CAPTAIN JACK MILL SUPERFUND SITE

Pre-Design Investigation and Subsurface Remedy Design Concept

Craig Weber, P.E., AMEC E&I
Abby Bazin, P.E., AMEC E&I
Bruce Wielinga, PhD, AMEC E&I
Acknowledgements

- Colorado Department of Public Health and Environment – Mary Boardman
- U.S. Environmental Protection Agency, Region 8 – Joy Jenkins

Key Partners
- Zonge International
- RAS, Inc.
- Multi-Phase Technologies, LLC
- James Drilling
- Flatirons Surveying, Inc.
- Agapito Associates, Inc.
- McCollum Excavating
Presentation Overview

- Technical and Regulatory Background for Captain Jack Site
- Pre-Design Activities and Findings
- Subsurface Remedy Schematic Design
  - Flow-through Bulkhead
  - Mine Pool Treatment
  - Long-term Monitoring
Concern is.... Acid Mine Drainage

Video shows flow emerging from a “spring” at 850 feet within mine at base of large collapse.

- 30 – 150 gpm (seasonal)
- pH – 2.5 to 4.5
- Discharge to Left Hand Creek
- Elevated Metals: Fe, Al, Cu, Mg, Mn, Zn
Regulatory Summary

- Mining and Milling Operations from 1890’s to 1992
- Listed on National Priority List (NPL) by USEPA in September 2003 due to Heavy Metals Loading to Left Hand Creek Watershed
- Colorado State Lead
- ROD Signed in September 2008 by EPA and CDPHE
- Remedial Effort Divided into Two Actions:
  1) Surface Cleanup
  2) Subsurface Remedy
- AMEC E&I Selected for Subsurface Remedy Remedial Design in February 2011
Selected Remedy in the ROD

**Alternative 3B from the RI/FS**

- **A bulkhead** with stainless steel through-piping and valves
- **Mine-pool mitigation** anticipated to include a neutralization loop with an injection and extraction well drilled into the tunnel reservoir
- **Operational monitoring**

**Treatment Concept**

- Treats mine water **“in-situ”**
- **Submerges source materials** (to the extent safely practicable) in order to minimize contact with oxygen
- Implement **active neutralization** of impounded mine-pool waters
- If needed, a second phase of remedial operations will include an ex-situ bioreactor
Site Characteristics

8,800 feet amsl
Site Characteristics

- Mixed Ownership
- Collapse Blocks Access Beyond 900 feet in Tunnel
- Cold, Snow
- Limited Site Security
- Steep Terrain
- Lack of Utilities
Historical Mine Workings

- Columbia Workings
- Niwot X-Cut
- Captain Jack Main Adit Portal
Historical Mine Workings

- Niwot X-Cut
- Columbia Vein
- Dew Drop Workings
- Portal
Dew Drop Workings

250 feet above Big Five and parallel

Connection to Big Five?

Dew Drop Mine

Dew Drop Portal
Columbia Vein Workings – Near Ward, CO
Pre-Design Investigation Summary May 2011 – January 2012

- **Treatability Evaluation**
  - Laboratory Neutralization Testing / Modeling
  - Sampling and Analytical Tests (mine flows)
  - Installation of Flow Meter
  - Dye Tracer

- **Geophysical Survey**
  - Dipole-Dipole/Zeta Electrical Resistivity and Induce Polarization
  - In-tunnel Mise-a-la-Masse (MALM) Resistivity

- **Tunnel Geotechnical Testing**
  - Visual Mapping
  - Coring

- **Drilling Program**
  - Access Road Construction
  - Air Rotary Investigative Borings
  - Borehole Geophysics (video, deviation, acoustic televiewer, electrical logs, optical televiewer, packer pressure testing)
  - Well Completions
  - Groundwater Monitoring/Sampling

- **Borehole to Borehole Electrical Resistivity Tomography (ERT)**
### Treatability Data

#### Test Conditions

<table>
<thead>
<tr>
<th>Test Conditions</th>
<th>Alkali Consumption</th>
<th>Solids Production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ca(OH)₂ (g/L)</td>
<td>NaOH (ml/L)</td>
</tr>
<tr>
<td>pH 7.5</td>
<td>0.195</td>
<td>0.271</td>
</tr>
<tr>
<td>pH 8.0</td>
<td>0.205</td>
<td>0.279</td>
</tr>
<tr>
<td>pH 8.5</td>
<td>0.215</td>
<td>0.282</td>
</tr>
<tr>
<td>pH 9.0</td>
<td>0.233</td>
<td>0.289</td>
</tr>
<tr>
<td>pH 9.5</td>
<td>0.247</td>
<td>0.296</td>
</tr>
</tbody>
</table>

#### Captain Jack AMD as Collected

<table>
<thead>
<tr>
<th>Metals scan</th>
<th>Analysis by AGAT Laboratories</th>
<th>Analysis by TestAmerica</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dissolved mg/L</td>
<td>Total mg/L</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>161</td>
<td>162</td>
</tr>
<tr>
<td>Cobalt (Co)</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>8</td>
<td>8.4</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>23</td>
<td>48</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>9.7</td>
<td>9.8</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>0.14</td>
<td>0.14</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>335</td>
<td>338</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>3.3</td>
<td>3.4</td>
</tr>
<tr>
<td>Sulfates (SO₄)</td>
<td>1005¹</td>
<td>1014¹</td>
</tr>
</tbody>
</table>

