Geophysical Characterization of Inactive Mine Tailings - A First Step for Revegetation

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RISE Symposium – October 2, 2010

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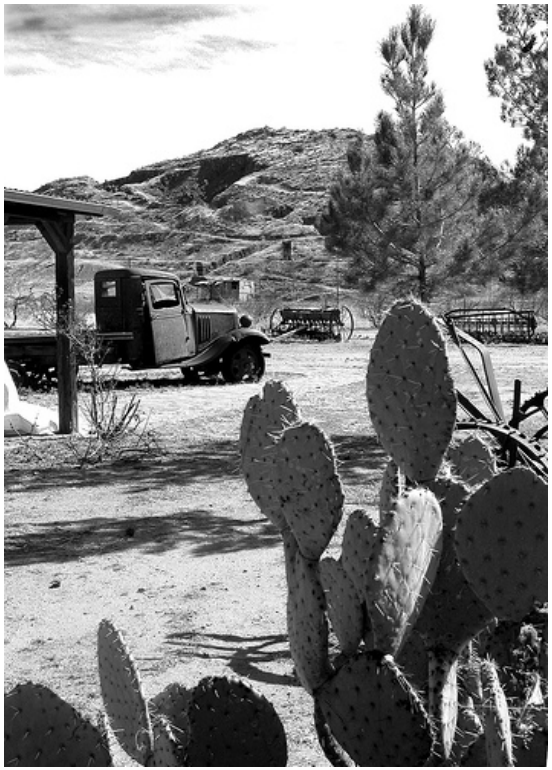
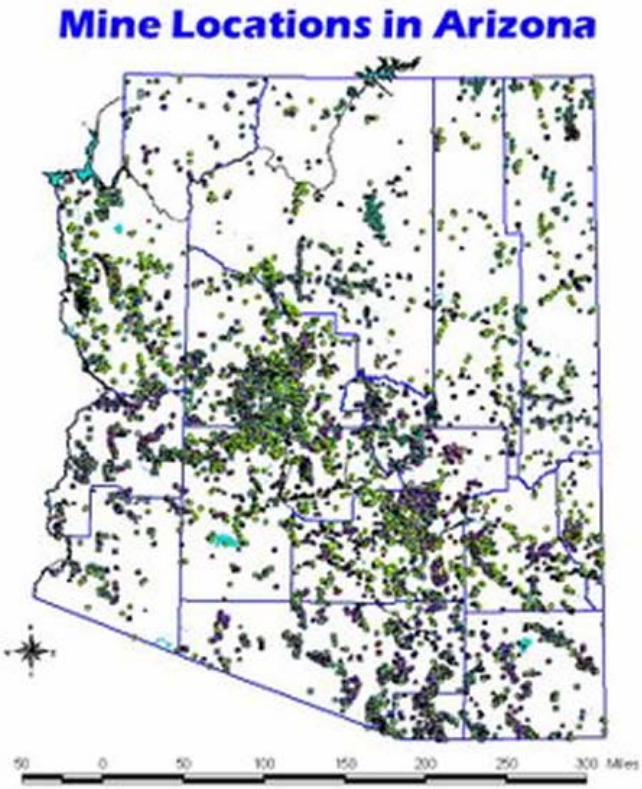
THE UNIVERSITY OF ARIZONA
Arizona's First University.

Mining in Arizona

- **In Arizona alone there are over 100,000 inactive or abandoned mine sites.**
- **They cover ~137,000 acres and pollute nearly 200 miles of surface water resources.**





Environmental Impacts

- **Wind & Water Erosion**
- **Runoff and Leaching of Hazardous Chemicals and Associated Public Health Concerns**
- **Loss of Biodiversity**
- **Aesthetic Appeal**

Seep draining a pile of mine tailings along Silver Creek, near Park City, Utah.

