The Appalachian Research Initiative for Environmental Science (ARIES): Update on coal research

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Why Science-Based Approaches?

- Most issues and problems have scientific and engineering components

- Scientific-based discussions allow for communication, cooperation and collaboration with all stakeholders

- Optimum planning, operation and post-mining use of mining projects relies on science-based approaches

- Government policies and regulations must be based on science-based solutions and practices not on politics or self-serving agendas

ARIES Funding

- Industrial Affiliate Partners committed to fund ARIES with a grant of nearly <u>$15 million</u> over the next five years

- A research strategy was chartered and approved for 2011-2016

- ARIES is committed to an "open door" policy, encouraging other companies and universities to join in the future

ARIES Announced March 31, 2011

Major Research Areas of ARIES

- Energy production in Appalachia
  - Coal mining
  - Natural gas
    - CBM
    - Shale gas
  - Electricity generation
  - Petroleum
  - Renewables
- First priority focus is coal mining

ARIES Member Companies

- Alpha Natural Resources
- Arch Coal
- Natural Resource Partners
- TECO Coal Corporation
- Patriot Coal Corporation
- Cliffs Natural Resources
- Mepco
- Norfolk Southern Corporation
- CSX Corporation

Coal associations are participants

In discussions with other companies interested to join

ARIES Partner Universities

- Virginia Tech
  - VCCER at VT is the managing entity for ARIES
- West Virginia University
- University of Kentucky
- Ohio State University
- Pennsylvania State University
- University of Pittsburgh
- University of Pennsylvania
- Marshall University*
- Edward Via College of Osteopathic Medicine*

* Joined later

ARIES Research Team

In total, nearly 60 Academic Researchers, over 50 Graduate and Undergraduate Students, almost 30 Academic Departments representing Colleges of Engineering, Science, Agriculture, Forestry, Liberal Arts and Human Sciences, Arts and Sciences, Public Health, Business and Medicine

Research Area Details

- Areas 1-4 focus on water issues
  - Impacts
  - Treatment
  - Prediction
  - Prevention (Material handling)
- Area 5 focuses on improved, environmentally-friendly, mining methods and processes
- Area 6 focuses on community well being and human health issues

Specific Research Areas under ARIES

- **Area 1**: Assessment of Mining Impacts on Ecosystem Health and Diversity (**WVU**, VT, MU)

- **Area 2**: Treatment and Minimization of Constituent Discharges (**WVU**, VT, UK, PSU, MU)

- **Area 3**: Prediction of Constituent Releases by Overburden and Refuse (**VT**, UK, WVU)

- **Area 4**: Overburden Handling and Fill Design (**UK**, VT, WVU)

- **Area 5**: Next-generation Eco-friendly Mining Systems (**VT**, WVU, UK, UPitt, PSU)

- **Area 6**: Evaluating impacts and optimizing contributions of mining on community well-being (**VT**, UPitt, PSU, OSU, VCOM, UPenn)

Area 1: Assessment of Mining Impacts on Ecosystem Health and Diversity (WVU, VT, MU)

❑ *What are the impacts of coal mining on water and aquatic organisms?*

- Mike Strager (WVU) – Regional geospatial database on water issues

- Todd Petty (WVU) – Modeling ecosystem response

- Stephen Schoenholtz (VT) – Mechanisms underlying biotic response

- Mindy Armstead (MU) – Develop cause-effect relationships

- John Craynon (VT) and Paul Ziemkiewicz (WVU) – Look at best regulatory approaches

Imagery Date: 4/13/2011   1996   38°05'22.50" N   81°54'37.70" W   elev 1205 ft   Eye alt   5144 ft
© 2011 Google
Image USDA Farm Service Agency
Image © 2011 DigitalGlobe
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Area 2: Treatment and Minimization of Constituent Discharges (VT, WVU, UK, PSU, MU)

❑ *What are the current and innovative technologies to treat water impacted by coal mining?*

■ Paul Ziemkiewicz (WVU) – identification of available treatment technologies

■ Emily Sarver (VT) – accelerated weathering of problematic source material

■ Bill Burgos (PSU) – biologic Fe(II)-oxidation

■ Richard Warner (UK) – alternative treatment systems

■ Mindy Armstead (MU) – minimizing treatment volumes

■ John Craynon (VT) – technical and economic feasibility

Area 3: Prediction of Constituent Releases by Overburden and Refuse (<u>VT</u>, UK, WVU)

- *How can we predict where coal mining operations may impact water?*

- Lee Daniels (VT) – spoil sampling
- Jeff Skousen (WVU) – detailed laboratory spoil analysis
- Richard Warner and Chris Barton (UK) – field screening techniques

Area 4: Overburden Handling and Fill Design (UK, VT, WVU, PSU)

❑ *Are there ways to handle coal mining materials and water flow to prevent water impacts?*

■ Richard Warner (UK) – spoil isolation and low permeability spoil barriers

■ Carl Zipper (VT) – alternative fill construction techniques

■ Jeff Skousen (WVU) – alternative fill construction techniques

Area 5: Next-generation Eco-friendly Mining Systems (VT/WVU, UK, UPitt)

- *How can coal mining and coal processing be done to improve environmental performance?*

- <u>Surface mining</u> – Vlad Kecojevic (WVU), Braden Lusk (UK), Carmen Agouridis (UK)

- <u>Underground mining</u> – Mike Karmis (VT), Tony Iannacchione and Jason Monnell (Pitt)

- <u>Coal preparation</u> – Jerry Luttrell (VT), Rick Honaker (UK), Mark Klima (PSU)

Area 6: Evaluating impacts and optimizing contributions of mining on community well-being (<u>VT</u>, UPitt, PSU, OSU, VCOM, UPenn)

- *What are the economic benefits and impacts of coal mining?*
- *Based on valid epidemiological studies, are there human health impacts from coal mining?*
- *What are the positive and negative contributions of coal mining to "community well-being"?*
- *What are the benefits and impacts of coal mining on society and communities in Appalachia?*
- *What can all interested parties - industry, government and communities - do to ensure that coal mining contributes to sustainable development?*

Area 6: (cont.)

