Tables

Table 1-1. Summary of Supporting Investigations and Reports

Corrective Measures Study Report, Former ASARCO East Helena Facility

Timeframe of Relevant Activity/ Investigation	Report Title	Author(s)	Entity Responsible	Report Year	Reference Location
June 1984	Remedial Investigation of Soils, Vegetation, and Livestock	CH2M HILL	USEPA	1987	Section 3.2
Nov 1984 - May 1988	Process Pond Remedial Investigation/Feasibility Study	Hydrometrics and Hunter/ESE	ASARCO	1989	Section 3.2
Fall 1984 - Spring 1988	Comprehensive Remedial Investigation/Feasibility Study for the Asarco East Helena Smelter	Hydrometrics	ASARCO	1990	Section 3.2
1998-1999	Current Conditions/Release Assessment, East Helena Facility	Hydrometrics	ASARCO	1999	Section 3.2
1984 - 2002	Phase I RCRA Facility Investigation Site Characterization Report - East Helena Facility	Hydrometrics	ASARCO	2005	Section 3.2
2003	Supplemental Ecological Risk Assessment for the East Helena Smelter Site, Montana	USEPA	USEPA	2005	Section 2.3.3
2009	U.S. East Helena Superfund Site, Operable Unit No. 2, Residential Soils and Undeveloped Lands, Final Record of Decision	USEPA	USEPA	2009	Sections 1.2, 2.3.1, 2.3.3, 3.2.5, 6
2010	Phase II RCRA Facility Investigation, East Helena Facility	GSI Water Solutions, Inc.	Custodial Trust	2014	Sections 3.2 and 3.3.5
2010	Baseline Ecological Risk Assessment: Former ASARCO East Helena Facility, East Helena, Montana	Gradient	Custodial Trust	2011	Section 3.4.2
2011	Preliminary Evaluation of South Plant Hydraulic Control at the East Helena Smelter Facility	GSI Water Solutions, Inc.	Custodial Trust	2011	Section 3.3.2
2011-2012	Draft Upper Lake Drawdown Test Technical Memorandum	Hydrometrics, Inc.	Custodial Trust	2012	Sections 3.3.2 and 5.2
2012	Former ASARCO East Helena Facility Interim Measures Work Plan - Conceptual Overview of Proposed Interim Measures and Details of 2012 Activities	CH2M HILL	Custodial Trust	2012	Section 5
2013	Former ASARCO East Helena Facility Interim Measures Work Plan – 2013	CH2M HILL	Custodial Trust	2013	Section 5.3
2014	Former ASARCO East Helena Facility Interim Measures Work Plan – 2014	CH2M HILL	Custodial Trust	2014	Section 5.3
2014	2014 Supplemental Contaminant Source Area Investigation at the Former East Helena Smelter	Hydrometrics, Inc.	Custodial Trust	2015	Section 3.3.5
2014	Groundwater Flow Model Calibration Refinement, Transient Verification, and Interim Measures Support, East Helena Site	NewFields	Custodial Trust	2014	Section 5
2014-2015	Groundwater Remedy Evaluation and Recommendations for the Former East Helena Smelter	CH2M HILL	Custodial Trust	2016	Sections 3.3.5 and 5
2015	Former ASARCO East Helena Facility Corrective Measures Study Work Plan	CH2M	Custodial Trust	2015	Sections 3.3.4, 3.3.5, and 3.4.2
2015	2015 Groundwater and Surface Water Corrective Action Monitoring Plan, East Helena Facility	Hydrometrics, Inc.	Custodial Trust	2015	Section 3.3.1 and 5
2015	Final Fate and Transport Model Design and Calibration, East Helena Site	NewFields	Custodial Trust	2015	Section 5
2015	Basis of Design Report for the ET Cover System, Interim Cover System 2, and Demolition Phase 3	CH2M HILL	Custodial Trust	2015	Section 5.3
2015	2015 Supplemental Contaminant Source Area Investigation at the Former East Helena Smelter	Hydrometrics, Inc.	Custodial Trust	2016	Sections 3.3.5 and 5
2015-2016	Former ASARCO East Helena Facility Interim Measures Work Plan – 2015 and 2016	CH2M HILL	Custodial Trust	2015	Section 5.3
2015-2016	East Helena Facility Supplemental RFI Sampling and Analysis Plan	CH2M HILL	Custodial Trust	2015	Section 3.3.4
2015-2016	Addendum to Former ASARCO East Helena Facility Interim Measures Work Plan – 2015 and 2016	CH2M HILL	Custodial Trust	2016	Section 5.3
January - March 2016	2016 Speiss/Dross Slurry Wall Evaluation Technical Memorandum	Hydrometrics, Inc.	Custodial Trust	2016	Section 3.3.5
2016	Addendum to East Helena Facility Supplemental RFI Sampling and Analysis Plan	CH2M	Custodial Trust	2016	Section 3.3.4
2016	2016 Groundwater and Surface Water Corrective Action Monitoring Plan, East Helena Facility	Hydrometrics, Inc.	Custodial Trust	2016	Section 3.3.1
2016	Existing Information and Data Compilation for the Former East Helena Smelter Slag Pile Area Technical Memorandum	Hydrometrics, Inc.	Custodial Trust	2016	Section 3.3.6

Notes:

ASARCO = American Smelting and Refining Company

RCRA = Resource Conservation and Recovery Act

RFI = RCRA Facility Investigation

USEPA = U.S. Environmental Protection Agency

Table 2-1. CMS Parcels - Media Cleanup Standards for Primary Inorganic Constituents in Soil
Corrective Measures Study Report, Former ASARCO East Helena Facility

Media	Constituent of Potential Concern	Land Use	Cleanup Standard (µg/L groundwater, mg/kg soil)[d]	Basis of Standard	Applications for Standard
Groundwater	Arsenic	All	0.010	MCL	Exceedance of MCS indicates need for remedial action and will be considered in identification of areal extent of institutional controls (Controlled Groundwater Area)
	Cadmium		0.005		
	Selenium		0.05		
Surface Soil	Lead	Ecological	650	Concentration established to be protective of ecological receptors (passerines) at other MT remediation sites[a]	Will be applied as a design criterion for IM and final remedy construction (final surface site work associated with Prickly Pear Creek and Tito Park excavation, surface layer of ET Cover System, etc.)
		Residential	400	USEPA RSL[b]	Establishes concentration threshold for remedy implementation on undeveloped properties when land use changes
		Industrial - Commercial	800		
		Recreational	3,245	OU-2 ROD	
	Arsenic	Residential	35	Hegeler Zinc ROD[c]	
		Industrial - Commercial	572	OU-2 ROD	
		Recreational	794	OU-2 ROD	
Soil at Depth	Arsenic		40	(MDEQ, 2013)	Establishes extent of remedial action required to prevent groundwater contact with contaminated soil and to control infiltration
	Cadmium		0.38	USEPA MCL-based SSL[b] (concentration needed to achieve MCLs in groundwater)	
	Selenium		0.26	USEPA MCL-based SSL[b] (concentration needed to achieve MCLs in groundwater)	

[a] Recommended based on its consistency with action levels developed at other similar smelter/mining sites: OU2 Record of Decision (ROD) East Helena, MT; Anaconda Smelter Superfund Site, Anaconda, MT; Bunker Hill Superfund Site, Coeur d'Alene, ID; and Tri-State Mining District (Oklahoma, Kansas, and Missouri) Superfund Site.

[b] USEPA June 2015 RSL or MCL-based soil screening level (SSL) where indicated

[c] The arsenic cleanup level is recommended based on risk-based concentrations currently being approved by USEPA at former smelter sites and similar facilities across the country. The Hegeler Zinc ROD is cited as an example of current practice (USEPA, 2014).

[d] Media cleanup standards for CMS Parcels as presented in the CMS Workplan (EPA Approval, October 22, 2015); OU-2 ROD standards will be applied to the Undeveloped Lands.

Abbreviations:

µg/L = micrograms per liter
ET = evapotranspiration
IM = interim measure
MCL = maximum contaminant level
MDEQ = Montana Department of Environmental Quality
mg/kg = milligrams per kilogram
OU2 ROD = Record of Decision for Operable Unit 2
RSL = regional screening level

Table 3-1. Summary of Interim Measures Completed by ASARCO
Corrective Measures Study Report, Former ASARCO East Helena Facility

Approximate Dates	Summary of Interim Measure
Sediment and Surface Water (Diversions/Modifications/Management):	
1996-1997	Surface water: 1996: Switch to use of water from Upper Lake rather than Lower Lake for dust control 1997: Wilson Ditch rerouted around plant site 1997: Improve plant stormwater system
1986-1991	Thornock Lake Removal – key items as follows: 1986-1987: soil excavated from Thornock Lake area. 1986: Thornock Lake replaced with 93,000 gallon steel tank 1991: 407 CY of soil excavated from former Thornock Lake and smelted
1989-1996	Lower Lake Dredging/Water Treatment Plant – key items as follows: 1989: Bench-scale testing for the treatment of Lower Lake water 1990: Discontinue regular discharge of plant water to Lower Lake (occasional discharge from tanks when needed). 1993: Begin construction of high-density sludge water treatment plant 1993: large-scale dredging and dewatering pilot testing of Lower Lake sediments 1994: HDS water-treatment plant comes on-line; discharges to Lower Lake cease 1994-1996: dredging of Lower Lake sediments 1996: MPDES permit issued for HDS plant discharge
Surface Soil and Demolition of the Ore Storage Area:	
1989	Shallow soil removed and stored in Lower Ore Storage Area, deeper soil consolidated in southeast corner of the storage yard
1997	Geomembrane cover is installed over stockpiled Lower Lake sediments as a temporary cover
2000	Construct Phase I CAMU for waste management
2009	Demolished process unit smelter stacks
Former Speiss Settling Pond and Granulating Pit:	
1988	Speiss Pond lined with high-density polyethylene
1989	Replace Speiss pond with settling tank and secondary leak detection
1989	2,500 CY soil excavated to 20 feet under former Speiss Pond
1991	Discontinue water granulation of Speiss
1992	Demolish Speiss pond and excavate soil
1993	Cap former Speiss pond area with concrete.
1995	Excavate and cap (concrete) former Speiss pit to 17-feet depth (235 CY removed)
2006-2007	Construct slurry wall and cap around Speiss-dross plant subsurface soil.
Acid Plant Water:	
1991	Eliminated wooden trough fluid transport system and settling dumpsters, reducing water losses.
1992	Complete water reclamation facility and discontinue use of sediment drying pad
1993	Demolish and excavate Acid plant settling pond
1997	Re-brick acid plant scrubber sump and install secondary containment
Acid Plant Sediment Drying Area:	
1991	Remove Acid plant sediments from former sediment drying pad
1993	Seal Former acid plant sediment drying pad
2001	Soil and debris stockpiles from remedial actions placed in the CAMU 1
2006	Construct slurry wall and cap around APSD subsurface soil

Table 3-2. Summary of Remediation Waste Generation and Management During Interim Measure Implementation

