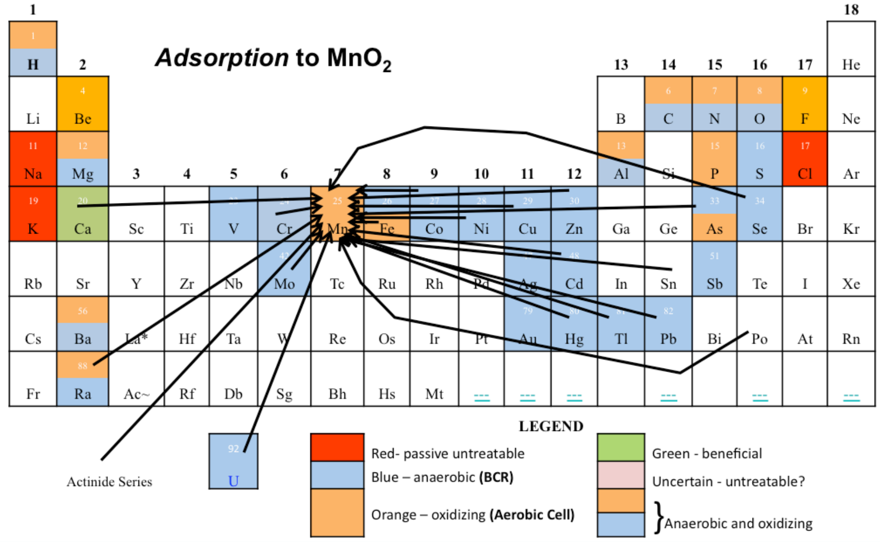
Periodic Table of Passive Treatment



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Passive Treatment Chemistry 101

REDUCING/ ANAEROBIC CONDITIONS

$SO_4^{-2} + 2\ CH_2O \rightarrow HS^- + 2HCO_3^- + H^+$

(Sulfate reduction and neutralization by bacteria)

$Zn^{+2} + HS^- \rightarrow ZnS\ (s) + H^+$

(Sulfide precipitation)

OXIDIZING CONDITIONS

$Fe^{+3} + 3\ H_2O \rightarrow Fe(OH)_3\ (s) + 3\ H^+$

(Hydroxide precipitation)

ALL CONDITIONS

$H^+ + CaCO_3 \rightarrow Ca^{+2} + HCO_3^-$

(Limestone dissolution)

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Settling/Surge Ponds

Collection of suspended solids & clarifying, flow equalization

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Anaerobic Biochemical Reactors (BCRs)

AKA

Vertical Flow Reactors

or

Sulfate Reducing Bioreactors (SRBRs)

Aluminum and heavy metal removal, selenium removal, de-nitrification, pH adjustment, alkalinity & hardness addition

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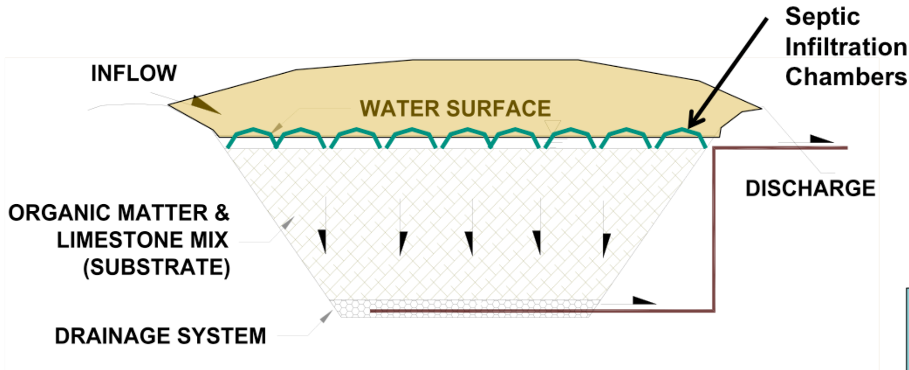
Anaerobic Biochemical Reactors (BCRs)



PLANTS ARE NOT REQUIRED FOR A BCR

SO IT CAN BE CONSTRUCTED UNDERGROUND OR BURIED

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BCR Cell Construction – Substrate Placing

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BCR Cell Construction – Burial

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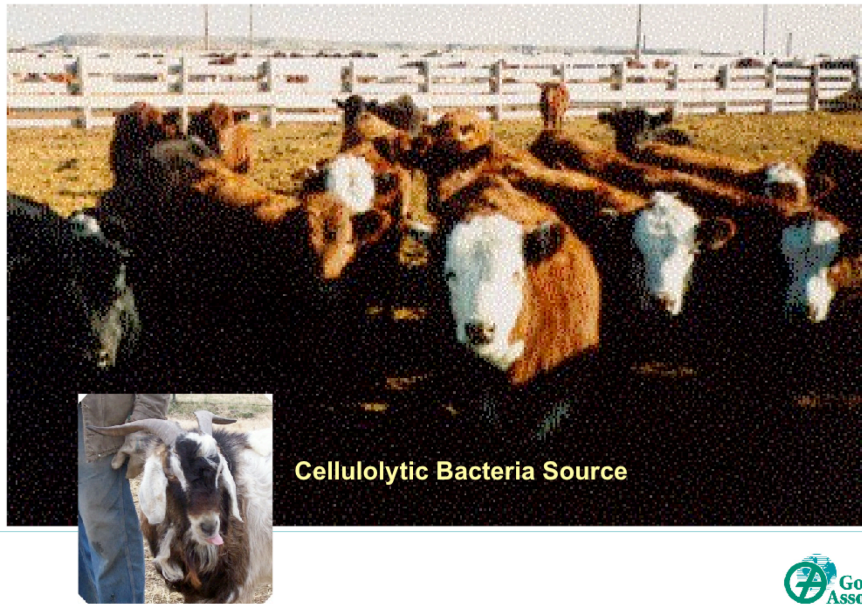
Sulfate Reducing Bacteria Sources