- Economics – Andy Kleit and RJ Briggs (PSU)
- Sociology – Linda Lobao et al. (OSU)
- Cultural impacts – TBD
- Exposures and pathways – Nick Basta (OSU)
- Public Health
  - Epidemiology – Jeanine Buchanich et al. (Pitt)
  - Comparative health studies – Susan Meacham et al. (VCOM)
  - Mechanisms – Emily Sarver and Leigh Anne Krometis (VT)

Benefits of ARIES

- Answers basic questions about cause and effect
- Allows for development of best practices and innovation
- Reduces environmental costs and promotes addressing key issues
- Removes regulatory conflicts by creating new focus on real problems and science
- Informs the public discussion and creates opportunity for "**social license**"

ARIES Status update

- The second year of research work is nearly concluded

- Progress has been made in each of the six areas

- Year 3 budgets and work plans are being finalized

- ARIES annual meeting was held in Morgantown, WV, September 10-12, 2012

- Society of Mining, Metallurgy and Exploration hosting "Environmental Considerations in Energy Production" symposium to be held in Charleston, WV, April 14-18, 2013
  - ARIES researchers
  - Other related work

Review of some important ARIES results

- Water quality
  - Selenium
  - Conductivity
- Mining practices
  - Protection of surface water
- Economics
  - Impact on local economies
- Human health
  - Health disparities
  - Biological impairment in streams

Water quality

Selenium

Paul Ziemkiewicz, West Virginia University Water Research Institute

1. Selenium is a major regulatory focus under the Clean Water Act, resulting in significant costs for coal mining companies and delays in permitting

2. ARIES studies show that using a byproduct of acid mine drainage treatment may immobilize the selenium at a very low cost

What we already know about selenium

- Between 25 and 40% of total selenium is potentially mobile
- 80-90% of selenium is in black shale associated with the coal seams
- Its release rate is rapid (Peak concentration of Se occurs at year seven in all three studies)
- Selenite is sorbed by FeOOH (a readily-available byproduct of the treatment of acid mine drainage)

Therefore:
- Good case for selective handling if an economic means can be found for immobilizing most of the selenium
- Hobet lysimeters were established to test whether FeOOH can immobilize selenium in the field

FeOOH sorption of selenium

18 in FeOOH, avg Se 20 ug/L
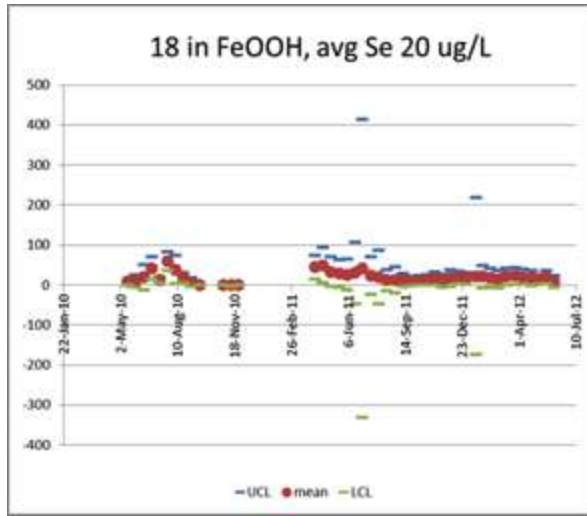
- Results of field tests at the Hobet Mine show that an 18 inch layer of FeOOH immobilizes most of the selenium
- The missing selenium appears to be permanently sequestered
- Study submitted for publication

Results demonstrate a possible low-cost solution to the selenium problem for Appalachian coal mining using readily available byproduct of AMD treatment

Ziemkiewicz's practical observations

- The success of this sequestration trial suggests that an inexpensive waste material (ferric iron-rich mine drainage treatment sludge) could be an effective spoil amendment that could reduce and control dissolved Se outbreaks at mine scale.

- Organic-rich shale tends to be among the most sulfur- and selenium-rich overburden lithologies. It is often found stratigraphically above coal seams which, in combination with its diagnostic color, makes it amenable to selective handling during the mining process.

- Placing layers of ferrihydrite placed within and at the base of selectively-handled cells of organic shale may be a practical method for immobilizing a significant proportion of the Se flux for an entire surface mine.

Strata – Conductivity and Se

Identification of strata with high or low specific conductivity (SC) - through simple screening techniques.

Stratum with higher SC - dark grey shale, black shale, grey sandy shale, and claystone (fireclay). > SO_4, Mg, Ca and lower pH.

70 to 90% of shale and fireclay contained < 2.5 mg Se/kg – many coal strata no or very low Se.

Se in black shale from a KY coal mine - zero-valent form particles – flocculation treatment.

Selenium Treatment (UK)

Se accumulators naturally exist in WV sediment ponds

Hyperaccumulators (times ambient Se)

Moss - 18,000

Algae *(Chara)* - 7,000

Periphyton - 5,000

Sequester selenate and selenite from water

Anaerobic microbes transformation to Se(0) nanoparticles (quite stable) or volatilize organic Se

Water quality

Conductivity

- Laura Kirby and John Craynon - Virginia Tech

1. Conductivity has been linked by the EPA to the health of the biologic communities in Appalachian streams and is being used as an indicator for permitting and regulatory actions under the Clean Water Act

2. There seems to be very little correlation between conductivity and VSCI scores in the Dumps Creek and Straight Creek watersheds. Data collected at different times show possible correlations that are very different from EPA regulatory guidance.

