Revegetation after mine waste removal and metals impacts:

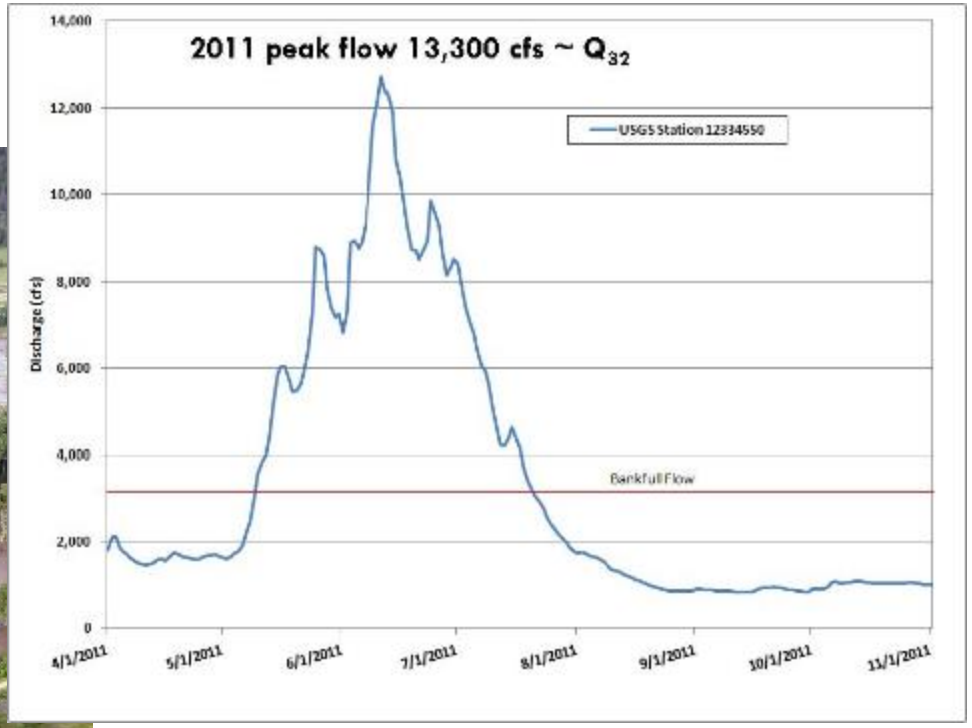
Examples from western Montana floodplains (and uplands)

Tom Parker, Geum Environmental Consulting

Stuart Jennings, KC Harvey

Floodplain restoration as part of mine waste cleanups

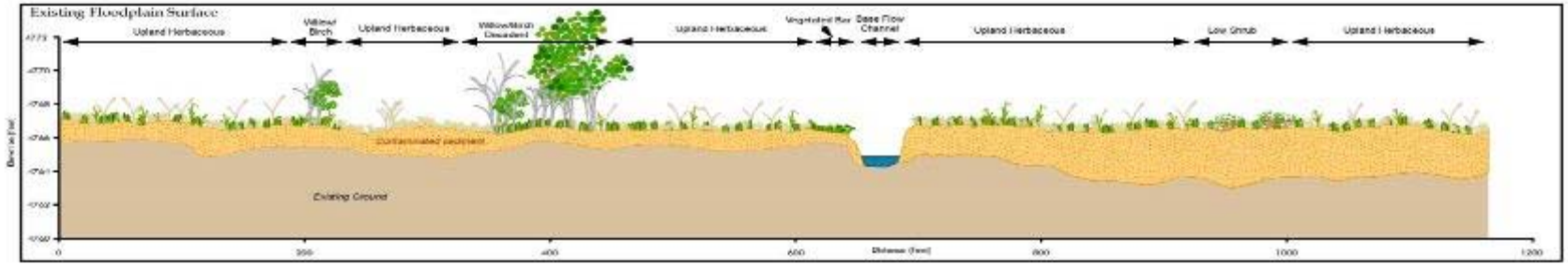
- Dynamic environments
- Contaminated materials not completely removed
- Some residual contamination in floodplain soils

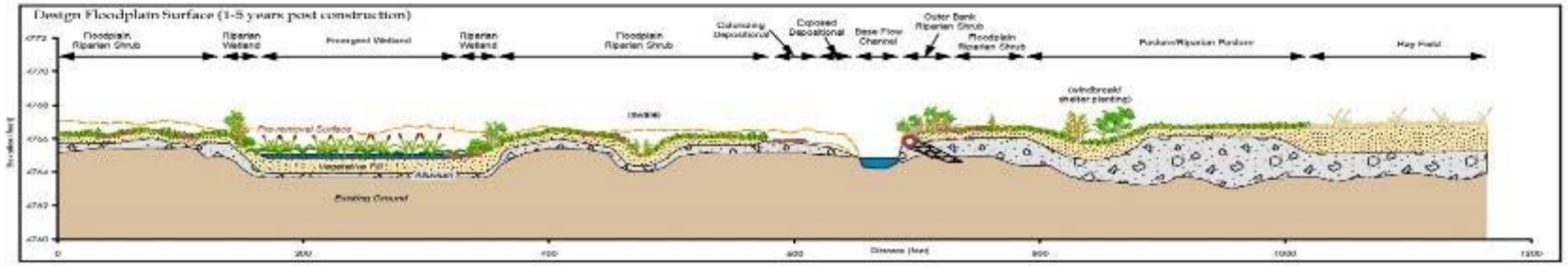


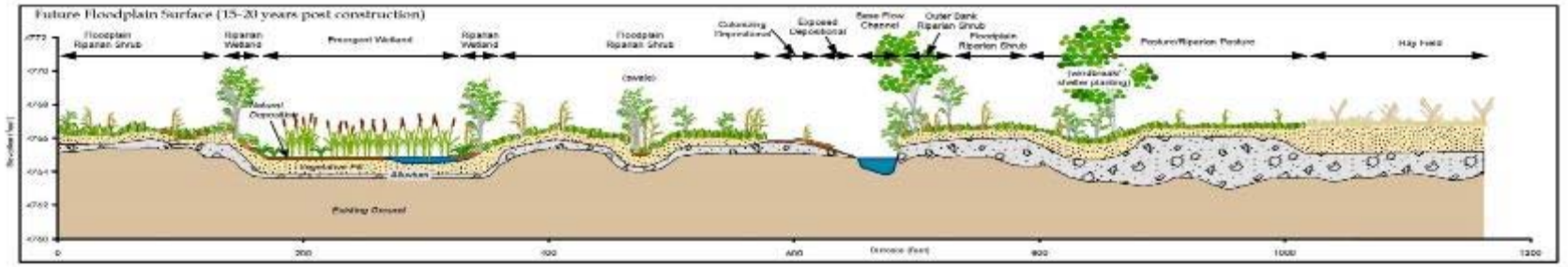
Floodplain Restoration Design Criteria

- Disturbance processes
- Hydrology
- Substrate
- Roughness & complexity
- Biological interactions
    - Herbivory
    - Plant competition

