BONITA PEAK MINING DISTRICT - HOWARDSVILLE SOURCE AREA

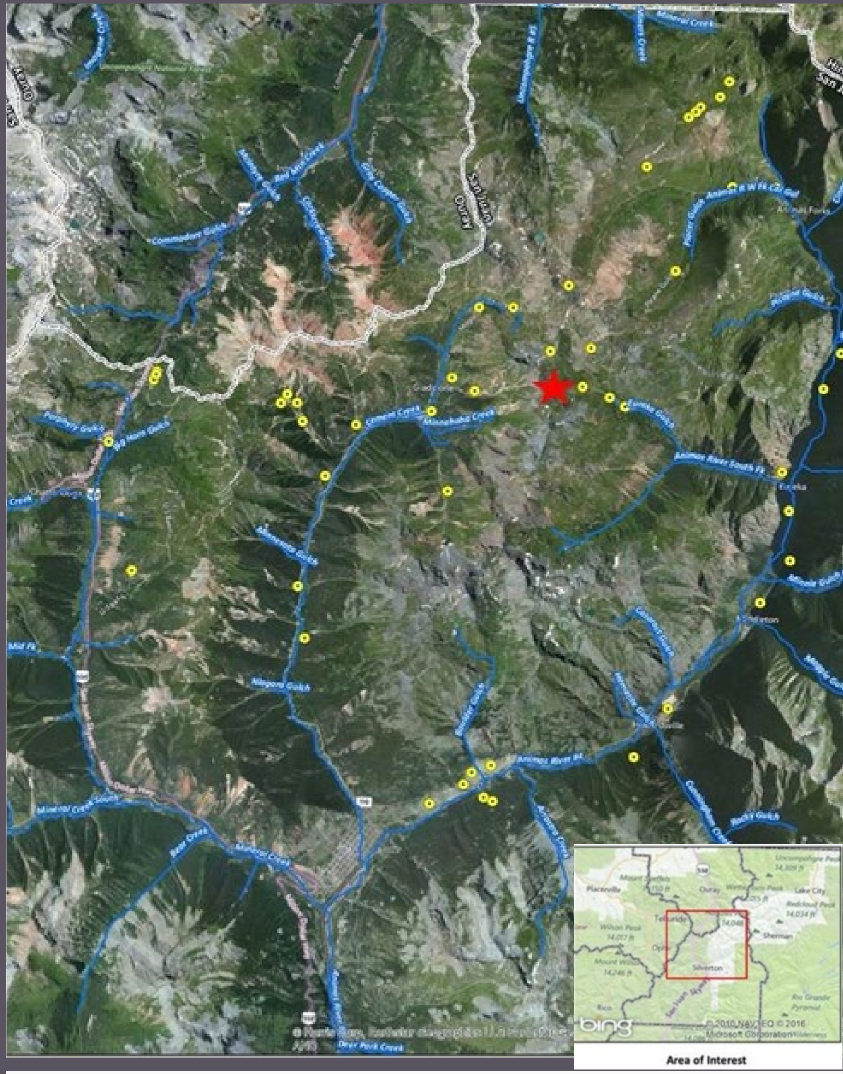
Remedial Investigation Activities

Background

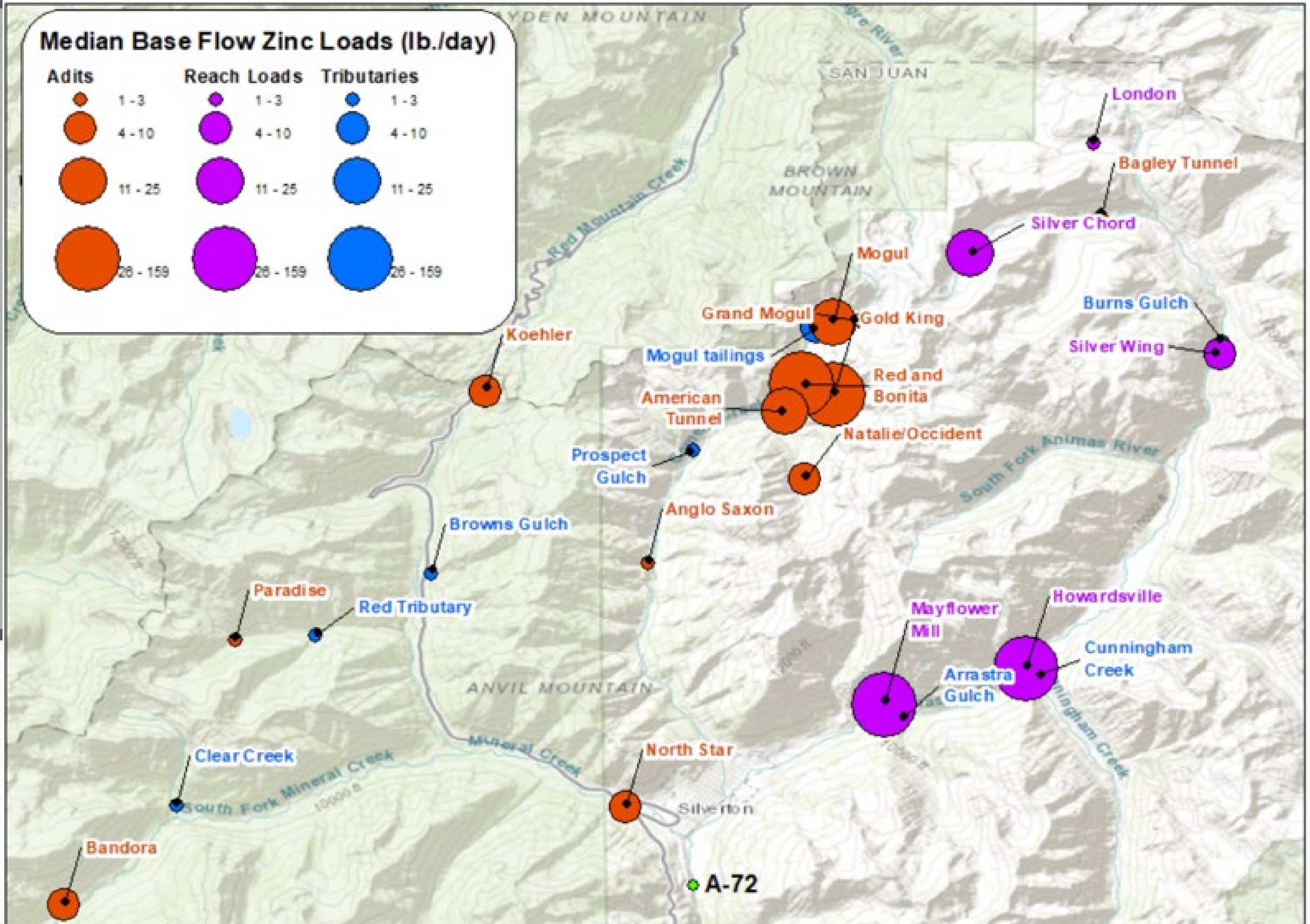
Howardsville Colorado Goldfields Tailings (Howardsville Tailings) is a tailings impoundment north of the Pride of the West Mill #4

Howardsville sits within Priority Reach #2 and has been investigated as part of the fluvial tailings focus area (Eureka to Howardsville stretch)

EPA has used SW loading of Zn to prioritize characterization investigations along with 4 priority areas based on fisheries. (2nd biggest loader in Animas at



Zn Loading in the BPMD



Metals Source	Type	Drainage	Median zinc load lb./d
North Star	Adit	Mineral	3.9
Bandora	Adit	Mineral	3.7
Koehler	Adit	Mineral	3.1
Paraside	Adit	Mineral	2.3
	Mineral largest sources		**13**
Gold King Level 7	Adit	Cement	159
Red and Bonita	Adit	Cement	53
American Tunnel	Adit	Cement	20
Mogul	Adit	Cement	16
Natalie/Occidental	Adit	Cement	4.1
Grand Mogul	Adit	Cement	1.6
Anglo-Saxon	Adit	Cement	1.3
	Upper Cement sources		**255**
	Upper Cement sources less Gold King		**96**
Mayflower Mill area	Impoundments	Animas	52
Howardsville	Impoundments	Animas	27
	Howardsville + Mayflower Mill		**79**
California Creek above Silver Chord	Reach	Animas	11
Silver Wing/Burns	mine area	Animas	10
London	Adit	Animas	2.9
Bagley Tunnel	Adit	Animas	1.6
	Other Animas Sources		**26**

Legend

- Surface Water&Seep Sample
- Pore Water Sample
- BPMD Listed Mining-Related Sources
- Other Mines (USGS)
- Other Mills (USGS)

Property Lines

- Property Lines

Figure 2-7
Surface Water and Pore Water Investigation Locations – Howardsville Tailings

Howardsville Tailings Impoundment Background

- The Howardsville Colorado Goldfields Tailings is a tailings impoundment associated with nearby Milling operations to process waste dump material
- Little Nation Mill operated from 1921 – 1940 SW of impoundment
- Pride of the West Mill built in 1940, expanded in 1968 and 1981 South of impoundment
- Colorado Division of Reclamation, Mining, and Safety, permit was revoked in 2016
- Tailings and waste rock are stored in several impoundments. One with a known liner which was partially reclaimed.
- Area covers approximately 15 -20 acres
- A degraded 3-4 ft drainage ditch runs along the irregular northern boundary of the impoundment

Howardsville Tailings Impoundment Background

- Based on the geologic map compiled by USGS, the general geology of the area excluding the mill tailings piles is considered to be alluvium with unconsolidated fluvial deposits (USGS 2007).
- The Animas River flows toward the southwest and is immediately west of the Howardsville Tailings site. Cunningham Creek flows approximately 0.25 miles to the south. The confluence of Cunningham Creek and the Animas River is just downstream from the Howardsville Tailings.
- Acidic MIW with orange staining emanates from the Howardsville Tailings through a wetland area and enters the Animas River just upstream of its confluence with Cunningham Creek.
- In 1997, Sunnyside Gold, Inc. removed approximately 84,000 yd^3 of mill tailings from the Howardsville Tailings (USGS 2007).
- In winter 2017 DRMS dewatered cell 1A and repaired geomembrane and wrapped the cell

Site Specific - Surface Water Quality Standard for Howardsville Stream Segment

The Commission has further determined that the Animas River between Maggie Gulch and Cement Creek (segment 3a) supports a population of brook trout that appears to be naturally reproducing in that it consists of multiple age classes. The segment also contains a diversity of macrobenthos and possesses physical habitat similar to other streams in the Southern Rocky Mountain ecoregion. Although the concentration of several metals, especially cadmium and zinc, are higher than what is required to protect the most sensitive aquatic life species, they are lower than the chronic toxic criteria for brook trout. Therefore a cold water aquatic life class 1 classification is being established to protect the resident aquatic life found in this segment. Ambient standards for cadmium and zinc are adopted to ensure that downstream use classifications and standards are not jeopardized.