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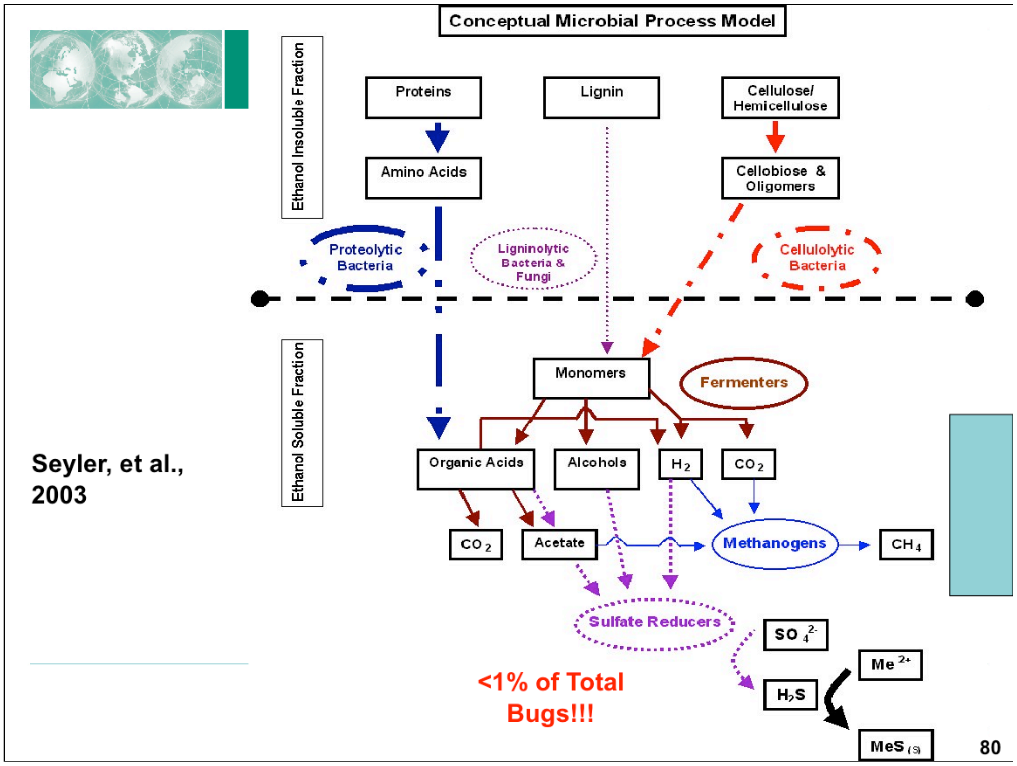
Conceptual Microbial Process Model
Seyler, et al., 2003
Ethanol Insoluble Fraction
Ethanol Soluble Fraction
Proteins
Lignin
Cellulose/ Hemicellulose
Amino Acids
Cellobiose & Oligomers
Proteolytic Bacteria
Ligninolytic Bacteria & Fungi
Cellulolytic Bacteria
Monomers
Fermenters
Organic Acids
Alcohols
H2
CO2
CO2
Acetate
Methanogens
CH4
Sulfate Reducers
SO4 2-
Me 2+
H2S
MeS (s)
<1% of Total Bugs!!!
80

Aerobic Cells

AKA Rock Filters

Fe, As, Biochemical Oxygen Demand (BOD), and **Mn** removal **(& adsorbed metals**)

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Aerobic Cell (Iron Terraces)

Fe, As, removal (& adsorbed metals)

Ref: Burgos, 2008
WV Mine Drainage Task Force Symposium

Ref: España et al., 2007
Geosphere 2007;3;133-151

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Passive Cell Design Parameters

NO COOKBOOK (YET)

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

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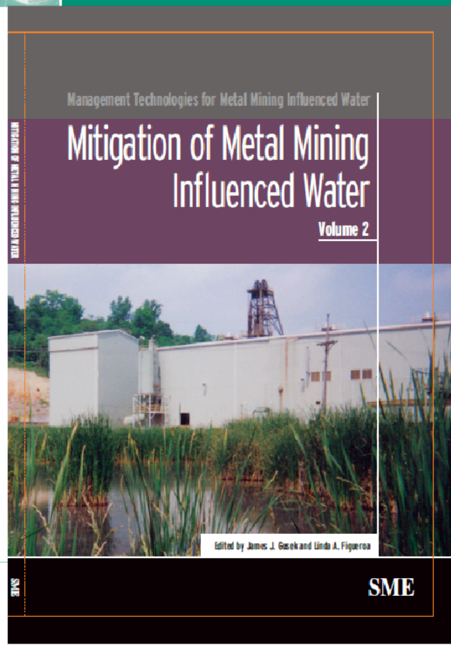
In the Meantime….



Available from SME Website
www.smenet.org

A collaborative effort of Acid Drainage Technology Initiative, Metal Mining Sector (ADTI/MMS)

Also:
www.gardguide.com

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Passive Treatment Staged Design Phases

- Lab (proof of principle) tests
- Bench tests
- Pilot tests
- Limited full scale (modules)
- Full scale implementation

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Lab - Proof of Principle Tests

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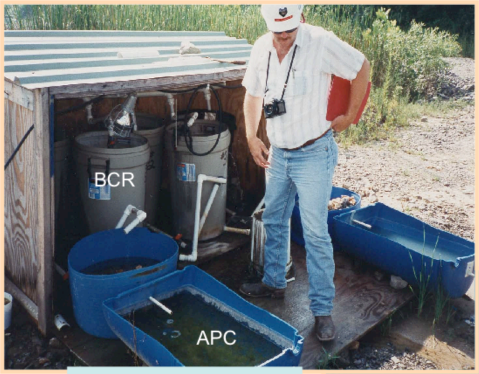
Bench Scale Tests



Weekly sampling schedule is typical

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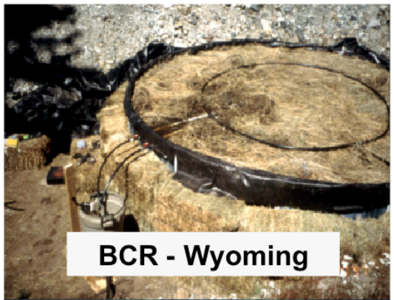
Pilot Scale Cells



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CASE STUDIES

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Passive Treatment - Full Scale BCR System

West Fork Lead Mine, Missouri
Constructed in 1996 for Asarco

pH = 7.8

Pb = 600 µg/L
Occurs as pH -insensitive aqueous lead carbonate complex

Flow = 1,200 gpm

NPDES Pb limit = 23 µg/L

No violations in 16.5 years

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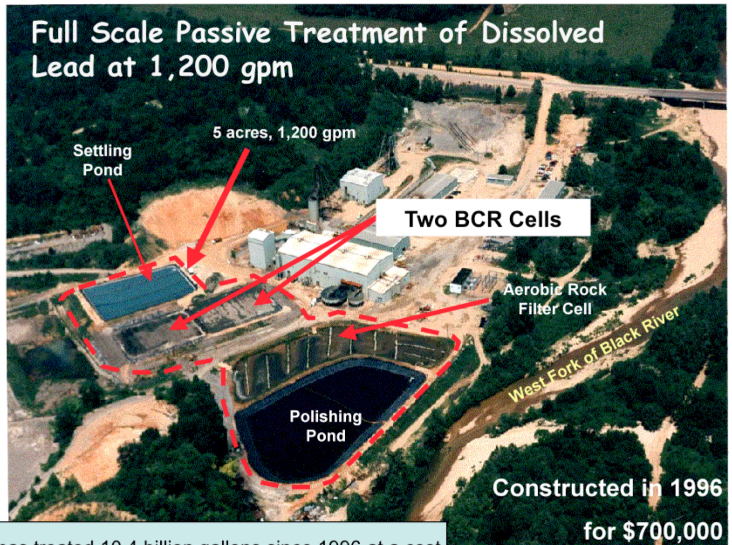
Full Scale Passive Treatment System Example



