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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 negative AML impacts on restoration success

Successful Stream Restoration

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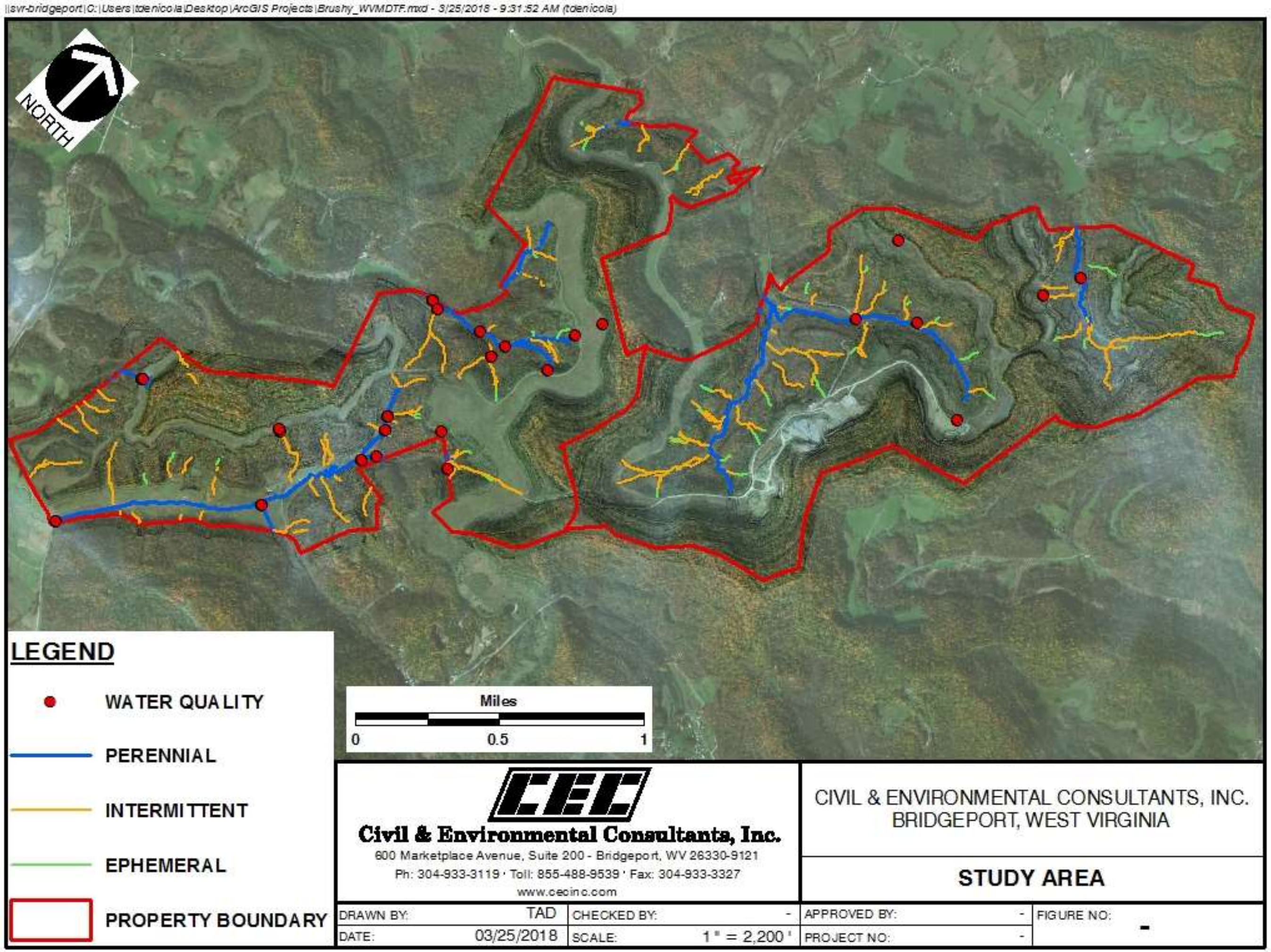

Study Area

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

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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

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Residual Mining Impacts






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Impacts on Stream Restoration