TABLE 1

ANIMAS RIVER BASIN
AQUATIC LIFE INDICATOR GOAL: BROOK TROUT

Segment 3a
Acute Standards

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Zn	720	780	1060	1200	760	410	280	340	380	440	510	590

Chronic Standards

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
Mn	TVS	TVS	2571	2179	TVS	TVS	TVS	TVS	TVS	TVS	TVS	TVS
Zn	720	780	1060	1200	760	410	280	340	380	440	510	590

Howardsville Tailings Characterization

EPA conducted characterization activities in the Fluvial Tailings focus area from 2021-2022.

The PSQs for the Howardsville Tailings are:

- PSQ 1: What is the nature and extent of contaminated solid media (impounded tailings, soils, dispersed tailings, ore stockpile area) at the Howardsville Tailings?
- PSQ 2: What is the nature and extent of groundwater contamination at the Howardsville Tailings?
- PSQ 3: What is the primary source of the contaminated groundwater and seepage emanating from the Howardsville Tailings?
- PSQ 4: What are the effects of the groundwater interception trench/French drain/diversion ditch that runs along the upgradient perimeter of the site? What are the effects of other water-routing infrastructure (such as pipes) at the site?
- PSQ 5: What is nature and extent of contaminated groundwater/surface water seepage and ponded water at the toe of the tailings impoundments (the “old tailings area”) and what effects do these features and flows have on the groundwater plume and flow direction?
- PSQ 6: Where does the contaminant loading enter the Animas River and how is the loading distributed along the reach?
- PSQ 7: Were the process chemicals found in the mill, laboratory, and/or leach buildings a source of contamination to groundwater?

Howardsville EPA Characterization

EPA conducted characterization activities in the Fluvial Tailings focus area from 2021-2022.

- **Installed a total of 24 monitoring wells**
- **Dug 12 Test Pits**
- **Conducted synoptic SW and porewater sampling**
- **Estimated volume of 282,000 cubic yards of tailings**
- **Estimated volume of 28,000 cubic yards of saturated tailings**

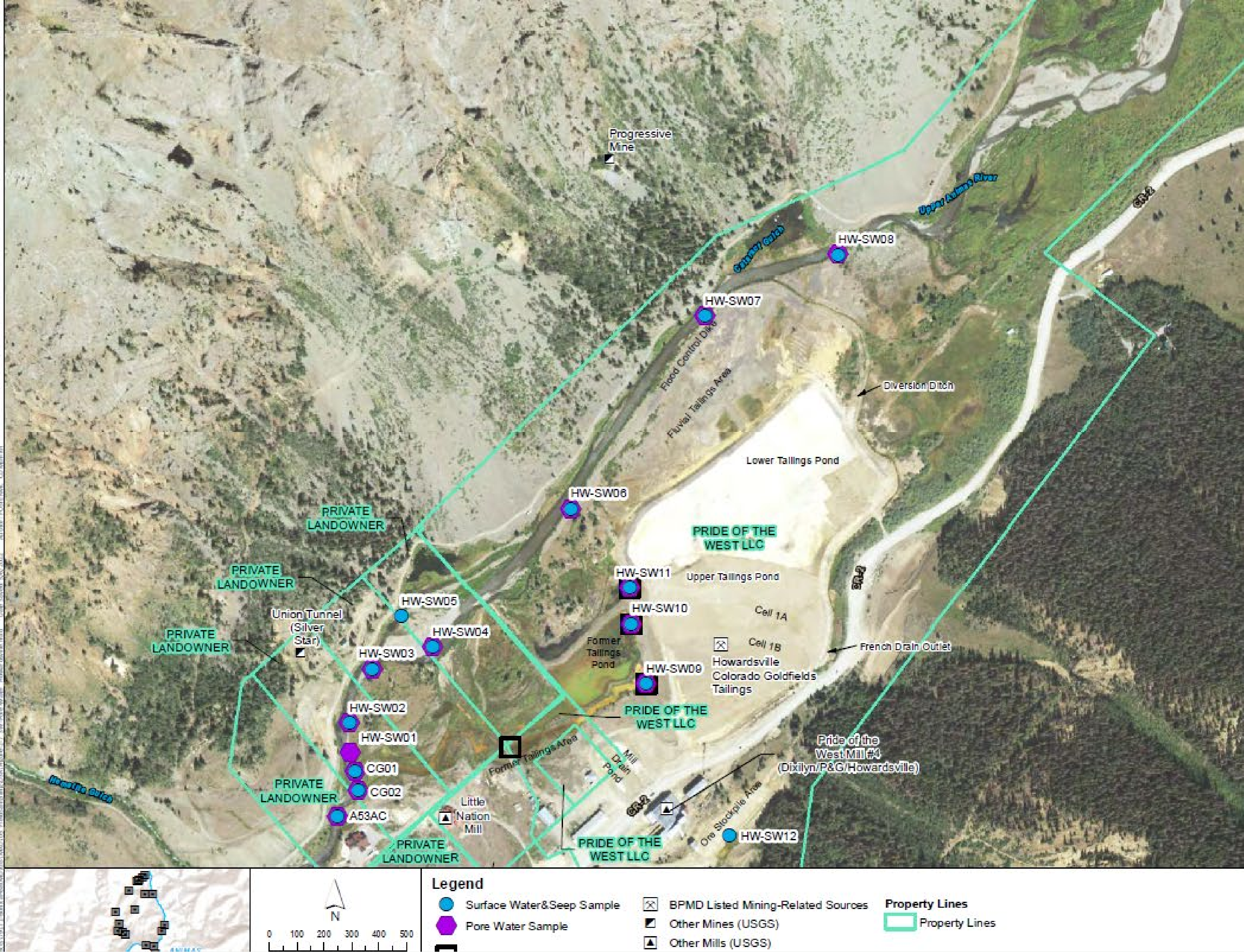
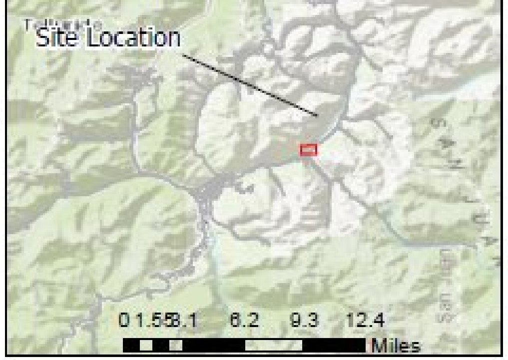


Figure 2-7
Surface Water and Pore Water
Investigation Locations – Howardsville Tailings



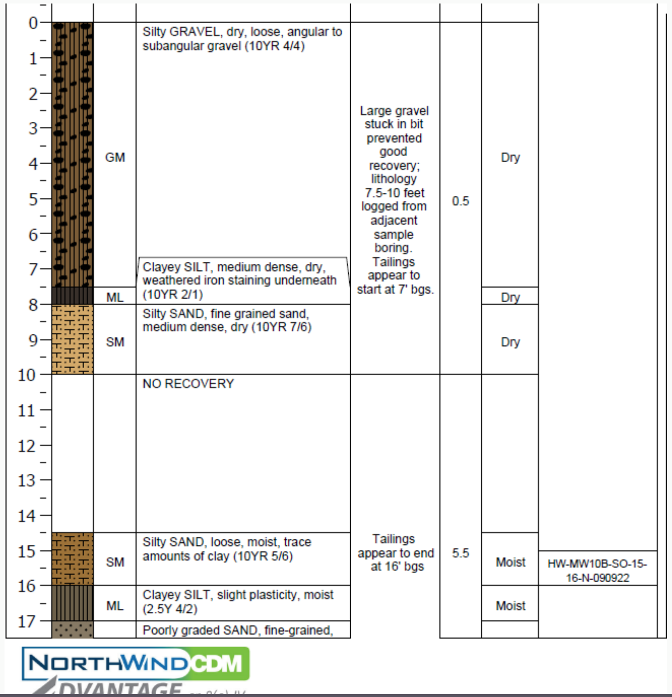
Legend

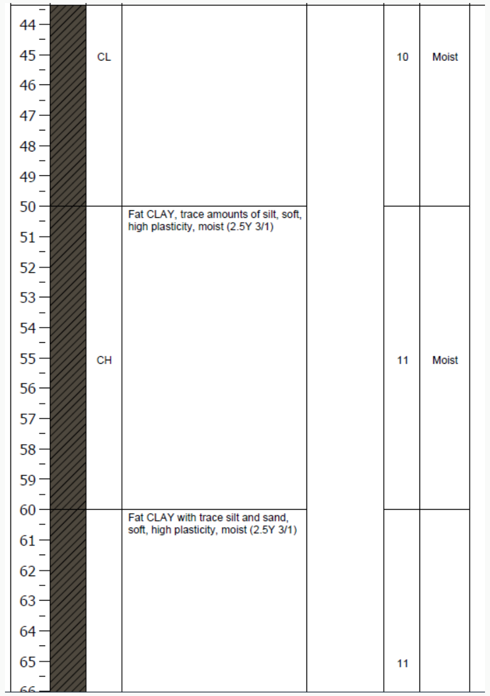
- USGS Mills
- Monitoring Wells
- BPMD Listed Mining-Related Sources
- Other Mines (USGS)
- Approximate Groundwater Elevation Contours