System has treated 10.4 billion gallons since 1996 at a cost of $0.000067 per gallon (6.7¢ per 1,000 gallons)

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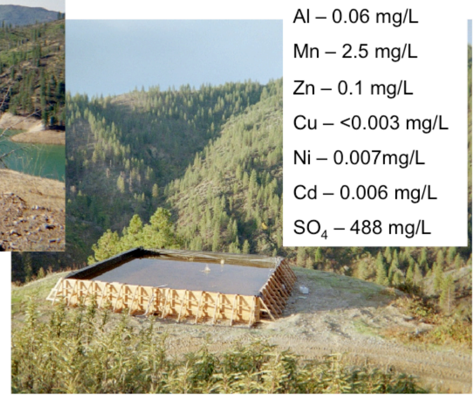
Golinsky Mine, CA (USFS)

Total cost with engineering: ~$350K



Influent

- pH – 3.0
- Fe – 104 mg/L
- Al – 24.5 mg/L
- Mn – 1.3 mg/L
- Zn – 54.9 mg/L
- Cu – 9.0 mg/L
- Ni – 0.031 mg/L
- Cd – 0.71 mg/L
- SO_4 – 797 mg/L

Pilot BCR

Effluent

- pH – 7.2
- Fe – 0.8 mg/L
- Al – 0.06 mg/L
- Mn – 2.5 mg/L
- Zn – 0.1 mg/L
- Cu – <0.003 mg/L
- Ni – 0.007mg/L
- Cd – 0.006 mg/L
- SO_4 – 488 mg/L

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Golinsky Site Access Challenges

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Golinsky BCR Construction, 2010

Construction Cost: $1.3 million (about $0.012 per gallon for 20 yr life)

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Golinsky BCR Startup, 2011

Influent

3/31/11

pH – 2.78

Fe – 34.4 mg/L

Al – 14.8 mg/L

Mn – 0.24 mg/L

Zn – 18.0 mg/L

Cu – 8.7 mg/L

Ni – 0.026 mg/L

Cd – 0.15 mg/L

SO_4 – 339 mg/L

Effluent

3/31/11

pH – 7.8

Fe – 1.4 mg/L

Al – 0.02 mg/L

Mn – 1.6 mg/L

Zn – 0.03 mg/L

Cu – 0.002 mg/L

Ni – 0.004 mg/L

Cd – 0.006 mg/L

SO_4 – 100 mg/L

3/31/11 Flow: 7.2 gpm (design = 10 gpm)

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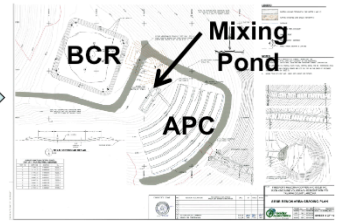
Golinsky BCR Steady State, 2013

BCR site is visible in Google Earth

Project Example – Arizona Copper Mine

Bench PT Tests (2006)

Glory Hole Capping & Reclamation (2007)
MIW Prevention



Passive System Design (2008) [Active not needed]

Active Treat Lab Tests (2006)

Passive System Construction (2009)

PTS Construction Cost $1.6 million

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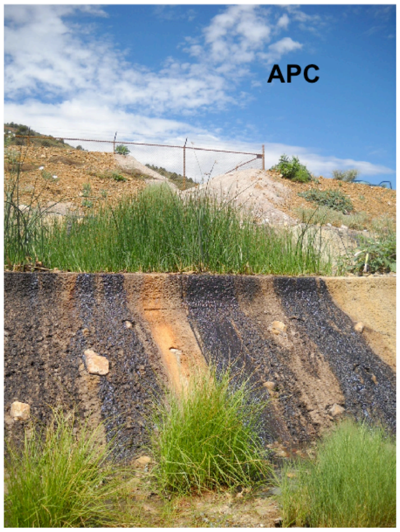
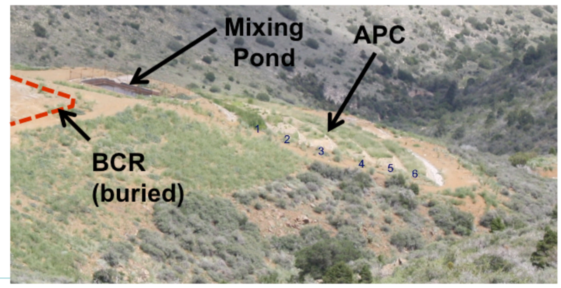
Arizona System 1 Year Later





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Arizona System 1 Year Later

Influent

pH – 3.0
Fe – 91.4 mg/L
Al – 14.5 mg/L
Mn – 33.5 mg/L
Zn – 92.7 mg/L
Cu – 55 mg/L
Ni – 0.12 mg/L
Cd – 0.30 mg/L
Se – 0.09 mg/L
SO_4 – 2,430 mg/L

Effluent

pH – 7.4 (APC)
Fe – 0.07 mg/L
Al – 0.09 mg/L
Mn (BCR) – 23.7 mg/L
Mn (APC) – 9.4 mg/L
Zn – <0.01 mg/L
Cu – 0.02 mg/L
Ni – 0.01 mg/L
Cd – <0.005 mg/L
Se – 0.01 mg/L
SO_4 – 1,580 mg/L

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Key Treatment Issues

- How much land surface is available?
- System longevity/maintenance
- Disposal of residuals (hazardous waste?)
- Performance criteria
- Cost (design, capital, operating, NPV)
  - *PT construction $ may be higher that active*
  - *PT O&M $ much lower*
  - *PT NPV is 50% less than active*
- Urgency of implementation
- Cold weather performance

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P.T. Advancements 1985 to 2013

- Established design protocol
  - Lab, bench, pilot studies
  - Physical and geochemical design parameters
  - Better understanding of microbiology
- Wide range of operating conditions
  - pH 2.5 to 8.5
  - Metals (Fe, Cu, Pb, Zn, Cd, Cr, Mn, Hg, Mo, Al, Se, As, U, Co, Tl)
  - *Adsorption to MnO_2 @ neutral pH gaining ground*
  - Non-metals (CN, SO_4, NO_3, NH_3, BOD_5, P)
  - Temperatures (0 to 30 deg C)
  - Flows up to 1,200 gpm (4,540 liters per minute)

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Advantages of Passive Treatment

- Low NPV cost
- No moving parts
- Simple to operate
- Resilient to quantity variations
- Wildlife habitat?
- Long term (but not walk-away) solution

- Mimics Mother Nature
- Blends into landscape
- Politically correct
- Non-hazardous residuals (typically)
- Regulatory acceptance
- *Resource recovery in future*

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Summary

- Any mine water can be treated… for a price; passive is **HALF** the cost of active treatment for identical chemistry.
- Passive treatment systems can handle a wide variety of flows, water, chemistry and site conditions (low to high: pH, metal concentration, flow and temperature).
- P.T. system longevity is on the order of decades.
- Design process is established; passive treatment is a proven methodology for treating MIW.