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

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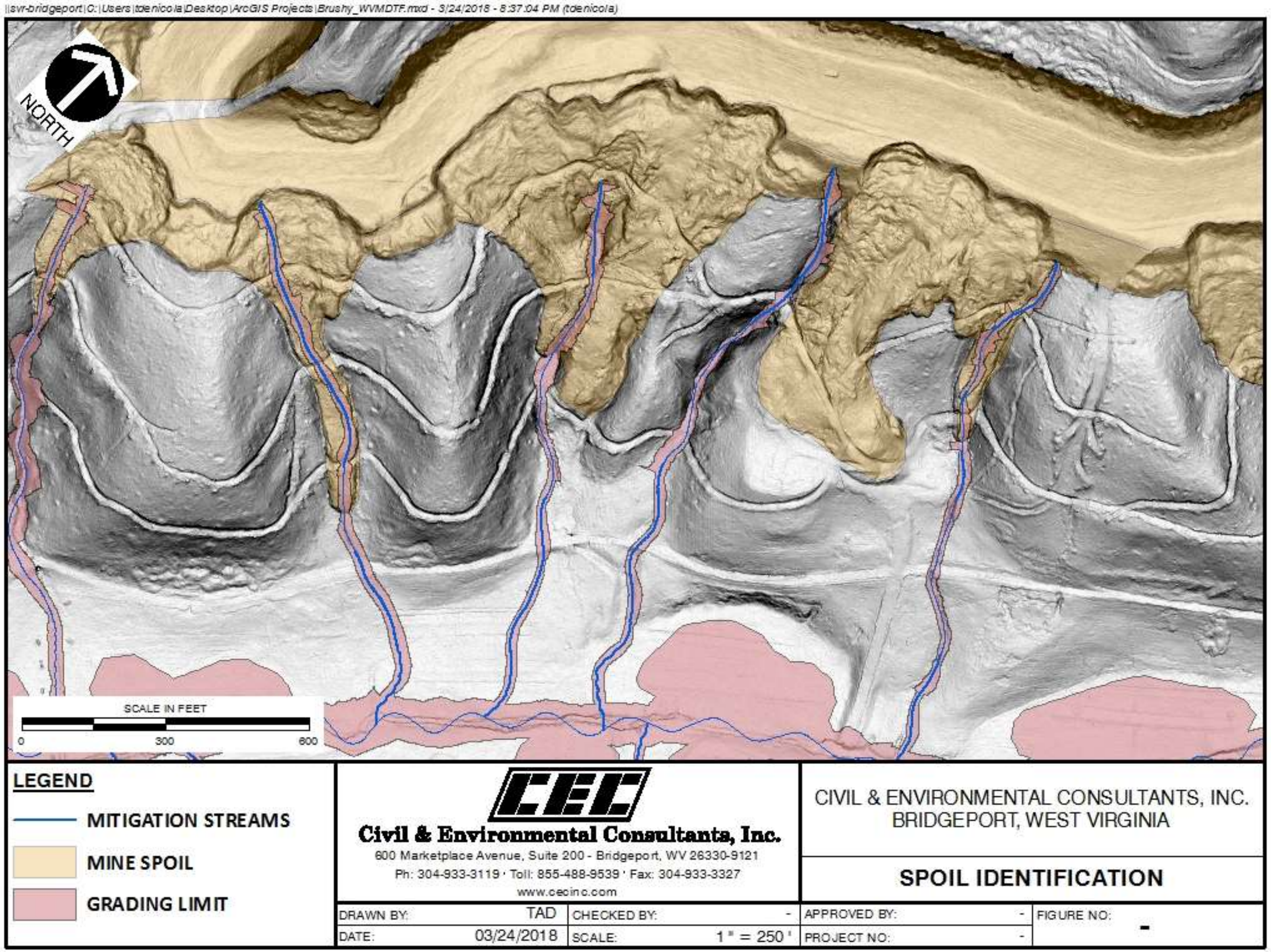

