Differentiating Mining and Non-mining Sourced Contaminants in the San Juan River Delta of Lake Powell, USA

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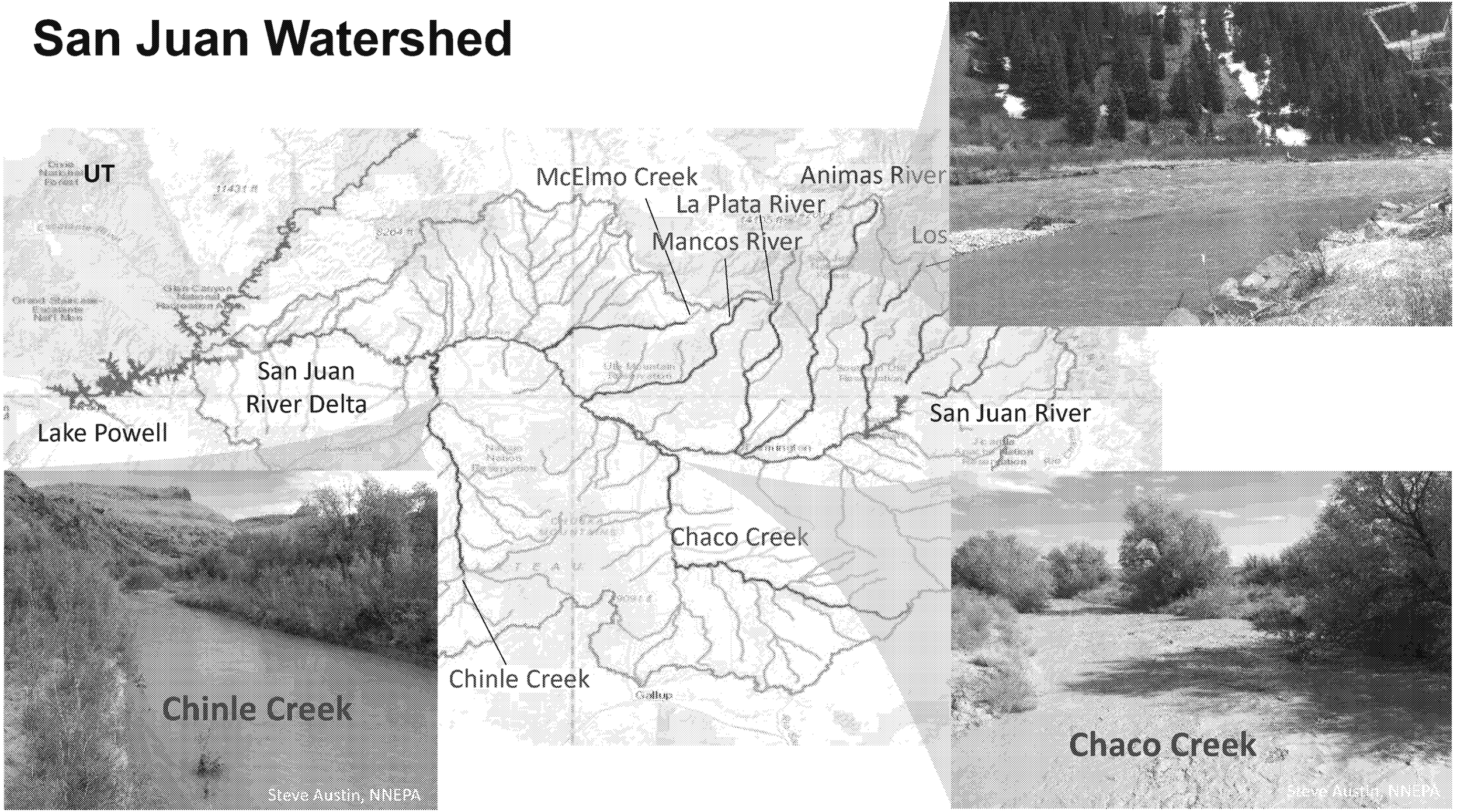
San Juan Watershed



United States Environmental Protection Agency

Bonita Peak Mining District among Superfund sites targeted for intense and immediate attention

EPA announces elevation of 21 sites nationwide

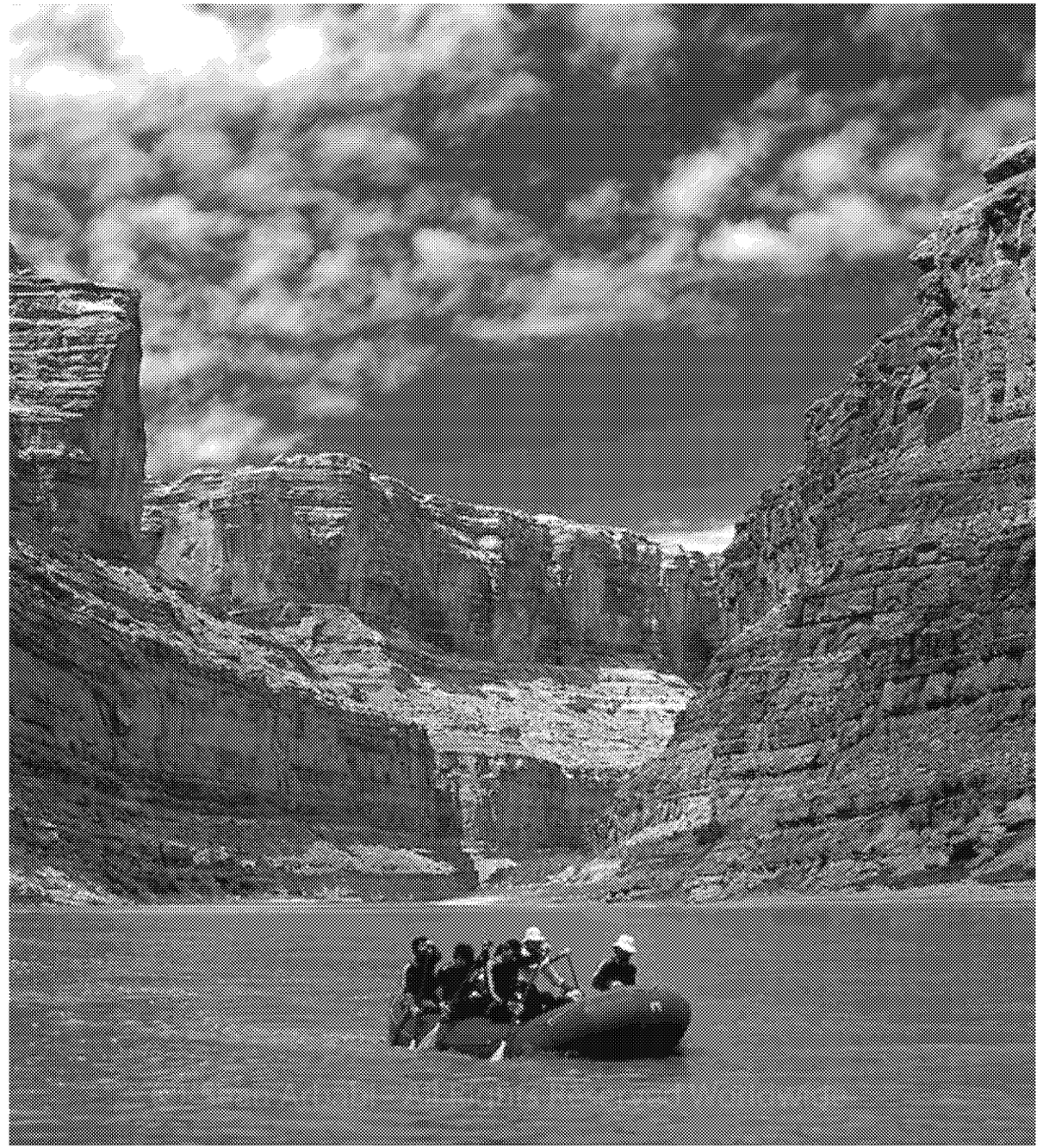
12/08/2017

In San Juan Watershed, what amount of particulate metals (PM) are from mining versus natural sources?

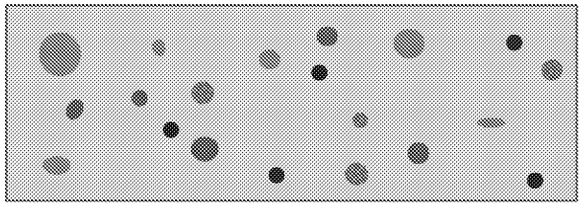
http://www.perfectflystore.com/fishing-san-juan-river.html

Outline

- San Juan Watershed
- Upstream Tributaries
  - Mining
  - Underlying geologic unit
  - Flow regime
  - Percent of susp. sediment from mining
- San Juan River Delta, Lake Powell
  - PCA
  - Enrichment factors
  - Pb isotopes
  - Percent of deposited sediment from mining
  - Age-dating of sediment cores



1. Water Quality Data

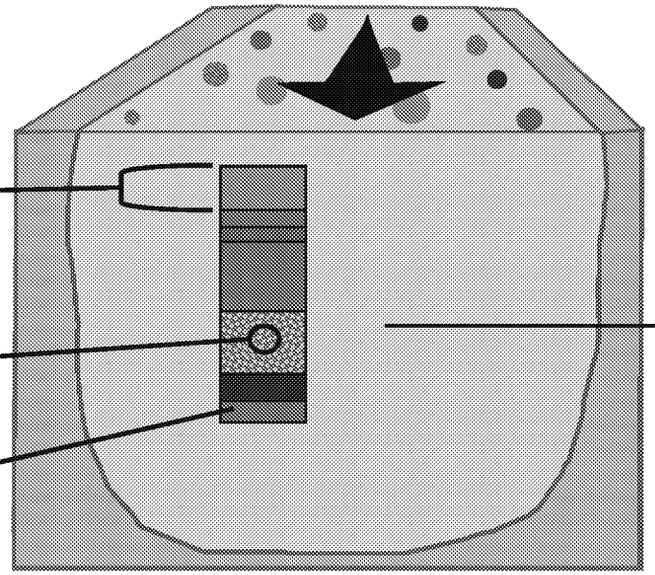


PM loads
($mass_{metal}$/time)

PM Concentrations
($mass_{metal}/mass_{sed}$)

Pb isotopes

2. Sediment Traps



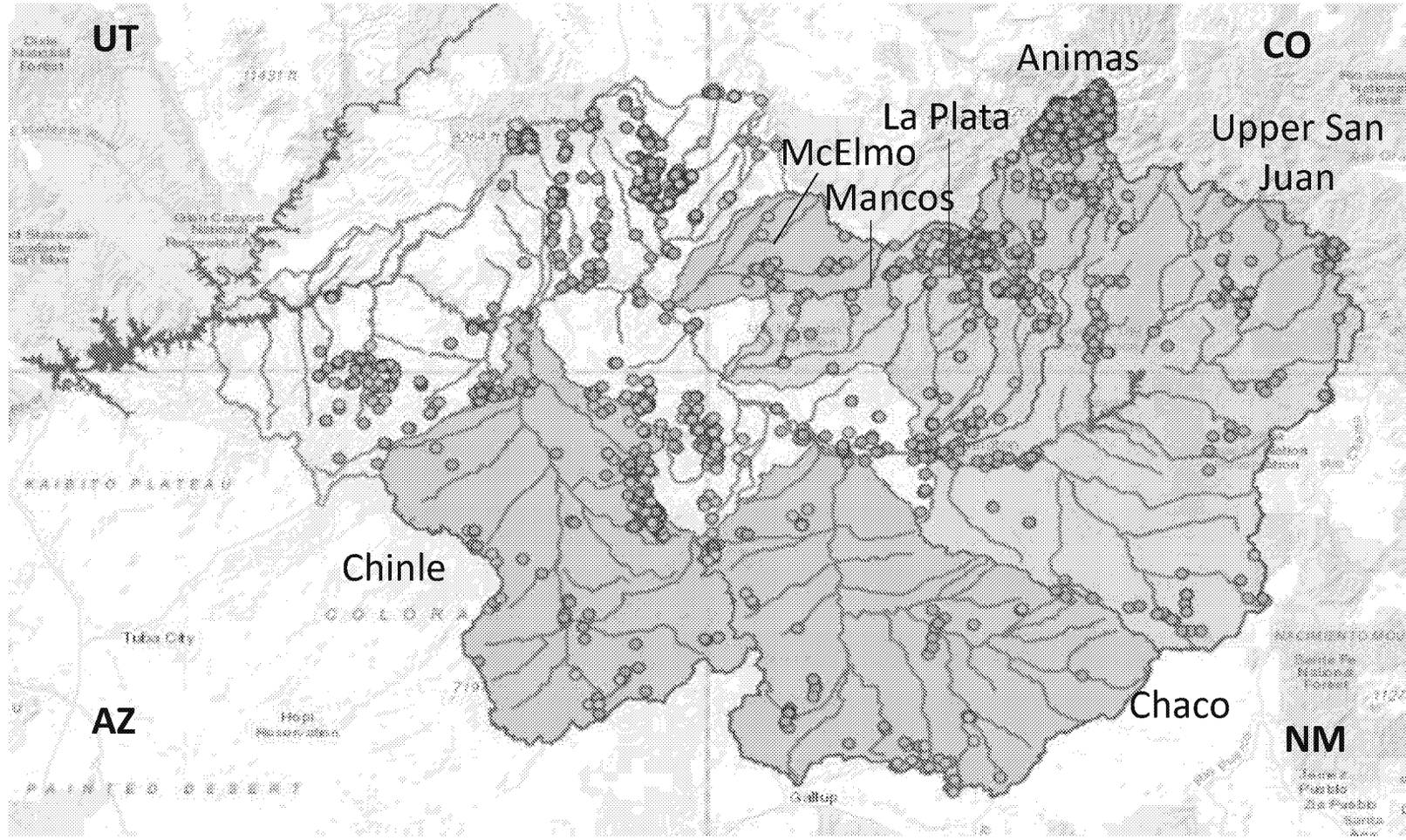
- Record of suspended sediment
- Known time

3. Sediment Cores

- Record of deposited PM
- Unknown time

Signatures of tributaries:
- Mining vs non-mining
- Underlying geology
- Dominant flow regime

Mined Tributaries



Legend

- Precious Metal Mine
- Vanadium/Uranium
- Stone/Gravel

Mined Trib.

