Soil Treatment at the California Gulch NPL Site for Vegetation Reestablishment and Mitigation of Metal Mobility

Stuart Jennings, RRG, Jan Christner, URS
Mike Holmes, EPA and John DeAngelis, PWT
Operable Unit 11 of the California Gulch Superfund Site near Leadville, CO
Irrigated Meadows

Before remediation

After remediation
Arkansas River Fluvial Tailing Areas

Fluvial Tailing Deposits

Unstable Streambanks
Prior Research and Demonstration Work

1999 EPA Demonstration

Harry Compton (EPA), Mark Sprenger, (EPA), Sally Brown (USDA/UW), Mike Zimmerman (EPA), Jan Christner (URS)

University Research

CSU Revegetation Research

Kevin Fisher, MS 1999
Joe Brummer, principal investigator
Two Treatment Strategies

**Irrigated Meadow Contamination**
- 153 acres treated to either 6 or 12 inch depth using a tractor-pulled plow
- Thin deposits of relatively uniform depth

**Fluvial Tailing Deposits**
- 18 acres treated with an excavator-mounted soil mixer
- Thick deposits of varying depths within the floodplain
Remedial Action Objectives

- Minimize future human exposures
- Minimize erosion
- Control leaching and migration of metals
- Reduce toxins in plants
- Reduce metal exposures of wildlife and livestock

Remedial Timeline

1990’s-2006—Data Collection, Research, Demonstration
2007—Work plan
2008-2009—Construction
2010-present—Monitoring and maintenance
Soil Treatment

Approach

- Add lime to control current and future acidity
- Add organic amendment to serve as basis for long-term soil fertility/nutrient cycling
- Add supplemental phosphorous
- Treat entire contamination thickness
- Seed
- Monitor and maintain

Expected Outcome

- Soil pH will remain between 7-8 and control soluble metals
- Nutrient cycling will be perpetuated by soil organisms
- Vegetation will not translocate harmful concentrations of contaminants into shoots
- Water balance will be improved
  - Reduced metal flux to groundwater
  - Reduced runoff/reduced erosion
  - Increased evapotranspiration
- Conventional land uses will be restored (grazing and recreation)
- Meet RAO’s and Performance Standards
Soil Treatment Polygons—
Irrigated Meadows North

12-inch tillage --Pink coded polygons
6-inch tillage – Yellow coded polygons
**Proposed Treatment**
Lime amendment rate: 150 tons/dry ton soil
Organic amendment rate: Default
Fertilizer rate: Default
Till Depth: 9” to 27”
Till Equipment: Deep till rotary mixer.
Seed Mix: Fluvial Deposit Seed Mix
Notes: Save healthy willows throughout site and grassy vegetation adjacent to tributary. Do not disturb vigorous willows located near the river bank or the large tree. Do not disturb well vegetated area between deposits OA and OC.

**Bank Stabilization**
Good grassy and woody vegetation is present between deposits OA and OC, so no stabilization is required. Limited grassy and woody vegetation is present along an erosive one foot high streambank along the Arkansas River. Type 2 bank stabilization is required.

**Physical Characteristics**
- Area: 1 acre
- Average Depth: 15”
- Depth Range: 9” to 27”
- Fine grained to sandy mine waste over sand and cobble alluvium.
- Timbers located on site may be used for bank stabilization.
- A large pine tree is located within the deposit.

**2006 Data**
- Arsenic: 67.3 mg/kg
- Cadmium: 21.8 mg/kg
- Copper: 145 mg/kg
- Lead: 1270 mg/kg
- Manganese: 1170 mg/kg
- Mercury: 0.92 mg/kg
- Zinc: 2940 mg/kg
- pH: 3.0
- ABA: -141.7 t/1000t
Lime Amendment Mixing into Fluvial Tailing Deposits
Lime Requirement for Soil Treatment

Fluvial ABA Histogram

Irrigated Meadow ABA Histogram

Remediation of Abandoned Mine Lands

Friday, October 3, 2008: 2:40 p.m.