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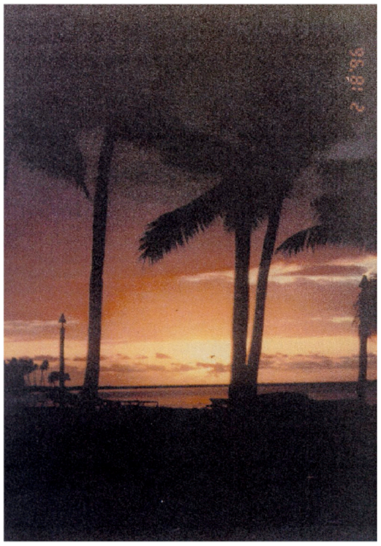
Thank You



In Water Treatment, if you're not part of the **solution**, you're part of the **precipitate**.

jgusek@golder.com

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Leviathan Mine Water Treatment

Kevin Mayer, Gary Riley,
Lily Tavassoli and John Hillenbrand
Superfund Project Managers

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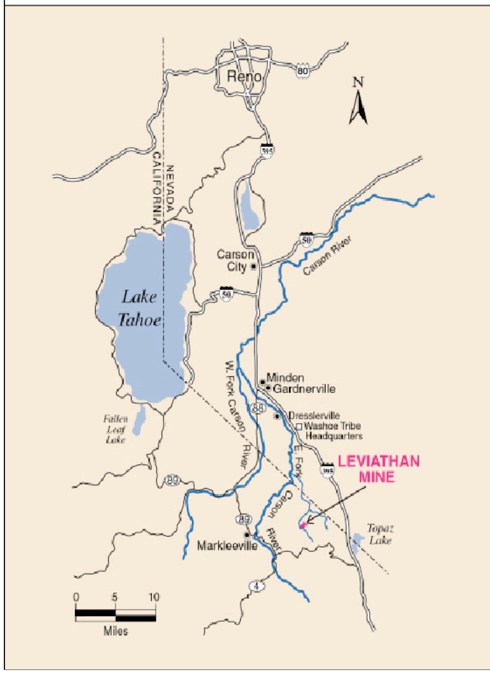
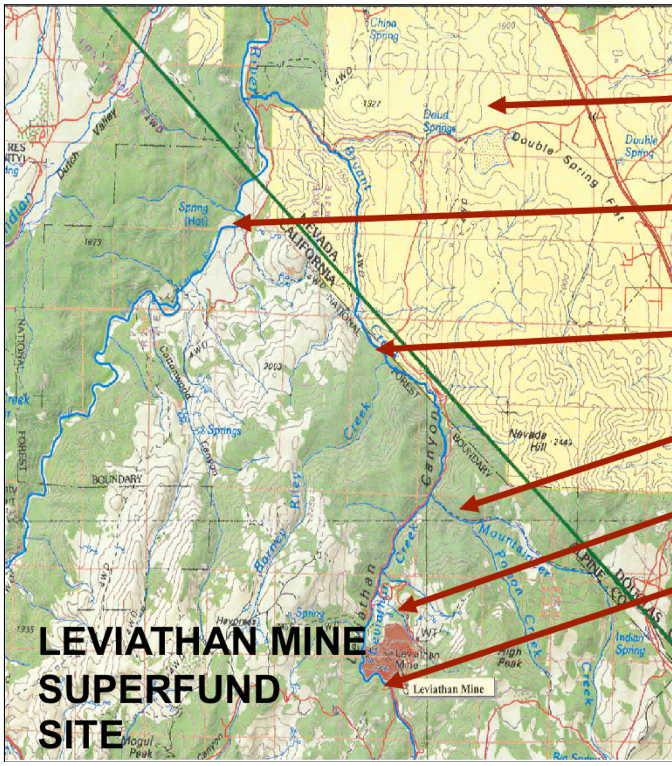
Leviathan Mine Location



7000 ft Elevation, Sierra Nevada
Open Pit Sulfur Mine In California
Flows into NV

106



WASHOE TRIBE

EAST FORK CARSON RIVER

BRYANT CREEK

MOUNTAINEER CREEK

ASPEN CREEK

LEVIATHAN CREEK

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Leviathan Mine History

- COMSTOCK ERA (1863-1872)
  - Copper Sulfate
- INACTIVE (1873-1935)
- **SULFUR MINING** (1935-1941)
  - Tunneling – Constructed "ADITS"
- **ANACONDA (1951-1962) OPEN PIT MINE**
  - Fish Kills first noted in 1952
- NINE MILES of WATERSHED
  - (Leviathan & Bryant Creeks, Carson River)
- **LAHONTAN REGIONAL WQ BOARD (1980s)**
- CURRENT PRP RESPONSE

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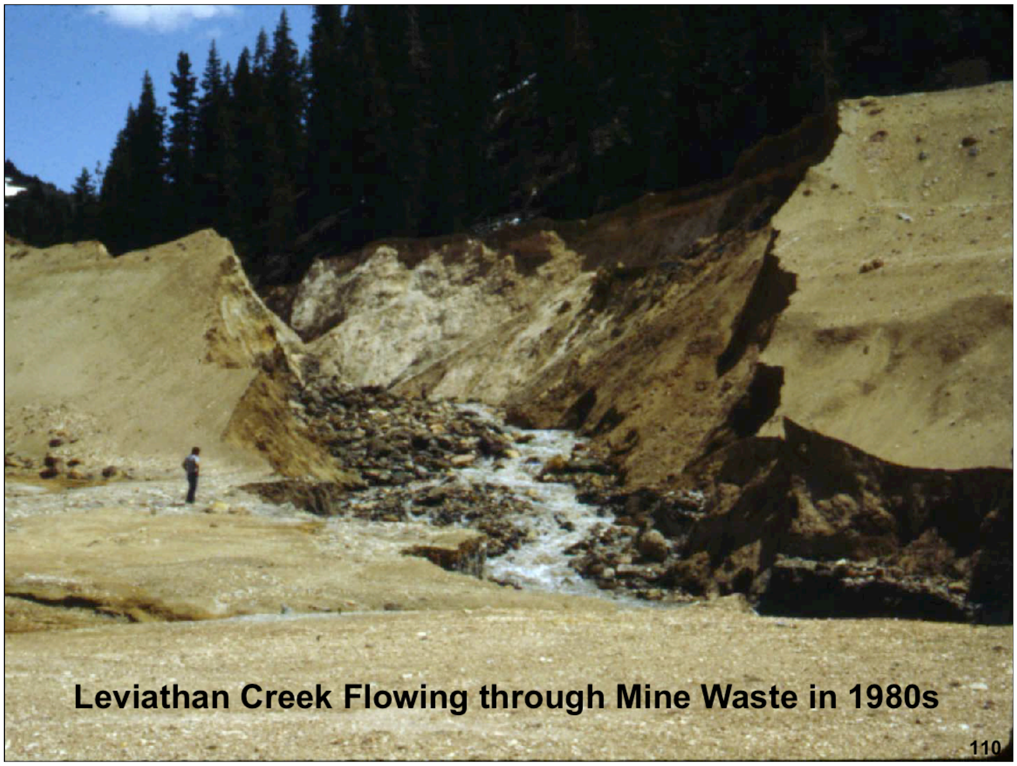