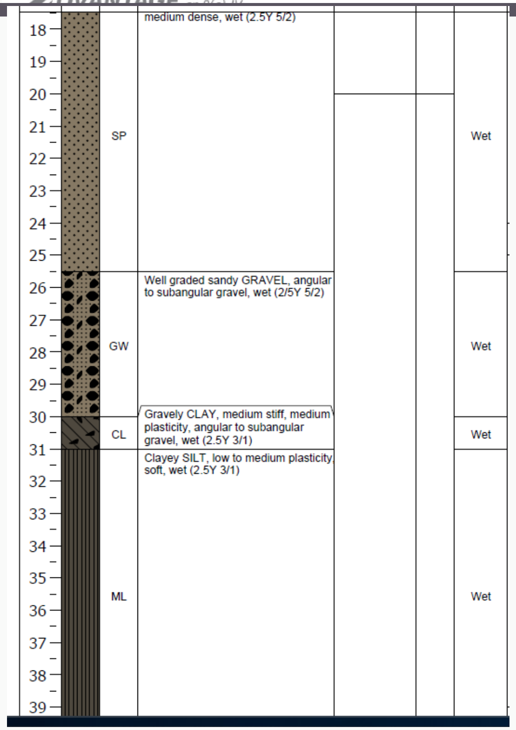
0 50 100 200 300 400 Feet

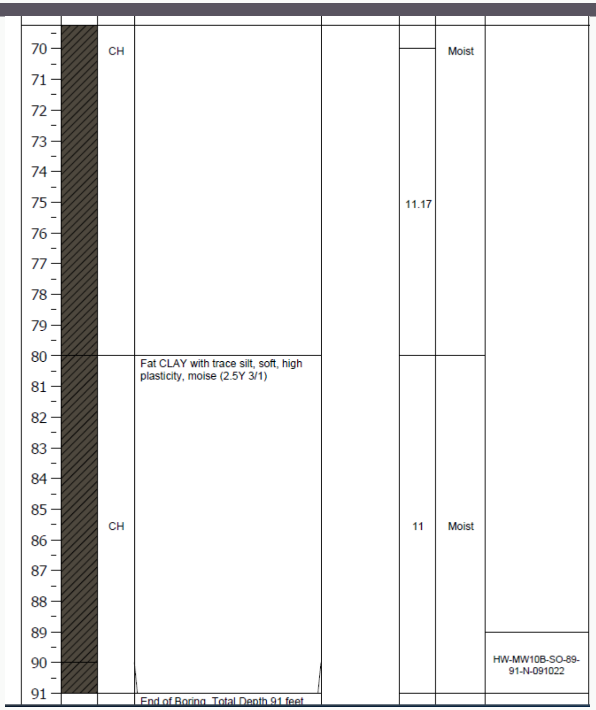
Prepared By: SJB	Bonita Peak Mining District, Upper Animas Mining Mining-Related Sources (OU1), San Juan County, Co, Fluvial Tailings and Groundwater Focus Areas 2023 Data Summary Report
Reviewed By: RA	

BORING LOGS FOR MW-10B









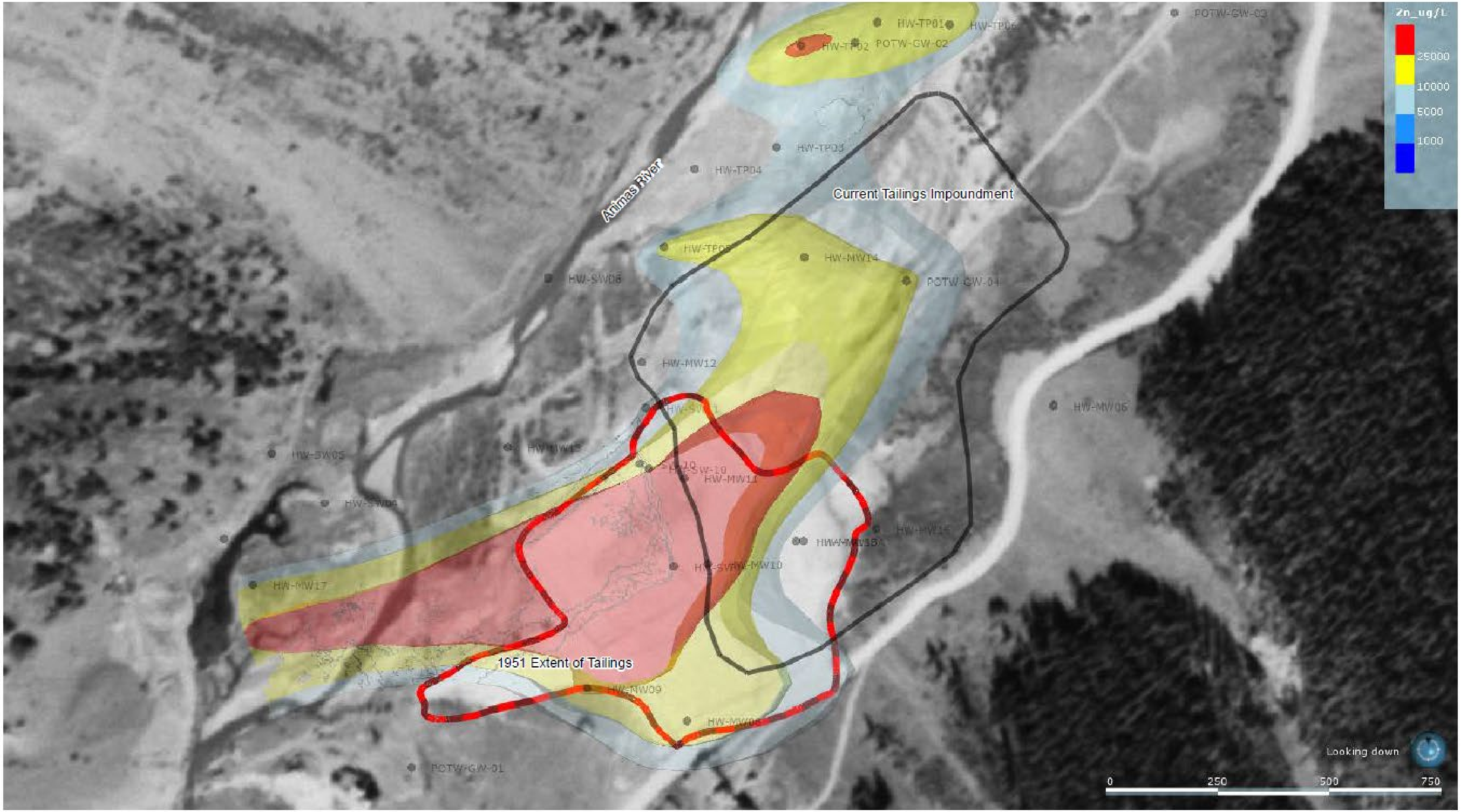
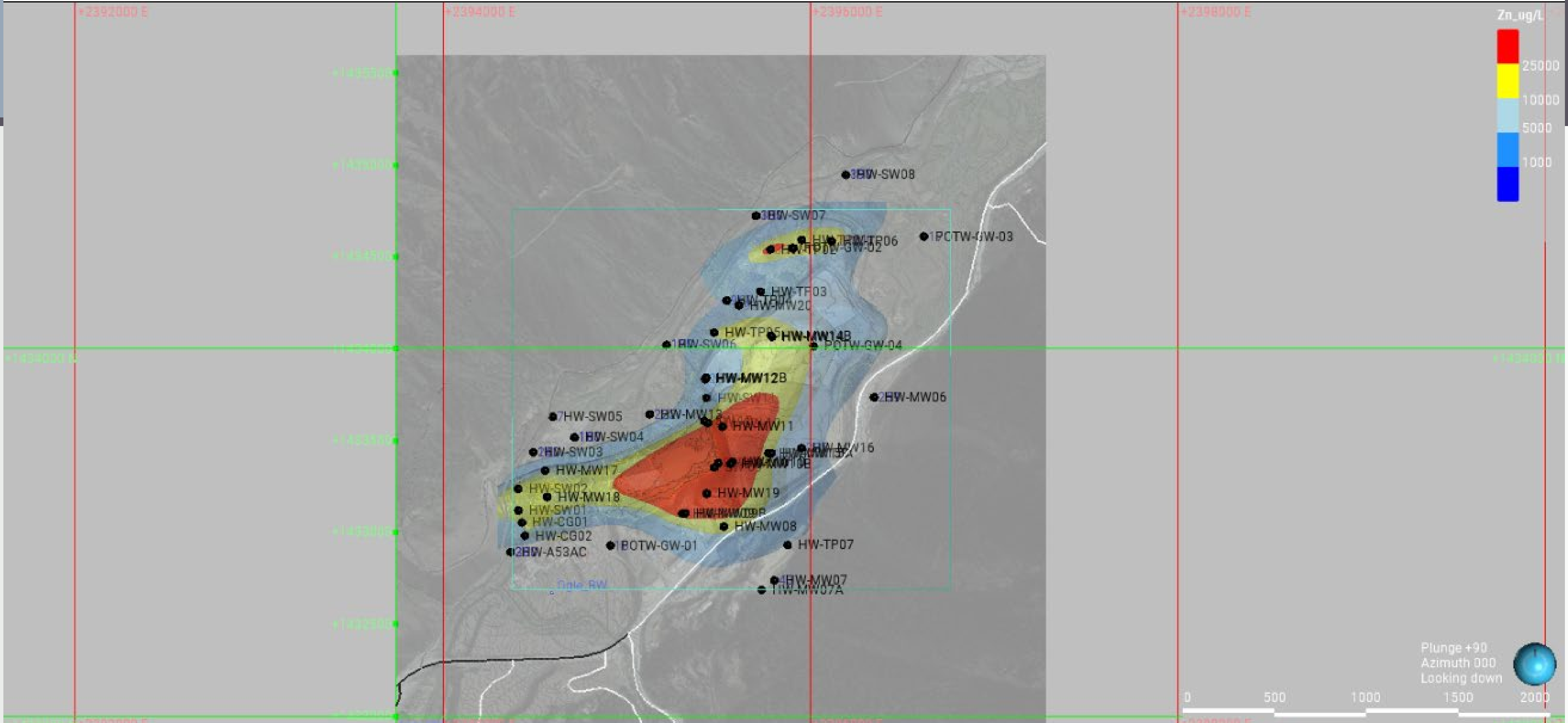
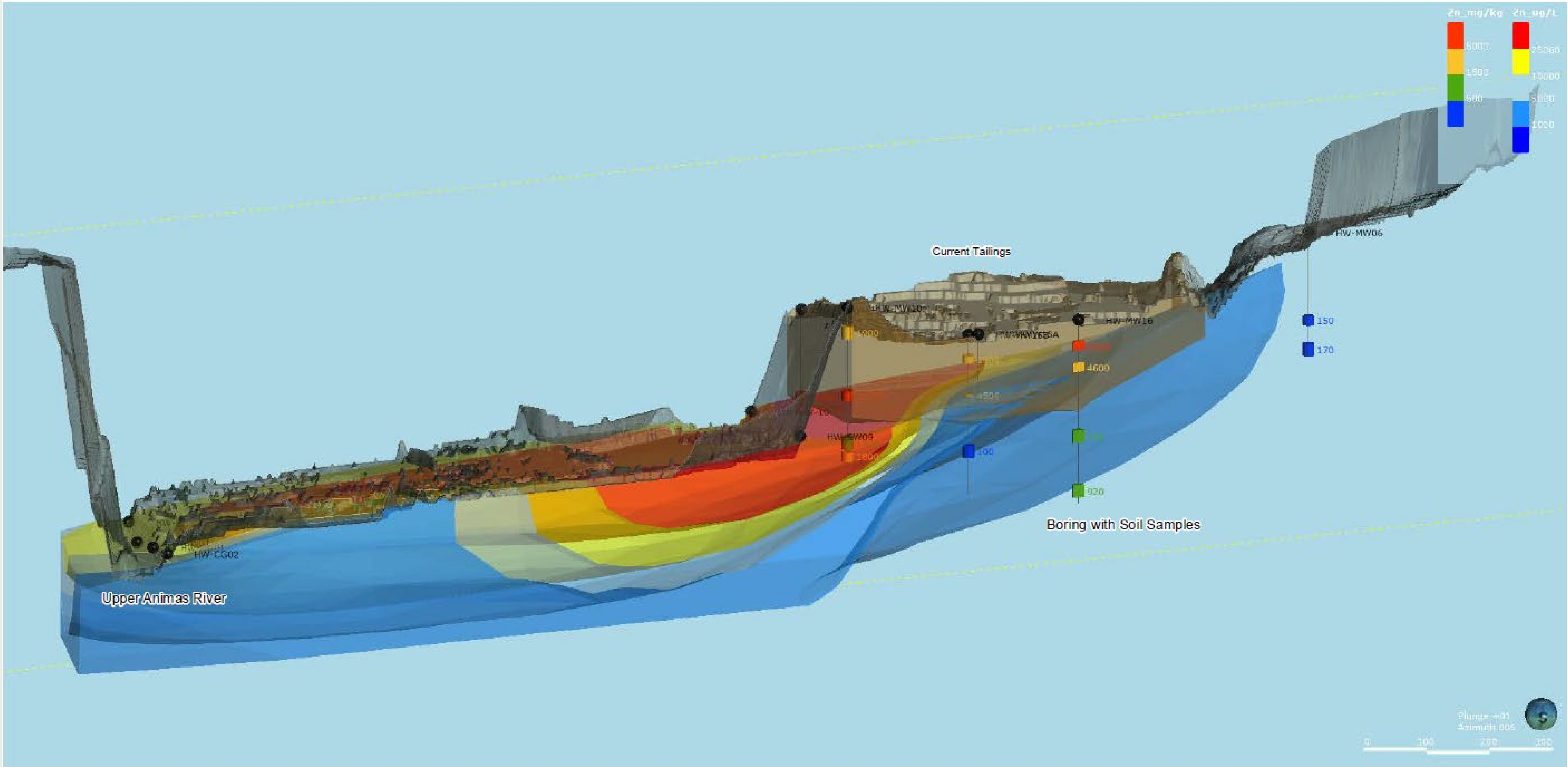