Approach

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

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Standard Approach

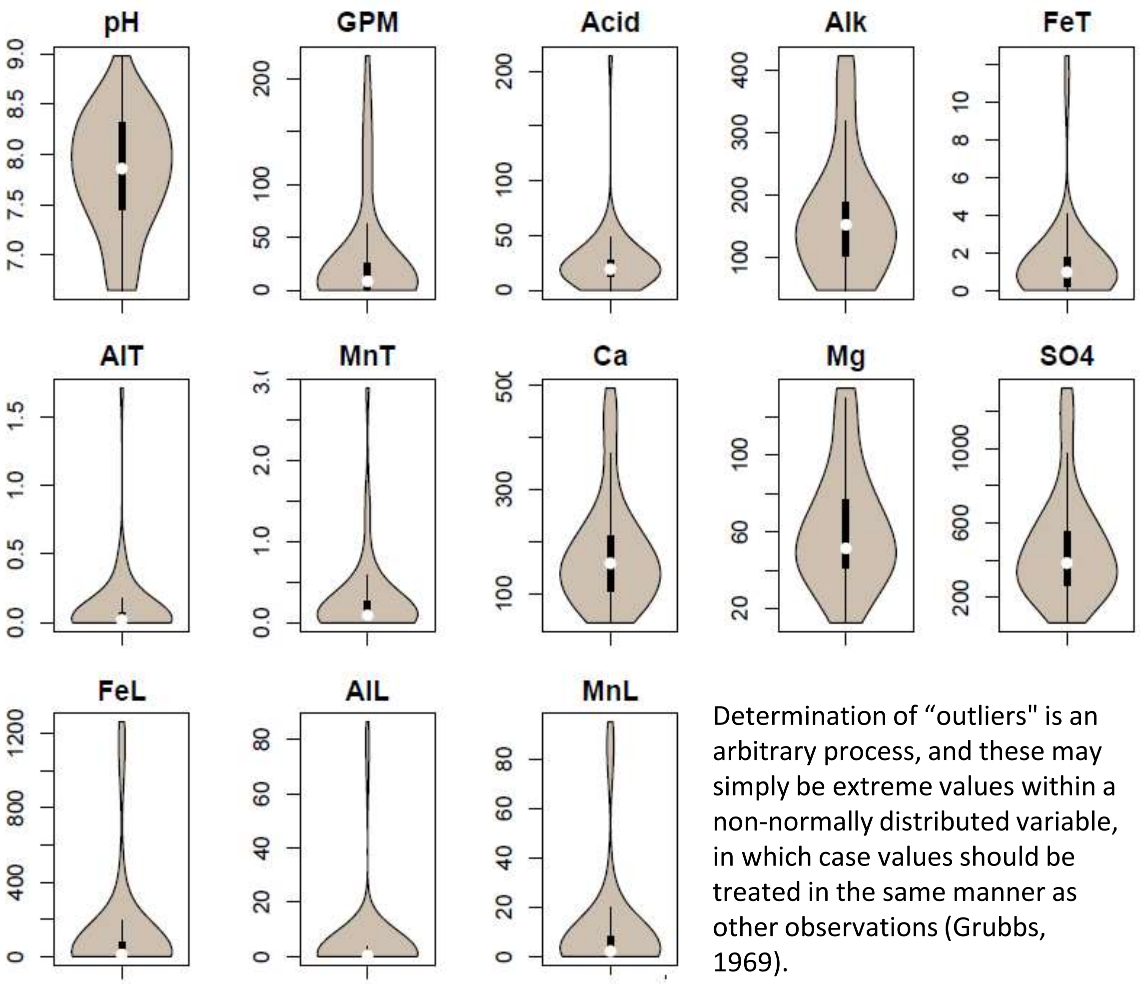
- Identify areas with potential for impairment
  - High Iron, discoloration, reduced substrate porosity
  - High TDS, aquatic impacts
  - Unstable construction material
- Geotechnical (Physical & Chemical)
  - Compressive & shear strengths, density, moisture, Atterburg Limits, factor of safety
  - Acid-base accounting (ABA), reactive sulfur, total iron
- Sampling Strategies (Barnhisel et. al. 2000)

Approach

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

Approach

- Quality Assurance / Quality Control (QA/QC)
  - Half minimum detection limit (MDL) for non-detects
  - Charge balance error (CBE)
  - Omitted CBE exceeding ±20%, two erroneous discharge measurements
- Univariate Statistical Techniques
  - Assessed distribution, median, lower/upper quartile, min/max, outliers
- Bivariate Statistical Techniques
  - Utilized principal component analysis (PCA) to identify variables
  - Utilized cluster analysis to assign variables to categories



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).

