PIONEER TECHNICAL SERVICES

Using Geospatial and Geostatistical Models Created with Leapfrog Works to Inform Remediation Design at a Historical Smelter Site in Butte, Montana

June 3, 2025

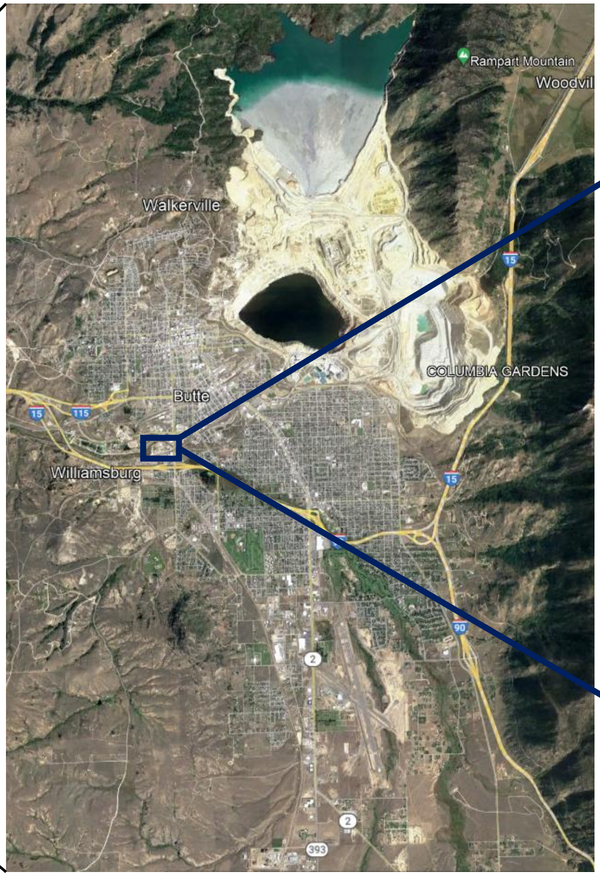
FORGING A BRIGHT & SUSTAINABLE FUTURE TOGETHER

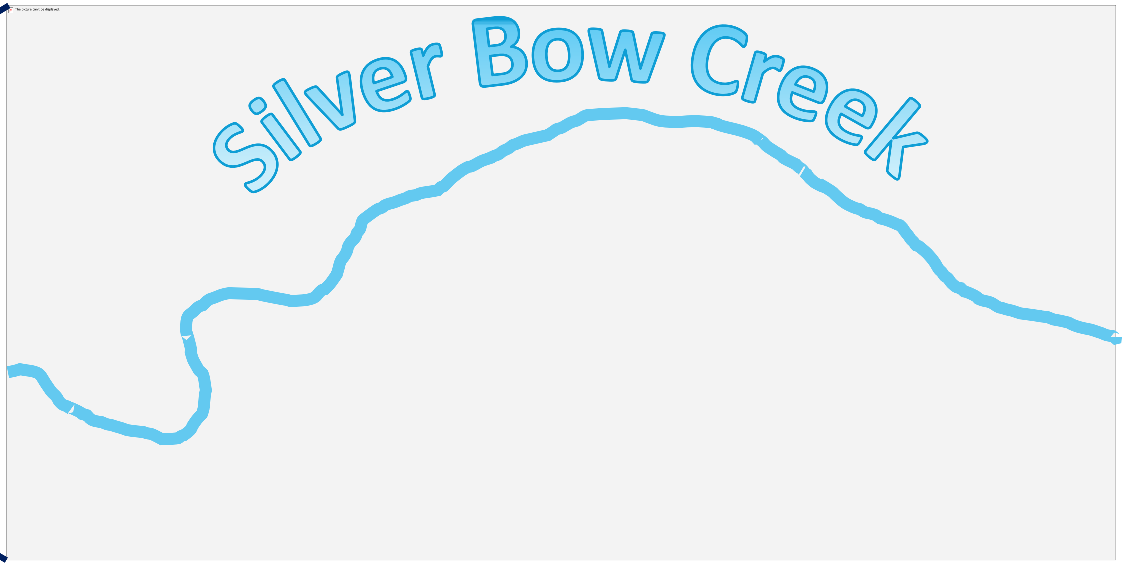
To Model or Not to Model, that Is the Question

Agenda

- Butte Reduction Works
- Remedy
- Available Data
- Modeling Objectives
- Model Development
- Questions