Figure 3-16
1951 Aerial Photo with 2021 Zinc Concentrations in Groundwater

Howardsville Zn Groundwater Concentration Plume

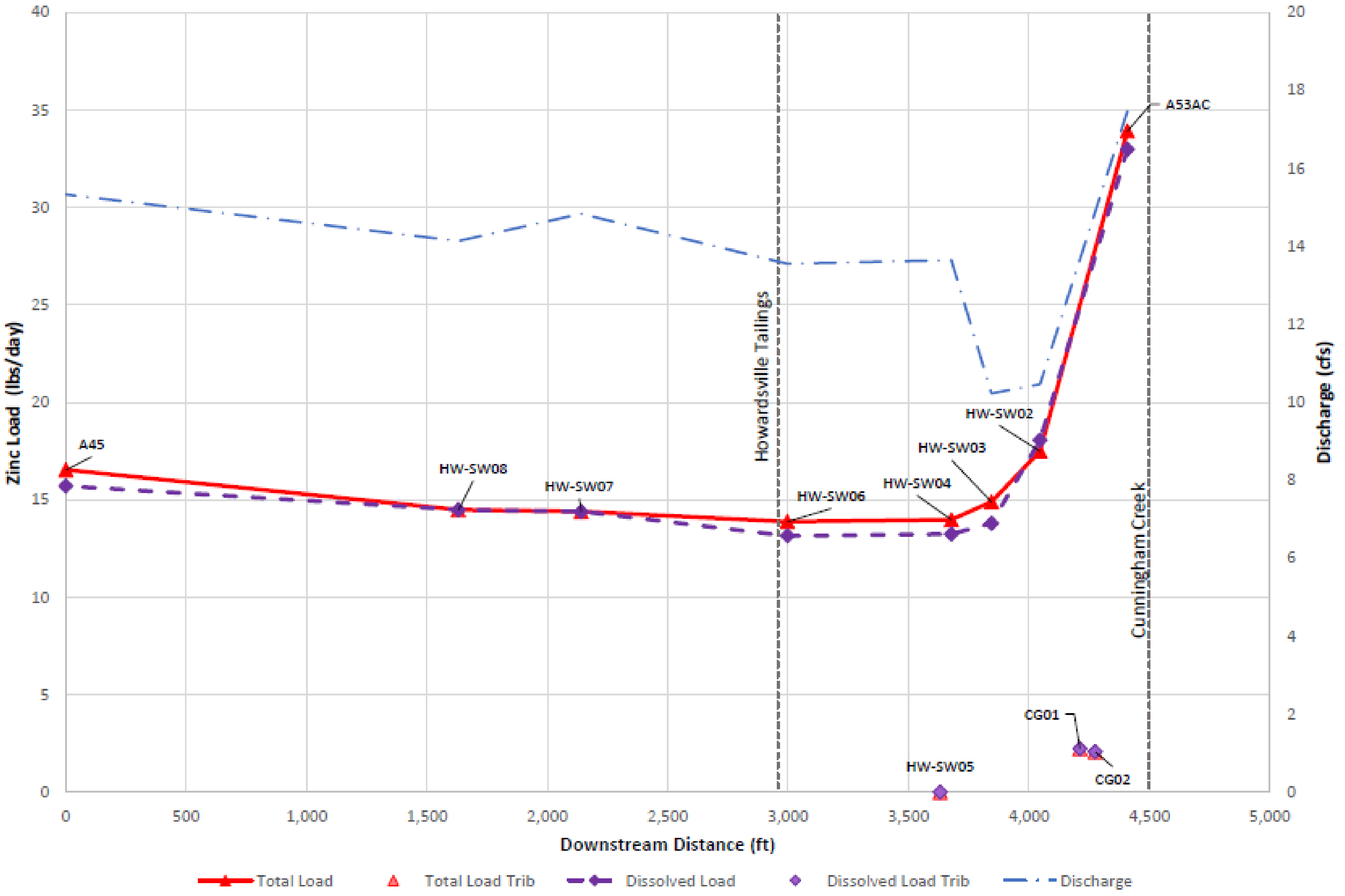




Note: Cross section is 10x vertical exaggeration

Figure 3-13
Section Slice with Zinc Groundwater and Soil Concentrations – Howardsville Tailings

Figure 3-19. Surface Water and Pore Water Zinc Loads and Discharge - Howardsville Tailings



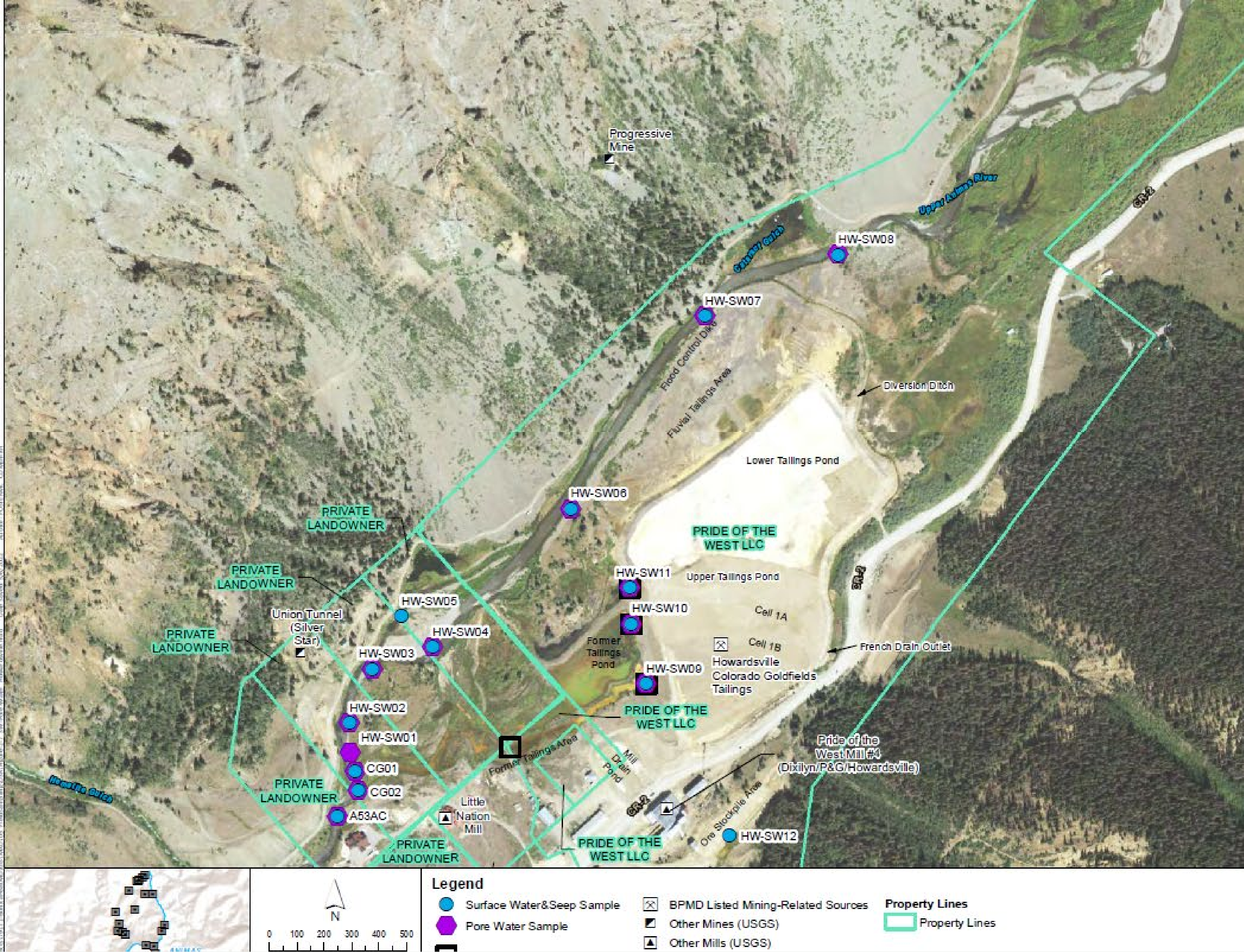


Figure 2-7
Surface Water and Pore Water Investigation Locations – Howardsville Tailings