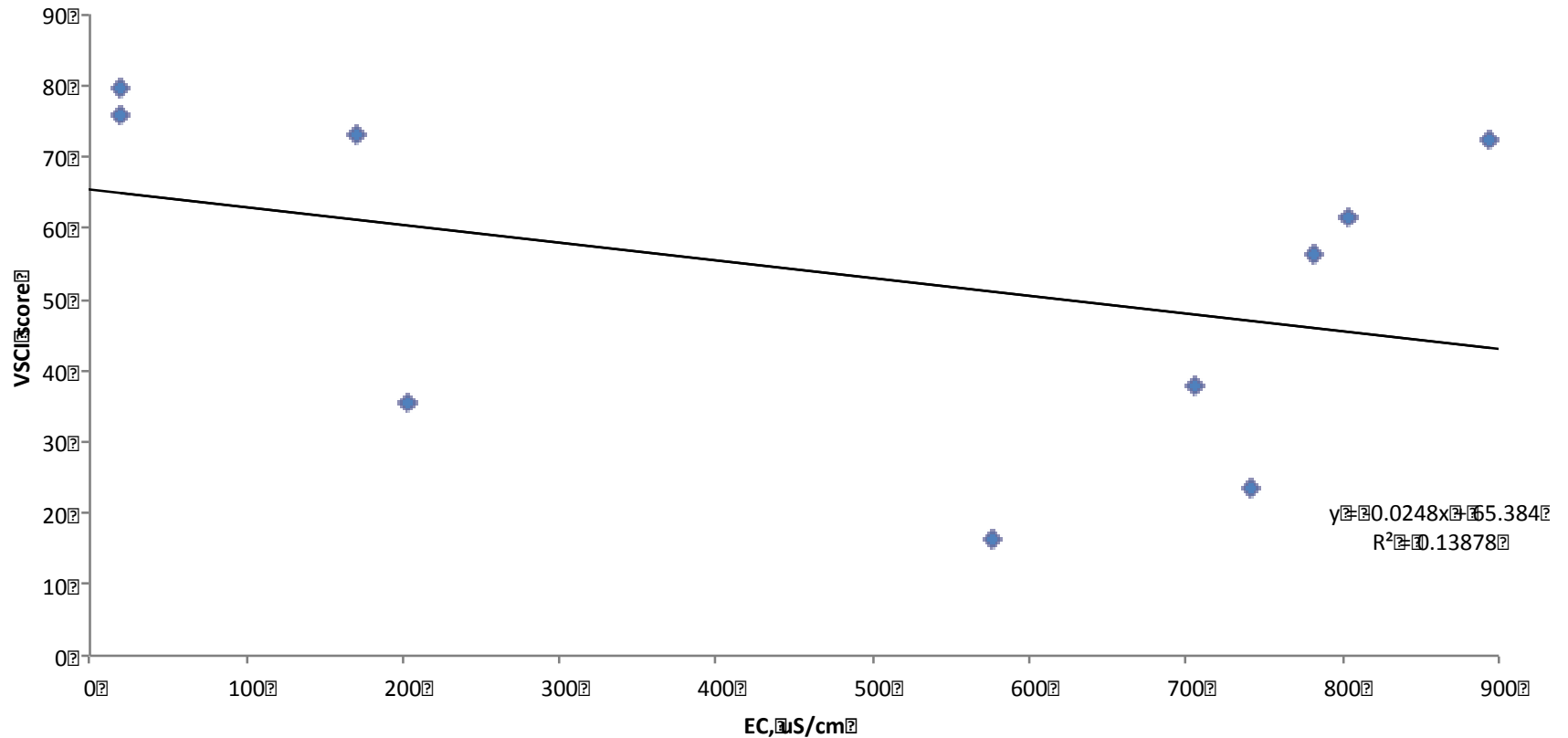# Conductivity versus VSCI scores based on historical data and VT study
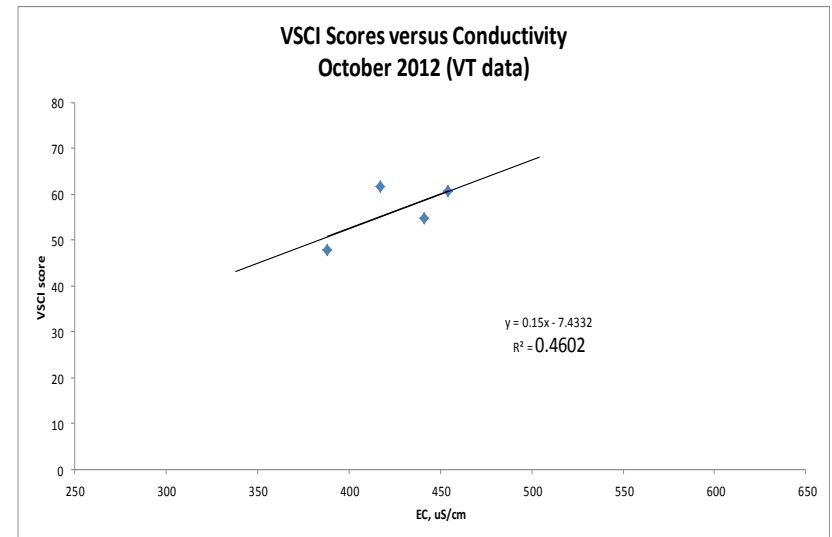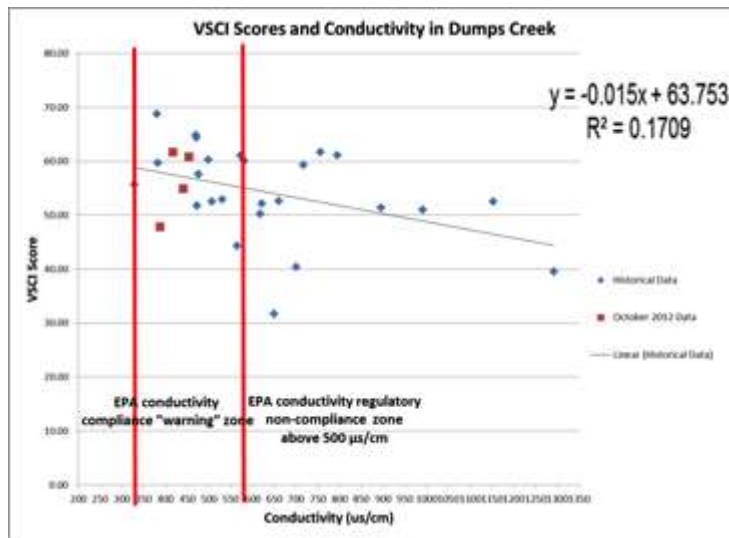
No reproducible correlation between conductivity and VSCI scores

