AMD and REE:
Watershed Scale Restoration

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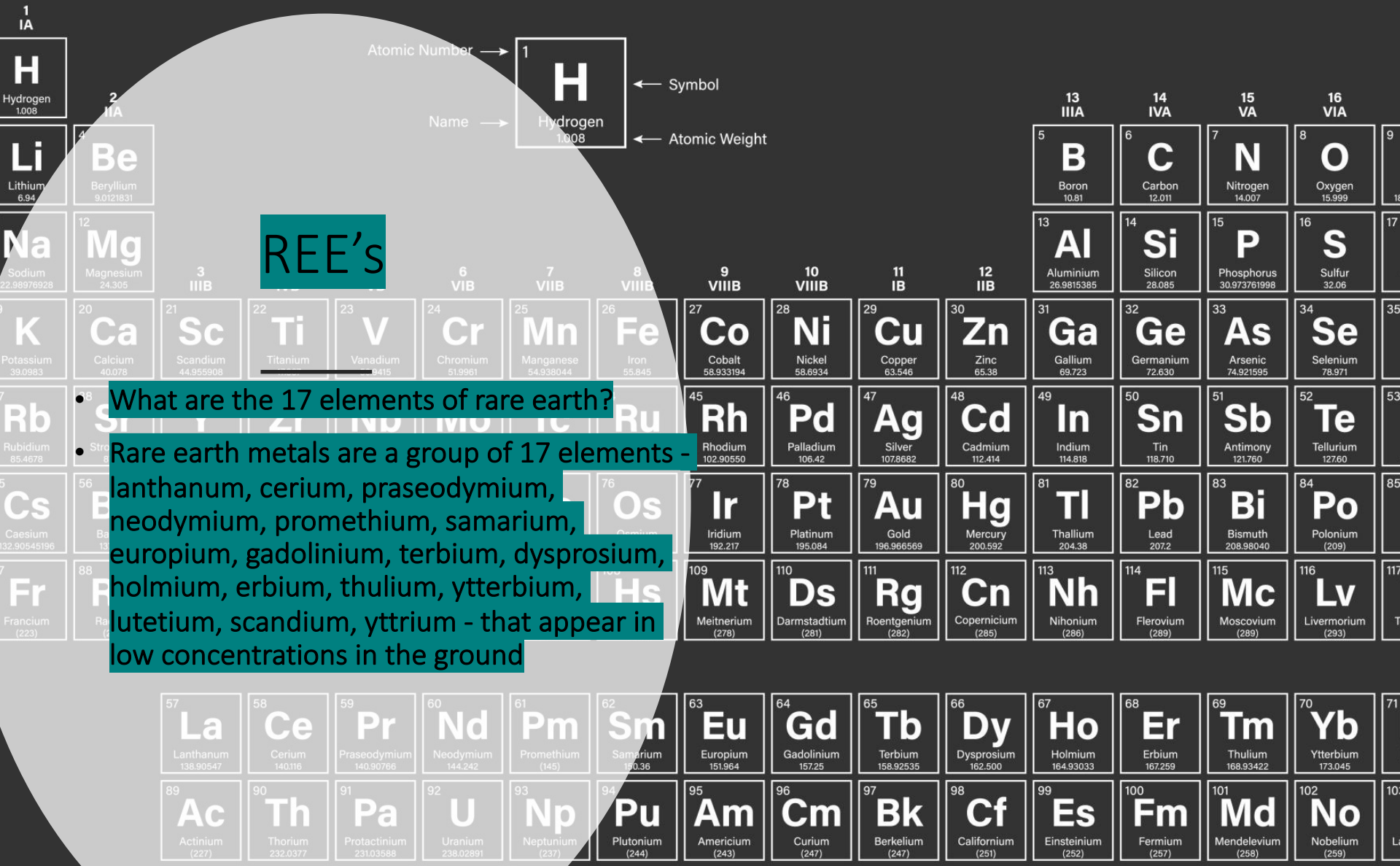
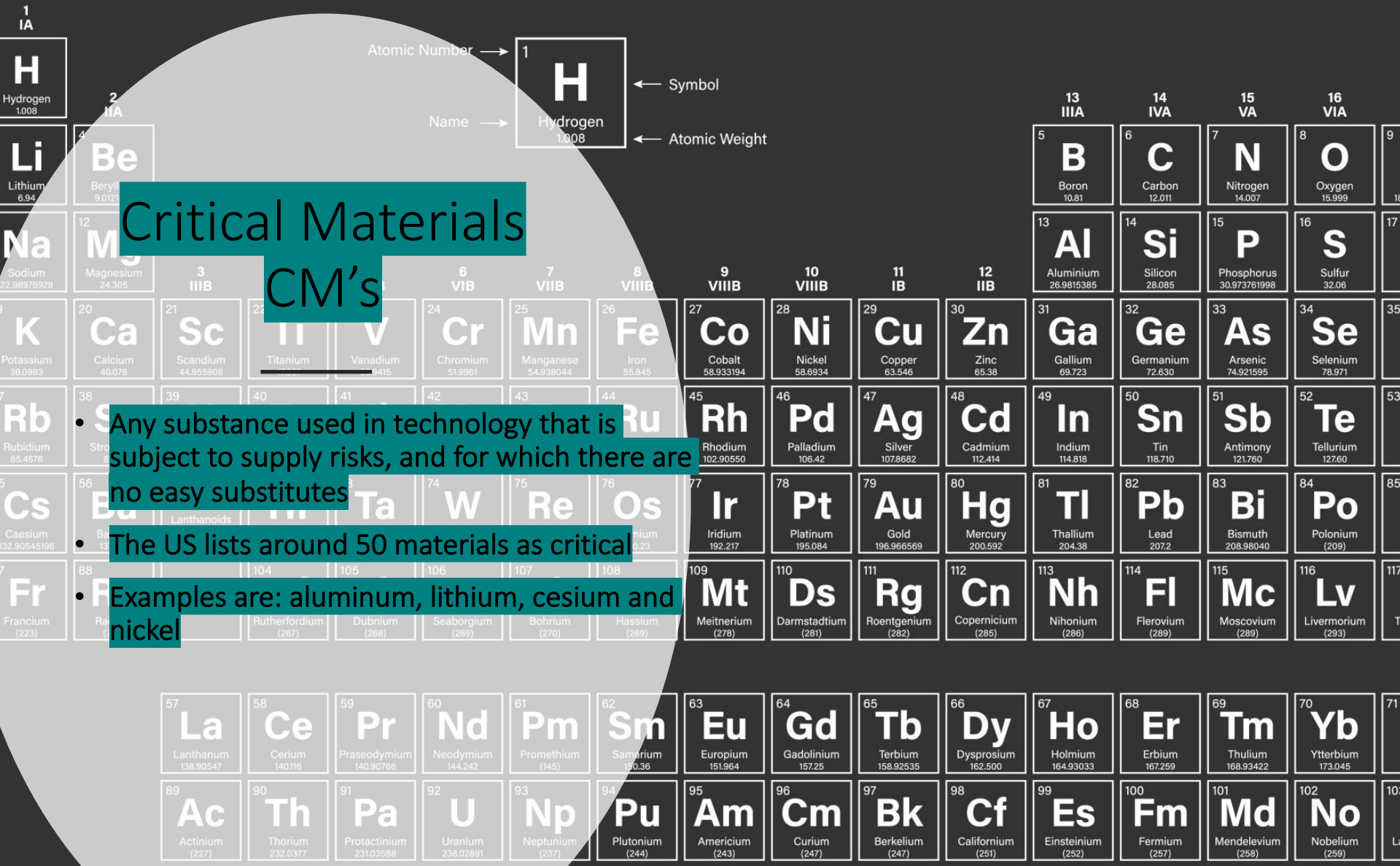
AMD and REE

