Elkhorn Mine & Mill

2021 Site Characterization Report

Prepared for
Big Hole Watershed Committee
& US Forest Service Northern Region

Prepared by

WindenWater, LCC

March 2022

Agenda

1. Roundtable
2. RAC Funding
3. Surface Water Quality
   - Elkhorn Creek → Wise River
   - Adit Trends
   - Dispersed AMD sources
   - Park Mine drainages
4. PCB Screening
   - Sampling grid & locations
   - Composite and randomized analyses
   - QA/QC
5. Soils characterization
   - Delineating impacted soils
   - Priority project polygons
   - XRF Screening
   - SAP/QAPP
6. 2022 Site Inspection
7. Graduate Research

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2021 WQ Sampling Locations

- 27 total sites
- 11 longitudinal Elkhorn sites
  - From upstream of mine → to confluence of Wise River
- 10 dispersed AMD sites
- 3 tributaries draining Park Mine complex
- 2 galvanized wells below waste rock pile

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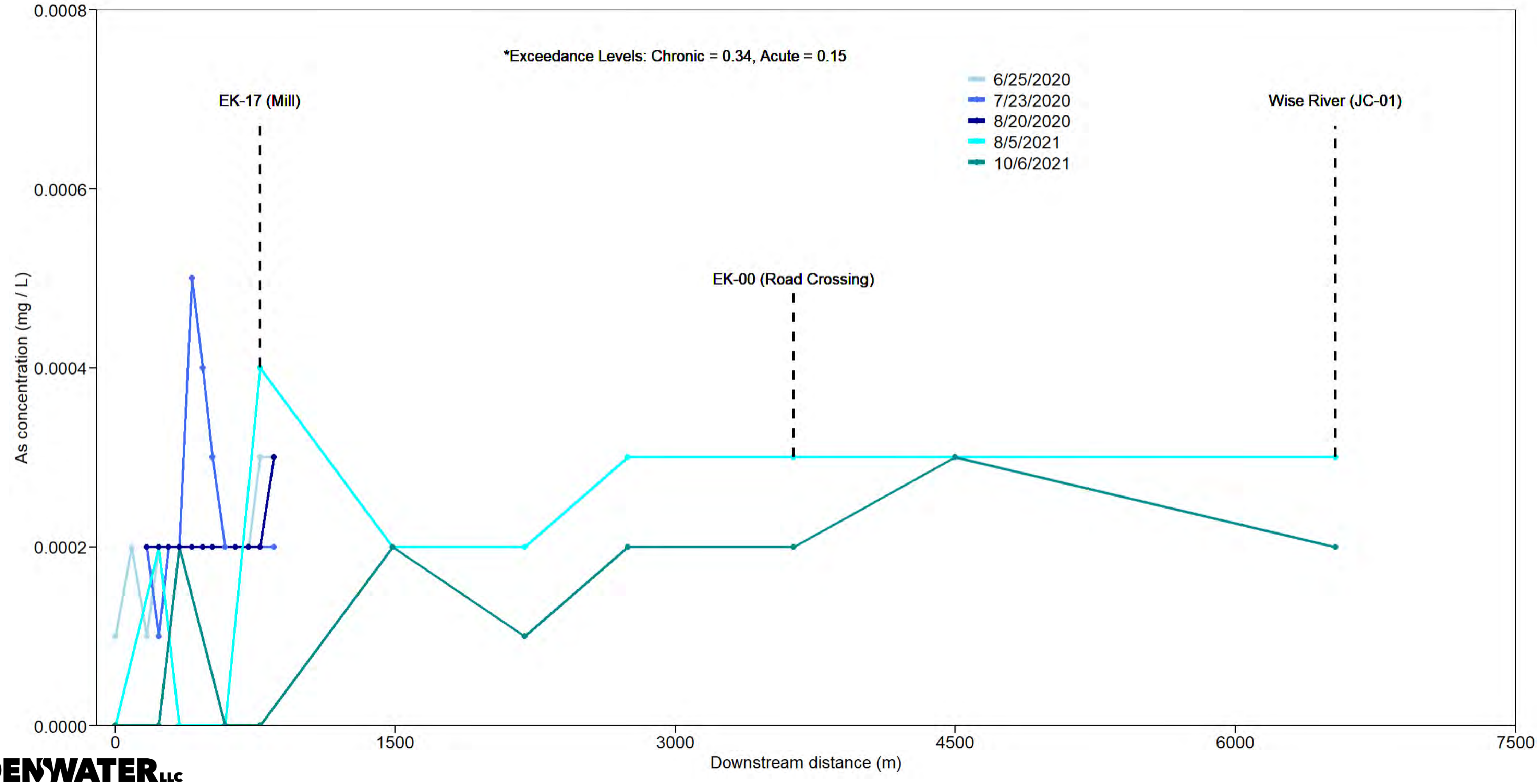
Longitudinal [As]

Elkhorn Creek → Wise River

- Concentrations are **not** in exceedance of acute or chronic toxicity levels
- Measurable spikes in proximity of waste rock pile & Mill; muted in 2021 compared to 2020



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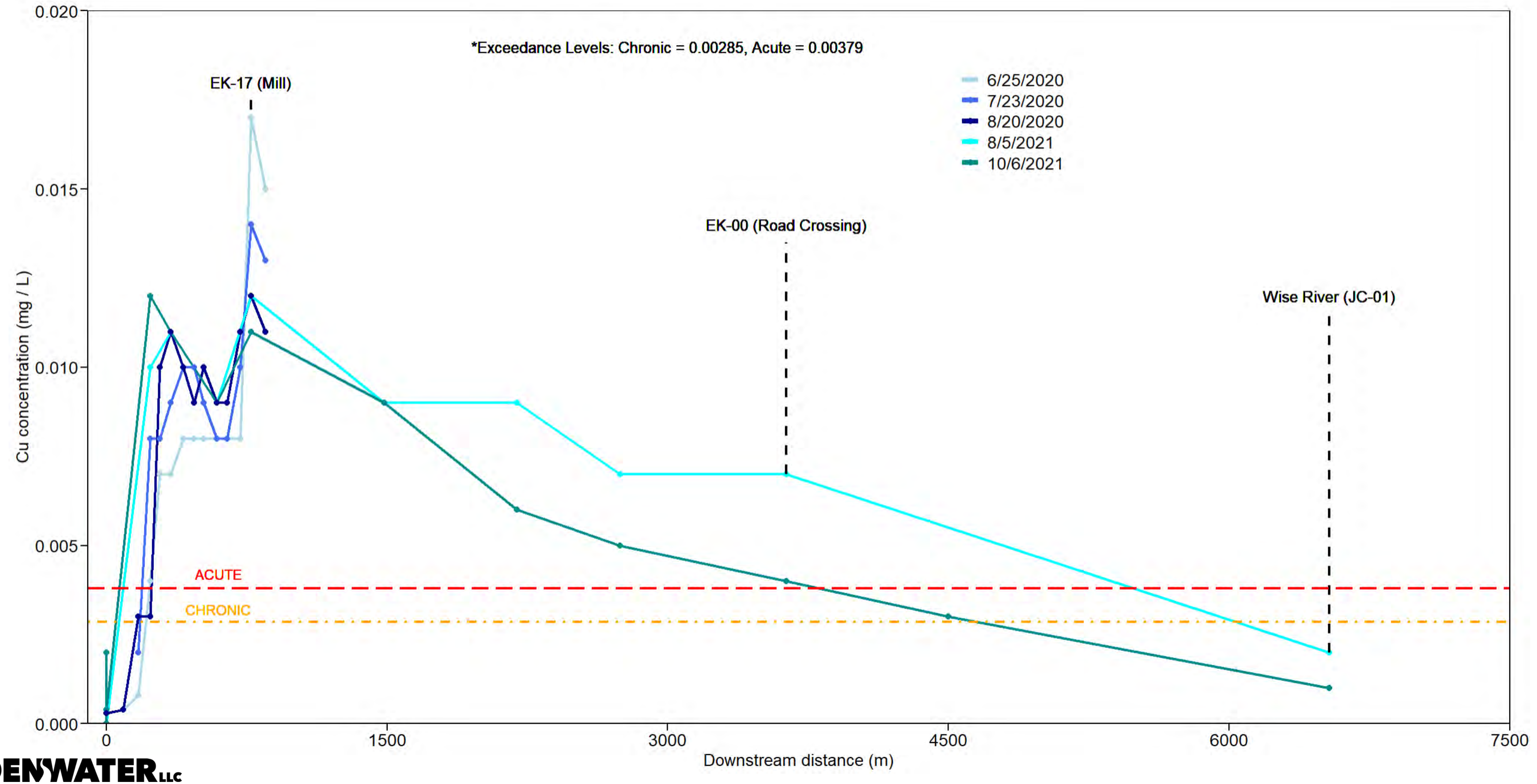
Longitudinal [Cu]

Elkhorn Creek → Wise River

- Concentrations **exceed** acute & chronic toxicity levels from mine downstream to road crossing
- Apparent seasonal and annual variability likely due to runoff & snowpack



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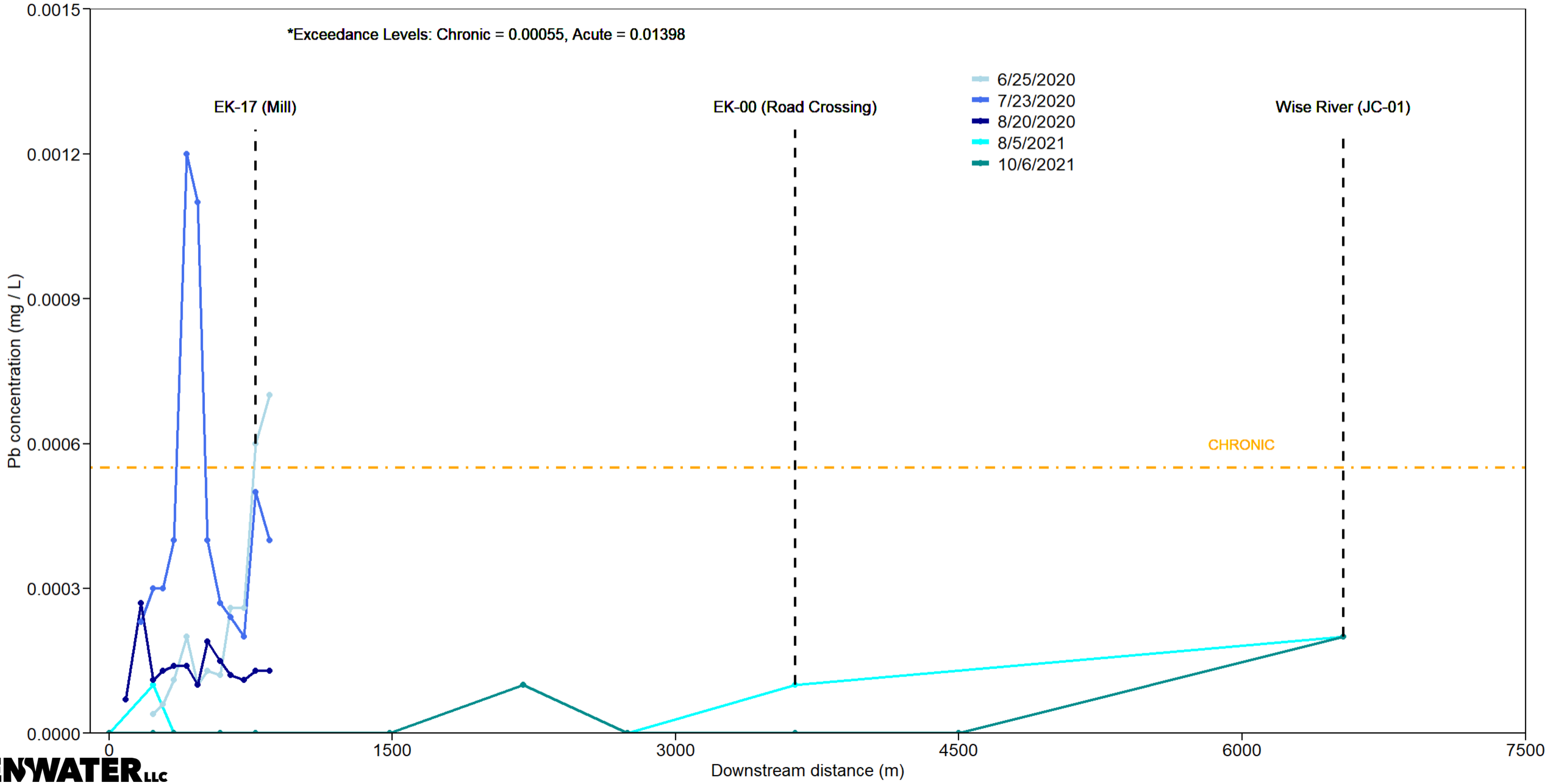
Longitudinal [Pb]

Elkhorn Creek → Wise River

- Concentrations **did not** exceed chronic or acute toxicity levels in 2021
- Muted signal in 2021 compared to 2020; possibly related to drier waste rock pile conditions



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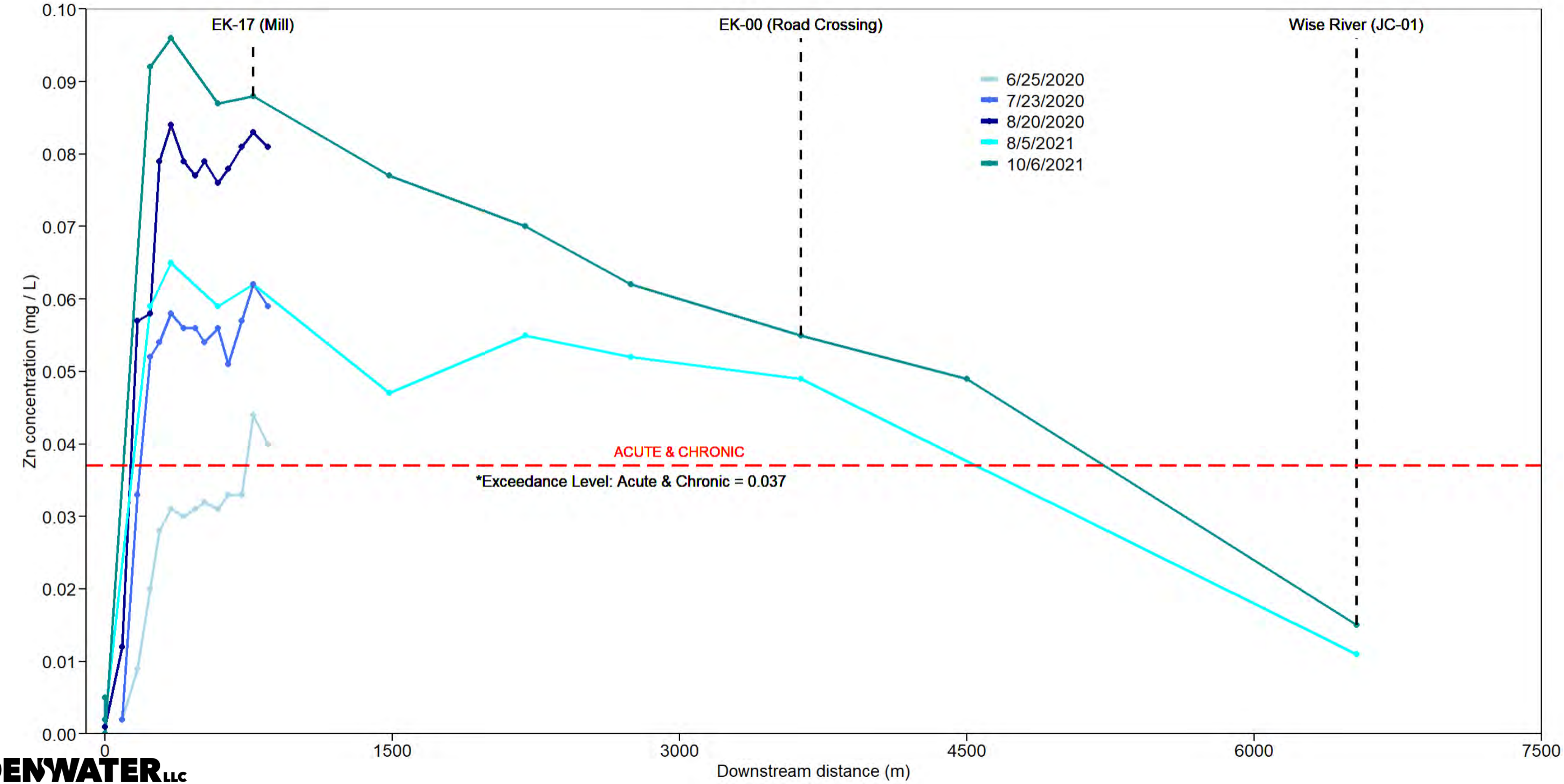
Longitudinal [Zn]