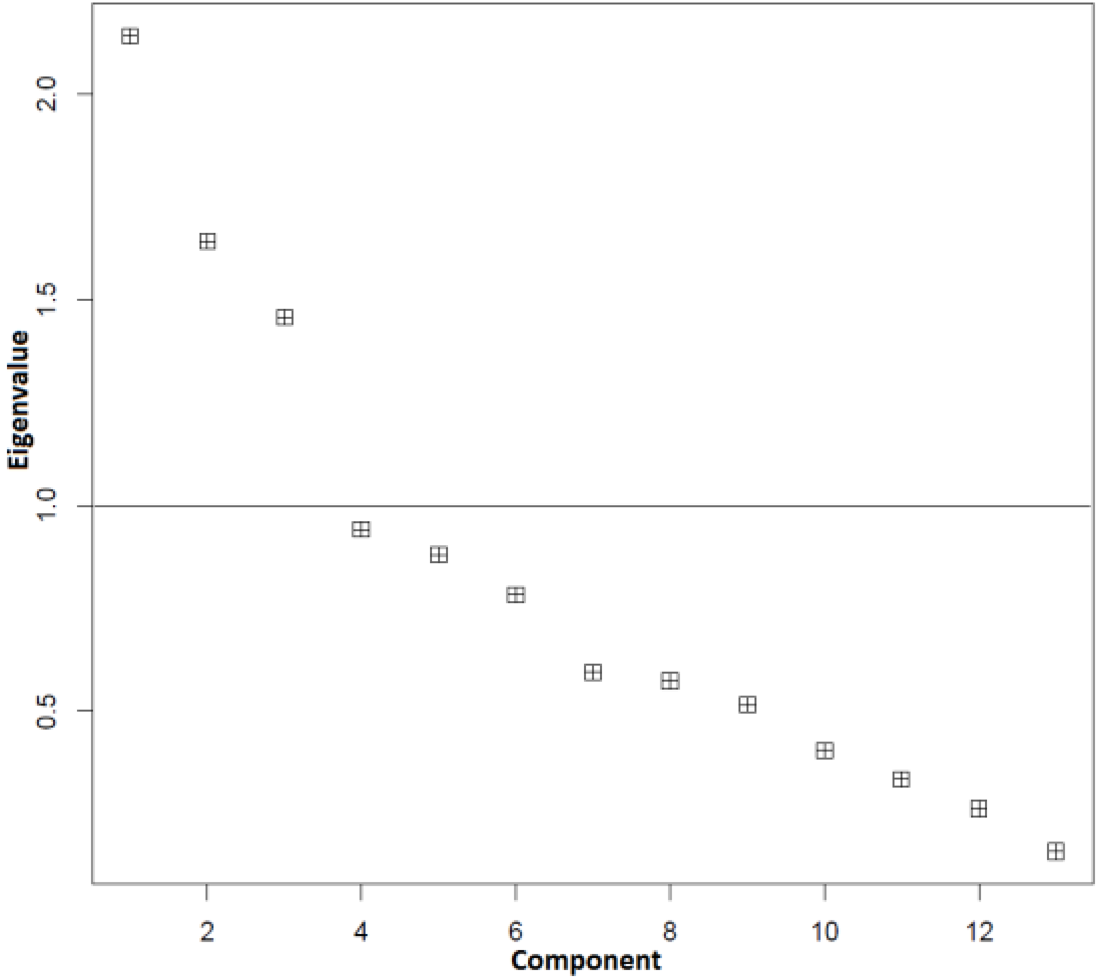
Results

- 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

Total Dissolved Solids

Sample ID	TDS	Ca	Alk	SO4	Total
	mg/L	%			%
1	1119	20%	34%	40%	94%
2	841	20%	27%	46%	92%
3	948	19%	23%	51%	92%
4	1350	19%	31%	45%	94%
5	378	17%	26%	50%	93%
6	2313	21%	16%	57%	95%
7	1428	22%	24%	49%	94%
8	1925	23%	10%	61%	94%
9	1086	15%	17%	55%	88%
10	299	15%	58%	22%	95%
12	644	22%	24%	45%	91%
13	432	19%	14%	62%	95%
14	790	20%	6%	68%	94%
15	614	21%	19%	53%	93%
16	939	19%	20%	54%	92%
17	978	20%	18%	54%	92%
18	784	17%	21%	56%	93%
19	888	20%	15%	58%	92%
21	526	21%	17%	55%	92%
22	1126	19%	24%	48%	92%
23	1087	19%	24%	51%	95%

Sample ID	TDS	Ca	Alk	SO4	Total
	mg/L	%			%
24	829	20%	32%	39%	92%
25	717	20%	22%	51%	93%
26	631	21%	19%	52%	92%
27	468	18%	23%	52%	93%
28	391	20%	15%	56%	91%
29	474	23%	11%	57%	91%
30	407	24%	12%	55%	91%
31	635	19%	28%	46%	93%
32	608	21%	24%	47%	92%
33	525	19%	24%	50%	93%
34	454	18%	17%	55%	90%
35	522	20%	12%	58%	90%
36	399	20%	12%	58%	91%
37	1346	17%	13%	63%	93%
38	1145	19%	12%	60%	92%
39	844	17%	14%	62%	93%
40	1307	23%	13%	54%	91%
41	2211	19%	19%	56%	94%
42	1699	24%	10%	61%	94%
43	814	26%	16%	52%	94%



