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A Watershed Scale Approach to Mine Drainage Management

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ASMR Laramie WY: 9 June 2026

Watershed scale AMD treatment

- Acid mine drainage (AMD) is a widespread pollutant caused by mining activities.
- AMD contaminates streams with acidity, sulfates, and metals.
- 12,400 miles of streams contaminated by AMD in the US.
  - 2500 (20%) of those miles are in WV.

The Problem with Mine Water Treatment: High cost, low return

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- The CWA, page 1 tells us that its objective is protecting and recovering streams to their designated use:
  - Public water supply
  - Fishery
  - Recreation
  - Agriculture, industry, navigation
- We spend tons of money treating individual, regulatory point sources without recovering stream miles

- **Why? Streams in historic mining districts are often impaired by dozens of discharges, MOSTLY pre-law, unregulated**
- **So, in an AML-rich watershed, treating only the regulated point sources won't recover stream miles.**
- **It <u>is</u> very expensive, though**

Perhaps we're using the wrong metrics

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- Discharge limits can be based on water quality discharge standards for mines in a particular region.
- Success is based on meeting those limits.
- Often that means putting very clean (and expensive) water into a stream that remains impaired downstream of the discharge.
- It doesn't matter, in that case, whether you've met your discharge limit, the receiving stream is still impaired.
- Recovered stream miles per a TMDL is probably a better metric.

Other things that can go wrong:

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- If the coal market deteriorates, the liabilities for maintaining those AMD treatment plants can devolve to a less-well capitalized company or default to the bond holder (surety company or state).
- They are not always in a position to address court-imposed penalties.
  - E.g. a ‘Liability Dump” where the public pays for maintaining the treatment plants or lives with increasingly polluted streams.
- Poorly documented underground mine voids may fill with AMD and start discharging years or decades after closure, increasing the total liability.
- The point source strategy lacks flexibility.

On the bright side:

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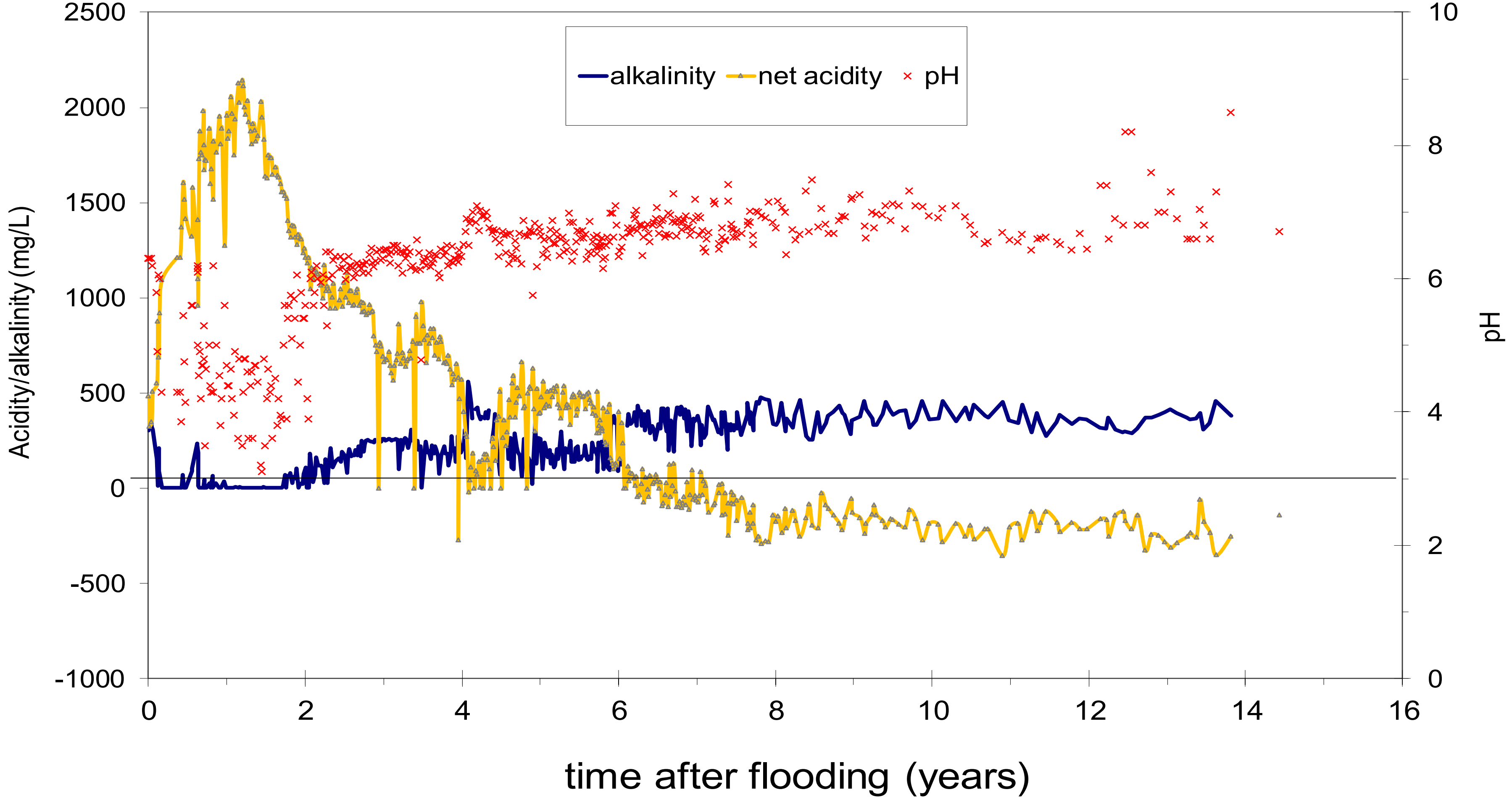
- Attenuation of AMD in above drainage surface mines may be 2-7%/yr due to pyrite exhaustion.
- In the right geology, below drainage underground mines may fully flood, cut off new oxygen and go net alkaline within 10 years.
- OSM's Acid Mine Drainage Policy of 1997 prohibits permitting new mines with a potential for indefinite AMD generation.
  - Alkaline addition
  - Spoil blending
  - Capping
  - Permit denial
- So, the pool of new AMD sources should continue to decline.
- Don't forget Rare Earth, Critical Mineral Recovery