Elkhorn Creek → Wise River

- Concentrations consistently **exceed** acute/chronic toxicity levels from the mine to Elkhorn confluence at Jacobson Creek
- Muted signal in 2020 compared to 2021; possibly related to drier waste rock pile conditions



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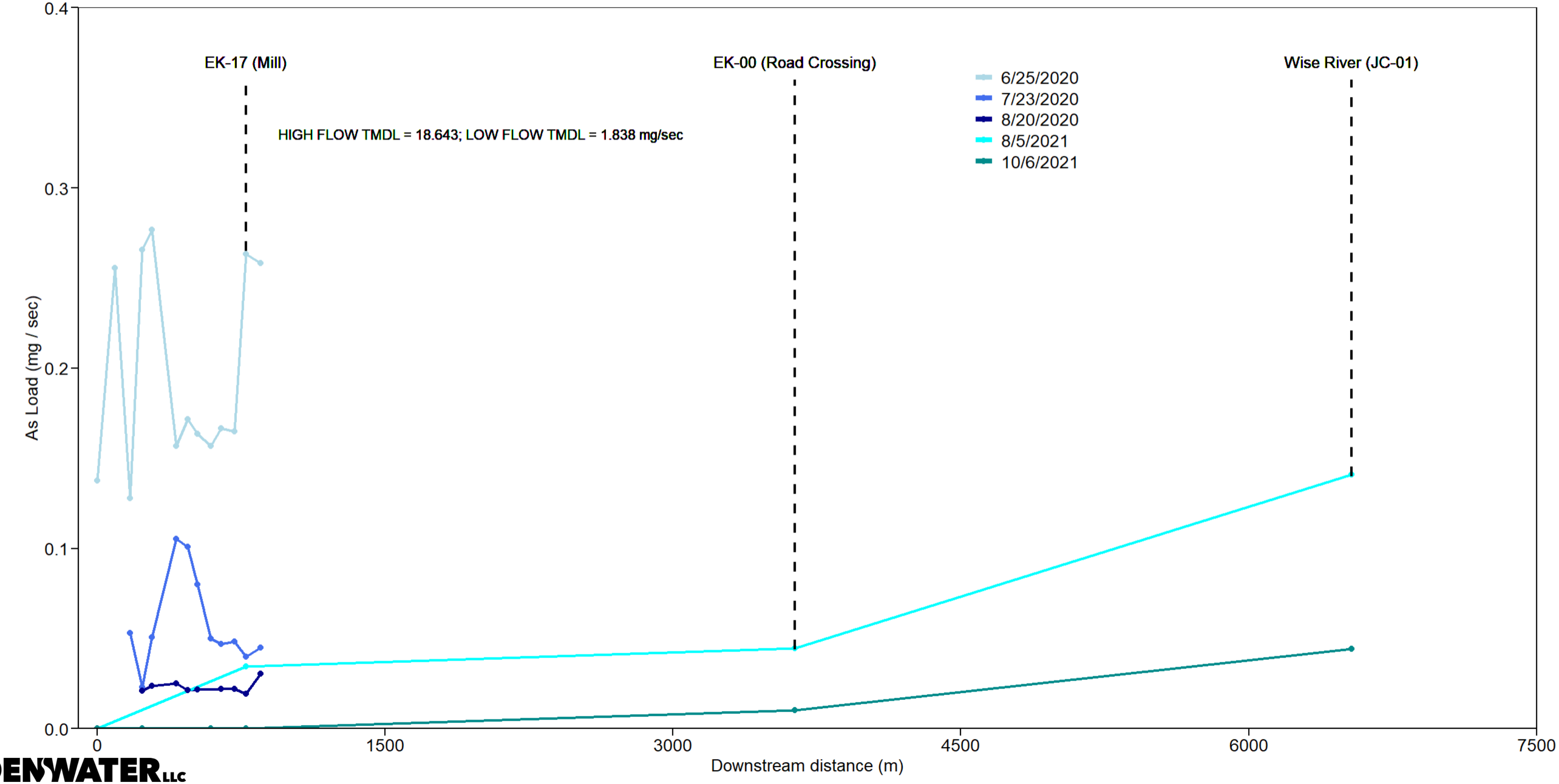
As Loading

Elkhorn Creek → Wise River

- **Below** TMDL during both high and low flow conditions
- Much lower loading in 2021 than 2021; perhaps due to low runoff year



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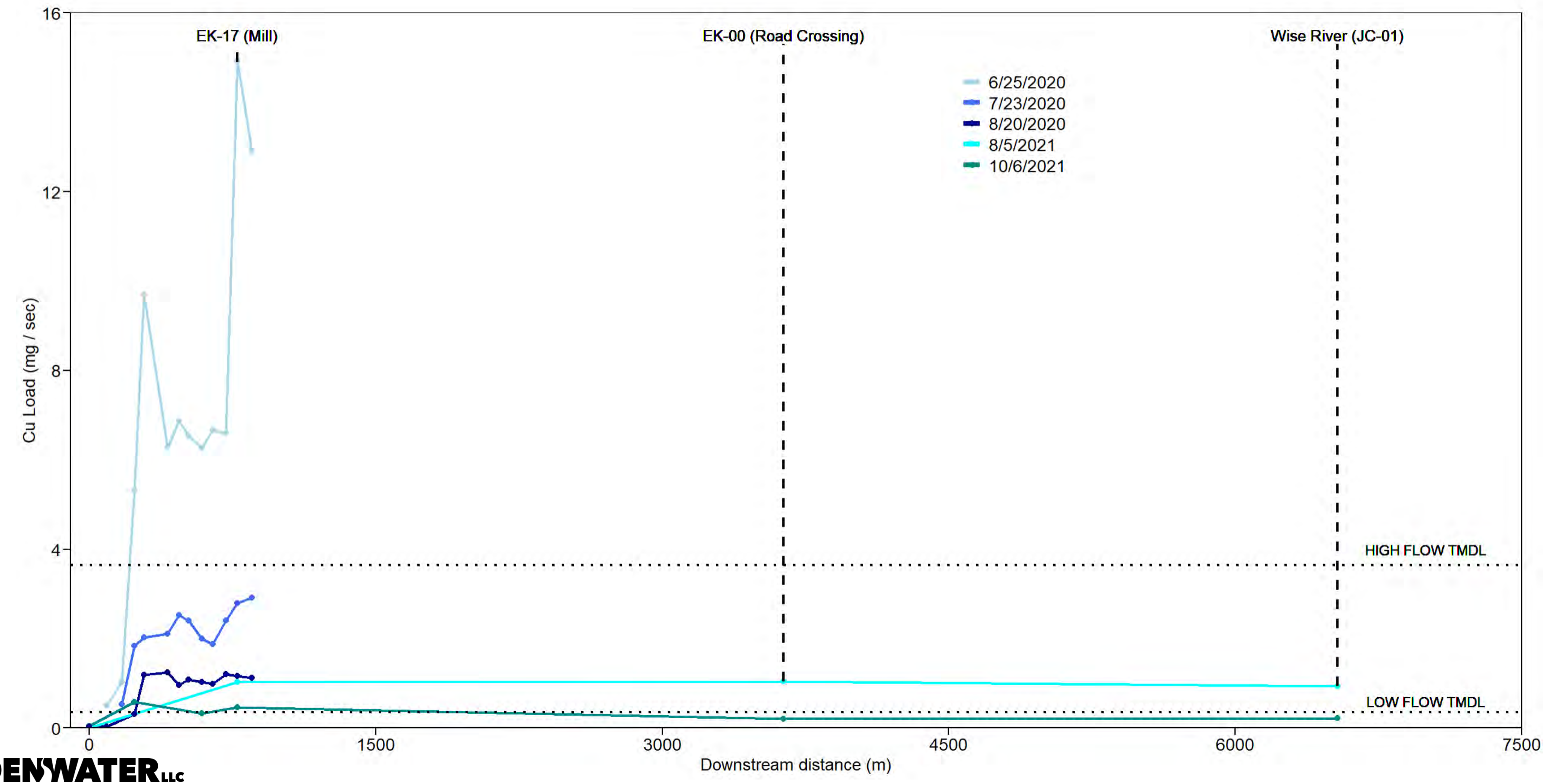
Cu Loading

Elkhorn Creek → Wise River

- Often **above** TMDL during low flows but **below** TMDL during high flows
- Much lower loading in 2021 than 2021; perhaps due to low runoff year



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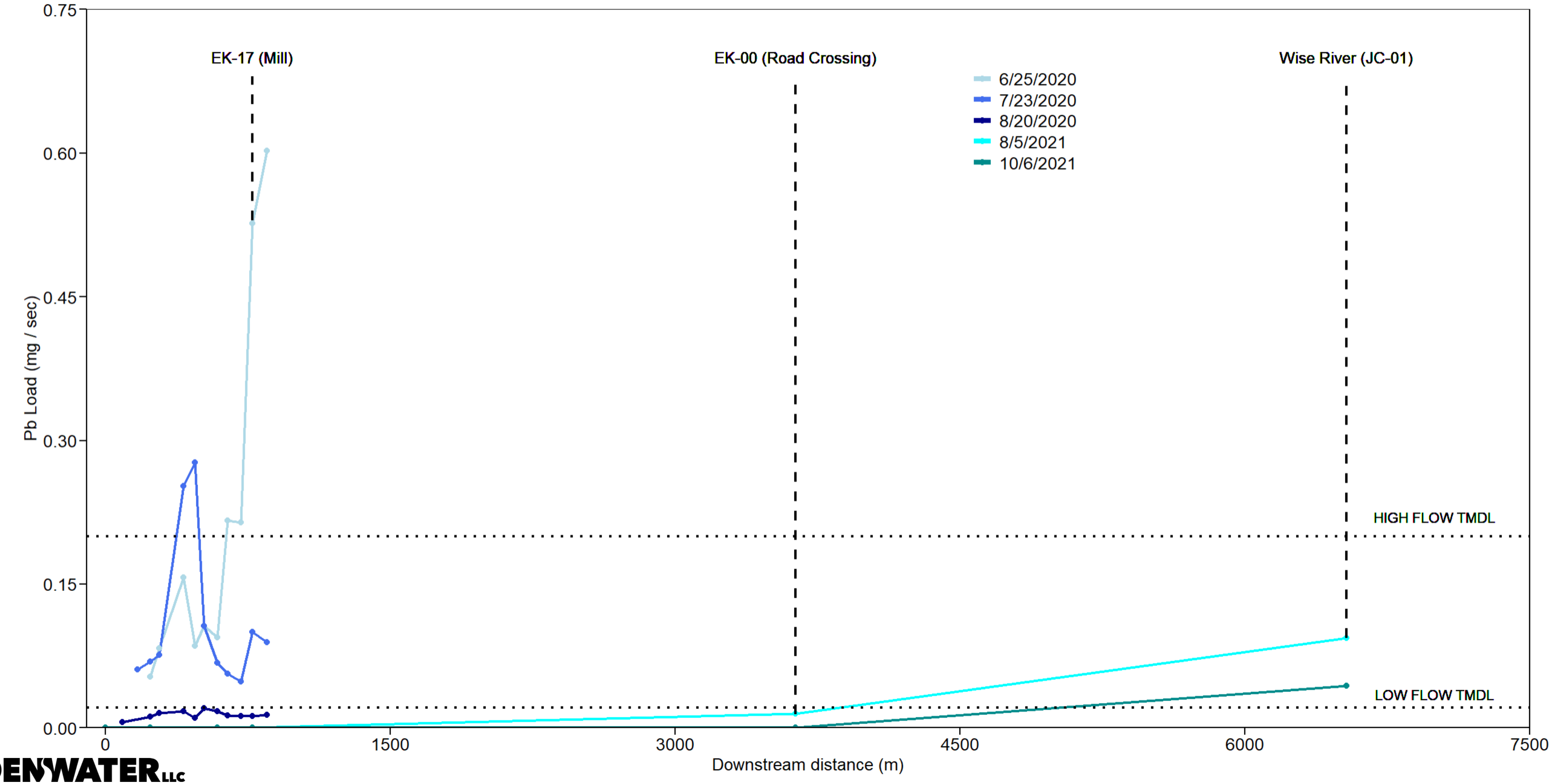
Pb Loading

Elkhorn Creek → Wise River

- Usually **below** TMDL for all flows except very high flows
- Potential other source of Pb from Jacobson Creek