Existing, Design and Future Floodplain Surface



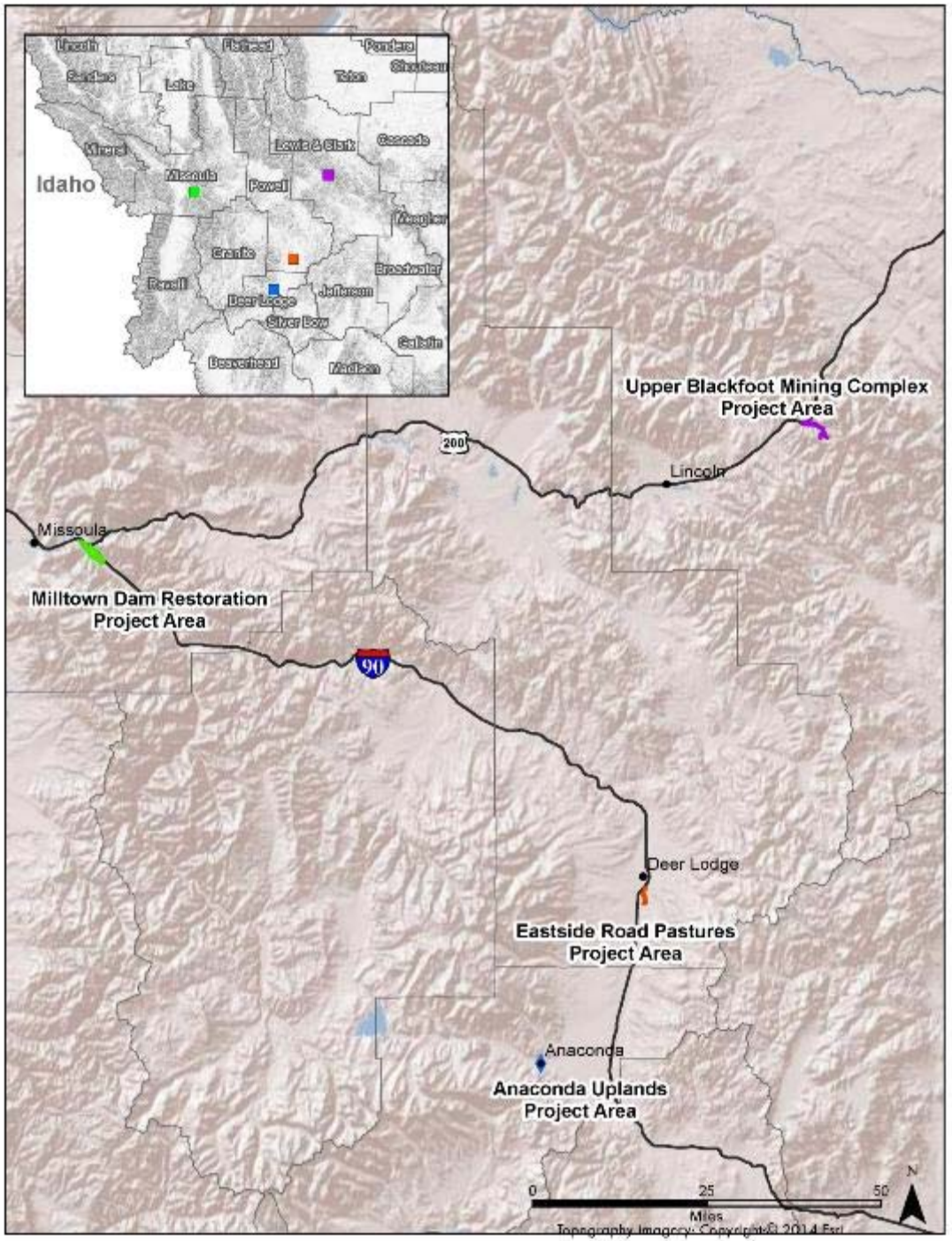


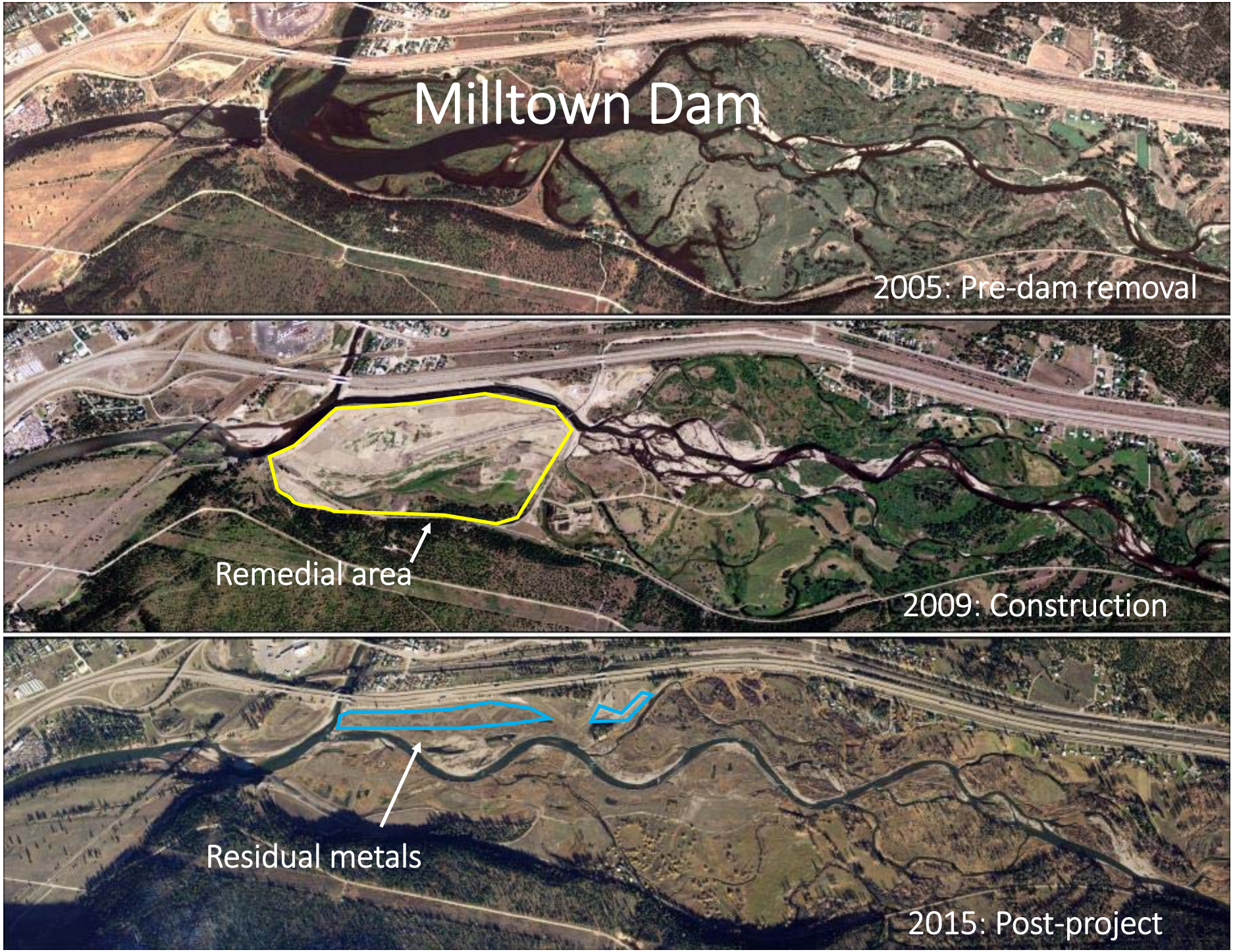


Residual Metals Scenarios

- Clark Fork River—remove contaminated material to a depth where substrate is clean, but metals remain at edges
- Eastside Road Pastures—upland pasture irrigated with contaminated irrigation water
- Upper Blackfoot Mining Complex—remove tailings to a native surface which is highly mineralized on some reaches
- Anaconda Uplands—soils contaminated by smelter

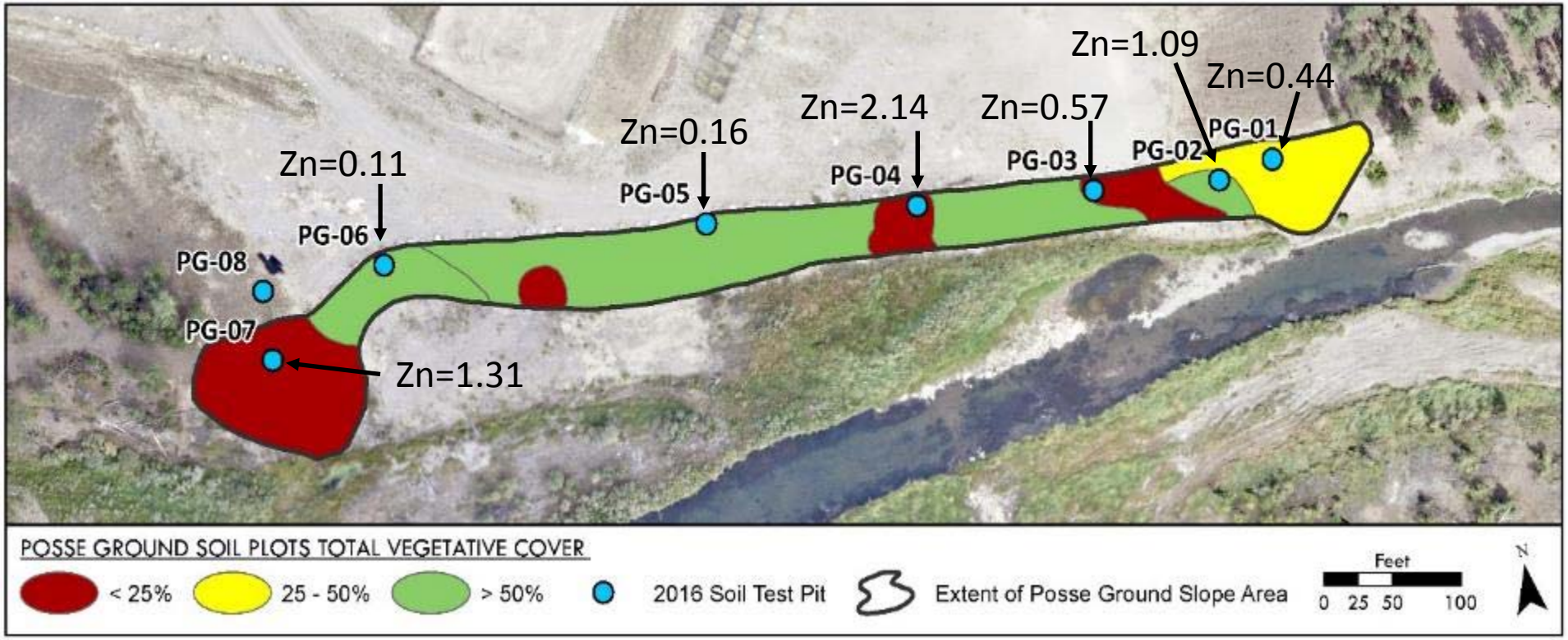
Residual Metals Scenarios




Milltown Dam
2005: Pre-dam removal
Remedial area
2009: Construction
Residual metals
2015: Post-project

Plant community succession in alluvial river floodplains in the semi arid Rocky Mountain Region is initiated by cottonwoods and willows colonizing bare, moist substrates