Results

- Three 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

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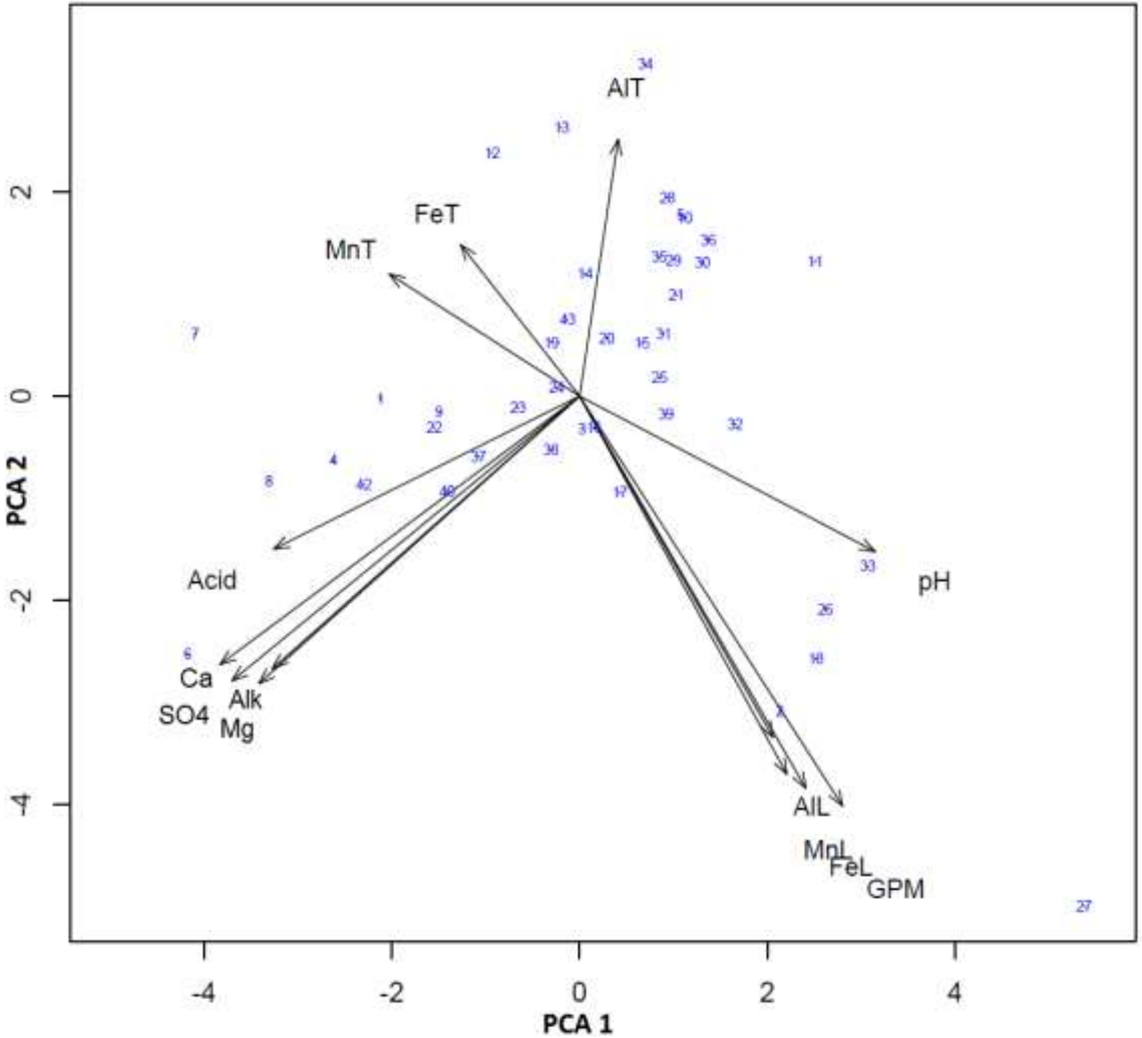
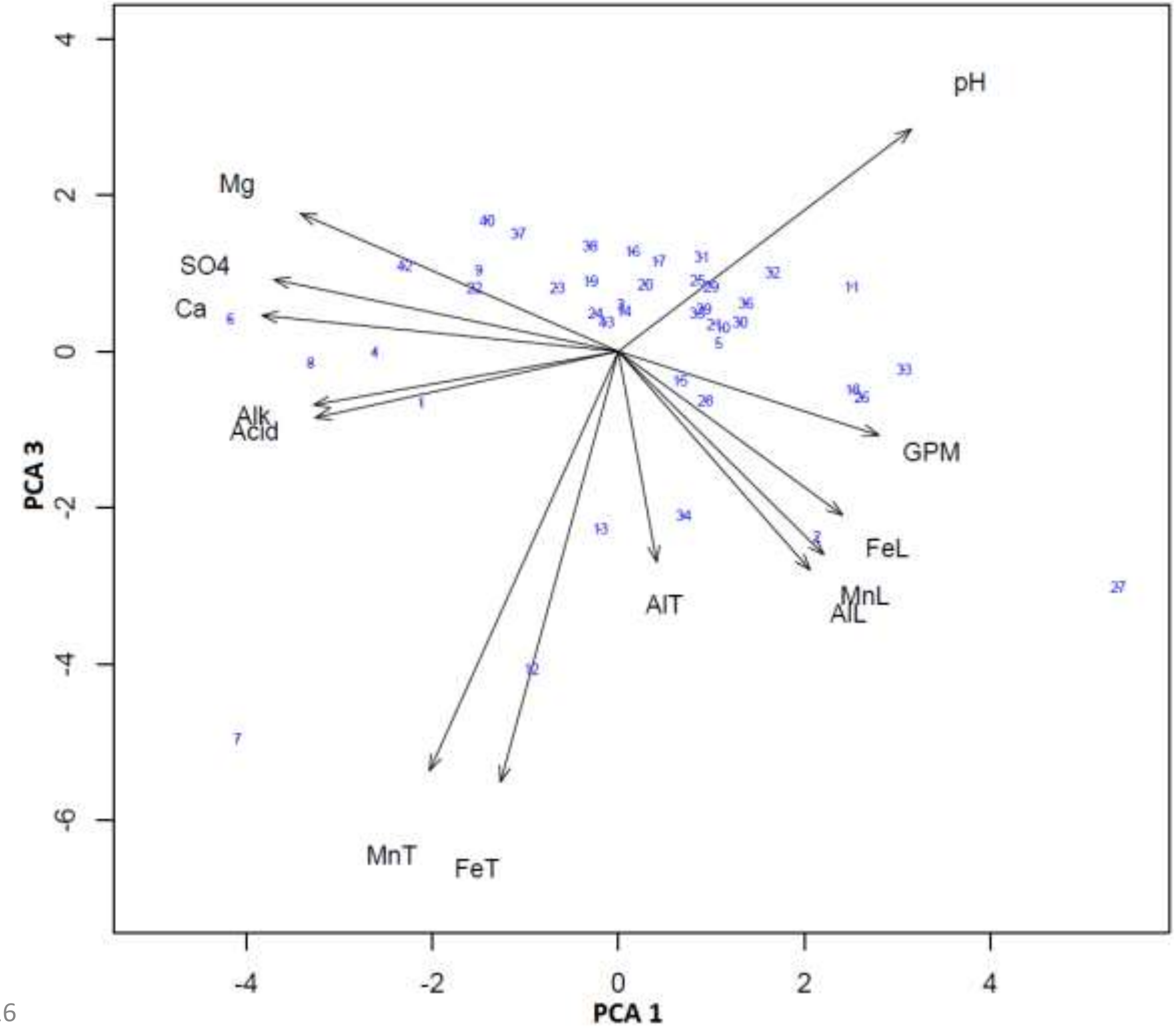