Mine Tailings – Current Remediation Approaches

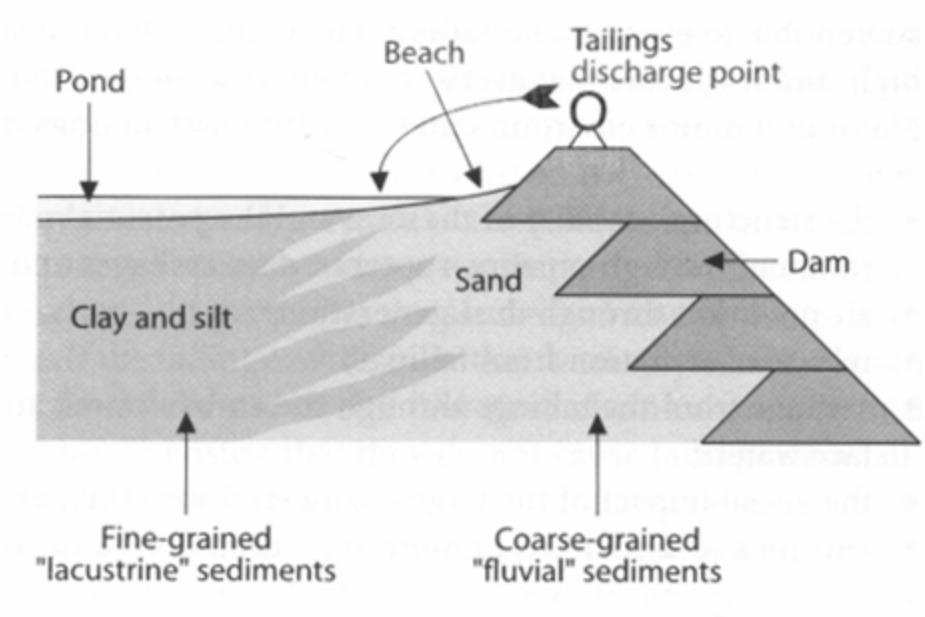
- **Wind Erosion:** Application of polymers for surface stabilization
- **Leaching:** Establishment of capillary barriers
- **Mass Movement:** Revegetation (biosolids, microbiology, chemistry)

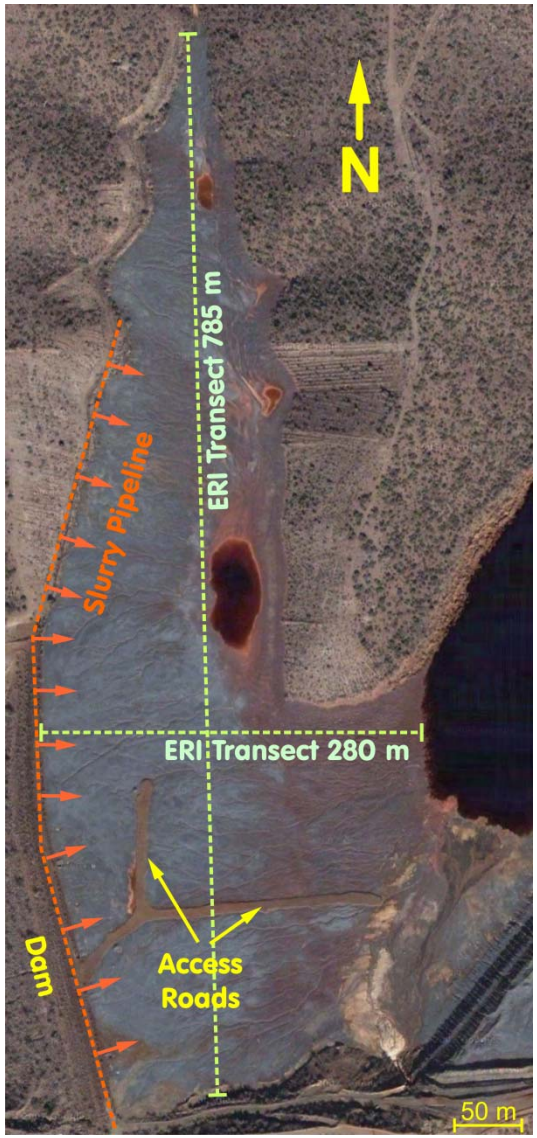
All revegetation measures in arid environments usually only work with startup irrigation, which is not desired given the already strained water resources.

