



Civil & Environmental Consultants, Inc.

Stream Restoration on Mining Impacted Watersheds

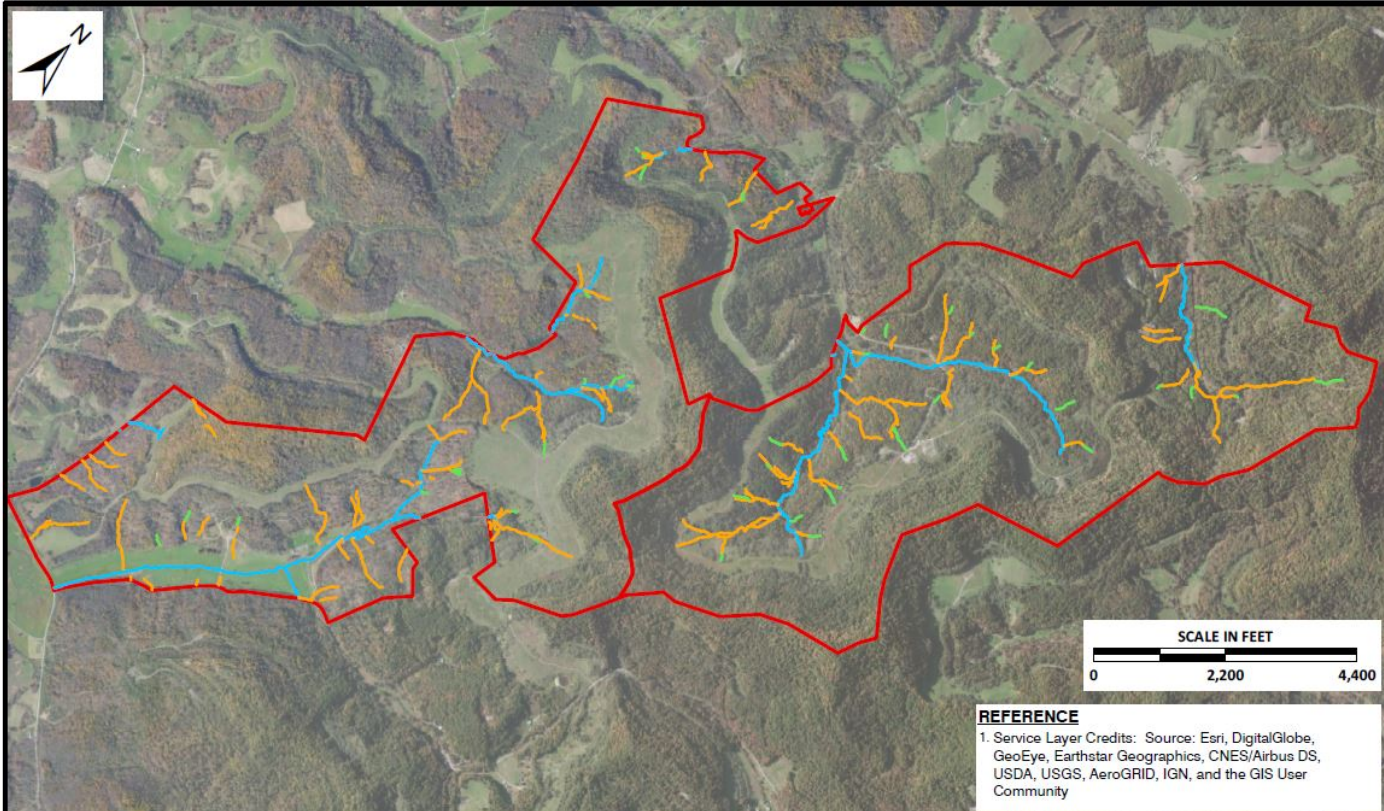
West Virginia Mitigation Banking

Timothy A. Denicola

Purpose

- ▶ Applying natural stream design to improve ecological function of degraded watersheds
 - Restore streams to stable geomorphologic condition
 - Revegetate stream buffers, eradicate invasive vegetation
 - Deed restrict property access
- ▶ Project Area located on Abandoned Mine Land (AML)
- ▶ Reduce AML impacts on restoration success





Study Area

- ▶ Northern WV
- ▶ Surface & Underground
 - Redstone Coal
 - Pittsburgh Coal
- ▶ Partial Reclamation
- ▶ 303(d) - TMDL
 - Total Iron

LEGEND	
	PERENNIAL
	INTERMITTENT
	EPHEMERAL
	PROPERTY BOUNDARY



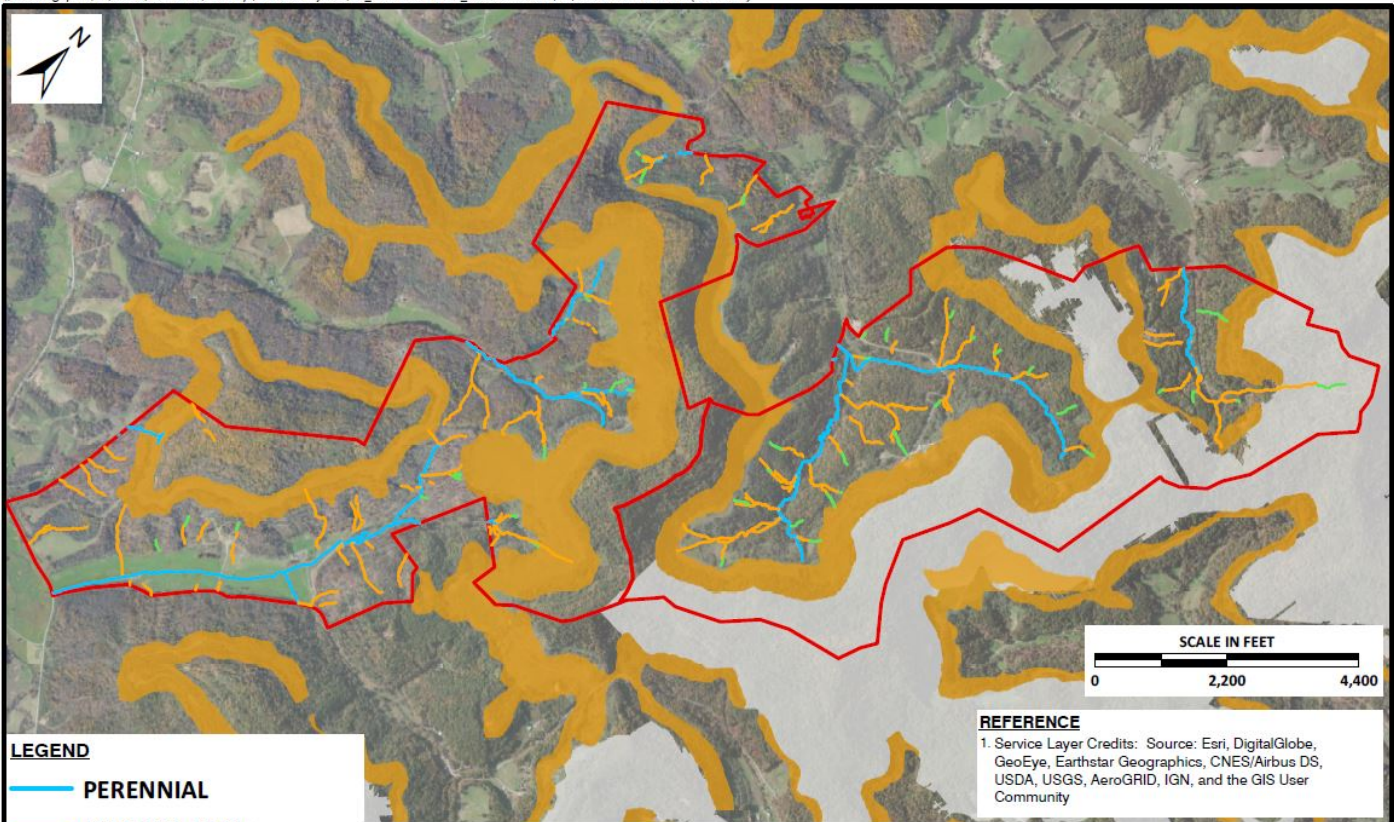
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 BRIDGEPORT, WEST VIRGINIA