Straight Creek Data (May 2008)
from Passmore and Pond, 2009

VSCI Scores versus Conductivity

$y = -0.0248x + 65.384$
$R^2 = 0.13878$

Improved Mining Practices

Barrier Pillars for Stream Protection in Appalachia

Michael Karmis – Virginia Tech

Zach Agioutantis – Technical University of Crete

An engineering approach has been developed under this project that can accomplish stream protection with smaller barrier pillars, as opposed to the current practice using empirical formulations.

Mechanism of caving and ground movements
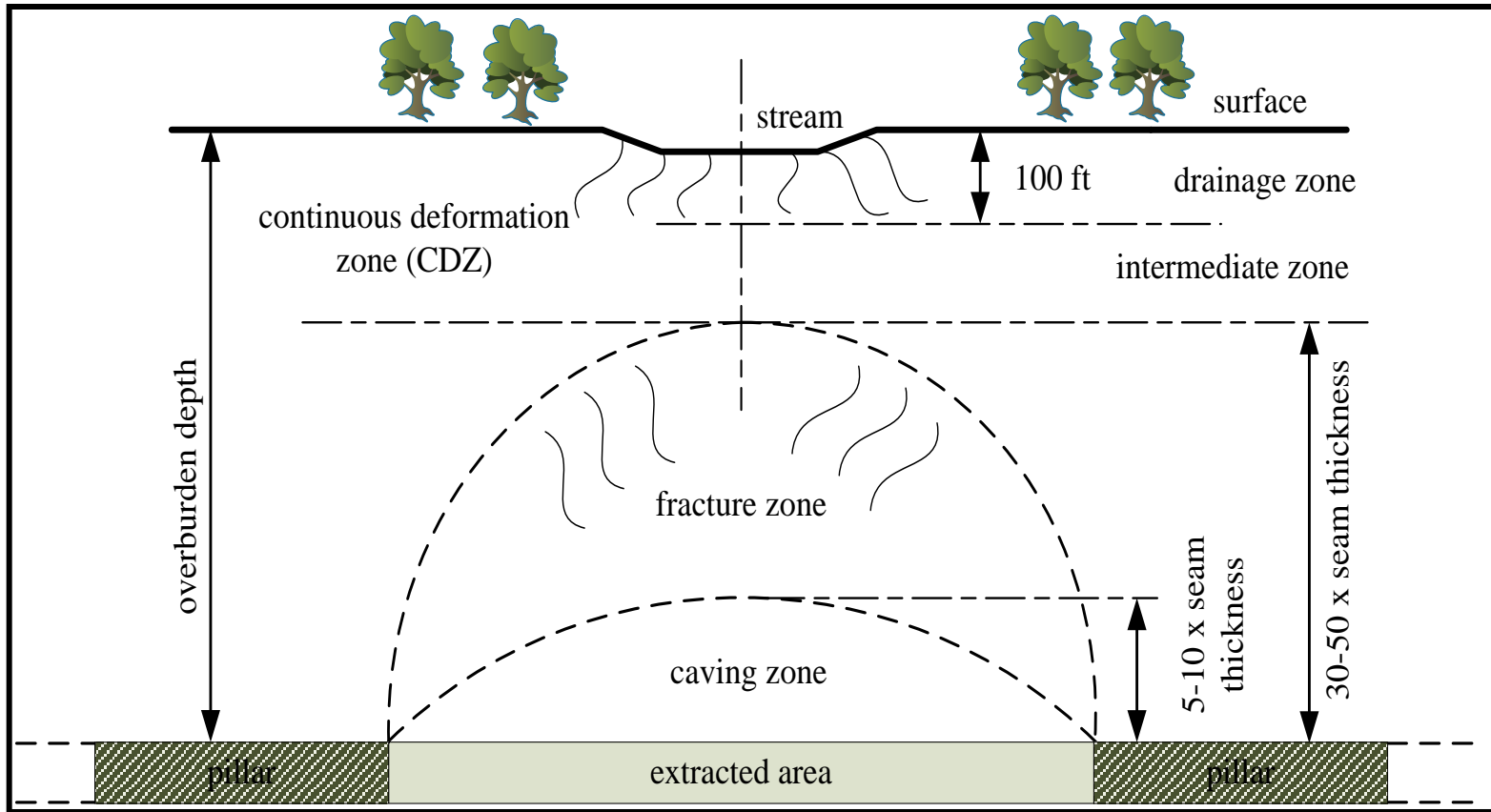
If depth < 50*t* + 100ft then barrier should be left in place
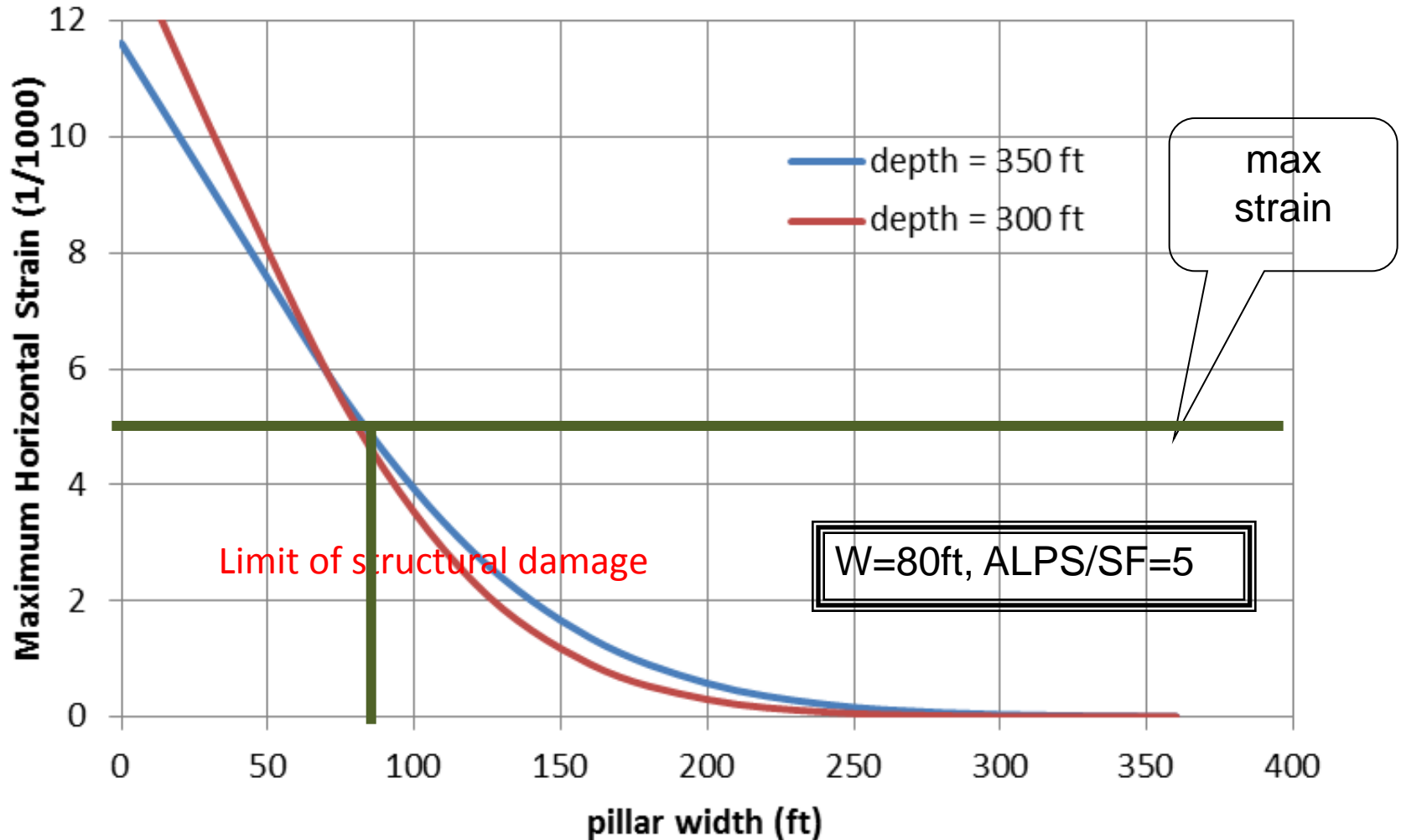If depth > 50*t* + 100ft then stream can be undermined