Results

- PCA 1+
  - pH, Load
- PCA 1-
  - Acid, Alk, Ca, Mg, SO4, Fe, Mn
- PCA 2+
  - Fe, Al, Mn
- PCA 2-
  - Acid, Alk, Ca, Mg, SO4, Load



Results

- PCA 3+
  - pH, Ca, SO4, Mg
- PCA 3-
  - Acid, Alk, Fe, Al, Mn, Load

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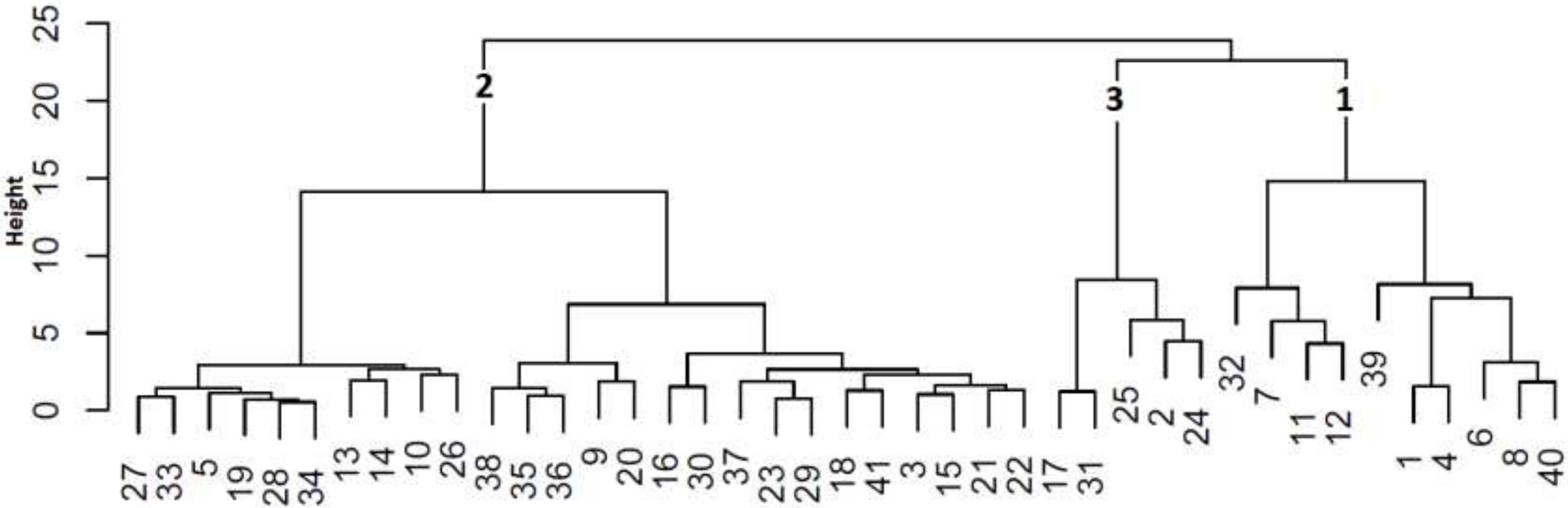
PCA Summary