STUDY AREA

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DATE:	08/15/2018	SCALE:	1" = 2,200'	PROJECT NO:	-		





LEGEND

- PERENNIAL
- INTERMITTENT
- EPHEMERAL
- SURFACE MINING
- UNDERGROUND MINING
- PROPERTY BOUNDARY

REFERENCE
 1. Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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Residual Mining Impacts

Disturbs local and regional geomorphology, hydrology, chemistry, and ecology

- ▶ Excavation of geologic units
- ▶ Disposal of overburden
- ▶ Development of surface seeps and mine pools
- ▶ Impacts to tributary headwaters
- ▶ Generation of acidity, metal precipitates (Fe, Al, Mn) , and Total Dissolved Solids (TDS)
- ▶ Degradation of aquatic habitats



Residual Mining Impacts



Impacts on Stream Restoration

- ▶ Acid generation;
- ▶ Ochres precipitate;
- ▶ High TDS;
- ▶ Disconnected tributary headwaters; and
- ▶ Excavation of unstable mine spoil.



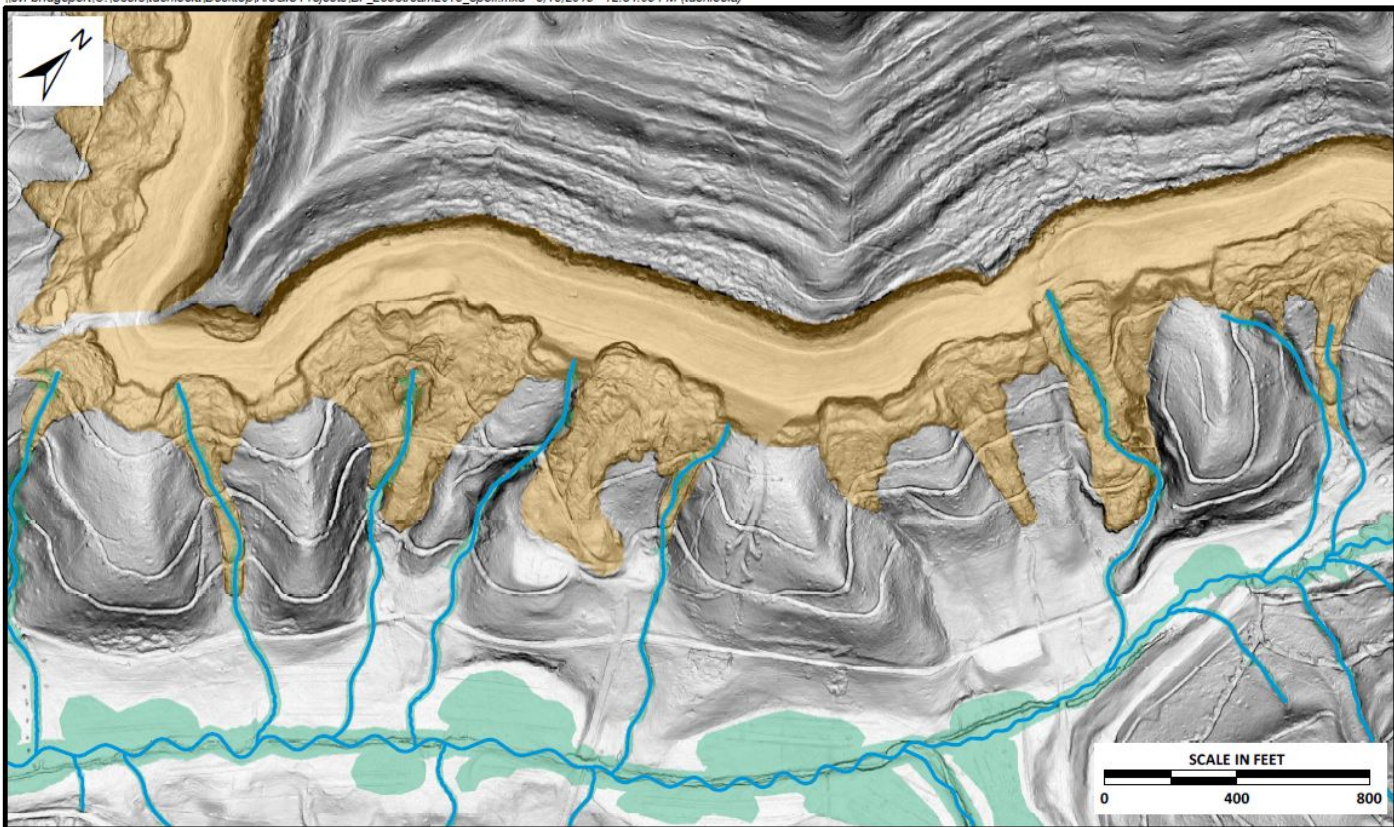
Standard Approach

- ▶ Identify areas with potential for impairment
 - High Iron, discoloration, reduced substrate porosity
 - High TDS, aquatic impacts
 - Unstable construction material

- ▶ Geotechnical (Physical & Chemical)
 - Compressive & shear strengths, density, moisture, Atterburg Limits, factor of safety
 - Acid-base accounting (ABA), reactive sulfur, total iron

- ▶ Sampling Strategies (Barnhisel et. al. 2000)





Approach

- ▶ Identify spoil from high resolution LIDAR imagery
- ▶ Overlay grading limits on digitized spoil area
- ▶ “Hot” material heterogeneously distributed
- ▶ Proceed with geotechnical assessment

