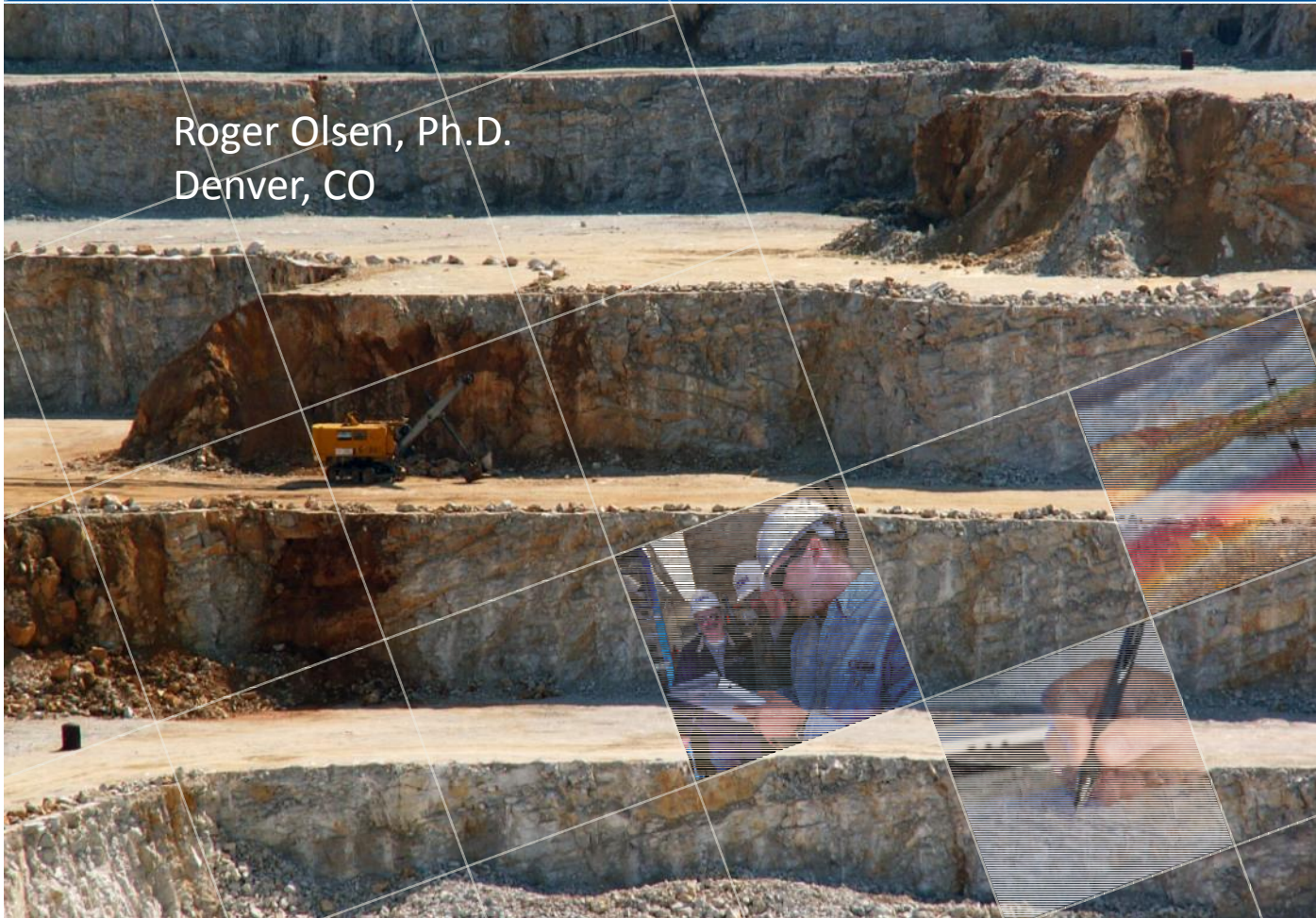


Superfund and Mining Sites: A Review of the Past and Observations Concerning the Future

U.S. EPA Hardrock Mining Conference:
Advancing Solution for a New Legacy

April 2012

Roger Olsen, Ph.D.
Denver, CO

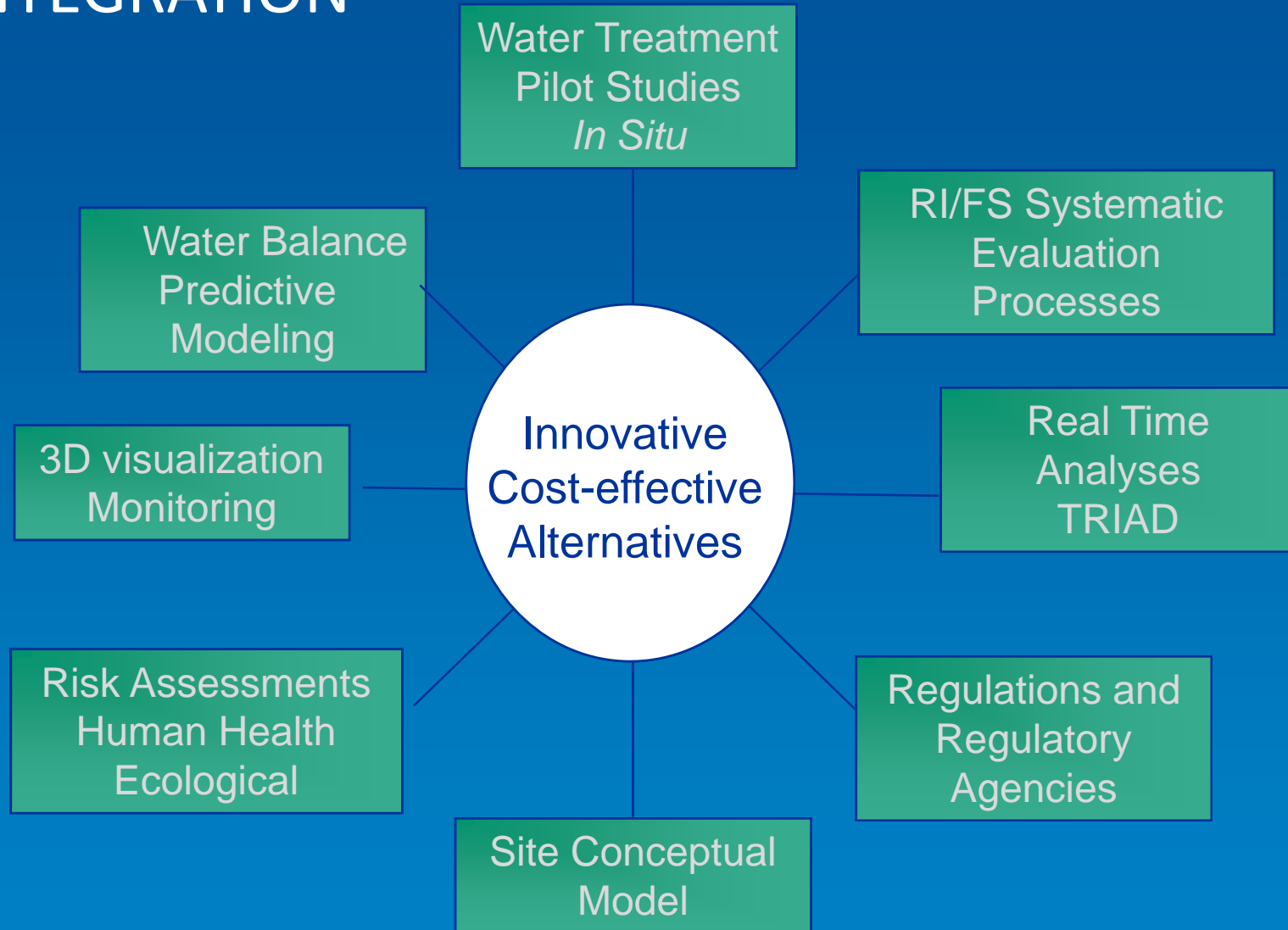


**CDM
Smith**

Discussion Topics

- Investigations
 - Real Time Analyses -> Triad
 - RI/FS Process
 - Site Conceptual Models
 - Water Balances
- Evaluations
 - Human Health and Ecological Risk Assessments
- Remediation
 - Regulatory Drivers
 - Water Treatment
 - *In Situ* Treatment

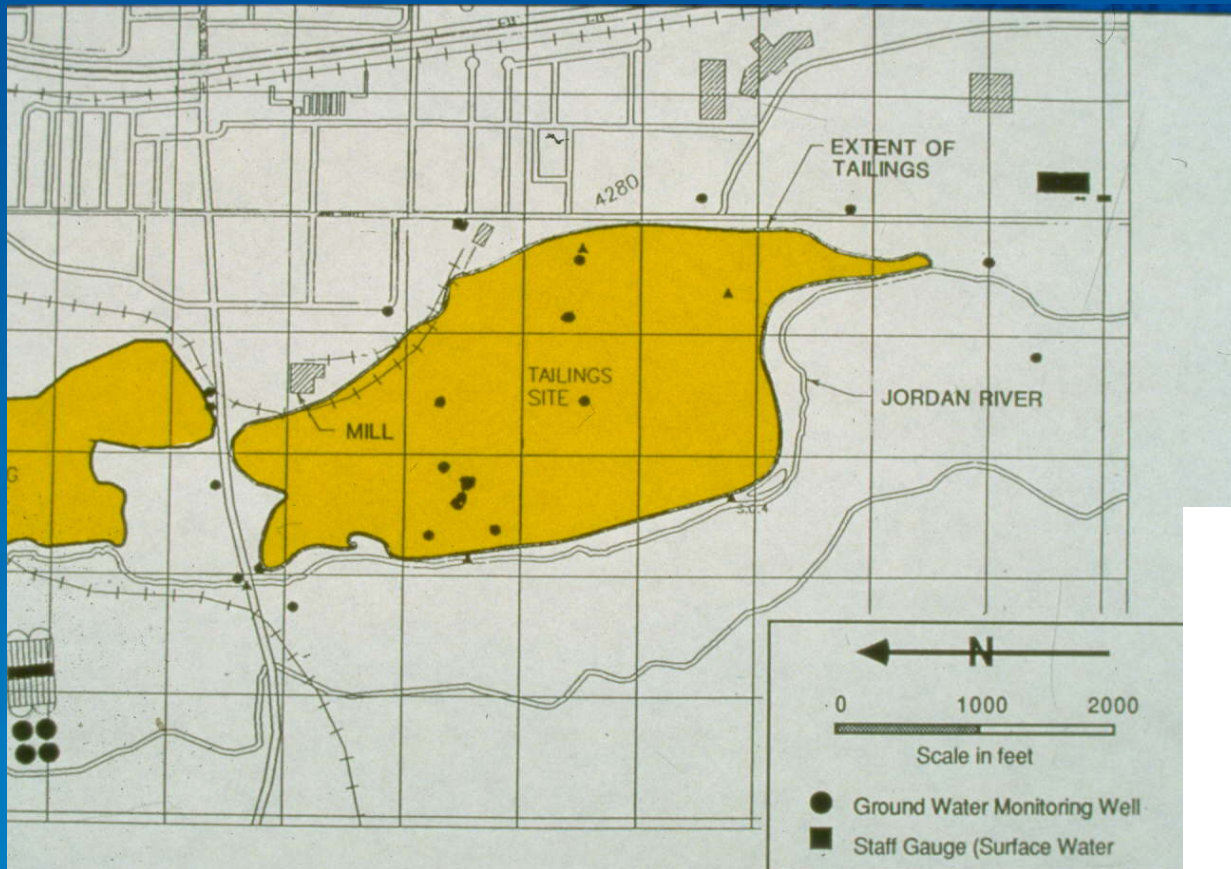
INTEGRATION



Discussion Topics

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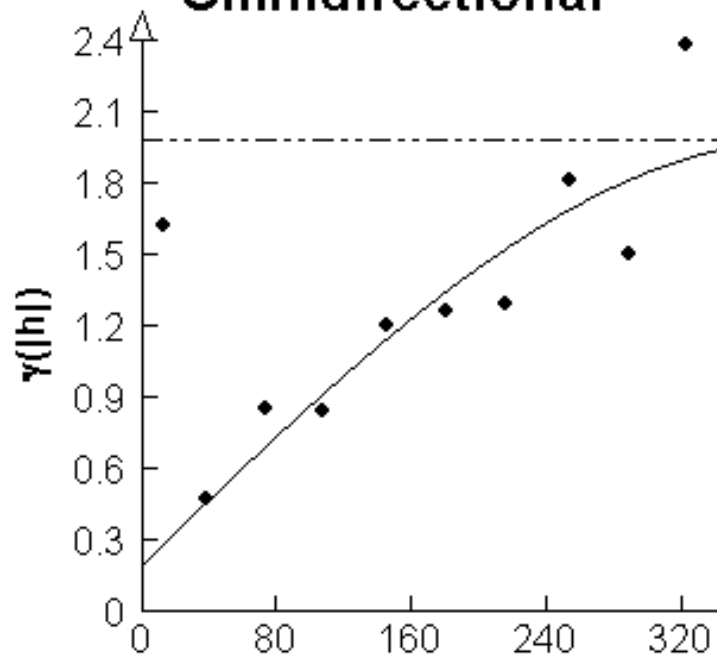
Sharon Steel - Real Time Analyses and Evaluations