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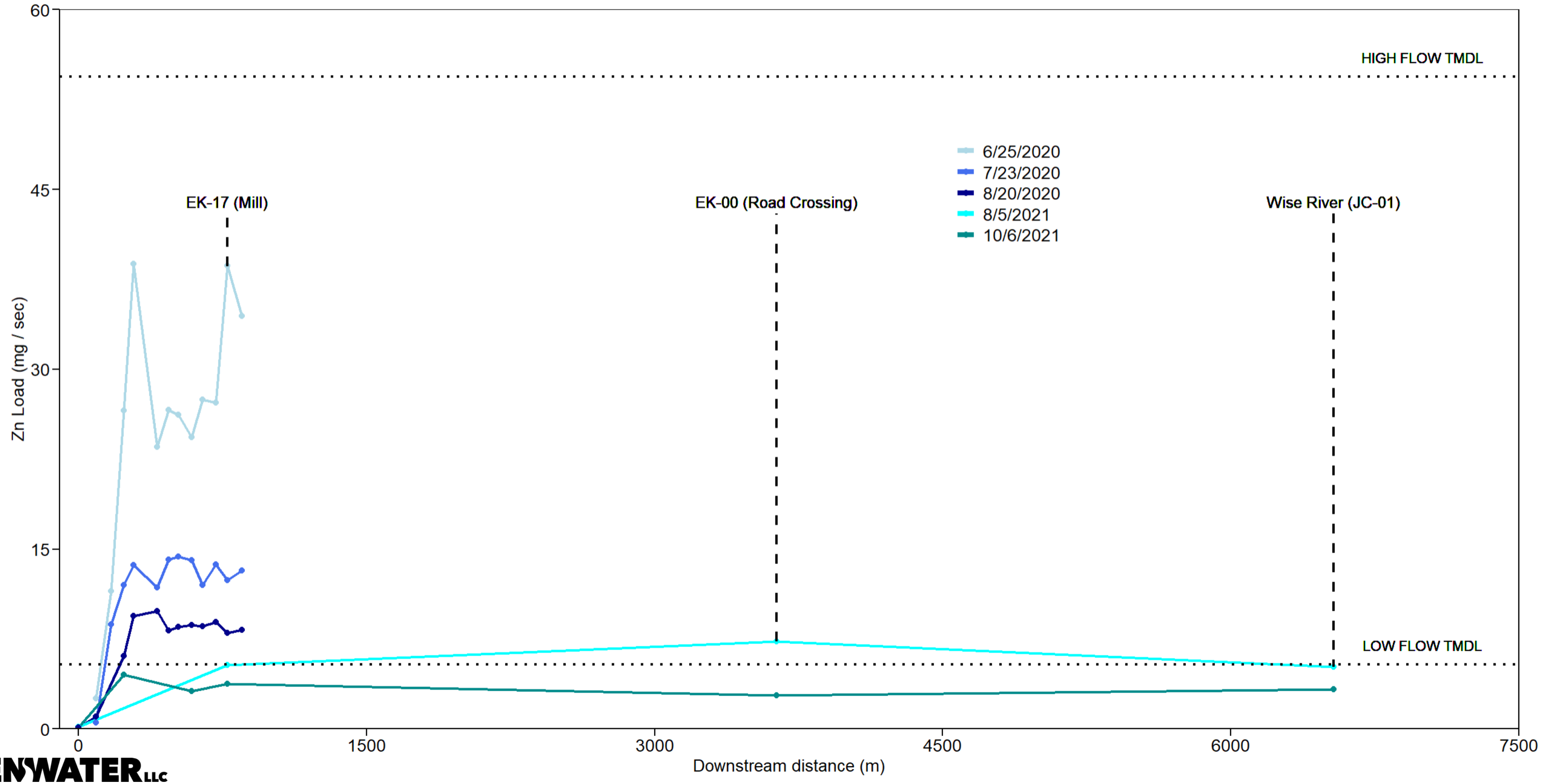
Zn Loading

Elkhorn Creek → Wise River

- Often **above** TMDL for low flows and approaching TMDL for high flows
- Smaller loads during 2021 than 2020



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Implications from Longitudinal Study

1. Both overland flow & seepage play important roles in driving exceedances in Elkhorn Creek
    - As → spikes align with waste rock pile seepage & Mill area runoff
        - higher runoff = higher concentrations & load
    - Cu → sourced from adit discharge & waste rock pile seepage
        - Second spike during Mill area runoff
        - higher runoff = higher concentrations & load
    - Pb → spikes at waste rock pile & Mill seep
        - peaks at waste rock pile; turns off during base flows
        - ‘other’ sources downstream of the Mine
    - Zn → spikes from adit discharge & waste rock pile, Mill area
        - Diluted concentration during high runoff, but load still greatest

2. ‘Turn off the spigot’ to the waste rock pile & Mill area by diverting upslope runoff around these areas

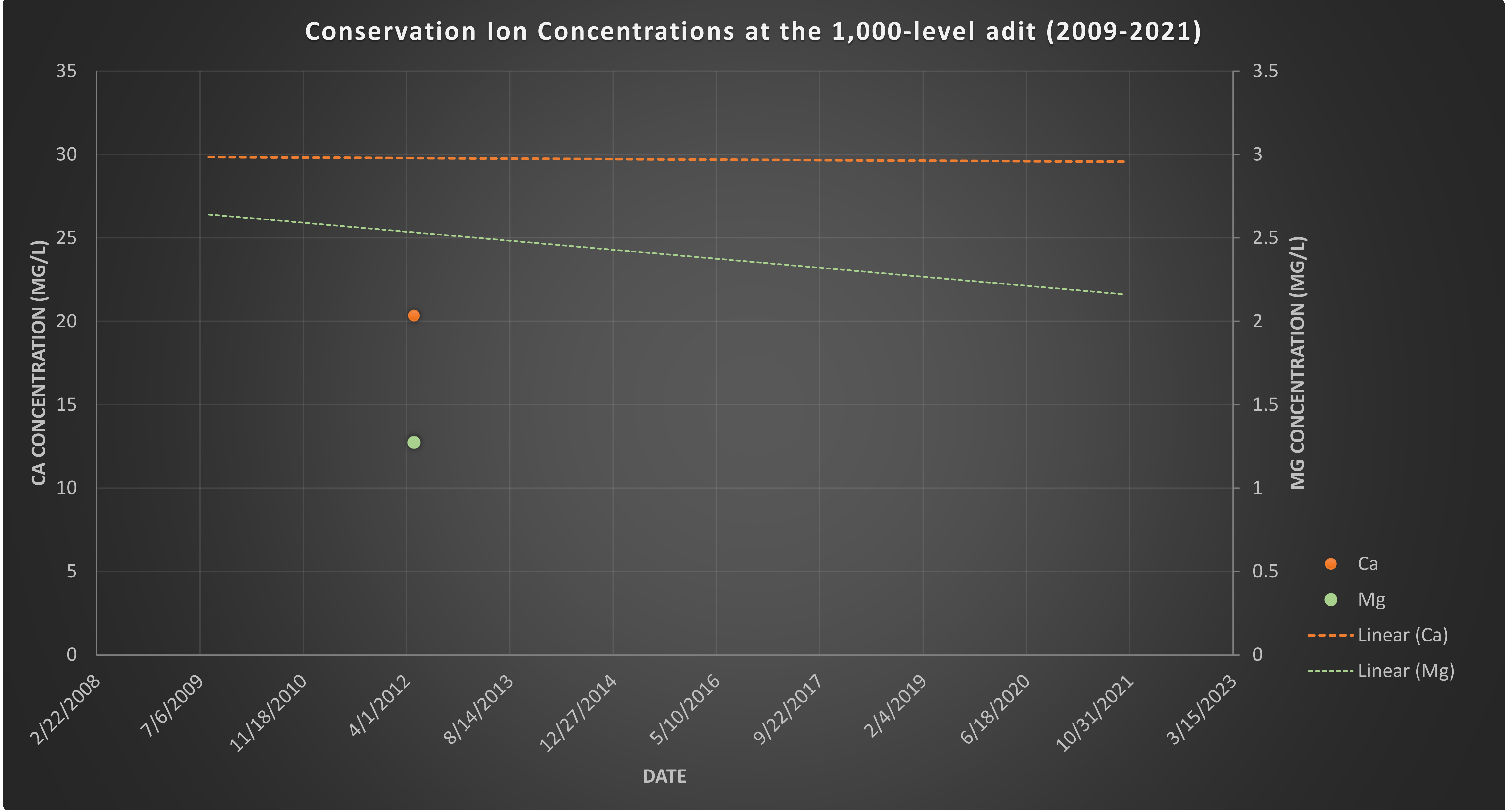
3. Control & mitigate site drainage → reduce exceedance frequency

1000' Adit – 1996 to 2021

Gray = comparable
Yellow = slight discrepancy
Red = 2-3 orders of magnitude discrepancy

Date	pH	SpC	Q	As	Ca	Cu	Mg	Mn	Pb	Zn	Source	Fraction
m/dd/yyyy		(uS/cm)	(cfs)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)		
9/9/1996	7.9			<1.00		15			28	<2.0	USFS	N/A
11/25/1998	6.16	250	0.25	4.2		264			2380	<2.0	USFS	N/A
6/2/1999	6.37	250	0.18	4.01		381			3520	16.3	USFS	N/A
7/30/1999	5.52	300	0.3	3.44		526			2860	80.2	USFS	N/A
9/2/1999	5.61	260	0.25	3.29		483			2810	36.9	USFS	N/A
10/5/1999	6.17	250	0.23	3.39		283			2380	7.8	USFS	N/A
11/9/1999	6.06	240	0.21	3.36		263			2390	9.8	USFS	N/A
8/18/2009	5.93	237	0.3	0.028	29.8	0.5	2.6	2.27	0.16	2.94	MTech	DISSOLVED
6/25/2020	6.34	258.3	0.323	0.065	33	0.309	3	2.46	0.178	2.24	BHWC	TOTAL
7/23/2020	6.35	201.6	0.323	0.036	27	0.245	2	1.67	0.139	1.98	BHWC	TOTAL
8/20/2020	6.82	189.6	0.28	0.014	29	0.136	2	1.74	0.0226	1.66	BHWC	TOTAL
6/29/2021	6.3	239.2	0.32								BHWC	TOTAL
7/2/2022		218		0.00584		0.0562		1.55	0.00562	1.323	MTech	TOTAL
8/5/2021			0.42	0.015	30	0.081	2	1.69	0.0215	1.48	BHWC	TOTAL
10/6/2021	7.19	223.8		0.016	29	0.108	2	1.79	0.0203	1.24	BHWC	TOTAL

Results taken from *Adit Discharge Monitoring Summary for the Elkhorn and Charter Oak Mines, MT* by USFS; *Elkhorn Creek Continuous Tracer Study Montana Tech August 2009* by C. Gammons; *Elkhorn Mine & Mill Site Characterization* by P. Hurley



**Ca & Mg concentrations have been relatively stable since 2009*

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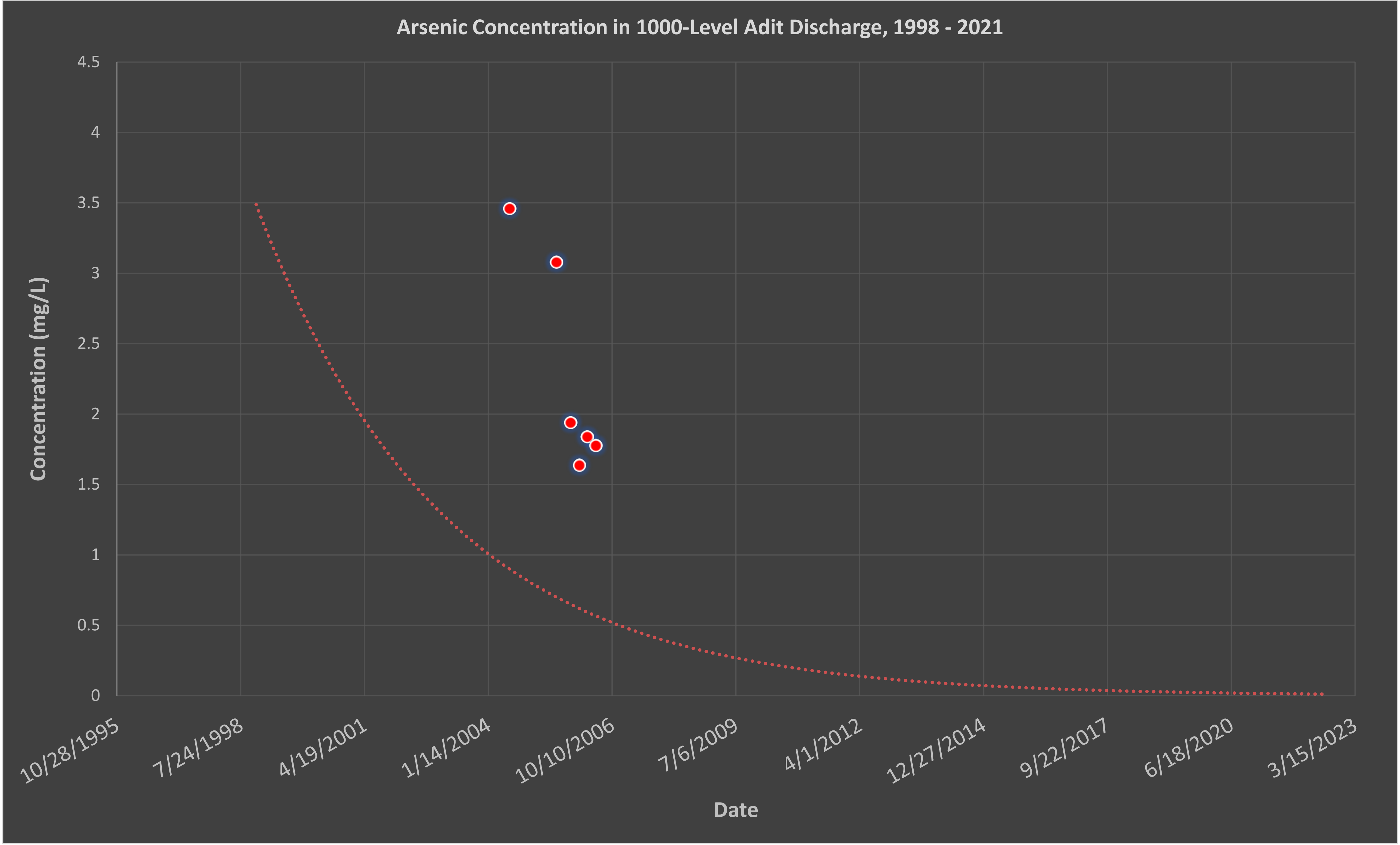

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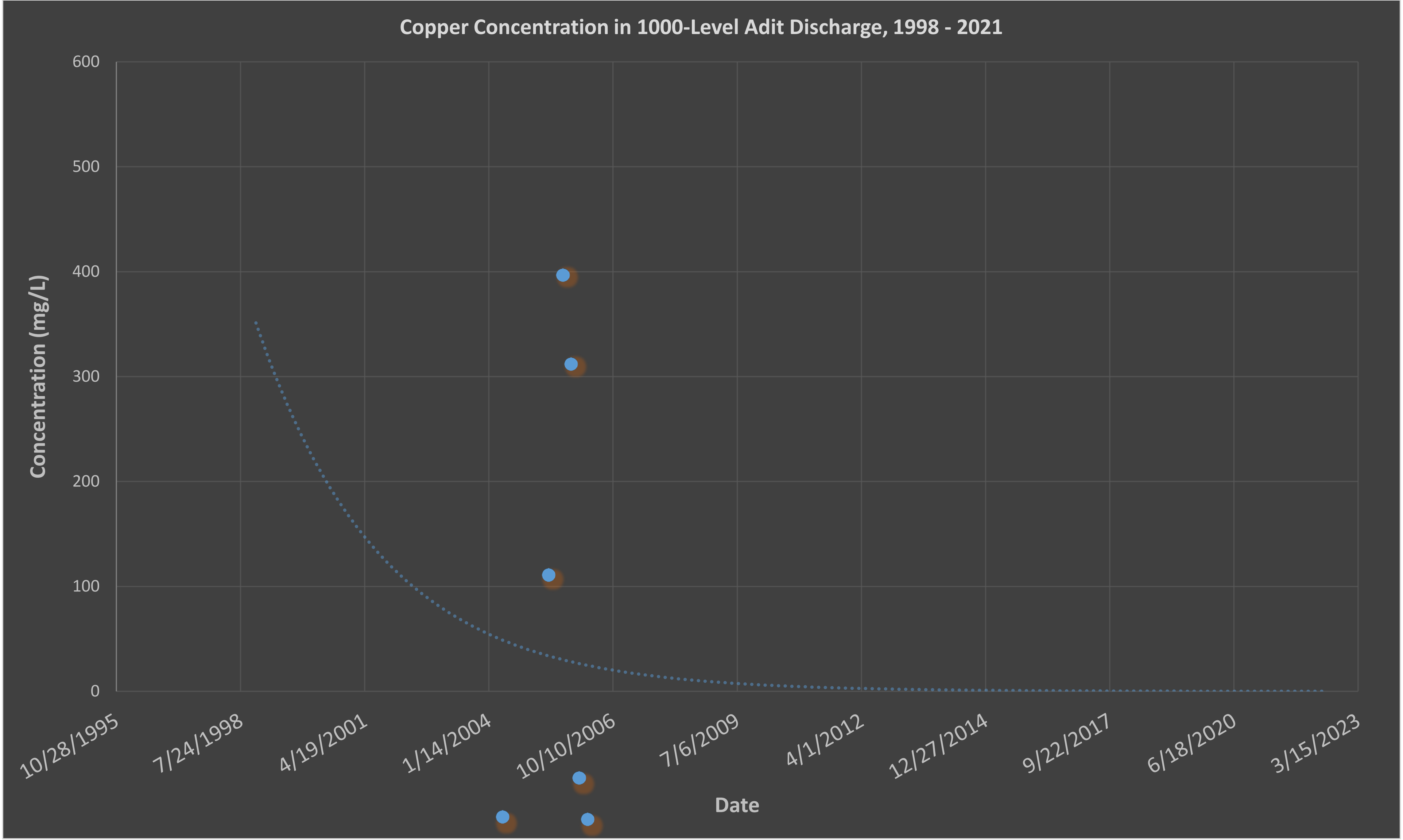