Below Drainage, Pittsburgh Seam Underground Coal Mine

Acid loads can be very dynamic



pH, alkalinity, and net acidity in pumped discharge from Montour 4 AMD plant

Why the point source strategy often fails to meet the objective of the CWA

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1. Often accounts for a fraction of the watershed's pollutant load
2. Declining coal production
3. Less revenue to the State's Bond Pool (water trust fund)
4. Permit holders spend money treating AMD while leaving little to no useful AMD treatment infrastructure behind
5. If 1, expenditures rarely lead to stream recovery
6. Encourages liability dumps/shenanigans/lawyers get rich
7. Permit liabilities default to the State's Bond Pool
8. State Agency invariably needs to rebuild the inherited AMD treatment facility

Impediments to Watershed Restoration

- Jurisdictional boundaries
  - AML (Pre SMCRA 1977) vs.
  - Bond Forfeiture (Post SMCRA 1977)
  - Regulatory focus on active NPDES permits
- Regulatory tools
  - CWA Sec 402 (NPDES): Point source discharge permitting
  - **TMDL = ΣWLA + ΣLA + MOS** should work but generally implementation only means further restriction of the **WLA**: NPDES discharge limits and calling it a day
  - Stream is still dead
  - Or: Account for all pollutants in the watershed: **ΣWLA + ΣLA**
  - Need voluntary tools for addressing the non-point sources
  - Must come with documentable costs and environmental benefits

Solution: The Watershed Strategy

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Develop a TMDL based Watershed Improvement Plan

1. Identify pollutant loads/sources: **TMDL = Σ WLA + Σ LA + MOS**
2. Determine load reduction goals
3. Develop implementation plan that addresses all AMD sources:
   a. Treatment strategies/costs
   b. Financing via:
      - AML (Pre SMCRA 1977)
      - Bond Forfeiture (post SMCRA 1977)
      - Active permits:
        - Permit holders can contribute to approved watershed improvement plan
        - Or continue NPDES maintenance
      - Other private sector contributions: ESG
4. Managed by the State DEP's Bond Pool or equivalent

Case Study:
The Muddy Ck Project

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- Point source discharges were regulated, AML discharges were not.
- Muddy Ck was responsible for about 50% of the acid load to the Cheat River
- Three of its main tributaries:
  - Fickey Run
  - Martin Ck
  - Glade Run

  Were severely polluted

  The Cheat River downstream of Muddy Ck was dead as was Cheat Lake

The Muddy Ck Project

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- Initially WVDEP operated many point source AMD treatment units on Bond Forfeiture sites
- This proved expensive and did not result in any stream recovery
- The Muddy Ck project was allowed to move forward because EPA granted an in-stream NPDES permit variance
- The results have been spectacular

Many point source, bond forfeiture AMD treatment units were replaced by the Central Muddy Ck AMD plant

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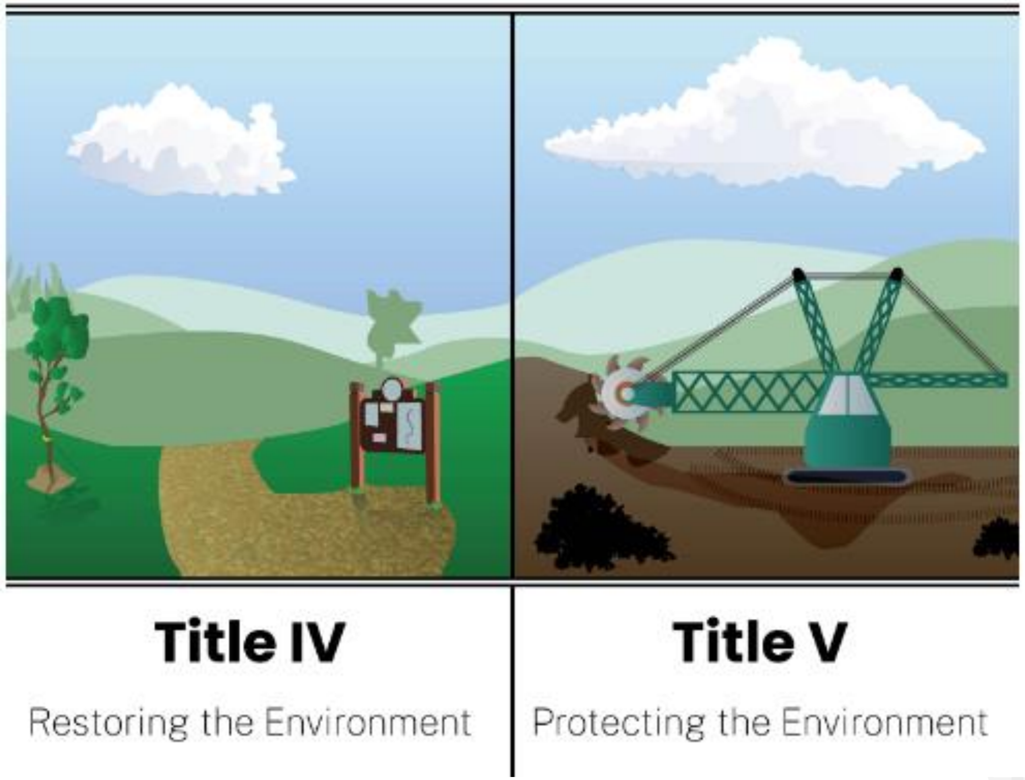
Point source: Rockville Mining