X-MET 840



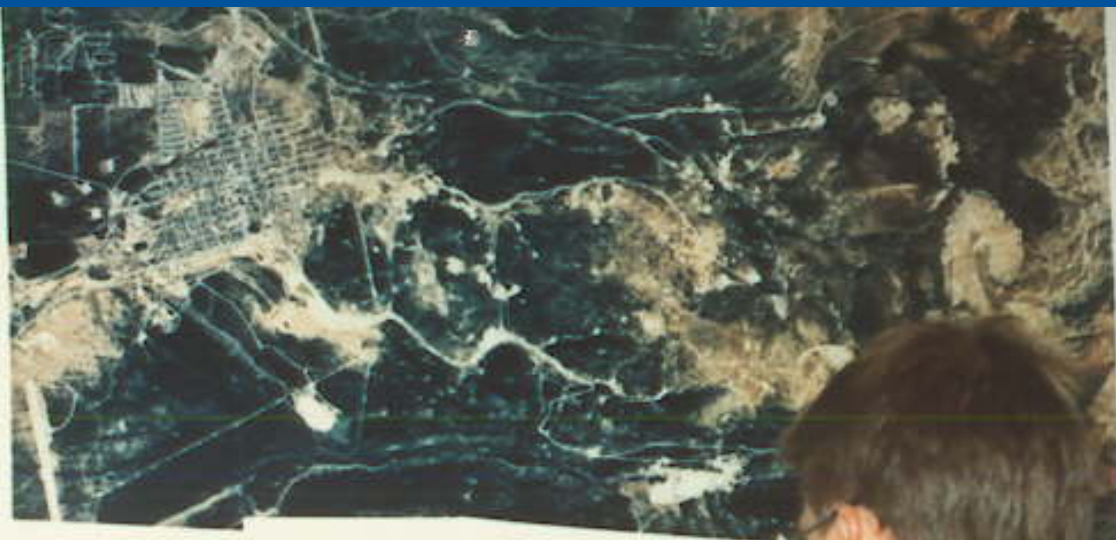
Omnidirectional



Sharon Steel
Kriged Pb Concentrations



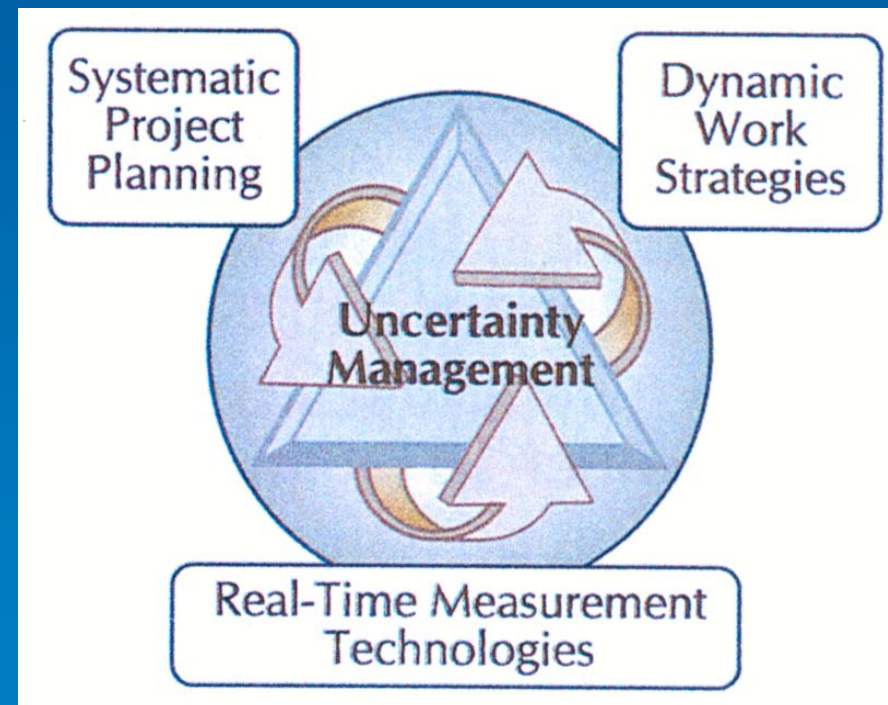
Leadville,
Colorado





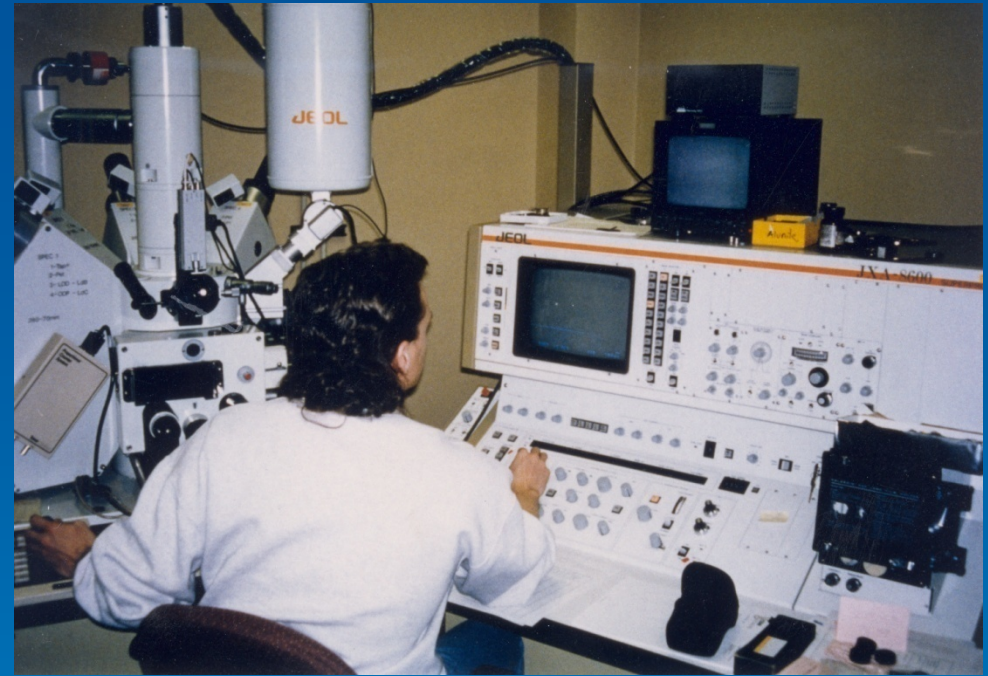
TRIAD Approach

- Systematic project planning providing roadmap and benchmarks
- Dynamic Work Plans
 - Guide Investigation
 - Flexible
- Use of real time measurement technologies
 - Real time data
 - Real time interpretation
 - Real time decisions

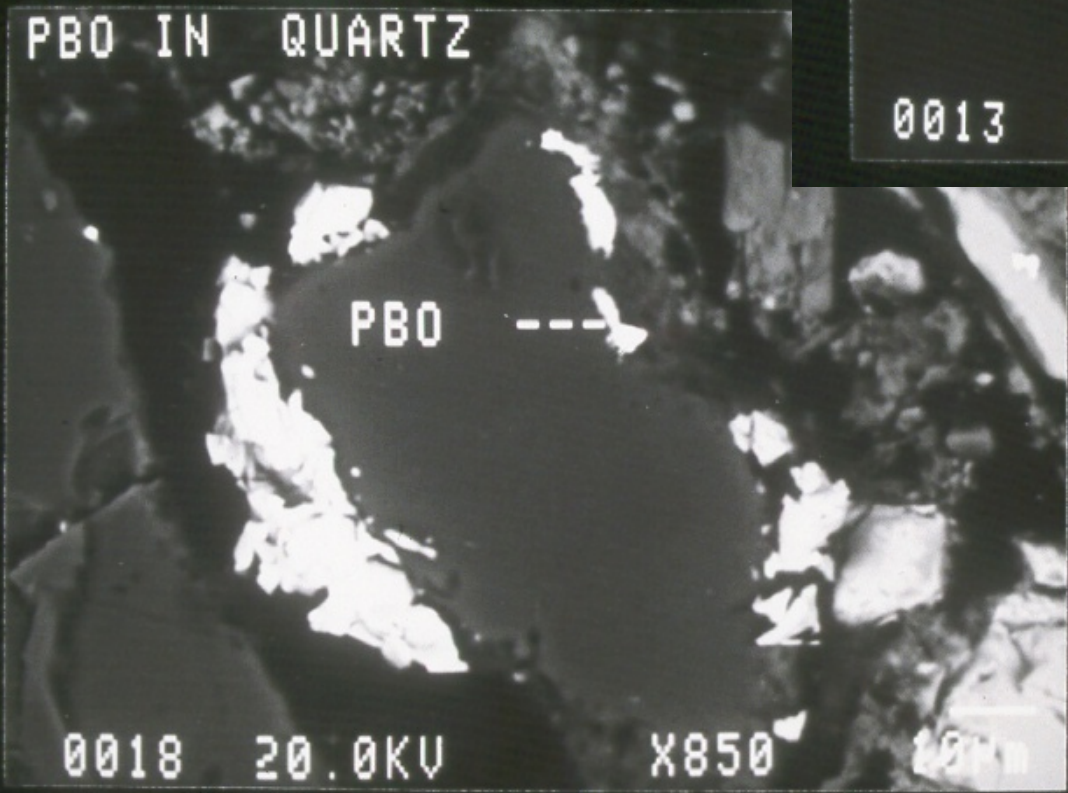
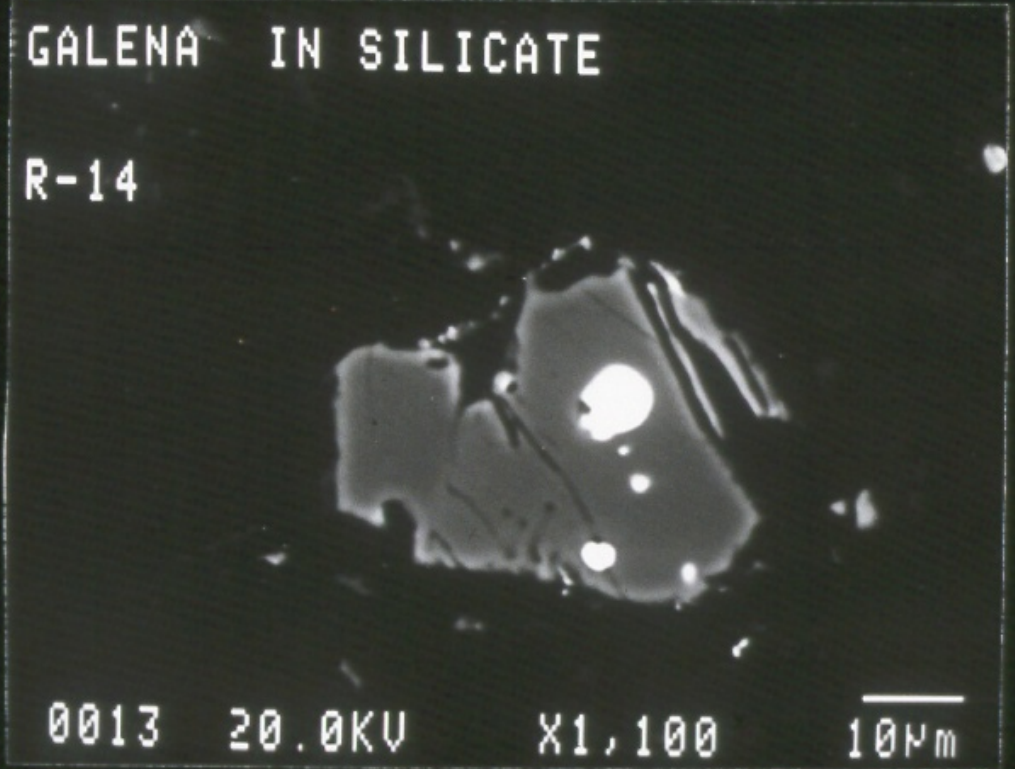