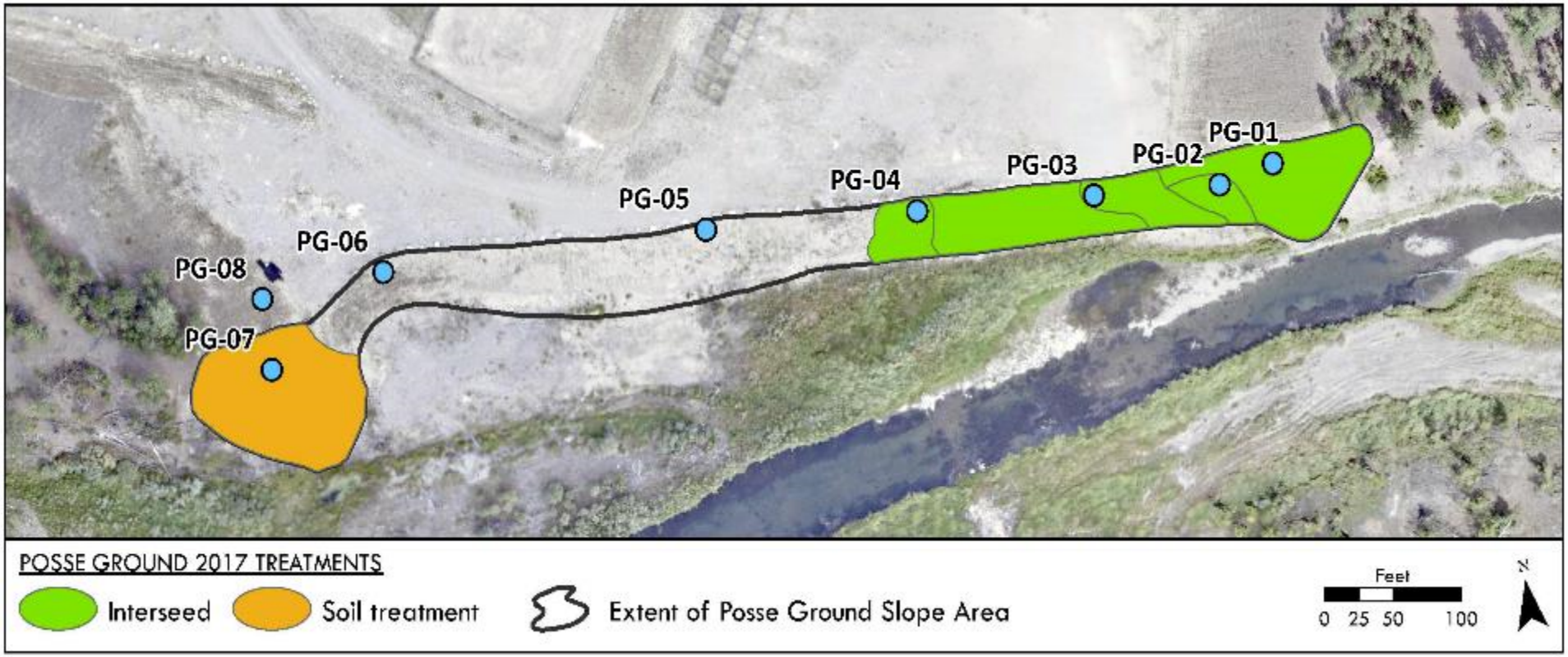
Milltown Posse Grounds Reclaimed Slope Condition



Total metals (Cu, Zn, Pb, As, Cd) 1500 to 2000 throughout this area

Soluble Zn is in mg/L (sat. paste)

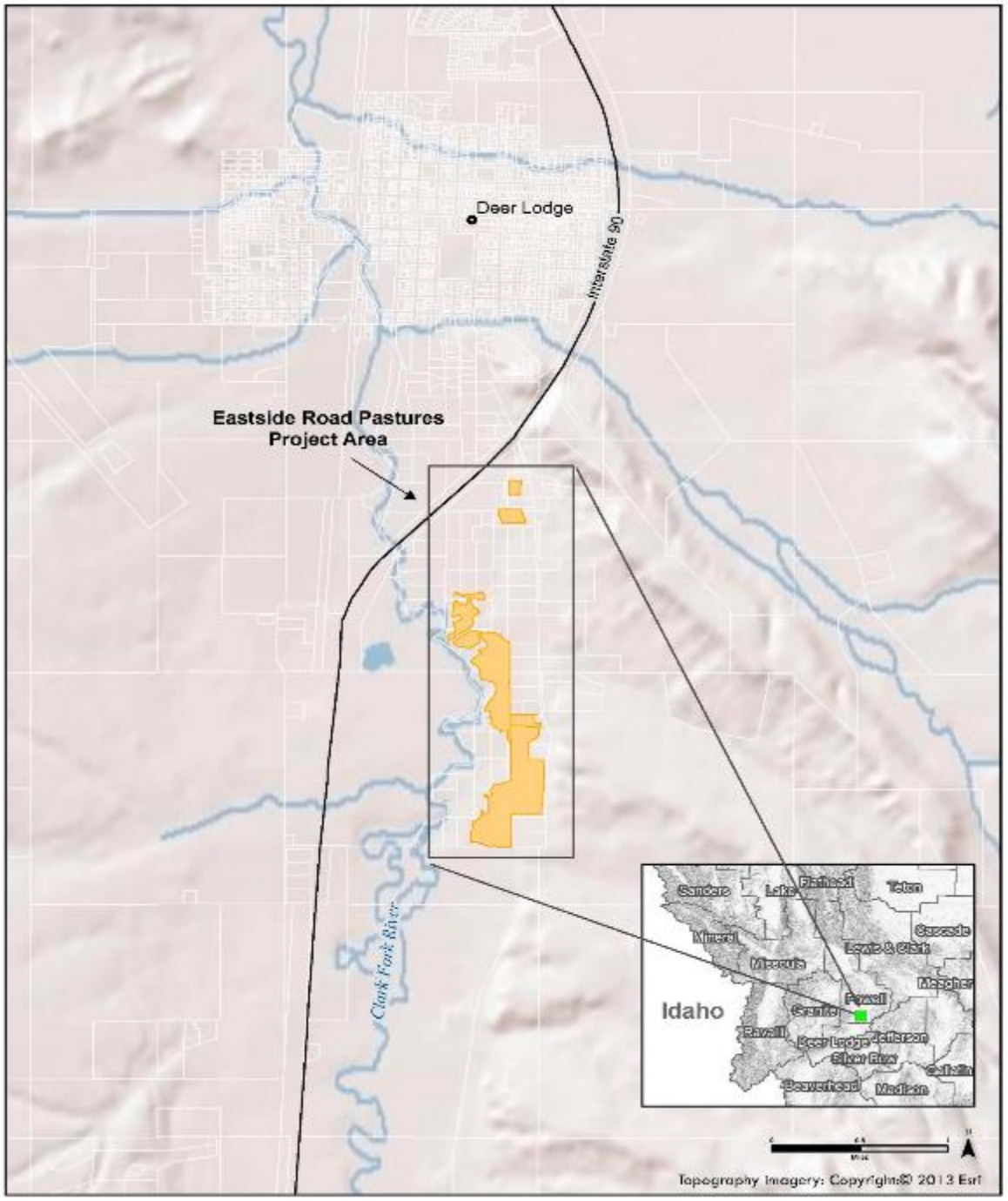
Milltown Posse Grounds Reclaimed Slope Treatments



Soil treatment:

- Decompact
- Lime at 15 tons CaCO3/acre
- Compost at 100 cu yds/acre
- Microtopography and woody debris

Eastside Road Pastures



Eastside Road Pastures

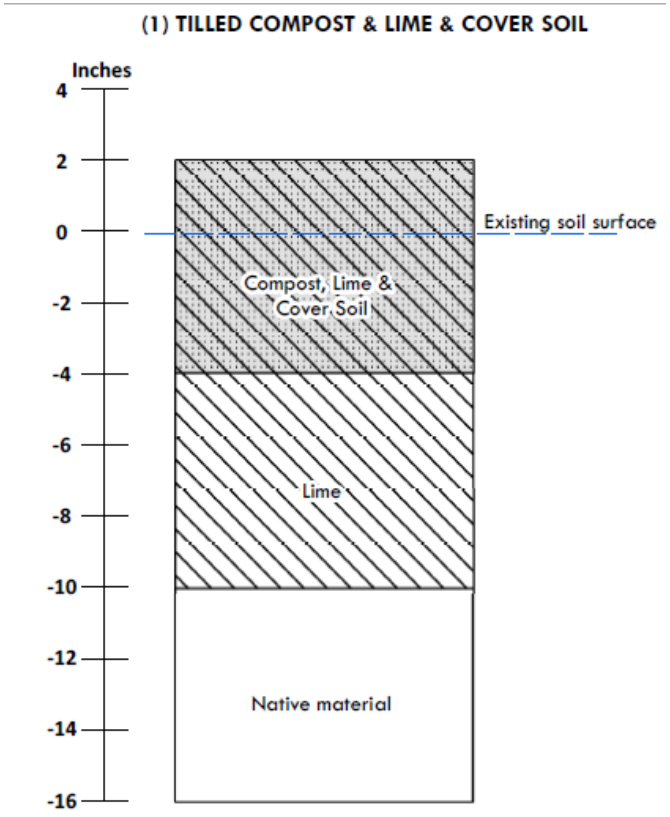
Eastside Road Pastures

Saturated Paste Extracts before and after adding Lime

Plot	pH	pH with Lime	Cu	Cu with Lime	Zn	Zn with Lime
ESP-2014-08-26	4.8	7.1	1.63	0.85	1.07	0.02
ESP-2014-09-02	5.0	7.2	1.78	0.79	1.22	0.04
ESP-2014-09-26	4.9	7.2	1.01	0.63	0.74	0.03
ESP-2014-10-26	4.8	7.2	1.21	0.64	1.12	0.02
ESP-2014-12-26	4.7	7.1	1.41	0.73	2.31	0.02
ESP-2014-12-612	4.7	6.9	0.88	0.51	1.88	0.02
ESP-2014-14-26	5.3	7.2	0.79	0.96	0.86	0.03
ESP-2014-15-02	5.0	7.2	0.94	0.93	0.80	0.06
ESP-2014-15-26	4.8	7.2	1.14	0.95	0.92	0.03
ESP-2014-16-02	5.1	7.2	0.93	0.75	1.04	0.04

Eastside Pastures Treatments—90 acres

- *Lime applied at 15 tons/acre—evenly mixed to 10 inches*
- *Cover soil applied at 200 cu yds/acre*
- *Compost applied at 70 cu yds/acre*
- *Drill seeded*
- *Straw crimped*