Watershed scale: Muddy Ck

Background: The “Titles”of AMD

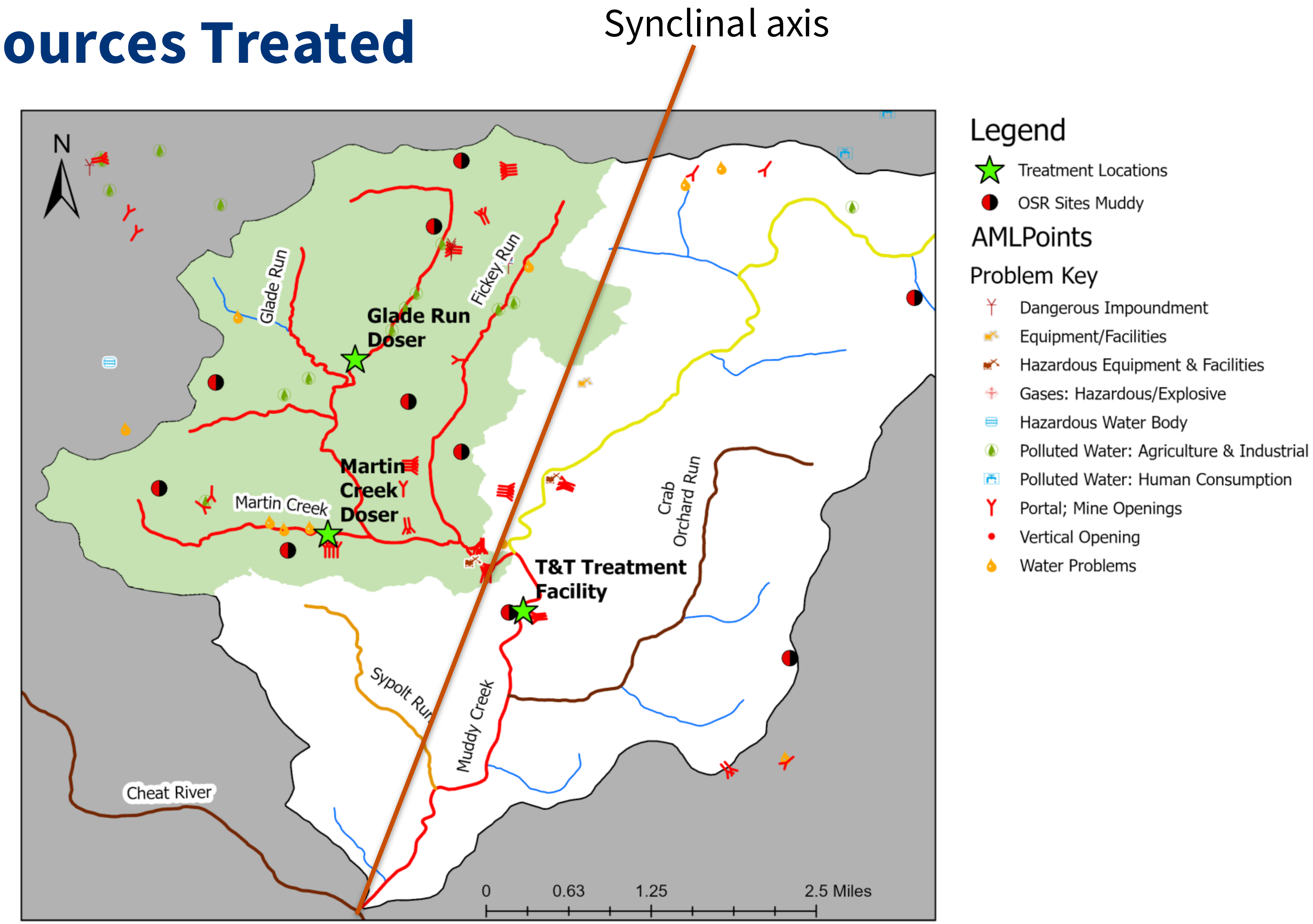
The Surface Mining Control and Reclamation Act (SMCRA) created the separation

- Abandoned mine lands (AML) – responsible for mines that were abandoned pre-1977 (Title IV)
- In WV, the Office of Special Reclamation (OSR) regulates mines and AMD that were active post-1977 (Title V)
  - —After 2010 OSR treated to WV State Water Quality Standards