Electron Microprobe Analysis

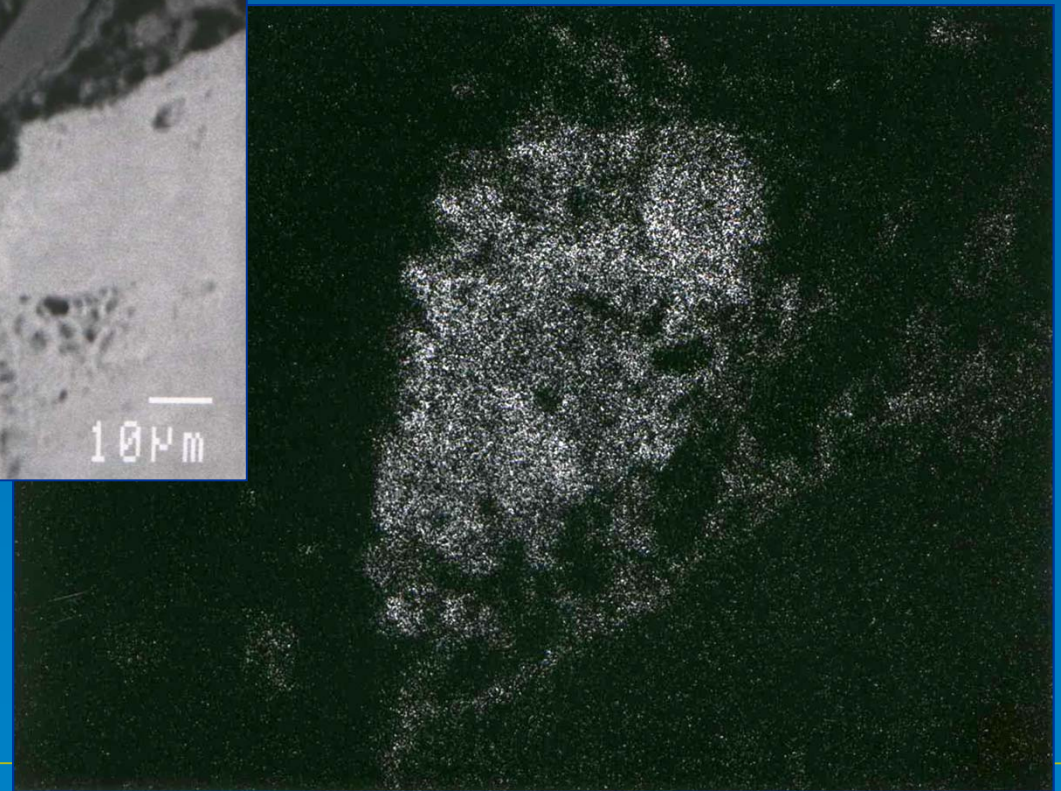
- Can view samples at 300,000X magnification
- Can analyze particles as small as 2 μm in diameter
- Can determine the forms (mineralogy) of As, Cu, Pb, and Zn



Sharon Steel, Utah
Residential Soil Samples



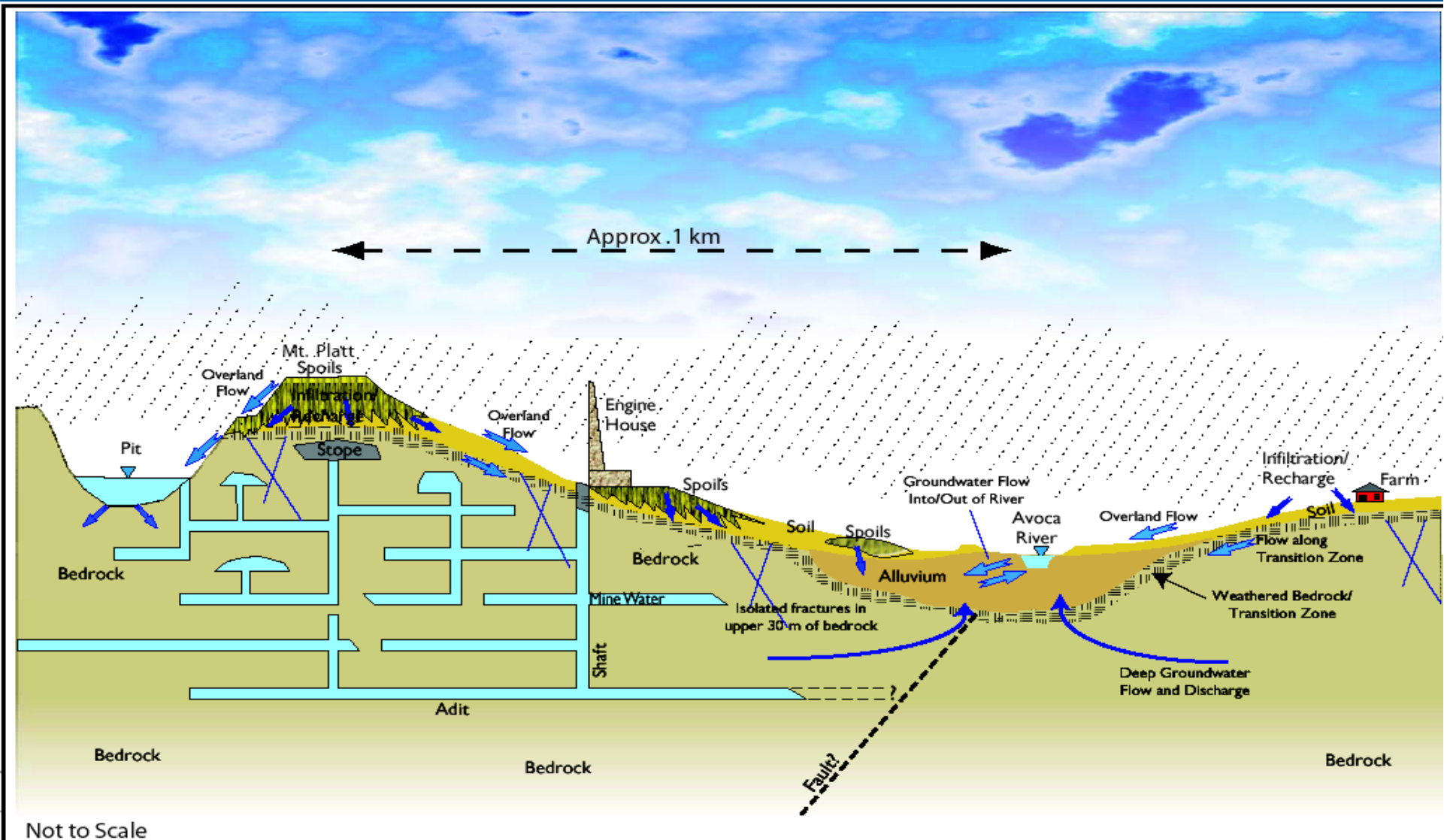
Sample As-25 - Iron Oxyhydroxide Dot Map



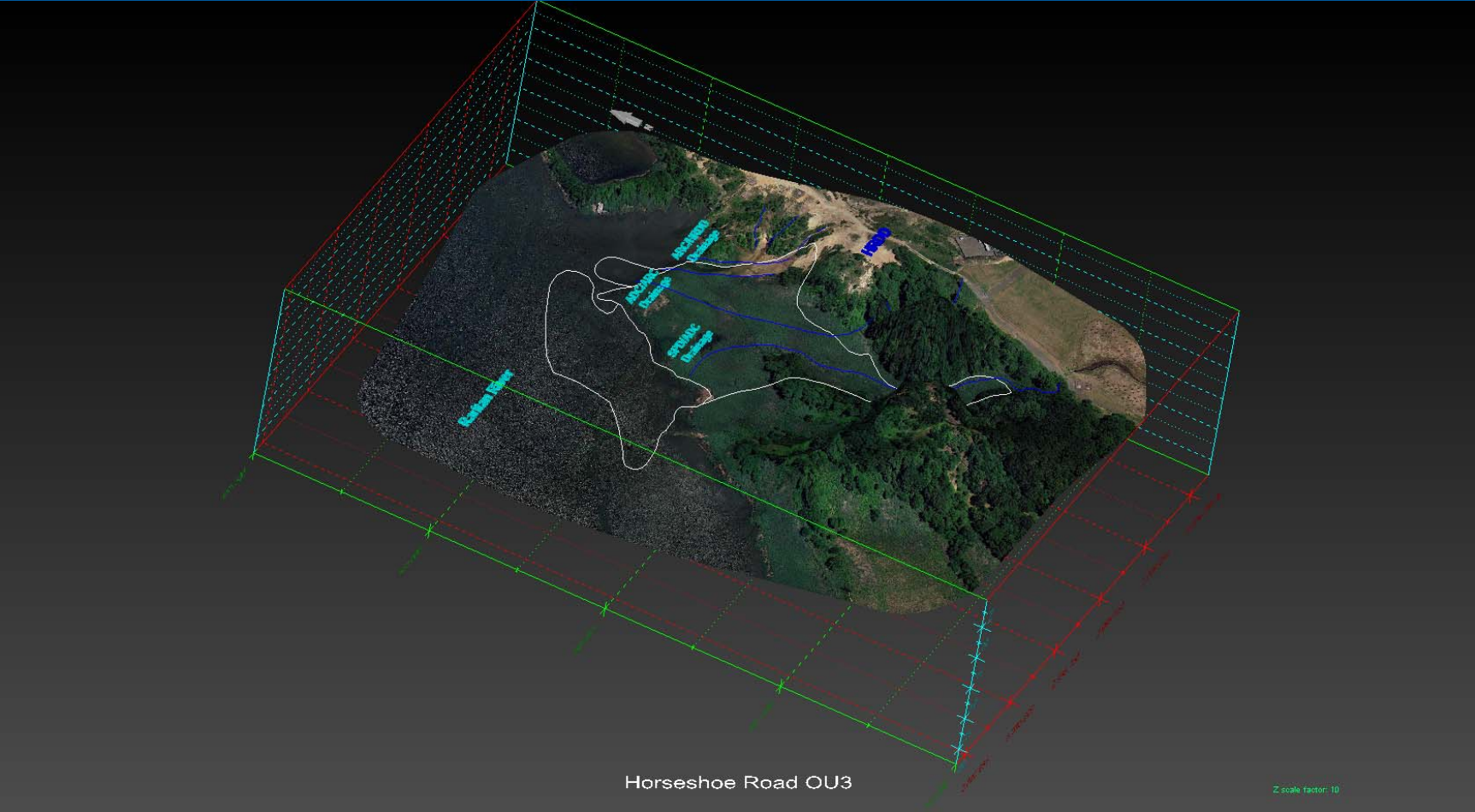
Systematic Early Planning

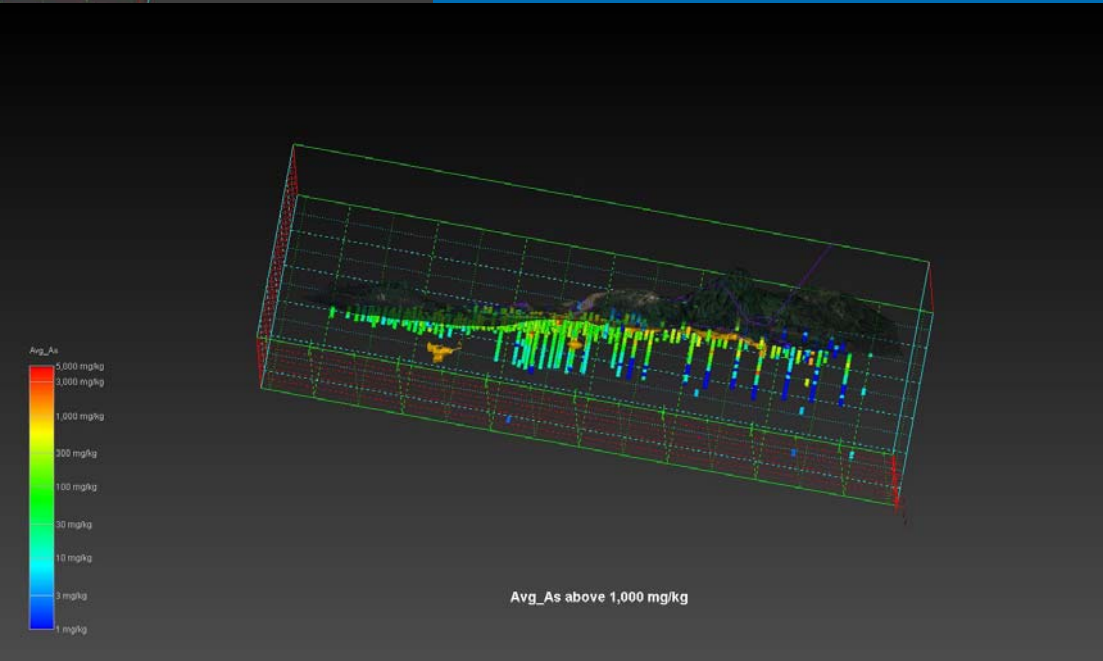
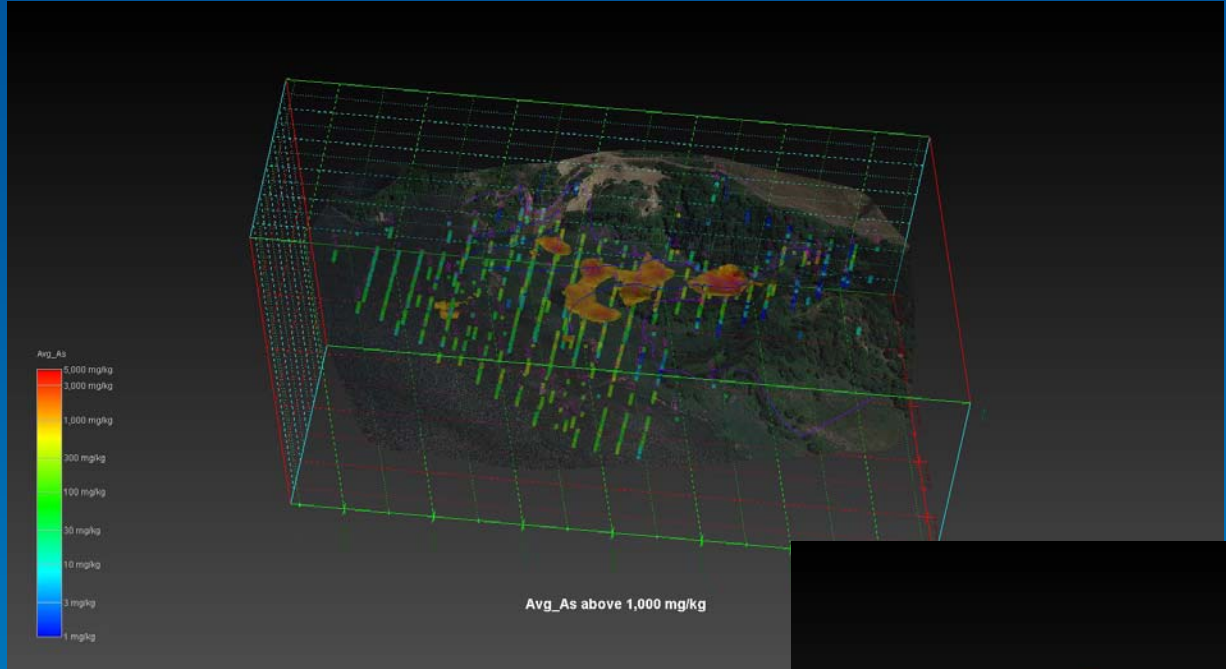