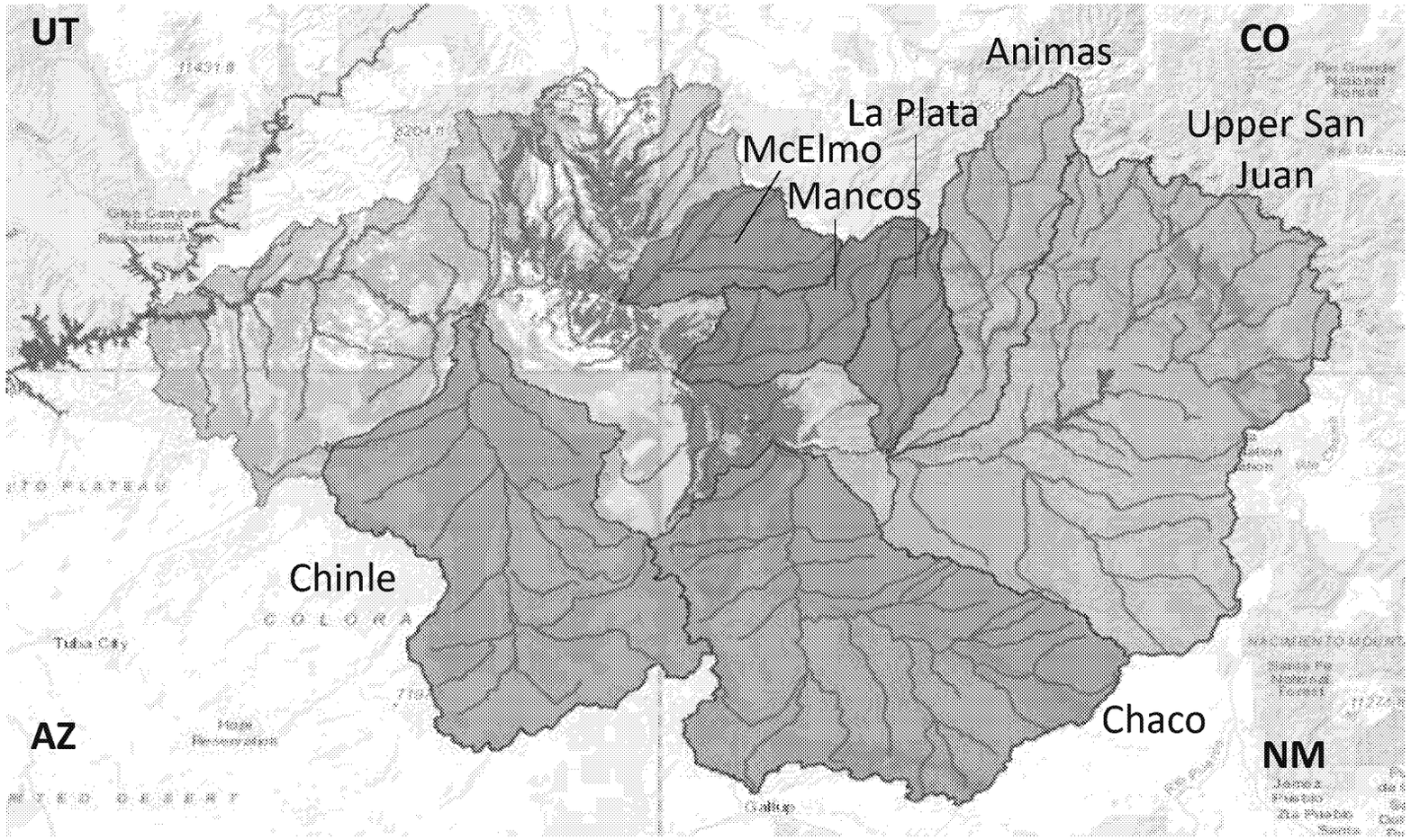
Animas (217)
La Plata (132)
Mancos (57)
Upper San Juan (51)

Unmined Trib.

McElmo (4)
Chaco (3)
Chinle (1)

Precious metals mines → Ag, Pb, Au, Zn, and Cu ore
Acid Mine Drainage → release of As, Pb, Zn, Cd, and Cu

Underlying Geology



Legend

- Sandstone
- Shale
- Sandstone/Shale
- Intrusive Igneous

Mancos Shale

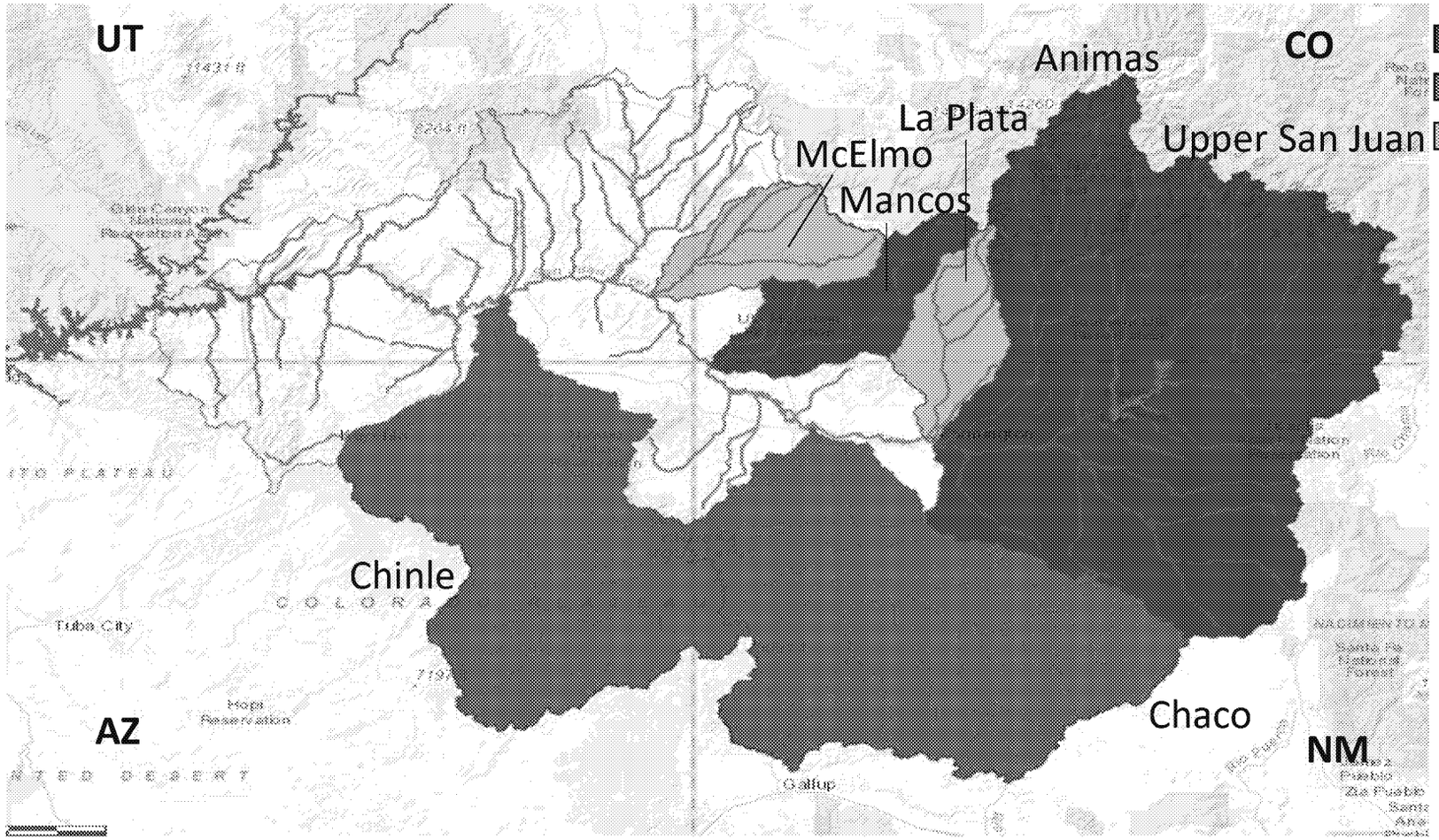
McElmo (76%)
Mancos (68%)
La Plata (52%)

Sandstone

Chinle (75%)
Chaco (50%)
Animas (34%)
Upper San Juan (30%)

Mancos Shale: As and Se (Dryer et al., 2016; DOE, 2011; Larrick and Ashmore, 2012)
Chinle Sandstone: Al, As, Co, Cr, Fe, V, and Zn (Newman, 1962)

Snowmelt vs Rainfall-dominated



Legend

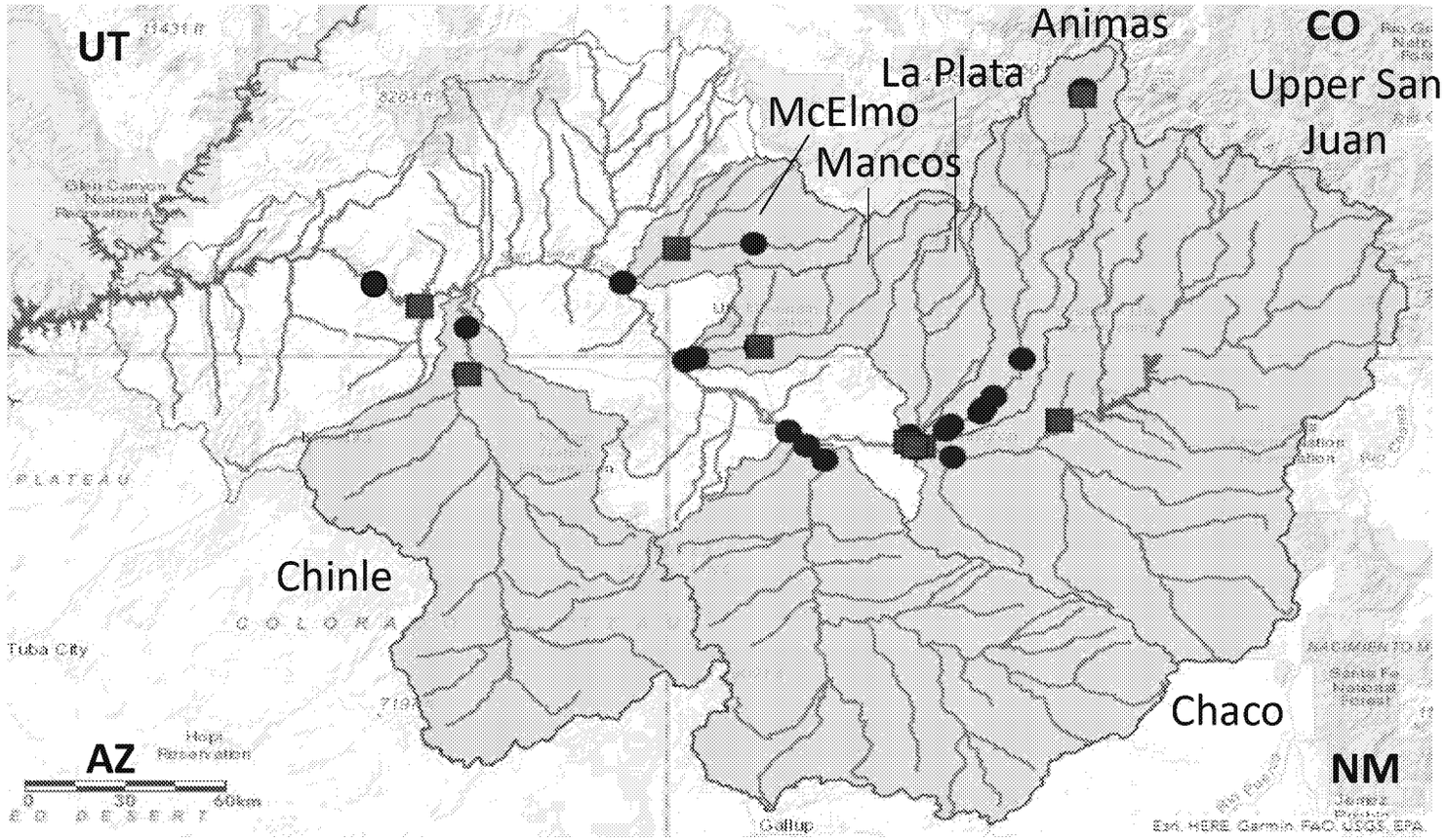
- Snowmelt-dominated
- Rainfall-dominated
- Mixed

Mobilization varies with flow duration and intensity.