Corrective Measures Study Report, Former ASARCO East Helena Facility

Remedial Activity	Waste Source Area	Waste Type(s)	Dates of Removal	Waste Disposal Location	Waste Quantities
ASARCO-Implemented Interim Measures					
Lower Lake Sediment Dredging	Lower Lake	Sediment	1994-1996	Temporarily stockpiled in Lower Ore Storage Area. Placed in CAMU 1 in 2001.	27,000 cy
				Smelted	4,000 cy
Thornock Lake Removal	Thornock Lake	Sediment	1986-1987	Smelted	Not Provided
	Thornock Lake	Sediment	1991	Smelted	407 cy
		Slag	1991	Placed on slag pile	185 cy
Speiss/Dross Area Removal	Speiss Pond	Soil	1988	Smelted	2,500 cy
	Speiss Pond	Soil	1992	Temporarily stockpiled in Lower Ore Storage Area. Placed in CAMU 1 in 2001.	235 cy
	Speiss Pond	Soil	1995	Temporarily stockpiled in Lower Ore Storage Area. Placed in CAMU 1 in 2001.	250 cy
Acid Plant Removal	Acid Plant Settling Pond	Soil	1993	Temporarily stockpiled in Lower Ore Storage Area. Placed in CAMU 1 in 2001.	2,200 cy
	Former Sediment Drying Pad	Sediment	1991	Smelted	Not Provided
	Original Sediment Drying Pad	Soil/Sediment	1993	Temporarily stockpiled in Lower Ore Storage Area. Placed in CAMU 1 in 2001.	Not Provided
Stockpile Removal	Lower Ore Storage Area, Shew Ridge, Lower Lake Sediment Stockpile, and Tito Park Area Stockpiles	Soil/Sediment/Debris	2001	CAMU 1	110,000 cy
2008 Facility Demolition	Site Structures (Process and Nonprocess) [a]	Building Debris (wood, brick, insulation, concrete, pipe, other cleanup waste)	2008	CAMU 2	37,471 cy

Table 3-2. Summary of Remediation Waste Generation and Management During Interim Measure Implementation

Corrective Measures Study Report, Former ASARCO East Helena Facility

Remedial Activity	Waste Source Area	Waste Type(s)	Dates of Removal	Waste Disposal Location	Waste Quantities
2009 Facility Demolition	Site Structures (Process and Nonprocess)[b]	Building Debris (wood, brick, insulation, concrete, pipe, building cleaning, other cleanup waste) Yard Debris (railroad ties, roadway sweepings)	2009	CAMU 2	18,565 cy
Custodial Trust-Implemented Interim Measures					
Phase 1 Demolition	Site Structures (Nonprocess)[c]	Metal	4/2013 - 7/2013	Offsite	2,176 tons
Phase 2 Demolition	Site Structures (Nonprocess)[d]	Metal	7/2013 - 10/2013	Offsite	1,249 tons
	Site Structures (Nonprocess)[e]	Building Debris (wood, brick, insulation, concrete, pipe) Yard Debris (dirt, fabrics, railroad ties, miscellaneous)	9/2013 - 10/2013	CAMU 2	2,618 tons
Tito Park Area Removal	Acid Plant Sediment Drying Area/ Tito Park Area	Slurry Wall Material, Speiss, Contaminated Soil, Sand, Rusted/Crushed Ore Barrels, Concrete	7/2014 - 8/2014	CAMU 2	30,270 cy
	Tito Park Area	Lower Lake Sediments, Contaminated Soil, Other Soil	6/2014 - 9/2014	ET Cover West Subgrade	150,000 cy
PPC Realignment	Upper Lake Marsh	Contaminated Marsh Sediments	9/2016 - 10/2016	ET Cover East Subgrade	21,000 cy
Phase 3 Demolition	Site Structures (Process)[c]	Construction and Debris, Universal Wastes, Refrigerants	6/2015 - 8/2016	Offsite	1,400 tons
		Metal	6/2015 -10/2016	Offsite	756 tons
	Speiss Disposal	Speiss; Contaminated Soil	7/2016 - 9/2016	ET Cover East Subgrade	8,000 cy
Acid Plant Removal	Acid Plant Settling Pond	Contaminated Soil; Concrete	4/2016 - 8/2016	ET Cover East Subgrade	20,000 cy

[a] Primary structures included: Acid Plant, Bag House, Bailey Building Stored Waste, Barnum Building Stored Waste, Ore Storage Stored Waste, Ringling Building, Spray Dryer, Blast Furnace Flue, Monier Flue

[b] Primary structures included: Acid Dust Silo, Crushing Mill, Sample Mill, Hopto Pad, Breaking Floor/Highline, Ore Storage RR Track Area, Ore Storage Walls Demolition, 200-foot Stack, 400-foot Stack, 425-foot Stack, Ore Storage Cleaning, Ore Storage Baghouse Cleaning, Ore Storage Sump Cleaning, Crushing Mill Cleaning, Sample Mill Cleaning, Hopto Pad Cleaning, Bailey Building Cleaning, Cement Silo Cleaning, Coke Hopper Cleaning, Direct Smelt Building Cleaning, High Grade Cleaning, Scale House Cleaning, Water Treatment Plant Sump Cleaning, Sump Near Scale House Cleaning, Sump South of Barnum Cleaning, Debris Around Bailey Building Cleaning, Million-gallon-tank Cleaning

[c] Primary structures included: Ore Storage and Handling, Barum and Bailey Buildings, Scales and Scalehouse

[d] Primary structures included: Powerhouse, Warehouse, Welding Shops, DOES Building, Direct Smelt Building, Zinc Plant O_2 Building, Other miscellaneous structures and debris

[e] Primary structures included: Engineering Building, Bathhouse Building, Stormwater Tanks; HDS Treatment; Transformer Pad Area; Power Building, etc.

Notes:
cy = cubic yards; HDS = high-density sludge

Table 3-3. Former East Helena Smelter Groundwater Contaminant Source Inventory

Corrective Measures Study Report, Former ASARCO East Helena Facility

General Source Area	Source #	Source Name	Primary COC As/Se	Description	Soil Conditions	Groundwater Conditions	Recommendations
West Selenium Area	1	Rail Corridor Soils	Se	Rail corridors adjacent to former ore storage building. SPLP leach samples showed 0.027 to 0.490 mg/L selenium. Leachability increased with depth while total concentrations decreased with depth.	Elevated total Se concentrations in near surface soils decrease with depth. Phase II RFI surface soil samples ranged from 569 to 754 mg/kg at RCSS-5 and RCSS-7 (0-6"), decreased to 13 to 96 mg/kg respectively at 2.5-5 feet. Boring RFI2SB-9 surface (slag) samples showed 151 to 281 mg/kg Se, decreased to <5 mg/kg in deeper samples.	Seasonal Se spikes up to 7 mg/L (DH-66), appear to have been mitigated by SPHC. "Baseline" concentrations still 1-2 mg/L range, most recent concentrations 4-6 mg/L (2014). Well DH-66 highly correlated with water table variations and other parameters (SO_4, Cl), DH-8 less so (different mechanisms?). Groundwater saturated with respect to gypsum ($CaSO_4$) and calcite ($CaCO_3$). Low arsenic concentrations in this area. Possible secondary mineral cement source.	Although they cannot be ruled out due to high leach concentrations, surface soils seem an unlikely source of seasonal spikes in groundwater. Additional data to be collected as part of 2014 source characterization work. Should be addressed through capping.
	2	Selenium-Loaded Saturated Soils: impacted from Speiss-Dross Area Groundwater	Se	Not a former process area. Downgradient of historic source areas (speiss/dross and/or acid plant). Selenium historically loaded onto saturated soils via groundwater transport, possibly precipitated or occluded within minerals former in aquifer matrix during mixing/neutralization of acid plant and speiss dross impacted groundwater. May be released over time, with changing geochemical conditions. Process water in speiss/dross reportedly contained ~40 mg/L selenium, acid plant process water ~6 mg/L selenium. Well DH-21 in speiss/dross area reported about 7 mg/L in 1999 as part of plant water release investigation.	Concentrations and leachability of Se in subsurface soils (both saturated and unsaturated) not well documented. Location estimated based on configuration of west selenium plume.		Possible significant source of current selenium loading to groundwater. Evaluate further for possible mitigation. Additional subsurface data needed.
	3	Selenium-Loaded Saturated Soils: Impacted from Acid Plant Area Groundwater	Se		Concentrations and leachability of Se in subsurface soils (both saturated and unsaturated) not well documented. Location estimated based on configuration of west selenium plume.		Possible significant source of current selenium loading to groundwater. Evaluate further for possible mitigation. Additional subsurface data may be needed.
North Plant Source Area	4	North Plant Site Saturated Soils	As (Se?)	Not a former process area. Downgradient of historic source area (speiss/dross) and slurry wall, upgradient of PRB. Arsenic historically loaded onto saturated soils via groundwater transport from upgradient sources; may be released over time with changing geochemical conditions. Also some potential for Se release based on RFI2SB-20 results (leached 0.7 mg/L Se during adsorption tests) and recent gw trends at well DH-36 (As decrease/Se increase).	Organic contamination at water table common in wells and soil borings. Deep (saturated) soil As concentrations highest at DH-13 (300-1400 mg/kg), DH-17 (300-700 mg/kg). More recent data somewhat lower: Phase II RFI borings in area range from 25-432 mg/kg; lower on As plume periphery. As adsorption observed at RFI2SB-8 and -21. As leaching at RFI2SB-16 (40-42'), adsorption at 25-32'.	Downgradient of slurry wall, gw concentrations are 3-12 mg/L range (SDMW-1, -2, -5, DH-13). 450' downgradient at DH-17 concentrations are 35 mg/L. DH-17 concentrations stable since 2002 but have recently decreased to minimum seen since 2002 (from 45 mg/L down to 31.5 mg/L). As(III) predominant at DH-17, continuing downgradient to DH-64, alters to As (V) as plume crosses Highway 12.	Possible primary current source of arsenic loading to downgradient groundwater. Potential future source of selenium loading to groundwater if geochemical conditions change. Evaluate further for possible mitigation. Additional subsurface data needed.
Slag Pile	5	Younger Unfumed Slag	As/Se	Slag not processed through zinc plant during periods prior to zinc plant construction (1930s) and following cessation of zinc plant operation (1982). Generally south end and "upper lift" of slag pile.	Unfumed slag shows higher total metals concentrations than fumed slag. Phase II RFI samples from well DH-74 showed 97 to 209 mg/kg Se and 814 to 1840 mg/kg As from 0-42 feet; deeper samples showed <5 to 17 mg/kg Se and 9 to 194 mg/kg As. Slag leach concentrations from Phase II RFI (SPLP) showed 0.009 to 0.130 mg/L As, 0.036 to 0.400 mg/L Se. RI/FS era slag leach and test basin samples showed 0.353 to 0.620 mg/L As in test basins and 0.31 mg/L As in bottle roll for unfumed slag. Fumed slag showed lower concentrations (0.0283 to 0.054 mg/L in test basins and 0.19 mg/L in bottle roll). Test basin K results were 54 to 74 mg/L for fumed slag, 1540 to 2650 mg/L for unfumed slag. Bottle roll K results were 3.9 mg/L for fumed and 22 mg/L for unfumed slag.	Selenium and arsenic concentrations in area currently highest near north and northwest portion of slag pile. Highest Se concentrations at well DH-56. Some Se (IV) contribution in this area. Very high K concentrations at DH-56 (400 mg/L). As about 1-2 mg/L and Se 0.4 to 1.0 mg/L in select wells, some wells lower. South of well DH-55 Se is below detect, As about 0.3 mg/L. Groundwater beneath south portion of pile appears more reducing due to influence of marsh sediments. Alluvial aquifer beneath slag pile shows downward vertical gradient and decreasing concentrations with depth; possible indication of loading from above (slag). Although lower concentration, selenium originating from slag pile area a significant source of downgradient selenium loading due to greater groundwater flux.	Large area and not well defined as a whole. Review of slag pile history (available analytical data, aerial photo and map review to determine placement of slag over time, field reconnaissance) recommended to evaluate potential areas of contaminant loading from slag; possible more detailed evaluation in future if warranted. Not a time critical source area relative to near-term remedial activities.