Site Conceptual Model



3D Visualization - MVS

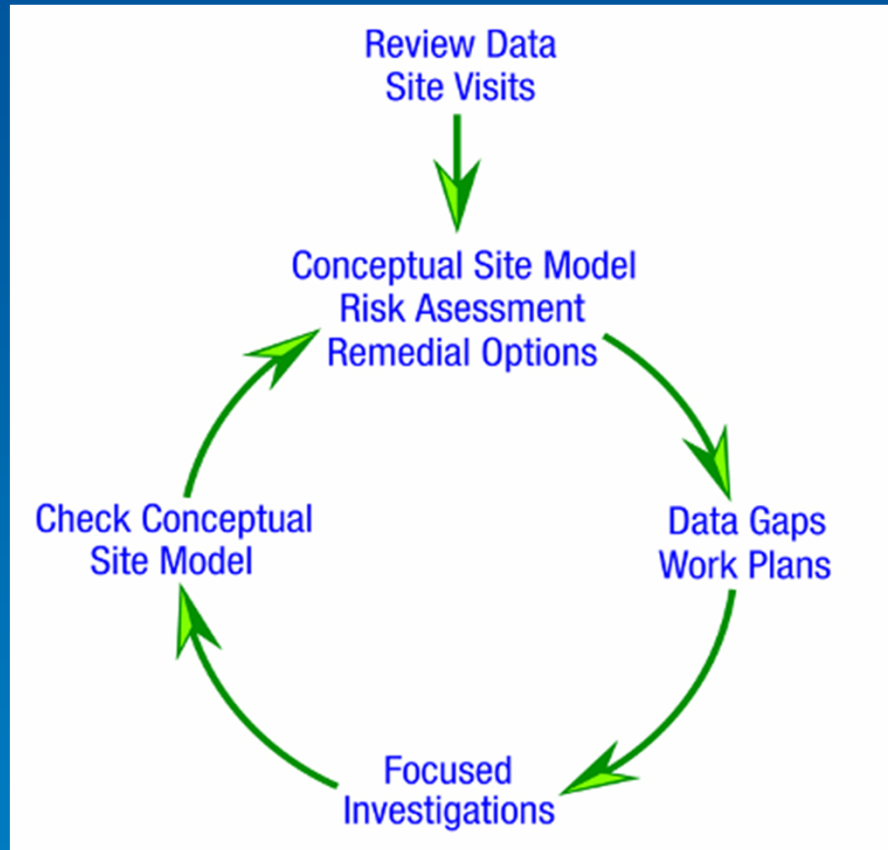




Investigative Approach

- Conceptual Site Model Development
- Preliminary Risk Assessment
- Identification and Evaluation of Potential Remediation Options

Outcome → Data Gaps



Key:

Site Understanding leads to
Innovative & Cost-effective Solutions

Water and Mass Balances Flow and Field Parameter Measurements



Tracer Study



Virginia Canyon – Nonpoint Source Load



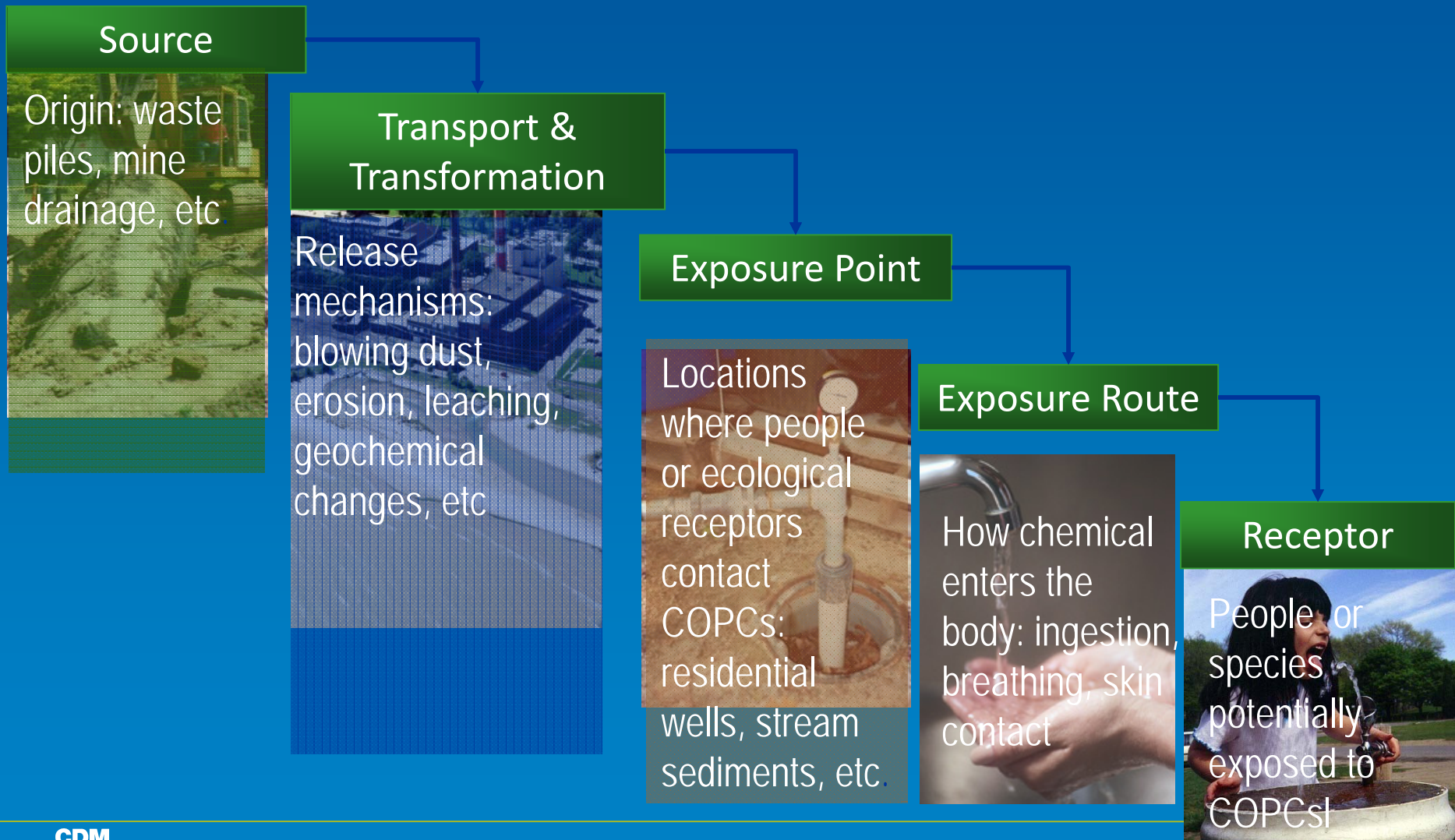
Virginia Canyon
Ground Water
Project: 200 to
500 lb zinc per day