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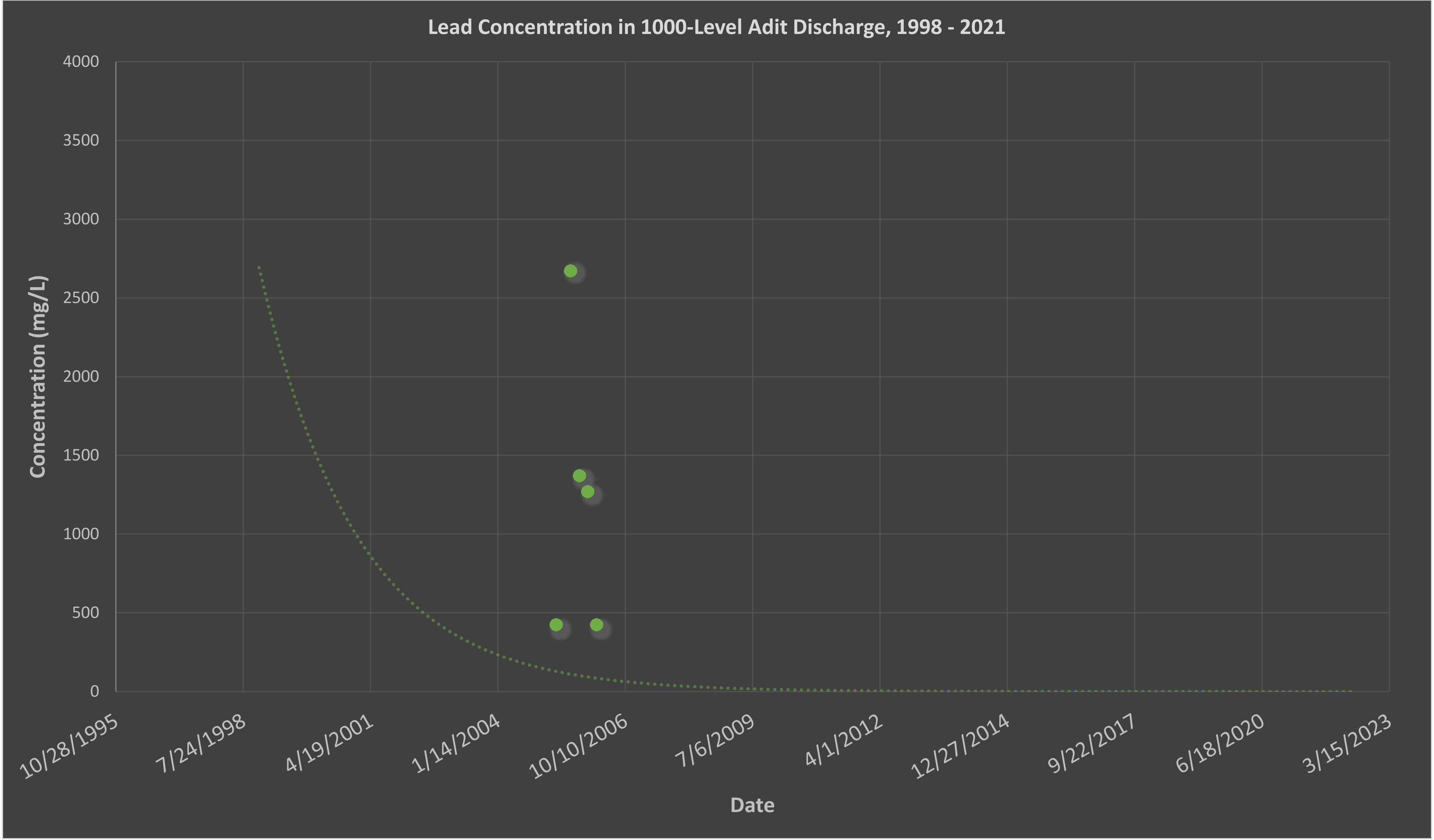

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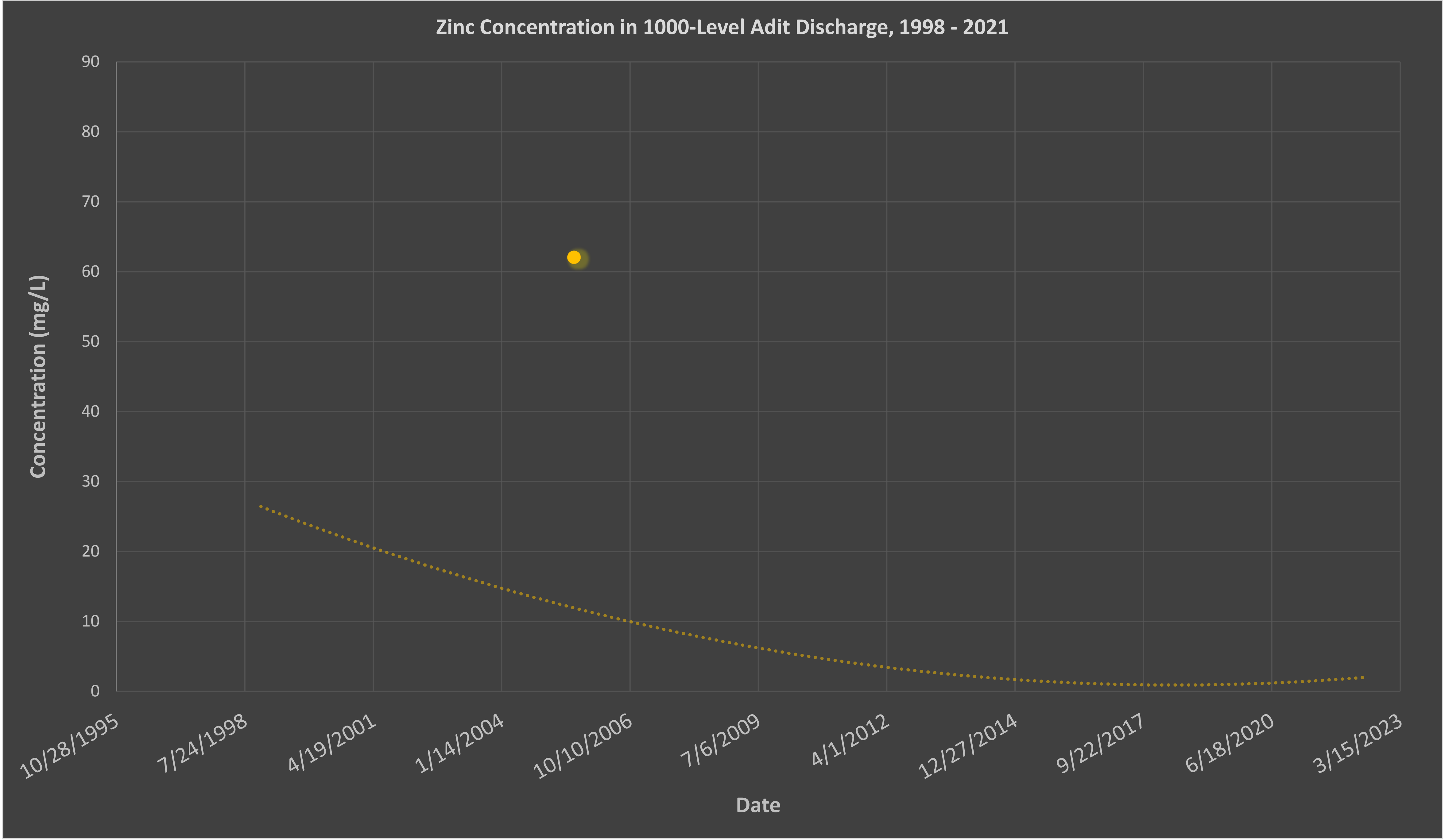

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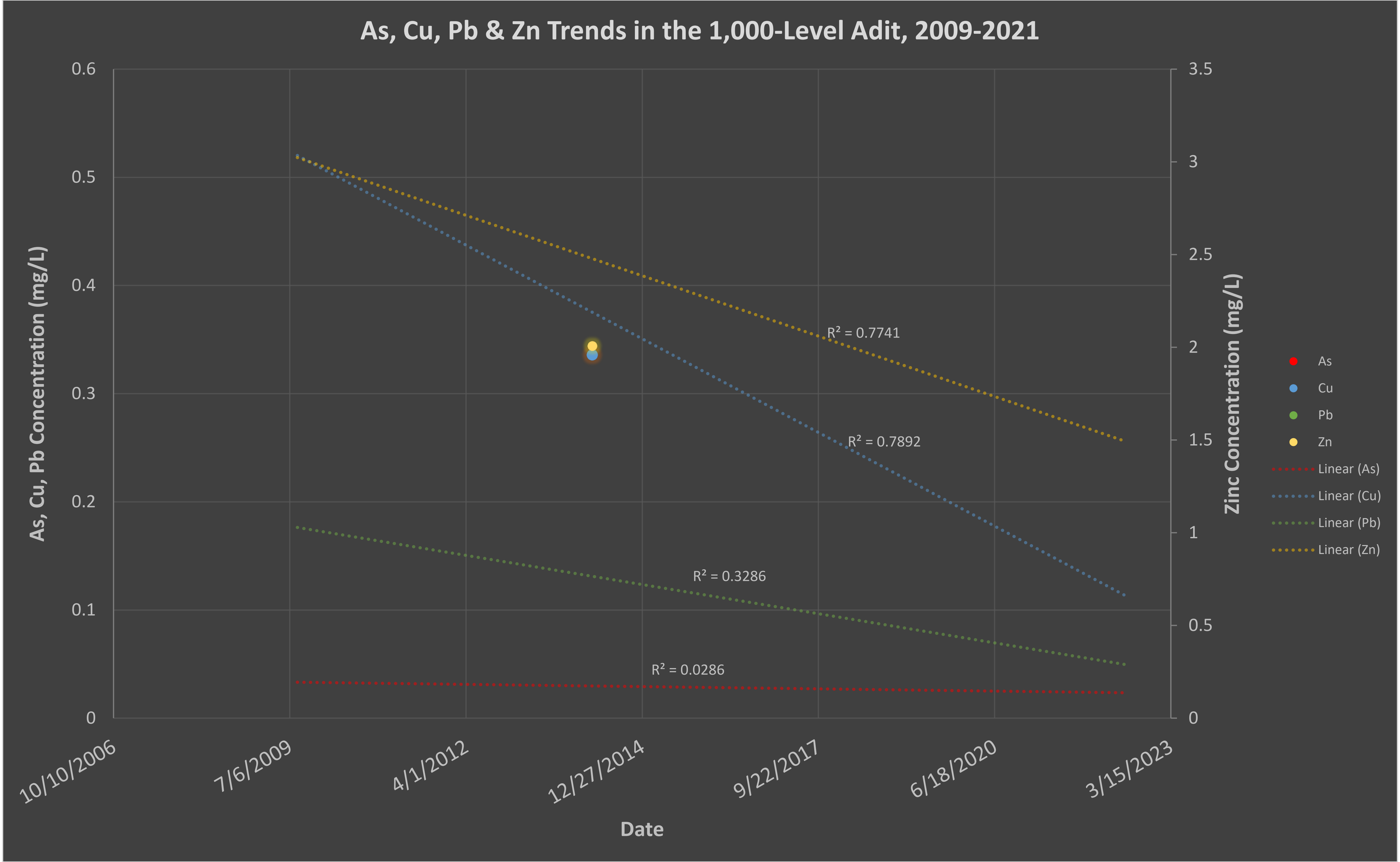

As, Cu, Pb & Zn Trends in the 1,000-Level Adit, 2009-2021
As, Cu, Pb Concentration (mg/L)
Zinc Concentration (mg/L)
Date
0
0.1
0.2
0.3
0.4
0.5
0.6
0.5
1
1.5
2
2.5
3
3.5
10/10/2006
7/6/2009
4/1/2012
12/27/2014
9/22/2017
6/18/2020
3/15/2023
R^2 = 0.7741
R^2 = 0.7892
R^2 = 0.3286
R^2 = 0.0286
As
Cu
Pb
Zn
Linear (As)
Linear (Cu)
Linear (Pb)
Linear (Zn)