Table 3-3. Former East Helena Smelter Groundwater Contaminant Source Inventory

Corrective Measures Study Report, Former ASARCO East Helena Facility

General Source Area	Source #	Source Name	Primary COC As/Se	Description	Soil Conditions	Groundwater Conditions	Recommendations
Former Thornock Lake	6	Former Thornock Lake Area Soils	As	Former process pond. Pond replaced with tank in 1986. Soils excavated in 1986-1987 and 1991.	Preremediation total As in soils as high as 120,000 mg/kg but quite variable. Post-excavation samples in 1991 showed total As 513 to 3055 mg/kg. SPLP As 0.22 to 3.8 mg/L. SPLP Se all <0.1 mg/L. Phase I RFI soil borings RFISB-1 and RFISB-2 showed relatively low total arsenic concentrations (<10 to 231 mg/kg, average of 32 mg/kg).	Groundwater at wells DH-57 in DH-58 in Thornock Lake area recently 1-2 mg/L arsenic, 0.01 to 0.05 mg/L selenium. Generally decreasing trends since plant shutdown.	Not associated with highest GW concentrations although some leachable arsenic probably remains in soils. Further consideration not warranted at this time given the other areas with much higher impacts to groundwater. May warrant further evaluation some time in the future depending on water quality trends and project developments.
Former Speiss/Dross Area	7	Speiss Granulation Area	As/Se	Very high historic process water concentrations for both arsenic (3,000+ mg/L) and selenium (40+ mg/L). Historic area of highest groundwater impacts due to use of ponds, process water releases. Elevated groundwater pH (11-13). Encapsulated in slurry wall in 2007; slurry wall appears effective at limiting downgradient migration of contaminants (As at SDMW-2 decrease of 50+mg/L to 10 mg/L since 2007).	Variable due to historic soil removal actions. Likely still some areas of elevated soil arsenic concentrations, particularly within saturated zone. Selenium concentrations unknown within wall. Phase I RFI soil borings RFISB-3 and RFISB-4 showed moderate arsenic soil concentrations (<10 to 777 mg/kg, average of 243 mg/kg). Phase II boring north of wall (RFI2SB-20) leached up to 0.7 mg/L Se from sample with total Se of 17 mg/kg.	Groundwater arsenic as high as 750 mg/L in the past, selenium as high as 7 mg/L but very limited data (well DH-21). Current arsenic concentrations within slurry wall 80 to 100 mg/L. Groundwater yield within wall appears to be decreasing over time.	Groundwater quality generally improving in area. May warrant further evaluation in future depending on water quality trends within and outside of slurry wall, and long-term integrity of wall. Potential source areas outside of slurry wall should be evaluated as potential source to West Selenium Area groundwater plume. Not a time critical source.
	8	Speiss Storage and Handling Area	As/Se	Outside storage bins and material handling area for speiss. Likely impacts from material spillage and water application. Partially encapsulated in slurry wall in 2007; slurry wall appears effective at limiting downgradient migration of contaminants. Portion outside (west) of slurry wall.	Limited soil data in this area. Well DH-38 soil samples showed 72 to 1906 mg/kg total arsenic. Concentrations increased from about 170 mg/kg just above water table to 700 mg/kg just below water table.	Arsenic concentrations up to 250 mg/L historically in groundwater at well DH-38. No recent water quality data from area.	Area outside slurry wall warrants further evaluation as potential source to West Selenium Plume area. Majority of high concentration soils within slurry wall, and limited downgradient migration of arsenic currently indicated. Long-term integrity of slurry wall should be evaluated.
Former Acid Plant Area	9	Cottrell/Scrubber Blowdown Area	As/Se	Area of significant process water leaks during plant operations; very high process water concentrations (1,800 mg/L As; 5 mg/L Se; 200 mg/L Cd). Extensive remediation conducted in Acid Plant Area in late 1980s/early 90s. Contaminated soils remain at depth at location of former acid plant settling pond and possibly other areas.	Soils highly impacted by historic process water releases; highest concentration soils excavated in 1990s. Current concentrations up to 12,000 mg/kg arsenic at former settling pond area. Highest concentration soils recently desaturated by SPHC IM. High concentration soils are localized and located under high-density sludge building.	DH-19 up to 416 mg/L arsenic in groundwater in 1991. Arsenic concentrations have decreased from about 11.5 to 9 mg/L since 2011. Selenium decrease recently from 60 to 25 ppb. Recent improvements attributed to SPHC.	Historically significant source of arsenic loading to groundwater, but groundwater quality improving due to past remedial activities and recent SPHC IM. Localized high arsenic concentration soils at former Acid Plant Settling Pond may warrant removal or other source control after high-density sludge demolition and before capping in late 2016. Monitor groundwater level and quality trends though 2015 to determine full response to SPHC, and select course of action for 2016.
	10	Acid Plant Settling Pond	As/Se				
	11	Original AP Sediment Drying Area	As/Se				
Monier Flue	12	Monier Flue Area Soils	Se	Soils beneath former Monier Flue, which was removed in 2008, are largely unsaturated. Potential contaminant mechanism was periodic washing out of flue with water and letting water infiltrate into ground. Soils sampled during demolition and during Phase II RFI.	Demolition soil samples up to 1,350 mg/kg selenium; highest document soil concentration. Phase II boring RFISB-6 up to 106 mg/kg at 2 to 5 feet; leached 0.28 mg/L. Very high cadmium (75,000 mg/kg), lead (53,000 mg/kg), copper (17,000 mg/kg). All concentrations decreased significantly below 5 feet bgs.	No data; aquifer very thin (2 to 0 feet thick).	Underlying soils dry down to clay layer in most areas; elevated selenium soils will be addressed through capping. No need to evaluate further.

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Table 3-3. Former East Helena Smelter Groundwater Contaminant Source Inventory

Corrective Measures Study Report, Former ASARCO East Helena Facility

General Source Area	Source #	Source Name	Primary COC As/Se	Description	Soil Conditions	Groundwater Conditions	Recommendations
South Plant	13	Upper Ore Storage Area	As/Se	Area used for storage of ore and other materials historically.	NA -- draining of Lower Lake and removal of soils to 3910 feet amsl in Tito Park/APSD/UOS areas conducted as part of TPA Source Removal/SPHC IM projects. Post-SPHC conditions to be determined.		To be addressed through TPA Source Removal and SPHC IMs.
	14	Former AP Sediment Drying Area	As	Former acid plant sediment drying area associated with elevated groundwater arsenic and metals concentrations, along with elevated soil concentrations. Encapsulated in APSD slurry wall in 2006.			
	15	Lower Lake/Tito Park	As/Se	Lower Lake historically used as process pond, more recently as water treatment plant MPDES discharge point. Contaminated sediments dredged from lake in mid-1990s. Tito Park used as storage area for various materials throughout plant history. Materials removed to CAMU in early 2000s.			

Notes:

General source areas are shown on Figure 3-7.

AP = Acid Plant Area

AS/SE = arsenic/selenium

bgs = below ground surface

CAMU = Corrective Action Management Unit

COC = constituent of concern

mg/kg = milligrams per kilogram

mg/L = milligram per liter

NA = not applicable

SD = Speiss/Dross Area

SPCH IM = South Plant Hydraulic Control interim measure

SPLP = Synthetic Precipitation Leaching Procedure

(yellow)	Recommended for additional evaluation
(green)	Not recommended for additional evaluation

Table 3-4. Overview of 2014 Source Area Investigation and Analyses Completed

Corrective Measures Study Report, Former ASARCO East Helena Facility

Source Area	Number of Borings	Number of Wells Completed	Number of Soil Samples	Summary of Analyses
West Selenium	6	2	33	Soil leach testing Total metals (soil) Arsenic and selenium (groundwater) Mineralogical analysis
North Plant Arsenic	2	0	9	Soil leach testing Total metals (soil) Arsenic and selenium (groundwater) Mineralogical analysis

Note:
Leach Testing = synthetic precipitations leaching procedure and saturated paste analyses.

Table 3-5. Overview of 2015 Source Area Investigation and Analyses Completed

Corrective Measures Study Report, Former ASARCO East Helena Facility

Source Area	Number of Borings	Number of Wells Completed	Number of Soil Samples	Summary of Analyses
West Selenium	7	2	43	Soil leach testing Total Metals (soil) Arsenic and selenium (groundwater)
North Plant Arsenic	2	0	16	Total metals (soil) Batch adsorption testing
Acid Plant	4	2	23	Soil leach testing Total metals (soil) Arsenic and selenium (groundwater)
Speiss-Dross Area	2	1	11	Soil leach testing Total metals (soil) Arsenic and selenium (groundwater)

Notes:

Leach Testing = synthetic precipitations leaching procedure and saturated paste analyses.

Intact Shelby tube soil cores were collected for potential geotechnical analysis at seven locations, as follows:

- Five locations in the West Selenium source area
- One location in the former Acid Plant source area
- One location in the Speiss-Dross source area

Table 3-6. Total and Leachate Concentrations (2001 - 2010) for Unfumed and Fumed Slag

Corrective Measures Study Report, Former ASARCO East Helena Facility

		Total Concentrations in Slag (mg/kg)					Slag Leachate Concentrations (mg/L)										
							Phase I and II RFI SPLP Samples		RI/FS Slag Infiltration Basins								
Slag Type	**Statistic**	**Arsenic**	**Copper**	**Lead**	**Selenium**	**Zinc**	**Arsenic**	**Selenium**	**Arsenic**	**Copper**	**Lead**	**Selenium**	**Zinc**	**Potassium**	**Sodium**	**Sulfate**	**pH (s.u.)**
Unfumed Slag (pre-early 1940s deep lift)[a]	**Minimum**	34.1	75.7	<10	10	1600	0.099	0.036	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Maximum	3060	54300	41600	160	114000	0.099	0.036	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Average	***622***	***3772***	***14334***	***70***	***58239***	***0.099***	***0.036***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***	***NA***
Unfumed Slag (post-1982 upper lift)[b]	**Minimum**	77	1900	<10	29	11119	0.009	0.059	0.353	0.043	0.021	NA	0.023	1950	2200	1200	9.48
	Maximum	1840	23100	20300	325	149000	0.130	0.4	0.62	0.13	0.098	NA	0.10	2650	3890	11750	9.97
	Average	***755***	***7261***	***8453***	***132***	***101874***	***0.072***	***0.196***	***0.529***	***0.097***	***0.066***	***NA***	***0.05***	***2173***	***3198***	***7225***	***9.66***
Fumed Slag[c]	**Minimum**	17	701	<10	<5	2080	0.028	NA	0.028	0.056	0.02	NA	0.788	54	45	480	6.16
	Maximum	377	5030	4425	14	28800	0.028	NA	0.054	0.28	0.045	NA	3.7	74	85	1450	7.77
	Average	***90***	***1584***	***136***	***10***	***11718***	***0.028***	***NA***	***0.037***	***0.153***	***0.028***	***NA***	***2.65***	***65***	***70***	***1179***	***7.34***

Notes:

NA = not analyzed

[a]Older unfumed slag totals from DH-69, -69, -76. SPLP results from DH-76 (one sample).