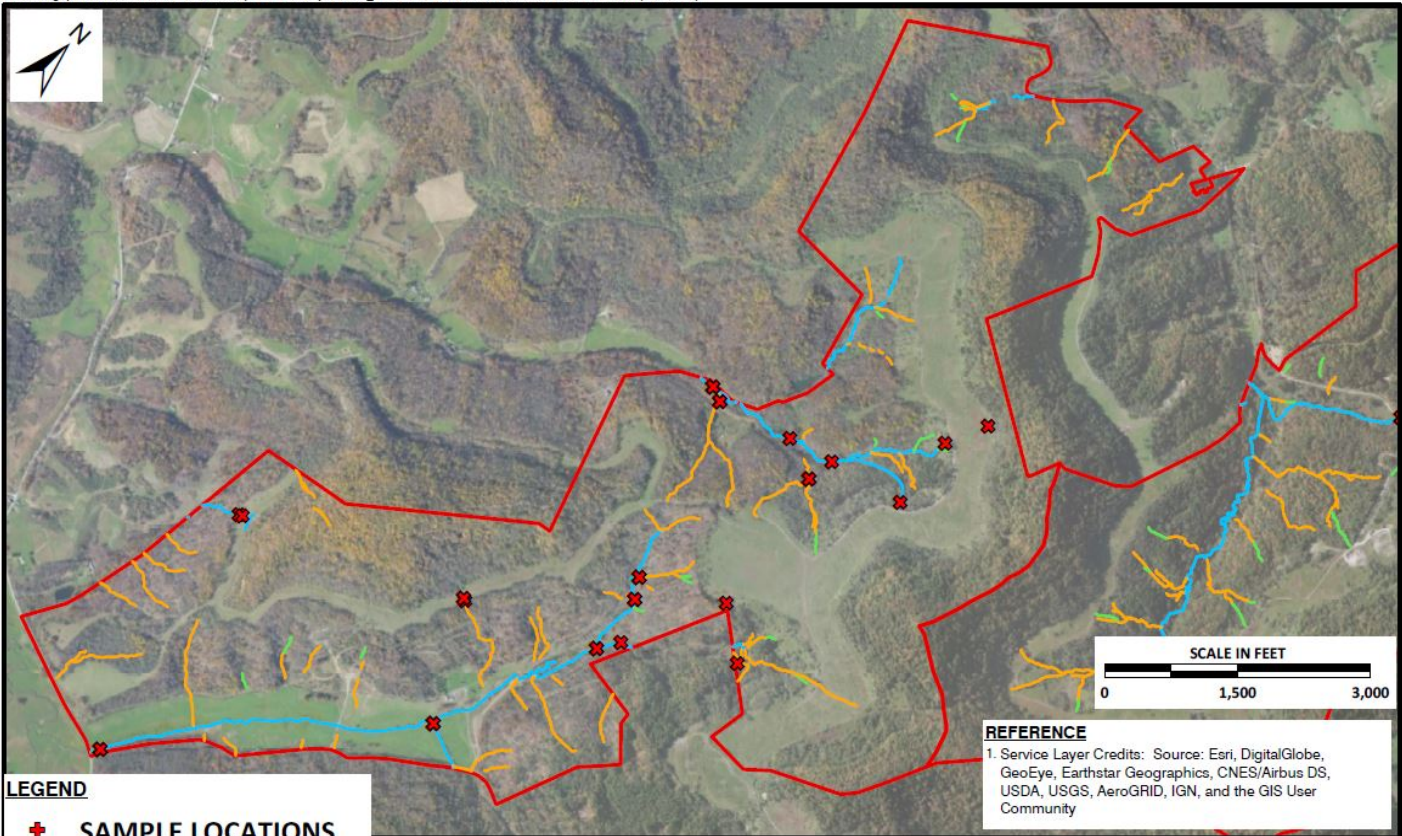
LEGEND MITIGATION STREAMS MINE SPOIL GRADING LIMITS	 Civil & Environmental Consultants, Inc. 600 Marketplace Avenue, Suite 200 - Bridgeport, WV 26330-9121 Ph: 304-933-3119 • Toll: 855-488-9539 • Fax: 304-933-3327 www.cecinc.com		CIVIL & ENVIRONMENTAL CONSULTANTS, INC. BRIDGEPORT, WEST VIRGINIA	
	MINE SPOIL		SCALE IN FEET 0 400 800	
	DRAWN BY: TAD DATE: 08/15/2018	CHECKED BY: - SCALE: 1" = 400'	APPROVED BY: - PROJECT NO: -	FIGURE NO: -



Modified Approach

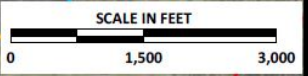
- ▶ Watershed approach vs. geotechnical approach
 - Utilize data collected for watershed planning purposes
 - Utilize statistical techniques to classify variables
- ▶ Data collection (43 water quality samples)
 - Collected spatially and temporally
 - Collected from headwaters, tributaries, mainstems, wetlands, seeps, etc..
 - Collected Nov 2016, Oct 2017, Nov 2017, Dec 2017





LEGEND

- + SAMPLE LOCATIONS
- PERENNIAL
- INTERMITTENT
- EPHEMERAL
- PROPERTY BOUNDARY



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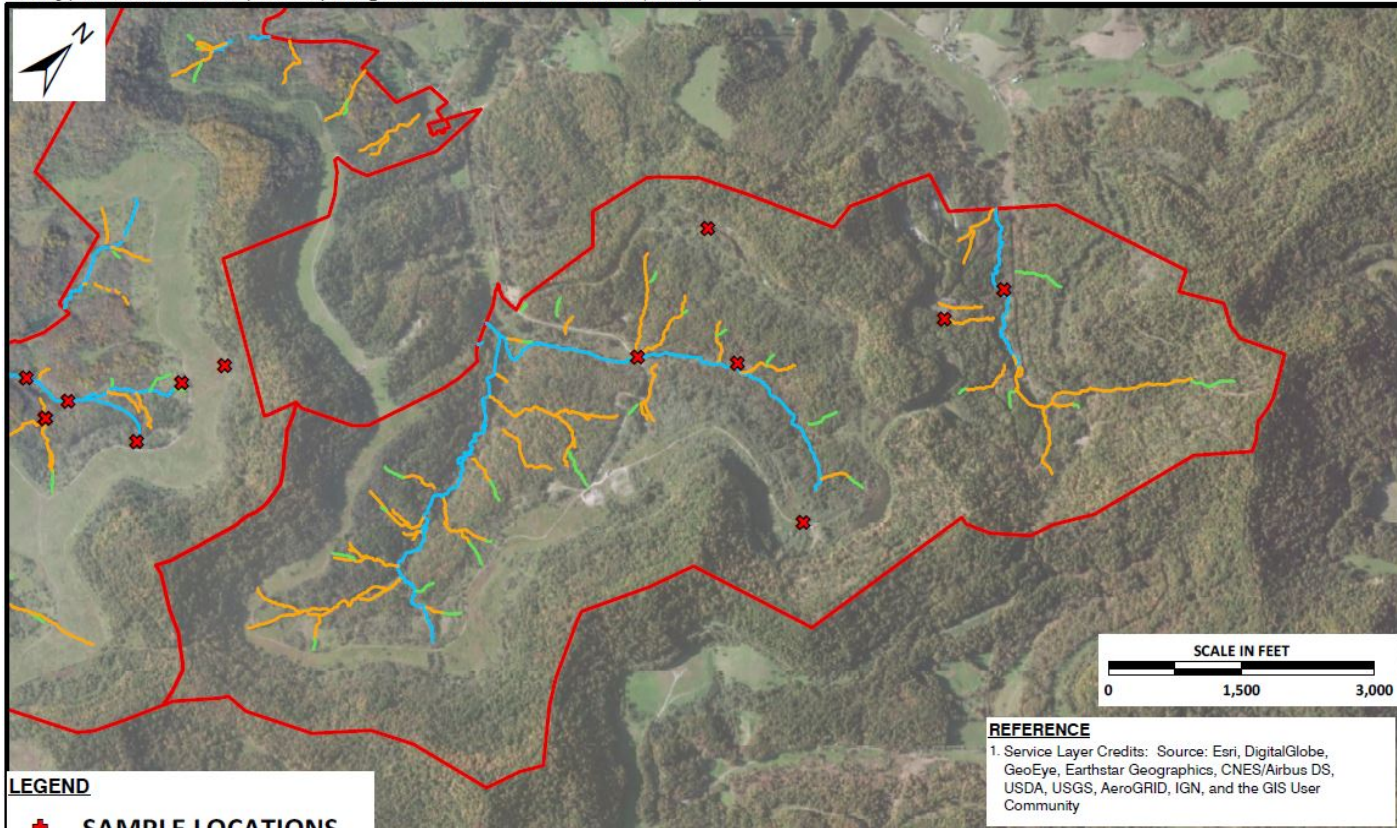
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PROJECT SITE