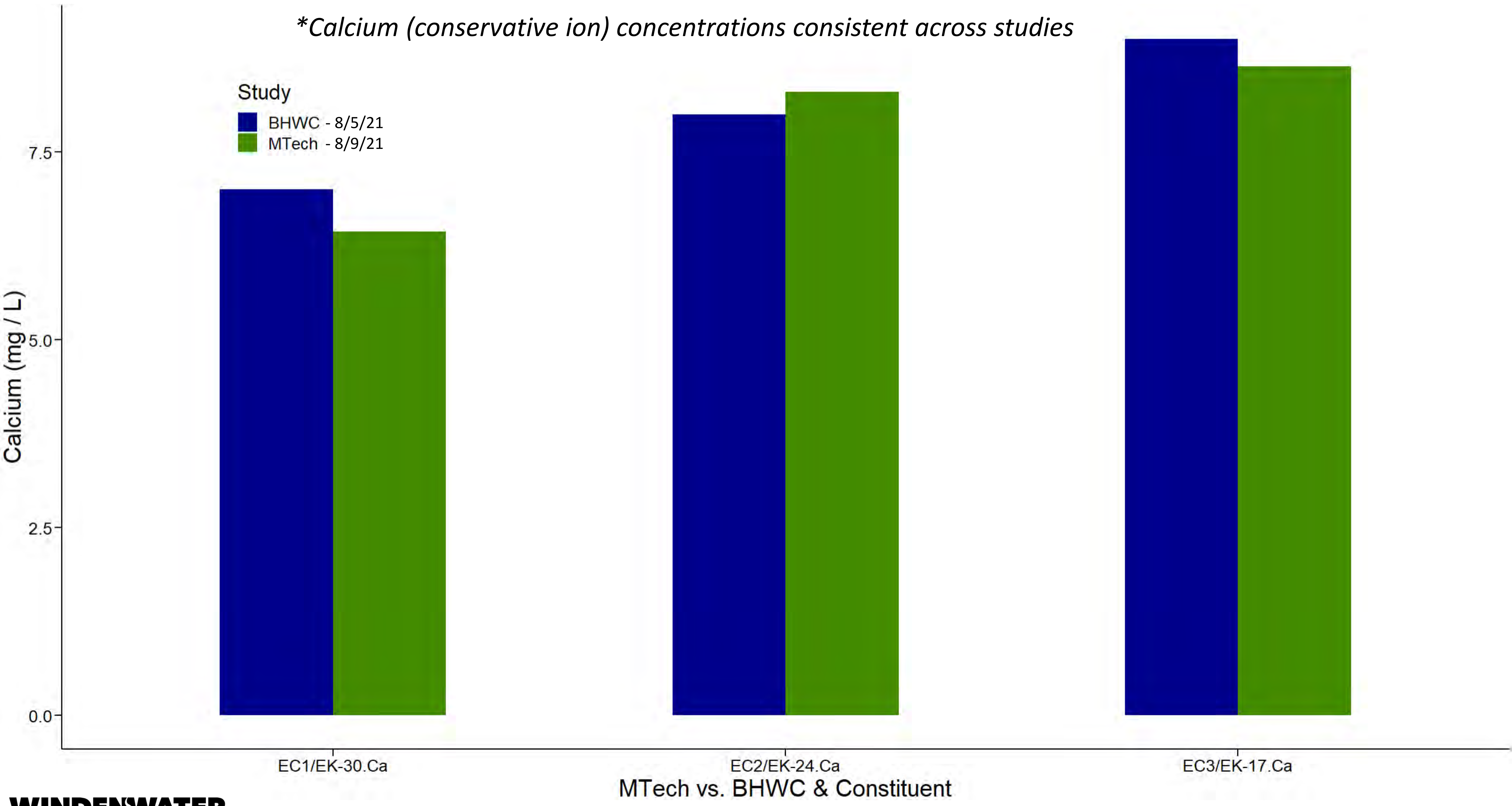
Implications from Adit Data

1. Multiple study approaches, sampling locations, & analytical methods → shaky interpretations

2. If 2009-2021 conservative ion (Ca, Mg) data are to be trusted, the ‘background’/ambient water is relatively constant

3. If trace metal data are also to be trusted, the adit is past peak loading phase and ‘leached’ out

4. Still hesitant to predict ongoing natural reductions



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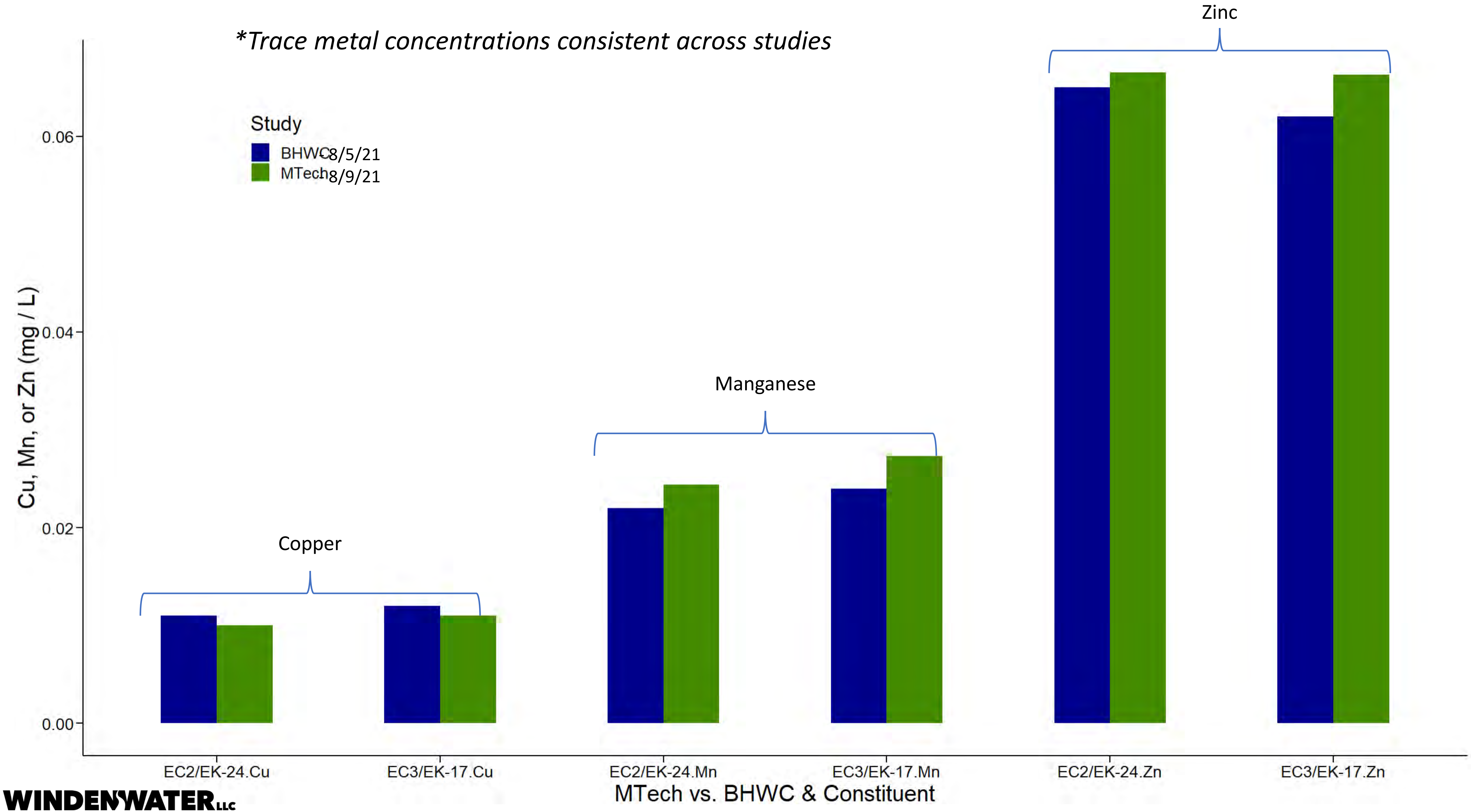

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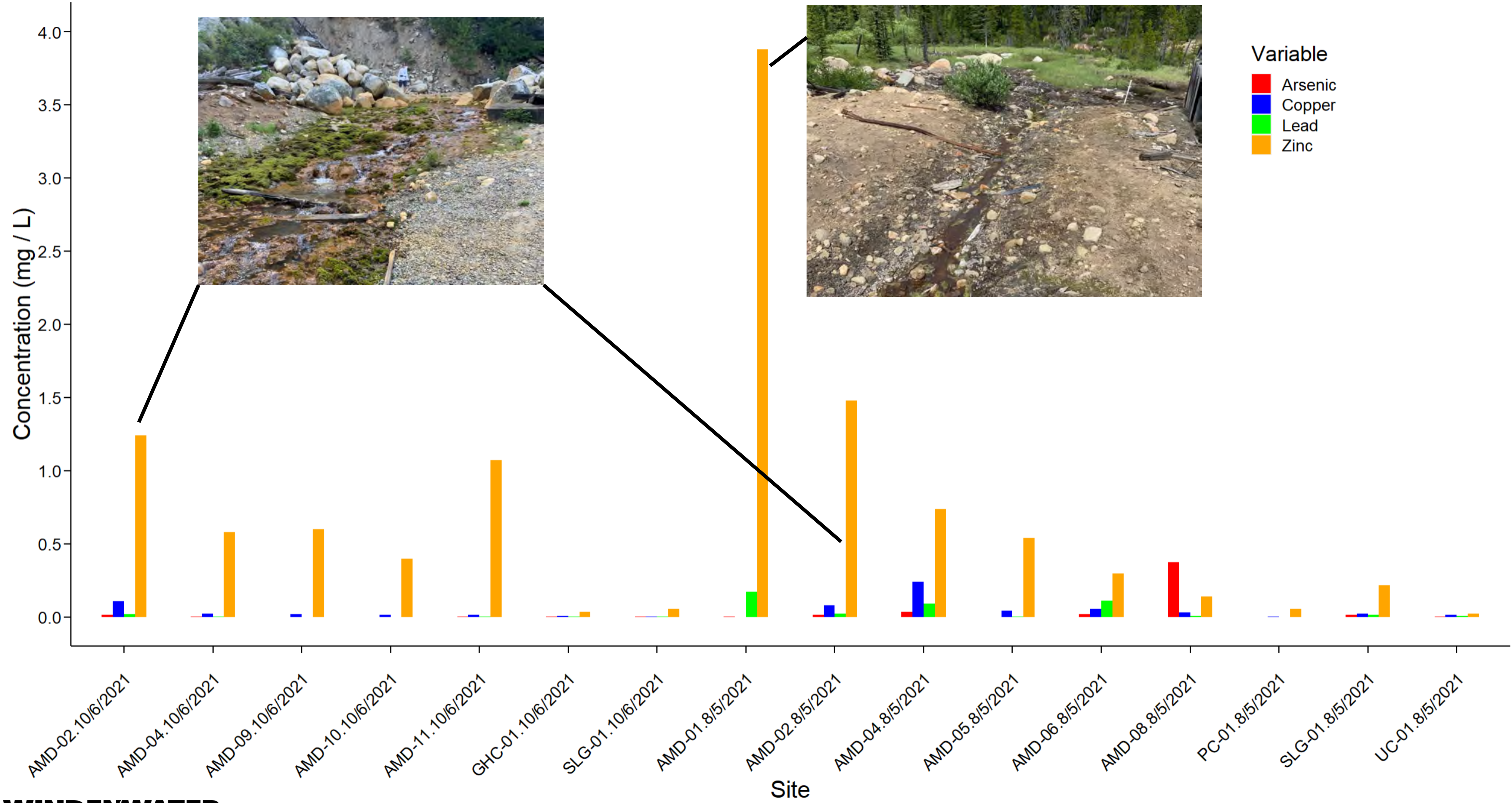
Dispersed AMD Sampling



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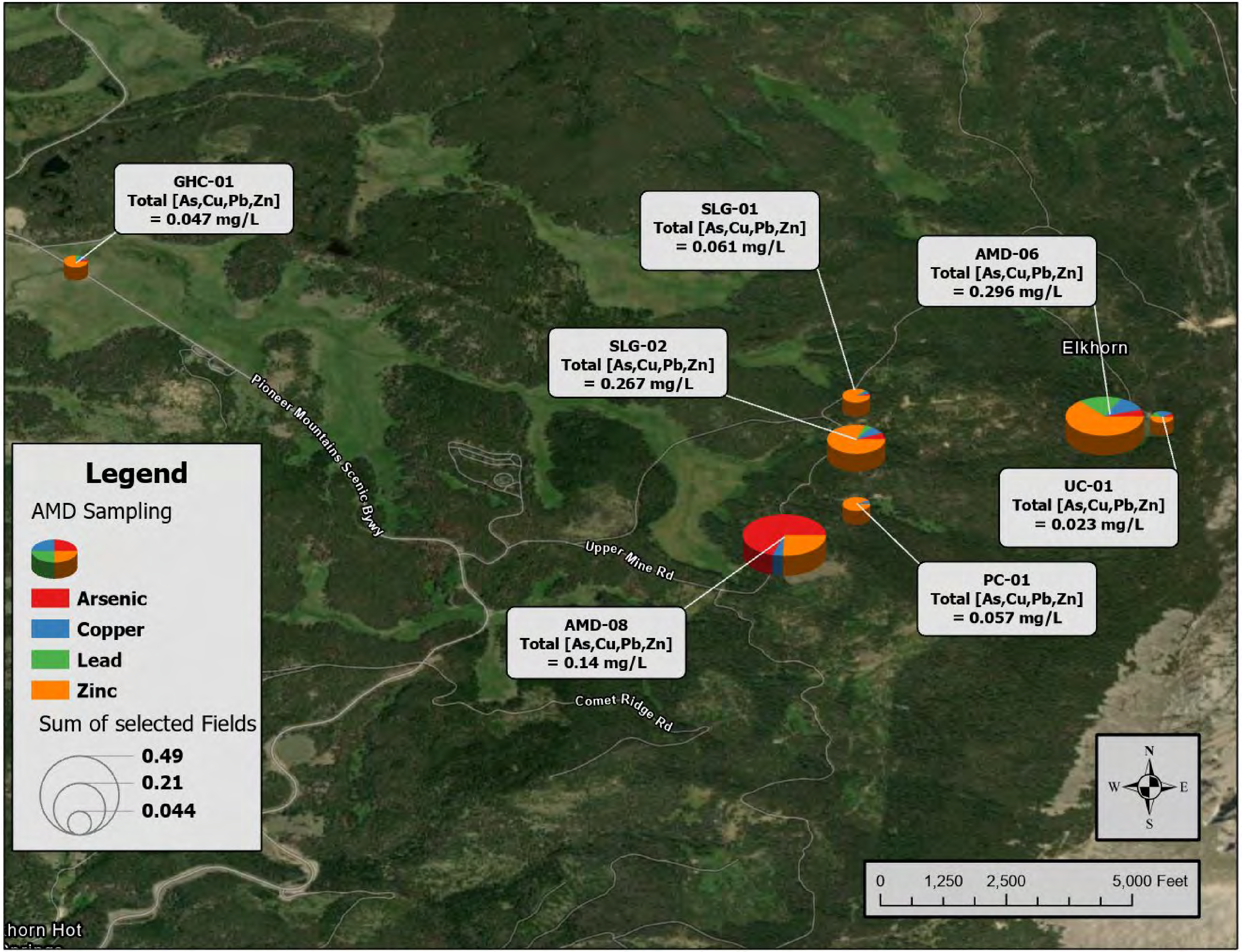
Park Mine Area AMD Sites

<u>Exceedances for Chronic or Acute Aquatic Life Standards</u>

- ✓ As – Only AMD-08 exceeded chronic & acute standards
- ✓ Cu – All sites exceeded chronic & acute standards
- ✓ Pb – All sites except PC-01 exceeded chronic standards
- ✓ Zn – All sites except UC-01 & GHC-01 exceeded chronic & acute standards