Revegetation - Associated Challenges

- **Little is known about adverse and highly variable physical and hydraulic properties of mine tailings and their spatial distribution.**

- **Tailings slurries are deposited in patterns similar to a river delta; coarser materials close to the discharge point and finer materials towards the decant pond.**





Objectives

- **To investigate the applicability of geophysical methods (EMI, ERI) for large scale characterization of physical and hydraulic properties.**

- **To create a physically favorable environment for plant growth by taking advantage of seasonal rain and increasing potential soil water storage.**

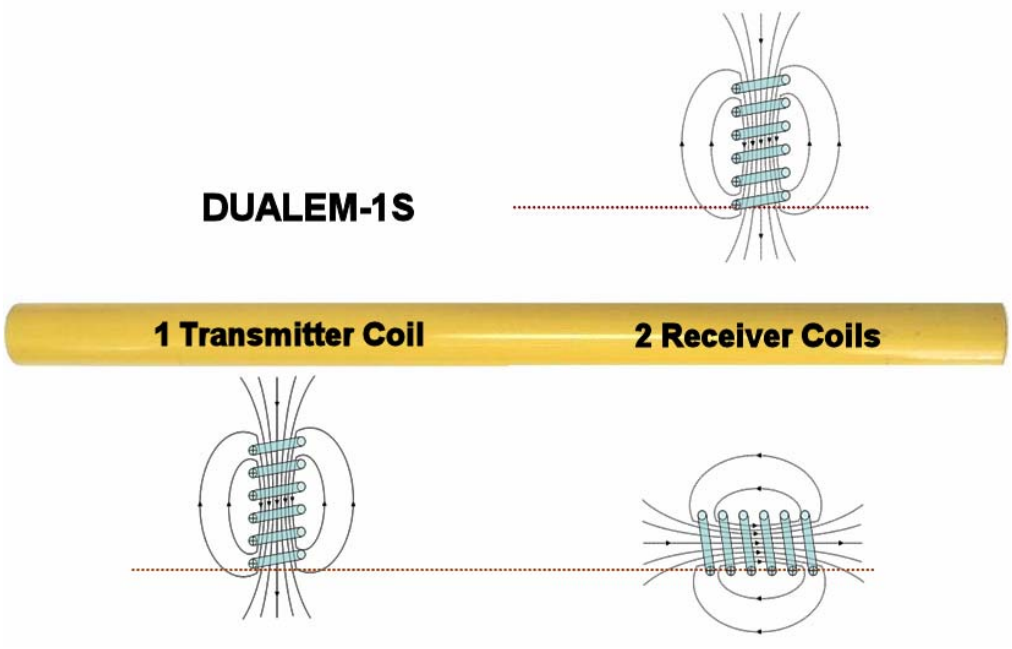
Slag piles at Resolution Copper Mining LCC in Superior, AZ.