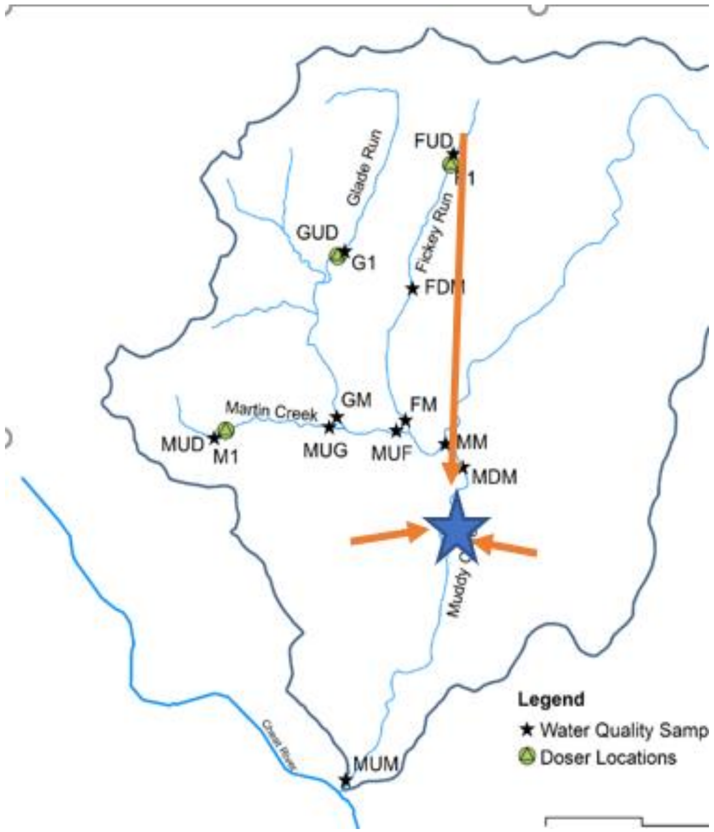


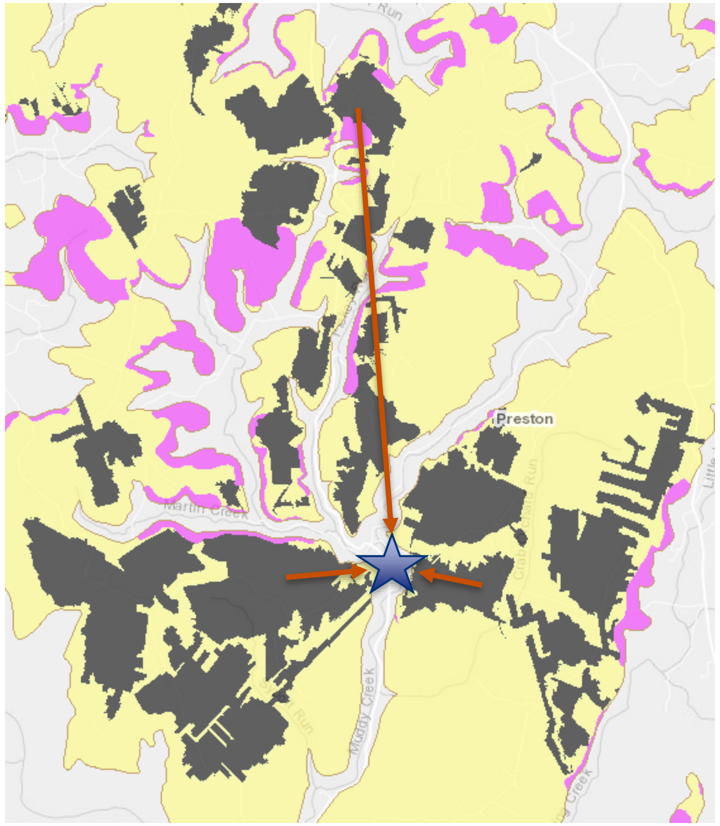
In-Stream Dosing and Sources Treated

- **Glade Run Doser**
  - Installed in late 2015
- **Martin Creek Doser**
  - Installed in 2022
- **Benefits**
  - targeted treatment of highly acidic tributaries, improving overall watershed water quality.