Butte Reduction Works

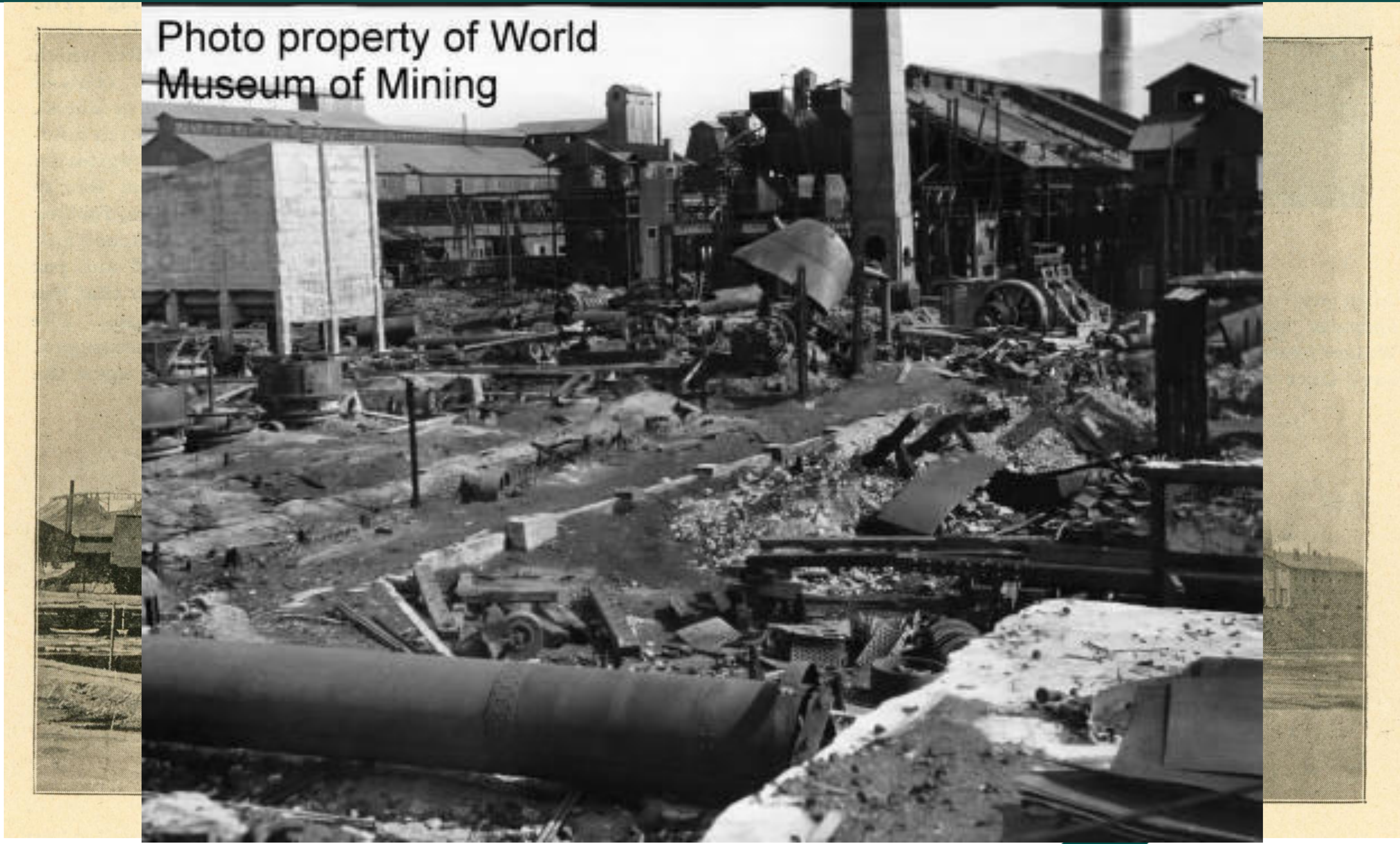




Butte Reduction Works

- **1868–1900:** Silver Mill and Mine Operations North of Site Deposit Mine and Mill Waste onto Site and SBC
- **1883–1910:** Smelter produces Copper and Copper Tailings at the Site
- **1909–1911:** Zinc Concentrator Added to Site. Destroyed in a Fire in 1911
- **1927–1992:** Manganese Stockpiled at the Site. First by Domestic Manganese (1927 to 1945) then General Services Administration and Department of Defense (1945 to 1992)
- **1943–1945:** GSA and DOD Construct a Flotation Mill, Produce Manganese, Dispose of Manganese Tailings, and Store Ore on Site.
- **1960–1963:** Phosphate Plant Processes Phosphate on-site.
- **1995–2024:** Local City-County Government Uses a Portion of the Site to House an Asphalt Plant and Aggregate Stockpiles

Butte Reduction Works



Butte Reduction Works – The Power of Slag

MAKING SLAG WALL AT BUTTE REDUCTION WORKS

Remedy – Timeline

- **1983** – **SBC added to National Priority List**
- **1987** – **Butte added to SBC Site**
- 1988–2005 – EPA Completed Several Removal Actions in Butte at former smelter sites, mine waste dumps, railroad beds, stream banks, and residential yards
- 1994–1998 – Lower Area One Expedited Response Action removed ~1.25 million cubic yards of mine waste from area west of the Site.
- 1998–2011 – Groundwater Monitoring Wells Installed Near and Around the Site
- **2006** – **Record of Decision**
- **2011** – **Explanation of Significant Differences to the Record of Decision**
- 2016 – Montana National Resources Damage Program Test Pit Investigation
- 2018–2020 – Phase I Investigation
- **2019** – **Consent Decree**
- 2020–2021 – Phase II Investigation
- 2021–2023 – Phase III Investigation
- 2022 – Microbial Analysis and Biotreatability Study