Howardsville FFS Tech Memo

Summarizes CSM;

Develop Preliminary Remedial Action Objectives;

- PRAO 1: Reduce Transport of COCs from mine waste, contaminated soil, and contaminated sediment into surface water that contribute to unacceptable ecological risk
- PRAO2: Reduce migration of COCs from alluvial GW into SW that contribute to unacceptable ecological risk

Identify Remedial Technologies for Mine Waste, Sediment, GW

Perform Initial cost evaluation for select technologies -50%/+100%

- On-site Repository, Ex-situ Stabilization, Slurry Wall

In Draft and being reviewed

Initial Technologies – Soils/Sediment

- No Action
- Monitoring
- Monitored Natural Recovery
- Institutional Controls
- Access Controls
- Containment
  - Surface Controls
  - Subsurface Controls
  - Subaqueous Surface Controls
  - Barriers
- Removal/Transport, Disposal
- Treatment
  - Ex-situ Treatment
  - In-Situ Treatment
- Reuse, Reclamation, and Recovery

Initial Technologies – Groundwater

- No Action
- Monitoring
- Monitored Natural Recovery
- Institutional Controls
- Containment and Hydraulic Isolation
  - Physical Barriers
  - Hydraulic Isolation, Diversion, and Separation Measures
- Removal/Transport, Disposal
- Treatment
  - Ex-situ Treatment
  - In-Situ Treatment
- Reuse, Reclamation, and Recovery

Howardville Bench Treatability Study

Bench Scale testing for solidification and stabilization of 7 different amendment types.

Included a modified IWTP sludge as an amendment 20% sludge +10% CaO

Panel A -- Summary of Average Reduction by Amendment Type

Analyte	Blastox 125	Limestone (Dosage 1)	Limestone (Dosage 2)	Terrabond (Rsa)	Terrabond/ Ferroblack (RSb)	Quicklime (Dosage 1)	Quicklime (Dosage 2)	Gladstone Sludge
Cadmium	56.85	-1325.26	-1109.38	38.13	-4.25	58.77	39.04	-754.68
Copper	-70.82	2.58	-36.05	-99.99	-75.61	-707.40	-817.51	-35.93
Lead	-197.39	26.11	-223.86	55.52	68.17	-5104.06	-10912.88	64.96
Manganese	87.97	31.80	27.51	50.19	64.33	99.65	99.82	-47.90
Zinc	96.74	68.26	65.71	94.65	95.32	90.93	92.30	51.72

Panel B -- Reduction of Fluvial Tailings Area (FTA) by Amendment

Analyte	Blastox 125	Limestone (Dosage 1)	Limestone (Dosage 2)	Terrabond (Rsa)	Terrabond/ Ferroblack (RSb)	Quicklime (Dosage 1)	Quicklime (Dosage 2)	Gladstone Sludge
Cadmium	86.80	78.60	81.27	92.77	99.01	98.97	98.97	59.28
Copper	96.90	95.11	94.77	88.45	98.00	-6.48	28.47	96.36
Lead	97.08	97.71	95.50	99.40	97.87	39.34	-202.28	96.21
Manganese	70.91	41.36	42.40	-34.83	13.60	99.96	99.99	-49.58
Zinc	93.29	81.18	84.41	97.99	99.50	99.58	98.44	54.37

Panel C -- Reduction of Pond Area (PA) by Amendment

Analyte	Blastox 125	Limestone (Dosage 1)	Limestone (Dosage 2)	Terrabond (Rsa)	Terrabond/ Ferroblack (RSb)	Quicklime (Dosage 1)	Quicklime (Dosage 2)	Gladstone Sludge
Cadmium	0.16	-65.99	0.24	-100.00	0.10	0.20	0.16	-66.66
Copper	-146.22	-59.75	-150.86	-621.05	-141.11	-244.42	-346.65	-106.75
Lead	-1365.30	2.36	-1052.17	-17.65	50.34	41.29	41.27	1.97
Manganese	69.12	9.29	-26.89	30.13	42.37	98.82	99.95	-33.54
Zinc	92.45	43.58	15.61	79.24	87.66	99.87	99.87	18.77

Panel D -- Reduction of Lower Tailings Pond Area (LTPA) by Amendment

Analyte	Blastox 125	Limestone (Dosage 1)	Limestone (Dosage 2)	Terrabond (Rsa)	Terrabond/ Ferroblack (RSb)	Quicklime (Dosage 1)	Quicklime (Dosage 2)	Gladstone Sludge
Cadmium	1.34	-6762.38	-5769.09	1.42	-316.00	1.58	-97.08	-3900.97
Copper	-361.72	-150.85	-251.41	-106.11	-416.44	-2747.45	-3194.07	-306.62
Lead	94.43	-83.16	-267.12	95.13	7.49	-2759.21	-33139.40	48.71
Manganese	99.99	36.42	37.85	87.51	82.59	99.97	99.84	23.97
Zinc	99.91	78.43	77.44	99.37	99.27	99.62	97.03	75.77

Panel E -- Reduction of Monitoring Well 19 (MW19) by Amendment

Analyte	Blastox 125	Limestone (Dosage 1)	Limestone (Dosage 2)	Terrabond (Rsa)	Terrabond/ Ferroblack (RSb)	Quicklime (Dosage 1)	Quicklime (Dosage 2)	Gladstone Sludge
Cadmium	98.8	77.30	82.02	99.31	98.77	98.78	98.77	59.59
Copper	99.9	99.64	99.68	99.84	99.90	99.35	98.98	99.72
Lead	99.9	81.24	83.35	99.67	99.43	43.88	-553.01	97.91
Manganese	99.9	37.99	42.90	79.10	90.19	99.95	99.73	-163.07
Zinc	99.9	94.28	95.32	99.77	99.58	99.83	99.43	70.58

Panel F -- Reduction of Upper Tailings Pond Area (UTPA) by Amendment

Analyte	Blastox 125	Limestone (Dosage 1)	Limestone (Dosage 2)	Terrabond (Rsa)	Terrabond/ Ferroblack (RSb)	Quicklime (Dosage 1)	Quicklime (Dosage 2)	Gladstone Sludge
Cadmium	97.2	46.17	58.65	97.17	96.86	94.35	94.36	75.37
Copper	-43.0	28.76	27.58	38.95	-18.43	-637.98	-674.29	37.62
Lead	86.9	32.41	21.16	1.05	85.72	-22885.61	-20710.97	80.01
Manganese	99.9	33.96	41.31	89.03	92.89	99.58	99.58	-17.28
Zinc	98.1	43.84	55.79	96.90	90.60	55.72	66.70	39.12

Howardsville Bench Test Results

Table 5.1 Evaluation of Semi-Dynamic Leaching Results
Bench-Scale Treatability Study
Solidification/Stabilization Testing
Howardsville Colorado Goldfield Tailings
Bonita Peak Mining District Superfund Site

Tailings Location	Amendment	Effectiveness						
		Cadmium	Copper	Lead	Nickel	Chromium	Antimony	Zinc
LTPA	TerraBond-FC (6%)	High	Low	High	Medium	High	low	High
MW19	Blastox 125 (3%)	High	Low	Low	Medium	High	low	High
MW19	Crushed Limestone (3%)	High	Low	Medium	Medium	Low	Medium	High
MW19	Terrabond-FC (6%) and FerroBlack-FS27 (3%)	High	Low	High	Medium	High	High	High
UTPA	Blastox 125 (3%)	High	Low	Low	Medium	High	high	High
UTPA	TerraBond-FC (6%)	High	Low	Low	Medium	High	high	High
UTPA	Gladstone sludge (50%)	High	Low	High	Medium	Low	high	High

- Results of all amendments showed relatively good success
- Amendment costs would be expensive to treat all material.
- Gladstone sludge considerably less costly, but has additional volume considerations
- Final Report under development

Table 7-1 Preliminary Amendment Comparisons
Bench-Scale Treatability Study
Solidification/Stabilization Testing for Howardsville Tailings
Howardsville Colorado Goldfield Tailings