[b]Younger (upper lift) unfumed slag totals from DH-55, -74, -75, -76. SPLP results from DH-74 and DH-76 (three samples).

[c]Fumed slag totals from DH-55, -56, -65, -74, -75. SPLP results from DH-55 (one sample).

mg/kg = milligrams per kilogram

mg/L = milligrams per liter

RFI = RCRA Facility Investigation

RI/FS = Remedial Investigation/Feasibility Study

SPLP = synthetic precipitation leaching procedure

Table 3-7. Constituent of Potential Concern Concentrations in Soil

Corrective Measures Study Report, Former ASARCO East Helena Facility

Sample Location	As	Pb	Sb	Ba	Cd	Cr	Co	Cu	Fe	Mn	Se	Ag	Tl	V	Zn	Hg	Cr VI
								Surface Soil									
Parcel 2a - Sampled 1991-2008																	
ASP-1	64	547	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-
ASP-2	59	661	-	-	19	-	-	-	-	-	-	-	-	-	-	-	-
ASP-3	81	1190	-	-	18	-	-	-	-	-	-	-	-	-	-	-	-
ASP-4	172	1941	-	-	37	-	-	-	-	-	-	-	-	-	-	-	-
ASP-5	158	1444	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-
EH-66	19.7	-	< 5	134	3.2	11.9	< 5	24.3	12500	224	58.9	5.6	20.9	37.4	65.2	< 0.5	-
EH-67	< 5	23.5	< 5	53.2	< 1	9.2	< 5	17.8	15100	222	< 5	< 5	< 5	36.9	31	< 0.5	-
EH-121	26.7	-	< 5	162	3.2	12.3	< 5	21.7	12400	274	57.3	< 5	20.9	43	70.6	< 0.5	-
S25-J4	108	2920	-	-	63	-	-	-	-	-	-	-	-	-	-	-	-
S25-J5	51	587	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-
S25-J6	39	221	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-
S25-K4	87	541	-	-	11	-	-	-	-	-	-	-	-	-	-	-	-
S25-K5	93	1104	-	-	23	-	-	-	-	-	-	-	-	-	-	-	-
S25-K6	73	806	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-
S25-L6-1	330	1492	-	-	43	-	-	-	-	-	-	-	-	-	-	-	-
S25-L6-2	231	2300	-	-	35	-	-	-	-	-	-	-	-	-	-	-	-
Parcel 2a - Sampled April 17 - 24, 2016																	
P2a-DU1	246	2390	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU2	223	2110	6	152	28.9	21	10	318	24600	3080	0.6	19.4	0.8	54	2280	1.8	< 0.3
P2a-DU3[a]	92	637	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU4	69	631	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU5	86	635	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU6	136	1480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU7	108	884	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU8	40	420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU9	69	666	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU10[a]	92	794	2.7	147	13.8	22.4	10	192	23700	1460	0.9	6.1	0.8	54	1080	1.4	< 1
P2a-DU11	67	566	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU12	103	1110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU13	111	1120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU14	34	543	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU15	27	350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU16	99	893	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU17[a]	69	541	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU18	114	1030	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU19	28	259	1.5	137	7.3	21.1	7	64	21300	469	< 0.5	1.4	0.6	51	153	0.64	< 1
P2a-DU20	27	388	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU21	39	423	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU22	95	800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-7. Constituent of Potential Concern Concentrations in Soil

Corrective Measures Study Report, Former ASARCO East Helena Facility

Sample Location	As	Pb	Sb	Ba	Cd	Cr	Co	Cu	Fe	Mn	Se	Ag	Tl	V	Zn	Hg	Cr VI
P2a-DU23	130	1060	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU28	99	729	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU24	21	142	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU25	27	316	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU26	36	534	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P2a-DU27	106	902	3.1	126	17.3	18.3	9	179	19700	1690	0.6	7.1	0.9	45	1050	1.3	< 1
Parcel 15 - sampled 1984-2001																	
41	110	620	0.45	168	18	14	8.5	60	14100	321	0.07	1.9	0.5	32	177.91	2.9	
43	46	373	0.27	153	12	11	8	38	13500	474	0.55	0.8	0.6	22	114.91	2.1	
S1AP-1	95	1911	-	-	37	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-10	122	2726	-	-	48	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-11	126	2758	-	-	51	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-12	188	5162	-	-	85	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-13	161	4263	-	-	70	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-14	148	4026	-	-	92	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-15	144	3313	-	-	88	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-16	63	1469	-	-	36	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-17	81	1538	-	-	42	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-18	32	45	-	-	< 5	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-2	69	1022	-	-	33	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-3	67	1070	-	-	28	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-4	77	1113	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-5	85	1272	-	-	38	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-6	74	1143	-	-	32	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-7	102	1736	-	-	44	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-8	104	2398	-	-	38	-	-	-	-	-	-	-	-	-	-	-	-
S1AP-9	107	2448	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-
Parcel 15 - sampled May 5 - 8, 2016																	
P15-DU1	75	480	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU2	35	367	1.8	174	10.7	22.7	7	76	18900	526	0.9	1.9	0.9	46	315	0.82	< 1
P15-DU3	54	2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU4	49	369	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU5	55	453	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU6	61	865	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU7	44	410	1.5	198	13	25.2	8	58	19700	437	0.9	1.9	0.9	55	165	1.6	< 1
P15-DU8	50	746	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU9	37	402	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU10[a]	35	378	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU11	34	284	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU12[a]	35	314	1.2	175	9.7	26.8	9	46	21800	467	0.9	1.5	0.9	58	128	1.1	< 1
P15-DU13	34	237	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DU14	34	238	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-7. Constituent of Potential Concern Concentrations in Soil

Corrective Measures Study Report, Former ASARCO East Helena Facility

Sample Location	As	Pb	Sb	Ba	Cd	Cr	Co	Cu	Fe	Mn	Se	Ag	Tl	V	Zn	Hg	Cr VI
P15-DU15	29	275	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DUA1	65	971	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DUA2	49	706	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DUA3	109	1890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DUA4	66	741	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P15-DUA5[a]	26	489	1.6	116	11.5	15.9	8	103	19700	356	0.8	3	0.8	58	236	1.2	< 1
Parcel 23 - Sampled 1984-2001																	
69	65	417	0.27	163	14	12	9	43	12500	430	0.07	1.4	0.46	17	127.91	2.5	
S12AP01-4	57	422	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-
S12AP01-5	78	739	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-
Parcel 23 - Sampled April 6-17, 2016																	
P23-DU1	68	510	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU2	63.7	456	1.9	131	12.4	23.6	9	100	22800	749	1.6	3.4	0.9	57	448	1.4	< 0.3
P23-DU3[a]	78	524	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU4	87	621	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU5	78	505	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU6	42	479	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU7	70	519	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU8	65	409	1.5	138	10.1	25.6	10	91	23400	790	1.3	3.3	0.8	62	434	1.4	< 1
P23-DU9	58	340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU10	64	420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU11	62	363	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU12	49	266	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU13	52	403	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU14	39	221	0.9	117	4.5	20.4	9	58	20800	1120	< 0.5	1.6	0.4	58	400	0.6	< 1
P23-DU15	53	438	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU16	53	297	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU17[a]	52	376	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU18	66	399	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU19	64	429	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU20[a]	57	357	1.6	155	10.4	24.5	11	90	24500	824	0.9	2.6	0.9	58	497	1.6	< 1
P23-DU21	79	476	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU22	72	400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU23	36	214	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU24	60	336	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU25	55	297	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU26	44.6	331	1	115	10.8	22	9	90	23600	500	0.9	1.8	0.8	68	510	1.6	< 0.3
P23-DU27	39	262	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU28[a]	29.2	198	0.8	76	3.8	23	6	52	20000	673	< 0.5	1.4	0.3	56	427	0.19	0.98
P23-DU29	40	260	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P23-DU30	59	377	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3-7. Constituent of Potential Concern Concentrations in Soil

Corrective Measures Study Report, Former ASARCO East Helena Facility

Sample Location	As	Pb	Sb	Ba	Cd	Cr	Co	Cu	Fe	Mn	Se	Ag	Tl	V	Zn	Hg	Cr VI
								Subsurface Soil									
Parcel 2a - Sampled 2008																	
EH-121-02	27.8	-	-	-	3.4	-	-	18	-	-	46.5	-	-	-	39.3	-	-
EH-121-03	31.8	-	-	-	3.9	-	-	29	-	-	29	-	-	-	37.8	-	-
EH-66-02	19.7	-	-	-	2.9	-	-	13.7	-	-	49.7	-	-	-	35.9	-	-
EH-66-03	28.8	-	-	-	2.8	-	-	23.1	-	-	18.8	-	-	-	34.4	-	-
EH-67-02	5.2	50.5	-	-	4.6	-	-	29.3	-	-	28.9	-	-	-	54.7	-	-
EH-67-03	< 5	141	-	-	7.3	-	-	46.6	-	-	36.4	-	-	-	89.4	-	-

Notes:

Results presented in milligrams per kilogram.

Ag = silver; As = arsenic; Ba = barium; Ca = calcium; Cd = cadmium; Co = cobalt; Cr = chromium; Cr VI = hexavalent chromium; Cu = copper; Fe = iron; Hg = mercury; Mn = manganese; Pb = lead; Sb = antimony; Se = selenium; Ti = titanium; V = vanadium ; Zn = zinc.

[a]The highest value is shown at field duplicate sample locations.

Subsurface soil sample interval reflected in sample location ID as follows:

02 = 2 to 4 feet below ground surface (bgs)

03 = 4 to 6 feet bgs

Table 3-8. Constituent of Potential Concern Concentrations in Sediment

Corrective Measures Study Report, Former ASARCO East Helena Facility

Sample Identification	Sample Location	As (mg/kg)	Pb (mg/kg)
23-1-SD	Upstream	25	150
23-2-SD	Upstream	15	83
23-3-SD[a]	Upstream	20	95
23-4-SD	Upstream	19	152
23-5-SD	Upstream	10	47
2a-1-SD	Downstream	12	83
2a-2-SD	Downstream	54	402
2a-3-SD	Downstream	21	132
2a-4-SD[a]	Downstream	33	284
2a-5-SD	Downstream	18	85
2a-6-SD	Downstream	20	139
2a-7-SD	Downstream	46	306
2a-8-SD	Downstream	20	106
2a-9-SD	Downstream	33	188
2a-10-SD	Downstream	26	138
2a-11-SD	Downstream	32	201

[a]The highest value is shown at field duplicate sample locations.