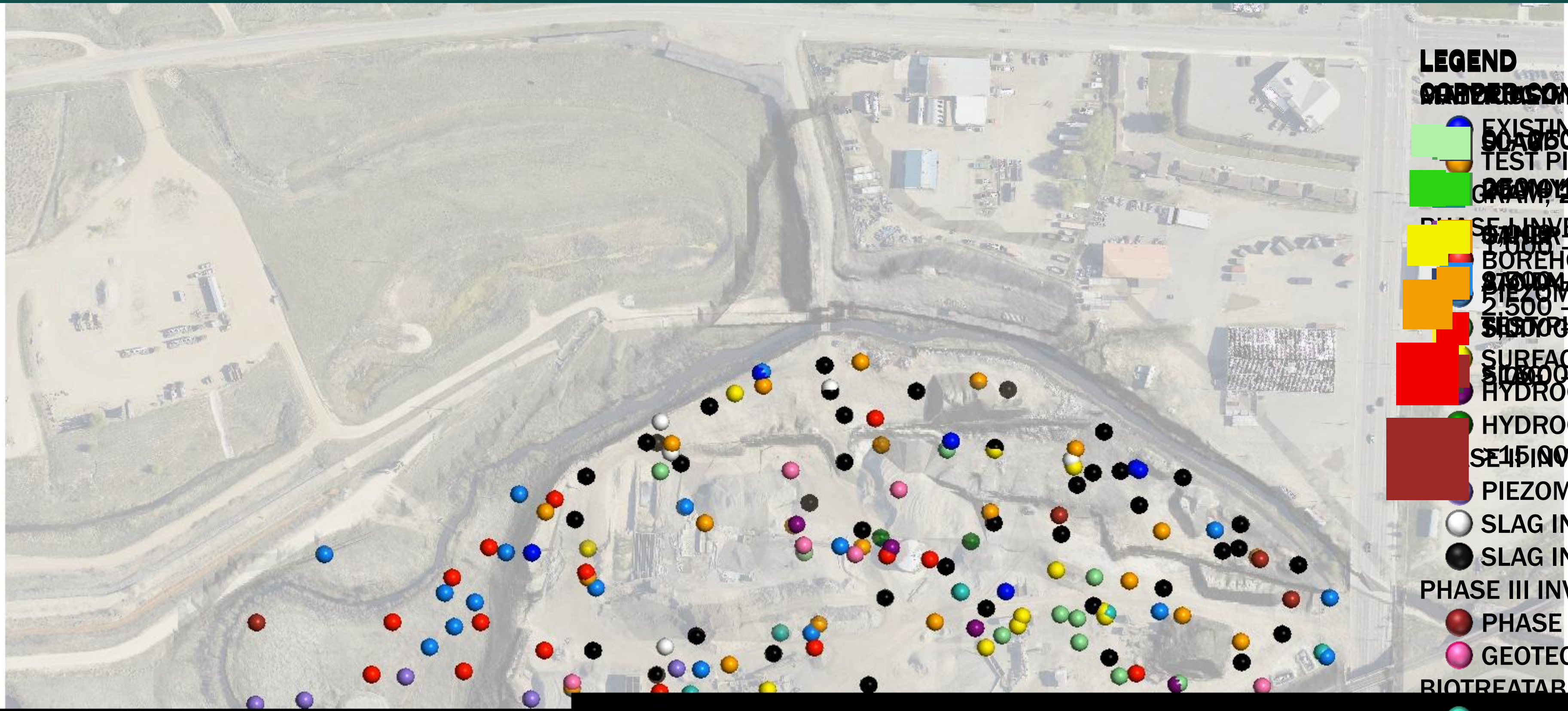
Remedy – Requirements and Objectives

Available Data

To Model or Not to Model, that Is the Question!

At the Very Least, Let’s Look at the Data.