Stabilization Chemical	Terrabond-FC	Terrabond-FC + Ferroblack-FS27	Blastox 125	Limestone	Gladstone Sludge with Calcium Oxide (0.3%)
Demonstrated Effectiveness in Bench-Scale Testing with Samples from Howardsville	Effective for cadmium and zinc. Least effective for copper with elevated long-term concentration to groundwater modeled to 7.7 mg/L in the LTPA.	Effective for cadmium and zinc. Least effective for copper with elevated long-term concentration to groundwater modeled to 6.21 mg/L at MW19.	Effective for cadmium and zinc. Best performer for copper but high concentrations. Medium effectiveness for all other elements at MW19 and the UTPA.	Effective for cadmium and zinc. Medium effectiveness for copper at MW19.	Effective for cadmium and zinc. Among the best performers for copper, lead, and nickel.
Health and Safety	Eye, skin, and respiratory irritation.	Eye, skin, and respiratory irritation. FerroBlack-FS27 may generate toxic gas in contact with acid.	Eye, skin, and respiratory irritation.	High pH; eye, skin, and respiratory irritation.	NA
Physical and Chemical Properties	Proprietary formulation that contains approximately 10% to 15% calcium hydroxide and calcium carbonates.	Proprietary formulation that contains approximately 10 to 15% calcium hydroxide and calcium carbonates. FerroBlack-FS27 contains 7% to 11% iron sulfide and up to 1% sodium sulfide in a proprietary slurry.	Powder that contains calcium silicates and aluminates (80%), and magnesium oxide (5%).	Fine grit pulverized material (less than 4 millimeters).	NA
Geotechnical Evaluation (Solidification)	UCS = 36.2 psi	Material did not withstand testing[2]	UCS = 24 psi	Material did not withstand testing[2]	UCS = 51.1 psi
Unit Cost	$334 to $355 per ton, delivered	$450 to $471 per ton, delivered	$365 per ton, delivered	$69 per ton, delivered. Average density of 1.4.	CaO: $410 per ton, delivered. No cost calculated for Gladstone sludge.
Quantity Required (assuming 282,000 cubic yards of tailings to be treated)[1]	17,000 cubic yards[3]	17,000 cubic yards TerraBond-FS + 8,500 cubic yards of FerroBlack-FS27[3]	8,500 cubic yards[3]	20,000 cubic yards. Average density of 1.4.	141,000 cubic yards Gladstone sludge, 850 yards of CaO (as quicklime)
Total Chemical Cost	$5.6 to $6 million	$6.5 to $7.1 million	$3.1 million	$1.38 million	$348,000 for CaO[4]
Handling, Delivery, and Implementation Considerations	Medium - delivery in 15-ton trucks. Applied via 6-foot auger rig.	Medium/High - Delivery in 15-ton trucks. Applied via 6-foot auger rig. Need to mix FerroBlack-FS27 with the TerraBond-FC prior to application.	Medium - Delivery in 15-ton trucks. Applied via 6-foot auger rig.	Medium - Delivery from Silverton, Colorado (Colorado lime) in 27-ton trucks. Applied via 6-foot auger rig.	Medium - Sludge is generated at the Bonita Peak Mining District site. Implementation: Medium - material is not dry and not consistent in particle size of moisture content. Applied via 6-foot auger rig. Significantly more quantities of material are required.

Comments/Concerns/Questions

Table 4-2a Screening of Potentially Applicable Remedial Technologies/Process Options Based on Effectiveness, Implementability, and Relative Cost –Contaminated Soils and Sediments
Howardsville Tailings Source Area, Bonita Peak Mining District
Draft Feasibility Study Technologies Screening Technical Memorandum

General Response Actions	Remedial Technology	Process Option	Description of Option	Effectiveness		Implementability		Relative Cost		Reasons for Elimination of Process Option from Consideration	Process Option Viability with Respect to Assembly of Remedial Alternatives
								Capital Cost	O&M Cost		
No Action	None	None	No action would be taken. The contaminated soils remain in their existing condition.	0	No action would be taken to protect human health or the environment. Does not comply with ARARs.	5	Easily implemented, as no action would be taken; however, it is not acceptable to regulatory agencies.	0	0	Retained (NCP requirement)	Not viable as a solution; however, it is required by NCP as a stand-alone alternative.
Monitoring	Physical and/or Chemical Monitoring	Nonintrusive Visual Inspection	A nonintrusive (surficial) visual inspection of the immediate ground surface to determine the presence or absence of contaminated soils.	0	Does not directly affect receptors and does not physically mitigate contamination. However, visual inspections may indicate that a remedy component has failed.	4	Easily implemented using available technical and labor resources.	$	0	Retained	Not viable as a solution; however, it is a potentially viable process option for combination with other technologies.
		Intrusive Visual Inspection	An intrusive visual inspection of the subsurface (using excavations or boreholes) to determine the presence or absence of contaminated soils.	0	Does not directly affect receptors and does not physically mitigate contamination. However, intrusive visual inspections may provide information on remedy effectiveness.	4	Easily implemented using available technical and labor resources.	$	0	Retained	Not viable as a solution; however, it is a potentially viable process option for combination with other technologies.
		Sample Collection and Analysis	Contaminated soil samples would be collected for chemical and physical analyses to determine the presence or absence of contaminated soils.	0	Does not directly affect receptors and does not physically mitigate contamination. However, monitoring contaminant concentrations may indicate contaminant migration has occurred or that a remedy component has failed.	4	Easily implemented using available technical and labor resources.	$	0	Retained	Not viable as a solution; however, it is a potentially viable process option for combination with other technologies.
Monitored Natural Recovery	MNR	MNR	Sample collection and analysis would be used to monitor ongoing, naturally occurring process that contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment to reduce risks to acceptable levels Natural recovery processes include dispersion, burial, dilution, and degradation of contaminants.	1	Physical transport generally increases exposure to contaminants and may result in unacceptable risks to downstream areas or other receiving water bodies. Works best in depositional areas. Effectiveness predicated on sources being addressed prior to implementation.	4	Easily implemented using available technical labor resources only if sources are reduced.	$	$	Retained	Potentially viable process option for combination with source controls.
	Enhanced Natural Recovery (ENR)	ENR	A thin layer of natural material such as sand would be applied over the contaminated sediment to enhance natural recovery processes which are not occurring at rates that reduce risks within an acceptable time frame. Sample collection and analysis would be used to monitor ongoing, naturally occurring process that contain, destroy, or reduce the bioavailability or toxicity of contaminants in sediment to reduce risks to acceptable levels.	2	Physical transport generally increases exposure to contaminants and may result in unacceptable risks to downstream areas or other receiving water bodies. Works best in depositional areas. Thin cap potentially will enhance the natural recovery by providing a low concentration surface soil/sediment layer. Effectiveness predicated on sources being addressed prior to implementation.	4	Implementable using available technical and construction resources only if sources are reduced.	$$	$	Retained	Potentially viable process option for combination with source controls.
ICs	Legal Controls	Governmental Controls, Proprietary Controls, Enforcement and Permit Tools, and Informational Devices	Contact with contaminated soils would be controlled through legal instruments. Examples of governmental (state or local) controls include, but are not limited to, local zoning, permits, codes, ordinances, or regulations. An example of proprietary controls are instruments such as environmental control easements. Some examples of informational devices include notices on property titles associated with environmental control easements and advisories such as the public health declaration.	2	Enhances awareness of potential site hazards and remedies and restricts future uses of the site that are not protective of human health and the environment but does not physically address contamination. Noncompliance with the legal instruments affects protectiveness. Is not effective for ecological receptors and does not physically address contamination.	4	Implemented using legal instruments and labor resources; potential public resistance to certain types of legal instruments.	$$	$	Retained	Potentially viable process option for combination with risk communication programs and access restrictions.
	Risk Communication Programs	Information and Education Programs	Community informational and educational programs would be undertaken to enhance awareness of potential hazards for contaminated soils. An example of a community information and education program includes a community or technical advisory group.	2	Protects human receptors by enhancing awareness of potential site hazards and remedies. Is not effective for ecological receptors and does not physically address contamination.	5	Easily implemented using available technical and community involvement labor resources.	$	$	Retained	Potentially viable process option for combination with other technologies.

Table 4-2a Screening of Potentially Applicable Remedial Technologies/Process Options Based on Effectiveness, Implementability, and Relative Cost – Contaminated Soils and Sediments
Howardsville Tailings Impoundment, Bonita Peak Mining District
Draft Feasibility Study Alternatives Development and Screening Technical Memorandum

General Response Actions	Remedial Technology	Process Option	Description of Option		Effectiveness		Implementability	Relative Cost		Reasons for Elimination of Process Option from Consideration	Process Option Viability with Respect to Assembly of Remedial Alternatives
								Capital Cost	O&M Cost		
Access Controls	Access Restrictions	Fencing and Posted Warnings	Contaminated soils would be enclosed by fences and warning signs to control access and warn people of dangers posed by the materials. In addition to fencing, closing select private roads via gates or physical road closures inhibits access to contaminated soils.	2	Protects human receptors through warnings and restricted access through fencing, though human receptors may choose to ignore warnings and circumvent fencing. Lesser degree of protection to ecological receptors that are able to circumvent fencing.	3	Easily implemented and resources readily available.	$	$	Retained	Potentially viable process option for combination with other technologies.
Containment	Surface Source Controls	In Situ Mixing	Contaminated soils with high contaminant concentrations are mixed with underlying uncontaminated soil or fill materials.	1	Contaminated soils that may benefit from this process option are generally concentrated within the large tailings impoundment. Mixing would not reduce leachability of metals from the contaminated soils.	2	Implemented using available construction resources. Contaminated soil areas are large and relatively thick and would require a deep mixing depth.	$$$	$$$	Effectiveness, Implementability	Eliminated from further consideration.
		Grading	Contaminated soils would be contoured to promote drainage and facilitate other technologies and process options.	2	Contaminated soils would be contoured to promote drainage and facilitate other technologies and process options. Enhances stability and partially mitigates erosion and infiltration. The grading reduces wind and water erosion transport and leaching of soluble contaminants. It does not protect receptors from direct exposure to contaminants by itself.	5	Easily implemented using available construction resources. Requires some maintenance for long-term protectiveness.	$$	$$	Retained	Potentially viable process option for combination with other technologies.
		Revegetation	Uncovered areas of contaminated soils, the soil layer of cover systems, and excavated/reclaimed areas would be planted with vegetation. Technology used in conjunction with other technologies and process options.	2	Uncovered areas of contaminated soils, the soil layer of cover systems, and excavated/reclaimed areas would be planted with vegetation. Technology used in conjunction with other technologies and process options.	4	Easily implemented using available construction resources. Requires suitable soil conditions for initial establishment and minor maintenance for long-term protectiveness.	$$	$	Retained	Potentially viable process option for combination with other technologies.
		Exposure Barrier	Contaminated soils would be covered with a simple layer of soil and vegetation or rock with sufficient thickness to eliminate surface exposure of the materials.	2	Limited effectiveness at reducing contact with receptors because of minimal human health exposure risk from surface soils. It does not significantly reduce dissolved phase contaminant migration.	4	Easily implemented using available construction resources. Requires minor maintenance for long-term protectiveness, especially on steep slopes.	$$$	$$	Retained	Potentially viable process option for combination with other technologies.
		Evapotranspiration Cover	Contaminated soils would be covered with engineered layers of soil or rock combined with select plant species to maximize evapotranspiration and eliminate surface exposure of the materials.	3	An appropriately designed cover will have sufficient storage capacity to hold the incoming precipitation until it can be removed by evapotranspiration, have limited deep percolation penetrates past the cover, can provide protection from surface erosion, and limit leaching and transport of contaminants within the contaminated soils. Areas with evapotranspiration covers can be reforested and/or planted with deep-rooted shrubs, so it can be more effective to restore habitat.	2	Easily implemented using available construction resources. Implementation would be challenging at the site because of high elevation and harsh winters limiting plant growth. Requires careful and robust analysis of the site variables, including soil water storage, evapotranspiration, and climatic factors. Requires maintenance for long-term protectiveness.	$$$$	$$	Retained	Potentially viable process option for combination with other technologies.
		Low-Permeability Cover	Contaminated soils would be covered with relatively impervious layers (i.e., bentonite-amended soil cover, geosynthetic multilayer cover) along with drainage and vegetative layers to reduce infiltration of precipitation and eliminate surface exposure of source media.	4	Protects receptors by eliminating surface erosion and transport of contaminants. Low-permeability covers may provide greater assurance (less risk) to inhibit infiltration and leaching within reactive contaminated soils than evapotranspiration covers. Effectiveness of clay-based covers may decrease over time because of development of desiccation cracking or penetration of woody vegetation if not maintained. Low-permeability covers must be maintained in perpetuity to remove trees and other deep-rooting plants and shrubs.	3	Implemented using available construction resources. Potentially difficult to obtain and transport large quantities of cover materials. Requires some maintenance for long-term protectiveness.	$$$$	$$$	Retained	Potentially viable process option for combination with other technologies.
		Pavement Cover	Contaminated soils would be covered with relatively impervious layers of manufactured paving materials, such as asphalt or concrete, to reduce infiltration of precipitation and eliminate surface exposure of contaminated bank and floodplain soils. This option is specifically intended to be only applicable to either current or future road areas that would require containment.	3	Protects receptors by eliminating surface erosion and transport of contaminants. Effectiveness of covers may decrease over time because of development of asphalt cracking if not maintained.	3	Implemented using available construction resources. Requires some maintenance for long-term protectiveness.	$$$$	$$$	Retained	Potentially viable process option for combination with other technologies.