- Snowmelt: steady flow, particles from high elevations
- Rainfall: flashy flow, particles from all elevations

Methods

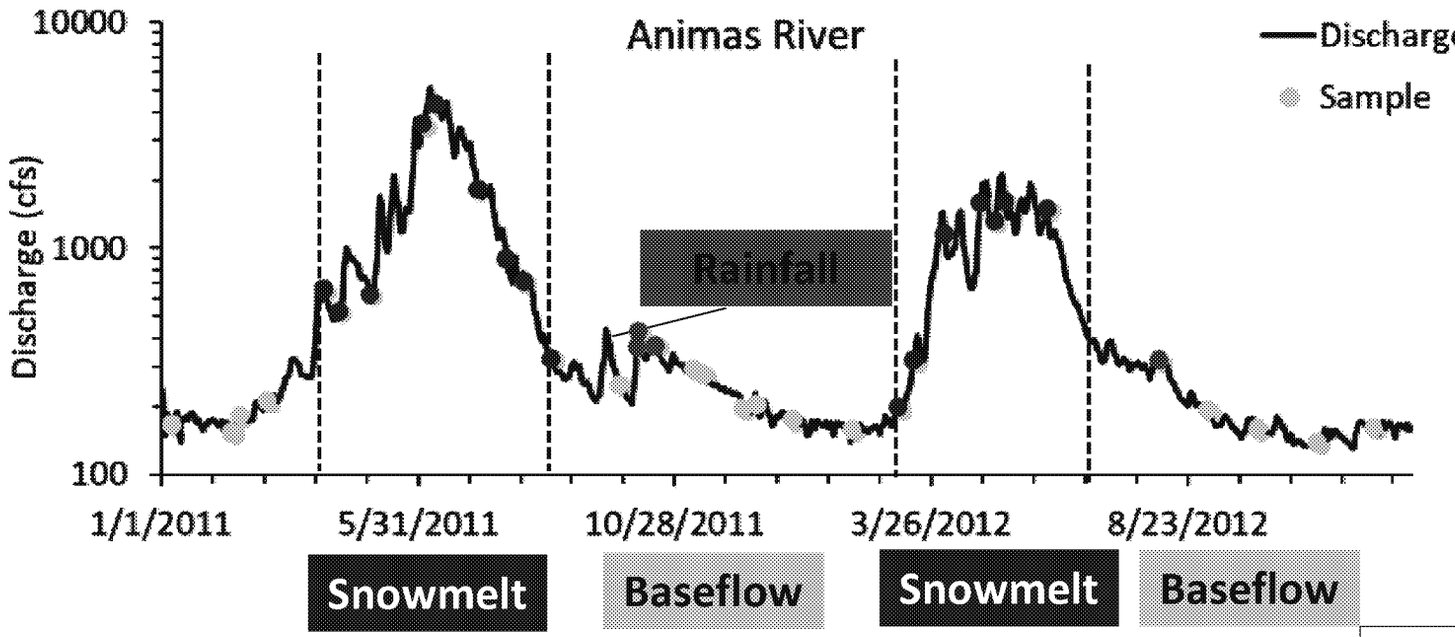
- Downloaded metals data STORET:
  - 1980 – 2017
  - Downstream most location on tributary → integrated signature
  - Total Metals, Filtered Metals (<0.45 µm), and Total Suspended Solids (TSS)
  - Measured ICP-AES or ICP-MS

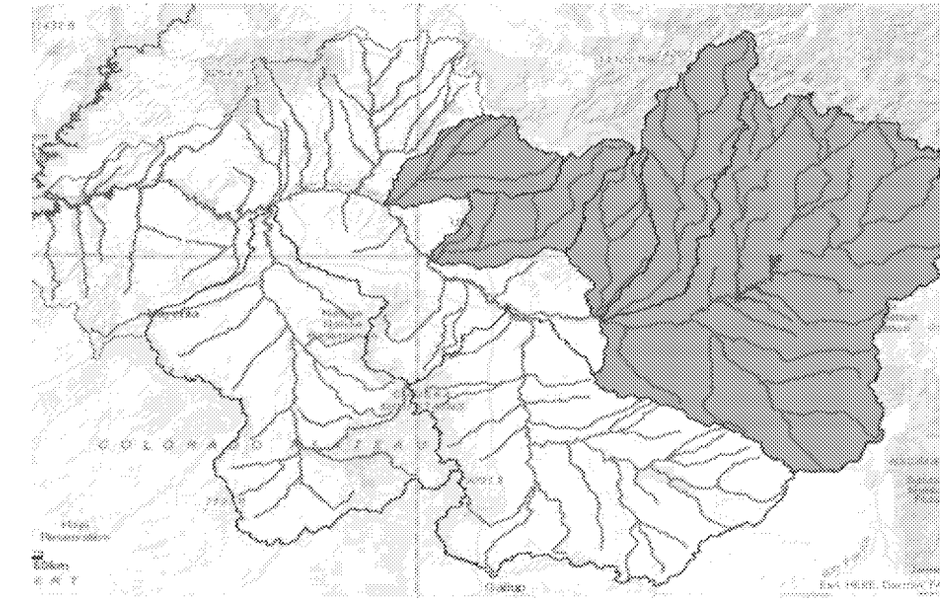


Legend

- ● Water Quality Sample
- ■ USGS Gauge

Methods





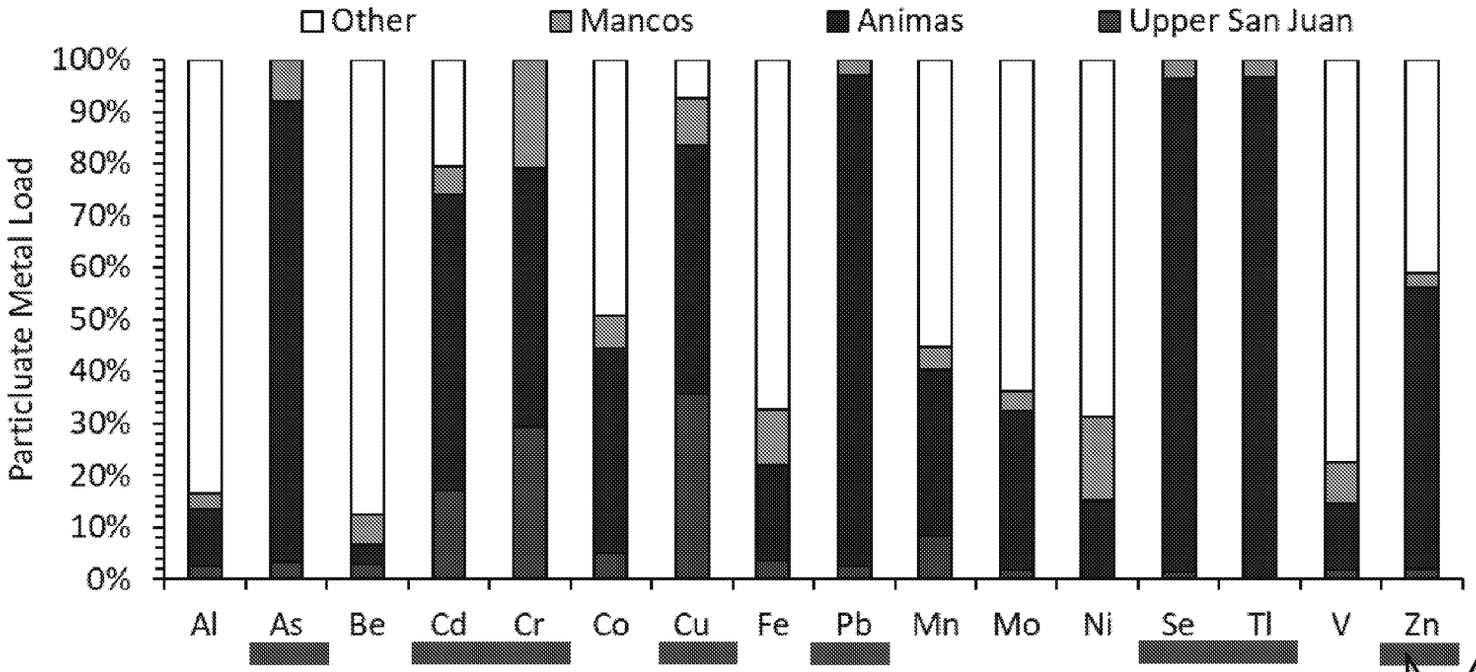
$$PM\ Load = (Total\ - Filtered) * Discharge$$

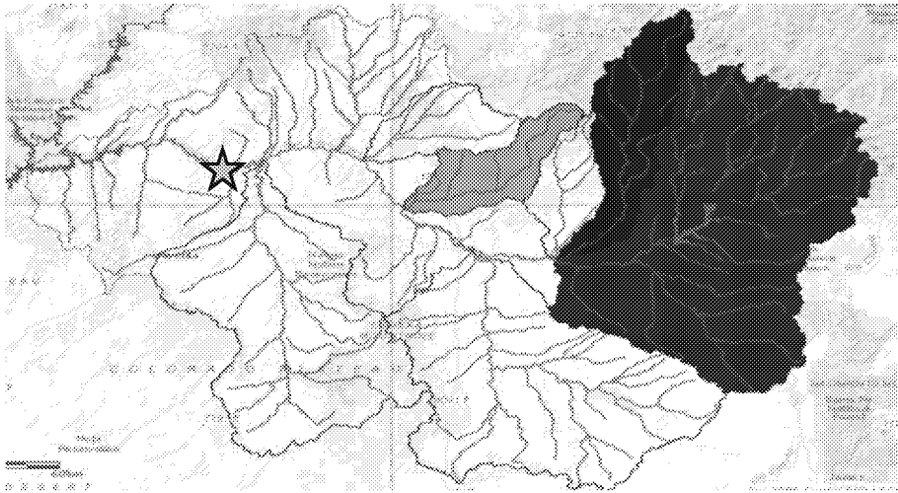
$$PM\ Concentration = (Total\ - Filtered)/TSS$$

- Categorize all PM load data by flow regime
- Average of discrete loads/concentrations
- Insufficient data to use regression

Tributary	Snowmelt	Rainfall	Baseflow
Upper San Juan	X	X	X
Animas	X	X	X
La Plata		X	X
Mancos	X	X	X
McElmo		X	X
Chaco		X	
Chinle		X	