Available Data



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Model Objectives

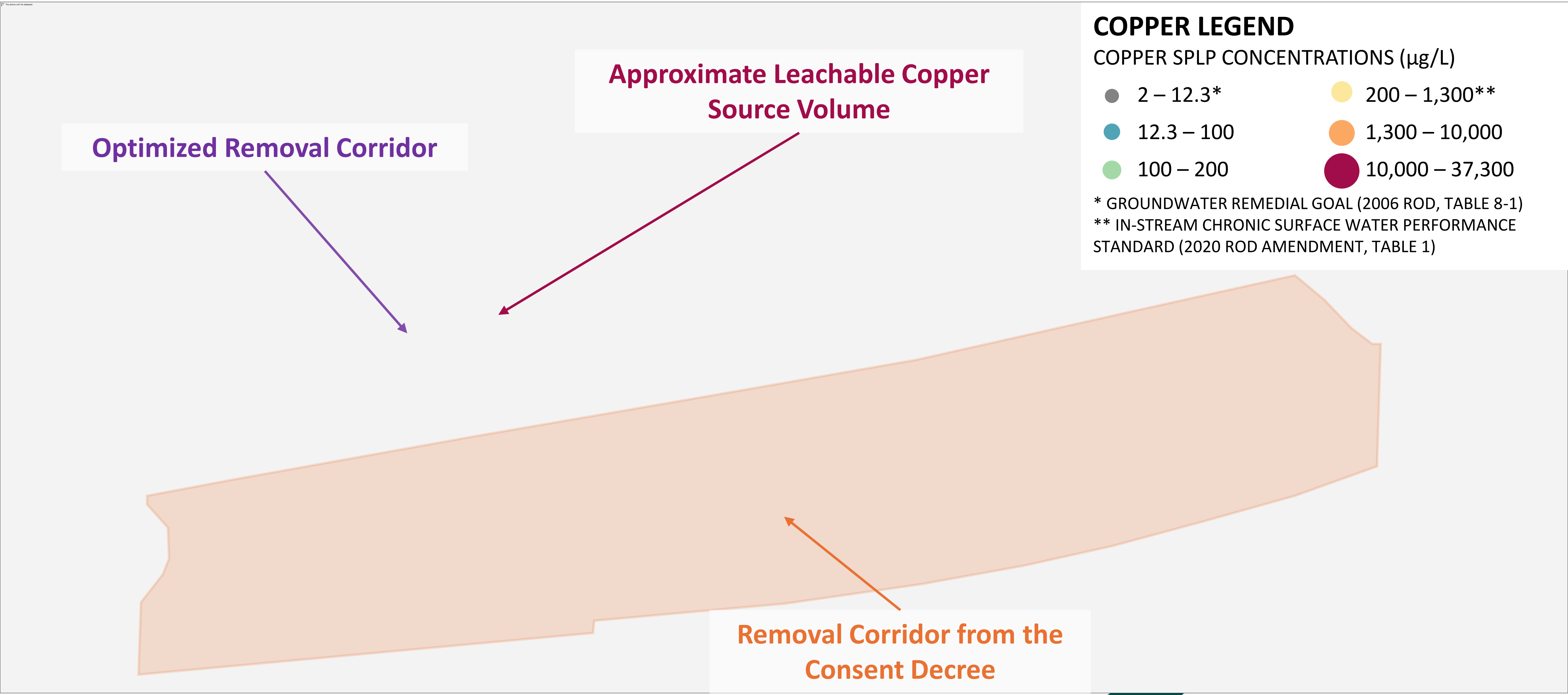
1. Optimize the Removal Corridor
   - Find the Leachable Copper Source and Optimize the Removal Corridor Area
2. Determine the Bottom of Waste in the Removal Corridor
   - Model the COCs and Inform the Excavation Surface
3. Inform the Estimation of Infiltration Rates in the Site Pre- and Post-Remedy
   - Model the Soil Lithology to Inform the Hydrologic Evaluation of Landfill Performance (HELP) Model
4. Determine the Hydrocarbon Impact
   - Estimate the Length of Hydrocarbon Source Parallel to Groundwater Flow for the RBCA Evaluation
   - Estimate the Volume and Location of Soils Exceeding RBCA Standards

Model Development – Optimize the Removal Corridor

Why Copper?

- Of the five COCs, copper has the highest leachable concentration in alluvial materials. The highest copper SPLP concentration is 37,300 µg/L. The next highest leachable concentration is a zinc concentration at 27,600 µg/L.
- Locations of higher copper leachability generally correlate well with the locations of higher cadmium, lead, and zinc leachability.
- Generally, copper groundwater concentrations either correlate well with cadmium, lead, and zinc concentrations or copper shows exceedances where cadmium, lead, and zinc show compliance.

Model Development – Optimize the Removal Corridor



Model Development – Bottom of Waste

Question 1: What is the Waste Criteria

Question 2: Where is the Bottom of Waste According to the Data?

Question 3: If we model the Individual COCs and Combine the Waste Volumes, Where is the Bottom of Waste?

Question 4: How to Make a Constructable Bottom of Waste Surface?

Question 5: How do We Confirm the Efficacy of the Excavation Surface?

Model Development – Bottom of Waste

Waste Criteria:

Consent Decree for the Butte Priority Soils Operable Unit
Partial Remedial Design/Remedial Action and Operation and Maintenance

Table 1: Waste Identification Criteria

(Source SSTOU)

If three of the six contaminant criteria listed are exceeded or any one contaminant is above 5,000 mg/kg then, the material is considered tailings, waste, or contaminated soil.

Arsenic	200 mg/kg
Cadmium	20 mg/kg
Copper	1,000 mg/kg
Lead	1,000 mg/kg
Mercury	10 mg/kg
Zinc	1,000 mg/kg
Any single analyte above 5,000 mg/kg	

No.	Combination of COCs
1	Arsenic – Cadmium – Copper
2	Arsenic – Cadmium – Mercury
3	Arsenic – Cadmium – Lead
4	Arsenic – Cadmium – Zinc
5	Arsenic – Copper – Mercury
6	Arsenic – Copper – Lead
7	Arsenic – Copper – Zinc
8	Arsenic – Lead – Mercury
9	Arsenic – Lead – Zinc
10	Arsenic – Zinc – Mercury
11	Cadmium – Copper – Mercury
12	Cadmium – Copper – Lead
13	Cadmium – Copper – Zinc
14	Cadmium – Lead – Mercury
15	Cadmium – Lead – Zinc
16	Cadmium – Zinc – Mercury
17	Copper – Lead – Mercury
18	Copper – Lead – Zinc
19	Copper – Zinc – Mercury
20	Lead – Zinc – Mercury
21	Any COC Over 5,000 mg/kg