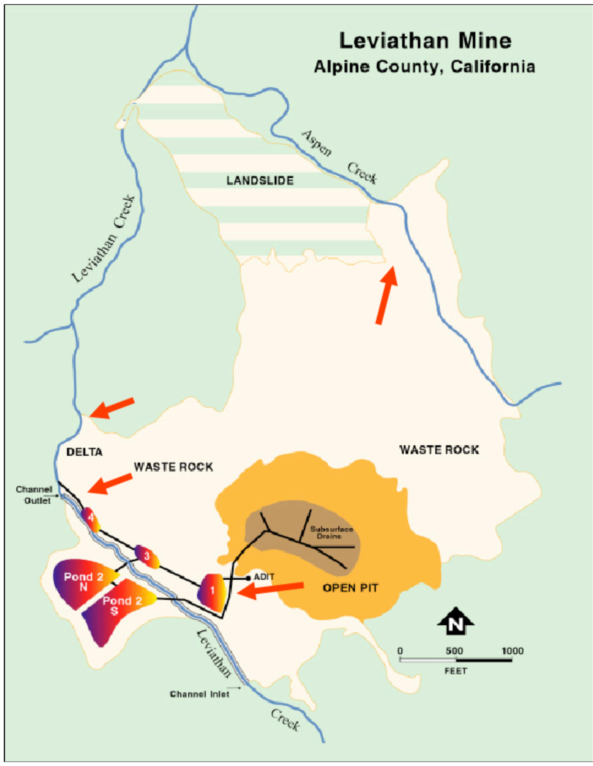
Leviathan Creek Flowing through Mine Waste in 1980s


Leviathan and Mountaineer Creeks
Three Miles Downstream from Mine (1999)
111


Leviathan Mine Acid
Mine Drainage –
Bryant Creek
112


Bryant Creek confluence with East Fork Carson River
9 Miles downstream of Leviathan Mine, Sept. 1969
113


Leviathan Creek Sediment, 2001
114



Identified Contaminant Sources

- Adit
- Channel Underdrain
- Delta Seep
- Aspen Seep

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State of California
1985 Pollution Abatement Project

- Constructed five lined evaporation ponds
  - 12.7 acres with16.5 million gallon capacity
- Captured two flows via gravity
  - Adit (9-15 gpm, max 45 gpm; pH<3.0)
  - Pit Underdrain (0-4 gpm, max 42 gpm; pH <3.0)
- Channelized Leviathan Creek
- Route clean storm water to Creek