Snowmelt PM Loads

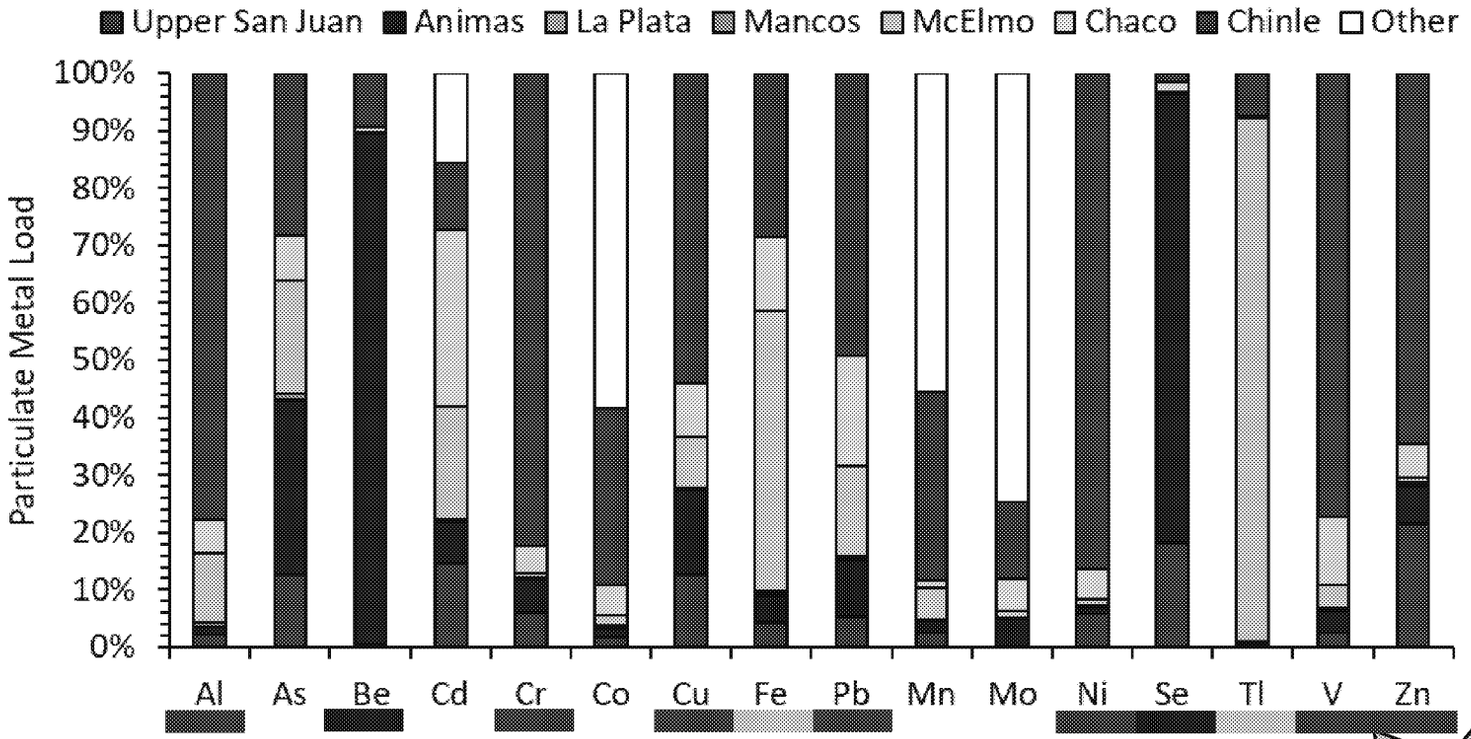


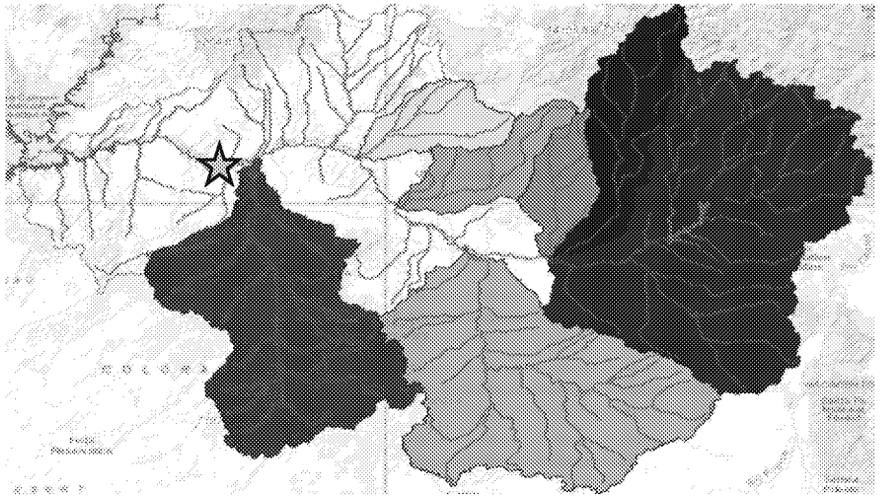


- ↑ mining associated metals
- Sourced from ↑ elevation
- ↑ mining

Animas Snowmelt = Mining-sourced

Rainfall PM Loads





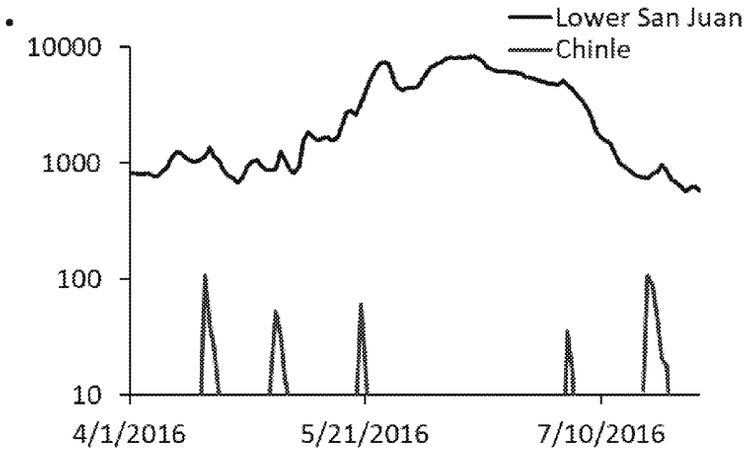
- ↑ Chinle Sandstone associated metals
- PM sourced from all elevations
- No mining

Chinle = Non-mining sourced

Unaccounted PM Loads

1. Rainfall during snowmelt periods
2. Uncharacterized washes
3. Underrepresentation of Upper San Juan River
4. Saltation/re-suspended bed load

1.



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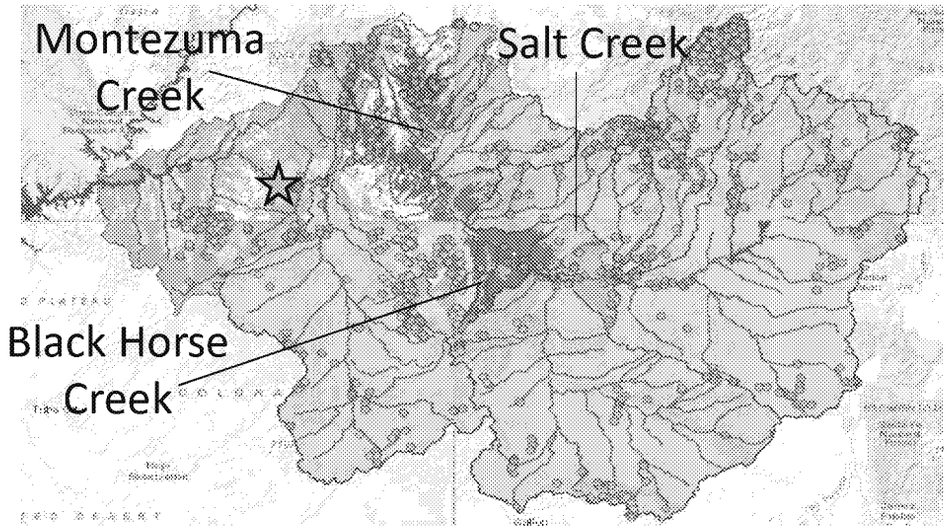

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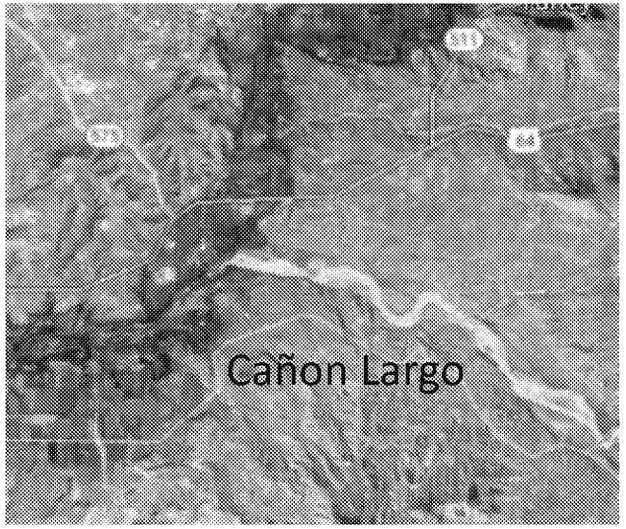

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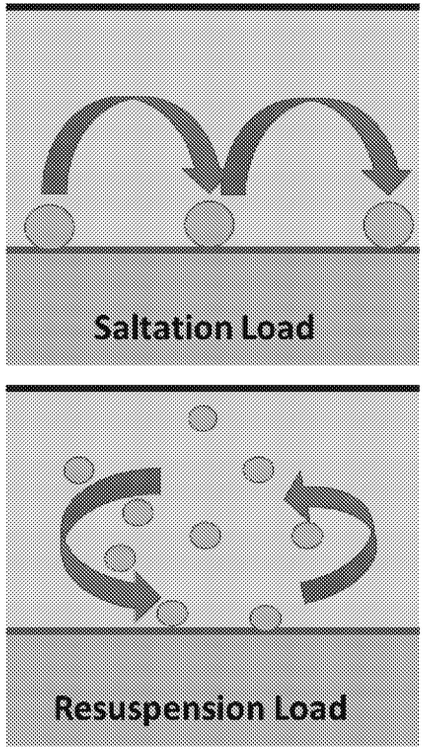
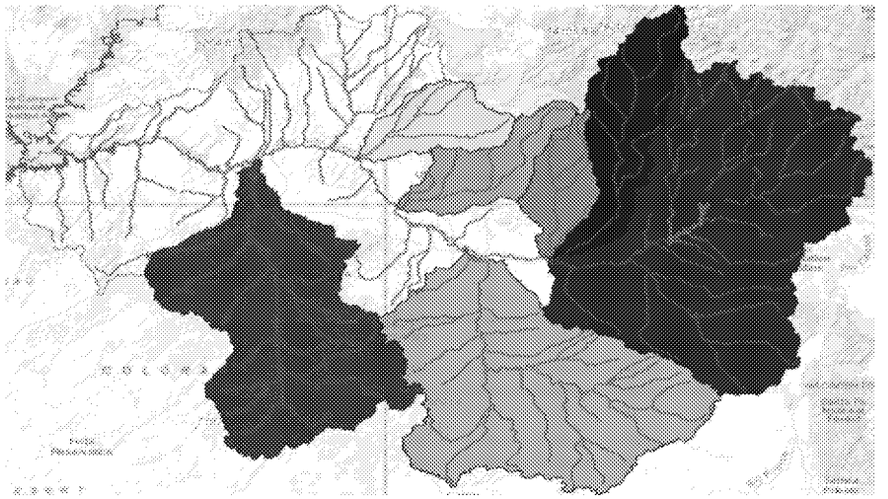
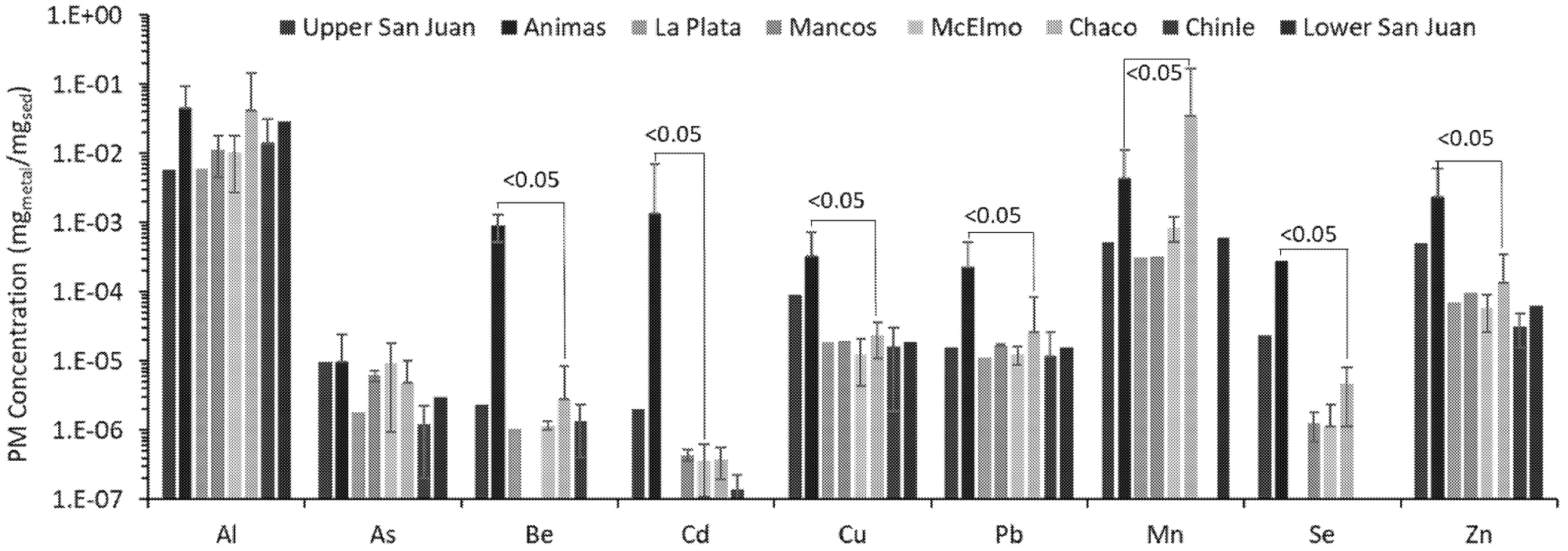


PM Concentration

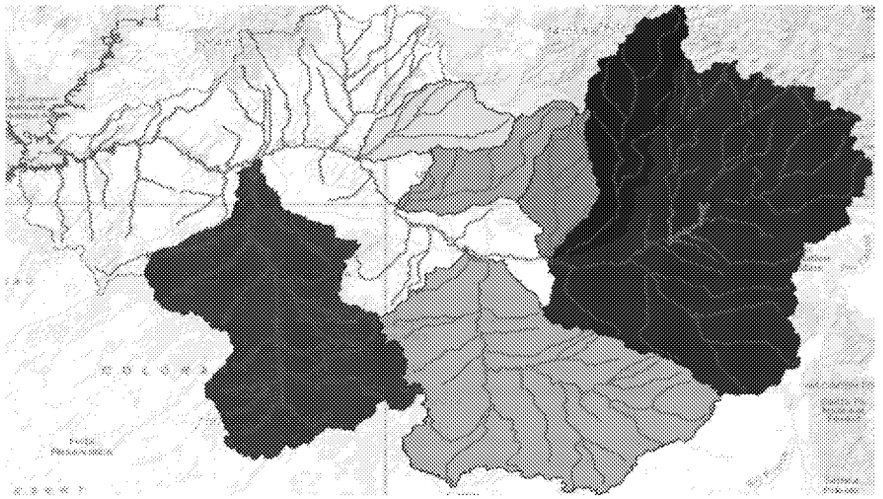
- No distinct PM concentrations with runoff category
  - Except ↑ As (snow) and ↑ Se (rain) in Animas
  - Except ↑Mo and Se (rain) in Mancos
- Animas PM concentrations > other tributary PM concentrations
  - Except = Al and As
  - Except ↑Mn in Chaco