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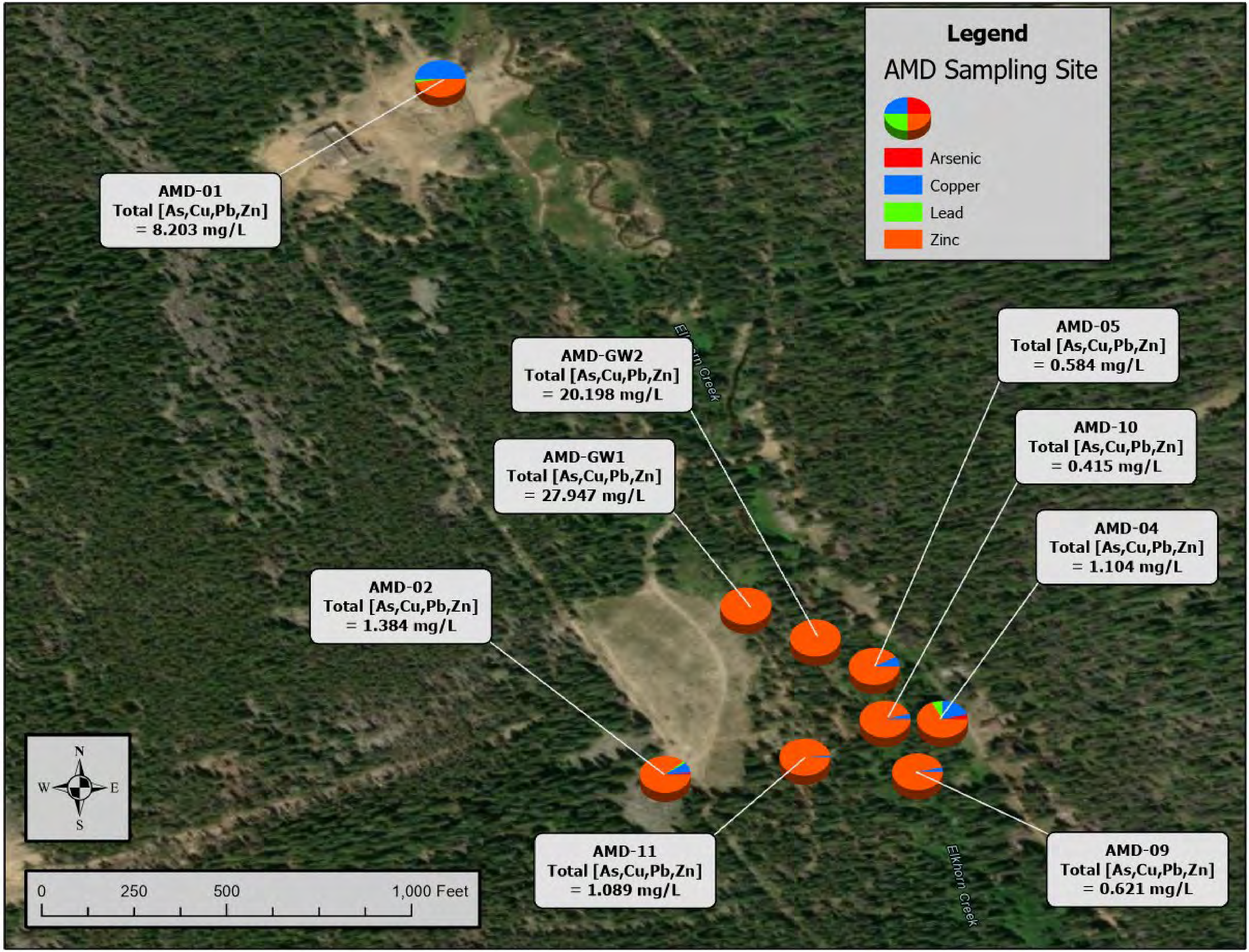
Elkhorn Mine AMD Sites

Exceedances for Chronic or Acute Aquatic Life Standards

- ✓ As – No exceedances
- ✓ Cu – All sites exceeded chronic & acute standards
- ✓ Pb – All sites except AMD-09 and AMD-10 exceeded chronic standards
- ✓ Zn – All sites exceeded chronic & acute standards

*[Zn] in AMD-GW1 and AMD-GW2 highly elevated; likely interference from galvanized well casings



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Dispersed AMD Sampling Exceedances (red)

site	name	Date	Arsenic	Copper	Lead	Manganese	Silver	Zinc
AMD-01	mill seep	8/5/2021	0.001	4.15	0.172	1.4	0.0005	3.88
AMD-02	adit	10/6/2021	0.016	0.108	0.0203	1.79	0	1.24
AMD-02	adit	8/5/2021	0.015	0.081	0.0215	1.69	0	1.48
AMD-04	bank seep	10/6/2021	0.0007	0.023	0.0014	0.029	0	0.581
AMD-04	bank seep	8/5/2021	0.035	0.241	0.0906	0.537	0.00009	0.737
AMD-05	bank seep	8/5/2021	0.0006	0.042	0.0034	0.042	0	0.538
AMD-06	collapsed park adit	8/5/2021	0.02	0.056	0.11	0.503	0.0017	0.296
AMD-08	roadside seep	8/5/2021	0.372	0.03	0.0052	0.806	0.0005	0.14
AMD-09		10/6/2021	0.0003	0.02	0	0.007	0	0.601
AMD-10		10/6/2021	0	0.015	0	0.0008	0	0.4
AMD-11		10/6/2021	0.003	0.014	0.0022	1.22	0	1.07
PC-01	private stream	8/5/2021	0.0006	0.004	0.0002	0.013	0	0.057
AMD-GW_well1	seep near galvanized well	10/6/2021	0.028	0.016	0.103	1.51	0.00007	27.8
AMD-GW_well1	seep near galvanized well	8/5/2021	0.012	2.26	0.0345	3.88	0.0035	7.06
AMD-GW_well2		10/6/2021	0.001	0.066	0.0307	0.476	0	20.1
SLG-01	roadside stream	10/6/2021	0.002	0.004	0.001	0.247	0.00006	0.054
SLG-01	roadside stream	8/5/2021	0.014	0.021	0.0135	1.51	0.0004	0.218
UC-01	d stream draining to upper (	8/5/2021	0.003	0.013	0.0048	0.08	0.00008	0.023
GHC-01	byway crossing	10/6/2021	0.002	0.006	0.004	0.297	0.00006	0.035

Copper, lead, and zinc routinely exceed chronic and occasionally acute aquatic life standards in adit discharge, streambank seeps, roadside springs, and shallow groundwater sources

Acute & Chronic Aquatic Life Standards (@75 mg/L hardness)

As (acute)	As (chronic)	Cu (acute)	Cu (chronic)	Pb (acute)	Pb (chronic)	Zn (acute and chronic)
0.34000	0.15000	0.00379	0.00285	0.01398	0.00055	0.03700

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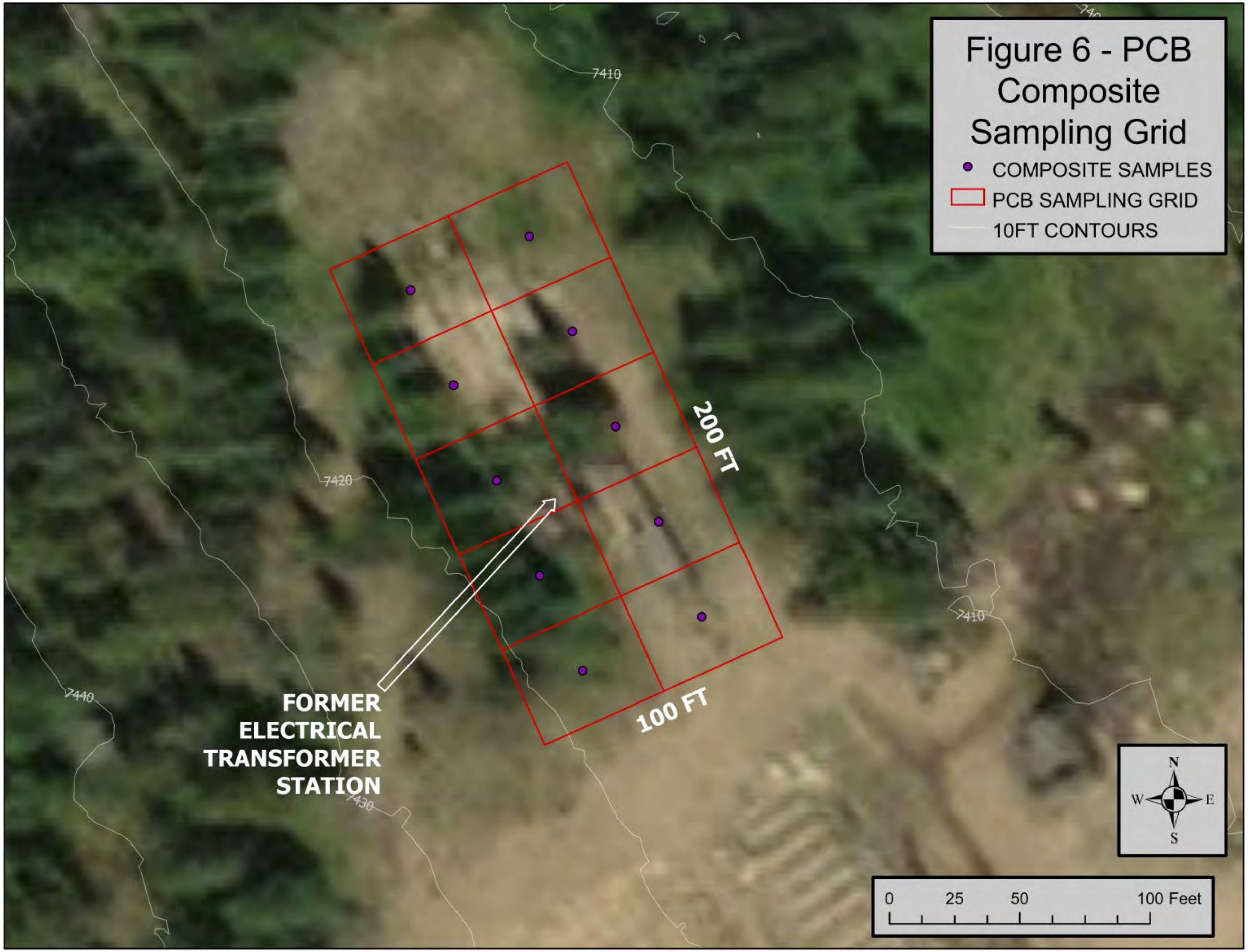
Polychlorinated Biphenyls (PCB) Screening

10 subsamples from grid

1 composite sample

1st analytical run
composite = **non-detect**

2nd analytical run
Subsample 1, 3, 5, 7, 9 = **non-detect**



METHODS USED:
Moisture
Moisture Prep SW3550C
8082 - Polychlorinated Biphenyls (PCB's)
Percent Moisture
Sonication Extraction SW3550C

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PCB non-detects pass QA/QC evaluations

1. Relative % Difference between spike samples: 1.1 – 8.7%
2. % Recovery for controls, blanks, and spikes: 68 – 100%
3. % Recovery internal standards for all samples: 76 – 98%

1ST ANALYTICAL RUN (COMPOSITE) QA/QC SUMMARY

QA/QC Sample	Result (mg/kg)	Reporting Limit	% Recovery	Relative % Difference
Laboratory Control				
Aroclor 1016	0.282	0.013	85	
Aroclor 1260	0.305	0.013	92	
Surr: Decachlorobiphenyl		0.0017	92	
Surr: Tetrachloro-m-xylene		0.0017	68	
Method Blank				
Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, 1268	non-detect	0.013		
Surr: Decachlorobiphenyl		0.017	96	
Surr: Tetrachloro-m-xylene		0.017	72	
Sample Matrix Spike				
Aroclor 1016	0.305	0.014	86	
Aroclor 1260	0.327	0.014	92	
Surr: Decachlorobiphenyl		0.0018	93	
Surr: Tetrachloro-m-xylene		0.0018	79	
Sample Matrix Spike Duplicate				
Aroclor 1016	0.333	0.014	94	8.7
Aroclor 1260	0.345	0.014	97	5.5
Surr: Decachlorobiphenyl		0.0018	99	
Surr: Tetrachloro-m-xylene		0.0018	86	

2ND ANALYTICAL RUN (004-009-0204) QA/QC SUMMARY

QA/QC Sample	Result (mg/kg)	Reporting Limit	% Recovery	Relative % Difference
Laboratory Control				
Aroclor 1016	0.279	0.013	84	
Aroclor 1260	0.314	0.013	94	
Surr: Decachlorobiphenyl		0.0017	93	
Surr: Tetrachloro-m-xylene		0.0017	71	
Method Blank				
Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, 1268	non-detect	0.013		
Surr: Decachlorobiphenyl		0.017	95	
Surr: Tetrachloro-m-xylene		0.017	75	
Sample Matrix Spike				
Aroclor 1016	0.305	0.014	88	
Aroclor 1260	0.351	0.014	101	
Surr: Decachlorobiphenyl		0.0018	99	
Surr: Tetrachloro-m-xylene		0.0018	90	
Sample Matrix Spike Duplicate				
Aroclor 1016	0.292	0.014	84	4.3
Aroclor 1260	0.347	0.014	100	1.1
Surr: Decachlorobiphenyl		0.0018	98	
Surr: Tetrachloro-m-xylene		0.0018	82	

- Samples collected from 0 – 4” depth intervals
- PCBs readily adsorb to soils and will not leach extensively (EPA 1979, 1988; Sklarew & Girvin 1987)
- Any tendency to leach will be greatest for least chlorinated congeners in soils with low organic carbon (Sklarew & Girvin 1987; Strek & Weber 1982)

*Actual sampling locations varied to accommodate cultural resource buffers and to avoid concrete pad

- Total absence of high chlorinated congeners in all samples indicate dispersed PCB contamination is unlikely
- Does not rule out isolated PCB contaminated if electrical waste unearthed during removal activities
- Consider testing groundwater to rule out PCB contamination

Delineating Project Area Polygons

- Reviewed ~1980s tailings pile survey maps to establish historic footprint of mining wastes
- Performed soil probing & visual assessments to demarcate approximate boundary of impacted areas

- Fine, chalky, milled wastes
- Crusts & algae
- Little vegetation
- Overlaying organic horizon at depth

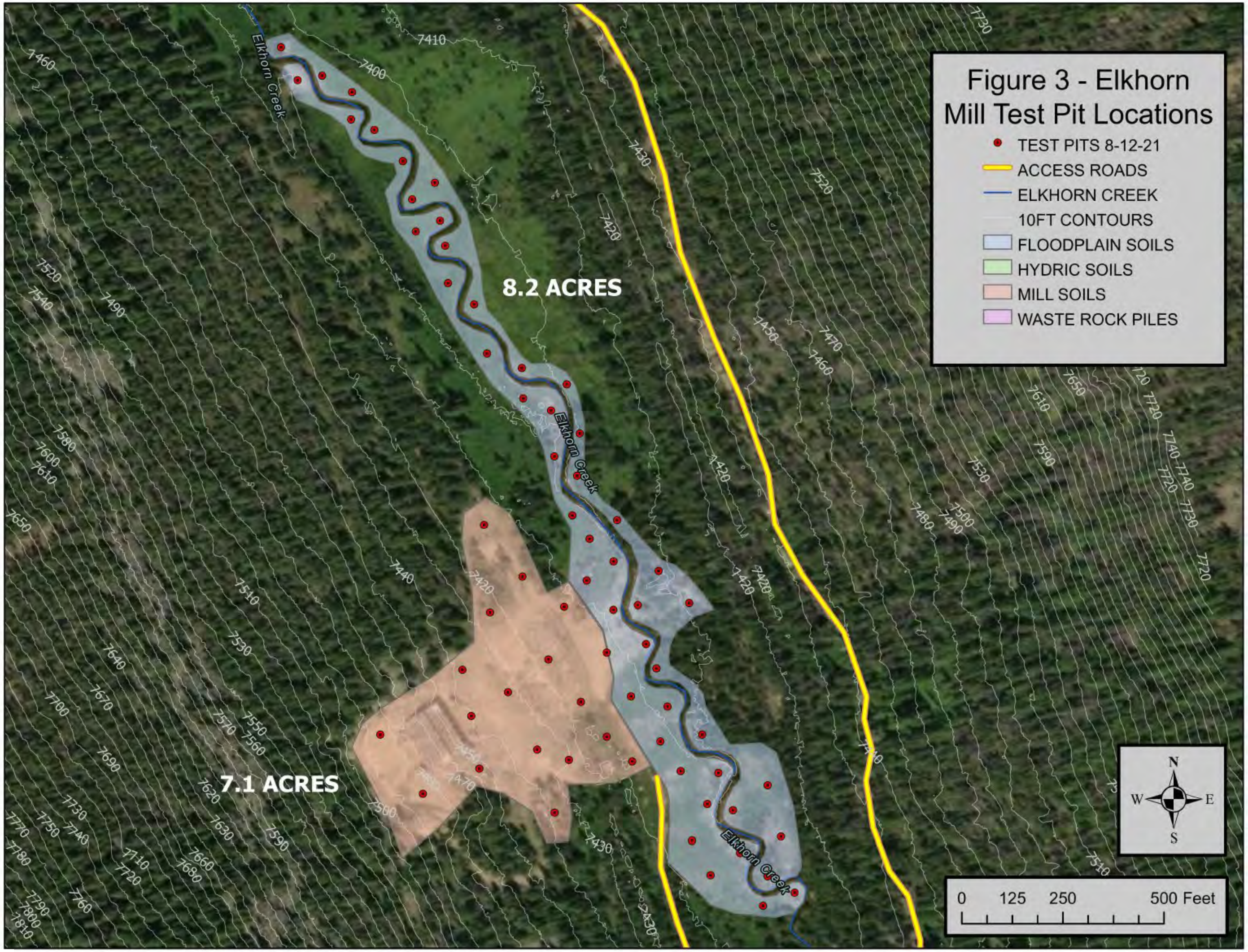
- Fine, chalky milled wastes
- No vegetation
- Deeper than 16”