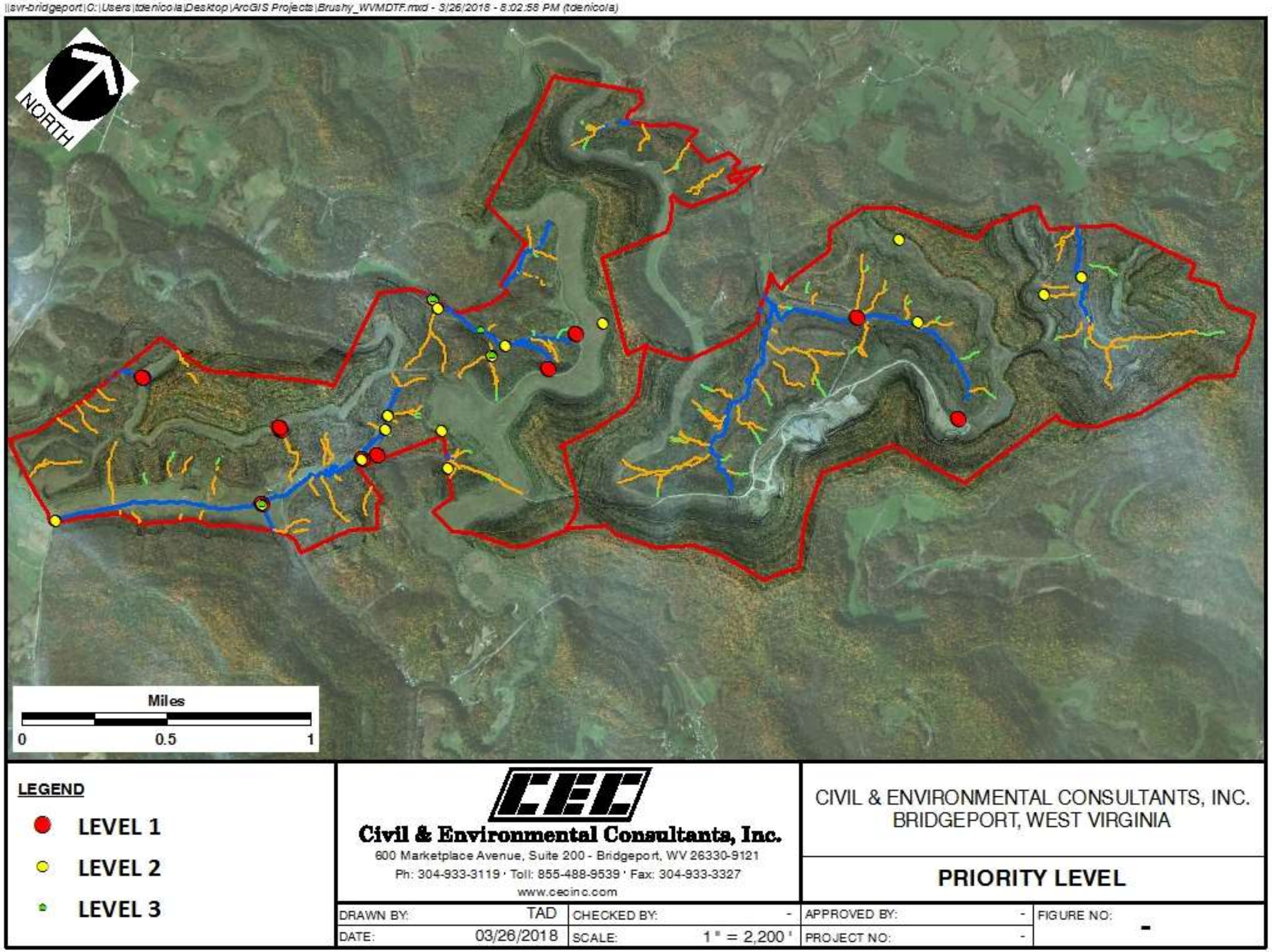
- Summary
  - PCA1+ (alkaline, low metal, high load)
  - PCA1- (high metal, high TDS, low load)
  - PCA2+ (high metal)
  - PCA2- (high TDS, low metal, high load)
  - PCA3+ (alkaline, low TDS, low metal)
  - PCA3- (high metal, high flow)

- Priority Level
  - Level 1 (PCA1-, PCA2+, PCA3-): high metal concentrations
  - Level 2 (PCA1+, PCA2-): high metal load or high TDS
  - Level 3 (PCA 3+): alkaline, moderate TDS, low metal concentration, low load

Cluster Analysis



- Cluster 1 – High metal conc. (10 samples)
- Cluster 2 – High TDS (26 samples)
- Cluster 3 – Low metal conc., moderate TDS, high flow (5 samples)



Results

- Headwaters:
  - high metal conc.
- Tributaries:
  - high TDS
- Mainstem:
  - low metal, mod. TDS, high flow
- Nonconformity:
  - Mainstem Fe seep
  - Impoundment Fe

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Additional Review

- Field reconnaissance of “Level 1” identified Fe seeps
- Data review of “Level 2” identified high TDS and/or high load
- Data review of “Level 3” identified low metal/TDS, high flow
- Additional Investigation
  - Field Testing Kits
  - Groundwater Piezometers