Eastside Road Pastures

Eastside Road Pastures

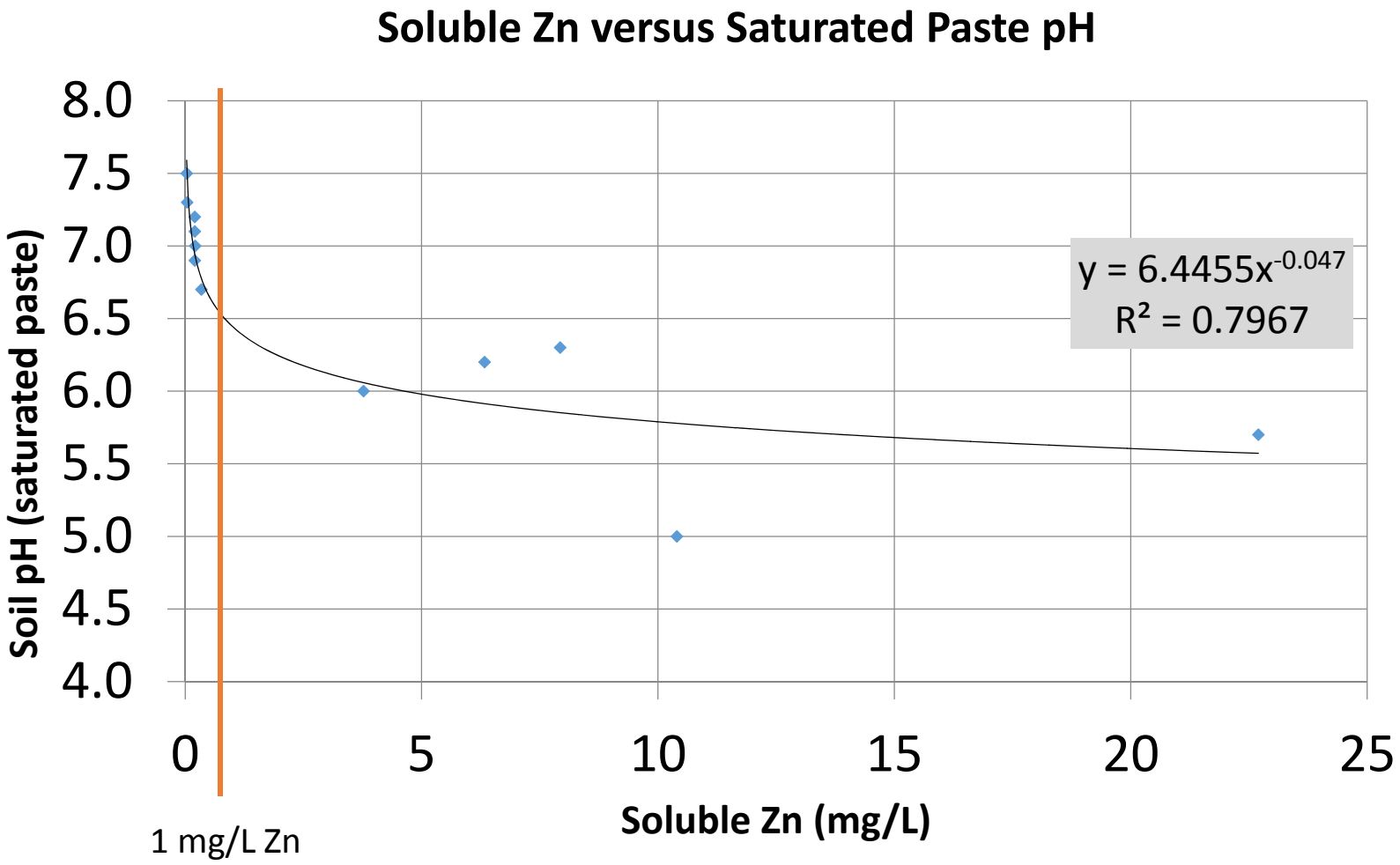
Upper Blackfoot River Mining Complex

Upper Blackfoot Mining Complex

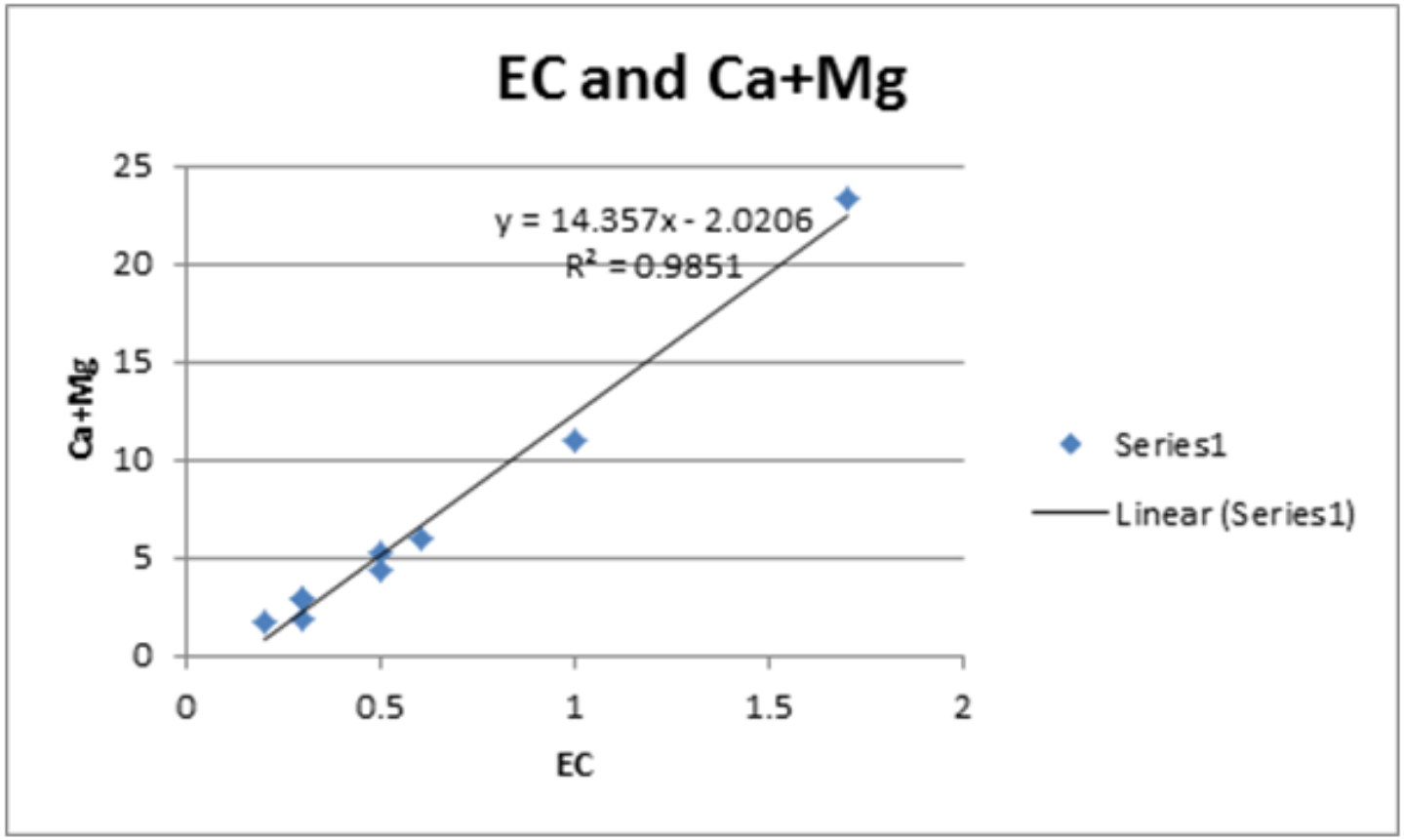
- Parent material is naturally mineralized – mine waste removal is possible, but in places there is no depth where metal concentrations are below SSCLs
- Capping may be required to protect human health
- Cover soil or soil amendments where SSCLs are not applicable