DRAWN BY:	TAD	CHECKED BY:	-	APPROVED BY:	-	FIGURE NO:	-
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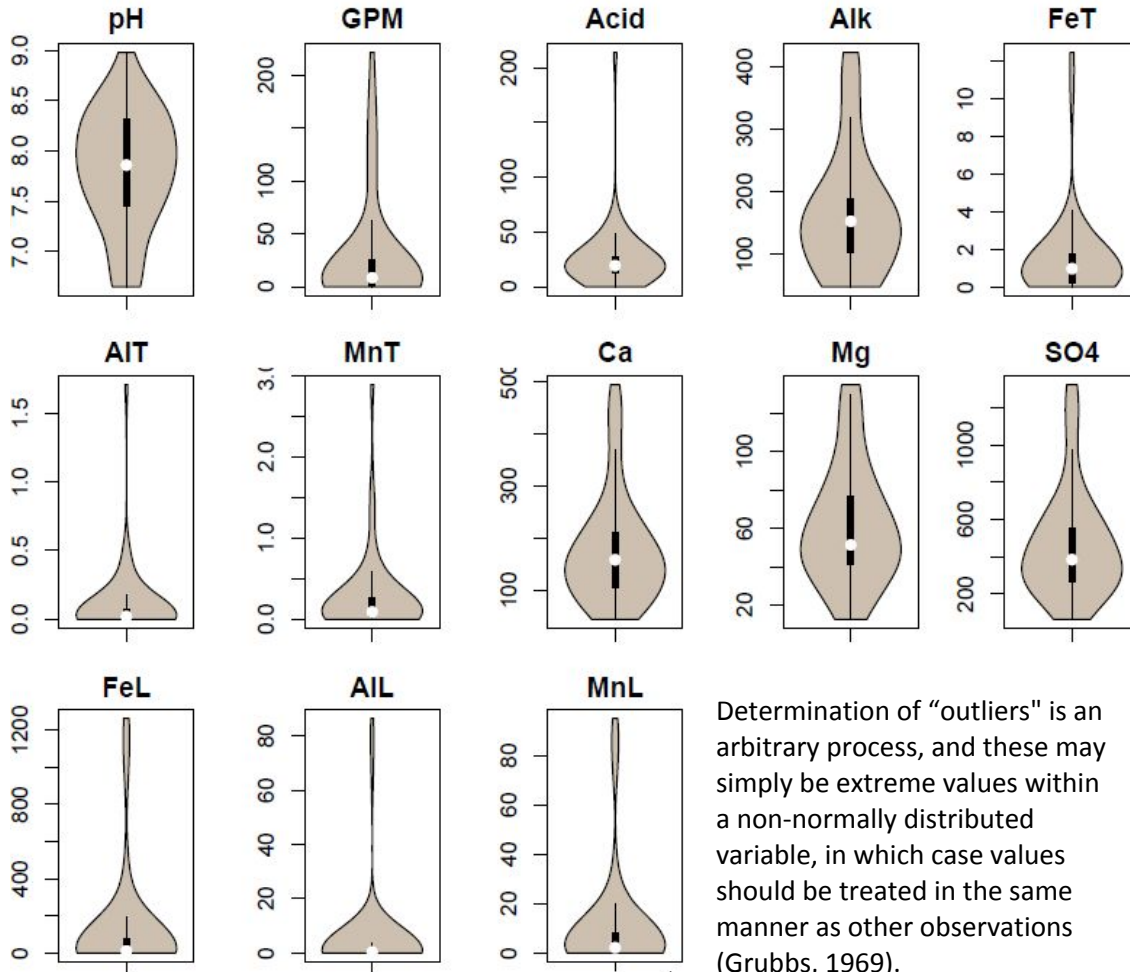
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Approach

- ▶ Quality Assurance / Quality Control (QA/QC)
 - Half minimum detection limit (MDL) for non-detects
 - Charge balance error (CBE)
- ▶ Univariate Statistical Techniques
 - Assessed distribution, median, lower/upper quartile, min/max, outliers
- ▶ Bivariate Statistical Techniques
 - Utilized principal component analysis (PCA) to classify variables
 - Utilized cluster analysis to assign variables to categories