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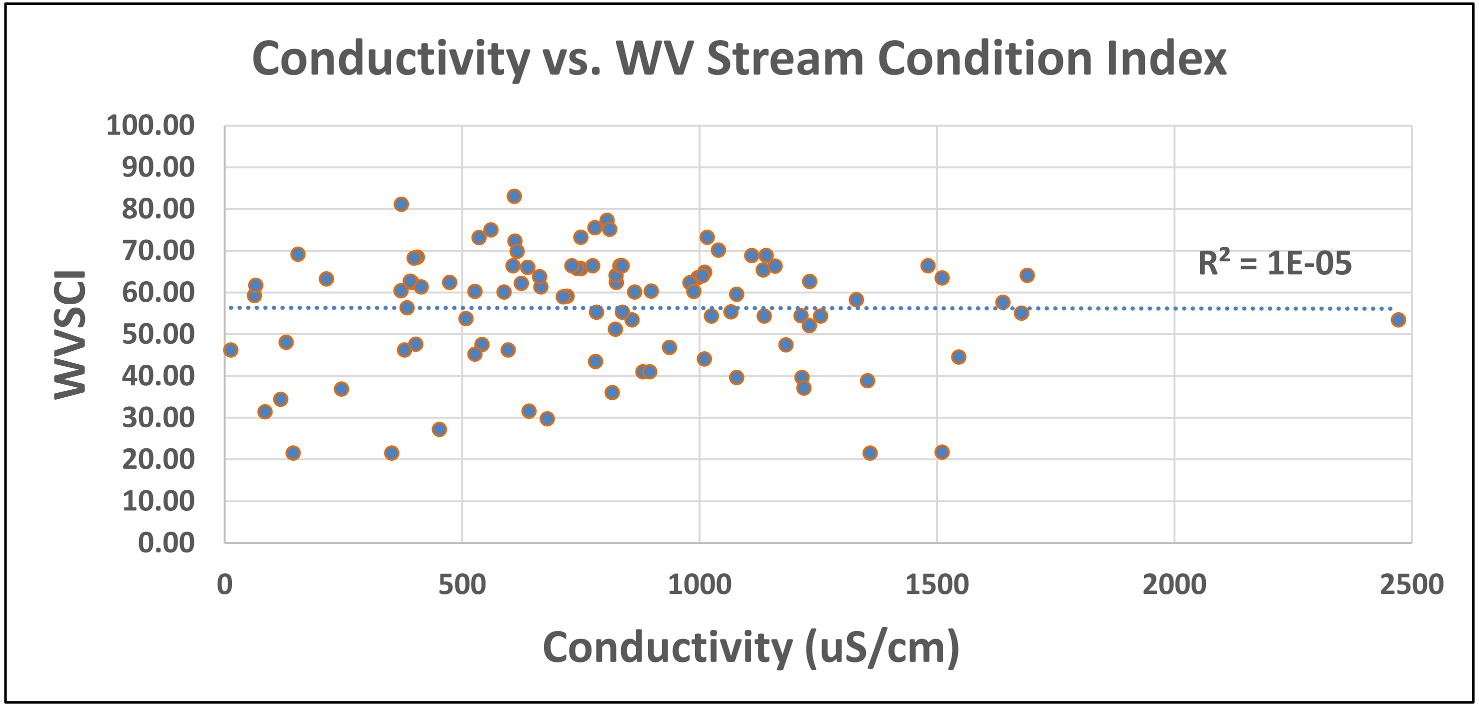
Total Dissolved Solids



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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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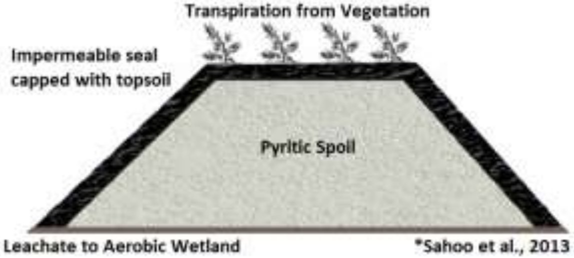
Modifications for Restoration

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

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



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Aerobic Wetlands (Treatment Cells)

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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

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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

Physical Stabilization

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 – Mitigation Banks on AML
  - Southern WV Coalfields (Alluvial Fan)
  - Tennessee Cumberland Plateau

AML Reclamation Literature

- WVDEP (2017) Division of Mining and Reclamation Permit Handbook
- WVDEP (2005) Division of Mining and Reclamation Geologic Handbook
- WVDEP (2001) Division of Mining and Reclamation Quarry Handbook
- WVDEP (1993) Division of Mining and Reclamation Technical Handbook
- WVDEP (1992) Division of Mining and Reclamation Inspection and Enforcement Handbook
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- University of Kentucky (1996) Kentucky Coal Mining Practice Guidelines for Water Quality Management
- Smart, et al. (2015) Assessment of Acid Neutralization Rates from Site Rock for AMD Control
- Sahoo et al. (2013) Current Approaches for Mitigating Acid Mine Drainage
- Gusek (2012) Sulfate-Reducing Bioreactor Design and Operating Issues
- Wilkin, et al. (2008) Contaminant Attenuation Processes at Mine Sites
- Johnson, et al. (2005) Acid Mine Drainage Remediation Options
- Barnhisel et. al. (2000) Reclamation of Drastically Disturbed Lands
- Office of Surface Mining (2000) Handbook for Calculation of Reclamation Bond Amounts
- Rose, et al. (1996) Remediation of Acid Mine Drainage Within Strip Mine Spoil by Sulfate Reduction Using Waste Organic Matter
- Vile, et al. (1992) Alkalinity Generation by Fe(III) Reduction Versus Sulfate Reductions in Wetlands Constructed for AMD Treatment

Questions / Comments

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