**Note ¹** Sulfate concentration reported was calculated based on S analysis (ICP) by AGAT Laboratory

**Note ²** Sulfate concentration reported was analyzed by ion chromatography at TestAmerica Laboratory
AMD Evaluations

Sample Collection at 800 feet

Flow Velocity Logger

One of Several Seeps

Flow Meter Installed

Flow Rate (gpm)
Geophysics – Locate Mine Workings

Transmitting Electrode Connected to Rails in Dew Drop Mine
Geophysics – MALM Summary

MALM Data August 2010 Legend:

- Road
- Interpreted Big Five and Nikot Location (by Geophysics)
- Interpreted Dew Drop Location (by Geophysics)
- Historic/Extrapolated Big Five Location (Provided by AMEC)
- Proposed Boreholes (Grey - as discussed 09/12/11, black - new)

Survey Line Locations (with data plot points/stations)

Scale 1:5000

AMEC
Captain Jack
Mise-a-la-Masse
Transmitter Source - Big Five Tunnel (Tx1)
Field work August 2011
September 2011

Zonge International, Inc.
Mine Tunnel Geotechnical Testing

Proposed Bulkhead

Portal
Geotechnical Work

Pneumatic Core Drill

Hydraulic Pressure Test
Drilling Effort

Air Rotary Rig (James Drilling)

Dew Drop Wells

Road Rough Cut (McCollum Excavating)
Drilling Summary
Borehole Investigation
Borehole Logging
Electrical Resistivity Tomography (ERT)

Figure 13. Borehole to surface data at the CDOT right of way. The adit depth is at approximately 225 feet and resembles the similar pattern as the theoretical model shown in Figure 1.
Dew Drop ERT Tunnel Locate

Location for Dew Drop 3 Borehole
Dew Drop 3 Video in Mine
Dew Drop Permanent ERT Installation

- Dew Drop #1 and #2 fitted with ERT Array
- 32 Electrodes per each cable array per boring spaced at 6 or 12 feet
- 12 Type K thermocouples at 25 foot spacing in boreholes
- Installed between 4-inch PVC well casing and borehole wall and backfilled with sand
Consolidated Plan View

Explanation
- Boring Locations
- Surface areas - mapped during May 2011 surface reconnaissance
- Surface Collapse
- Drainage
- Pond
- Dew Drop Portal
- Surveyed Big Five Tunnel
- Approximate location of Columbia Mine workings
- New Road

Interpretation from Surface Geophysical Investigations (5/15/2011)
- Dew Drop
- Big Five Tunnel
- Niwot Crossout (dashed where inferred outside limit of geophysical investigation study area)

Number represents elevation references in Table 4

REFERENCE POINTS FOR MINE Pool ELEVATION
Captain Jack Subsurface Remediation
Ward, CO

By: [signature]
Date: 5/15/2011
Reference: [reference number]
Plan and Profile

Legend:
- HWY TO HWY HIGHWAY
- BIG 5 TUNNEL
- EXISTING BORINGS

Note: * = denotes water level measurement prior to drain down in Dew Drop #5

Plan and Profile Views of Exploratory Borings
Captain Jack Superfund Site
Ward, Colorado

By: JDU  Date: 05/12  Project No: 061180305

Figure 5
Remedy Concept
Key Engineering Objectives

- Plug Big Five Mine Tunnel to Flood Mine Workings and Eliminate Portal Discharge
- Treat Portion of Resulting Mine Pool In-Situ to Raise pH and Precipitate Metals
- Minimize Long-Term Operating and Maintenance Costs of Treatment
- Monitor Mine Pool Development and Water Quality; and Surrounding Surface and Subsurface Conditions
- Minimize Costs of Long-term Monitoring with Remote Data Acquisition
Data Gaps and Assumptions

DATA GAPS:
- Condition of Mine Beyond 900 Feet
- Extent of Connected Mine Workings (Volume)
- Main Source of AMD (Columbia vein via Niwot X-cut??)
- Mine Pool Leakage Rate vs. Pressure Increase
- Equilibrium Pressure
- Potential to “flood” workings on Columbia Vein near Ward

ASSUMPTIONS:
- Current Assumption: 1,000 feet of tunnel = 710,000 gallons
- Bulkhead will leak treated water suitable for discharge to creek
- New pathways for surface leaks (springs) would likely manifest east of Hwy. 72 where pressure is greatest and distance to surface is shortest
Concrete “Mass” Bulkhead

CONCRETE MASS BULKHEAD (PLUG)
Recirculation Alternative – Short

CAPTAIN JACK TUNNEL IS DRAWN TO SCALE. CIRCULATION UTILITIES AND PIPING ARE APPROXIMATE.
“Passive” Limestone Bed

CAPTAIN JACK TUNNEL IS DRAWN TO SCALE. CIRCULATION UTILITIES AND PIPING ARE APPROXIMATE.

NOT TO SCALE
In-Situ Sulfate Reducing Bioreactor

CAPTAIN JACK TUNNEL IS DRAWN TO SCALE. CIRCULATION UTILITIES AND PIPING ARE APPROXIMATE.
Autonomous Long Term Monitoring - ERT
Long-Term Monitoring – Automated Samplers
Power Supply

- Line Power – Not available on site; 2,500 feet to nearest potential source
- Generator – Long term maintenance; fuel storage; fuel resupply
- Wind – Erratic in this vicinity
- Solar – Good potential pending power demand
  - Estimate 3 Kw/hr max. (as needed, intermittent)
  - Estimate 500 ft² of PV panel – direct connect (no battery storage)
Thank You – Questions?

Craig Weber, AMEC E&I
303.630.0771
craig.weber@amec.com