Upper Blackfoot Mining Complex

Upper Blackfoot Mining Complex



Upper Blackfoot River Mining Complex

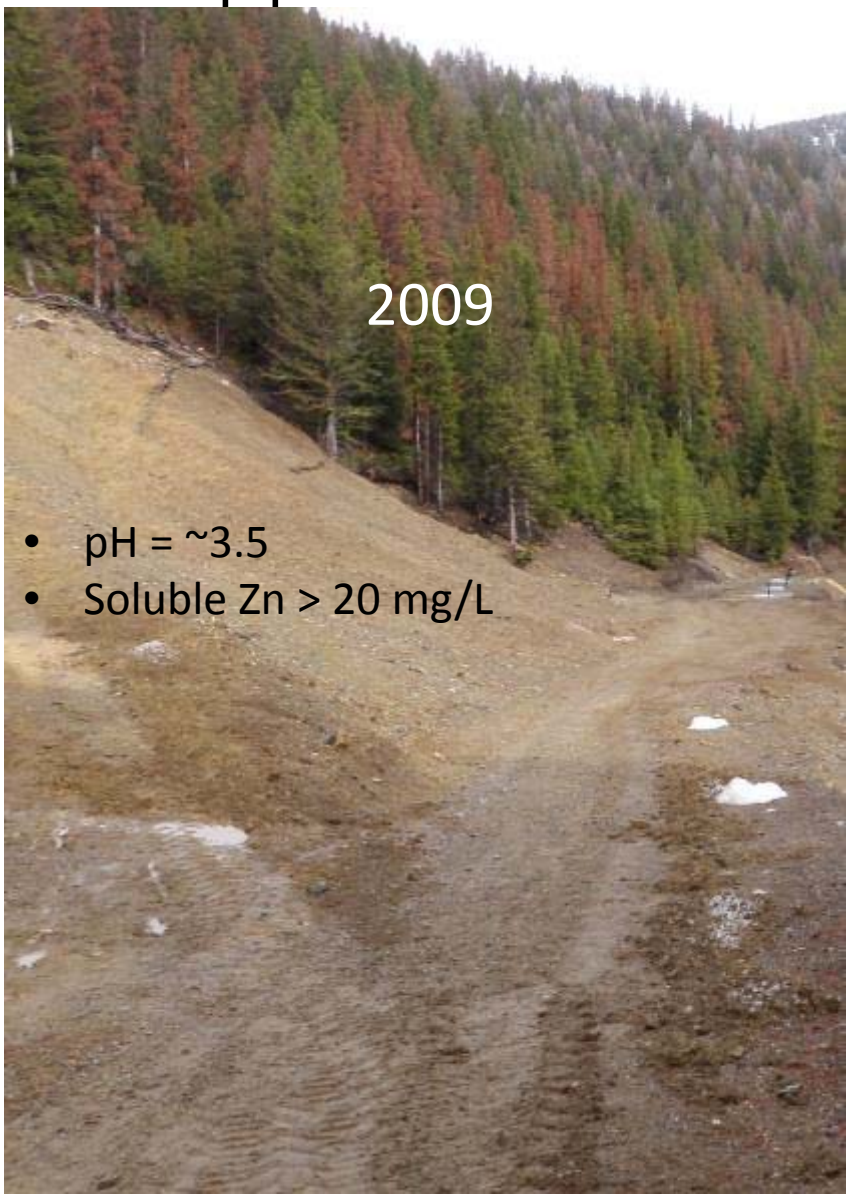


Upper Blackfoot River Mining Complex

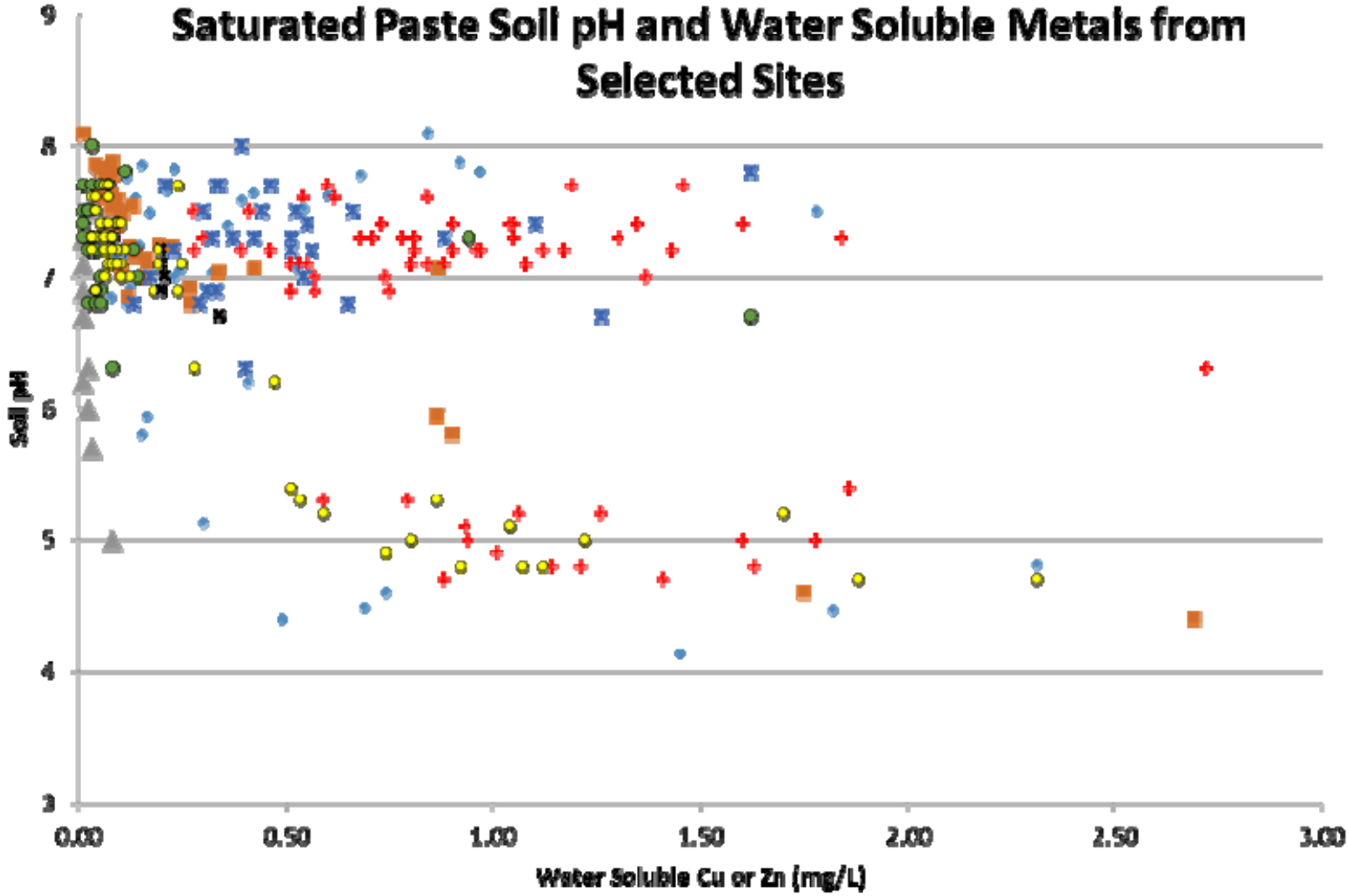
Floodplain backfill design criteria		
Condition at Excavation Surface	Gravel and Sand	Rocky parent material
pH < 6.5 Ec < 1 Saturated	6 inches Amended Backfill	Minimum 12 inches Backfill plus 6 inches Amended Backfill
pH < 6.5 Ec < 1 Not Saturated	Minimum 18 inches Backfill plus 6 inches Amended Backfill	
pH > 6.5 Ec > 1	None	Minimum 18 inches Backfill

Upper Blackfoot River Mining Complex

Upper Blackfoot River Mining Complex

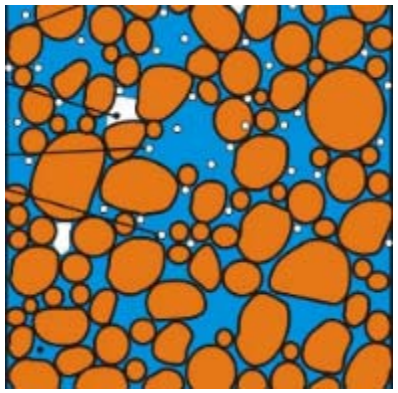


Upper Blackfoot River Mining Complex


Saturated Paste Soil pH and Water Soluble Metals from Selected Sites
Soil pH
9
8
7
6
5
4
3
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Water Soluble Cu or Zn (mg/L)

Pore Water/Saturated Paste Extract

Soil +
Deionized Water



Soil Solution Toxicity to Plants

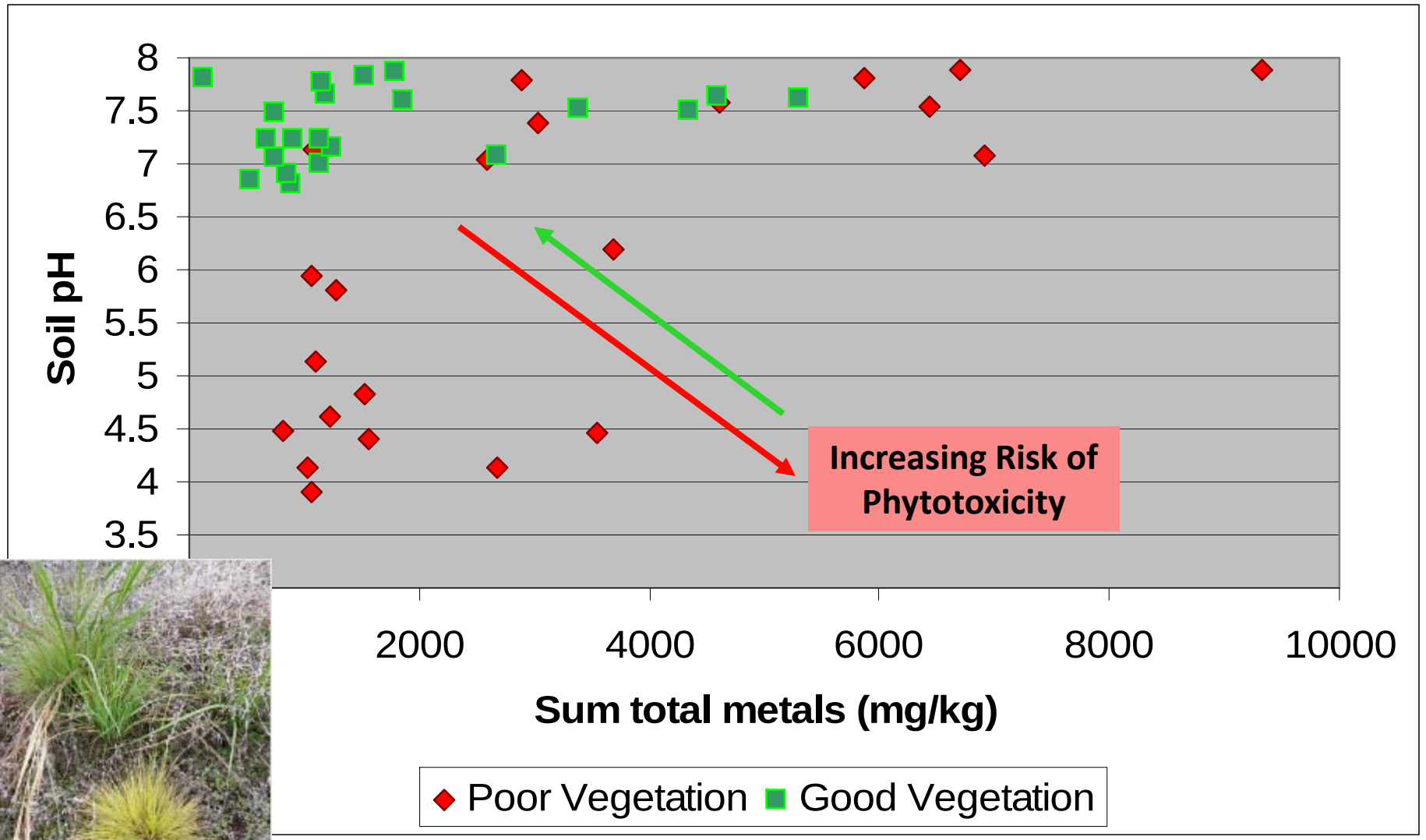
None: Dominated by Ca, Mg, Na, S, N, P, K, DOC, trace amounts of metals