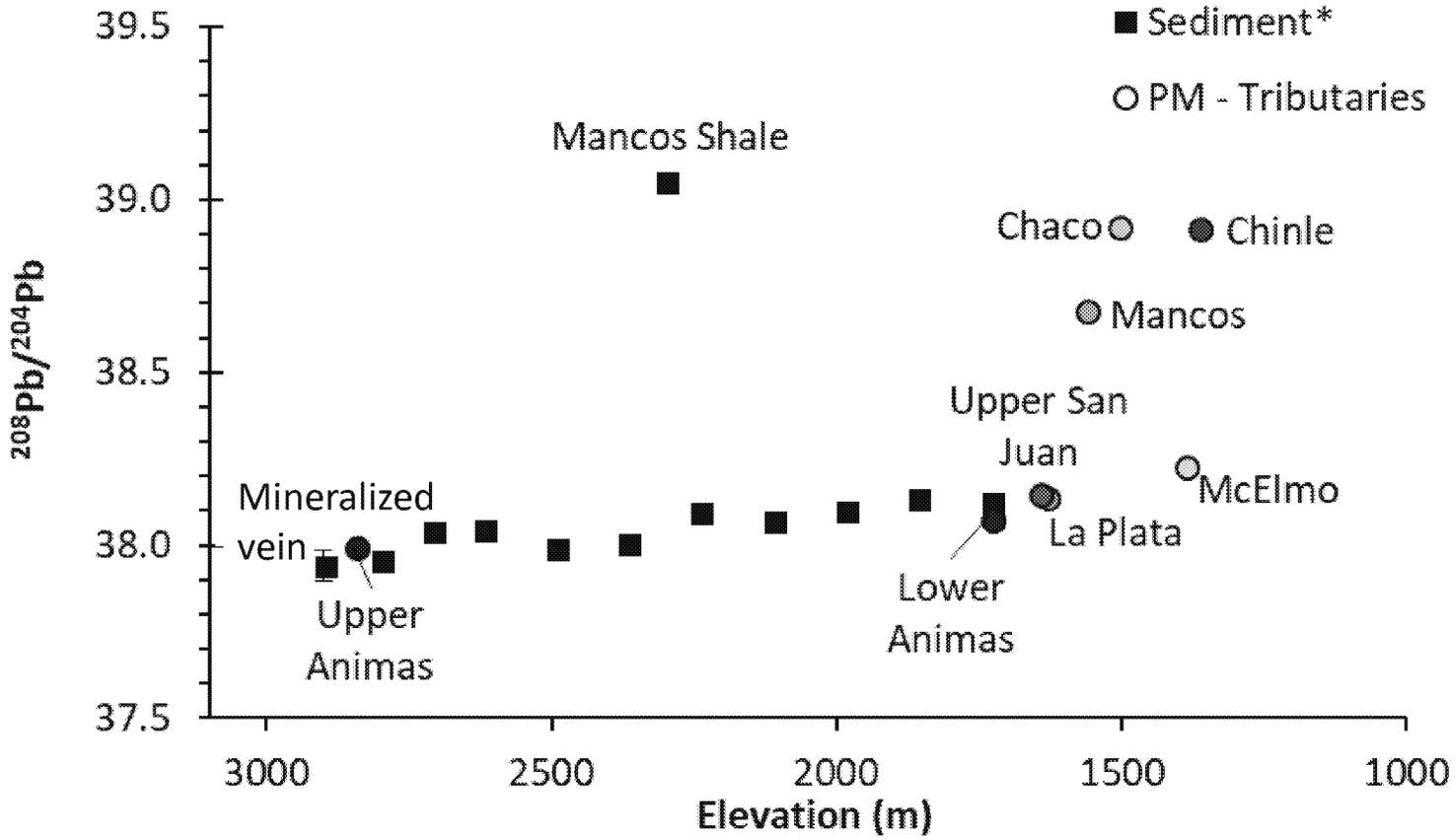




Pb Isotopes

- Pb-isotopes can be used to 'fingerprint' different sources of Pb
- Bed sediment (Church et al., 1997) = PM
- Animas, La Plata, and McElmo → Mineralized vein
- Mancos River → Mancos Shale/Mineralized vein
- Chaco and Chinle → Chinle Sandstone?





Church et al., 1997

Summary of upstream tributaries

Mining signatures: Animas snowmelt

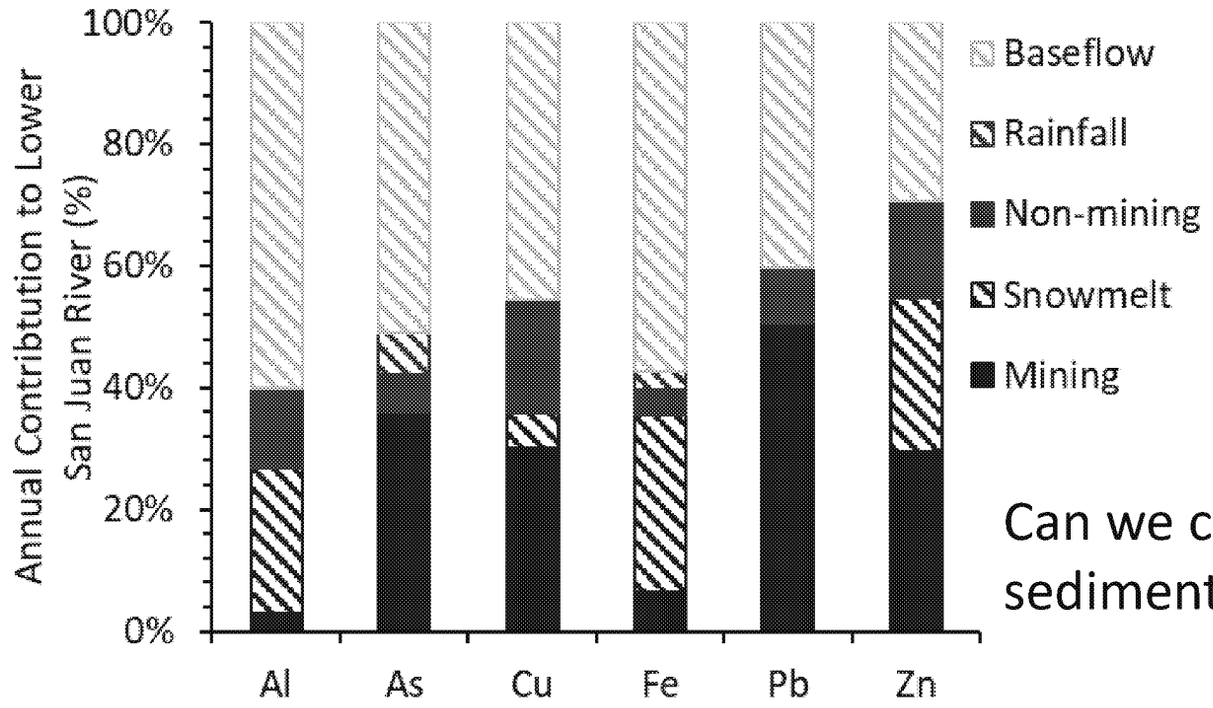
- PM loads → mining
- ↑ PM concentrations
- Pb isotope of mineralized vein

Non-mining signatures: Chinle and Chaco rainfall

- PM loads → Chinle Sandstone
- ↓ PM concentrations
- Pb isotope of Chinle?

Mixed signatures: Baseflow

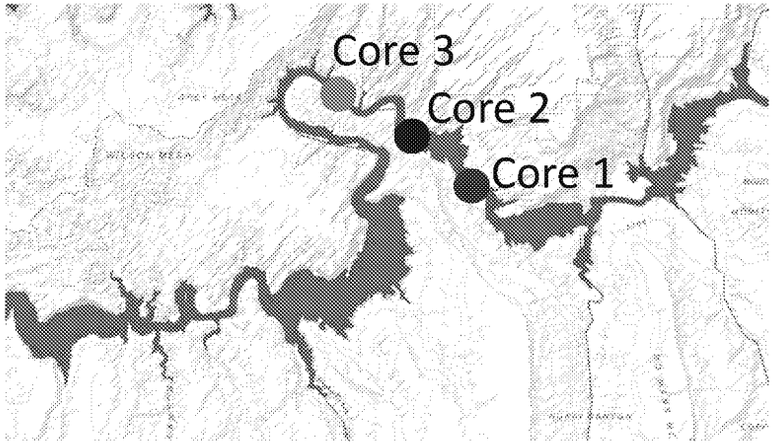
- Animas, La Plata, McElmo, Mancos, rainfall
- Mancos, Upper San Juan snowmelt



Can we connect signatures to Lake Powell sediment?

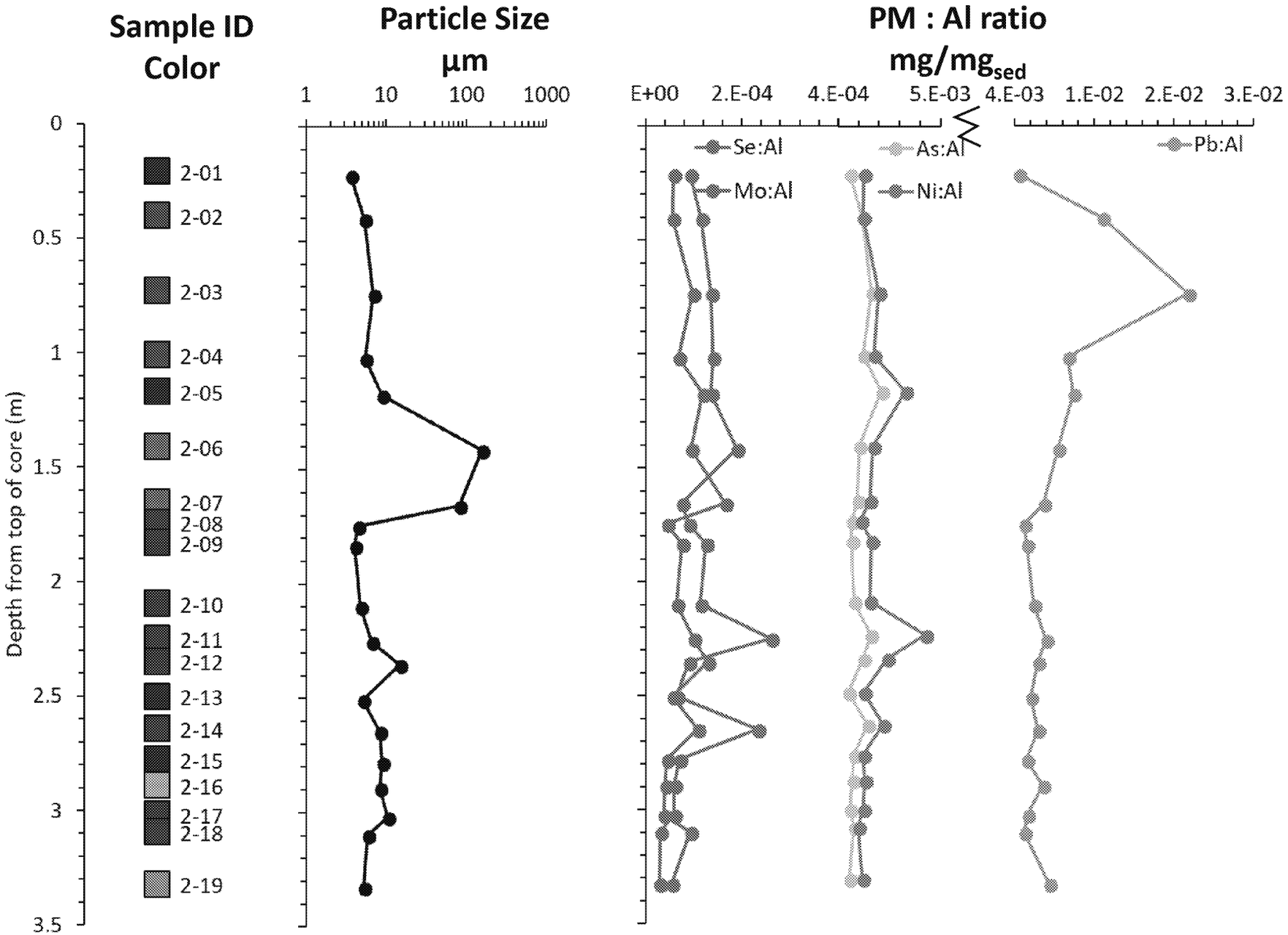
Sediment Cores

- USGS collected 3 cores in 2011
- Core 2 = 3.37 m
  - 1.7 years (sed traps) – 7 years (Vernieu, 2012)