Empirical Rule
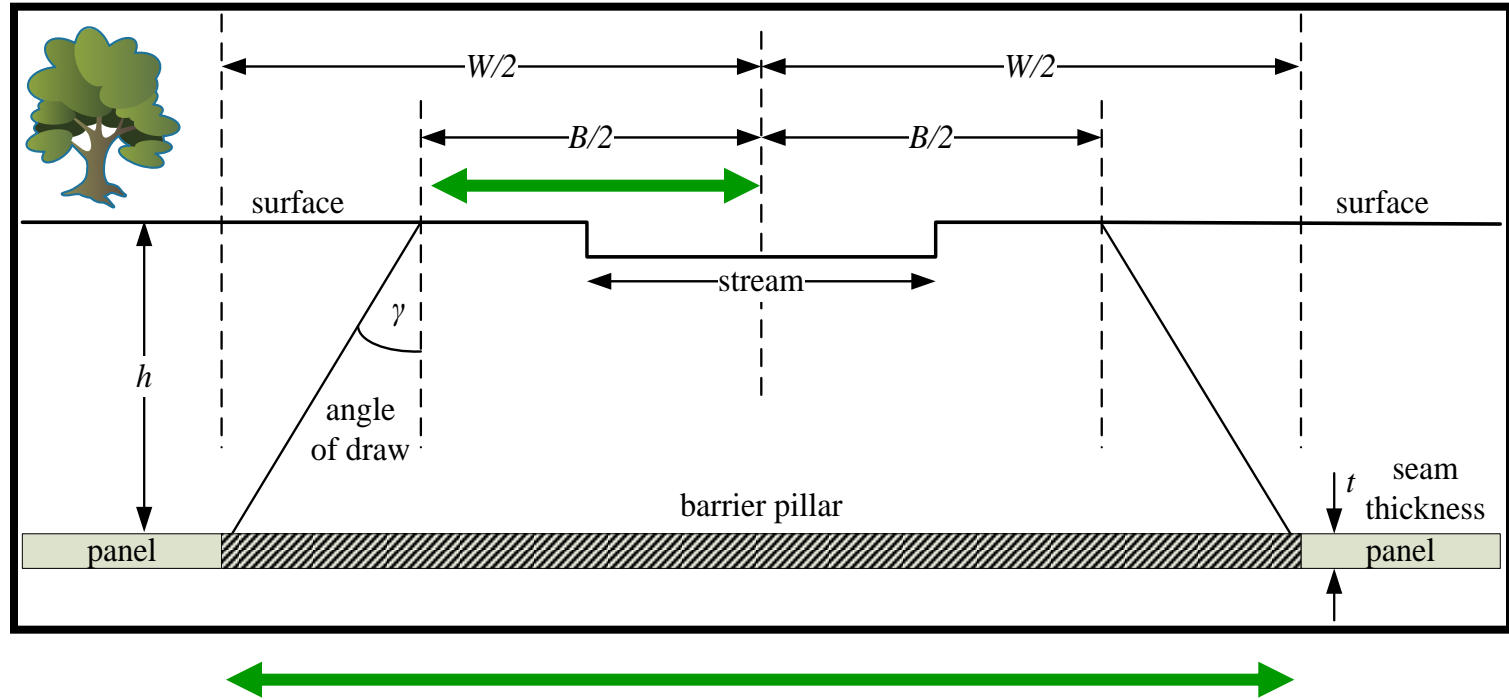
Barrier pillar width (W) = 2 x (50 ft + h tan 28)