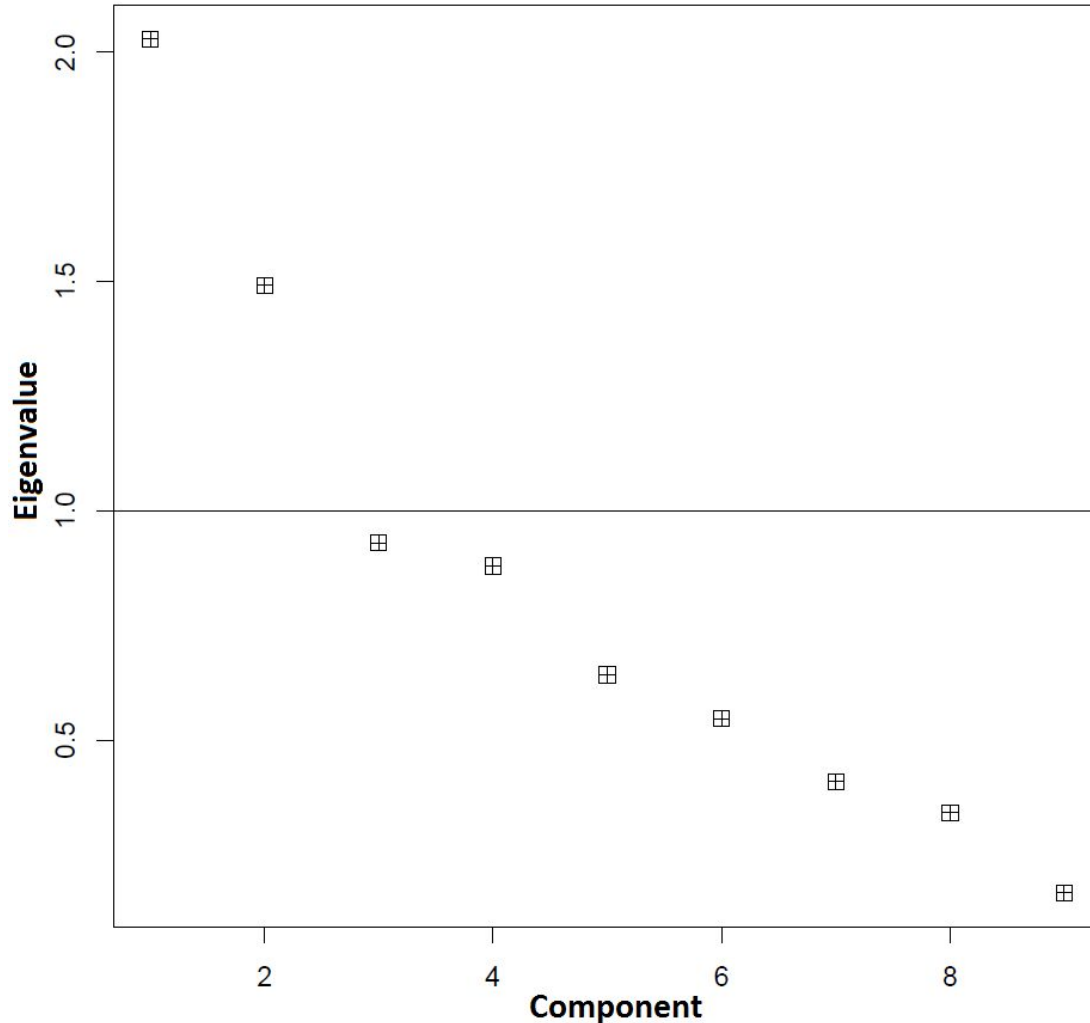


Results

- ▶ Normal Distribution
 - pH and TDS
- ▶ Skewed Distribution
 - Metals and Load
- ▶ Outliers
 - Grubs, 1969
- ▶ Overall alkaline, low metal, high TDS
 - TDS driven by Ca, Alk, SO4

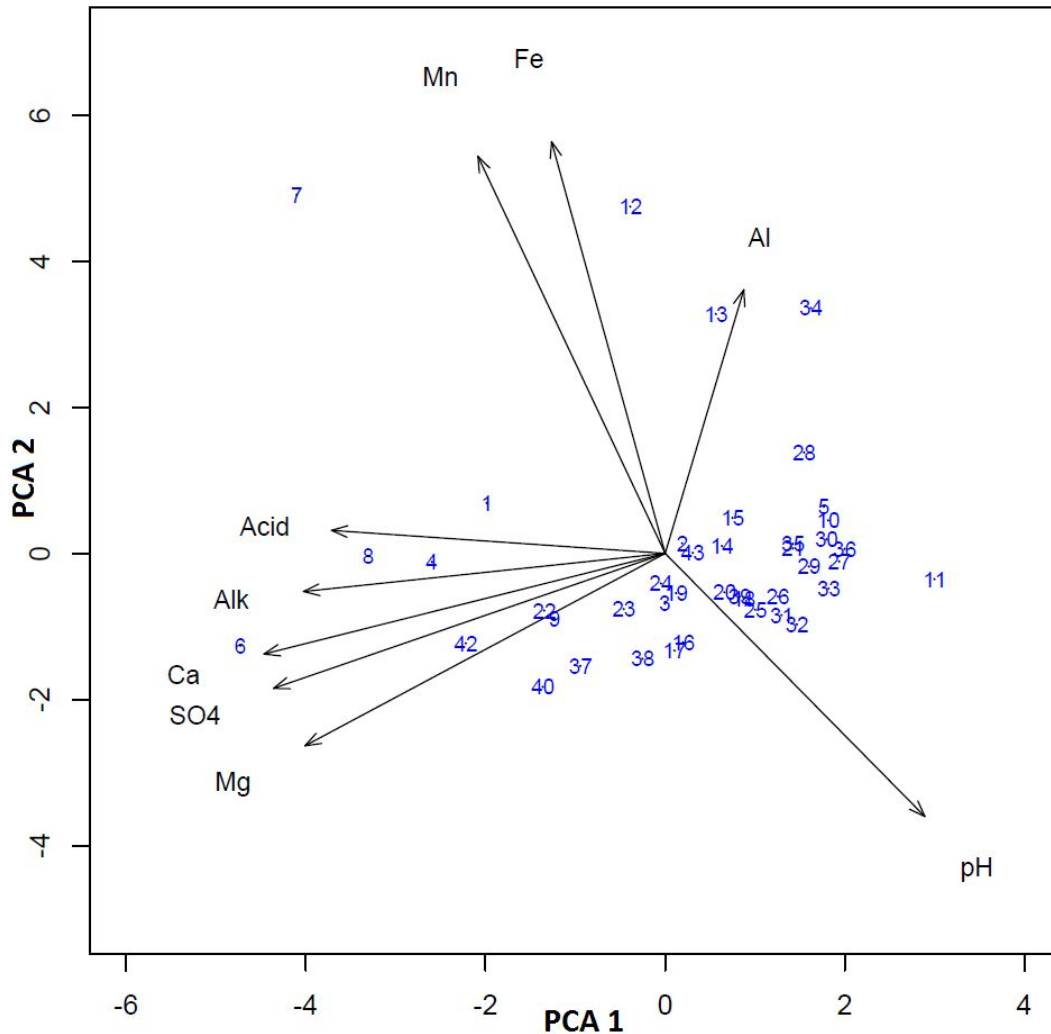
Determination of "outliers" is an arbitrary process, and these may simply be extreme values within a non-normally distributed variable, in which case values should be treated in the same manner as other observations (Grubbs, 1969).