Study Site

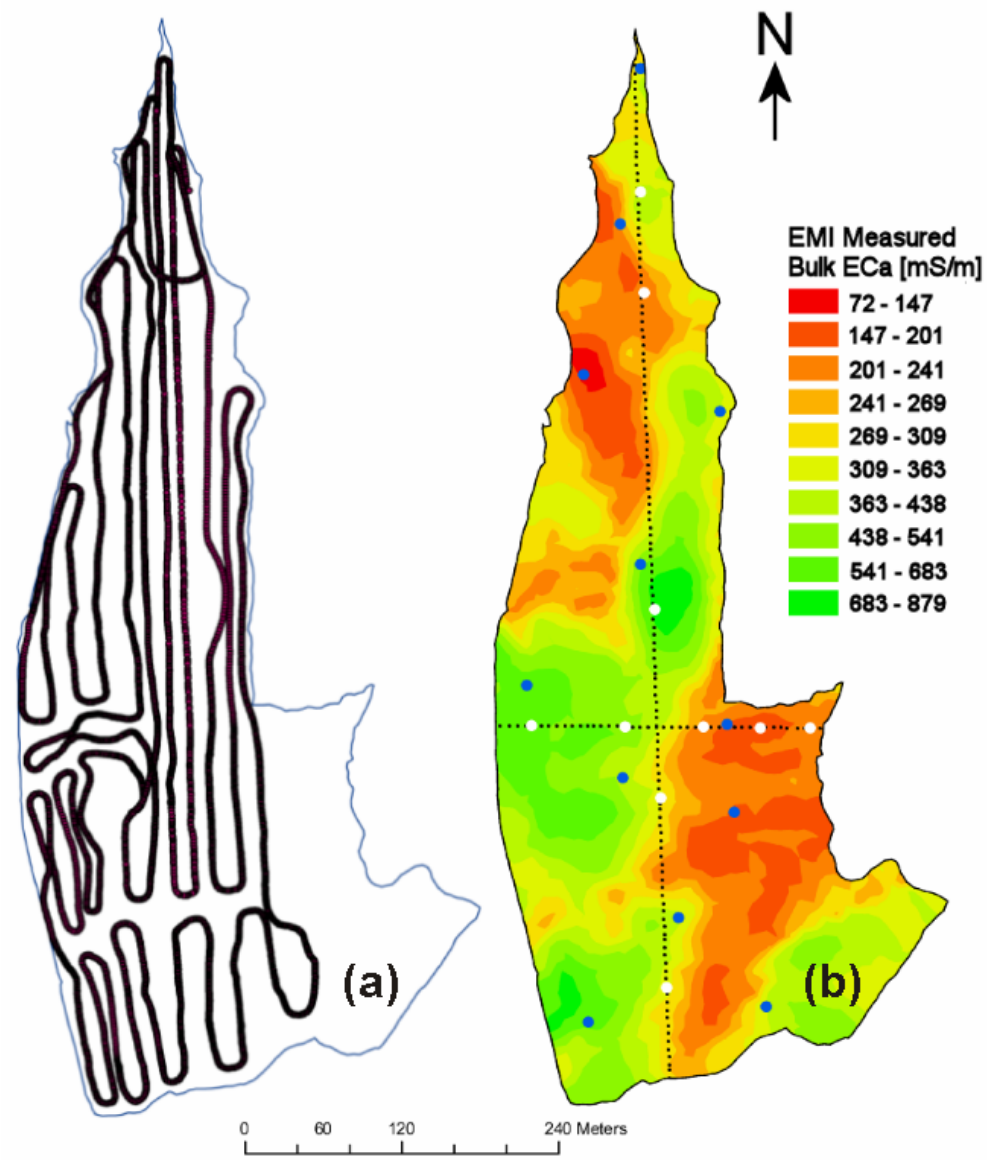
Methods - Geophysical Characterization

Electromagnetic Induction (EMI) with DUALEM-1S

- **A time-varying electromagnetic field emitted from the transmitter coil induces weak circular eddy current loops in the soil, which in turn generate a secondary electromagnetic field that differs in amplitude and phase. From the magnitude of amplitude and phase differences between primary and secondary fields apparent electrical conductivity EC_a is inferred.**