Link sediment to tributaries:
- Pb Isotopes
- Color
- PM Concentration

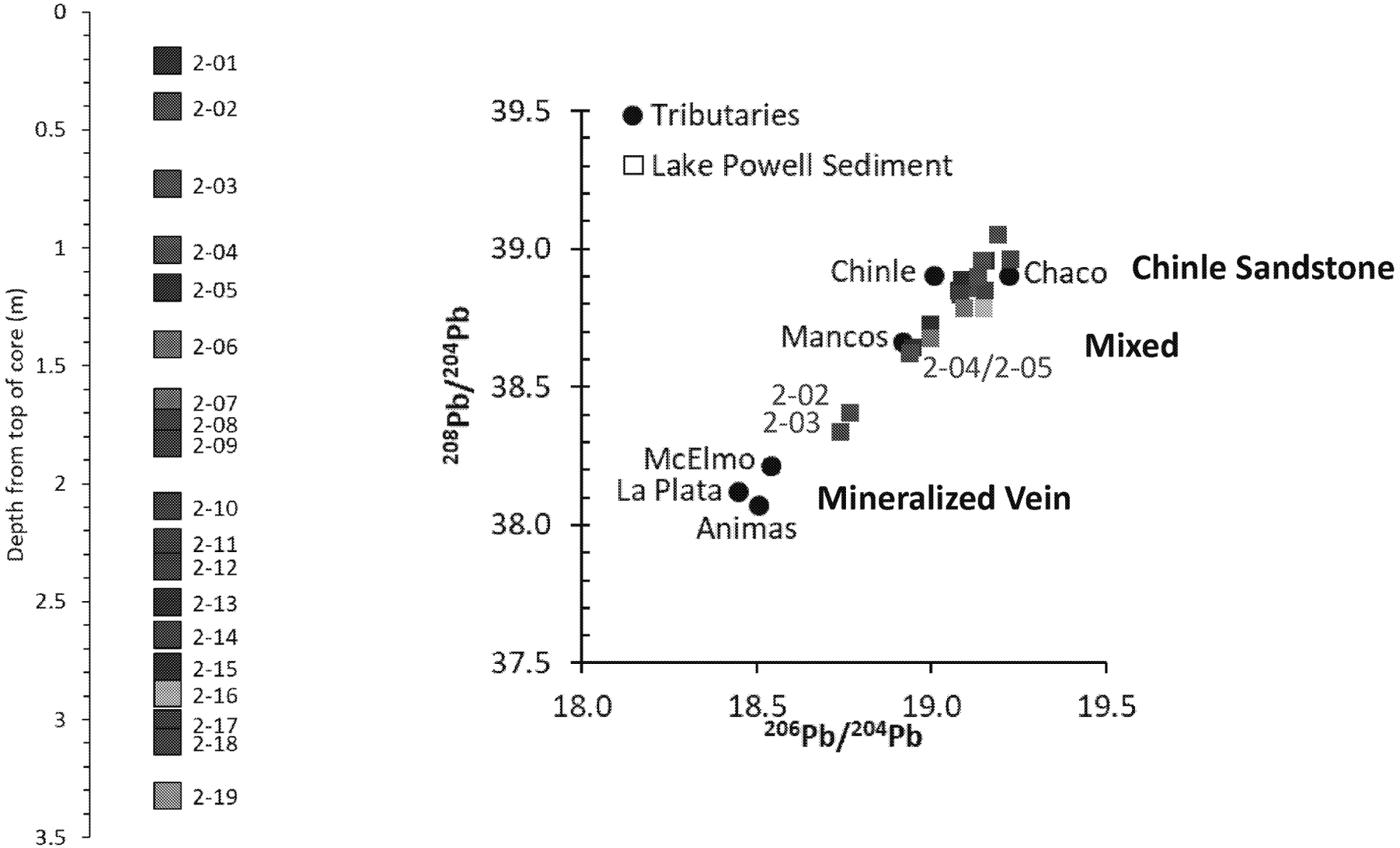
Sediment Cores



UDEQ Long-term Monitoring Plan, 2016

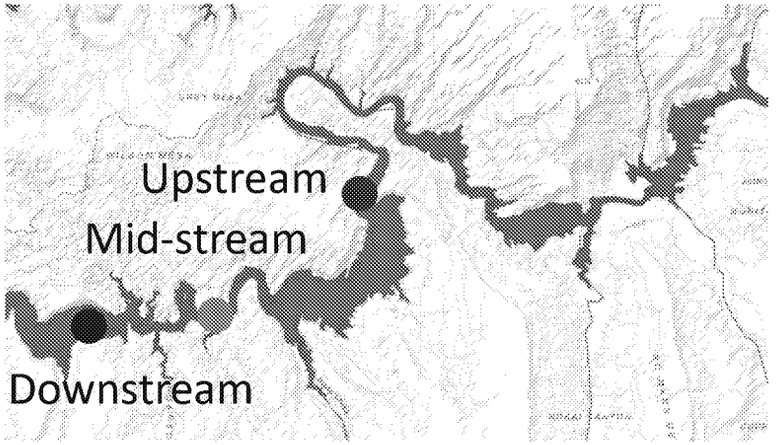
Sediment Cores

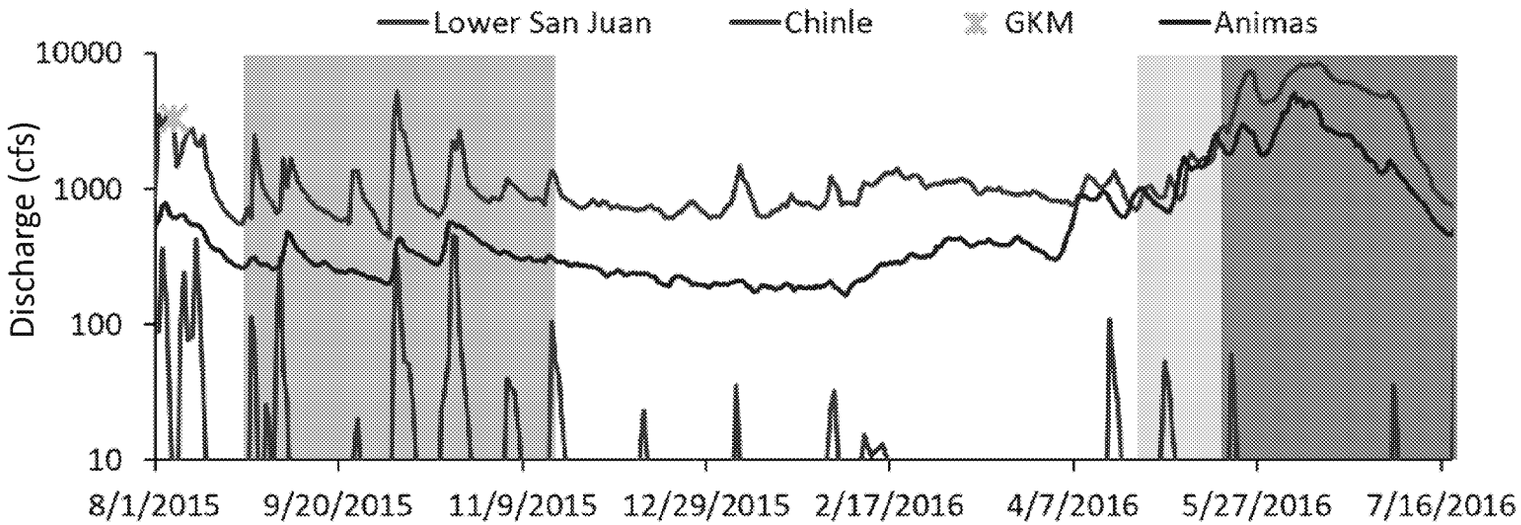
- 2-02 and 2-03 → mineralize vein → mining signature → Animas Snowmelt
- 2-01, 2-12, 2-13, 2-15, 2-18 → red in color → enriched Pb → non-mining → Chinle/Chaco rainfall



Sediment Traps

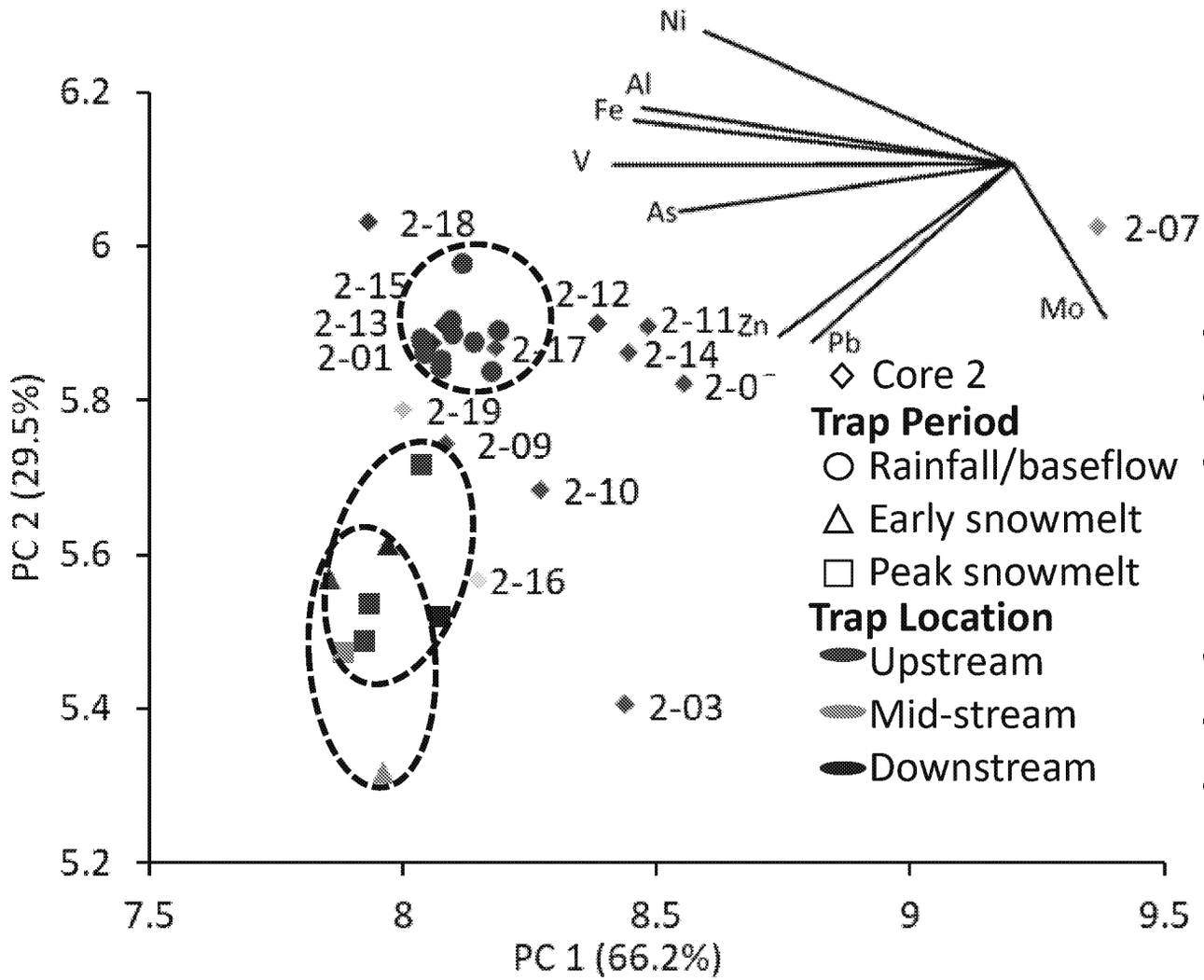
- USGS deployed sediment traps:
  - 3 periods – rainfall/baseflow, early snowmelt, peak snowmelt
  - 3 locations – upstream, mid-stream, and downstream