Notes:

mg/kg = milligrams per kilogram

As = arsenic

Pb = lead

Table 3-9. Hydraulic Parameters by Source Area

Corrective Measures Study Report, Former ASARCO East Helena Facility

Source Area	Average Saturated Thickness (ft)	Conductivity (ft/day) [Ka]	2014 Gradient [i] (ft/ft)	Effective Porosity [n_e] (%)	Seepage Velocity (ft/day)
West Selenium	4	200	0.0087	18	9.7
North Plant	10	200	0.0085	18	9.4
Speiss-Dross	36	140	0.011	18	8.6
Acid Plant	11	50	0.0193	12	8.0

Seepage Velocity Calculated via:

$$v = \frac{K_a i}{n_e}$$

where:

v= seepage velocity (ft/day)

K_a = hydraulic conductivity (ft/day)

i = gradient

n_e = effective porosity

Table 4-1. Summary of Human Health Risk Assessment Exposure Point Concentrations in Soil and Sediment

Corrective Measures Study Report, Former ASARCO East Helena Facility

Parcel	Medium	Depth Grouping	Exposure Scenario	Analyte	EPC (mg/kg)	Commercial/ Industrial MCS	Recreational MCS	EPC Exceeds MCS?	Notes	Arsenic Risk
2a	Sediment	Surface	Recreational	Arsenic	45.47	na	794	no	EPC < MCS	8.6E-06
				Lead	306.2		3245	no	EPC < MCS	
	Soil	Surface	Commercial/ Industrial	Arsenic	133.5	573	na	no	EPC < MCS	3.5E-05
				Lead	1169	800		yes	**EPC > Commercial/Industrial MCS**	
		Subsurface	Commercial/	Arsenic	29.8	573		no	EPC < MCS	
15	Soil	Surface	Commercial/ Industrial	Arsenic	64.07	573	na	no	EPC < MCS	1.7E-05
				Lead	1028	800		no	EPC < MCS	
23	Sediment	Surface	Recreational	Arsenic	29.91	na	794	no	EPC < MCS	5.6E-06
				Lead	204		3245	no	EPC < MCS	
	Soil	Surface	Commercial/ Industrial	Arsenic	69.31	573	na	no	EPC < MCS	1.8E-05
				Lead	465.2	800		no	EPC < MCS	
Parcels 8W, 10, 11, 12, 17 and 18	Soil	Surface	Commercial/Industrial	These parcels were remediated as part of the SPHC IM and do not exceed a EPC compared to MCS; significant excavation was needed to relocate PPC and excavated areas outside the new creek channel were backfilled using soil with concentrations below the MCSs. Potential human exposures to concentrations in soil higher than MCSs are therefore not expected to occur at these parcels.						
		Subsurface	Commercial/Industrial							

Notes:

mg/kg = milligrams per kilogram

EPC = Exposure Point Concentration. Note that the maximum Chebyshev-based UCL was selected as the EPC for ISM samples (ITRC, 2012) and the maximum recommended UCL was selected for discrete samples.

EPC values considered the potential exposure pathways for soil ingestion (direct contact) and inhalation of dust suspended into the air

MCS = Media Cleanup Standard

na = not applicable

ND = non-detect

UCL = 95 percent Upper Confidence Limit

Subsurface = greater than 2 feet below ground surface

Surface = 0 to 2 feet below ground surface

Arsenic risks are characterized by calculating lifetime cancer risks. See Appendix E for details of the calculation.

Lead risks are characterized by directly comparing the EPC with the MCS. The MCSs for lead are based on a blood-lead level of 10 µg/dL.

µg/dL = micrograms per deciliter

Table 4-2. Summary of Ecological Risk Assessment Exposure Point Concentrations in Soil

Corrective Measures Study Report, Former ASARCO East Helena Facility

Parcel	Medium	Depth Grouping	Analyte	EPC (mg/kg)	MCS (mg/kg)	Receptor for MCS	HQ	Explanatory Notes
2a	Soil	Surface	Lead	1169	650	Passerine birds	1.8	Population-level effects are unlikely with an HQ slightly elevated above one
				1169	955	Cattle	1.2	
15	Soil	Surface	Lead	1028	650	Passerine birds	1.6	
				1028	955	Cattle	1.1	
23	Soil	Surface	Lead	465.2	650	Passerine birds	0.7	HQ < 1
				465.2	955	Cattle	0.5	
8W, 10, 11, 12, 17, and 18	Soil	Surface						These parcels were remediated as part of the South Plant Hydraulic Control interim measure and do not exceed an EPC compared to MCS; significant excavation was needed to relocate Prickly Pear Creek and excavated areas outside the new creek channel were backfilled using soil with concentrations below the MCSs. Potential human exposures to concentrations in soil higher than MCSs are therefore not expected to occur at these parcels.

Notes:

mg/kg = milligrams per kilogram

EPC = exposure point concentration. Note that the maximum Chebyshev-based upper confidence limit (UCL) was selected as the EPC for ISM samples (ITRC, 2012) and the maximum recommended UCL was selected for discrete samples.

HQ = hazard quotient

MCS = media cleanup standard

Table 4-3. Remaining Unacceptable Risk Post-Interim Measure Construction

Corrective Measures Study Report, Former ASARCO East Helena Facility

CMS Parcel	Exposure Media	Receptors	Potential Exposure Pathway	Assessment of Potential Exposure	Assessment of Risks
2a	Soil	Industrial/ Commercial Recreational	Direct contact	Pathways potentially complete under current or future land uses	Overall lead exposures are lower than levels protective of human health (i.e., blood-lead levels are less than 10 µg/dL). Concentrations of arsenic fall within target risk range.
		Ecological (passarine)	Direct contact	Pathway potentially complete	Risk from concentrations of lead are minimal and do not require remediation.
	Sediment	Recreational	Direct Contact	Pathways potentially complete under current or future land uses	Overall lead exposures are lower than levels protective of human health (i.e., blood-lead levels less than 10 µg/dL). Concentrations of arsenic fall within target risk range.
	Groundwater	Residential	Ingestion	Potentially complete[a]	None: concentration of arsenic and selenium are below MCS (i.e., drinking water MCLs).
8W, 10, 11, 12, 17, 18	Soil Sediment Surface water	Recreational	Direct contact	Potentially complete	Risk unlikely to be present due to implementation of SPHC IM to meet MCSs.
15	Soil	Industrial/ Commercial	Direct contact	Pathway complete under current or future land use	Lead concentrations fall below MCS and levels protective of human health; lifetime cancer risk from arsenic falls within target risk range.
		Ecological (passarine)	Direct contact	Pathway potentially complete	Risk from concentrations of lead are minimal and do not require remediation.
	Groundwater	Residential	Ingestion	Potentially complete[a]	Concentration of arsenic (West Arsenic Source Area) higher than MCS (i.e., drinking water MCLs).
16, 19	Soil	Ecological (passarine)	Direct contact	Potentially complete	Risk unlikely to be present due to implementation of ET Cover System IM to meet MCSs.
	Groundwater	None	None	Incomplete	None: groundwater use is prohibited within the Facility.
	Unfumed Slag	Trespasser	Direct contact	Potentially complete	Risk not quantified due to ongoing evaluation of corrective measures.
23	Soil	Recreational	Direct contact	Pathways potentially complete under current or future land uses	Concentrations of lead and arsenic are lower than MCSs; overall lead exposures are lower than levels protective of human health; concentrations of arsenic fall within target risk range.
		Ecological (passarine)	Direct contact	Pathway potentially complete	Risk from concentrations of lead is minimal and requires no remediation.
	Sediment	Recreational	Direct contact	Pathways potentially complete under current or future land uses	Concentrations of lead and arsenic are lower than MCSs; overall lead exposures are lower than levels protective of human health; concentrations of arsenic fall within target risk range.

Note:

[a] Groundwater pathway potentially complete if used as a drinking water source.

MCS = media cleanup standard (see Table 2-1)

µg/dL = microgram(s) per deciliter

Table 5-1. Overview of Source Area Screening-Level Evaluation

Corrective Measures Study Report, Former ASARCO East Helena Facility

Source Area[a]	Remedy Screening Evaluation: Preliminary Alternative	Notes on Scoring	Recommended for Further Evaluation (Y/N)
Affected Groundwater Area	Baseline action: includes planned IMs, CGWA, and MNA	Baseline action will be implemented regardless of recommendation of the evaluation. All other potential groundwater remedies and their associated costs are considered supplemental.	NA
	Pump and treat onsite and offsite groundwater	Not cost-effective.	No
	Pump and treat onsite groundwater	Not cost-effective.	No
	Pump and treat combined with slurry wall	Uncertain effects on downgradient plume stability and geometry and not cost effective.	No
West Selenium Source Area	Source Removal	Recommend using the groundwater flow model to determine effectiveness in comparison to other remedies. Moderate cost.	Yes
	PRB, with funnel-and-gate system	Favorable effectiveness and implementability with low cost.	Yes
	Slurry Wall (hydraulic enclosure of source area)	Slurry walls have been shown to be effective and appears to be cost-effective.	Yes
	Focused pump and treat	Reasonably effective, and favorable implementability with potential for low cost.	Yes
North Plant Arsenic Source Area	Source Removal	Not cost-effective.	No
	PRB, with funnel-and-gate system	Effective, technology is readily available, reasonably cost-effective.	Yes
	Slurry Wall (hydraulic enclosure of source area)	Slurry walls have been observed to be effective and appears to be cost-effective.	Yes
	In-situ treatment (dosing of aquifer with Fe), to augment slurry wall	Can be effective if used in conjunction with slurry wall.	Yes
	In-situ treatment (to augment slurry wall)	High costs and difficult to implement.	No
Former Speiss/Dross Source Area	No Further Action (includes existing slurry walls)	Already implemented, and is cost-effective.	NA
	Source Removal	Additional cost not justified when existing slurry wall appears generally to be effective.	No
	Expand slurry wall system to encompass former Speiss Storage and Handling Area	Technologies are available but high implementation factor due to technology being installed close to the Ore Storage Building.	No
	In-situ treatment (dosing of aquifer with Fe), to augment slurry wall	Would be effective with another technology such as a slurry wall, but not effective alone.	No

[a] Further investigation and evaluation of the former Acid Plant and Slag Pile areas was deferred.