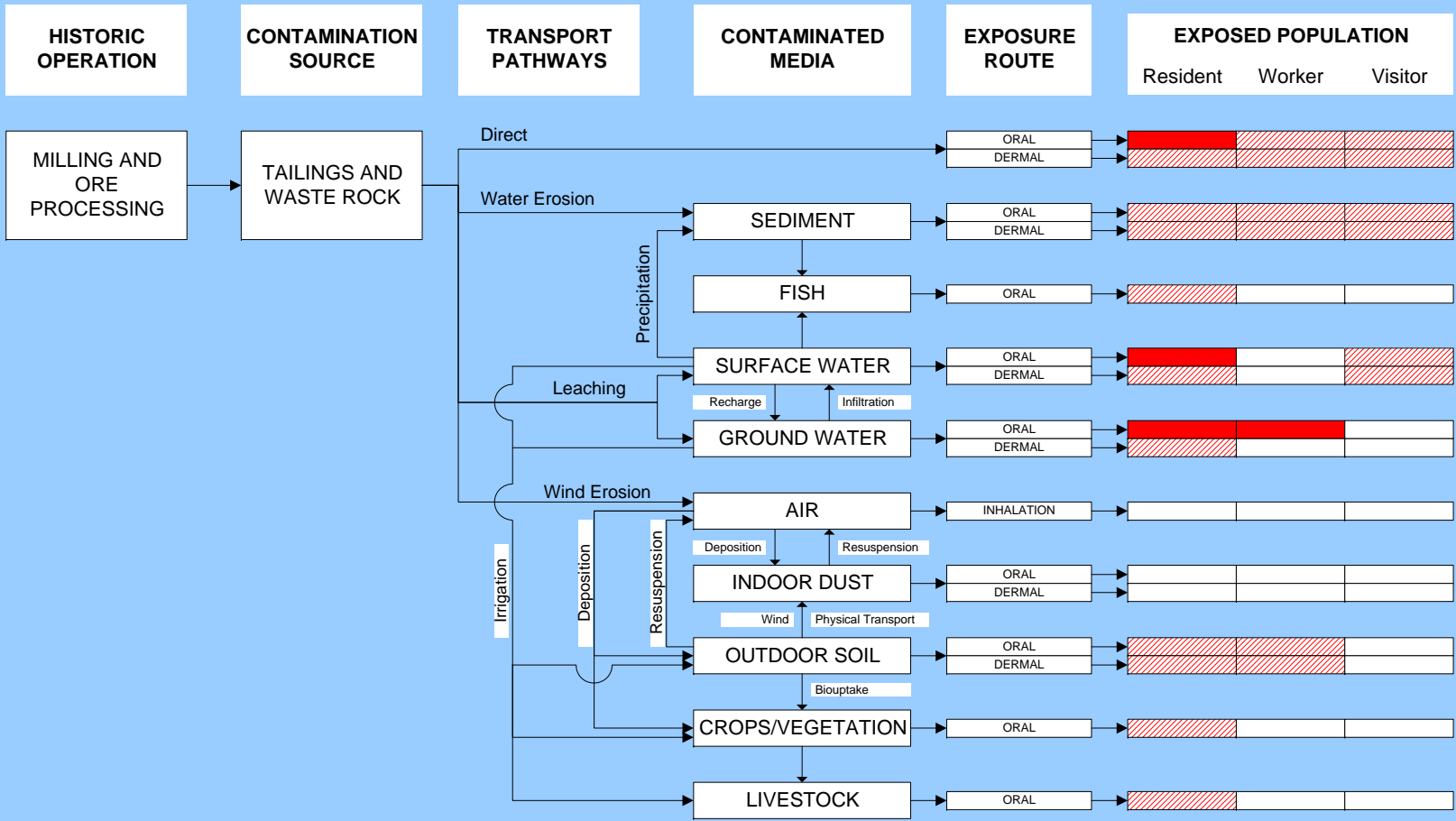
Discussion Topics

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Risk Assessment

Elements of an Exposure Pathway



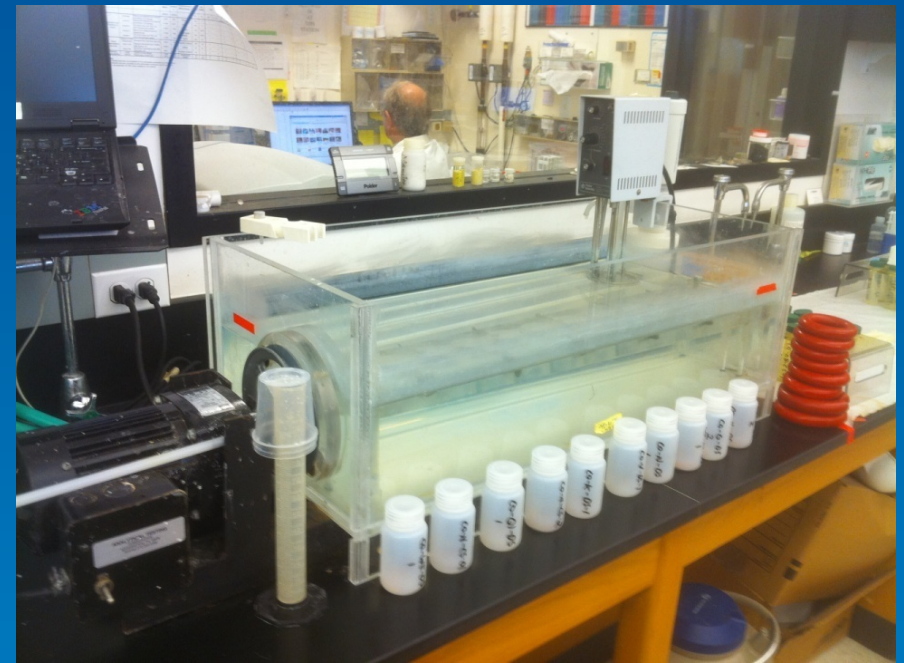
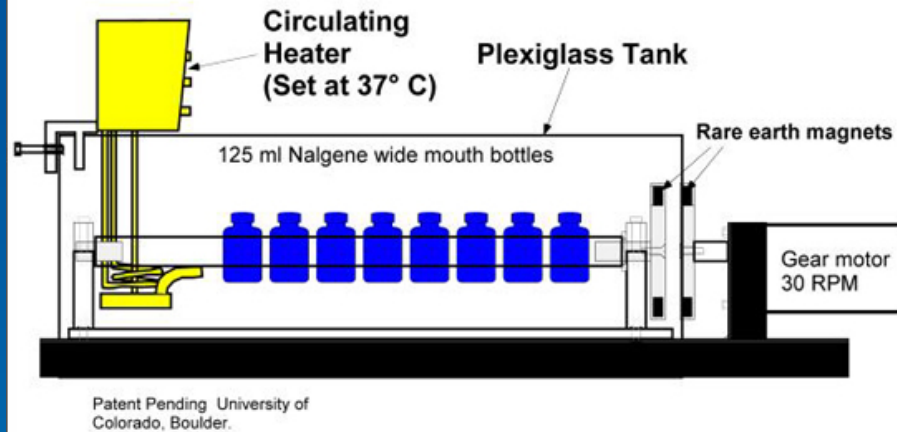


LEGEND

- Exposure pathway not complete.
- Exposure pathway may be complete. However, data are lacking.
- Exposure pathway is complete.

Figure 1.4-2. Conceptual Model for Historic Mining Site - Human Health - Milling and Ore Processing.

In-Vitro Bioassay



- 1 g spoils (<math><250\ \mu\text{m}</math>), 100 mL leach solution
- Leach solution (glycine solution adjusted to pH 1.5)
- Agitated for 1 hr in a rotary tumbler
- EPA Approved Methodology

Bioassay Results

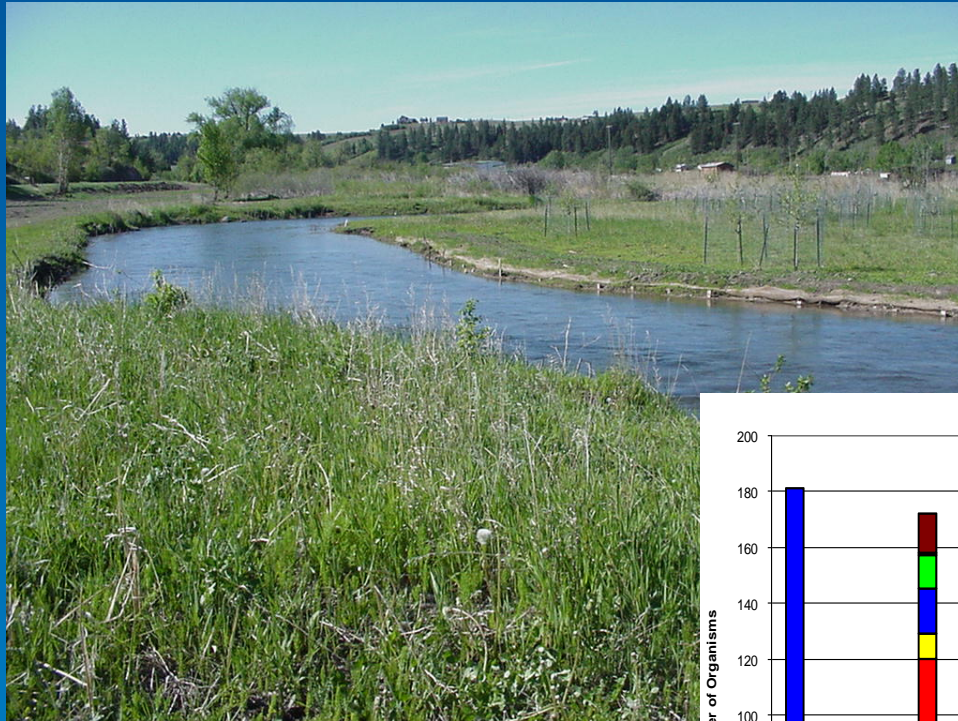
	Pb in <250 μ m Fraction (mg/kg)	Bioavailable Pb	As in <250 μ m Fraction (mg/kg)	Bioavailable As
Minimum	58.6	0%	14.8	0%
Maximum	56,022	28%	2,560	8%
Median	5,524	3%	706	0%
Mean	15,194	5.5%	927	0.5%
Standard Deviation	17,948	6%	673	1%
Covariance (%)	118%	118%	73%	302%

Other Human Health

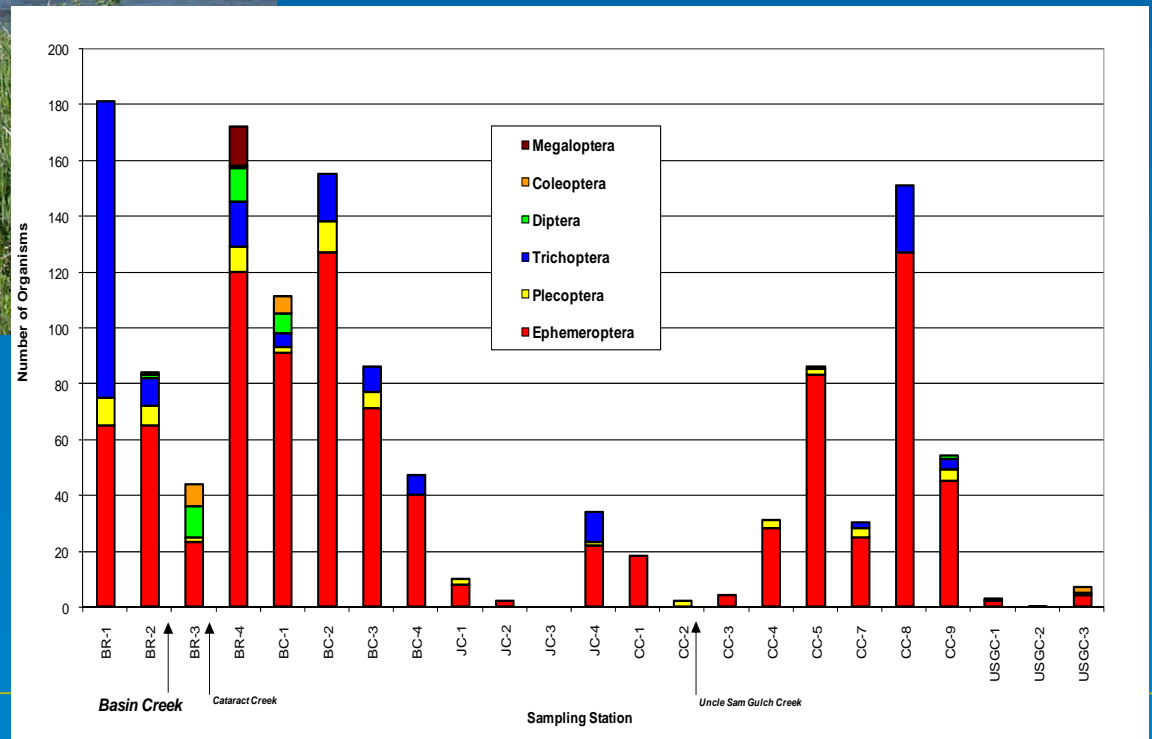
- Activity based exposures and sampling
- Realistic scenarios: less conservative and more accurate
 - Transfer coefficients dermal
- Site specific evaluations and values
- Bioavailability: Se, Sb , Mo



Ecological Risk Assessment



Aquatic Macrofauna as Ecological Sentinels



Chronic Surface Water Criteria and Toxicity Reference Values (TRVs)

COPC	National Recommended WQC, chronic ug/L	Site Specific TRV µg/L	Comment
Aluminum-total ¹	87	617	Trout-specific TRV based on trout-specific hardness equations (RBT, BK)
Barium	NONE	50	Gold Book, "toxicity unexpected at conc below 50 ug/L"
Beryllium	NONE	57	Tier II Secondary CV based on estimated lowest CV for fish, 1986 Gold Book
Boron	NONE	70	in Eisler 1990, Bio. Report 85(1.20), Contam. Hazard Reviews
Cadmium-dissolved ²	0.25	3.45	Trout-specific TRV based on trout-specific hardness equations (RBT, BT, BK)
Chromium (trivalent)-dissolved ³	74	178	Trout-specific TRV based on trout-specific hardness equations (RBT)
Chromium (hexavalent)	11	139	in EPA 440/5-84-029, geo mean of 2 CVs, ELS RBT
Cobalt	NONE	290	in Suter and Tsao 1996, Tier II Secondary CV based on lowest CV for fish (FHM)
Copper-dissolved ⁴	9.0	22	Trout-specific TRV based on trout-specific hardness equations (RBT, BT, BK)
Iron	1000	1,300	in Suter and Tsao 1996, Tier II Secondary CV based on lowest CV for fish (ELS FHM)
Lead-dissolved ⁵	2.5	169	Trout-specific TRV based on trout-specific hardness equations (RBT, BK)
Manganese-total ⁶	NONE	4,869	Trout-specific TRV based on trout-specific hardness equations (RBT, BT, BK)
Molybdenum	NONE	3,200	FCV based on 3 warmwater fish genera and 1 aquatic worm genus
Nickel-dissolved ⁷	52	160	Trout-specific TRV based on trout-specific hardness equations (RBT)
Selenium	NONE	64.4	in EPA 440/5-87-006, geo mean of two CVs for ELS RBT, Se IV
Vanadium	NONE	80	in Suter and Tsao 1996, Tier II Secondary CV based on lowest CV for fish
Zinc-dissolved ⁸	120	752	Trout-specific TRV based on trout-specific hardness equations (RBT, BT, CT, BK)

ELS = early life stage
 RBT = rainbow trout
 FHM = fathead minnow
 BT = brown trout
 CT = cutthroat trout
 BK = brook trout

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Regulatory Drivers

- Water Quality Standards Challenges
 - Strict Enforcement and no partial improvement
 - Designated use at highest level
 - Numeric criteria protective of complex and variable ecosystems
 - Lack of precision
- Potential Solutions: Use of Site-Specific Cleanup Goals
 - Performance Based Criteria
 - Risk Assessment
 - Use Attainability Analyses
 - Technical Impracticability
 - Alternate Cleanup Levels
 - Water Quality Trading

ITRC Mining Waste Treatment Technology Selection

Butte, Montana – Technical Impracticability Waiver Deep Groundwater

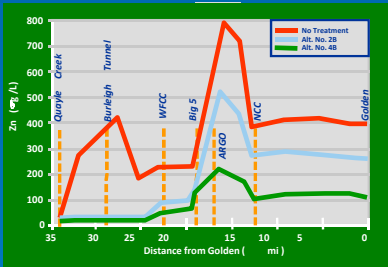
- Mining began in the 1870s and continued until 1975
- 10,000 miles of mine workings beneath the city.
- Mining in the Berkeley Pit began in 1955.