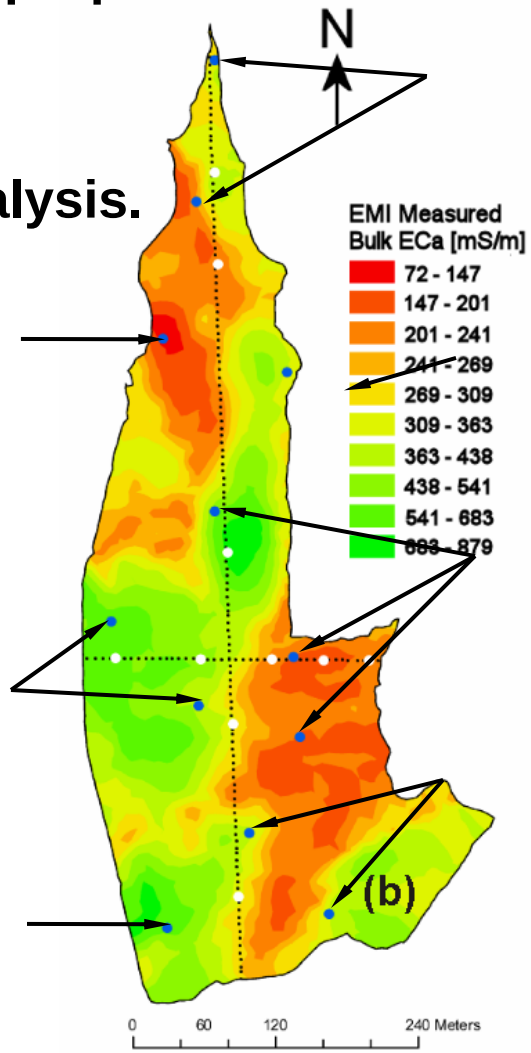
EMI with DUALEM-1S



- **(a) Bulk ECa measured with the DUALEM-1S.**
- **(b) EMI near-subsurface conductivity map generated with ArcGIS. Blue dots indicate sampling locations determined onsite with ESAP-95 (Lesch et al., 2000); white dots indicate visually determined sampling points along transects.**

EMI with DUALEM-1S

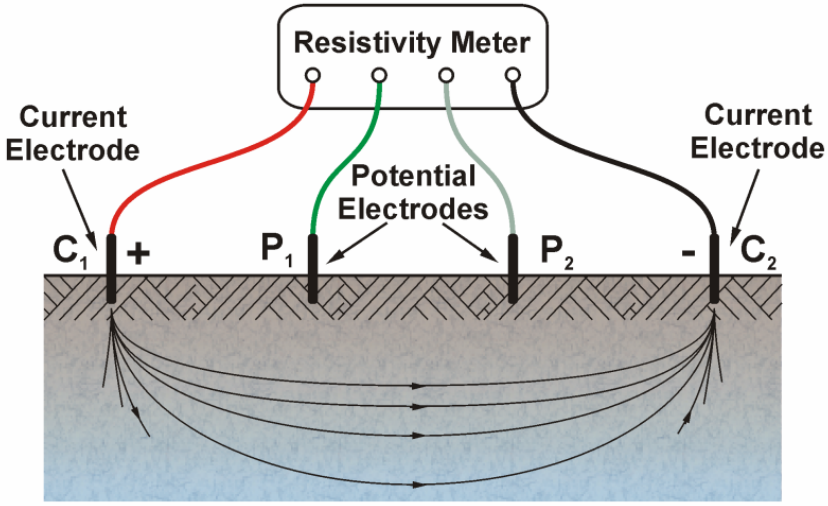
- EC_a maps were generated onsite and used in combination with a response surface method (RSM) to determine appropriate locations for core sampling.
- Core samples were extracted shortly after the surveys and transferred to the laboratory for analysis.