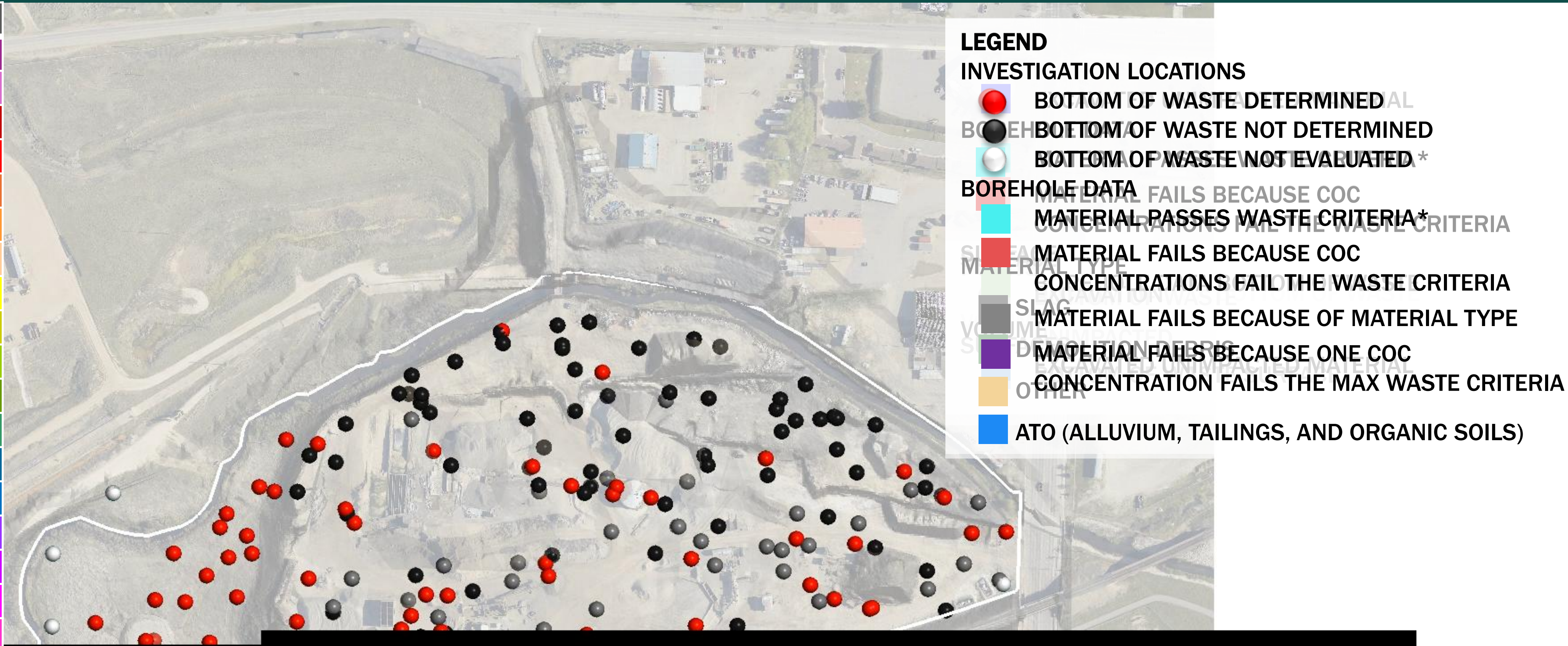
Model Development – Bottom of Waste

Modeling the Bottom of Waste:

- Step 1: Determine the Bottom of Waste in the Data
- Step 2: Connect the Bottom of Waste Points in the Data
- Step 3: Model the COC Concentrations
- Step 4: Combine the Waste Volumes Determined by the Data and Modeled Concentrations
- Step 5: Add in Any Other Waste Volumes
- Step 6: Create a Block Model with the Total Waste Volume
- Step 7: Create a Point File at the Interface between Waste and Unimpacted Material
- Step 8: Create a Bottom of Waste Surface from the Point File
- Step 9: Smooth out the Bottom of Waste Surface, Add Safe Excavation Slopes, and Account for the Creek Design to Make an Excavation Surface

Model Development – Bottom of Waste

No.	Combination of COCs
1	Arsenic – Cadmium – Copper
2	Arsenic – Cadmium – Mercury
3	Arsenic – Cadmium – Lead
4	Arsenic – Cadmium – Zinc
5	Arsenic – Copper – Mercury
6	Arsenic – Copper – Lead
7	Arsenic – Copper – Zinc
8	Arsenic – Lead – Mercury
9	Arsenic – Lead – Zinc
10	Arsenic – Zinc – Mercury
11	Cadmium – Copper – Mercury
12	Cadmium – Copper – Lead
13	Cadmium – Copper – Zinc
14	Cadmium – Lead – Mercury
15	Cadmium – Lead – Zinc
16	Cadmium – Zinc – Mercury
17	Copper – Lead – Mercury
18	Copper – Lead – Zinc
19	Copper – Zinc – Mercury
20	Lead – Zinc – Mercury
21	Any COC Over 5,000 mg/kg