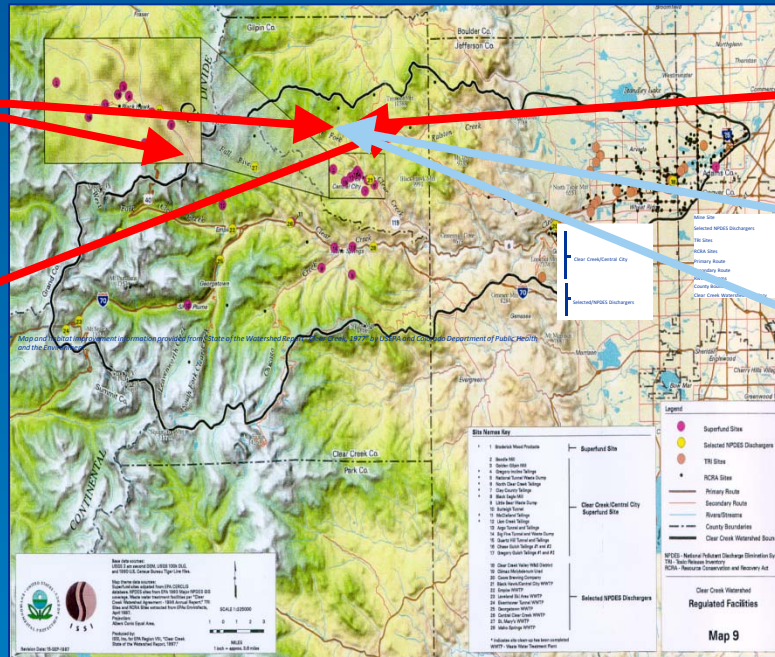
Clear Creek/Central City Superfund Site



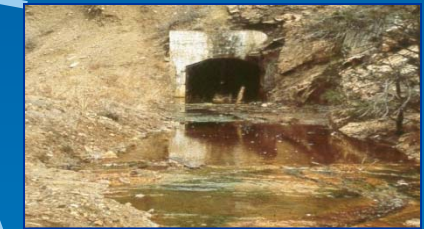
Wetland Treatment



Receiving Water Modeling



Runon/Runoff Control at Waste Rock Piles

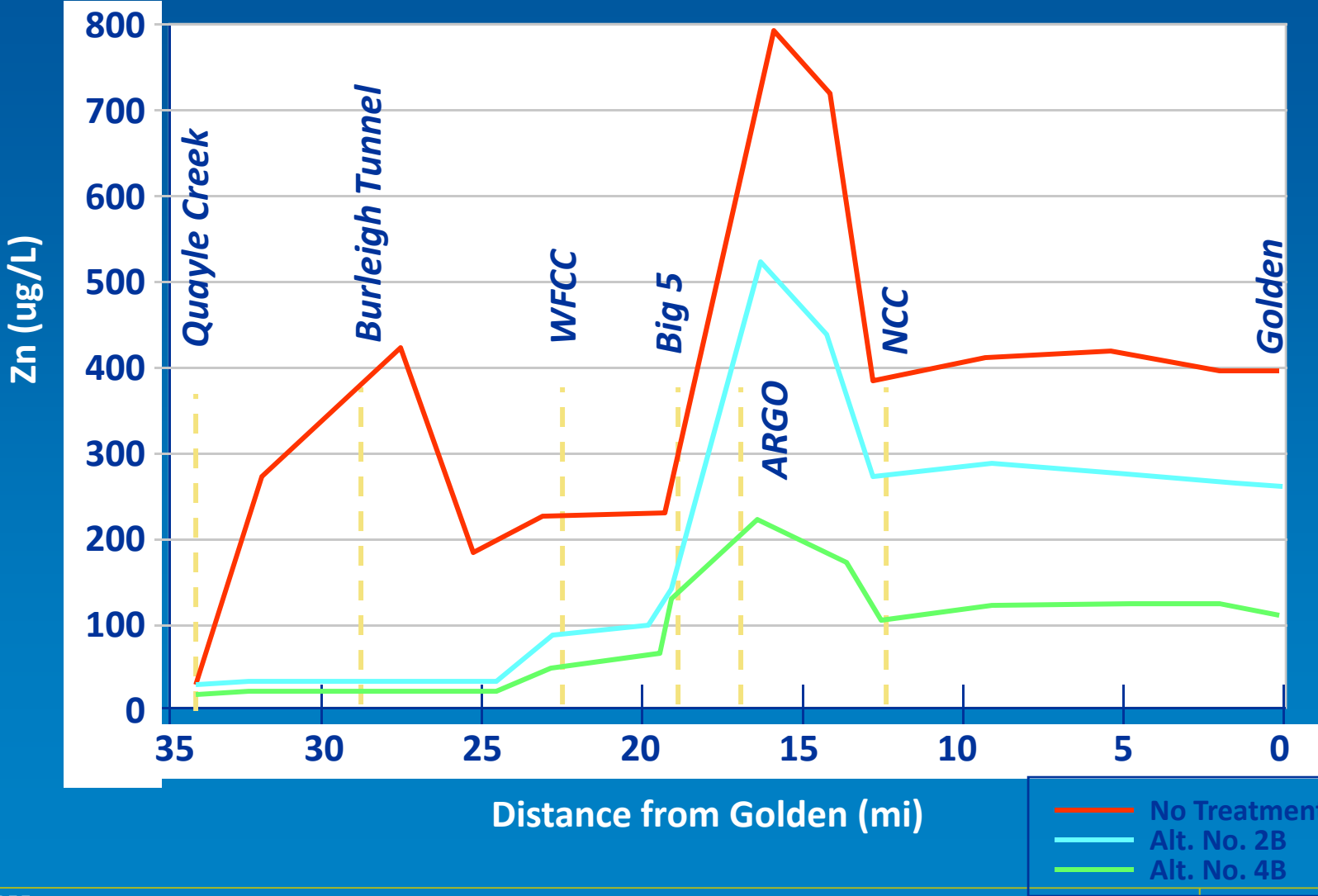


Argo Tunnel Before Remediation

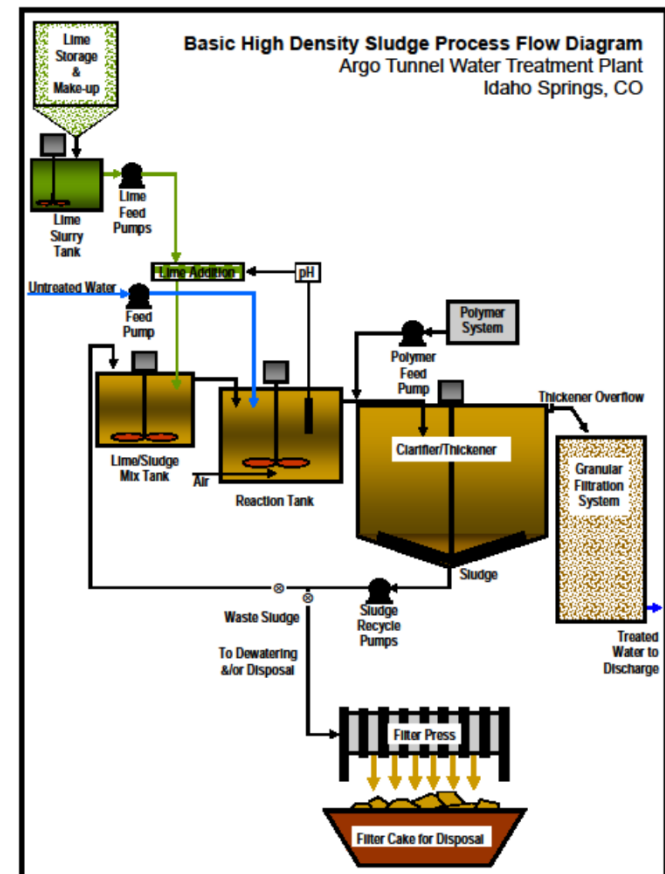


Argo Tunnel After Remediation

Predicted Zinc Concentrations in Clear Creek

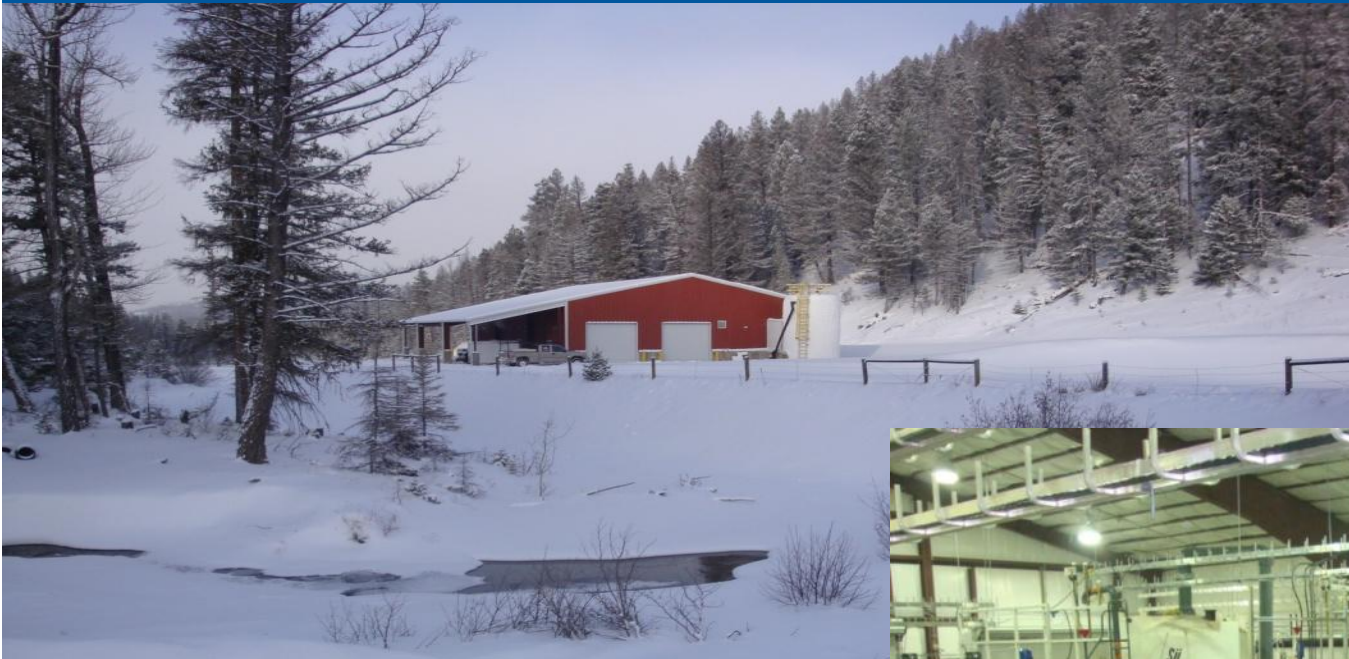


Argo Treatment Plant



This diagram illustrates the concept behind improvements planned for the Argo Tunnel Water Treatment Plant.