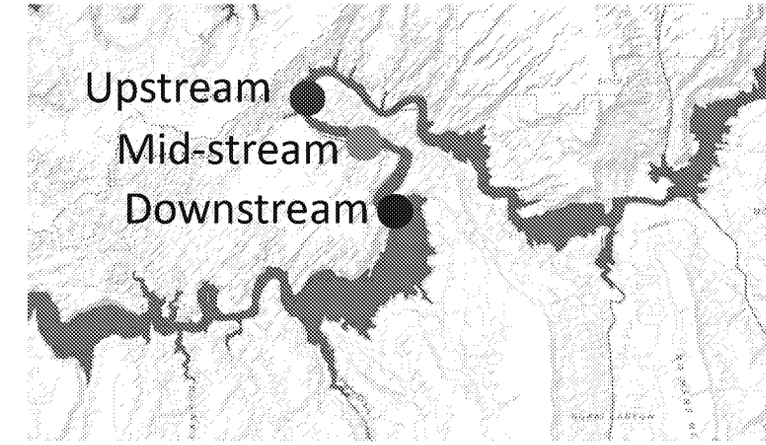




Sediment Traps

- PCA = Principal Component Analysis
- Linear combination of PM concentrations

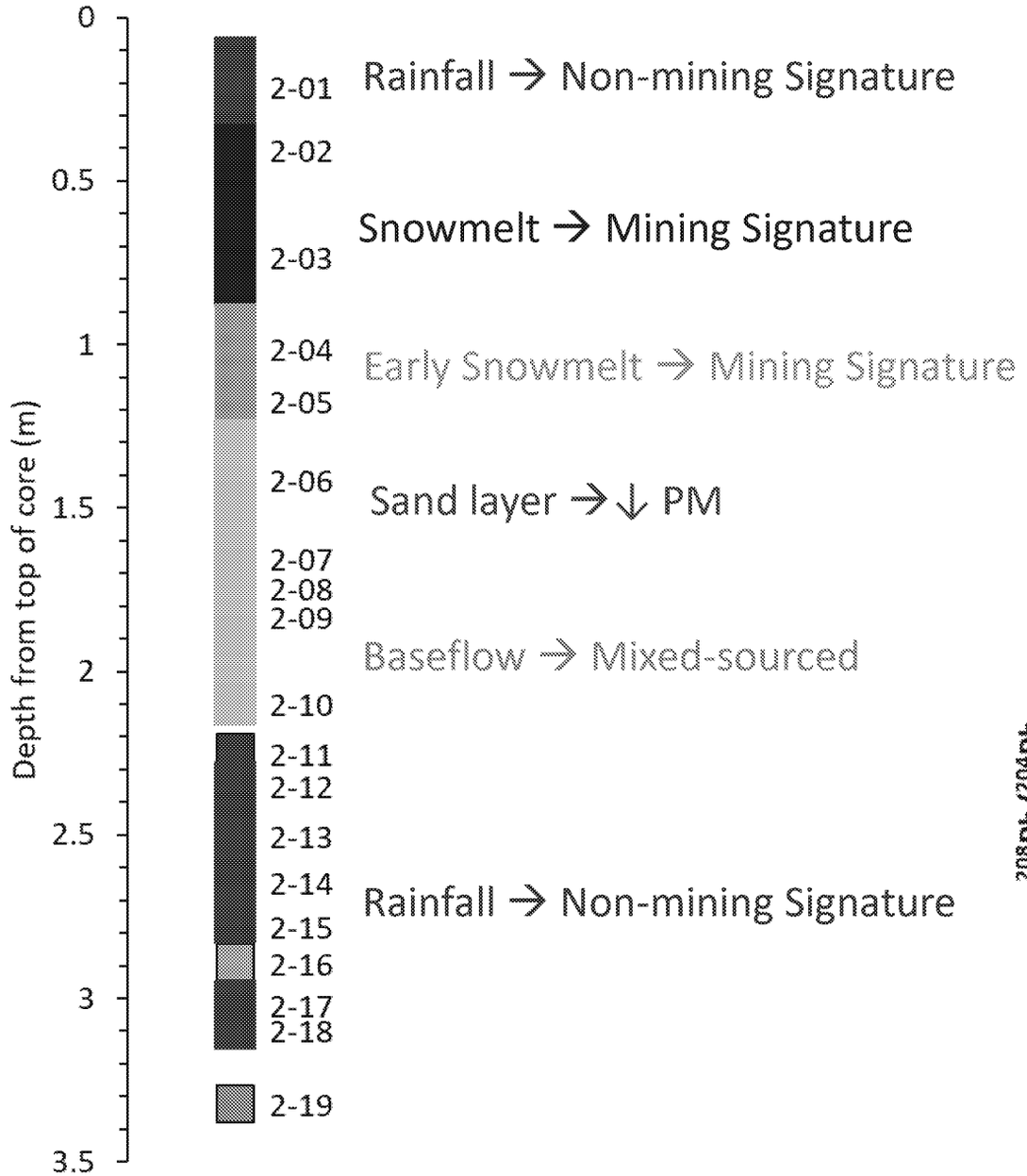


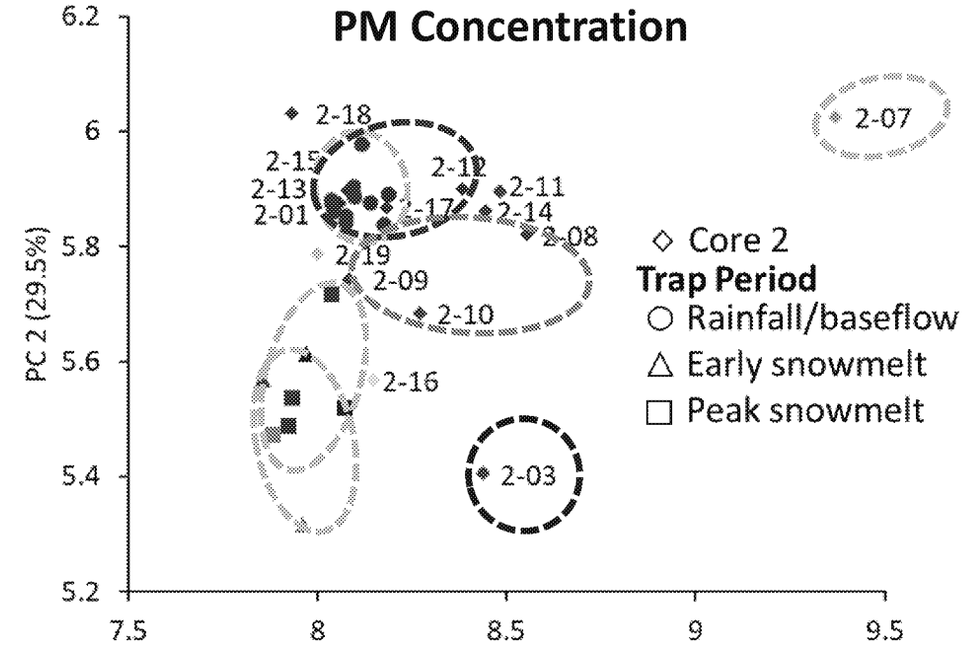


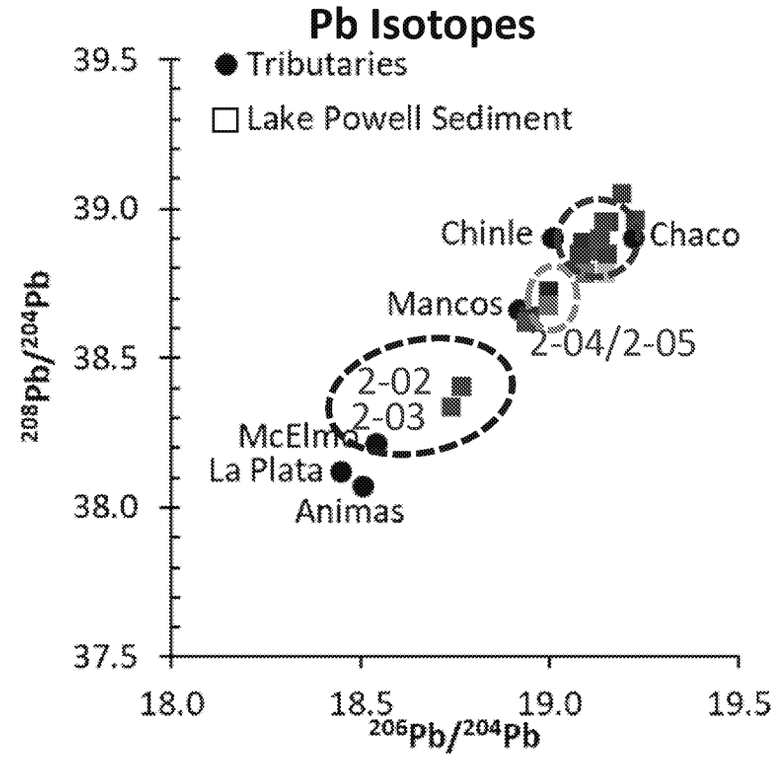
- Early snowmelt similar to peak snowmelt
- Rainfall/baseflow ↑Ni, Al, and Fe
- Snowmelt ↑As, Zn, and Pb

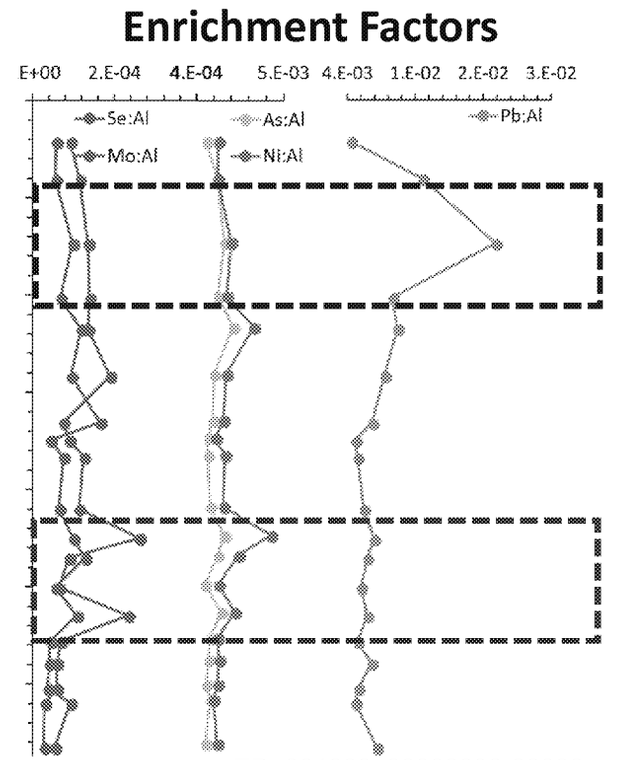
- 2-03 and 2-16 similar to snowmelt
- 2-07 is different
- 2-12 to 2-18 similar to rainfall/baseflow