Consolidation of deep mine AMD





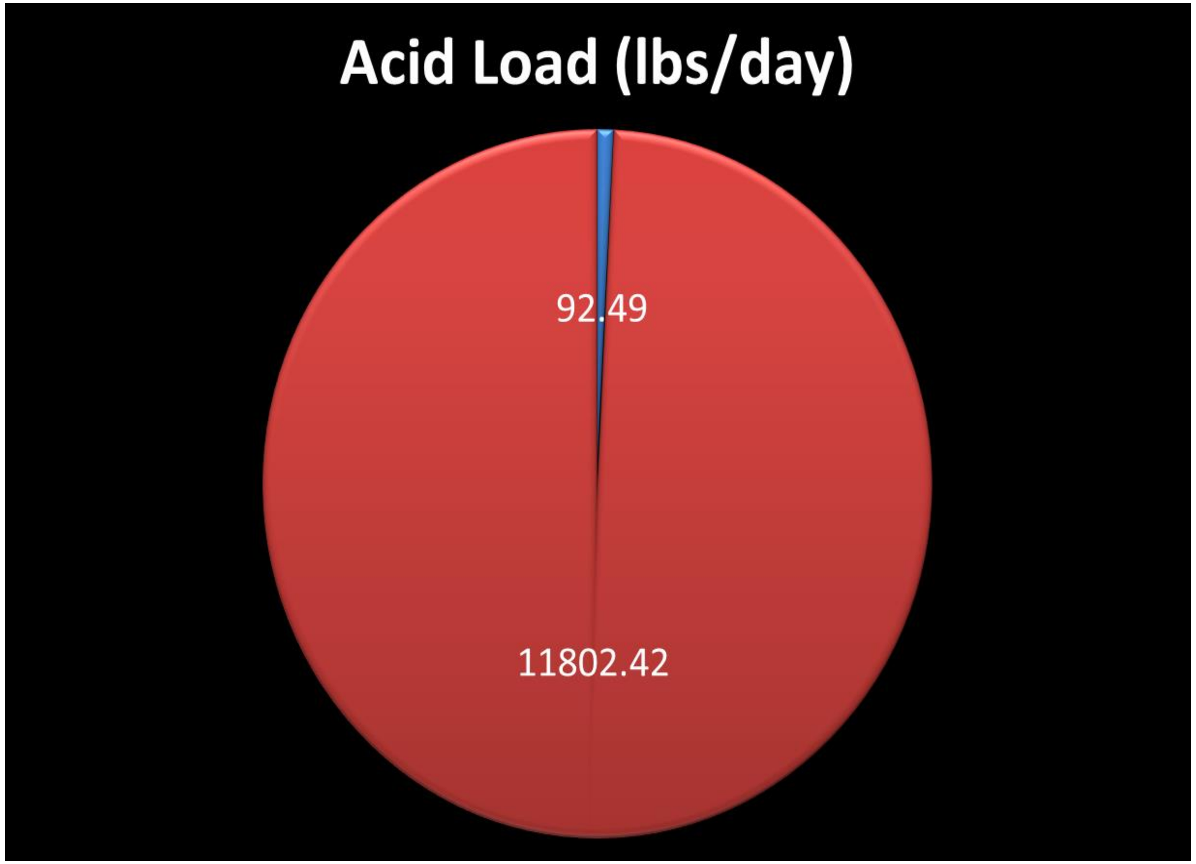
The Watershed Strategy

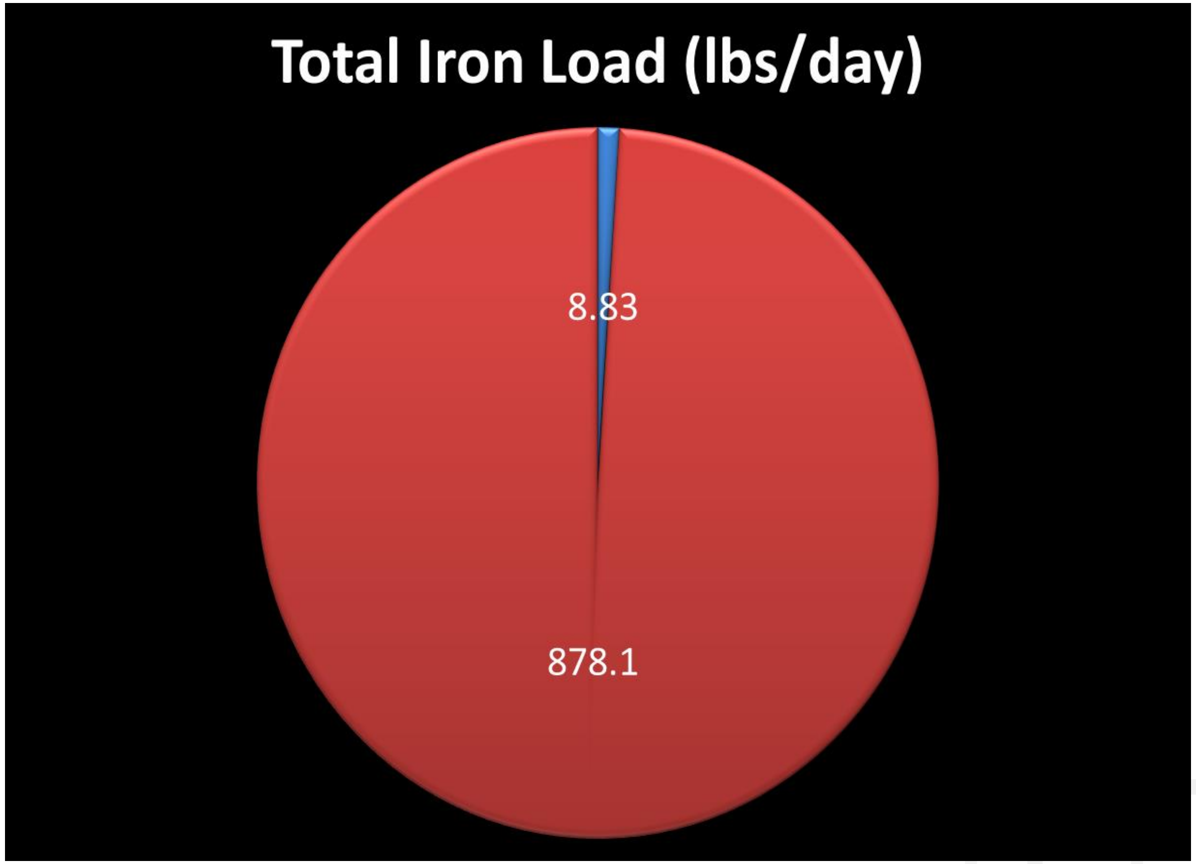
- Higher CapX: water transfer, central facility
- Lower OpX: road maintenance, compliance monitoring, QC, supplies
- Southwestern Energy volunteered to help:
- The Cheat River is now a walleye fishery
- Documented costs and benefits are attractive to external sponsors
- ESG, offsets, charitable contributions

Watershed vs. point source

	W/SWN	WO/SWN
CapX	7%	21%
OpX	-456%	-89%
Total	-48%	-6%

Develop a strategy that addresses all pollutant loads in Muddy Ck. AML loads in red. Regulated discharges in blue





Implementation: T&T Treatment Facility: Designed and built by WVDEP

- **Location**
  - Built along Muddy Creek, 0.5 miles downstream of Martin Creek confluence.
- **Capacity**
  - Treats approximately 4,500 gallons per minute of AMD.
  - The T&T facility treats AMD from four bond forfeiture sources, including three partially flooded deep mines and one surface mine.
  - In addition, approximately 250 gallons per minute of pre-1977 AML water from a refuse coal area and one deep mine are conveyed from the headwaters of Fickey Run to the facility.
- **Treatment Process**
  - Uses lime slurry, polymers, mixing tanks, and clarifiers to raise pH and remove metals.