Results

- ▶ Two eigenvectors exceed the Kaiser criterion of 1.0 (1960)
- ▶ Average eigenvalue expected to equal 1.0
- ▶ Values greater than 1.0 indicate scores with greater sample variance

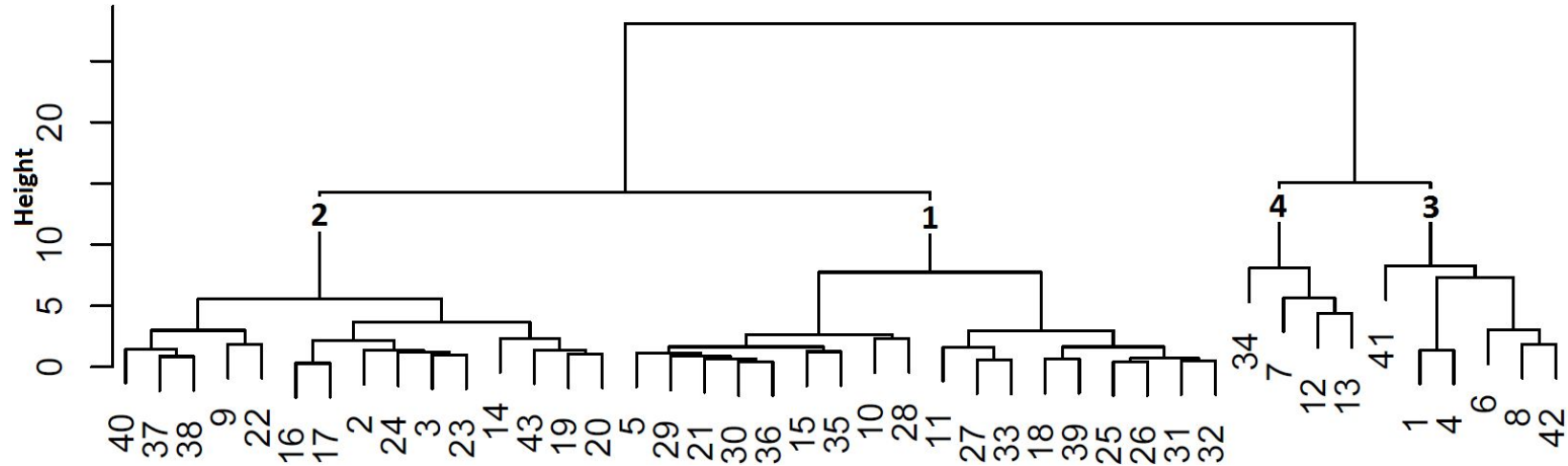


Results

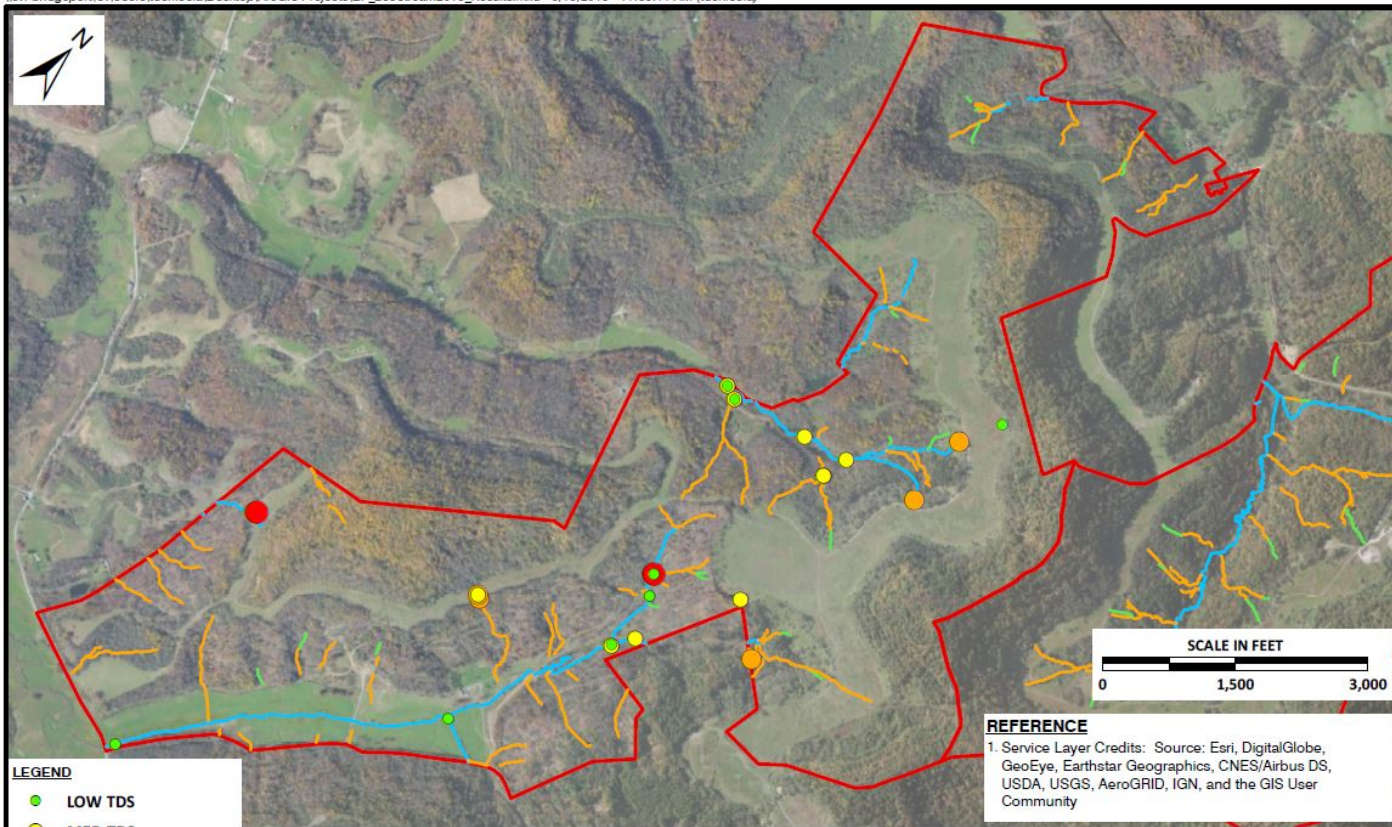
- ▶ **PCA 1+**
 - Low TDS
 - pH, Al
- ▶ **PCA 2-**
 - Mod. TDS
 - pH, Alk, Ca, Mg, SO4
- ▶ **PCA 1-**
 - High TDS
 - Acid, Alk, Fe, Mn, Ca, Mg, SO4
- ▶ **PCA 2+**
 - High Metals
 - Acid, Fe, Al, Mn



Cluster Analysis



- ▶ Cluster 1 – Low TDS (15 samples)
- ▶ Cluster 2 – Mod. TDS (18 samples)
- ▶ Cluster 3 – High TDS (6 samples)
- ▶ Cluster 4 – High Iron (4 samples)



Results

- ▶ Headwaters:
 - High TDS
- ▶ Tributaries:
 - Moderate TDS
- ▶ Mainstem:
 - Low TDS