W = 432 ft [for h = 300 ft]-- (ALPS/SF=62!!

W = 472 ft [for h = 350 ft]-- (ALPS/SF=69!!

Design of Barrier Pillars Using Ground Movement Criteria, +E=10ms (impoundments)-5ms

Economics

Impact on local economies

- Linda Lobao, Mark Partridge, Lawrence A. Brown and Mike Betz – Ohio State

- R.J. Briggs and Andy Kleit – Penn State

1. "Studies" have alleged that coal mining has negative economic impacts on the communities in which it occurs

2. Two separate ARIES studies show that mining has positive contributions to income and does not have negative economic impacts

Study findings: poverty

- The Appalachian region still experiences higher poverty levels than the rest of the U.S.

- Coal mining's past positive association with poverty (found in 1999 models) changed to a negative association in the post-2000 period.

Study findings: income

- Increases in mining have significant, positive impacts on real incomes

- Decreases in mining activity do not show concomitant negative effects on income

- Increases in population in coal producing counties also tend to increase income

- Coal mining does have measurable, positive impacts on per capita incomes

- Mining affords good employment opportunities for adults, with or without a high school diploma

Human Health

Health disparities

- Jeanine Buchanich et al. – University of Pittsburgh

1. A series of "studies" have suggested human health disparities in areas of Appalachia with coal mining

2. ARIES studies focused on independent evaluation of data and show:

- Age-adjusted mortality rates higher in mining counties across all time periods. With exception of all cause, rates are converging

- Data do not imply mining causally associated with mortality

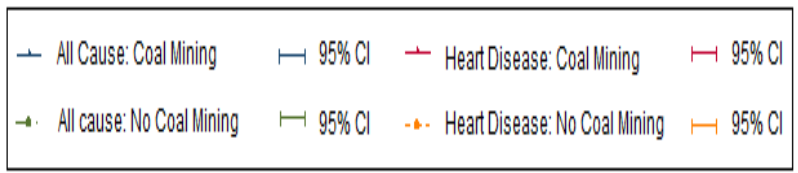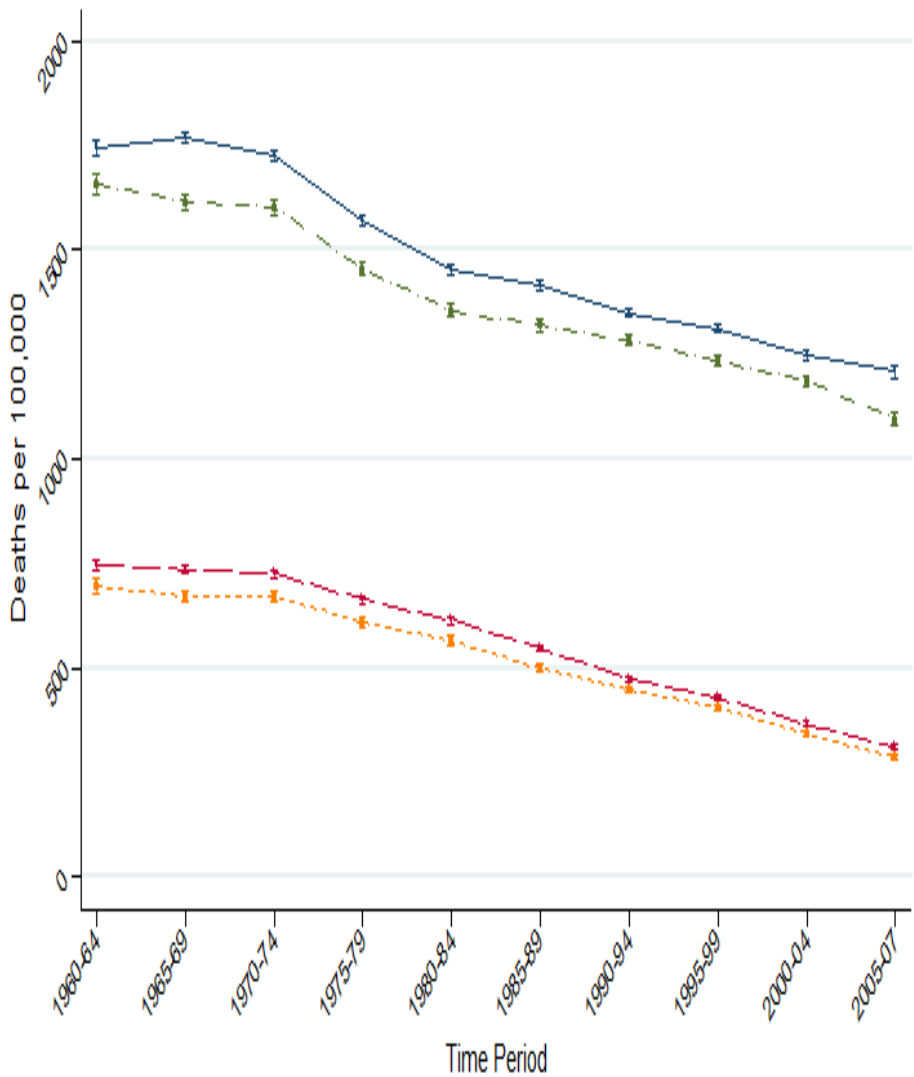- ARIES work points out that many confounding factors were not considered in the analyses of other "studies"