Table 4-2a Screening of Potentially Applicable Remedial Technologies/Process Options Based on Effectiveness, Implementability, and Relative Cost – Contaminated Soils and Sediments
Howardsville Tailings Impoundment, Bonita Peak Mining District
Draft Feasibility Study Alternatives Development and Screening Technical Memorandum

General Response Actions	Remedial Technology	Process Option	Description of Option	Effectiveness		Implementability		Relative Cost		Reasons for Elimination of Process Option from Consideration	Process Option Viability with Respect to Assembly of Remedial Alternatives
								Capital Cost	O&M Cost		
Containment (Cont.)	Surface Source Controls	Dust Suppression	Regular application of dust suppression methods (e.g., water, chemicals) to reduce generation of potentially contaminated dust from contaminated soils.	2	Protects humans by minimizing the disturbance of the accumulated dust during construction activities.	5	Easily implemented using readily available resources. Requires ongoing maintenance while roads are expected to be disturbed.	$$$	$$$	Retained	Potentially viable process option for combination with other technologies.
	Subsurface Source Control	Liner System	A liner system would be placed at the bottom of a constructed facility for disposal of contaminated soils to prevent migration of contaminants or leaching of mining-influenced water that may form in the consolidated materials.	4	Effective at subsurface isolation of contaminated soils. Effectiveness is dependent on proactive management of collected leachate. The interface between the liner and underlying soil may cause geotechnical stability issues.	4	Implemented using available construction resources. Specialized synthetic materials may be required. The interface between the liner and underlying soil may cause installation issues. Typically requires installation of a subsurface leachate collection system and management and/or treatment of collected leachate.	$$$$	$$$	Retained	Potentially viable process option for combination with other technologies.
	Barriers	Retaining Structures	Contaminated soil surfaces would be stabilized using retaining structures.	3	Protects receptors by reducing erosion and transport of contaminants to surface water by retaining contaminated soils behind structures, depending on the type of structure.	2	Implemented using available construction resources. Requires some maintenance for long-term protectiveness.	$$$$	$$	Retained	Potentially viable process option for combination with other technologies.
Removal, Transport, Disposal	Removal	Mechanical Excavation	Contaminated soils would be excavated using mechanical methods.	4	Protects receptors by eliminating contaminated soils at the excavation location that could result in erosion and transport of contaminants to surface water. Must be combined with transport, disposal, and/or treatment technologies.	5	Implemented using available construction resources. Excavation may be more difficult on steep slopes.	$$$$	0	Retained	Viable as a long-term solution; must be combined with transport, disposal, and/or treatment technologies.
	Transport	Mechanical Transport (Hauling/Conveying)	Excavated contaminated soils would be transported by truck or other mechanical conveyance method to disposal site.	4	Protects receptors by eliminating contaminated soils at the excavation location which could result in erosion and transport of contaminants to surface water. Transport of contaminated soils on roads or rail may cause adverse impacts to the public. Must be combined with removal, disposal, and/or treatment technologies.	4	Easily implemented using available construction resources assuming sufficient dewatering was completed during excavation; efficient for all sizes of materials.	$$$	0	Retained	Viable as a long-term solution; must be combined with removal, disposal, and/or treatment technologies.
	Disposal	Disposal at Proposed Facility	Excavated contaminated soils would be disposed of at a proposed repository within a facility constructed within the site.	4	Protects receptors by eliminating exposure to contaminants by placing within a disposal facility that eliminates surface erosion and transport of contaminants. Must be combined with removal, transport, containment, and/or treatment technologies.	4	Implemented using available construction resources. Property to construct disposal repository has not been identified and may require extensive administrative efforts and coordination. Land use and other restrictions, such as existence of floodplains, wetlands, and fault zones, may affect the administrative implementability of this process option. Requires some maintenance for long-term protectiveness.	$$$	$$$	Retained	Viable as a long-term solution; must be combined with removal and transport technologies.

Table 4-2a Screening of Potentially Applicable Remedial Technologies/Process Options Based on Effectiveness, Implementability, and Relative Cost – Contaminated Soils and Sediments
Howardsville Tailings Impoundment, Bonita Peak Mining District
Draft Feasibility Study Alternatives Development and Screening Technical Memorandum

General Response Actions	Remedial Technology	Process Option	Description of Option	Effectiveness		Implementability		Relative Cost		Reasons for Elimination of Process Option from Consideration	Process Option Viability with Respect to Assembly of Remedial Alternatives
								Capital Cost	O&M Cost		
Treatment	Ex Situ Treatment	Biochemically Reduced Submergence	Contaminated soils would be excavated and submerged in a chemically reduced environment constructed using anaerobic microorganisms to immobilize soluble metals as metal-sulfide precipitates. Technology used in conjunction with other technologies and process options such as removal and disposal.	3	Does not directly protect receptors from erosion and transport of contaminants. Effectiveness of chemically reduced submergence can be variable depending on the conditions; effectiveness of chemically reduced submergence may decrease over time if saturated and reducing conditions are not maintained. Effectiveness not ensured if submerged contaminated soils and groundwater are not neutralized. Occasional maintenance, monitoring, and addition of organic reagent may be required to maintain effectiveness.	1	Implemented using available construction resources. Maintenance required to maintain consistent water levels within submerged contaminated soils. Monitoring of subsurface conditions also required to maintain a chemically reduced environment. Water supply issues are also present at the site.	$$$$$	$$$$$	Implementability, Cost	Eliminated from further consideration.
		Biochemical Inhibition of Sulfide Oxidation	Contaminated soils would be excavated and mixed on-site with substrates (e.g., wood chips and compost) and bacteria inoculum to inhibit sulfide oxidation before disposal. Technology used in conjunction with other technologies and process options such as removal and disposal.	1	Does not protect receptors from erosion and transport of contaminants. Long-term effectiveness of technology is unknown because of the limited research and field-scale implementation. Would require a permeable cover system to allow some moisture to move through the contaminated soils and encourage bacterial activity. Effectiveness during cold winters/heavy snow cover is unknown. Desiccation of the amended materials during the dry season would be expected to reduce the effectiveness.	2	Implemented using available construction resources. Potential difficulty obtaining and transporting large quantities of suitable amendments needed from off-site sources. Monitoring of subsurface conditions to maintain an anoxic environment may be necessary. Requires mixing of contaminated soils.	$$$$	$$	Effectiveness	Eliminated from further consideration.
		Pozzolan- or Cement-Based Stabilization/Solidification	Contaminated soils would be excavated and mixed on-site with a pozzolan- or cement-based binding agent before disposal. Technology used in conjunction with other technologies and process options such as removal and disposal.	4	Protects receptors by eliminating erosion and transport of contaminants to surface water. Effectiveness of stabilization may decrease over time because of development of freeze–thaw cracking or sulfate attack.	3	Implemented using available construction resources. May be difficult to obtain and transport large quantities of cement-based binding agent. Requires some maintenance for long-term protectiveness. This process option will be most appropriate on a smaller scale and for more homogeneous materials.	$$$$	$	Retained	Potentially viable process option for combination with other technologies.
		Neutralization	Contaminated soils generating acid rock drainage would be mixed in place or excavated and mixed with an alkaline material such as agricultural lime ($CaCO_3$) or hydrated lime ($Ca(OH)_2$) to neutralize acidity and increase pH. Technology used in conjunction with other technologies and process options such as removal and disposal.	3	Does not protect receptors from erosion and transport of contaminants. Effectiveness of neutralization may decrease over time. Neutralization could help to facilitate revegetation and support development of a self-sustaining vegetative cover in reclaimed areas.	3	Implemented using available construction resources. Potential difficulty obtaining and transporting large quantities of suitable neutralization materials. Requires some maintenance (e.g., reapplication) for long-term protectiveness. This process option will be most appropriate on a smaller scale and for more homogeneous materials.	$$$	$	Retained	Potentially viable process option for combination with other technologies.
		Chemical Immobilization	Contaminated soils would be excavated and treated on-site with chemicals to inhibit sulfide oxidation and reduce the potential for metals leaching before disposal. Technology used in conjunction with other technologies and process options such as removal and disposal.	3	Does not protect receptors from erosion and transport of contaminants. Effectiveness of chemical immobilization may decrease over time because of degradation of chemical coating or amendment material.	2	Implemented using available construction resources; however, technology is proprietary and subject to patents. May require periodic reapplications for long-term effectiveness.	$$$$	$$$	Retained	Potentially viable process option for combination with other technologies.
Treatment (continued)	Ex Situ Treatment (continued)	Hydrometallurgical Processing (Flotation)	Contaminated soils would be excavated, crushed, and ground and flotation (addition of chemicals to contaminated soils-water slurry) would be used to remove sulfide minerals, producing a concentrate and nonacid-generating tailings (remove all sulfide minerals from tailings). Technology used in conjunction with other technologies and process options such as removal and disposal.	2	Protects receptors by treating source materials, which would eliminate erosion and transport of contaminants to surface water. May facilitate additional recovery of metals.	1	Implemented using available equipment and construction resources. However, the process option would require construction of a new mineral processing facility on-site, electrical power and other infrastructure, and removal/reclamation of these facilities after contaminated soils are treated. Obtaining concurrence from agencies to construct the facilities may be challenging. Treatability testing would be required to assess performance of hydrometallurgical processing.	$$$$$	0	Implementability, Cost	Eliminated from further consideration.