- Mix of sand, ore, organics, mill wastes
- Heavily worked during Phase 4 cleanup
- Sparse mosses, stunted grasses & lodgepole

- Dark, organic soils
- Healthy, dense vegetation
- No obvious impacted soils

- Coarse sands, gravels
- Widely dispersed
- Deep

- Coase and fine sands
- Resembles a ‘slicken’; no vegetation
- Deposited from Upper Camp runoff
- Retained by a berm



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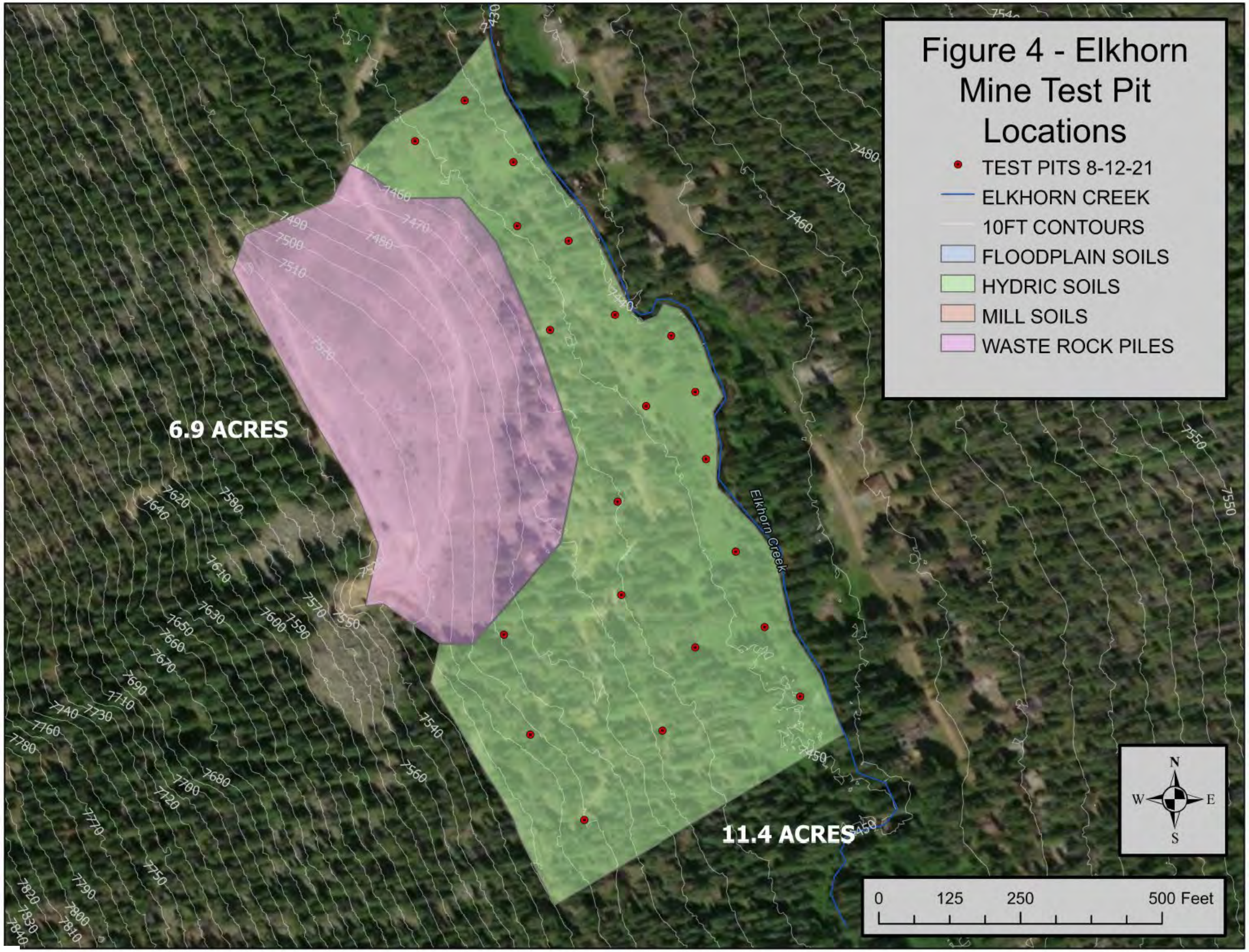

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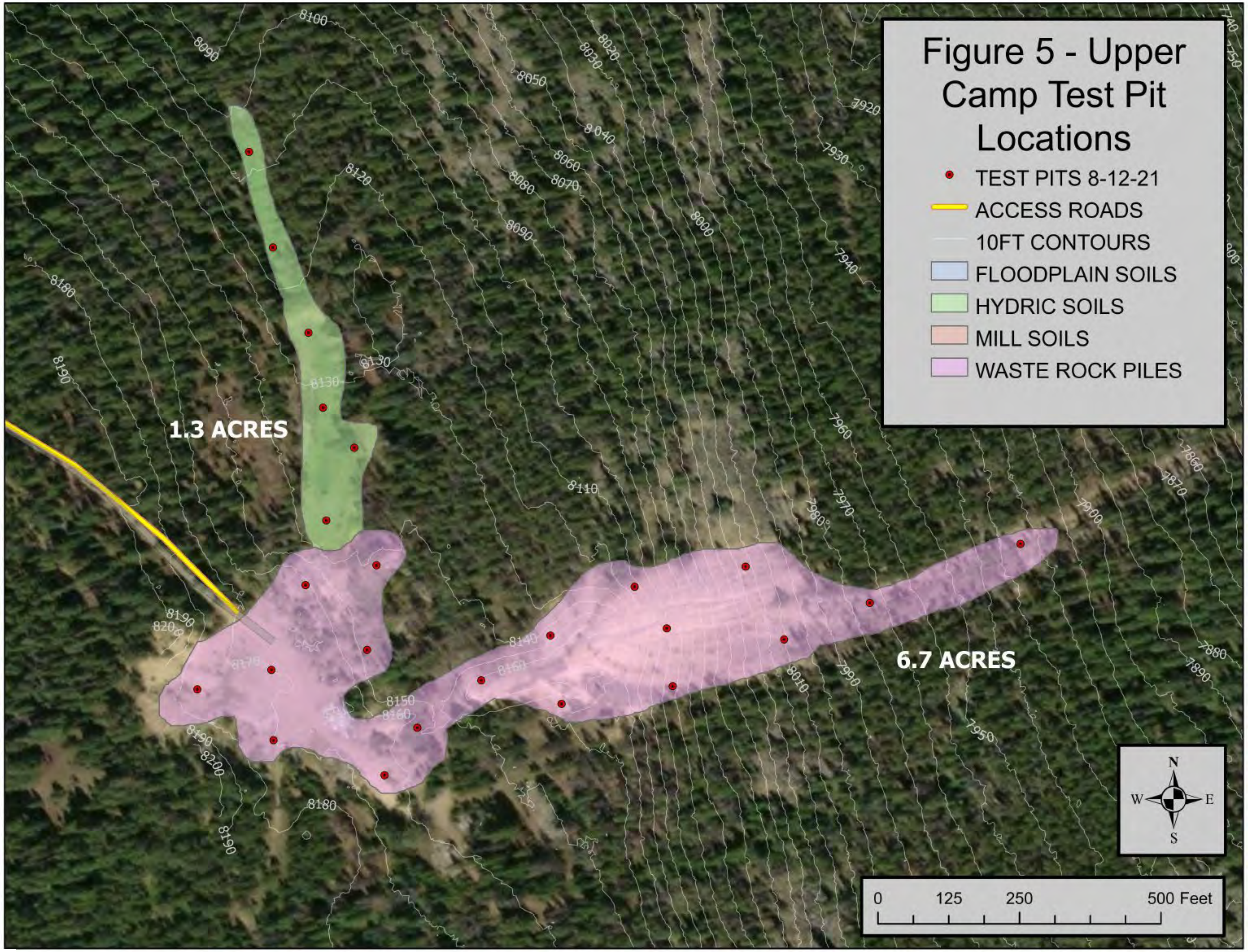

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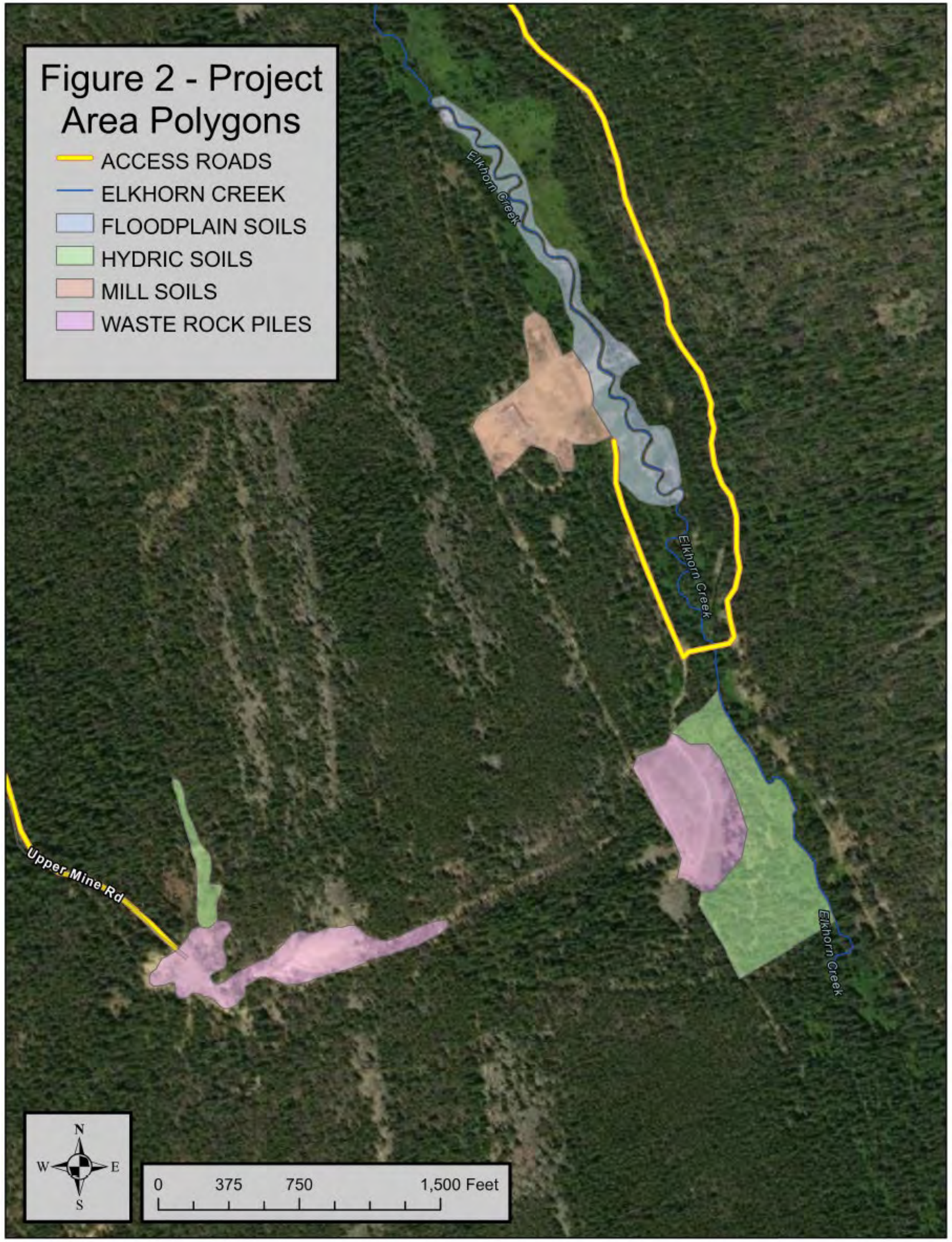
Summary of polygons

1. Floodplain Soils –
    a) Evidence of dispersed tailings, but very heterogeneous
    b) Likely have concentrated deposits near streambanks and downstream of EK-17
    c) Follow elevation contours in lower floodplain for determining removal extents

2. Hydric Soils –
    a) Most difficult to ascertain; could be either 'flushed' or 'saturated' with contaminants or 'saturated'
    b) Dewatering & runoff diversion will be necessary during removal