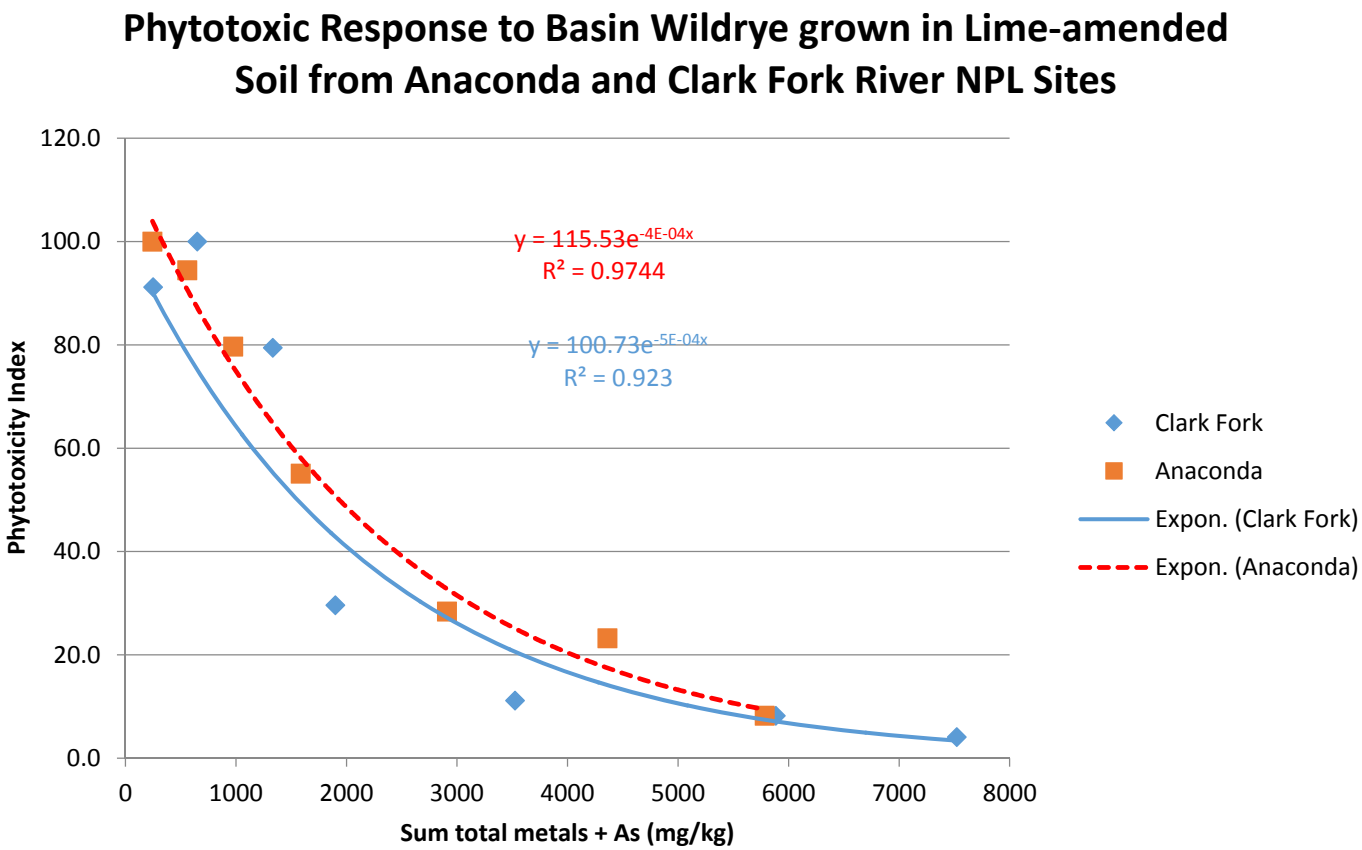
Phytotoxic: Dominated by metals, low pH, no or low nutrients

Remediated: Some soluble trace elements, near neutral pH, nutrients replaced, lime addition adds Ca, Mg

Can be toxic to sensitive species depending on levels

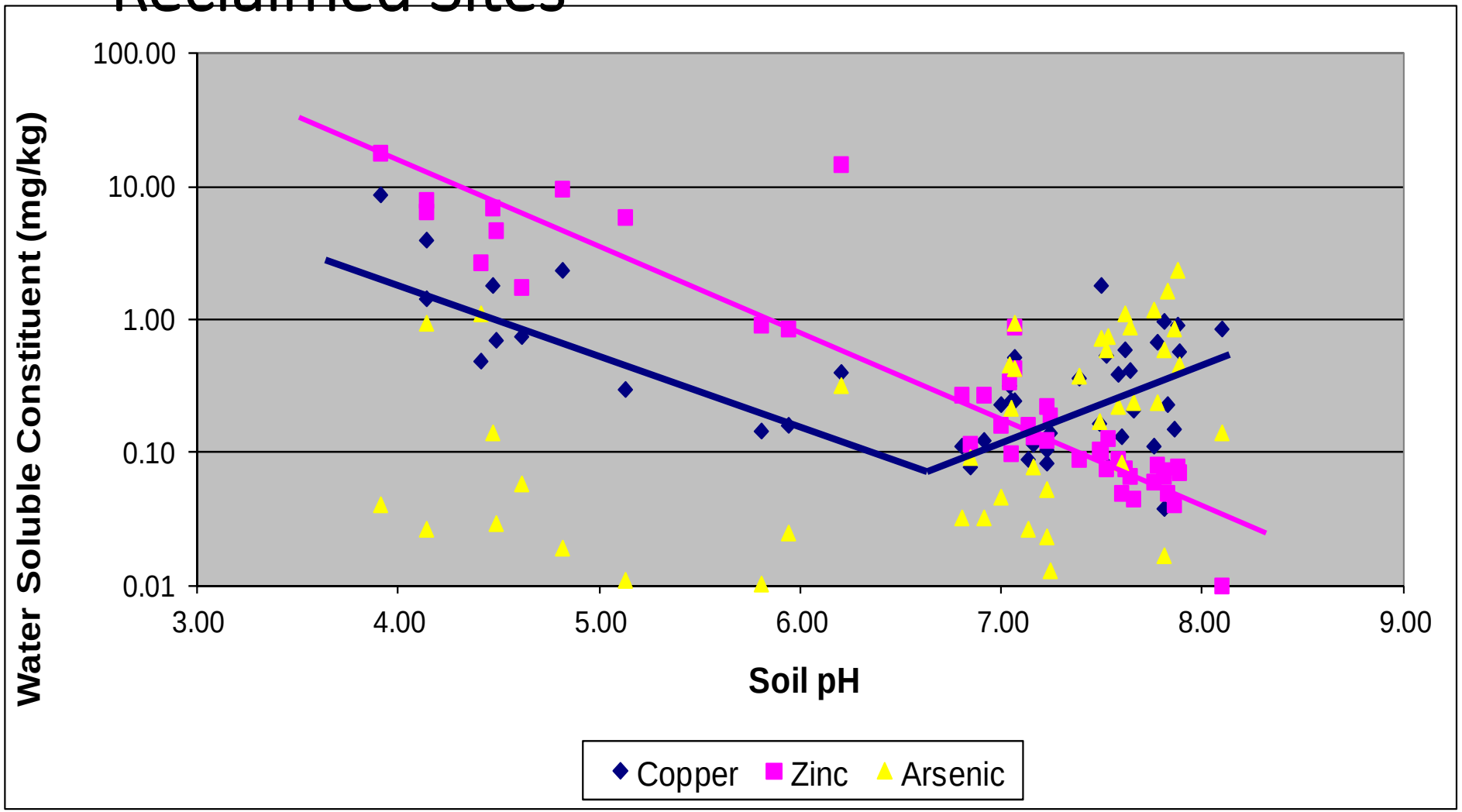
Increasing Chance of Successful Reclamation