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Leviathan Creek, 1983
Leviathan Adit Discharge
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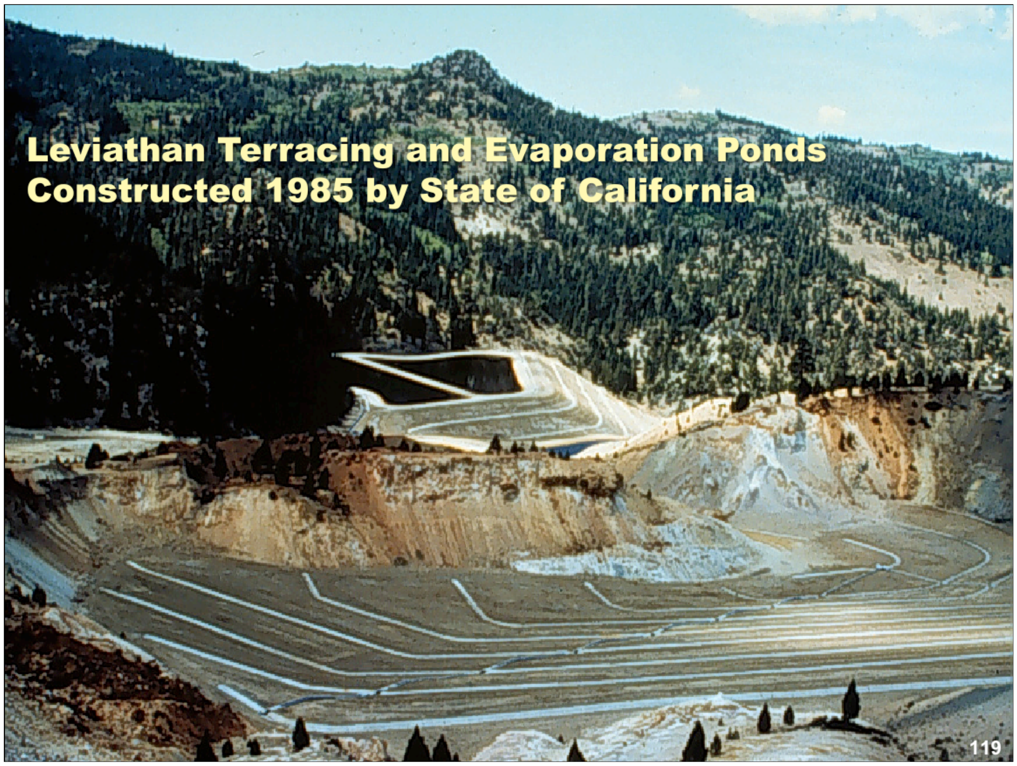
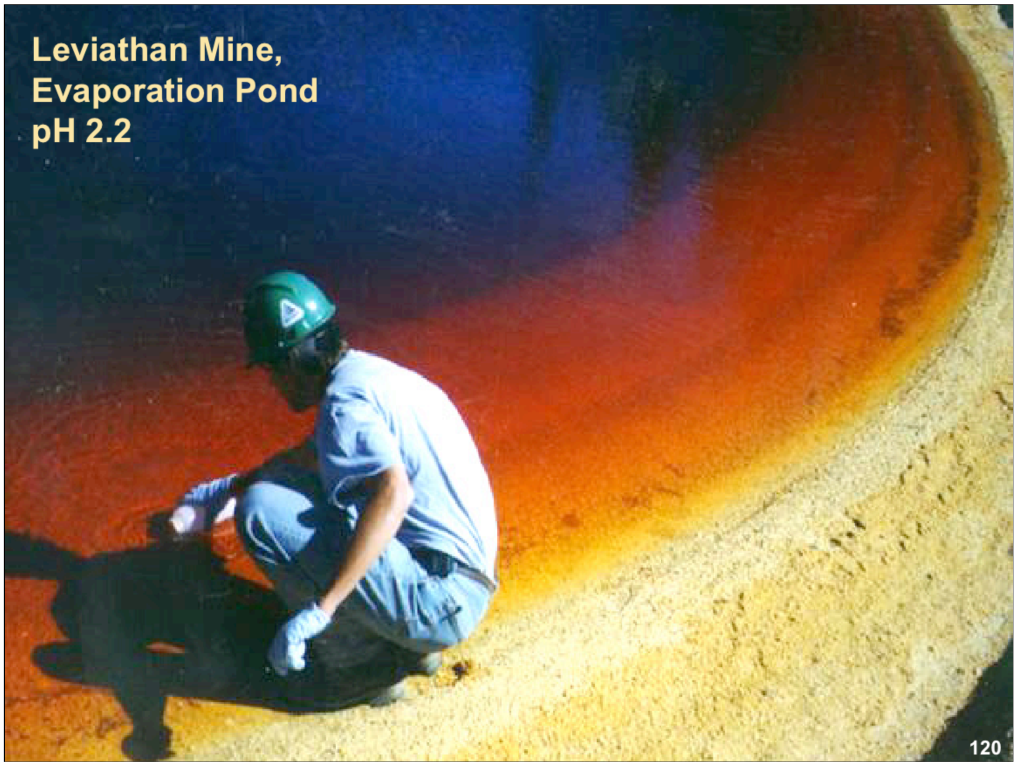
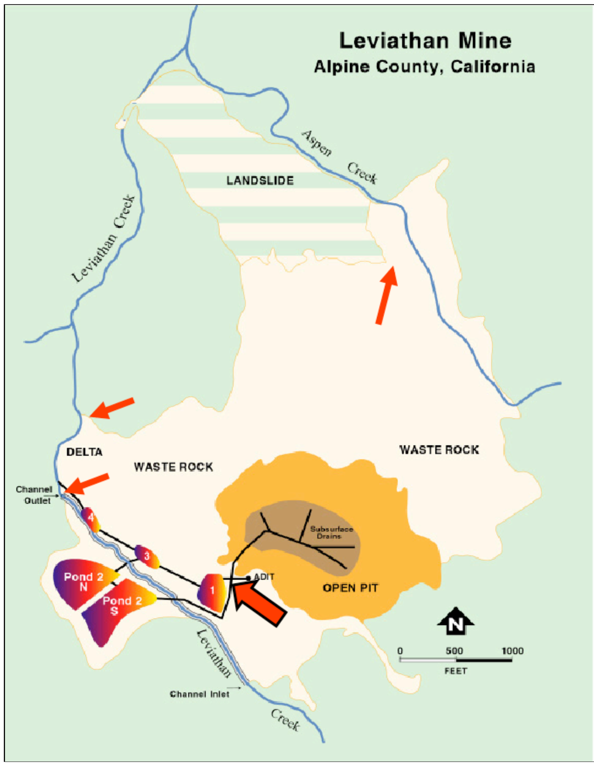
Leviathan Mine
Approx. 250 Acres
Stream diversion/
Evaporation Ponds
118


Leviathan Terracing and Evaporation Ponds
Constructed 1985 by State of California
119


Leviathan Mine,
Evaporation Pond
pH 2.2
120



Identified Contaminant Sources

- Adit
- Channel Underdrain
- Delta Seep
- Aspen Seep

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Leviathan Summer Lime Treatment by
State of California
122


2001 Construction of Settling Basin: "Pit Clarifier"
123

Adit and Pit Under-Drain Capture & Treatment

- Ponds capture flows from Adit and Pit Under-drain sources via gravity year-round
- Summer Lime Neutralization system, plus early season “emergency” treatment if needed to prevent pond overflow
- Plant cost $700K in 1999
- Annual cost (2011) was $690K to treat 9.8 million gal of AMD [$0.07/gal]
- 2011 Early 8.2 Mgal; 9.8 Mgal Summer
- 2012 Summer 2.8 Mgal

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Lime Neutralization Sludge Management

Photo: Lahontan RWQCB

- Clarifier accumulates sludge; dries fall through winter
- Trucked for off-site disposal
- 1,082 tons of sludge from 6.7 Mgal of AMD treated in 2010; 1000 tons in 2012

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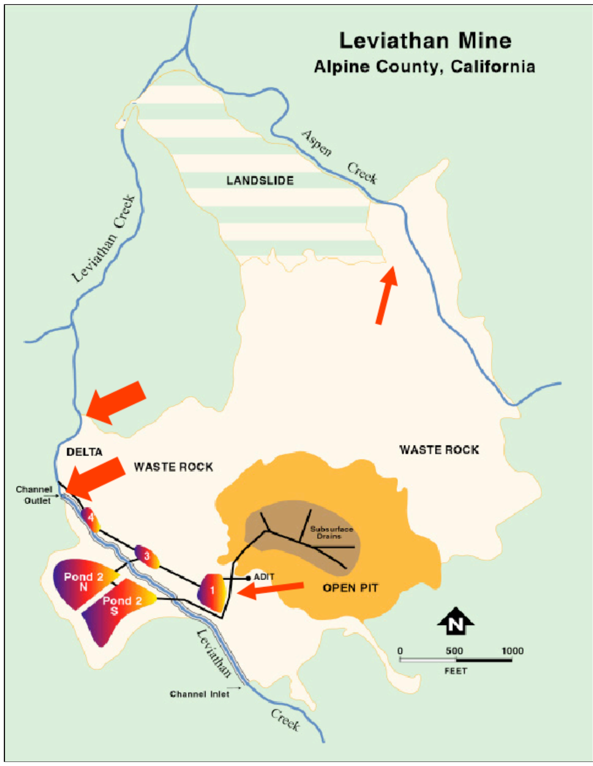

Identified Contaminant Sources

- Adit
- Channel Underdrain
- Delta Seep
- Aspen Seep

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Channel Under-Drain & Delta Seep

- Spring-to-Fall capture and treatment
- Pumped up-gradient to equalization pond
- Treatment via high density sludge system, lime neutralization