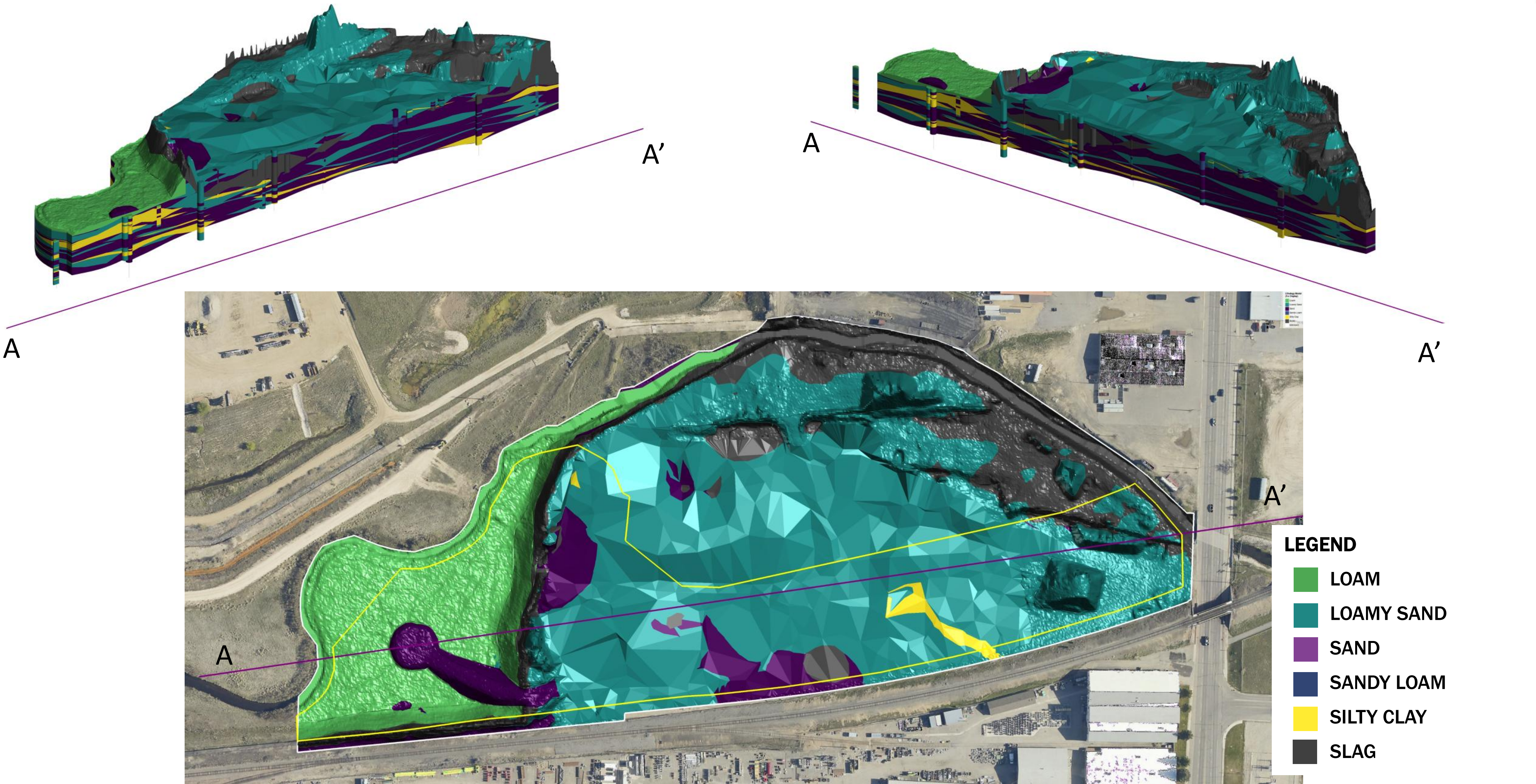


Model Development – Bottom of Waste

Determining Efficacy of Excavation Surface:

Location	Borehole Data Regression Bottom of Waste Depth	Borehole Data Upper 95% Bottom of Waste Depth	Modeled COC Waste Depth	Excavation Depth	Added Waste Depth Comparing Regression and Upper 95%	Added Waste Depth Comparing Upper 95% and Model	Excavation Depth Below Upper 95%	Excavation Depth Below Modeled COC Waste	On the Edge of the Excavation?
BRW18-BH01	25	25.8	26.1	26.8	0.8	0.3	1.0	0.7	NO
BRW18-BH02	23.4	23.4	24.2	24.6	0	0.8	1.2	0.4	NO
BRW18-BH03	25.4	25.4	25.0	26.0	0	-0.4	0.6	1.0	NO
BRW18-BH05	21.9	21.9	22.6	26.7	0	0.7	4.8	4.1	NO
BRW18-BH06	20	20	20.0	20.1	0	0.0	0.1	0.1	NO
BRW18-BH07	5.7	5.9	7.6	8.0	0.2	1.7	2.1	0.4	NO
BRW18-BH16	6.2	6.2	6.2	6.7	0	0.0	0.5	0.5	NO
BRW18-BH18	6.1	6.1	6.8	7.0	0	0.7	0.9	0.2	NO
BRW18-BH20	7.7	7.7	8.5	9.3	0	0.8	1.6	0.8	NO
BRW18-BH21	10	10	10.4	10.7	0	0.4	0.7	0.3	NO
BRW18-BH22	8.6	8.6	9.2	9.7	0	0.6	1.1	0.5	NO
BRW18-BH23	7.3	7.3	9.5	10.2	0	2.2	2.9	0.7	NO
BRW18-BH24	7.9	7.9	9.1	9.3	0	1.2	1.4	0.2	NO
BRW18-BH25	10.8	10.8	11.1	11.3	0	0.3	0.5	0.2	NO
BRW18-BH26	7.2	7.2	9.1	9.6	0	1.9	2.4	0.5	NO
BRW18-BH27	9.2	9.2	8.8	9.5	0	-0.4	0.3	0.7	NO
BRW18-BH28	8.6	8.6	9.6	9.6	0	1.0	1.0	0.0	NO
BRW18-BH29	11.1	11.1	11.8	11.9	0	0.7	0.8	0.1	NO
BRW21-TP4	BOW ND	BOW ND	13.0	13.0	N/A	N/A	N/A	0.0	NO
BRW19-HCW41	4.5	4.5	4.5	4.9	0	0.0	0.4	0.4	NO
BRW18-PZ01	8.7	8.7	10.4	11.3	0	1.7	2.6	0.9	NO