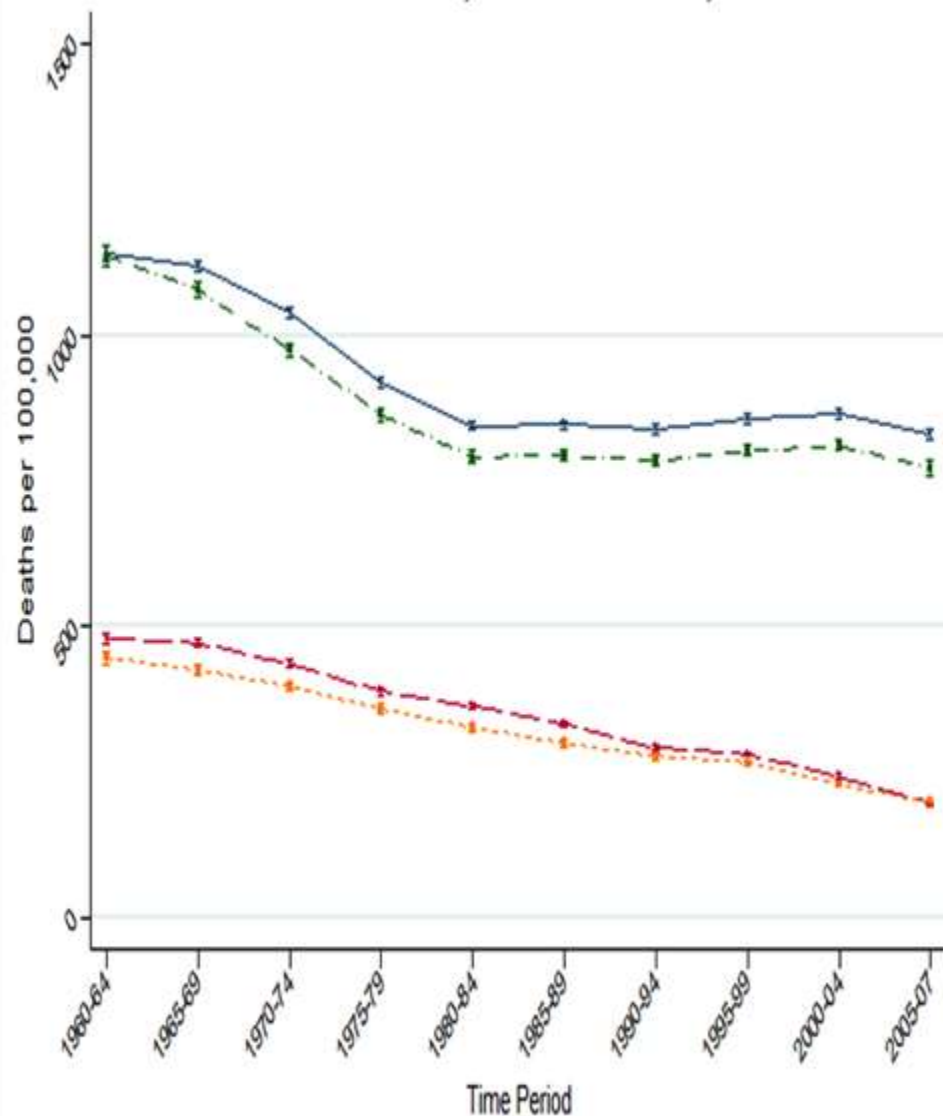# Specific Aim

Ecological evaluation

Compare mortality in Appalachian coal-mining versus non-coal mining counties

Examine total and select cause-specific mortality rates

White Male All Cause Mortality and Heart Disease Mortality Rates

White Female All Cause Mortality and Heart Disease Mortality Rates

Increased concerns about health

- A number of "studies", primarily conducted by a small group of researchers, have concluded coal mining is associated with various negative impacts on human health

- The USGS has begun conducting research focused on health impacts of coal mining, including impacts from dust and water contamination

- Questions about these findings
  - Dr. Jonathan Borak and his colleagues have questioned previous results
  - EPA staff recently presented on problems with research "proofiness" which misuses statistics and other analysis

ARIES health research emphasis

- Epidemiological studies focused on determining disparities in human health among mining and non-mining counties

- Analysis of exposure, bioavailability and metabolism of materials associated with mining

- Analysis of exposures via dust

- Analysis of other factors contributing to health issues
    - Lifestyle, poverty, obesity, etc.
    - Exposure to biocontamination (inadequate or non-existent sewage treatment)

Human Health

Biological impairment

- Emily Sarver, Leigh-Anne Krometis and Nicholas Cook – Virginia Tech

1. ARIES study shows that there are impacts on water quality in the coal mining areas of Appalachia other than coal mining, which have the potential to create human health impacts.