Went online March 2018

Results: The Cheat River is no longer impaired

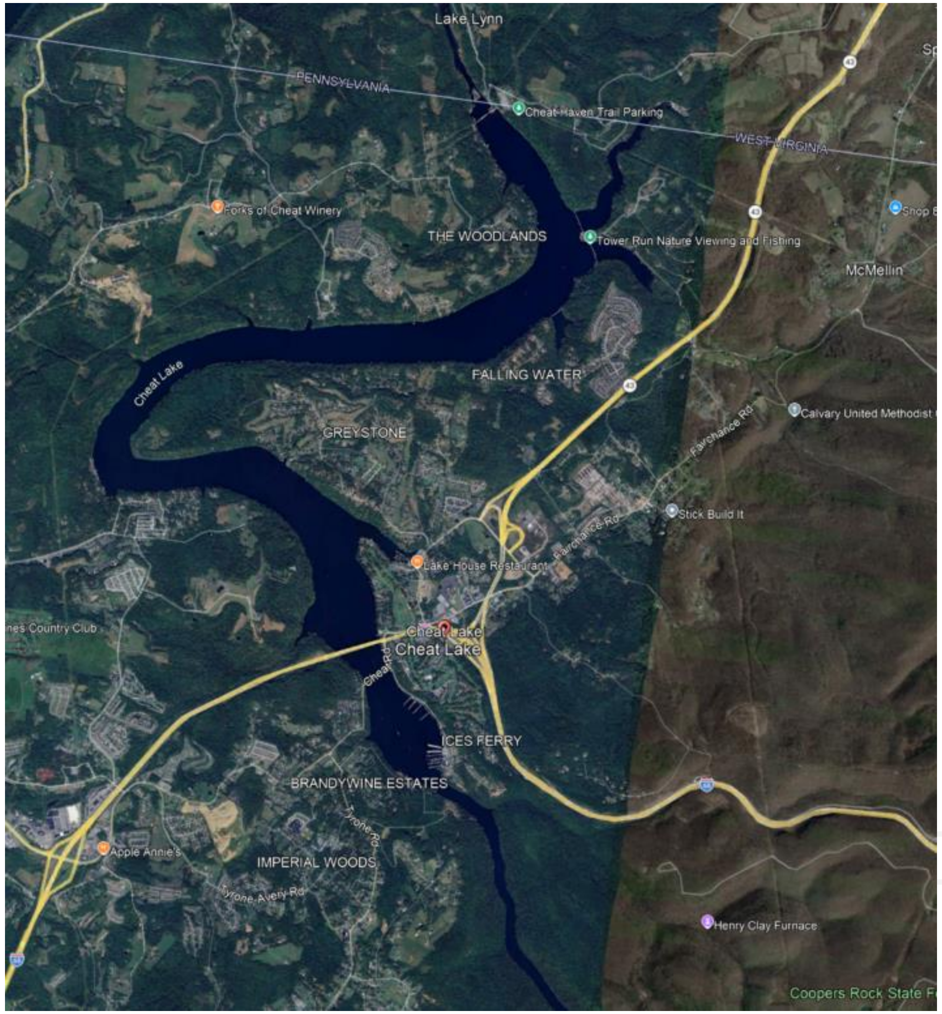
Confluence of Muddy Ck and the Cheat R before and after completion of the Project

Muddy Creek: Before and After

10 Nov 2015

25 Oct 2023

Cheat Lake: before and after



Point source vs. Watershed Strategy

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Project selection criteria:

$/t pollutant removed/yr

Does not count 9 miles of Cheat Lk recovery

	Strategy		
Cost ($ million)	Point Source	Watershed *	Watershed **
CapX	$ 12,500,000	$ 15,920,000	$ 15,920,000
Southwestern Energy Contribution		$ (2,500,000)	
Net CapX	$ 12,500,000	$ 13,420,000	$ 15,920,000
OpX per year	$ 1,000,000	$ 530,000	$ 530,000
Southwestern Energy Contribution		$ (350,000)	
Net OpX (10 yrs)	$ 10,000,000	$ 1,800,000	$ 5,300,000
Total costs over 10 years	**$ 22,500,000**	**$ 15,220,000**	**$ 21,220,000**
Savings		$ 7,280,000	$ 1,280,000
Stream Miles Recovered			
Muddy Ck	0	3.20	3.20
Cheat River	0	16.00	16.00
Total stream recovery	**0**	**19.20**	**19.20**

* with SWE contribution

** without SWE contribution

Summary

- Muddy Creek has seen improvements since the program began ~ 2016
  - The Goal was to restore the 3.4 miles of Muddy Creek below Martin Creek
- Muddy Creek is no longer a significant contributor of AMD to the Cheat
- **19 MILES OF THE CHEAT RIVER AND CHEAT LAKE ARE NOW FISHERIES**
- Higher CapX: water transfer, central facility:
- Lower OpX: road maintenance, compliance monitoring, QC, supplies: **MUCH of the CapX & OpX COVERED BY SOUTHWESTERN ENERGY**
- Has potential for recovering rare earth elements (REEs) and critical materials (CMs)

AMD and REE

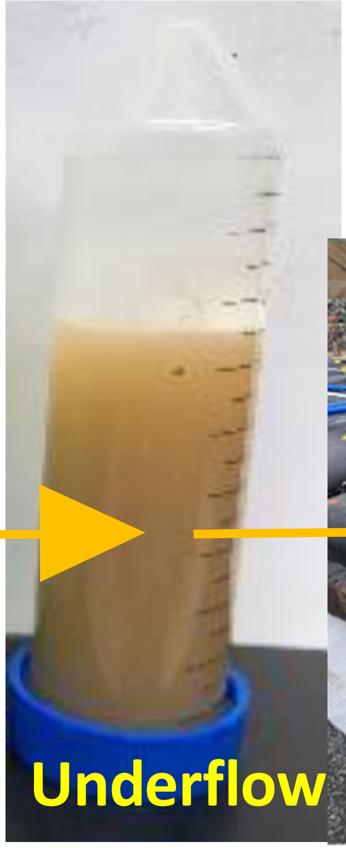
- Acid mine drainage (AMD)
  - Pyrite oxidizes to form sulfuric acid.
  - Leaches metals.
  - Including REE/CM
  - Lower pH=higher REE/CM
  - REE/CM precipitate as easily dissolved hydroxides