Model Development – Soil Lithology Model



Model Development – Supporting Infiltration Estimates

LEGEND

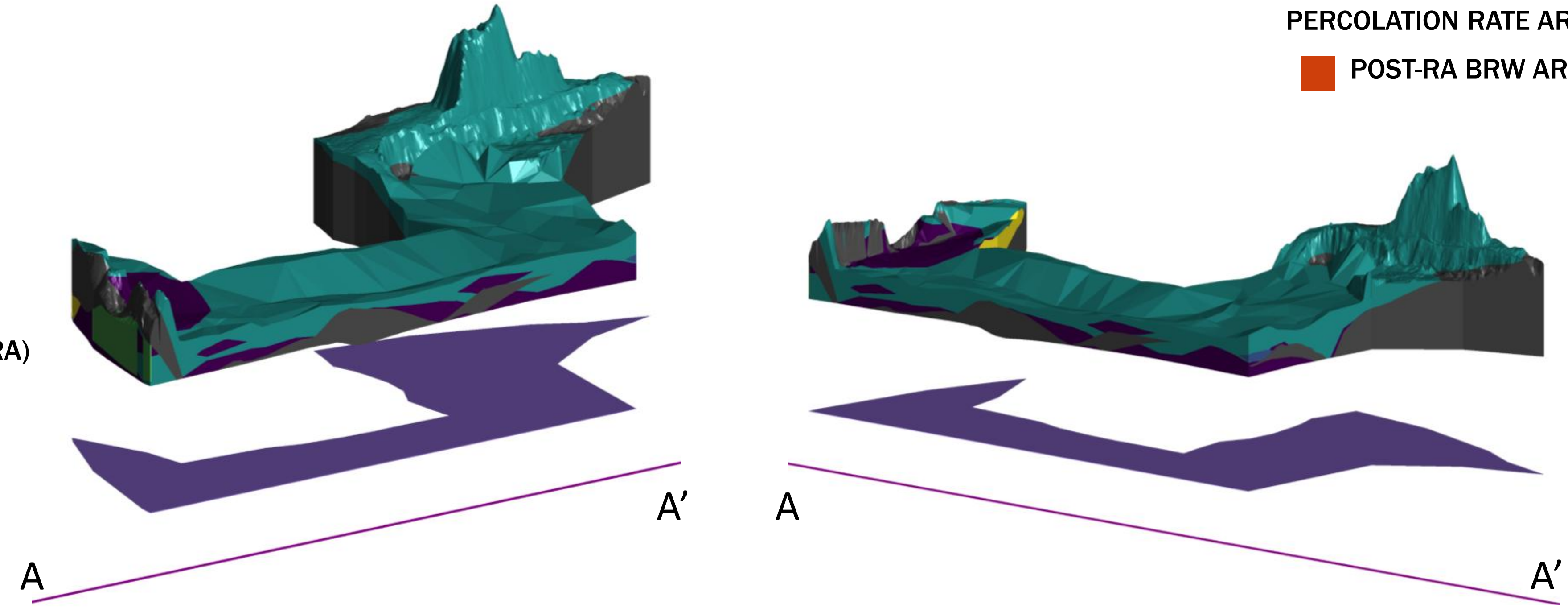
- LOAM
- LOAMY SAND
- SAND
- SANDY LOAM
- SILTY CLAY
- SLAG

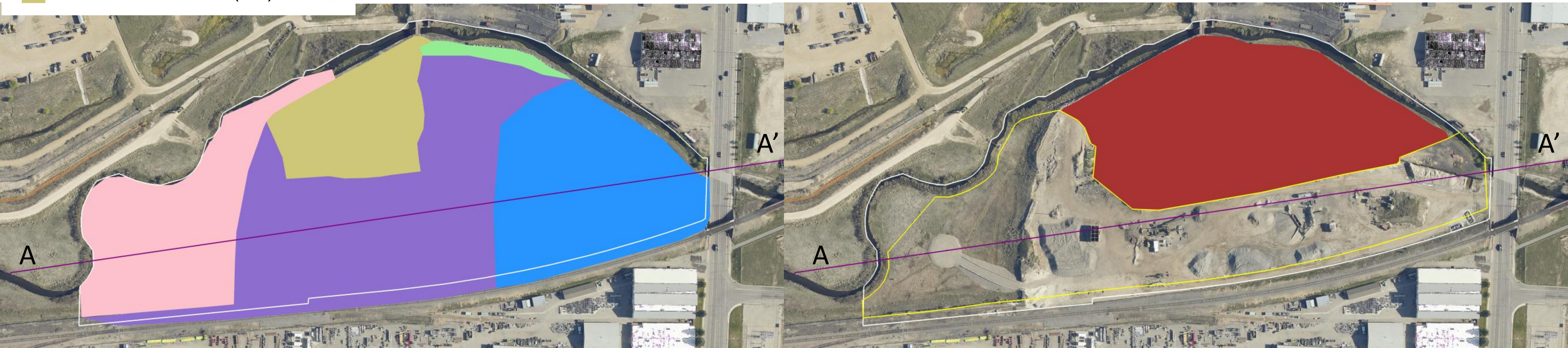
PERCOLATION RATE AREAS (PRE-RA)