Table 4-2a Screening of Potentially Applicable Remedial Technologies/Process Options Based on Effectiveness, Implementability, and Relative Cost – Contaminated Soils and Sediments
Howardsville Tailings Impoundment, Bonita Peak Mining District
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General Response Actions	Remedial Technology	Process Option	Description of Option	Effectiveness	Implementability	Relative Cost: Capital Cost	Relative Cost: O&M Cost	Reasons for Elimination of Process Option from Consideration	Process Option Viability with Respect to Assembly of Remedial Alternatives
		Solvent/Chemical Extraction (Leaching)	Contaminated soils would be excavated, crushed, ground, and placed into a leaching facility. A solvent/chemical is then dispersed through the contaminated soils to remove specific contaminants. Technology used in conjunction with other technologies and process options such as removal and disposal.	❸ Protects receptors by treating source materials which would eliminate erosion and transport of contaminants to surface water. This process may have limited effectiveness/efficiency for metal extraction; therefore, some contaminants may remain in wastes after the extraction process.	❶ Implemented using available equipment and construction resources. However, the process option would require construction of leaching facilities such as leach vats or leach pads, construction of electrowinning facilities on-site, electrical power and other infrastructure, and removal/reclamation of these facilities after contaminated soils are treated. Obtaining concurrence from agencies to construct the facilities may be challenging.	$$$$$	⓿	Implementability, Cost	Eliminated from further consideration.
	In Situ Treatment	Pozzolan- or Cement-Based Stabilization/Solidification	Contaminated soils would be mixed in situ with a pozzolan- or cement-based binding agent using a soil auger mixing/injection technique.	❷ Protects receptors by eliminating erosion and transport of contaminants to surface water. Effectiveness of stabilization may decrease over time because of development of freeze–thaw cracking or sulfate attack. Only effective to stabilize wastes within a shallow upper layer accessible by application equipment and subject to leaching as cement degrades. May be effective in a smaller, targeted setting or for a small volume of material.	❷ Implemented using available construction resources. Difficult to obtain and transport large quantities of binding agent and homogenize binding agent with contaminated soils. Requires some maintenance for long-term protectiveness. This process option will be most applicable on a smaller scale and for more homogeneous materials.	$$$	$$$	Retained	Potentially viable process option for combination with other technologies.
		Neutralization	Contaminated soils would be treated with an alkaline material such as sodium hydroxide or hydrated lime ($Ca(OH)_2$) to neutralize acidity and increase pH.	❸ Does not protect receptors from erosion and transport of contaminants. Effectiveness of neutralization may decrease over time if sufficient quantities are not used initially. Neutralization is more effective on a small-scale basis. Neutralization could help to facilitate revegetation and support development of a self-sustaining vegetative cover in reclaimed areas.	❷ Implemented using available construction resources. Potential difficulty obtaining and transporting large quantities of suitable neutralization materials needed from off-site sources. Difficult to implement in the subsurface; contaminated soils are highly heterogeneous. May require periodic reapplication of alkaline materials for long-term effectiveness.	$$$$	$$	Retained	Potentially viable process option for combination with other technologies.
Treatment (continued)	In Situ Treatment (continued)	Chemical Immobilization	Contaminated soils would be treated with chemicals to inhibit sulfide oxidation and/or reduce the potential for metals leaching or reduce metal bioavailability.	❷ Does not protect receptors from erosion and transport of contaminants; however, bioavailability of some metals can be reduced by application of certain chemicals (i.e., phosphates). Effectiveness of chemical immobilization may decrease over time because of degradation of chemical coating or abrasion of waste with the chemical coating. Chemical immobilization will likely only be effective in conjunction with in situ mixing within lower-concentration contaminated soils.	❷ Implemented using available construction resources; however, technologies may be proprietary and subject to patents. Potential difficulty obtaining and transporting large quantities of suitable immobilization materials needed from off-site sources. Difficult to implement because technology is mainly dependent on creating saturated conditions in the subsurface; contaminated soils are highly heterogeneous. Periodic reapplication of chemicals may be required for long-term effectiveness.	$$$$	$$$	Retained	Viable on limited basis in combination with other technologies.
		Biochemical Inhibition of Sulfide Oxidation	Contaminated soils would be treated in situ with biochemical reactor (BCR)-treated water effluent or similar water containing liquid organic carbon and bacteria to inhibit sulfide oxidation and reduce the potential for metals leaching. BCR effluent or other liquid amendments would be applied to the contaminated soils using a land-application sprinkler system and/or via drilled boreholes.	❷ Does not protect receptors from erosion and transport of contaminants to surface water. Long-term effectiveness of technology is unknown because of the limited research and field-scale implementation. Desiccation of the amended materials would be expected to reduce the effectiveness.	❶ Implemented using available construction resources. Potential difficulty obtaining and transporting large quantities of suitable amendment materials needed from off-site sources. Difficult to implement because technology is mainly dependent on creating saturated conditions in the subsurface; contaminated soils are highly heterogeneous. Monitoring of subsurface conditions to maintain an anoxic environment may be necessary. Long-term application/injection of BCR effluent or other liquid amendments may be required for long-term effectiveness.	$$$$	$$$	Implementability	Eliminated from further consideration.

Table 4-2a Screening of Potentially Applicable Remedial Technologies/Process Options Based on Effectiveness, Implementability, and Relative Cost – Contaminated Soils and Sediments
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								Capital Cost	O&M Cost		
		Biologically Mediated Stabilization	Contaminated soils would be treated with amendments and bacteria that produce calcium carbonate ($CaCO_3$) to bind contaminants and inhibit leaching.	❸	Protects receptors by eliminating erosion and transport of contaminants to surface water. Effectiveness of stabilization may decrease over time because of development of freeze–thaw cracking or sulfate attack, especially in acidic saturated conditions such as in streams.	❶	Implemented using available construction resources. Difficult to design and homogenize bacteria with contaminated soils. Technology is dependent on wet or saturated conditions in the subsurface. Water supply issues are present at the site and saturated conditions would not be sustainable. Technology is proprietary and subject to patents. Requires some maintenance for long-term protectiveness.	$$$$	$$	Implementability	Eliminated from further consideration.
Treatment (continued)	Thermal Treatment	Pyrometallurgical Processing (Smelting)	Smelting (application of heat to a charge of contaminated soils and flux in a furnace) would be used to separate molten streams of metals, slag, and dust. Contaminated soils would be excavated, crushed, ground, and then smelted. Additional process options such as hydrometallurgical processing (flotation) may be required prior to smelting.	❶	This is a process that could be used to recover metals from concentrates produced by hydrometallurgical processing. Smelting is not applicable as a process option for on-site treatment of contaminated soils.	❶	It is unlikely that an on-site smelter could be constructed because of the extensive infrastructure and regulatory permitting needs.	$$$$$	⓿	Effectiveness, Implementability, Cost	Eliminated from further consideration.
Reuse, Reclamation, Recovery	Remining/Reprocessing	Flotation, Leaching, and Smelting	Contaminated soils would be excavated and processed using methods, such as flotation and smelting, to separate valuable metals from the contaminated soils. These processes are described in greater detail under chemical/physical treatment remedial technologies. This technology is intended to represent the potential for generation of materials that could be sold for a positive cost benefit, whereas treatment technologies are intended to treat and dispose of the waste with no potential for positive cost benefit.	❸	Protects receptors by recovering metals, which would eliminate erosion and transport of contaminants to surface water. Waste products produced during smelting would be disposed in accordance with site-specific requirements at the existing smelter.	❶	Treatability testing would be necessary to evaluate recoverable metals in the concentrate, and infrastructure would be required as described for hydrometallurgical processing (flotation). The concentrate produced may be suitable for shipment to an operating smelter for metals recovery. It would be difficult to locate a smelter in the United States capable and willing to accept the contaminated soils because of air emission issues associated with problematic inorganic contaminants, especially given the types and relatively low concentrations of desirable metals within the wastes. Additionally, it may be difficult to transport high volumes of material.	$$$$	⓿	Implementability	Eliminated from further consideration.

Notes:
1. The screening process for effectiveness, implementability, and relative cost involves a qualitative assessment of the degree to which process options address evaluation criteria presented in Section 4.4.
2. Shading indicates remedial technologies/process options have been eliminated from further consideration based on lack of effectiveness, implementability, and/or cost. Remaining (unshaded) remedial technologies/process options have been retained for consideration in remedial action alternatives.

Legend for Qualitative Ratings System: The following ratings were used for evaluation and presentation of effectiveness, implementability, and relative cost:

Effectiveness and Implementability		Relative Cost	
⓿	None	⓿	None
❶	Low	$	Low
❷	Low to Moderate	$$	Low to Moderate
❸	Moderate	$$$	Moderate
❹	Moderate to High	$$$$	Moderate to High
❺	High	$$$$$	High