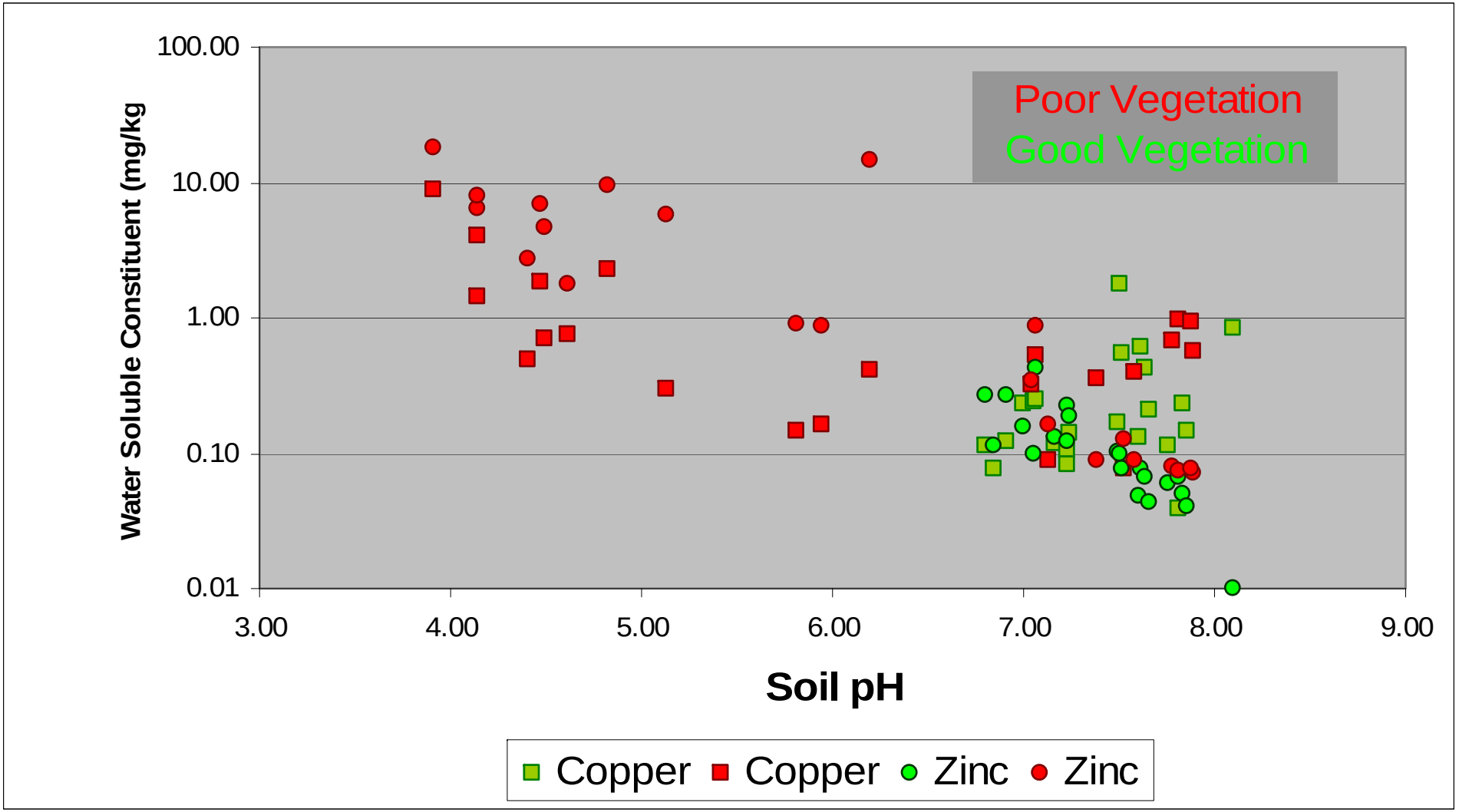


EMERGENCE AND GROWTH OF SEVEN GRASS SPECIES ACROSS A GRADIENT OF METALS AND ARSENIC IN LIME-AMENDED CONTAMINATED SOILS (Martin, 2009)