Lime Amendment of Contaminated Soil and Acid-Producing Fluvial Tailing Deposits along the Upper Arkansas River, Colorado

Stuart R. Jennings, Redemption Research Group LLC
Sugar Beet Lime

13,000 tons used for project
Compost Amendment

28,000 tons used for project (45,000 cy)
RESULTS

Soil Total Metal Levels (2011) Post-Treatment

<table>
<thead>
<tr>
<th></th>
<th>Ca (mg/kg)</th>
<th>Mg (mg/kg)</th>
<th>Al (mg/kg)</th>
<th>Fe (mg/kg)</th>
<th>Mn (mg/kg)</th>
<th>Cu (mg/kg)</th>
<th>Cd (mg/kg)</th>
<th>Pb (mg/kg)</th>
<th>Zn (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated Meadows-North 1</td>
<td>22,200</td>
<td>3,300</td>
<td>10,700</td>
<td>21,000</td>
<td>1,250</td>
<td>105</td>
<td>21</td>
<td>2,000</td>
<td>2,350</td>
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<tr>
<td>Irrigated Meadows-North 2</td>
<td>25,500</td>
<td>4,060</td>
<td>7,230</td>
<td>34,500</td>
<td>2,390</td>
<td>210</td>
<td>27</td>
<td>8,460</td>
<td>6,470</td>
</tr>
<tr>
<td>Irrigated Meadows-South</td>
<td>11,200</td>
<td>3,440</td>
<td>8,400</td>
<td>16,400</td>
<td>996</td>
<td>58</td>
<td>14</td>
<td>1,090</td>
<td>1,675</td>
</tr>
<tr>
<td>Fluvial Deposits</td>
<td>36,800</td>
<td>4,780</td>
<td>6040</td>
<td>30,200</td>
<td>825</td>
<td>158</td>
<td>18</td>
<td>2,300</td>
<td>2,490</td>
</tr>
</tbody>
</table>

Elevate metal levels and essentially unchanged from pre-treatment
Changes in SPLP **Soluble** Metal Levels Before and After Treatment

**Post-Treatment Comparisons between Totals and Water Soluble levels**

<table>
<thead>
<tr>
<th></th>
<th>Pb</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water soluble as a percent of total</td>
<td>0.022%</td>
<td>0.065%</td>
</tr>
<tr>
<td>Total as a factor of soluble</td>
<td>4588X</td>
<td>1543X</td>
</tr>
</tbody>
</table>
Soil Conditions

**Soil pH and Electrical Conductivity**
- Acidic prior to treatment
- Neutral to slightly alkaline following lime addition (7-8)
- Soil solution dominated by metals prior to treatment
- Soil solution dominated by alkaline cations and nutrients following treatment

**Soil Organic Matter and Fertility**
- Prior to treatment organic matter varied widely from near zero (bare areas) to adequate (sparse areas)
- Prior to treatment plant macronutrients N/P/K were deficient in nearly all barren/sparsely vegetated areas
- Following treatment adequate to abundant fertility levels were observed
Lead levels in Vegetation

The amount of Pb in vegetation appears unrelated to total Pb in soil. Differences are apparent by site.
Lead levels in Vegetation

Water soluble Pb also appears to be a poor predictor of Pb in vegetation.
SPLP soluble Pb appears to provide good discrimination of Pb in vegetation by site location.
2011 Vegetation Monitoring

Fluvial Deposit QF

Irrigated Meadow SM-06

<table>
<thead>
<tr>
<th>Total Metal Levels (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
</tr>
<tr>
<td>QF</td>
</tr>
<tr>
<td>SM-06</td>
</tr>
</tbody>
</table>
On-going Maintenance

Streambank Repairs due to High Flow in 2011

Reseeding Bare Spots caused by Excess Salinity
On-going Management

Grazing Intensity

Weed Control
Remediation and Stabilization Using Natural Materials

- Lime
- Compost
- Local Borrow Soil and Rock
Remediation and Stabilization Using Natural Materials

*Carex*  
*Willows*
## Soil Treatment and Vegetation Trends—Arkansas River OU 11

<table>
<thead>
<tr>
<th>Soil Characteristic</th>
<th>Pre-Treatment</th>
<th>Post-Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Metals</td>
<td>Elevated</td>
<td>Elevated</td>
</tr>
<tr>
<td>Soluble Metals</td>
<td>Elevated</td>
<td>Reduced</td>
</tr>
<tr>
<td>Soil pH</td>
<td>Acidic</td>
<td>Neutral/alkaline</td>
</tr>
<tr>
<td>Soil Fertility</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Soil Organic Matter</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Biological Function</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Erosion</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetation Characteristics</th>
<th>Pre-treatment</th>
<th>Post-treatment*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation Cover</td>
<td>Bare-Sparse</td>
<td>Moderate-Heavy</td>
</tr>
<tr>
<td>Plant Production</td>
<td>Very Low</td>
<td>Low-Heavy</td>
</tr>
<tr>
<td>Metals in Vegetation</td>
<td>Elevated</td>
<td>Low-Moderate</td>
</tr>
<tr>
<td>Typical Species</td>
<td>Weedy/Low-value forage</td>
<td>Non-weedy/High-value forage</td>
</tr>
<tr>
<td>Utility for Grazing</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>
10 year old treated tailings

Livestock grazing remediated land
Questions/Discussion

Contact Information:
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