Methods - Geophysical Characterization

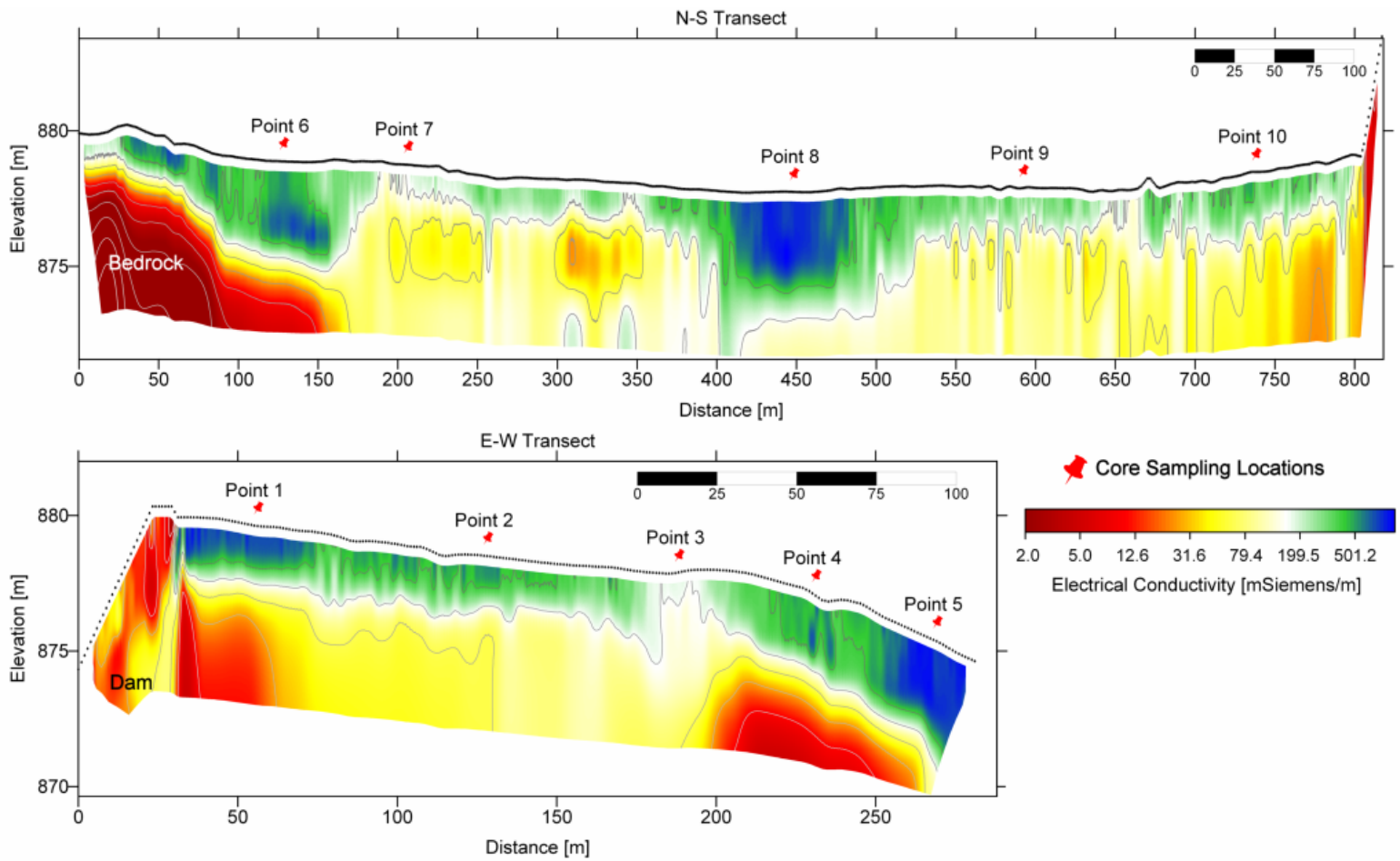
Electrical Resistivity Imaging (ERI) with SYSCAL PRO Switch

- **ERI non-invasively images state variables with high spatial resolution if they give rise to a contrast in electrical conductivity. Galvanically coupled four-electrode measurements were collected using a quasi-direct current injection over two electrodes and measurement of the potential difference between the remaining two electrodes.**



ERI with SYSCAL PRO Switch

- **As with EMI, maps were generated directly in the field and locations with contrasting resistivity responses were chosen for immediate core sampling.**



Laboratory Analysis (86 Samples)

- Oven drying at 105°C to determine water contents and bulk densities
- Dispersion to separate primary particles
- Measurement of pH and EC_s in water extract
- XRD analysis
- Particle size analysis with Laser Diffractometry

Preliminary Results - 01

Correlation EMI EC_a – Mean Particle Diameter

- **While first results indicate large correlation coefficients between apparent surface electrical conductivity (EC_a) and tailings texture (expressed as mean particle size or clay fraction), all other measured parameters have small to medium correlation coefficients**