Notes:

CBS = combined balancing score
CGWA = Controlled Groundwater Area
Fe = ferrous sulfate
IM = interim measure
NA = not applicable
O&M = operations and maintenance
PRB = permeable reactive barrier
Se = selenium

Table 5-2. RCRA Balancing Criteria, Definitions, and Interpretation/Application to Remedy Evaluations
Corrective Measures Study Report, Former ASARCO East Helena Facility

Balancing Criteria	Definition (per RCRA [USEPA, 2000])	Interpretation and Application of Balancing Criteria to Remedy Evaluation	Scoring Logic [+ positive, 0 neutral, - negative]
1. Long-term Effectiveness and Permanence	Decision-makers should evaluate remedies based on the long-term reliability and effectiveness they afford, along with the degree of certainty that they will remain protective of human health and the environment. Additional considerations include the magnitude of risks that will remain at a site from untreated hazardous wastes, hazardous wastes and hazardous constituents, and treatment residuals; and the reliability of any containment systems and institutional controls. A remedial option should include a description of the approaches and facilities that will be used to assess long-term performance and effectiveness.	Criteria evaluated as the relative improvement in groundwater concentrations for the COPC of interest (selenium for West Selenium and arsenic in North Plant) as a result of implementing the alternative in addition to interim measures; and also the permanence the alternative provides. Model simulations (by Newfields) will be used to quantify effectiveness considering the following metrics: (1) mass removal (in weight and percent), (2) plume geometry/volume reductions below DEQ-7 water quality standards, and (3) the temporal timeframe to achieve stable ('steady-state') conditions following implementation. Alternatives providing the highest degree of long-term effectiveness are those that achieve the most mass and volume reductions, have the highest degree of permanence, leave little or no waste (source), do not require long-term maintenance, and minimize the need for institutional controls.	"+" = Highest degree or substantive improvements in groundwater metrics (reductions in mass and plume reduction); alternative is permanent over the long-term. "0" = Moderate or marginal improvement in groundwater metrics; and/or some uncertainties or risks relative to permanence. "-" = No substantive improvement in groundwater metrics and/or the alternative is lacking permanence or considered a high-risk, unproven technology.
2. Toxicity, Mobility, and Volume Reduction	Decision-makers should evaluate remedies based on the degree to which they employ treatment, including treatment of principal threats, that reduces the toxicity, mobility, or volume of hazardous wastes and hazardous constituents, considering, as appropriate: the treatment processes to be used and the amount of hazardous waste and hazardous constituents that will be treated; the degree to which treatment is irreversible; and the types of treatment residuals that will be produced.	Criteria focus on the degree to which an alternative does or does not employ a treatment technology. For alternatives that require treatment technology (such as PRB, pump and treat, and injections), the evaluation will describe (1) quantities and quality (i.e., concentrations) of groundwater requiring treatment, (2) degree in which treatment is irreversible, and (3) types and volumes of treatment residuals. For alternatives that do not require a geochemical alteration/treatment technology (such as source removal and slurry wall), the volume of source material will be estimated.	"+" = Alternative reduces toxicity and mobility of hazardous material; irreversible with limited or no residuals management. "0" = Alternative reduces toxicity, mobility, or volume; irreversible but with some residuals for management. "-" = Alternative has limited effect on toxicity, mobility, or volume reduction; reversible or has significant residual management.
3. Short-term Effectiveness	Decision-makers should evaluate remedies based on the short-term effectiveness and short-term risks that remedies pose, along with the amount of time it will take for remedy design, construction, and implementation.	Criteria address the effects during construction and implementation (i.e., short-term) and will focus on (1) short-term impacts/risks to human health (related to construction), (2) short-term impacts (i.e., releases) to the environment related to implementation of remedy, and (3) and how long it will take to design, construct, and implement the alternative.	"+" = No substantive risks/impacts to human health or environment. Short duration to establish effectiveness. "0" = Moderate risks/impacts to human health or environment. Longer duration to establish effectiveness. "-" = High-degree of risks/impact to human health or environmental impacts. Requires significant duration to establish effectiveness.
4. Implementability	Decision-makers should evaluate remedies based on the ease or difficulty of remedy implementation, considering as appropriate: the technical feasibility of constructing, operating, and monitoring the remedy; the administrative feasibility of coordinating with and obtaining necessary approvals and permits from other agencies; and the availability of services and materials, including capacity and location of needed treatment, storage, and disposal services.	Criteria focus on (1) administrative components, (2) regulatory coordination and approvals, and (3) overall ease or difficulty of constructing, operating, and monitoring the remedy; including availability of services relative of the types of alternatives and/or complexity of specialty services needed. Alternatives that are considered easiest or most favorable to implement are those which (1) do not require substantive agency approval or permits, (2) do not require long-term O&M, and (3) do not rely on specialty technologies, services, or materials.	"+" = Administrative items, regulatory approvals, construction, operation, and monitoring are considered relatively easy, feasible, or readily implementable. No long-term O&M. Short duration to implement alternative. "0" = Neutral score if not easy or "complex." Longer duration to establish effectiveness. "-" = Alternative requires agency substantive or nonstandard approvals or permits, substantive long-term O&M, specialty technology, and/or significant duration to implement alternative.
5. Cost	Decision-makers should evaluate remedies based on capital and O&M costs, and the net present value of the capital and O&M costs.	Estimated costs have been developed for each alternative using Study or Feasibility Class 4 guidance (Association for the Advancement of Cost Engineering, 2005) with expected accuracy of -30 to +50 percent. Costs reflect both capital and long-term O&M (when applicable) assuming a 30-year period net present worth at 5 percent rate of return (unless specified otherwise). The total cost reflects capital and long-term O&M (if applicable). Costs are based on conceptual designs and are not considered final designs; if an alternative is selected, a final design will be developed before implementation.	"+" = Relatively low. Cost is less than $2M. "0" = Moderate. Cost ranges from $2 to $5M. "-" = Relatively high. Cost is greater than $5M.
6. Community Acceptance	Decision-makers should evaluate remedies based on the degree to which they are acceptable to the interested community.	The evaluation is based on the first five technical criteria (listed above). Community acceptance will be evaluated as part of the public involvement process.	
7. State Acceptance	Decision-makers should evaluate remedies based on the degree to which they are acceptable to the state in which the subject facility is located. This is particularly important where the U.S. Environmental Protection Agency, not the state, selects the remedy.	The evaluation is based on the first five technical criteria (listed above). State acceptance will be evaluated as part of the public involvement process.	

Notes:
COC = constituent of concern
COPC = constituent of potential concern
M = million
MCL = maximum contaminant level
O&M = operations and maintenance
RCRA = Resource Conservation and Recovery Act

Reference: U.S. Environmental Protection Agency (USEPA). 2009. *Fact Sheet #3: Final Remedy Selection for Results-based RCRA Corrective Action*. RCRA Corrective Action Workshop on Results-Based Project Management: Fact Sheet Series. March.

Table 5-3. Description of Remedial Alternatives Retained for Detailed Evaluation
Corrective Measures Study Report, Former ASARCO East Helena Facility

Area	Alternative	Technology Description/Assumptions	Dimensions/Unit Quantities	Construction Approach and Key Assumptions
West Selenium Area (COPC is selenium)	1 – Source Removal	Assumes physical excavation and relocation of saturated zone source materials to an onsite location that is beneath the future ET cover but above the saturated zone. The alternative is expected to reduce ongoing mobilization and leaching of selenium from the primary source area to groundwater. Primary source area boundaries assumed to capture an estimated 70 percent of source/mass (personal communication with Bob Anderson/Hydrometrics, January 9, 2015).	Area 100 x 200 x 48 ft bgs. Quantity estimates: • Interim measure cover: 2,222 yd^3 • Unsaturated zone: 29,629 yd^3 • Saturated zone (source removal): 4,444 yd^3 • Backfill of clean borrow material: 4,444 yd^3 (West Bench)	• Saturated zone material placed under ICS-2 (and ET cover). • Clean borrow material via West Bench placed in saturated zone. • Unsaturated zone soils placed back into excavation in unsaturated zone. • Dewatering limited because of soldier pile-sheet pile walls; sump-pump used to dewater saturated zone, groundwater pumped to temporary tank and hauled to existing treatment plant. • All earthwork done onsite; no offsite hauling or disposal.
	2 – PRB for Selenium	Technology assumes passive groundwater flow through the reactive media to treat selenium. PRB media consist of 90 percent organic mulch and 10 percent limestone sand placed across saturated interval. Influent selenium concentrations assume 3.0 mg/L; treatment targets assume 0.05 mg/L (MDEQ-7 groundwater standard). Media will have finite life and will require monitoring to determine when media needs replacement.	100-ft-long PRB with 25-ft funnels (slurry walls) at either end. PRB installed across saturated interval, wall width of 12 ft (perpendicular to flow) designed to achieve residence time of 2 days. Funnel walls installed from ash/clay to ground surface and designed to have limited influence on groundwater flow patterns.	• Passive treatment of selenium considered 'pilot study'; long-term viability/effectiveness uncertain. Limited formal research/documentation on full-scale studies over long-term. • Construction approach assumes long-arm excavator to install PRB and funnel ends. • Long-term O&M assumes full replacement of PRB media in years 10 and 20; actual replacement schedule determined from monitoring/effectiveness. • Spent media disposed of offsite; volume estimated at 444 yd^3.
	3 – Slurry Wall Enclosure	Technology assumes an effective, low-permeability enclosure "wall" located around the primary source area saturated zone; design assumptions are to reduce the mobility/flux from within the enclosure area. Design assumes slurry wall permeability of $1x10^{-6}$ cm/sec or lower.	Perimeter of 1,100 linear feet based on enclosure dimensions of 100 x 450 ft in plan view. Depth of slurry wall assumes 48 ft bgs down to ash/clay layer. Typical construction approach assumes slurry wall installed from ash/clay layer to ground surface.	• Construction approach assumes long-arm excavator to install slurry wall and use of excavated soil in soil-bentonite blend. • Permeability options: soil-bentonite wall $1x10^{-7}$ cm/sec or cement-bentonite wall $1x10^{-6}$ cm/sec; difference in cost is about $3/VSF. Costing approach is conservative and assumes soil-bentonite wall.
	4 – Pump and Treat (P&T)	Technology assumes a long-term groundwater extraction system extending across a width of about 100 ft (approximate width of plume) and then conveyance of groundwater to passive treatment system, which includes: • Biochemical reactor beds consisting of organic mulch, limestone, and sand • Aeration channel • Oxidation/settling ponds • Discharge to existing wetlands and Prickly Pear Creek	Groundwater Extraction System: • Three wells – combined total flow of 30 gallons per minute • Buried conveyance pipe: about 4,800 ft Treatment System: • Dual biochemical reactor beds: total volume 12,400 yd^3 • Dual oxidation ponds: total volume 584 yd^3 • See process flow diagram in Appendix C for details	• P&T option will require regulatory approvals and discharge permit to set monitoring requirements and effluent/discharge limits • Treatment system will require routine maintenance (weekly), monitoring, and intermittent replacement of spent media. Costing approach assumes biochemical reactor beds are replaced at years 10 and 20; actual replacement cycle depends on monitoring. • Treatment system will require winterization design for year-round operation (such as buried conveyance line, buried biochemical reactor beds, heat-traced lines, and heated blower or mechanical agitator). These items will add capital costs and also replacement costs to replace media.

Notes:

Alternative 7 (in-situ injections) is assumed supplemental to Alternative 6 (injections within the slurry wall). If Alternative 6 is selected, then the need for Alternative 7 may be evaluated and decided on after the slurry wall is constructed and the effectiveness evaluated, among other criteria.