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Delta Seep
2001
Delta Seep
2008
DELTA SEEP
128


Leviathan Creek
Channel Under-Drain
FIRE EXTINGUISHER
129


LIME TREATMENT – High Density Sludge
CUD & Delta Seeps, Atlantic Richfield 2009
130

HDS System Performance/Costs

- Treated and discharged approximately 13.0 million gallons of AMD (2011) and 6.6 million gallons in 2012.
- Generated 138 tons of sludge in 2011
- Total 2011 cost $1.228 million + $95,000 for sludge disposal
- Note the system is complex and construction costs were high

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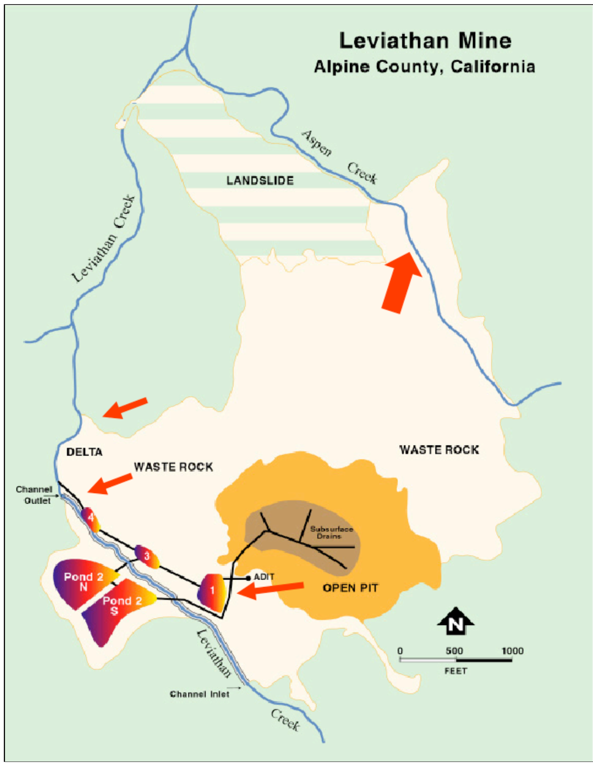

Identified Contaminant Sources

- Adit
- Channel Underdrain
- Delta Seep
- **Aspen Seep**

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Aspen Seep 2001
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Second Generation Aspen Seep Compost Bioreactor 1999

- University of Nevada – Reno
- Horse manure & wood chips

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First Generation Rock Bioreactor 2000
135

Compost Free Bioreactor - Aspen Seep 2002-3

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Bioreactor at Aspen Seep

Year Round Treatment

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Aspen Seep Bioreactor Operations

- 7.2 million gal AMD treated in 2011;
  3.8 million gal AMD treated in 2012
- 86 tons of sludge (12 tons/Mgal) in 2011
- O&M cost $710,000
- Sludge an additional $541,000
- Considerations:
  - System operates year-round
  - But: biological does not mean no O&M
  - Significant support systems and personnel

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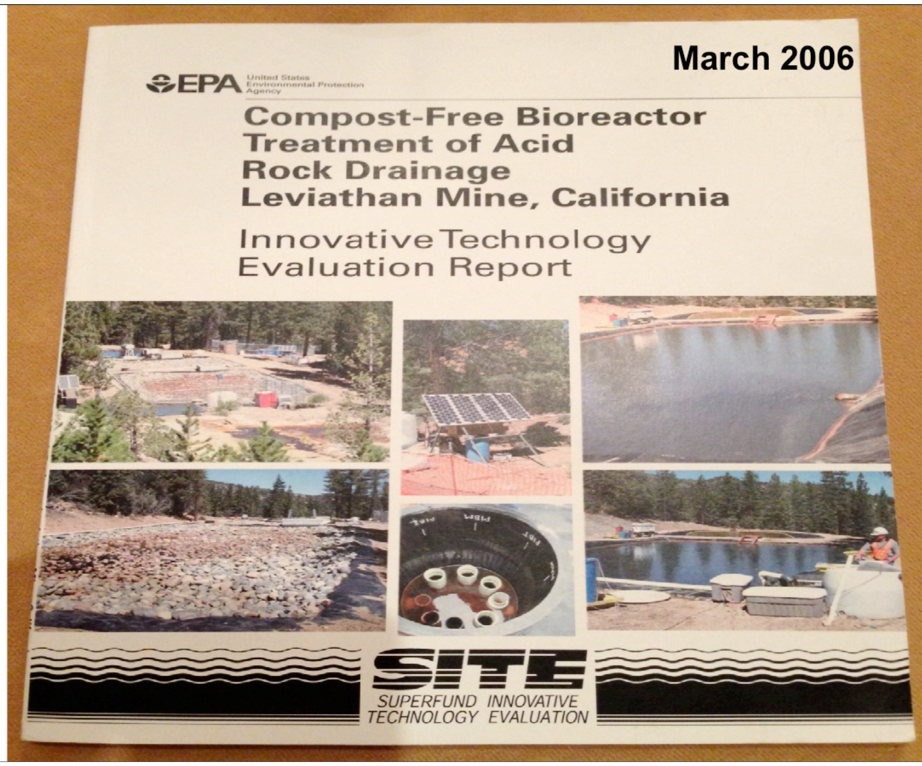
March 2006
EPA United States Environmental Protection Agency
Compost-Free Bioreactor Treatment of Acid Rock Drainage Leviathan Mine, California
Innovative Technology Evaluation Report
SITE
SUPERFUND INNOVATIVE TECHNOLOGY EVALUATION

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Early Response Treatment Systems

- Not “one site fits all”
  - Different waters need different solutions
- Spectrum from more passive to active systems
  - Preventing generation of ARD is preferable
  - Consider construction cost and relative O&M complexity
- Pilot test and early actions
  - helpful but challenging to implement at scale

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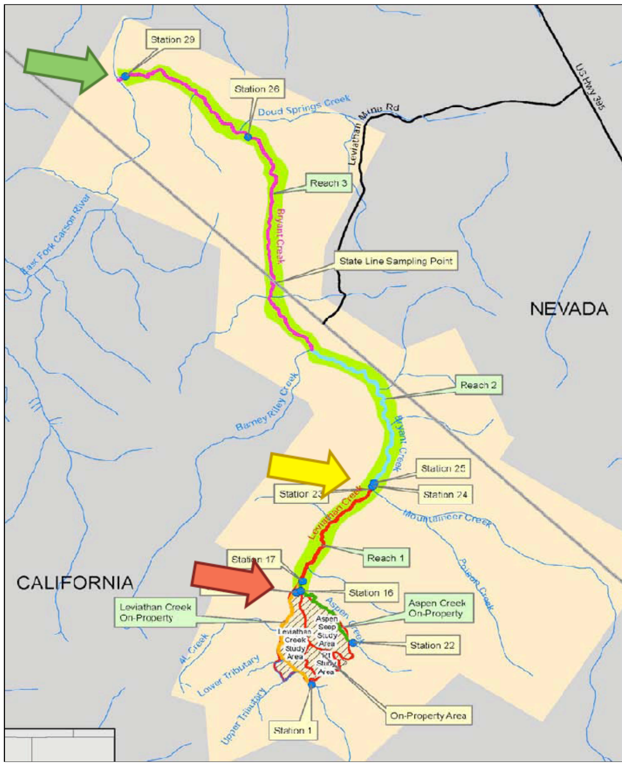