- VEGETATED AREA (VA)
- INDUSTRIAL AREA 1 (IA1)
- INDUSTRIAL AREA 2 (IA2)
- INDUSTRIAL AREA 3 (IA3)
- INDUSTRIAL AREA 4 (IA4)

PERCOLATION RATE AREAS (POST-RA)

- POST-RA BRW AREA





Model Development – Hydrocarbon Impact

Model Development – Hydrocarbon Impact

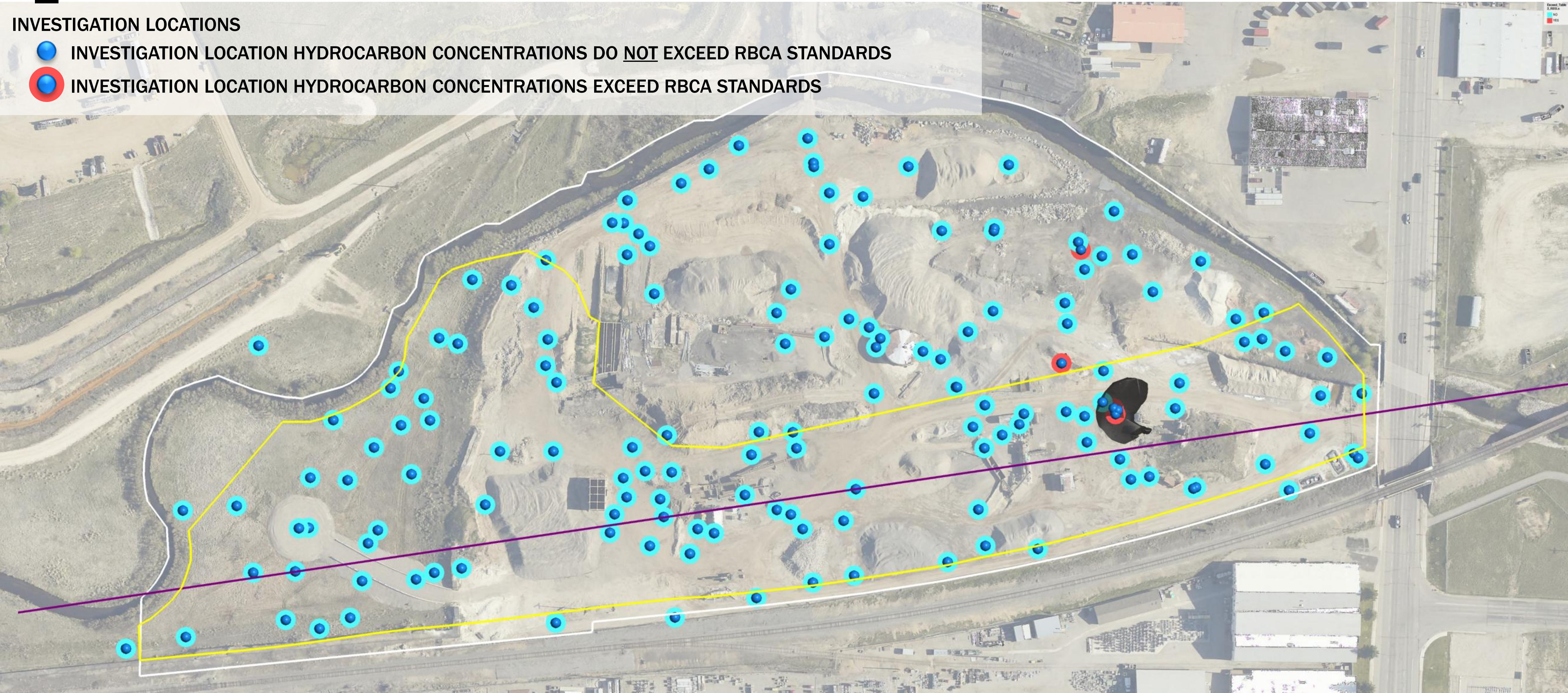
LEGEND

VOLUMES

■ VOLUME OF SOILS EXCEEDING THE TABLE 2 RBCA STANDARDS AS MODELED IN LEAPFROG

INVESTIGATION LOCATIONS

- INVESTIGATION LOCATION HYDROCARBON CONCENTRATIONS DO NOT EXCEED RBCA STANDARDS
- INVESTIGATION LOCATION HYDROCARBON CONCENTRATIONS EXCEED RBCA STANDARDS



Questions