3. Mill Soils –
    a) Includes both milled (chalky) wastes and mixed/worked soils
    b) Highly heterogeneous

4. Waste Rock Soils –
    a) Likely low concentrations, but highly erodible



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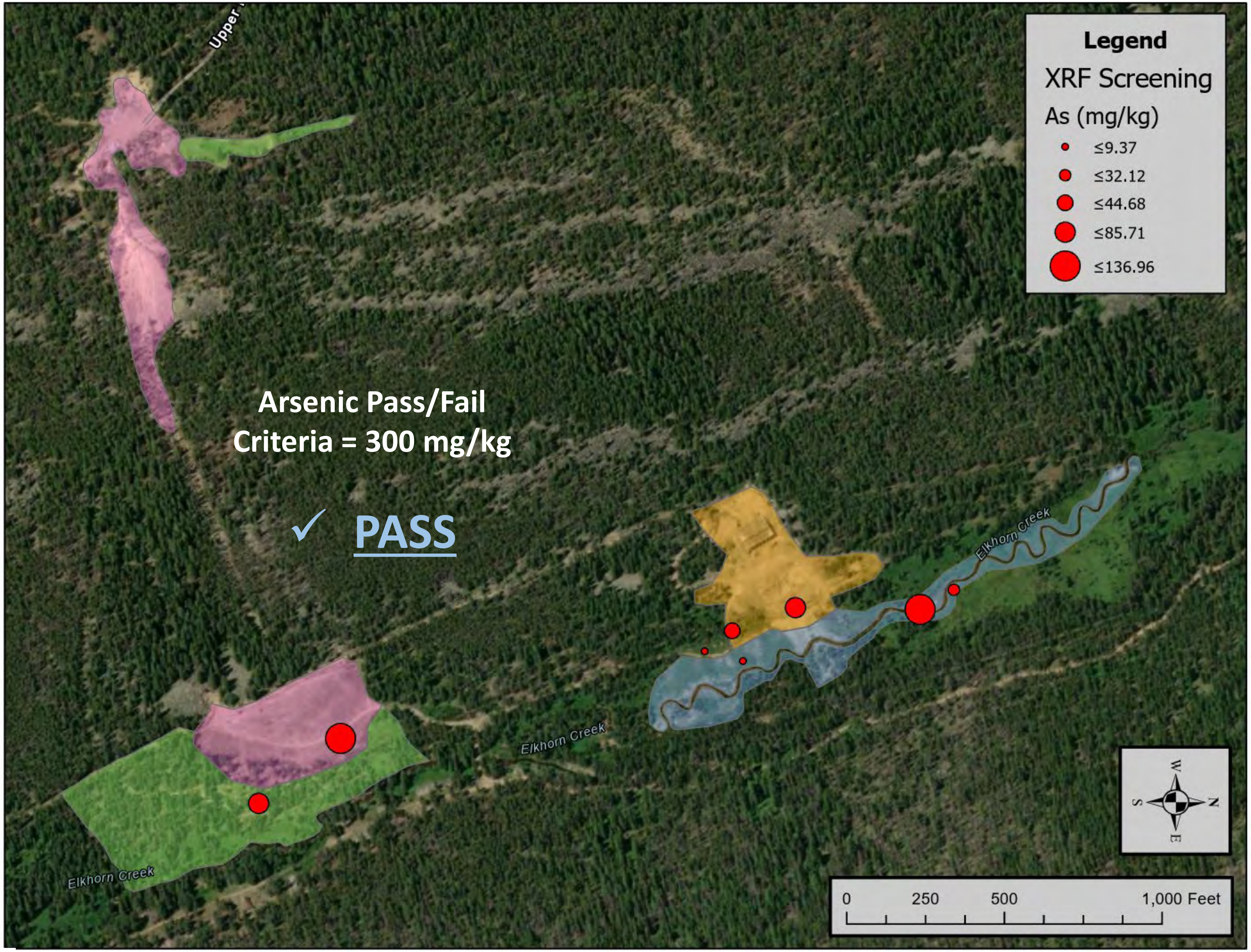

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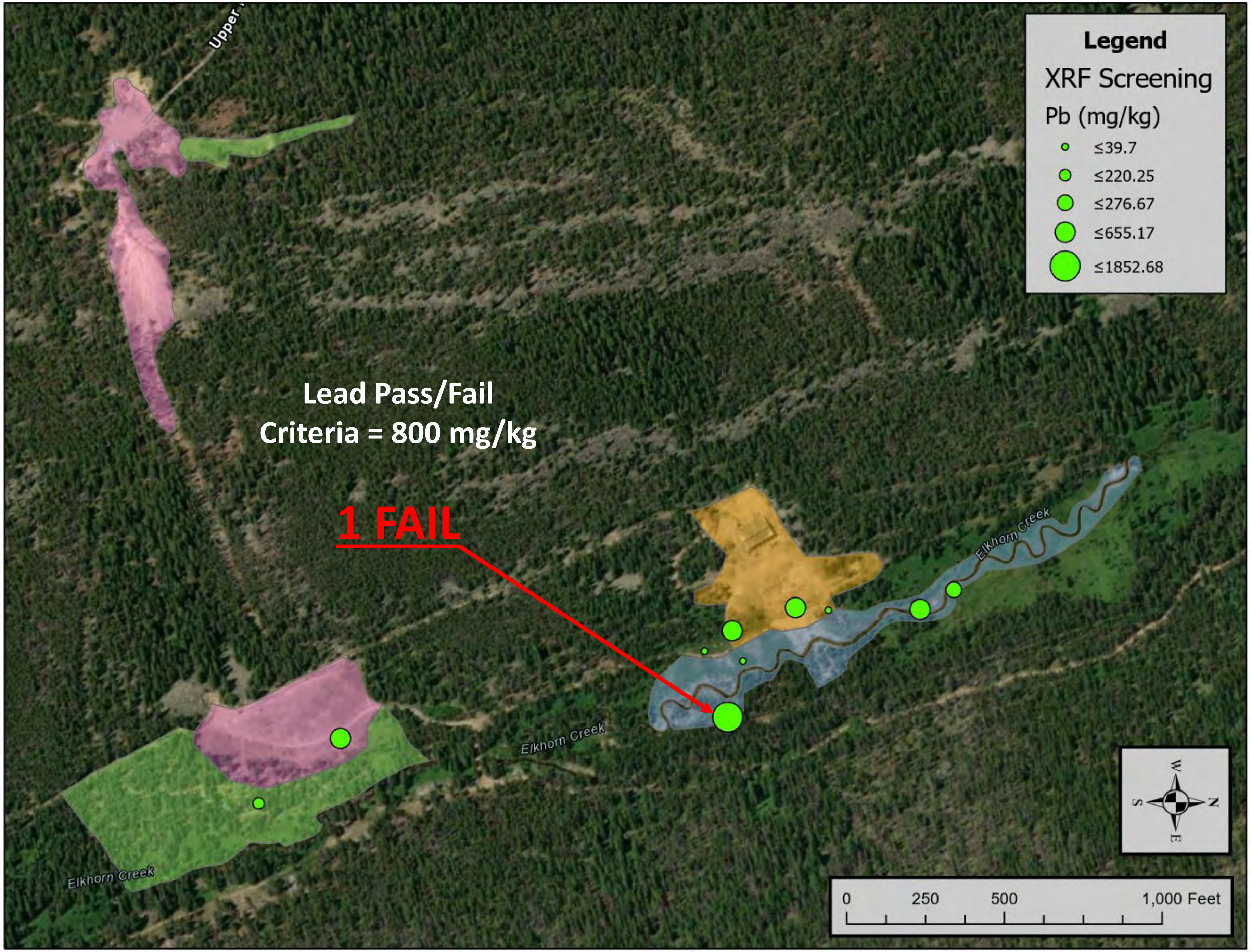

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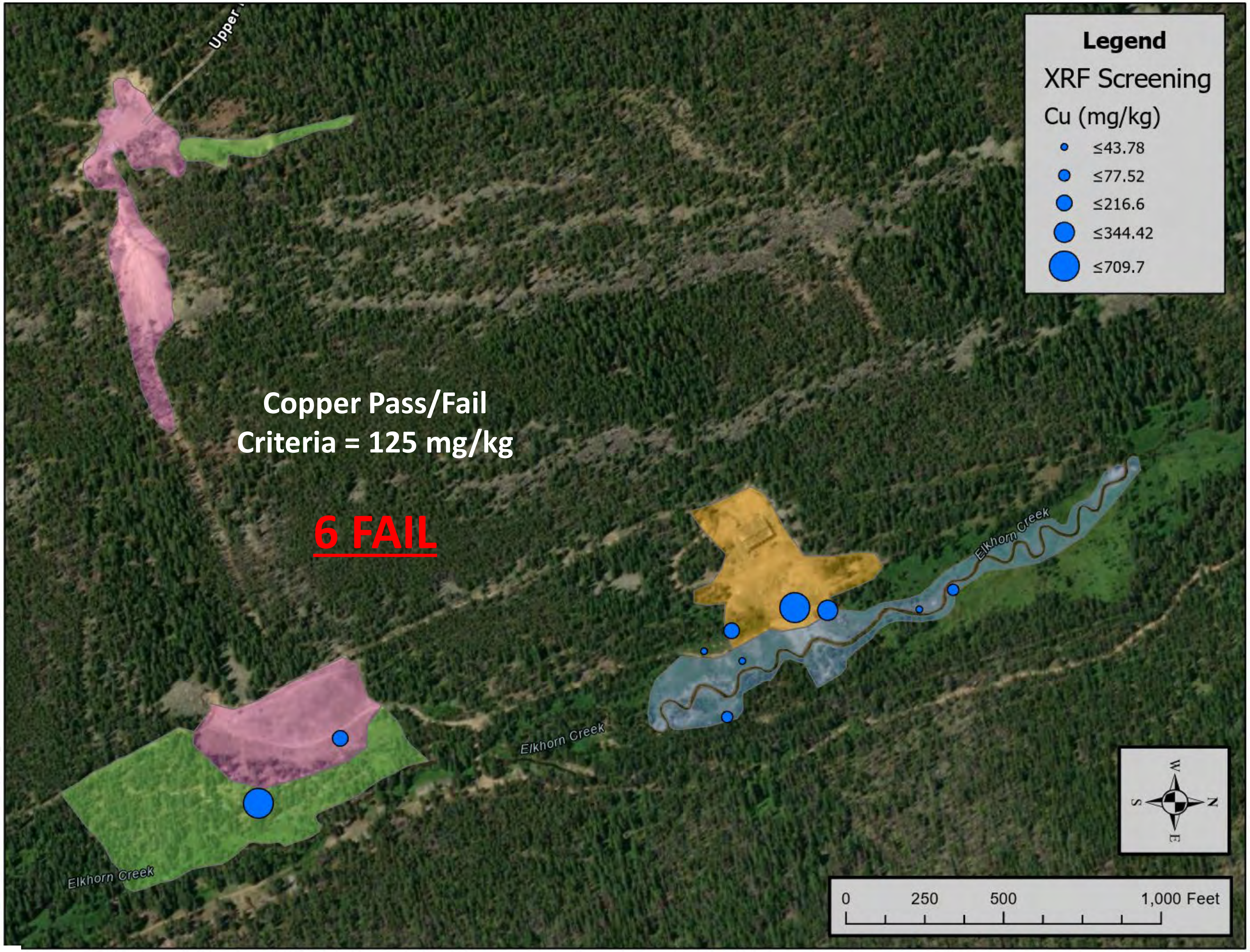

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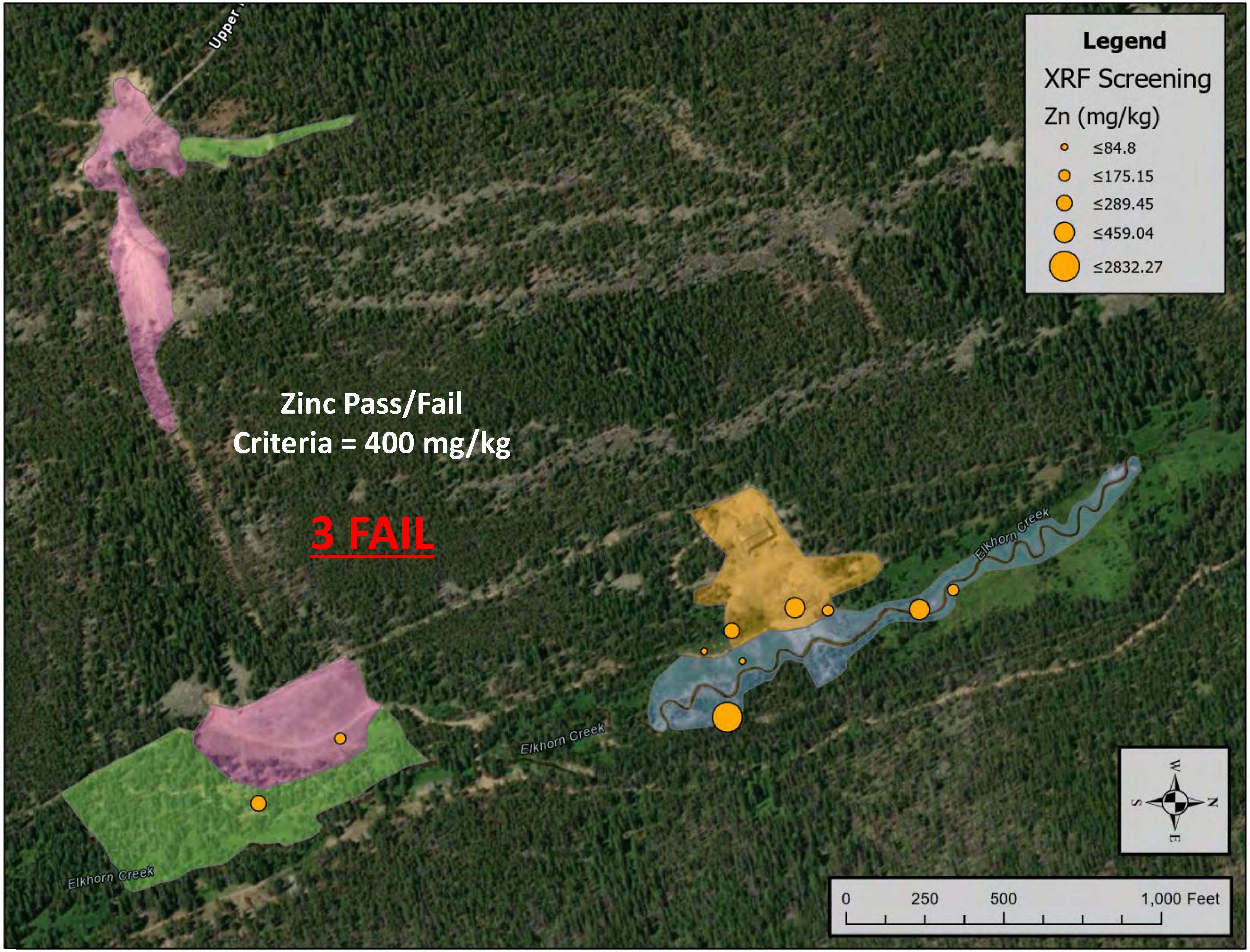

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Preliminary XRF Screening

- ✓ Field verify visual delineations of impacted areas
- ✓ Dry-run proposed field methods
- ✓ Revise SAP-QAPP protocols
- ✓ Evaluate Pass/Fail Critieria

SITE	Lat	Long	Pb	As	Hg	Mn	Fe	Co	Cu	Zn
P3	45.4941	-113.04045	34.99	9.37		408.55	15644.58		36.6	70.32
P6	45.494325	-113.040714	560.19	44.68		206	8021.69		216.6	258.04
P4	45.494433	-113.040344	194.64	84.69		275.12	18313.6		208.85	145.66
P10	45.494867	-113.041042	655.17	75.08		336.24	19063.24	118.74	709.7	403.76
P11	45.495153	-113.041022	13.95			229.49	7017.49		344.42	131.8
EK-17	45.49595	-113.041083	493.37	120.74		78.83	3256.84		42.09	459.04
EK-16	45.496237	-113.041341	276.67	32.12		79.37	3935.14		77.52	175.15
EK-20	45.494323	-113.039641	1852.68		11.21	93.8	1942.42		58.04	2832.27
Waste Rock Pile	45.49097	-113.039171	606.1	136.96		443.47	21961.27		191.78	168.34
Settling Pond	45.490284	-113.038318	220.25	85.71		1665.87	30573.56		702.79	289.45

Soil Contaminant of Concern	Pass/Fail Criteria (mg/kg)
Arsenic	300
Copper	125
Lead	800
Zinc	400

Concentration = FAIL