Mike Horse Mine Water Treatment System, Montana



Active Treatment System

Upper Blackfoot River Mike Horse Mine Water Treatment System, Lincoln, Montana

- For treating acid mine drainage from two adits
- Replaced a passive wetlands system
- Caustic precipitation and ceramic microfiltration treatment system
- Design Build Operate
- Ceramic filtration to 0.1 μm
- Re-circulates water through the system at a rate of 2,100 gpm



Gilt Edge Superfund Site – South Dakota



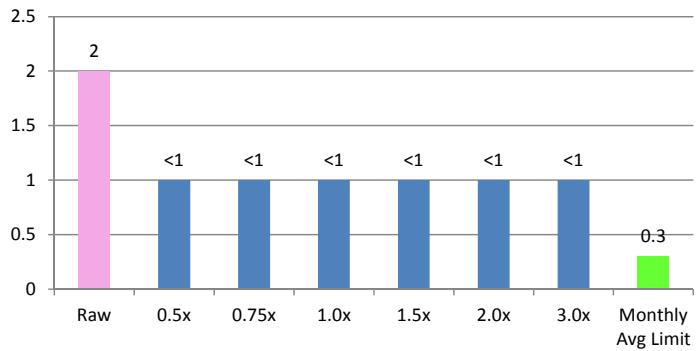
Gilt Edge Active Treatment Plant



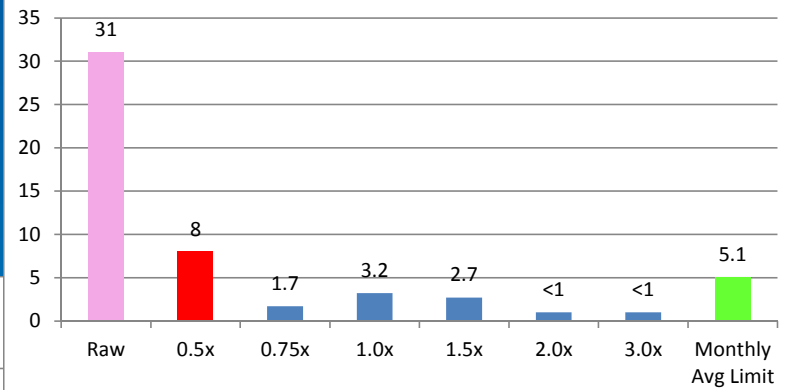


Bench Testing Water Quality Results ($\mu\text{g/L}$) – Sulfide Addition + pH Adjustment

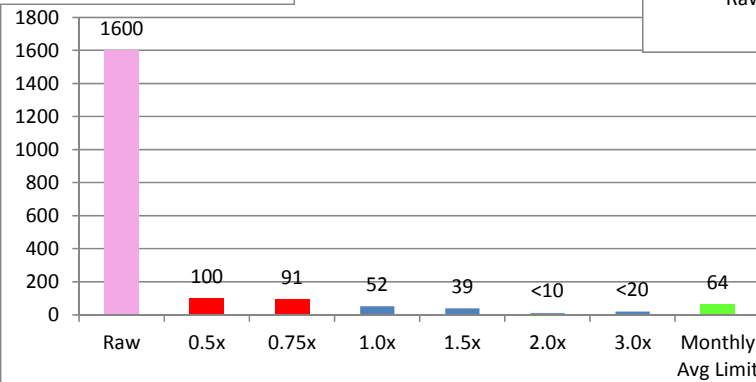
Cd - pH 9



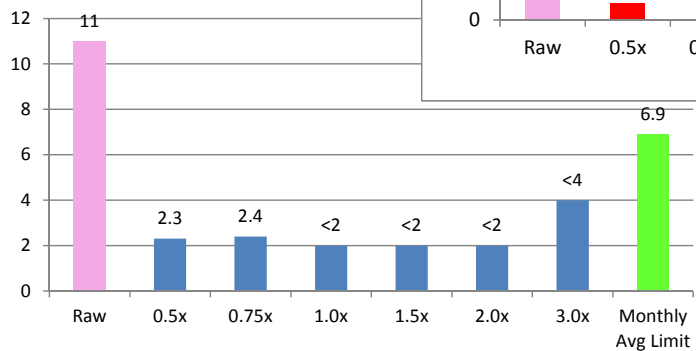
Pb - pH 9



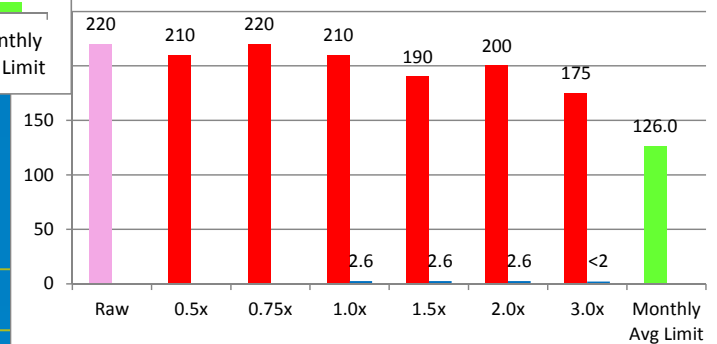
Zn pH 9



Cu - pH 9



Ni - pH 9/10



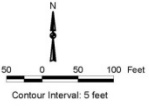
Anchor Hill Pit

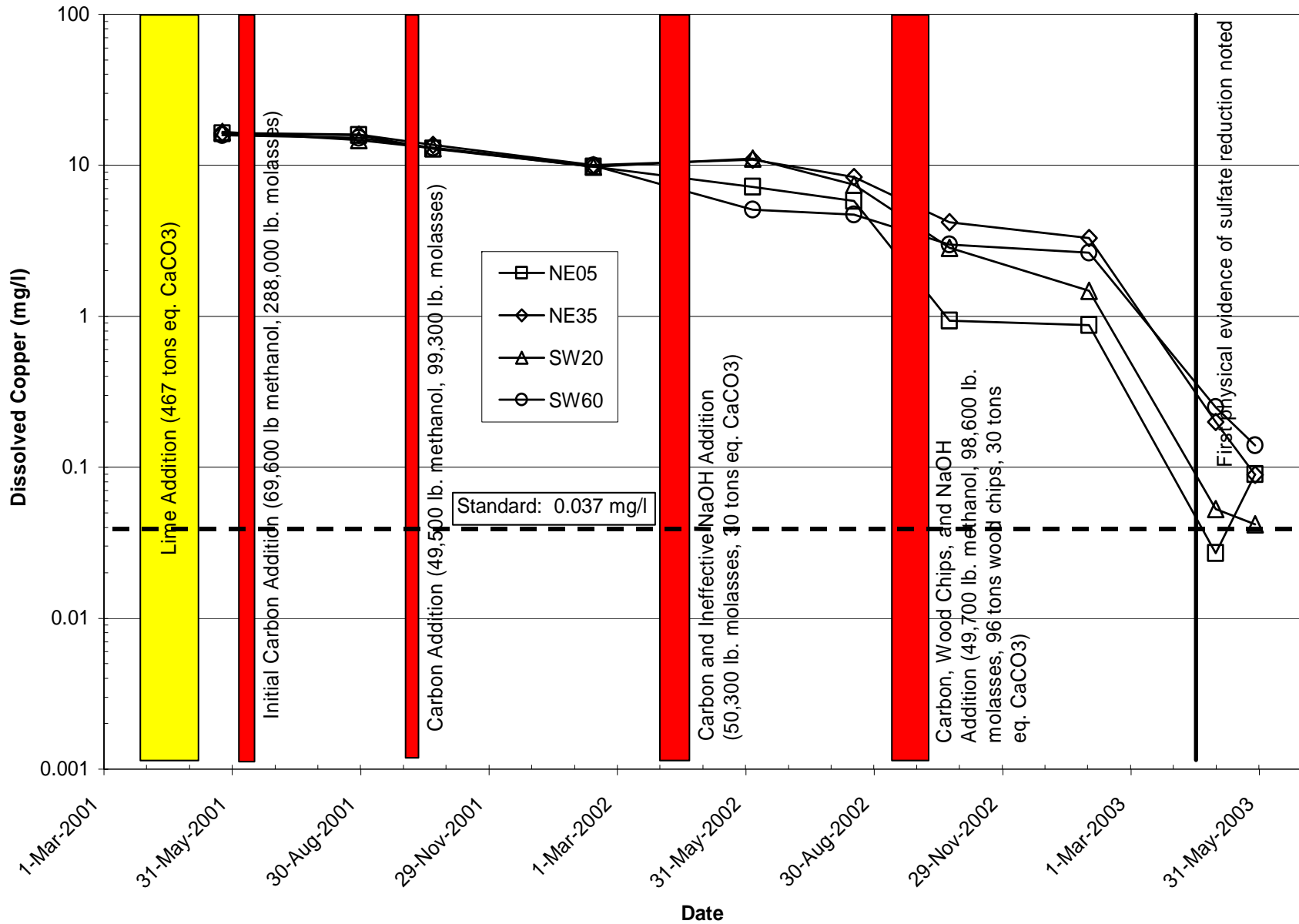


1:13,000 @ 11/15/2011 11:15:00 AM

CDM Federal Programs Corporation
A Subsidiary of CDMC (Contractors & Builders Inc.)

GILT EDGE MINE SITE
ANCHOR HILL PIT

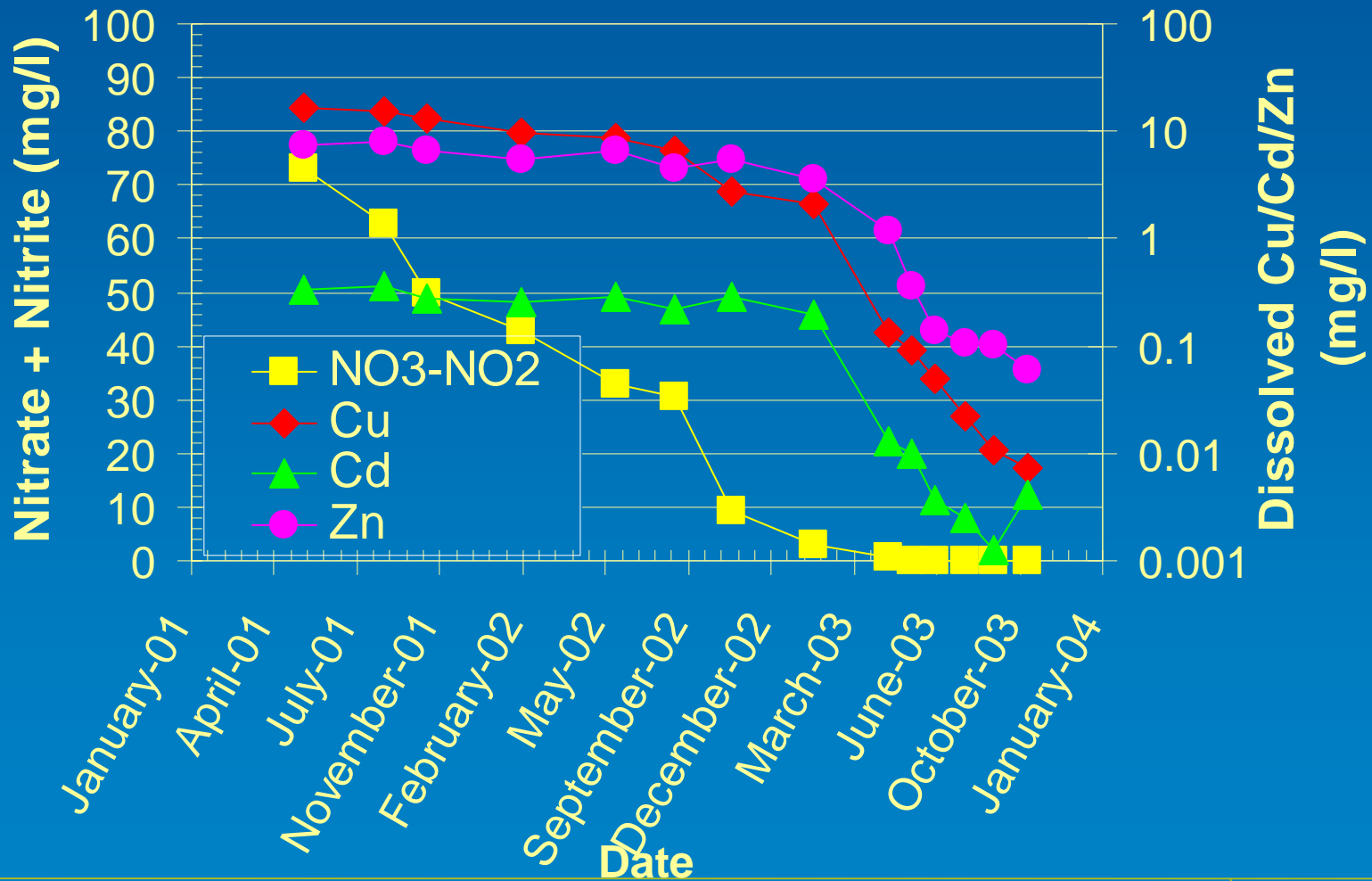




Ambient Water Quality Criteria
 Total Recoverable Copper (Chronic): 0.037 mg/l

Anchor Hill Pit Lake
Figure 1. Dissolved Copper Concentrations

NO3-NO2 and Dissolved Cu/Cd/Zn vs. Time



Captain Jack Mine Left Hand Creek, Colorado



In Situ Mine-Pool Treatment
Big Fiver Tunnel

Mine Waste Remediation and Sediment Control Clear Creek/Central City



- Church Placer Repository

Pre-Remediation



Capping, cover and
Revegetation - Woburn,
MA

Post-Remediation



Anaconda Smelter Reclamation

- ✓ Record of Decision (1998) specified in-place land reclamation for 11,600+ upland acres
- ✓ Design Specifications (2005-2006):
 - in-place soil tillage for metals dilution (6, 12, 18")
 - amendments: organic matter and lime for pH adjustment
 - coversoil or soil removal
 - custom seed mixtures for soil conditions and land use