Abbreviations:

bgs = below ground surface
cm/sec = centimeter(s) per second
COPC = constituent of potential concern
ET = evapotranspiration
ft = foot/feet
ICS = Interim Cover System
MDEQ = Montana Department of Environmental Quality
mg/L = milligram(s) per liter
P&T = pump and treat
PRB = permeable reactive barrier
VSF = vertical square foot
yd^3 = cubic yard
ZVI = zero-valent iron

Table 5-3. Description of Remedial Alternatives Retained for Detailed Evaluation
Corrective Measures Study Report, Former ASARCO East Helena Facility

Area	Alternative	Technology Description/Assumptions	Dimensions/Unit Quantities	Construction Approach and Key Assumptions
North Plant (COPC is arsenic)	5 – PRB for Arsenic	Technology assumes passive groundwater flow through the reactive media to treat arsenic. PRB media consist of 100 percent pure ZVI (granular iron) placed across saturated interval. Influent arsenic concentrations assume 20 to 25 mg/L; treatment targets assume 0.01 mg/L (MDEQ-7 groundwater standard). Media will have finite life and will require monitoring to determine when media needs replacement.	400-ft-long PRB with 125-ft funnels at either end; alignment is adjusted to stay on Custodial Trust-owned property. PRB is 8 ft thick to achieve residence time of 2+ days. Funnel walls installed from ash/clay to ground surface and designed to have limited influence on groundwater flow patterns.	• Construction approach assumes long-arm excavator to install PRB and funnel ends • Long-term O&M assumes full replacement of PRB media in year 10 and 20; actual replacement schedule determined from monitoring/effectiveness. • Spent media disposed of offsite; volume assumed at 2,370 yd^3. • Unit cost of pure ZVI is $1,020/ton; volume estimates assume the PRB will require approximately 5,000 tons, which is about 75 percent of the overall cost.
	6 – Slurry Wall Enclosure	Technology assumes an effective, low-permeability enclosure "wall" located around source area saturated zone; design assumptions are to reduce mobility/flux from within the enclosure area. Design assumes slurry wall permeability of $1x10^{-6}$ cm/sec or lower.	Perimeter of 1,560 linear feet. Depth of wall to 51 ft bgs to ash/clay layer. Alignment of wall adjusted to stay within Custodial Trust-owned property.	• Construction approach assumes long-arm excavator to install slurry wall and use of excavated soil in soil-bentonite blend. • Permeability options: soil-bentonite wall $1x10^{-7}$ cm/sec or cement-bentonite wall $1x10^{-6}$cm/sec; difference in cost is about $3/VSF. Costing approach is conservative and assumes soil-bentonite wall.
	7 - In-Situ Injections (in conjunction with Alternative 6 slurry wall enclosure).	Technology assumes installation of injection wells within slurry walls to deliver (via injection) nanoslurry mixture within slurry wall enclosure. ZVI nanoparticles have relatively high-surface area to volume ratio and are demonstrated to be effective at binding arsenic in solution.	Design assumes five injection wells placed within the slurry wall enclosure. Injections assume ZVI micro/ nanoparticles placed (injected) via slurry form. Treatment assumes 2.4M gallons within the slurry walls.	• Conceptual-design estimates of weight/volume of ZVI nanoparticles assume 2 tons; however, actual volume needed for treatment dependent on batch testing and effectiveness monitoring after the first of four proposed injections. • Unit cost of ZVI nanoparticles in dry form (to be mixed into slurry) assumed at $40 per pound. • Costs assume that the 2 tons (total) applied over four separate injection events.

Notes:

Alternative 7 (in-situ injections) is assumed supplemental to Alternative 6 (injections within the slurry wall). If Alternative 6 is selected, then the need for Alternative 7 may be evaluated and decided on after the slurry wall is constructed and the effectiveness evaluated, among other criteria.

Abbreviations:

bgs = below ground surface
cm/sec = centimeter(s) per second
COPC = constituent of potential concern
ET = evapotranspiration
ft = foot/feet
ICS = Interim Cover System
MDEQ = Montana Department of Environmental Quality
mg/L = milligram(s) per liter
P&T = pump and treat
PRB = permeable reactive barrier
VSF = vertical square foot
yd^3 = cubic yard
ZVI = zero-valent iron

Table 5-4. Combined Balancing Criteria Evaluation
Corrective Measures Study Report, Former ASARCO East Helena Facility

Area	Alternative	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, or Volume through Treatment	Short-Term Effectiveness	Implementability	Cost ($millions) (total cost includes capital and long-term O&M [if applicable])	Combined Balancing Criteria Score (CBS)	Comments
West Selenium (COPC is selenium)	1 – Source Removal	+	+	0	0	0 **Total Cost: $2.8M** Capital: $2.8M Long-term O&M: none	+2	
	2 – PRB for Selenium	0	0	+	0	0 **Total Cost: $2.8M** Capital: $1.5M Long-term O&M: $1.3M	+1	
	3 – Slurry Wall Enclosure	+	0	+	+	+ **Total Cost: $1.7M** Capital: $1.7M Long-term O&M: none	+4	
	4 – Pump and Treat	0	0	+	-	0 **Total Cost: $4.1M** Capital: $2.4M Long-term O&M: $1.7	0	
North Plant (COPC is arsenic)	5 – PRB for Arsenic	0	-	+	0	- **Total Cost: $20M** Capital: $10M Long-term O&M: $10	-1	
	6 – Slurry Wall Enclosure	0	-	+	+	0 **Total Cost: $2.1M** Capital: $2.1M Long-term O&M: none	+1	
	7 – Slurry Wall Enclosure with Injections	0	-	+	+	0 **Total Cost: $2.5M** ALT6: $2.1M ALT7 Capital: $0.1M (wells) ALT7 Long-term O&M: $0.3M (injections)	+1	

Notes:

Cost assumptions: long-term O&M assumed 30 years with Net Present Worth at 5 percent rate of return; refer to *Tier II Source Control Measure/Groundwater Remedy Evaluation—Phase 2 Results and Recommendations* (CH2M, 2015), included in Appendix C of the CMS Report, for supporting ROM Class 4 costing information.

Refer to Table 5-3 for alternative descriptions, Table 5-4 for balancing criteria and definitions, and Appendix B for tables that show details on the individual balancing criteria evaluation.

Alternative 7 is slurry wall with injections. If Alternative 6 is selected, then the need for Alternative 7 may be decided after the slurry wall is constructed and the effectiveness is evaluated.

CBS = combined balancing score

COPC = constituent of potential concern

M = million

O&M = operations and maintenance

P&T = pump and treat

PRB = permeable reactive barrier

Table 5-5. Overview of Source Area Remedy Evaluation Results

Corrective Measures Study Report, Former ASARCO East Helena Facility

		Remedy Evaluation	
Source Area	**Carried Forward from Screening-level Evaluation**	**Notes on Scoring**	**Evaluation Results**
West Selenium Source Area	Source Removal	CBS of plus two (+2); would be more effective at reducing toxicity, mobility, or volume through treatment; with uncertainty of source capture and cost limiting the overall score.	Recommend supplemental data and additional modeling to support continued evaluation.
	PRB, with funnel-and-gate system	CBS of plus one (+1); a positive score for short-term effectiveness, but with lack of proven Se removal effectiveness and cost requirements for O&M limit the overall score.	Not evaluated further.
	Slurry Wall (hydraulic enclosure of source area)	Highest CBS of plus four (+4); long-term effectiveness and permanence, short-term effectiveness, implementability, and cost.	Recommend supplemental data and additional modeling to support continued evaluation.
	Focused pump and treat	Combined balancing score at neutral (0); negative scoring based on implementation with moderate cost effectiveness.	Not evaluated further.
North Plant Arsenic Area	PRB, with funnel-and-gate system	CBS of negative one (-1); with positive score for short-term effectiveness, but negative scores on reduction in toxicity, mobility, or volume through treatment; the lack of significant contaminant mass and plume volume reduction and the cost limit the score.	Not evaluated further.
	Slurry Wall (hydraulic enclosure of source area)	CBS of plus two (+2); positive scores for short-term effectiveness and implementability; the lack of significant contaminant mass and plume volume reduction and contaminated groundwater that remains within the slurry wall long-term limits the score.	Recommend supplemental data and additional modeling to support continued evaluation.
	Slurry Wall Enclosure with In-situ treatment	CBS of plus three (+3); positive scores for reduction in toxicity, mobility, or volume through treatment, short-term effectiveness, and implementability. The remaining criteria were scored 0 (neutral).	To be considered based on evaluation results of previous alternative (Slurry Wall).

Notes:

CBS = combined balancing score
CGWA = Controlled Groundwater Area
Fe = ferrous sulfate
IM = interim measure

NA = not applicable
O&M = operations and maintenance
PRB = permeable reactive barrier
Se = selenium

Table 5-6. Summary of Predictive Results from Groundwater Flow Model

Corrective Measures Study Report, Former ASARCO East Helena Facility

Model Scenario	Constituent	Mass Flux Rate Across Facility Boundary (grams/day)	Flux Rate Decrease from 2011 (percent)
Groundwater 2011	Arsenic	11,300	0%
Groundwater 2011	Selenium	581	0%
Groundwater 2014	Arsenic	6,054	47%
Groundwater 2014	Selenium	360	38%
Predicted IM 2025	Arsenic	3,874	66%
Predicted IM 2025	Selenium	188	68%
Predicted IM with Acid Plant (70%) Removal 2025	Arsenic	3,862	66%
Predicted IM WSA Finite Mass 2025	Selenium	178	69%

Notes:

IM = Interim Measure

WSA = West Selenium Area

Table 5-7. Estimated Selenium Reduction for Slag Pile Cover Alternatives
Corrective Measures Study Report, Former ASARCO East Helena Facility

Cover Alternative	Estimated % Reduction of Selenium in Groundwater in General Areas			
	Slag Pile (DH-10A, 56, and 74)	**Downgradient of Slag Pile (DH-6, 15, and 51)**	**Lamping Field Area (EH-126, 138, and 139)**	**Canyon Ferry Road Area (EH-142 and 143)**
Minimum	73%	69%	35%	38%
Intermediate	76%	73%	38%	41%
Maximum	94%	93%	56%	58%
GW Model Estimate 10% Recharge Rate	*85%*	*83%*	*47%*	*50%*

Table 6-1. Summary of Proposed Corrective Measures and Supplemental Institutional Controls

Corrective Measures Study Report, Former ASARCO East Helena Facility

Proposed Remedy Elements	Engineering/Activity Components	Applicable Parcels	Applicable Media or Pathway
ENGINEERING CONTROLS			
ET Cover System - Building Demolition, Utility Abandonment, Subgrade Fill, Final ET Cover	ET Cover to mitigate infiltration of precipitation, control wind erosion	Facility (Parcels 16,19)	Groundwater
			Soil
			Sediment
	Surface water/stormwater collection		Surface water
South Plant Hydraulic Controls: Upper Lake and Lower Lake Removal; PPC Bypass; PPC Realignment; wetland construction	Reduce surface water loading to groundwater by removing Upper Lake and Lower Lake	Facility (Parcels 16,19)	Groundwater
	Establish natural stream channel flow and geomorphic conditions within Smelter reach		Surface water
	Establish natural wetland/riparian conditions		Sediment
Speiss Dross Slurry Wall	Isolate impacted soil and prevent impacts to groundwater		Groundwater
Source removals - Excavation and Removal of Impacted Media at Tito Park Area, former Acid Plant, and Upper Lake Marsh	Remove through excavation impacted soil/sediment that could potentially leach to groundwater or surface water	Facility (Parcels 16,19)	Groundwater
			Soil
	Protectively manage removed soil under ET cover system		Surface water
			Sediment
CAMU 1 and CAMU 2	Isolate impacted soil, sediment and remediation waste and prevent impacts to groundwater	Facility (Parcels 16,19)	Groundwater
	Surface water/stormwater collection		Surface water
Slag Pile - Grade and Cover	ET Cover over unfumed slag to reduce infiltration	Facility (Parcels 16,19)	Groundwater
	Slag pile regrading		Soil/Slag
			Sediment
	Surface water/stormwater collection		Surface water
INSTITUTIONAL CONTROLS IMPLEMENTED BY CUSTODIAL TRUST			
Custodial Trust Well Abandonment Program	Contact all residents with existing supply wells; Abandon existing residential wells and/or provide alternative water supply	Non Trust-Owned Properties	Groundwater
Custodial Trust Deed Restrictions	Implement deed restriction on Trust-owned property to restrict use to commercial/industrial only and prohibit groundwater use	Trust-Owned Properties including Facility (Parcels 16, 19)	Soil and Groundwater