Anaconda Water Soluble Constituents at Reclaimed Sites



Vegetation Condition and Water Soluble Chemistry at Research Sites

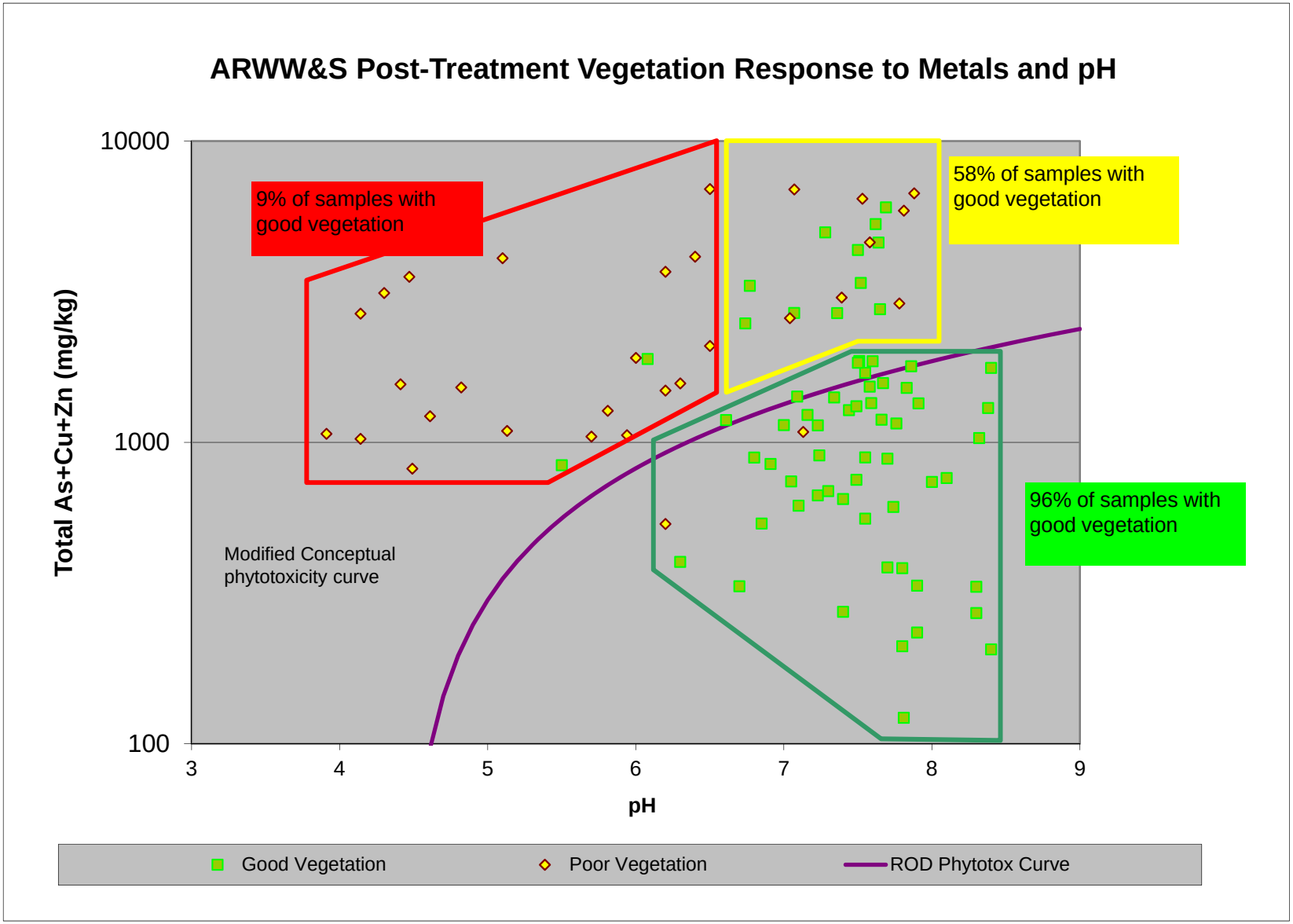


Residual soil phytotoxicity

3 years old

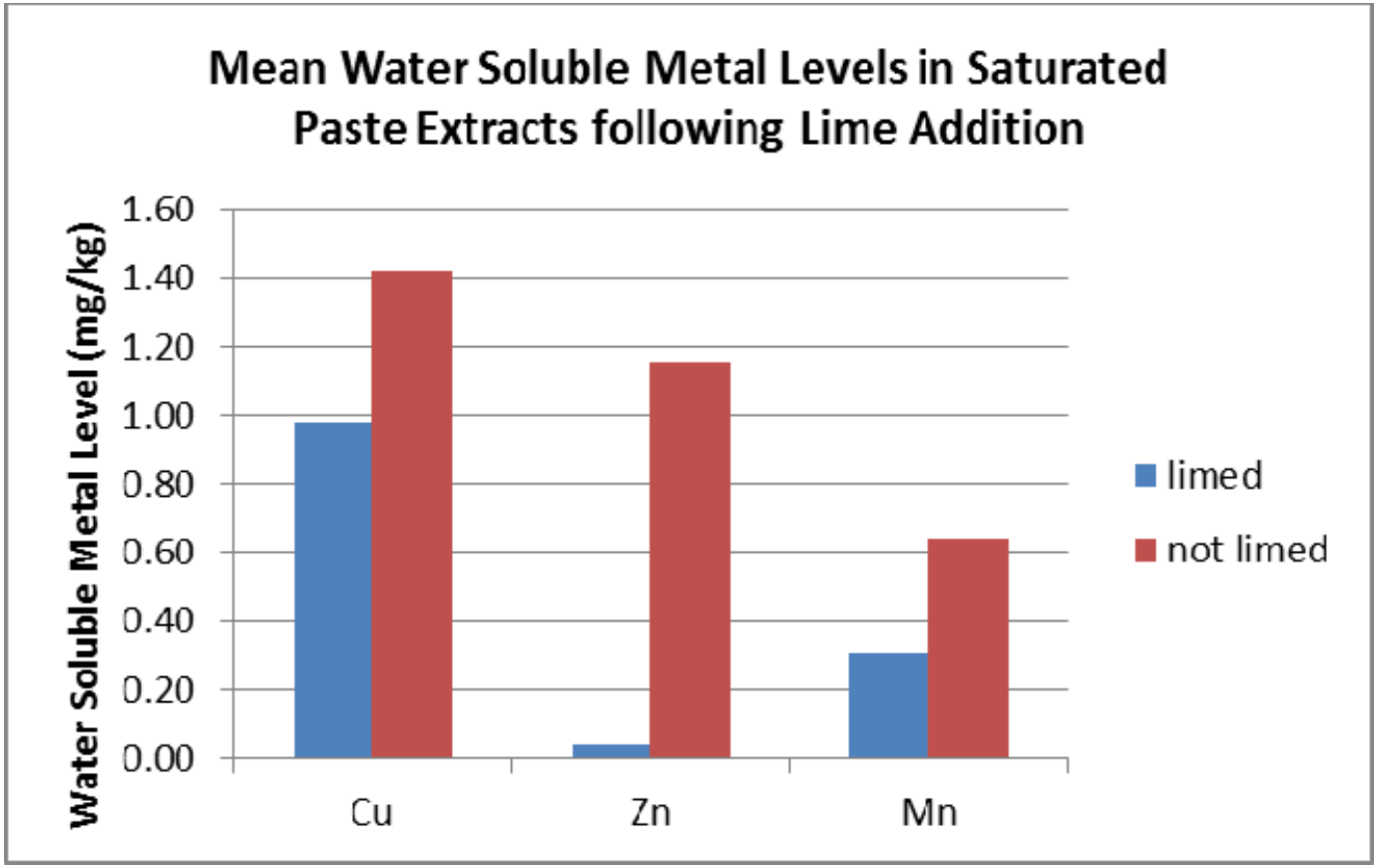
8 years old

16 years old

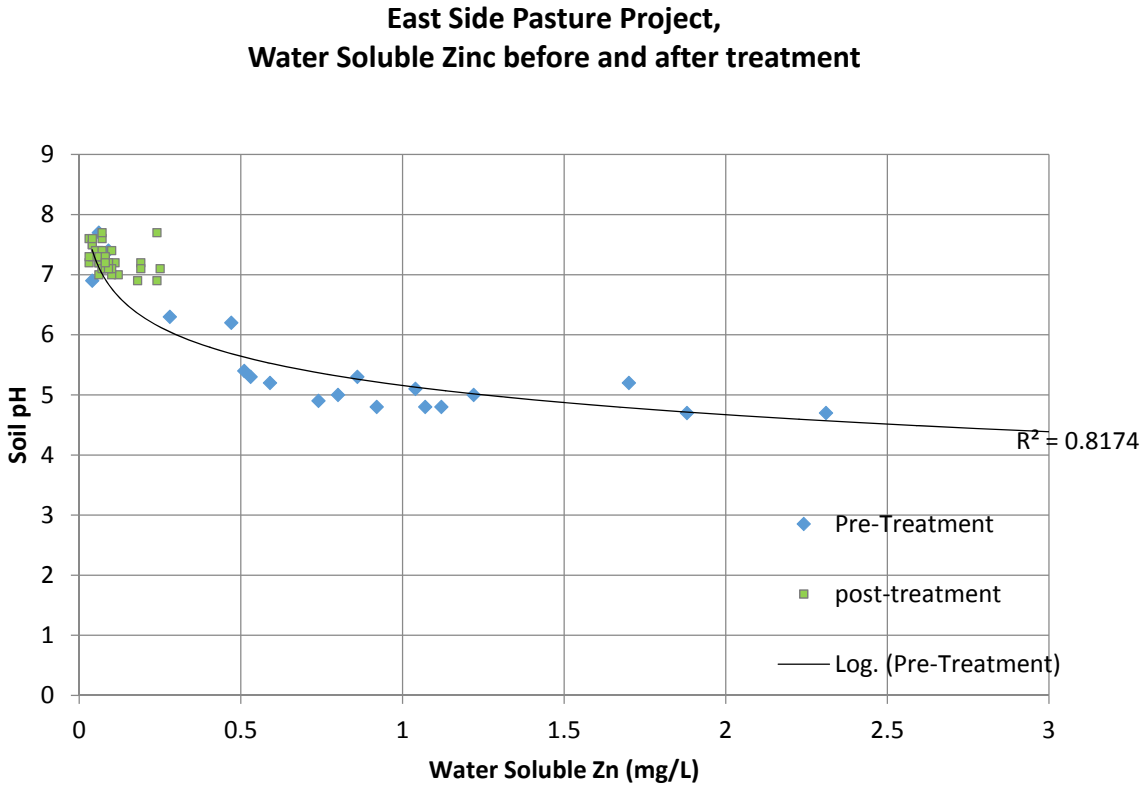

ARWW&S Post-Treatment Vegetation Response to Metals and pH
Total As+Cu+Zn (mg/kg)
10000
1000
100
3
4
5
6
7
8
9
pH
9% of samples with good vegetation
58% of samples with good vegetation
96% of samples with good vegetation
Modified Conceptual phytotoxicity curve
Good Vegetation
Poor Vegetation
ROD Phytotox Curve

What the sites look like

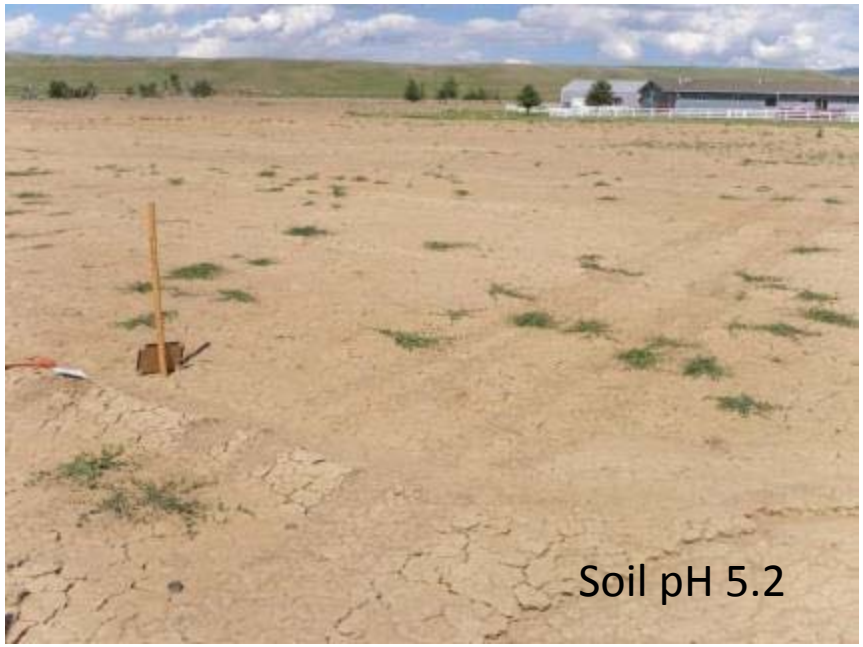
East Site Road Pastures:
Water Soluble Metal Levels in Soil



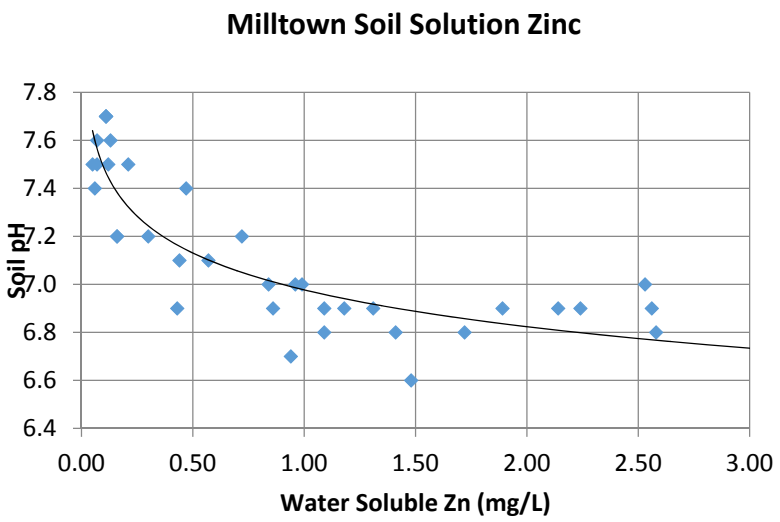
Water Soluble Zinc Before and After Soil Treatment with Lime and Compost

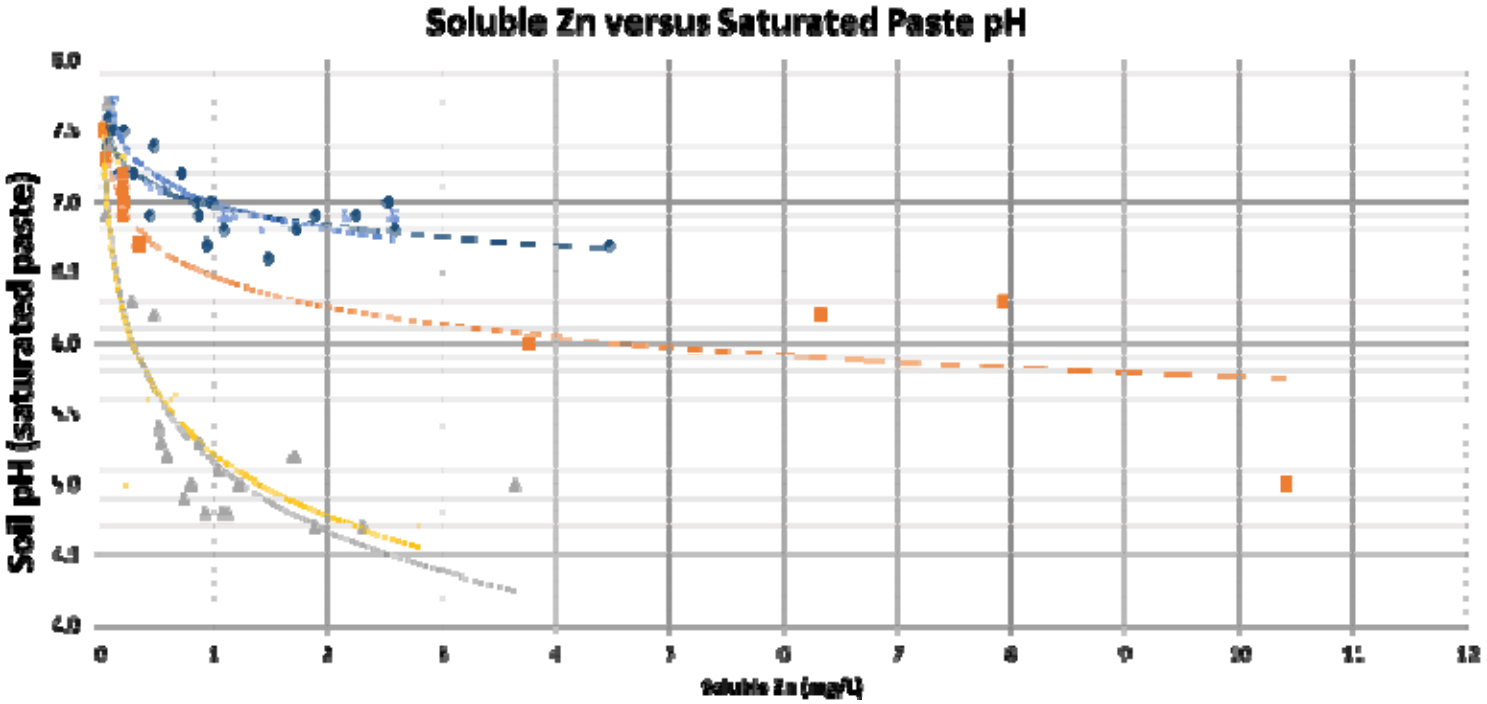


Pre-treatment condition (2014)



After reclamation using lime and organic matter (May 2016)…seeded May 2015


Milltown Soil Solution Zinc
Soil pH
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Water Soluble Zn (mg/L)


Soluble Zn versus Saturated Paste pH
Soil pH (saturated paste)