- High potential for human contact with impaired water

- Great opportunity to reduce human health risk through better sewage treatment

Bacterial impairments

- Bacterial contamination remains the single largest identified cause of surface water impairments in the US
  - Identified by fecal indicator bacteria (FIB) → coliforms, *E. coli*
  - Typically associated with urban storm-water, municipal wastewater or agricultural discharges
  - Association with direct residential discharges is often locally understood, but neglected in terms of TMDL (or other mitigation) implementation
  - Human health risks due to potential spread of pathogens *(particularly in cases of human sources)*
  - Ecological health risks due to water quality *(dependent on levels of bacteria overall discharge makeup)*

Project goals

In Central Appalachia, plenty of anecdotal evidence suggests that bacterial water impairments are huge problem

In terms of community wellbeing, we aim to:

- Understand just how big the problem is

- Understand what the primary contributors and potential effects are

- Put this problem into context with other "high priority" water quality issues

- Contribute to sustainable solutions

Assessing extent of problem

State	% Regional Impairments Attributed to Fecal Indicator Bacteria	
	Central App	Non-Central App
Kentucky	47	46
Virginia	77	64
West Virginia	29	n/a
Maryland	39	31
Ohio	4	12
Pennsylvania	5	12
TOTAL	**32**	**25**

Total impaired stream miles in Central Appalachian counties: ~42,000
Total impaired stream miles in non-Central Appalachian counties: ~63,000
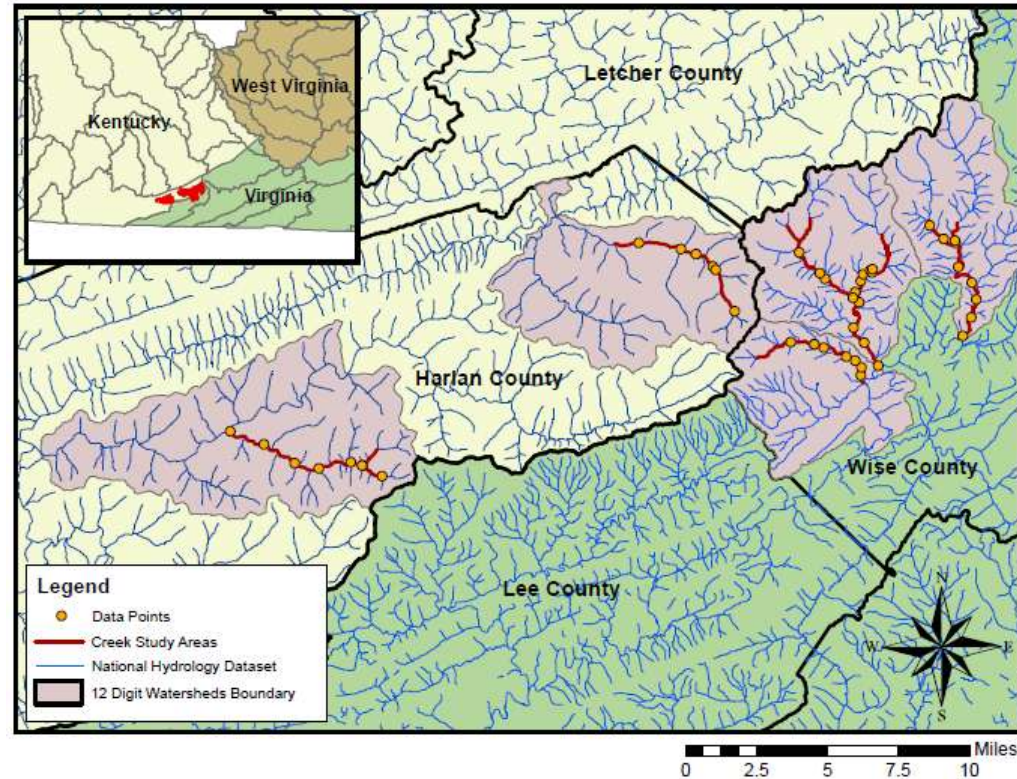
Assessing extent of problem

Recreation?

Irrigation?

Field study

- 2-year study of 5 paired watersheds
  - Water quality (monthly)
  - Benthic surveys (fall/spring)*

	SIGNIFICANT WASTEWATER DISCHARGES	ADEQUATE WASTEWATER TREATMENT
MINING	Roaring Fork & Callahan Creek, VA	Looney Creek, VA
NON-MINING	Yocum Creek, KY	Looney Creek, KY

Legend
- Data Points
- Creek Study Areas
- National Hydrology Dataset
- 12 Digit Watersheds Boundary

*surveys at 9 locations are being conducted as part of this project; surveys results from approximately 24 other locations are being shared by industry

Summary and Status

- ARIES has already gotten meaningful results and publications in less than two years

- Commitment to the program essential to get return on investment

- Program of research being reviewed for efficiencies and to deal with funding levels

- Major restructuring of ARIES website underway

- Consideration of expansion to utility, oil and gas, and potentially hard rock mining issues

"Environmental Considerations in Energy Production" symposium

- International symposium to focus on ARIES and similar work

- Fourteen technical sessions on various topics – plus plenary sessions involving political and industry leaders

- To be held at the Charleston Marriott, Charleston, WV, April 14-18, 2013

- Brochure and registration available

Conclusions

- Since coal mining (and use) will be important for decades to come, focus needs to be on doing it the best possible way based on good science

- Other aspects of energy production also need the development of good science

- Regulations and other structures that can lead us to "sustainable development" need to have good science to get full participation and acceptance

Conclusions (cont.)

- ARIES is a new paradigm for research
  - Funded and supported by industry but directed by researchers
  - Independent research conducted at universities
  - Focus on wide dissemination of results and peer-reviewed publications
  - Realistic timeframes for research and reporting
  - Focused on developing good science

ARIES

- For more information:

  http://www.energy.vt.edu/ARIES

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