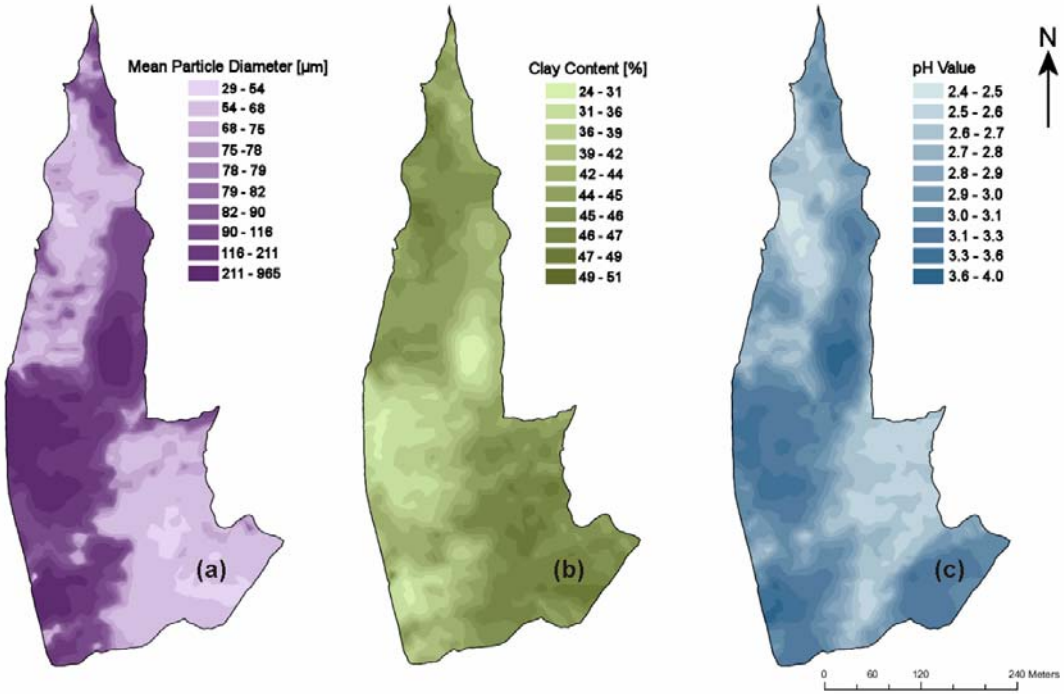
- **It is interesting to note that the clay fraction is negatively correlated to EC_a**

- **Major minerals determined with XRD were:**
  - **Pyrite** (highly conductive - associated with larger particles)
  - **Quartz** (insulator)
  - **Illite and Muscovite** (high resistivity - associated with finer particles)

Preliminary Results - 02

Correlation EMI EC_a – Mean Particle Diameter

- From EMI measured EC_a we produced a mean particle size map for the top 0.6 m with a multiple linear regression (MLR) model.
- Stepwise linear regression was applied to identify EC_a followed by latitude & longitude as significant covariates to fit the MLR model.