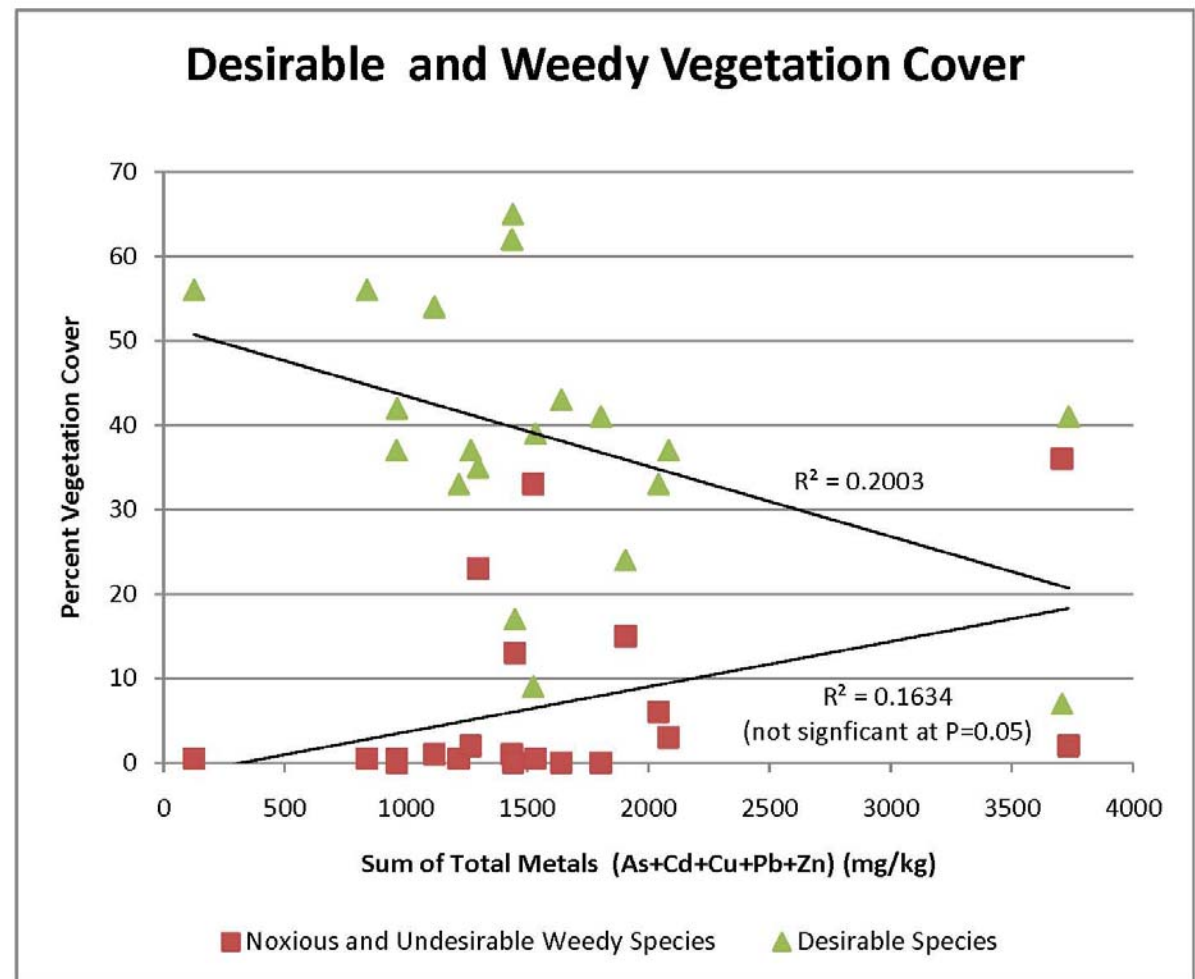




2011 Phytotoxicity Studies

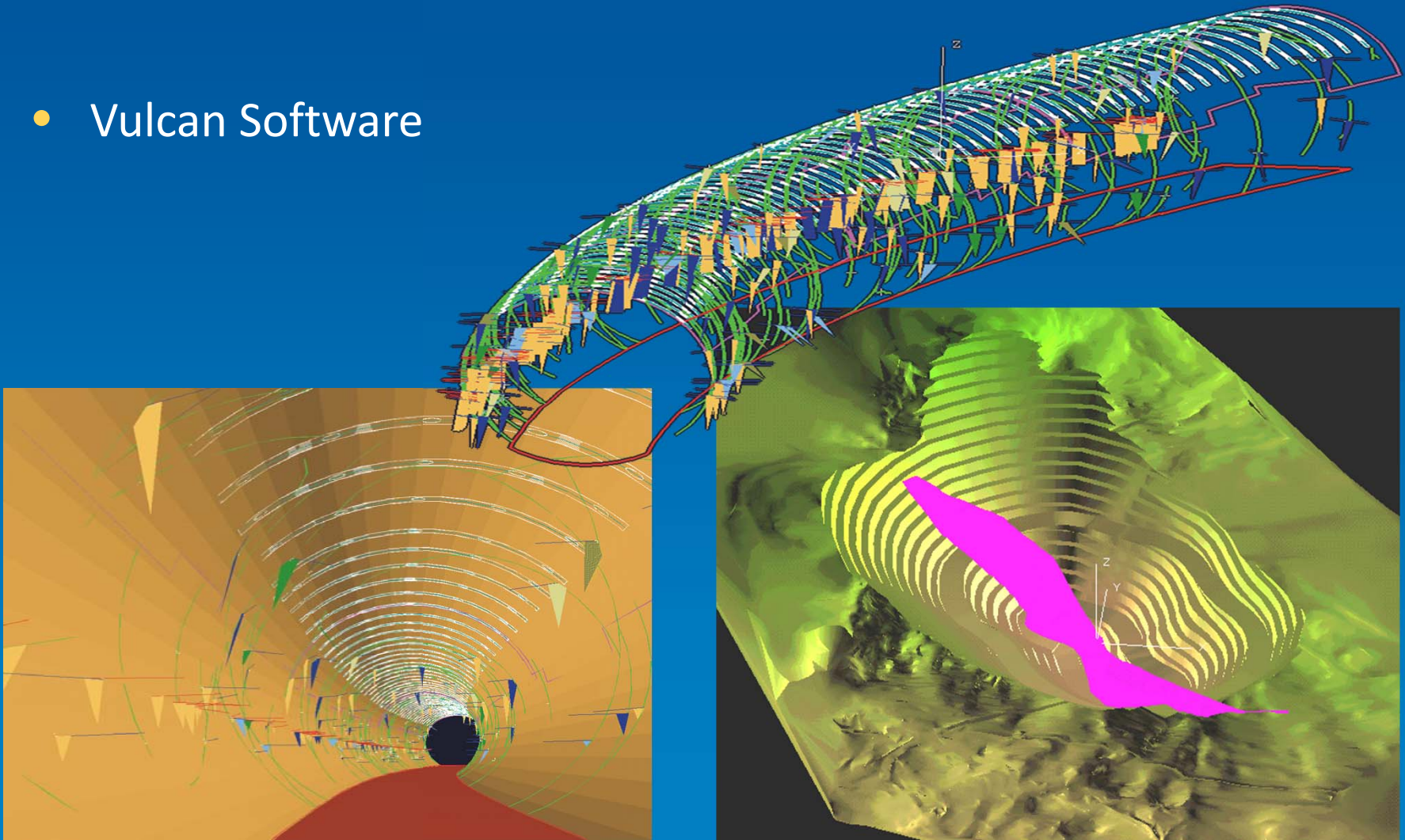
Key Plant and Soil Relationships

Significant decrease
in desirable species
cover with increase
in soil metal
concentrations.

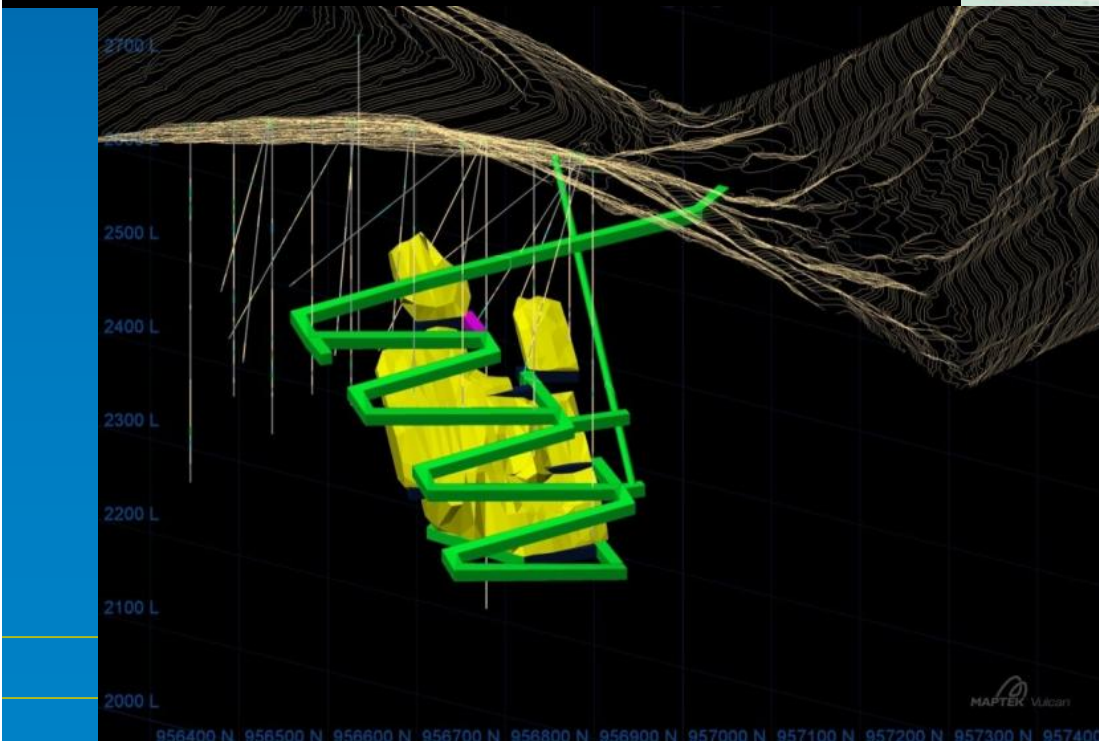
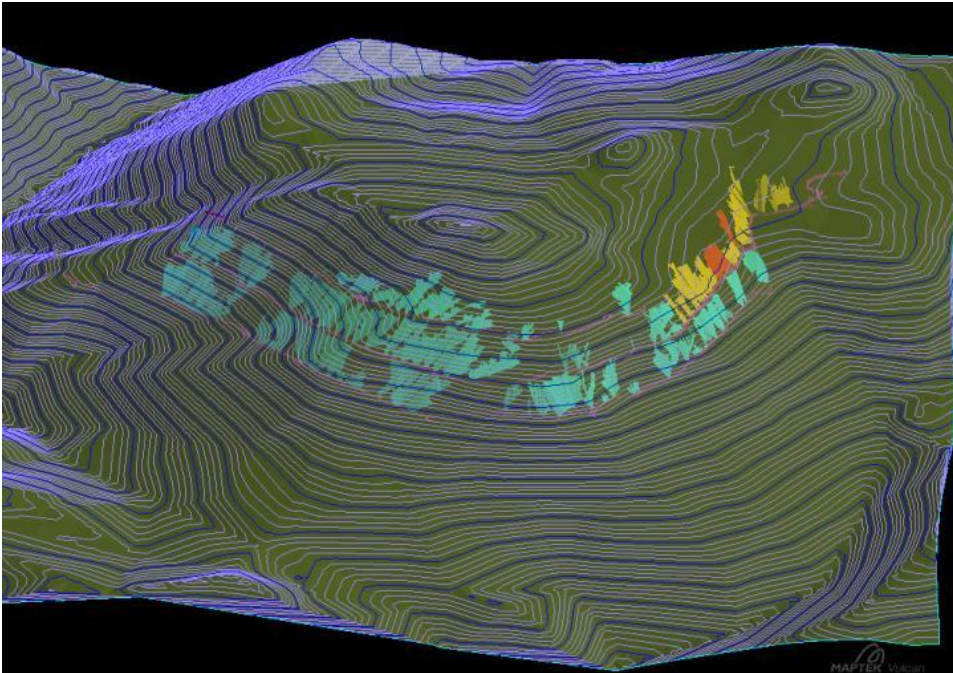


Need to Work in a 3-D World

- Vulcan Software



Closures and Planning Using Vulcan



Future is Now - INTEGRATION

- Do What You Can: basin wide approaches with water quality improvement in lower river segments as indicated by biological community + regulatory acceptance
- Do it *In Situ*: *In situ* water treatment + 3D visualization + real time monitoring and maintenance
- Do a better job:
 - Risk assessments
 - soil covers + species selection
 - nonpoint contamination control
 - water management, run-off/run-on and sediment control
 - Monitoring and maintenance

Questions and Answers?