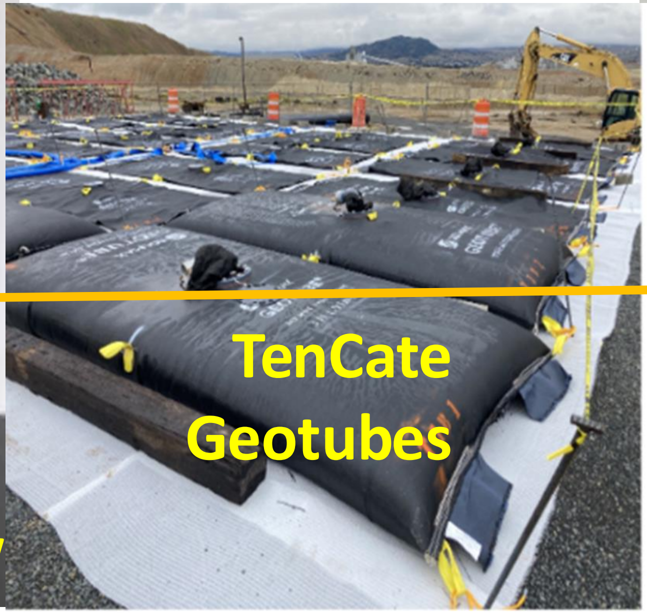
Image Source: Eliza Siefert, WVWRI

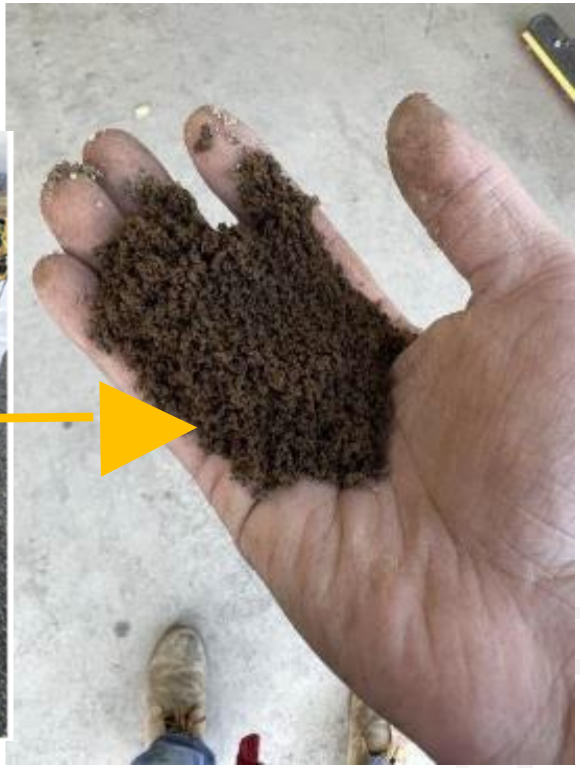
Conceptual Operations Model
Upstream

Modified AMD treatment plants treat AMD and produce Hydraulic Preconcentrate

Input:	Raw acid mine drainage	Output:	Hydraulic preconcentrate (HPC)
			Clean water
REE grade	0.3 -7.0 mg/L	REE grade	0.5-5.0%
% moisture	100%	% moisture	20-40%







Minimum Requirements:

- Two clarifiers with independent pH control
- High REE load
- Access
- Site operator agreement