Downstream RESULTS

Major Recovery In Bryant Creek from Mountaineer Creek to East Fork Carson - 6 Miles

- Native macroinvertebrates
- GoodTrout & Daphnia toxicity test results

Significant but Incomplete Recovery from Aspen Creek Confluence to Mountaineer Confluence – 2+ Miles

- Chronic Toxicity observed

Still Problems within 1 Mile of Mine Discharge

- Beaver colonies

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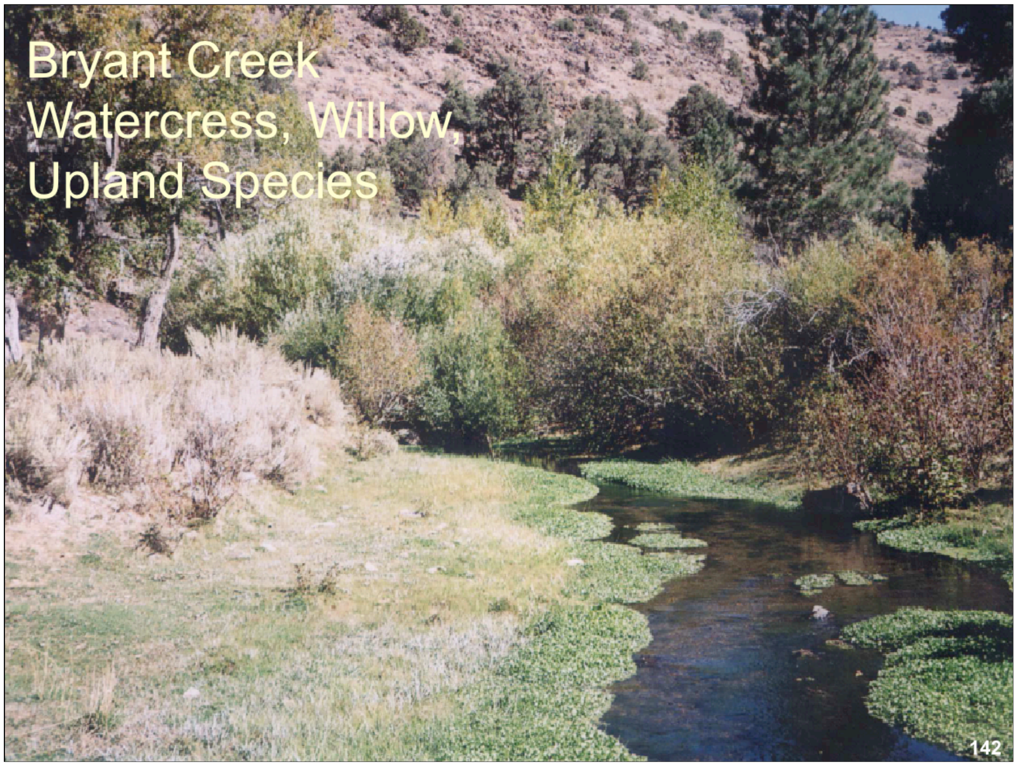
Bryant Creek
Watercress, Willow,
Upland Species
142


Leviathan Creek during Water Treatment
143


Long Term Remedy Challenges
Site access
Power
Residuals
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Clu-in.org Webinar Series on Mining Sites

- Next webinar will be in Spring 2013
- Visit www.CLU-IN.org/mining/events for updates

We want your feedback!

Are these topics interesting to you?
Do you want to hear about them on the next webinar? Any other suggestions?
Leave us your comments on this webinar's feedback form.

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Workshops on Hardrock Mine Geochemistry and Hydrology

- Sponsored by EPA Region 10, ORD, and HQ
  - Workshop 1: February 13 – 1:00-3:00 PM EST
    - Topic: Evaluating water chemistry predictions at mine sites
    - Registration: http://www.clu-in.org/conf/tio/r10hardrock/
  - Workshop 2: February 27 – 2:00-4:00 PM EST
    - Topic: Mining-influenced water - pathways for offsite releases
  - Workshop 3: March 5 – Time TBD
    - Topic: Monitoring, adaptive management, and ways to control contaminated sources

Visit www.CLU-IN.org/mining/events for updates

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Later in February and March, EPA's Region 10, the Office of Research and Development, and Headquarters will be hosting a three-part series of free, two-hour webinar workshops on hardrock mine geochemistry and hydrology. The workshops are intended to help participants understand the key issues regarding water chemistry predictions, identify the potential sources of contamination from mine sites, and learn practices to mitigate or reclaim facilities to protect natural resources. The workshops will be held on February 13, 27, and on March 5. Registration for Workshop 1 is now open. The events page on the CLU-IN Mining Sites Focus Area contains more information and the links to registration for these workshops.

New Ways to stay connected!

- Follow CLU-IN on Facebook, LinkedIn, or Twitter

https://www.facebook.com/EPACleanUpTech

https://twitter.com/#!/EPACleanUpTech

http://www.linkedin.com/groups/Clean-Up-Information-Network-CLUIN-4405740

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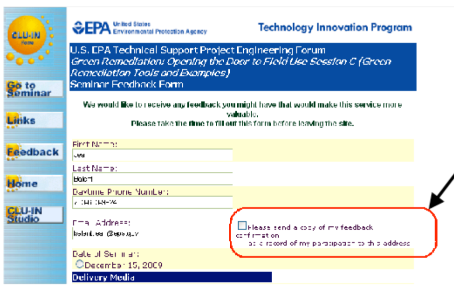
Resources & Feedback

- To view a complete list of resources for this seminar, please visit the **Additional Resources**
- Please complete the **Feedback Form** to help ensure events like this are offered in the future



Need confirmation of your participation today?

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

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Thank you again for your attention and comments. I want to remind each of you that we are looking for your specific responses to many of the issues discussed today in our feedback form following this session.

Also, there are several resources and related documents included in the links to more resources on this page.

If you have any additional questions or comments, please feel free to contact myself or fill out a comment form on CLUIN.

Thank you and have a great afternoon.