Preliminary Results - 03

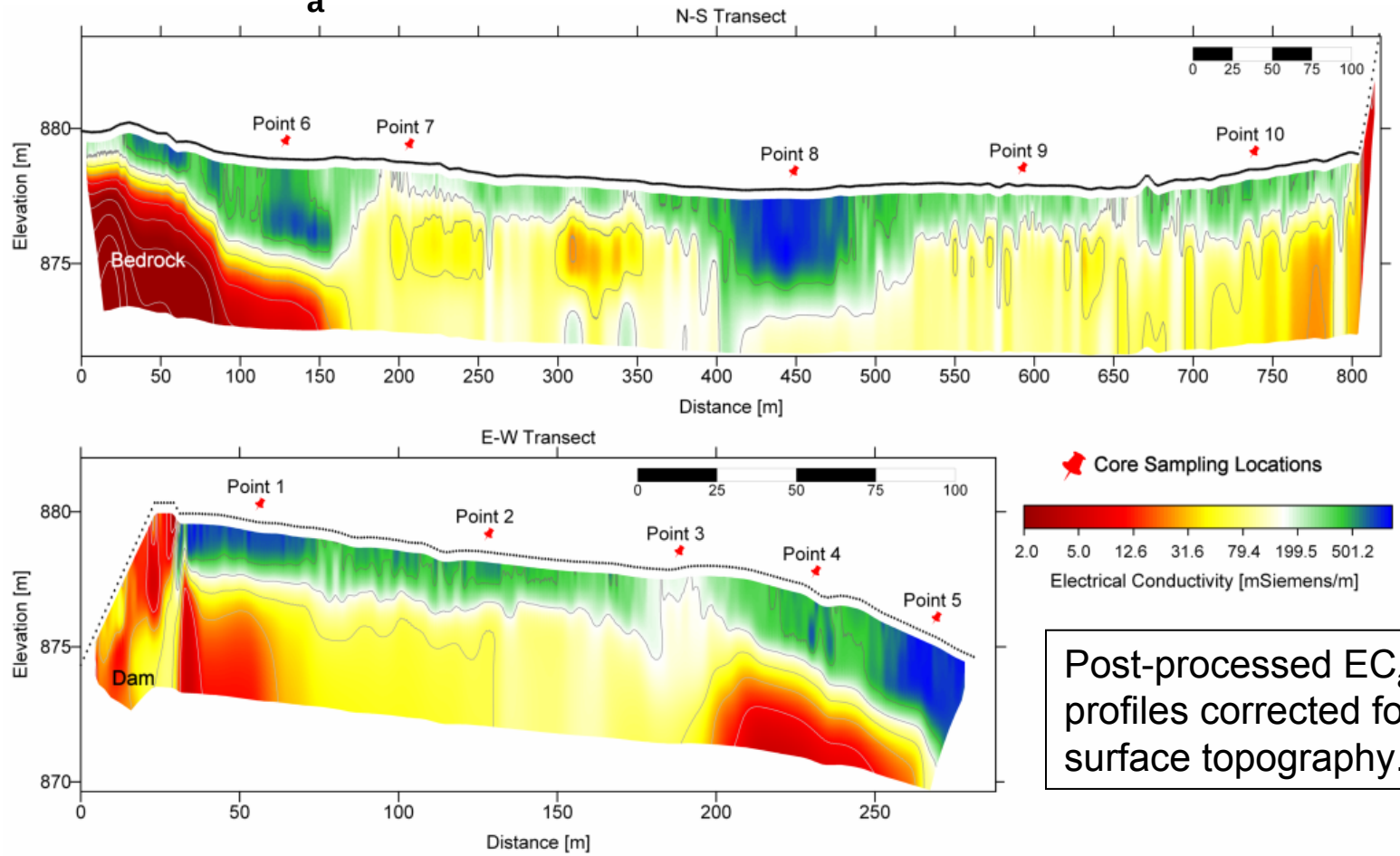
Geochemical Analysis

- **Average pH ~4 (increases with depth)**
  - Max ~ 7.5
  - Min ~ 2.0

- **Average EC_s ~16 mS/cm (decreases with depth)**
  - Max ~ 30 mS/cm
  - Min ~ 4.3 mS/cm

Ongoing and Future Work

- **We recently finished laboratory measurements for core samples extracted along the transects and are currently working on the statistical analysis to correlate lab measurements to post-processed EC_a distributions.**



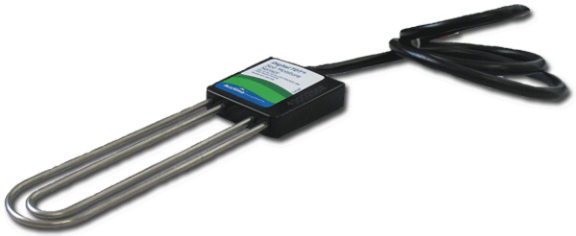
Post-processed EC_a profiles corrected for surface topography.

Future Work

- **Based on generated property maps we will chose 5 locations with highly contrasting physical and geochemical properties and install arrays of TDT sensor for monitoring moisture dynamics throughout the season.**

- **Obtained data, in combination with simultaneously measured atmospheric conditions, will be used to parameterize numerical models for simulating moisture dynamics and geochemical processes**

- **Simulations will yield the scientific basis for design of cost-efficient and sustainable vegetative covers.**



Acknowledgements

- **University of Arizona**
  - Grey Nearing
  - Mercer Meding
  - Phyllis Berger
  - Pamela Gallo
  - Marcel Schaap
  - Janick Artiola
  - Raina Maier
  - Jon Chorover
- **Utah State University**
  - Scott B. Jones
  - Robert Heinse
- **Resolution Copper Mining LLC**
  - David Salisbury (CEO)
  - Casey McKeon (Environmental Superintendent)
- **This project is funded by the TRIF Superfund Basic Research Program.**