LEGEND

- LOW TDS
- MED TDS
- HIGH TDS
- HIGH IRON
- PERENNIAL
- INTERMITTENT
- EPHEMERAL
- ▭ PROPERTY BOUNDARY

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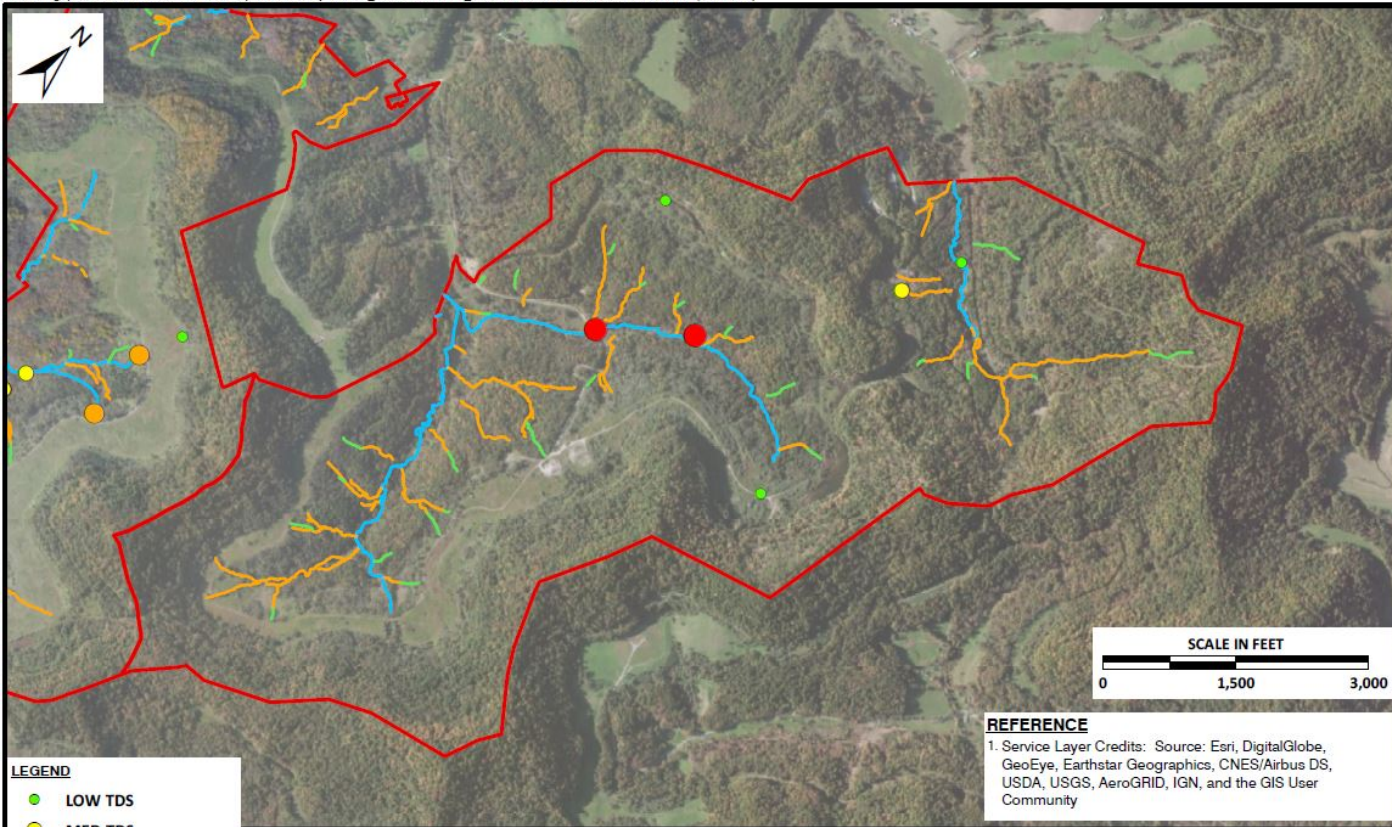
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RESULTS

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Results

Nonconformity:

- Headwater Iron
- Mainstem Iron

Mine Benches

- Low TDS

Mainstem

- Temporal variation

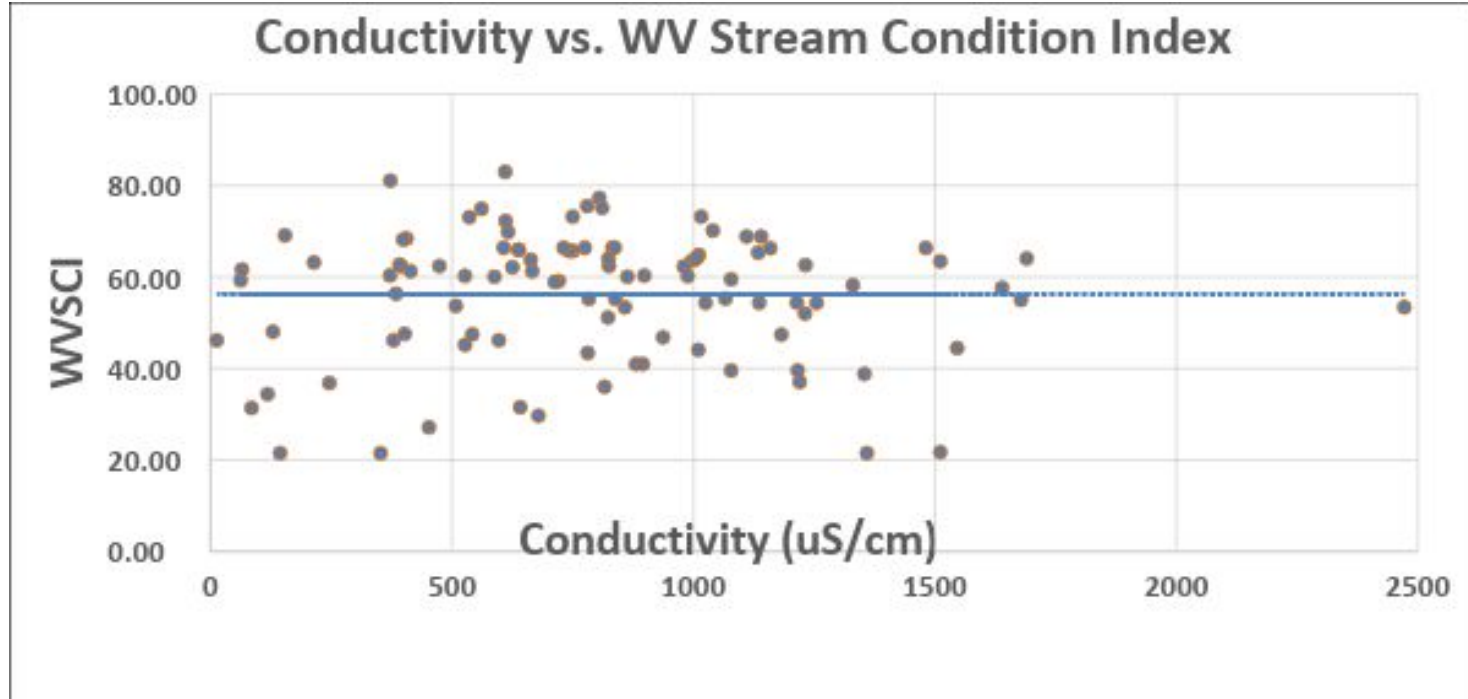


Field Verification

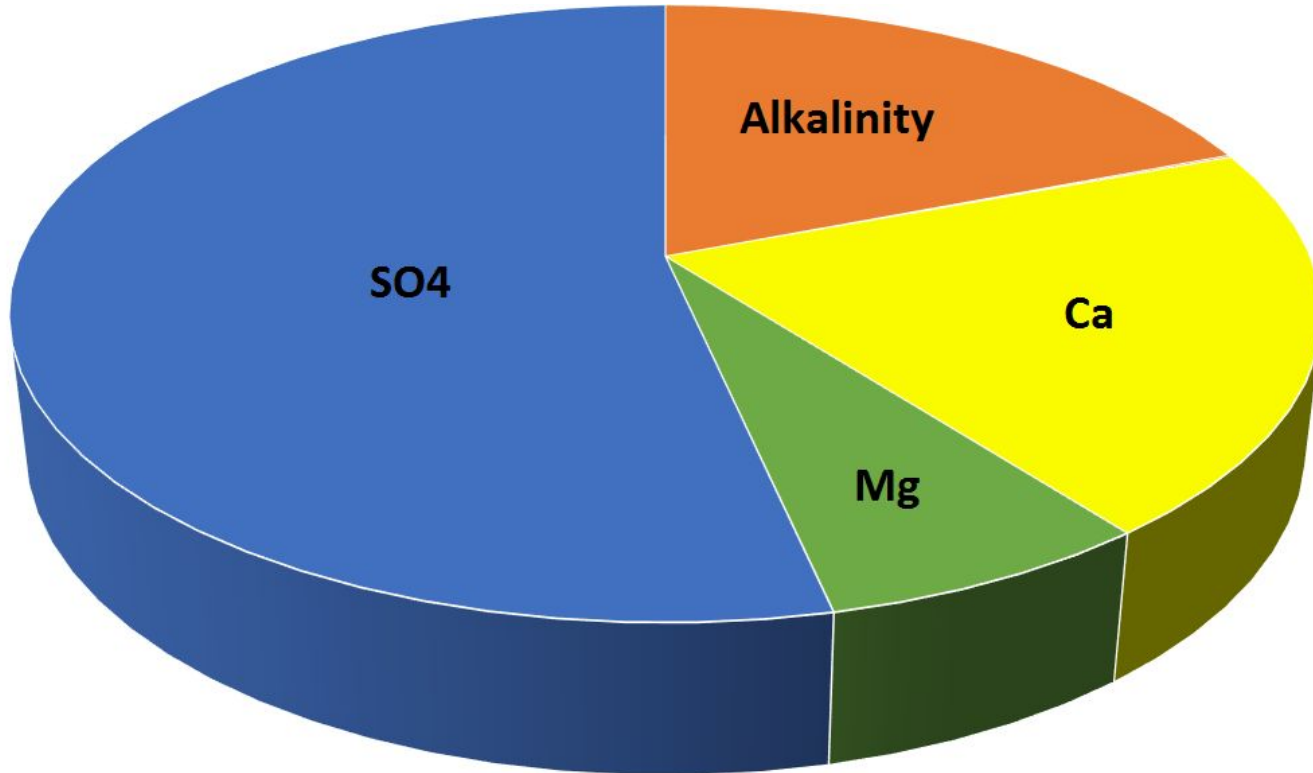
- ▶ Field reconnaissance of select areas identified iron seeps
 - Field Testing Kits, Groundwater Piezometers



Total Dissolved Solids



Total Dissolved Solids



- ▶ Minimum
 - 288 mg/L
- ▶ Average
 - 879 mg/L
- ▶ Maximum
 - 2,313 mg/L



Reclamation Techniques for AML

- ▶ Grading and drainage
- ▶ Material handling plans for “hot” material
 - Disposal of reactive material offsite
 - Encapsulating reactive material onsite
- ▶ Active, semi-active, and passive chemical treatment
 - Fully automated treatment facilities
 - Semi-automated reagent delivery with passive techniques
 - Limestone beds, settling ponds, aerobic wetlands



Example Techniques for AML



*Bingmaps.com



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Modifications for Restoration

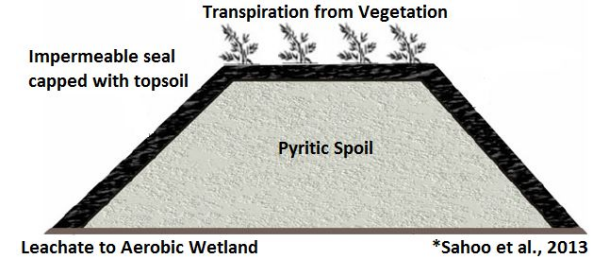
- ▶ “Hot” mine spoil identification
- ▶ Excavation and sequestration
- ▶ Soil amendment
- ▶ Aerobic wetland construction (“treatment cells”)
- ▶ Impermeable barrier installation
- ▶ Hydraulic structures for spoil stabilization
- ▶ Alluvial fans to reconnect headwaters
- ▶ Natural site stabilization / revegetation



Mine Spoil Handling

- ▶ Excavate and sequester “hot” material to designated disposal areas
 - Encapsulate with impermeable material
 - Revegetate
 - Construct BMPs for leachate (treatment cells)

- ▶ Amend remaining spoil within grading limits
 - Limestone fines (Ag. Lime) and organic compost
 - Alkalinity reduces prevalence of acidophilic, iron-oxidizing bacteria
 - Organic compost depletes oxygen available for mineral oxidation



Aerobic Wetlands (Treatment Cells)



Impermeable Barriers

- ▶ Onsite clay-rich soil
 - Excavated from nearby pastureland
- ▶ Soil/bentonite slurry
 - Mixed onsite with grout-like application technique
- ▶ Bentomat or Claymax brand geo-synthetic liners
 - Keyed in beyond bankfull



Physical Stabilization



Alluvial Fans



Natural Site Stabilization

- ▶ Initial Construction
 - Introduces oxygenated groundwater
 - Increases mineral surface area exposure
 - First-flush of recently exposed/oxidized constituents
- ▶ Post-Construction
 - Progressive depletion of groundwater oxygen
 - Stabilization of water table
 - Depletion of first-flush mineral concentrations
- ▶ Revegetation
 - Aides site stabilization
 - Increased transpiration, reduces groundwater/mineral interaction



Anticipated Outcome

- ▶ Anticipated Outcome
 - Reduced discoloration
 - Reduced conductivity
 - Increased WV Stream Condition Index (WVSCI) scores
 - Increased Stream and Wetland Valuation Metric (SWVM) scores
- ▶ Prior Successes – Stream Restoration on AML
 - Southern WV Coalfields
 - Tennessee Cumberland Plateau



Questions / Comments

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