Table 6-1. Summary of Proposed Corrective Measures and Supplemental Institutional Controls
Corrective Measures Study Report, Former ASARCO East Helena Facility

Proposed Remedy Elements	Engineering/Activity Components	Applicable Parcels	Applicable Media or Pathway
SUPPLEMENTAL INSTITUTIONAL CONTROLS IMPLEMENTED BY OTHERS			
East Valley Controlled Groundwater Area (CGWA)	Implement and maintain program through CGWA process	CMS Parcels (including Facility), Undeveloped Lands, Non Trust-Owned Properties	Groundwater
	Apply groundwater use restriction areas		
City of East Helena Well Restrictions	Implement and maintain program through COEH process	CMS Parcels (including Facility), Undeveloped Lands, Non Trust-Owned Properties	Groundwater
	Apply groundwater use restriction areas		
Lewis and Clark County and City of East Helena Soil Ordinance	Implement and maintain lead education and abatement program through COEH process	Non Trust-Owned Properties	Soil
	Apply property use restrictions		

Notes:
ET = evapotranspiration
PPC = Prickly Pear Creek
COEH = City of East Helena
Facility - Parcels 16, 19
CMS Parcels - Parcels 10, 11, 12, 15, 16, 17, 18, 19, 23, the portion of 8 located west of State Highway 518 (8W), and portions of Parcel 2 near Prickly Pear Creek (PPC; Parcel 2a)
Undeveloped Lands - Parcels 2, 3, 4, 6, 7, 9, 13, 14, the portion of 8 located east of State Highway 518 (8E), 21, and 22

Table 6-2. Summary of Remedy Performance Standards by Parcel
Corrective Measures Study Report, Former ASARCO East Helena Facility

			Remedy Performance Standards			
CMS Parcel	**Proposed Remedy**	**Media with Potential Unacceptable Risk**	**Protect HH and Environment**	**Achieve MCSs**	**Control Sources**	**Meets Current and Future Exposure/Use**
2a	Operable Unit 2 Record of Decision	Soil	No unacceptable risk (Table 4-1)	To be evaluated upon transfer of property ownership	Windborne deposition mitigated by ET Cover	Currently land is undeveloped similar to Operable Unit 2 Record of Decision parcels
	South Plant Hydraulic Control and ET Cover	Groundwater		Yes	Interrelated IMs to reduce downgradient concentrations	
8W, 10, 11, 12, 17, 18	South Plant Hydraulic Control: Upper Lake and Lower Lake Removal, Prickly Pear Creek Bypass and Realignment, wetland construction	Soil Sediment Surface water	No unacceptable risk (Table 4-1); IMs are reducting contaminant mass loadings and remediy is protective in combination with CGWA and COEH restrictions	Yes - contaminated soil and sediments were removed and replaced with clean materials	N/A - sources removed	Constructed riparian corridor appropriate for industrial (future) or recreational use (current)
15	Operable Unit 2 Record of Decision	Soil	No unacceptable risk (Table 4-1)	To be evaluated upon transfer of property ownership	Windborne deposition mitigated by ET Cover	Meets industrial MCSs (future use); no risk to ecological receptors (current use)
	CGWA (supplemental institutional control implemented by others)	Groundwater	Reduce potential for contact with and ingestion of impacted groundwater	Contaminant concentrations are expected to decrease over time due to reductions in mass loading from remedy implementation	No source: plume in this area is attributed to naturally occurring arsenic	Protected by the CGWA
16, 19	ET Cover, Source Removal, Speiss Dross Slurry Wall, CGWA (supplemental institutional control implemented by others)	Soil	- Prevent contact with impacted media through removal or under protective ET Cover - Locally improve water quality through removal - Improve downgradient water quality over time	Yes	Removed or under protective ET Cover	Meets industrial MCSs
		Groundwater		Contaminant concentrations are expected to decrease over time due to reductions in mass loading from remedy implementation	Excavated where possible, reduce infiltration, prevent migration from slurry wall, lower water levels (South Plant Hydraulic Control IM)	Use prohibited by CGWA
	Grade and Cover	Unfumed Slag		Yes	Reduce potential for slag and stormwater runoff to discharge in Prickly Pear Creek	Fumed slag available for recovery and industrial use
23	Operable Unit 2 Record of Decision	Soil	No unacceptable risk (Table 4-1)	Yes	Windborne deposition mitigated by ET Cover	Currently land is undeveloped similar to Operable Unit 2 Record of Decision parcels
Undeveloped Land	**Proposed Remedy**	**Exposure Media**	**Protect HH and Environment**	**Achieve MCSs**	**Control Sources**	**Meets Current and Future Exposure/Use**
2, 3, 4, 6, 7, 9, 13, 14, 8E, 21, and 22	Operable Unit 2 Record of Decision, COEH Soil Ordinance, COEH Well Restrictions	Groundwater	Reduce potential for human contact with and ingestion of impacted groundwater	Contaminant concentrations are expected to decrease over time due to reductions in mass loading from remedy implementation	Reduced concentrations at Facility will eventually propogate downgradient	Ensures protection until groundwater meets MCSs
	Operable Unit 2 Record of Decision, COEH Soil Ordinance	Soil	Reduce potential for human contact with impacted soil	MCS will be achieved by adherence to COEH soil ordinance or a Trust institutional control if not within COEH	Windborne deposition mitigated by ET Cover	Ensures property use is appropriate to existing conditions
Non-Custodial-Trust-Owned Properties	**Proposed Remedy**	**Exposure Media**	**Protect HH and Environment**	**Achieve MCSs**	**Control Sources**	**Meets Current and Future Exposure/Use**
	Custodial Trust Well Abandonment Program; COEH Well Restrictions; CGWA (supplemental institutional control implemented by others)	Groundwater	Reduce potential for human contact with and ingestion of impacted groundwater	Contaminant concentrations are expected to decrease over time due to reductions in mass loading from remedy implementation	Reduced concentrations at Facility will eventually propogate downgradient	Ensures protection until groundwater meets MCSs
	Operable Unit 2 Record of Decision, COEH Soil Ordinance	Soil	Reduce potential for human contact with impacted soil	MCS will be achieved by adherence to COEH soil ordinance or a Trust institutional control if not within COEH	Windborne deposition mitigated by ET Cover	Ensures property use is appropriate to existing conditions

Notes:

8E = the portion of parcel 8 located east of Highway 518

8W = the portion of parcel 8 located west of Highway 518

CGWA = Controlled Groundwater Area (supplemental institutional control implemented by others)

COEH = City of East Helena

ET = evapotranspiration

IM = interim measure

MCS = media cleanup standard

NA = not applicable

Table 6-3. Preliminary Summary of Performance Monitoring Requirements

Corrective Measures Study Report, Former ASARCO East Helena Facility

Proposed Remedy Elements	Engineering/Activity Components	Applicable Media or Pathway	Remedial Objectives	Performance Monitoring Requirements: Monitoring (Media)	Performance Monitoring Requirements: Engineering Components Monitoring
ENGINEERING CONTROLS					
Slag Pile - Grade and Cover	ET Cover over unfumed slag to reduce infiltration	Groundwater	- Reduce infiltration through unfumed Slag and subsequent leaching of metals from unfumed Slag	CAMP Program (Groundwater)	Cover Inspections and Maintenance
	Slag pile regrading	Soil/Slag Sediment	- Maintain access to slag for sale - Reduce potential for slag discharge to Prickly Pear Creek	Slag pile slope grading plan	Slope inspections and comparison to design parameters
	Surface water/stormwater collection	Surface water	- Reduce potential for slag and stormwater runoff from discharging to Prickly Pear Creek	CAMP Program (Surface Water)	Cover Inspections and Maintenance
ET Cover System - Building Demolition, Utility Abandonment, Subgrade Fill, Final ET Cover	ET Cover to mitigate infiltration of precipitation, control wind erosion	Groundwater	- Reduce infiltration of precipitation through impacted soil to groundwater - Eliminate uncontrolled water collection and discharge to groundwater through buried utilities - Improve Site and down-gradient groundwater quality	CAMP Program (Groundwater)	Cover Inspections and Maintenance
		Soil Sediment	- Reduce potential for direct contact of impacted media with human and ecological receptors	Not Applicable	
	Surface water/stormwater collection	Surface water	- Reduce volume of stormwater and prevent stormwater contact with impacted media	CAMP Program (Surface Water)	
South Plant Hydraulic Controls: Upper Lake and Lower Lake Removal; PPC Bypass; PPC Realignment; wetland construction	Reduce surface water loading to groundwater by removing Upper Lake and Lower Lake	Groundwater	- Lower groundwater table to reduce groundwater contact with impacted subsurface soil - Reduce offsite flux	CAMP Program (Groundwater)	Not applicable
	Establish natural stream channel flow and geomorphic conditions within Smelter reach	Surface water	- Improve surface water quality of PPC by reducing loading from tributary sources	CAMP Program (Surface Water)	
	Establish natural wetland/riparian conditions	Sediment	- Reduce impacted sediment discharge to PPC within Smelter reach - Prevent flooding	Not Applicable	
Source removals - Excavation and Removal of Impacted Media at Tito Park Area, Acid Plant, Upper Lake Marsh, and Speiss Disposal Area	Remove through excavation impacted soil/sediment that could potentially leach to groundwater or surface water	Groundwater	- Improve localized groundwater conditions within removal areas - Improve down-gradient groundwater quality	CAMP Program (Groundwater)	Not applicable (see ET Cover System)
		Soil	- Reduce potential for human contact with impacted soil	Not Applicable	
	Protectively manage removed soil under ET cover system	Surface water	- Improve surface water quality of PPC by reduced loading from tributary sources	CAMP Program (Surface Water)	
		Sediment	- Reduce impacted sediment discharge to PPC within Smelter reach	Not Applicable	
Speiss Dross Slurry Wall	Isolate impacted soil and prevent impacts to groundwater	Groundwater	- Improve localized groundwater conditions outside of slurry wall area - Improve down-gradient groundwater quality	CAMP Program (Groundwater)	Not applicable
INSTITUTIONAL CONTROLS (ICs)					
Custodial Trust Well Abandonment Program	Contact all residents with existing supply wells; Abandon existing residential wells and/or provide alternative water supply	Groundwater	- Reduce potential for human contact with and ingestion of impacted groundwater	Verification of Alternative Water Supply or Treatment System	Formally confirm all residents with existing supply wells are notified
SUPPLEMENTAL ICs IMPLEMENTED BY OTHERS					
Controlled Groundwater Area (CGWA)	Implement and maintain program through CGWA process Apply groundwater use restriction areas	Groundwater	- Reduce potential for human contact with and ingestion of impacted groundwater	CAMP Program (Groundwater)	Maintain CGWA program until conditions are met
COEH Well Restrictions	Implement and maintain program through COEH process Apply groundwater use restriction areas	Groundwater	- Reduce potential for human contact with and ingestion of impacted groundwater	CAMP Program (Groundwater)	Monitored through COEH program
COEH Soil Ordinance	Implement and maintain program through COEH process Apply property use restrictions	Soil	- Reduce potential for human contact with impacted soil - Ensure that property use is appropriate to existing conditions	Not Applicable	Monitored through COEH LEAP program