Sediment Cores

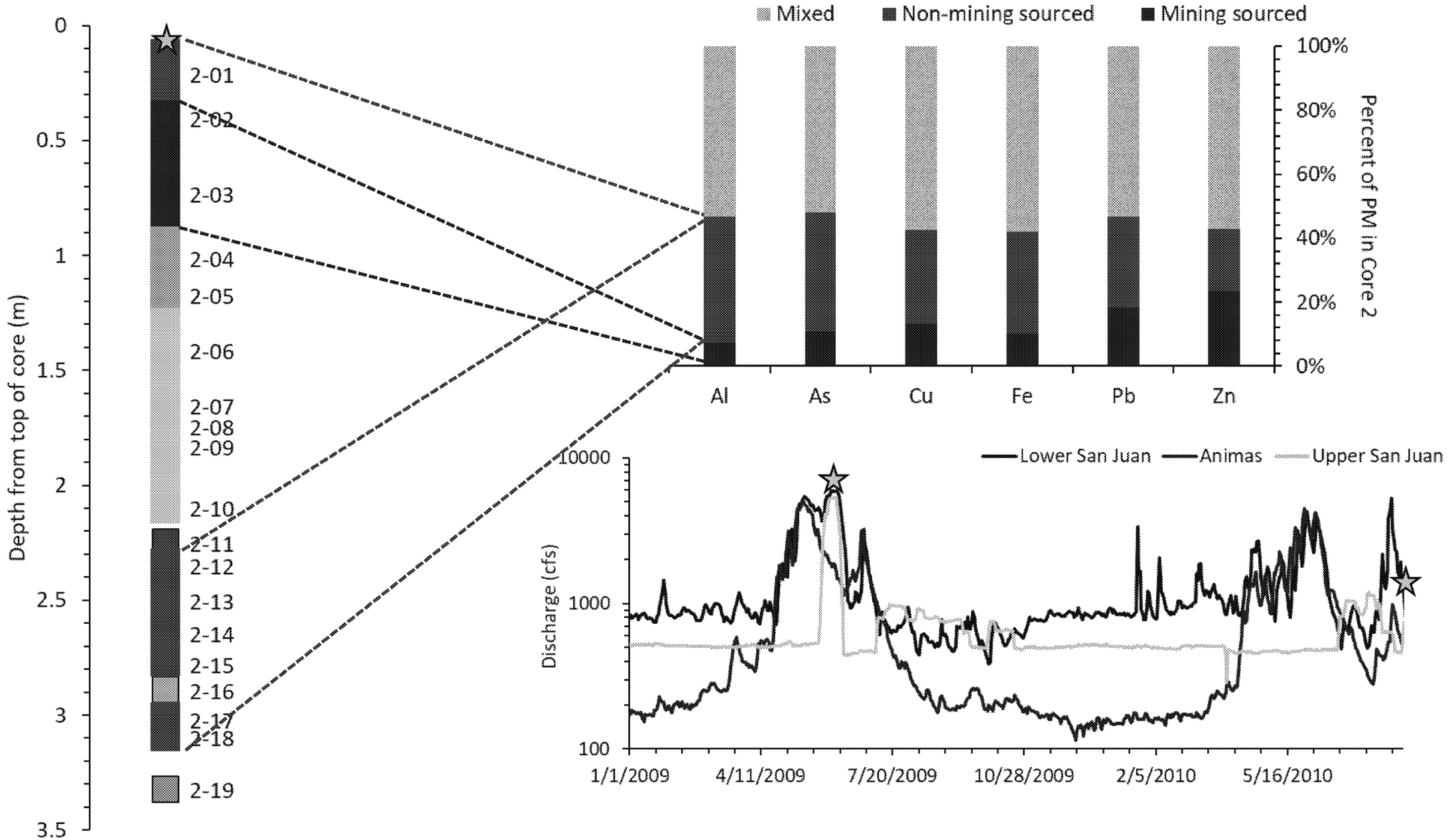








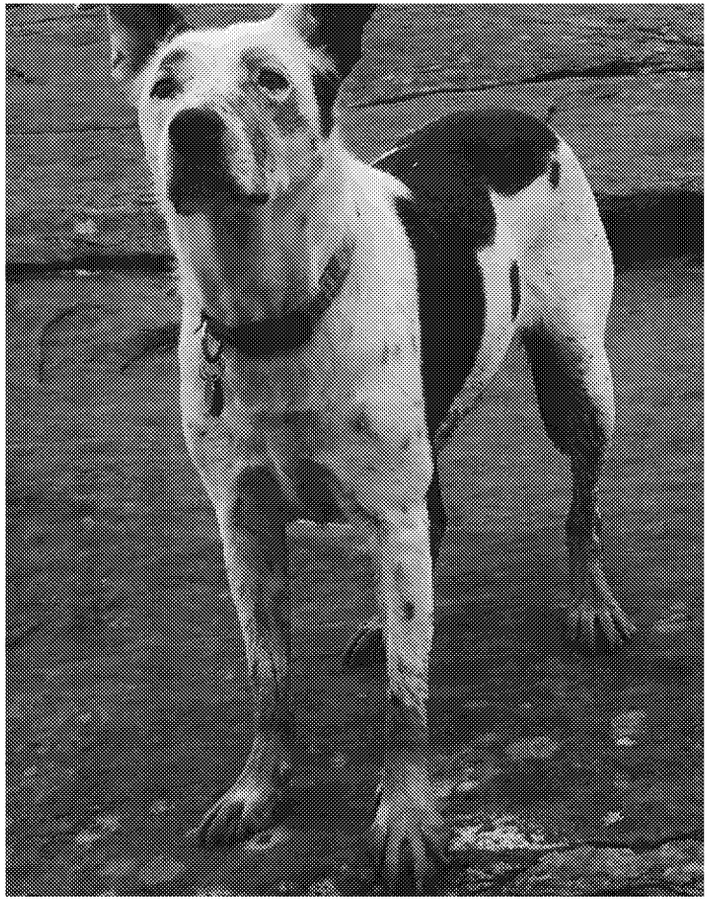
Sediment Cores



Conclusions

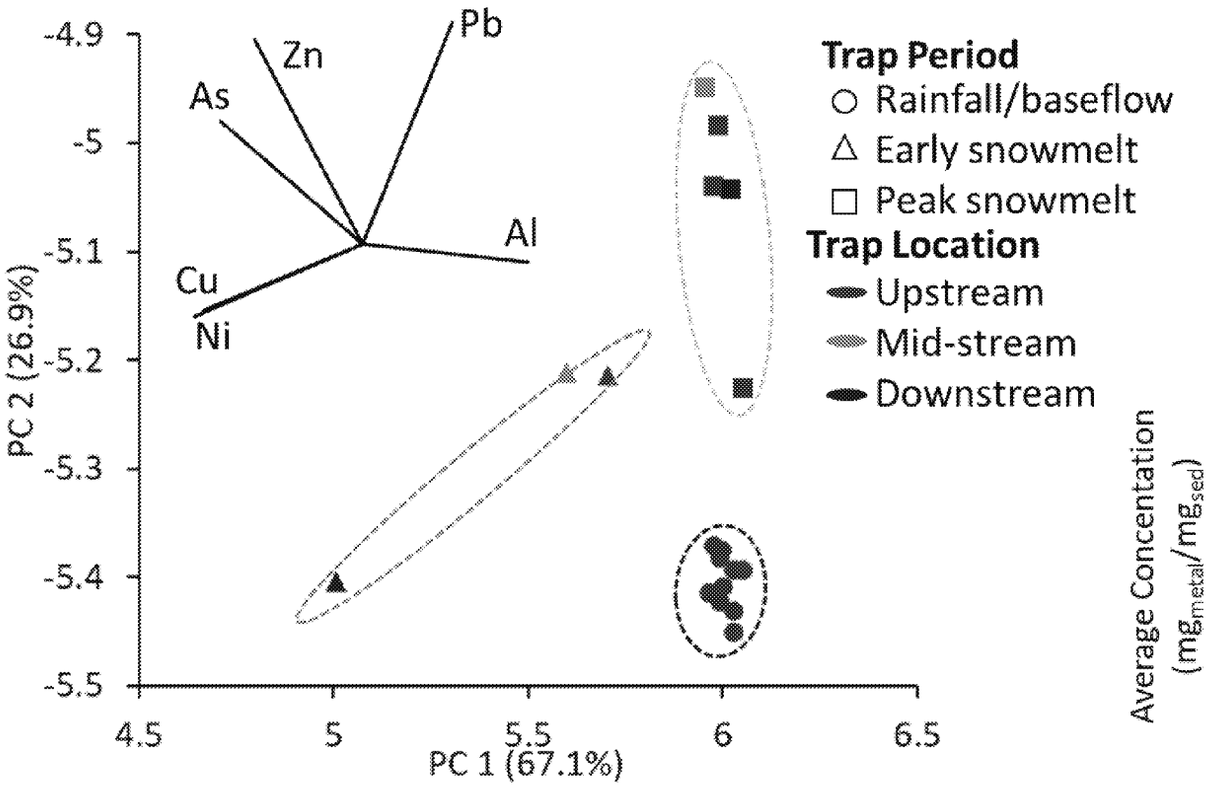
- Animas snowmelt → PM mining
- Chinle/Chaco rainfall → PM non-mining
- Other tributaries → mix of sources

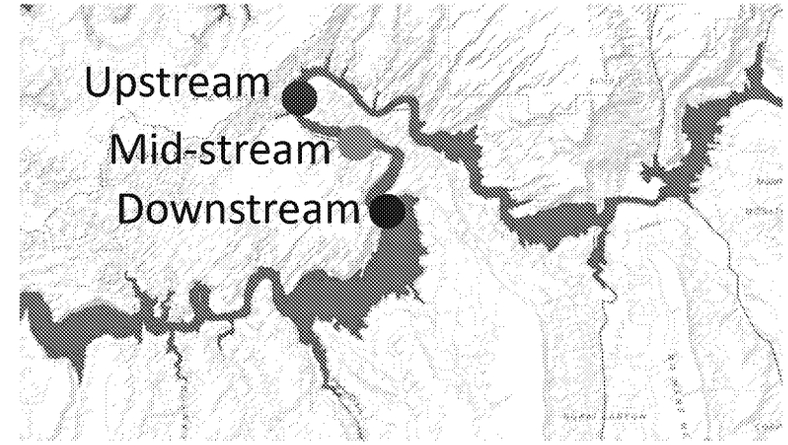
- Use tributary signatures to determine age of sediment core
- Mass of metals sourced from mining

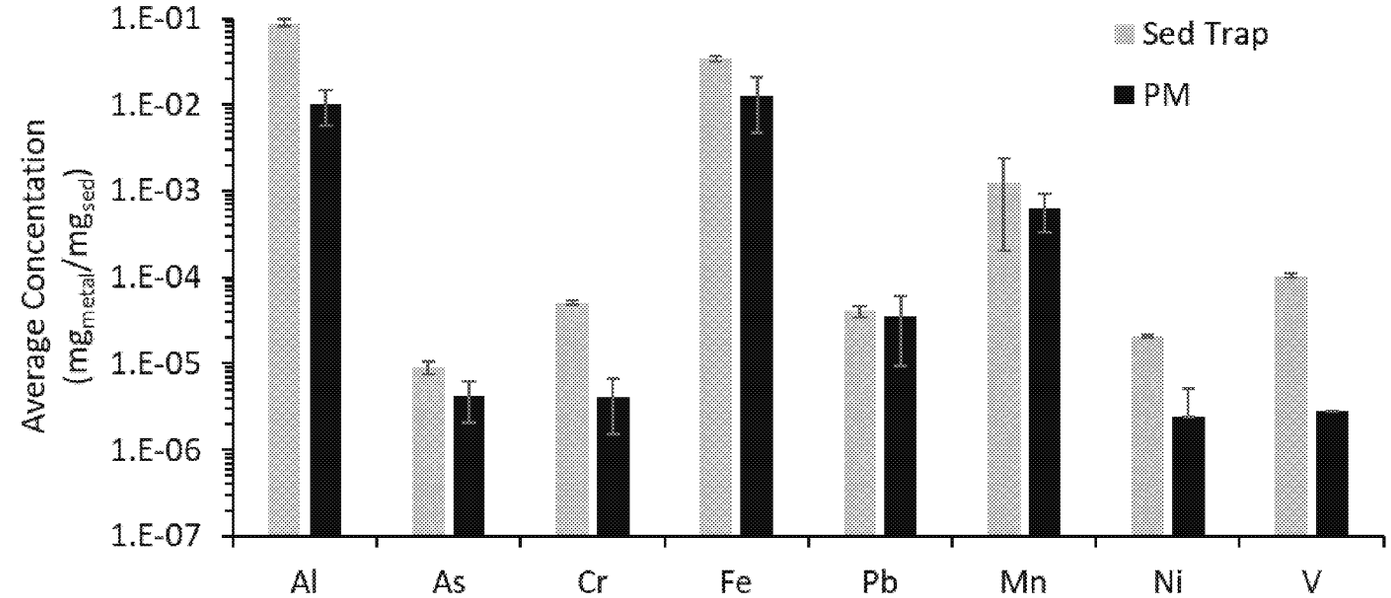


Questions?

Sediment Traps





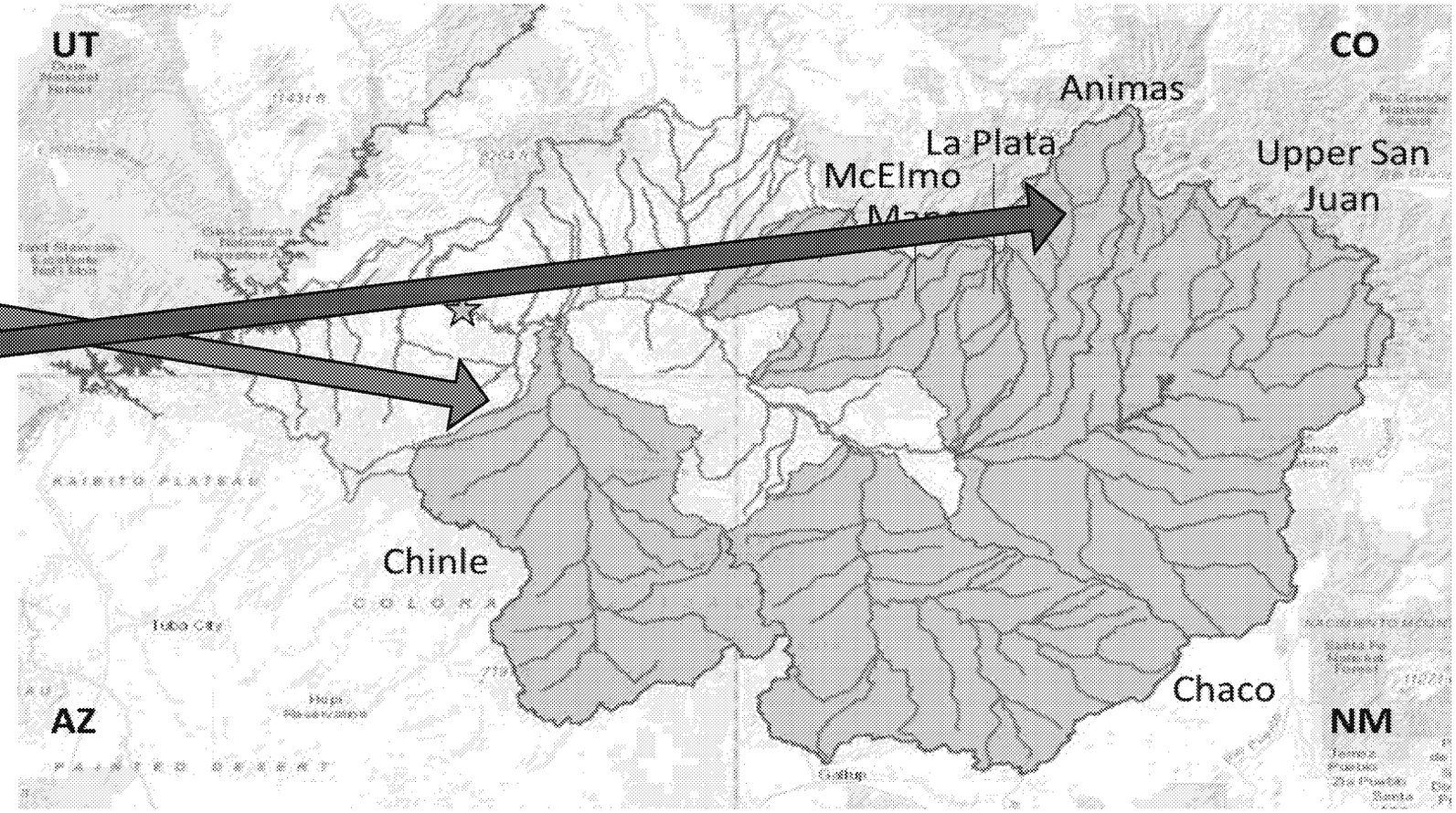


- Larger variation between locations than between runoff event
- Peak snowmelt ↑Pb, Zn, and As
- Early snowmelt ↑Cu and Ni

- Different digestion methods
- Sed traps >> greater than PM concentration

Can we differentiate mining versus non-mining PM in Lake Powell?

UDEQ Long-term Monitoring Plan, 2016



Tie sediment signatures back to upstream tributaries:

1. Sediment Cores
2. Sediment Traps
3. Water Quality Data