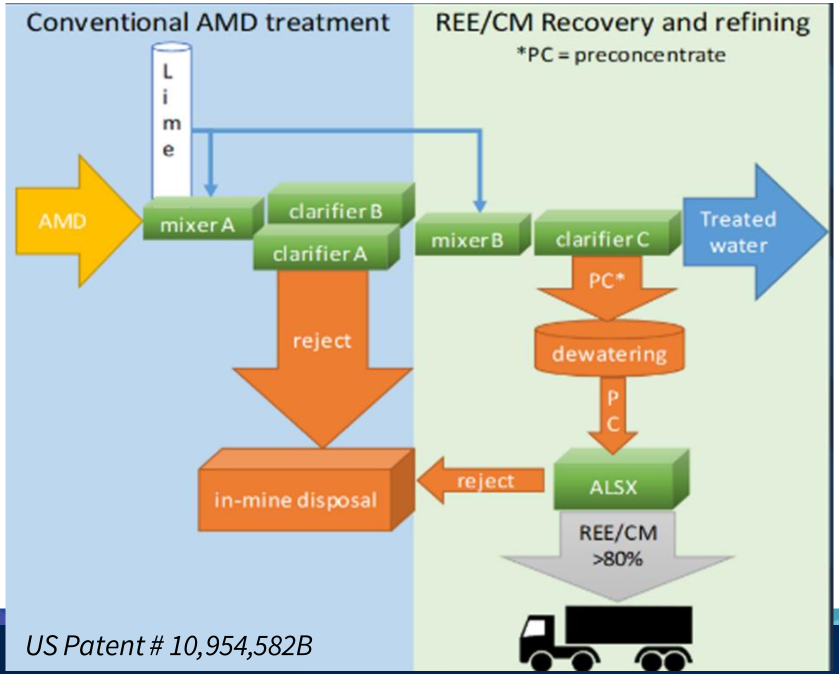
REE/CM Recovery from AMD

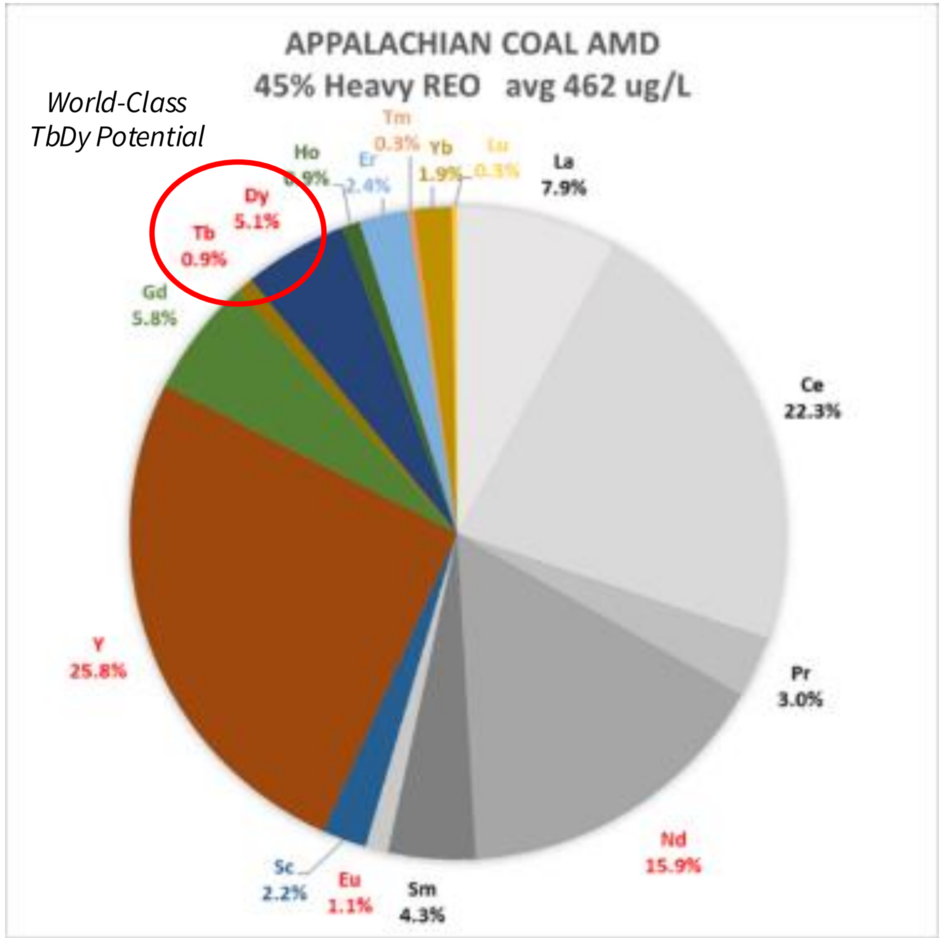
Advantages:

- Concentrates are 45% HREE
- Incentivizes AMD treatment
- Discharges CWA compliant water
- Already permitted sites
- Can go into production almost immediately
- Modest additional CapX
- No rads, solid rejects are non-hazardous

Disadvantages

- Small, dispersed, upstream production sites





Financial Profile

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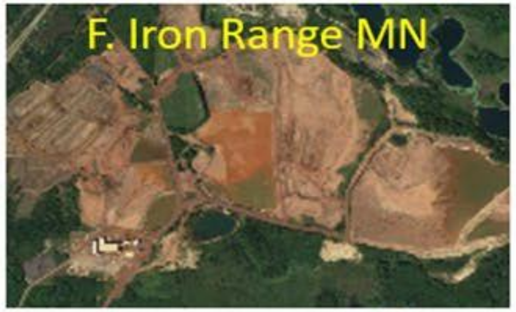
Estimated REE/CM yields: USDOE requirements 1-3 tpd, >50% coal based

Estimated Yield	n	Source	Oxide TREE t/yr	Oxide Co t/yr	Oxide Mn[2] t/yr	Oxide REE+Co t/yr	Oxide REE+Co+Mn t/yr
measured	112	WVU samples 2017	17.8	20.3	180.0	38.1	218.1
measured	51	WVU samples 2021	36.0	40.0	417.9	75.9	493.8
measured	28	USGS PA[4]	10.8	26.4	257.5	37.2	294.7
	191	Measured coal AMD	64.6	86.6	855.4	151.2	1006.6
Inferred [1,3]	132	TN, KY, WV, OH, PA, MD	72.4	81.6	857.3	154.0	1011.3
	323	Total Coal	137.0	168.2	1712.7	$\boxed{305.2}$	2018.0
	6	Measured Hard Rock	167.2	114.0	1644.6	$\boxed{281.3}$	1925.9
Total yield	329	Coal + Hard Rock	304.2	282.3	3357.4	586.5	3943.9
		Coal/Hard rock	0.82	1.48	1.04	1.09	1.05

Conceptual Operations Model
Upstream

HPC is produced at AMD treatment plants in major source districts (A-F), feed regional concentrators and deliver MREO to a Central Refinery.



Potential source districts

A: Northern/Central APP

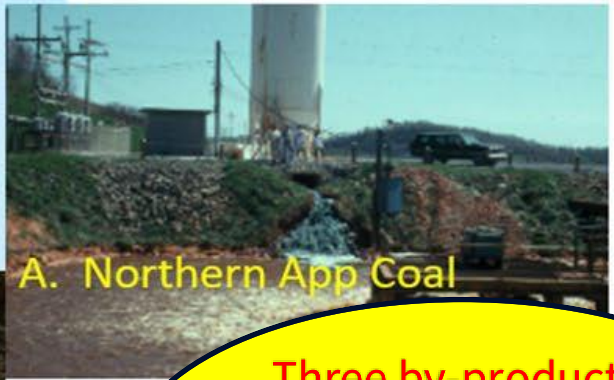
B: Southern APP/Illinois basin

C: Southern Rockies metal belt

D: Sierra metal belt

E: Northern Rockies metal belt

F: Minnesota iron range



Three by-products:

1. Clean Water
2. 95% pure MREOs
3. Multiple CMs

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Thank You

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