Periodic Table of the Elements



- What are the 17 elements of rare earth?
- Rare earth metals are a group of 17 elements - lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, scandium, yttrium - that appear in low concentrations in the ground

Periodic Table of the Elements



Critical Materials CM's

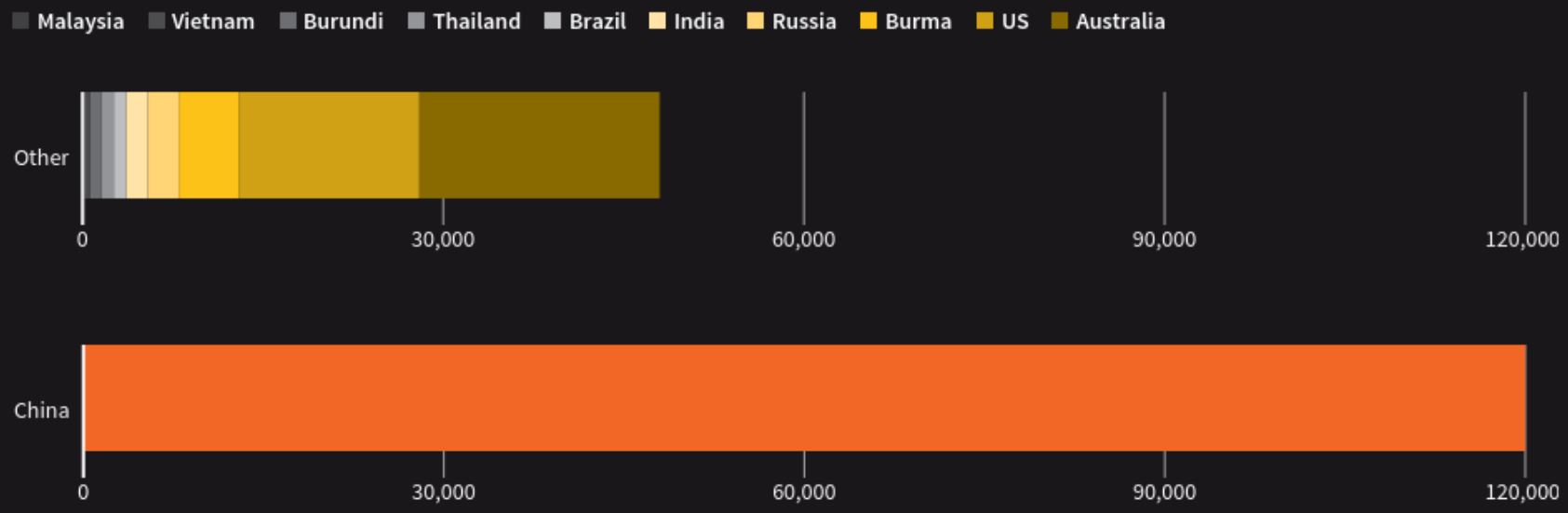
- Any substance used in technology that is subject to supply risks, and for which there are no easy substitutes
- The US lists around 50 materials as critical
- Examples are: aluminum, lithium, cesium and nickel

Rare earth production

China accounts for around 80% of U.S. rare earths supply, materials used in many high-tech goods, ranging from consumer items like electric cars all the way to cutting-edge weapons and communications systems.

MINE PRODUCTION IN 2018

In tons



Source: U.S. Geological Survey

Christian Inton | REUTERS GRAPHICS

How do REE/CM's Relate to WV Watersheds-First a look at WV watersheds

7 Major basins within West Virginia

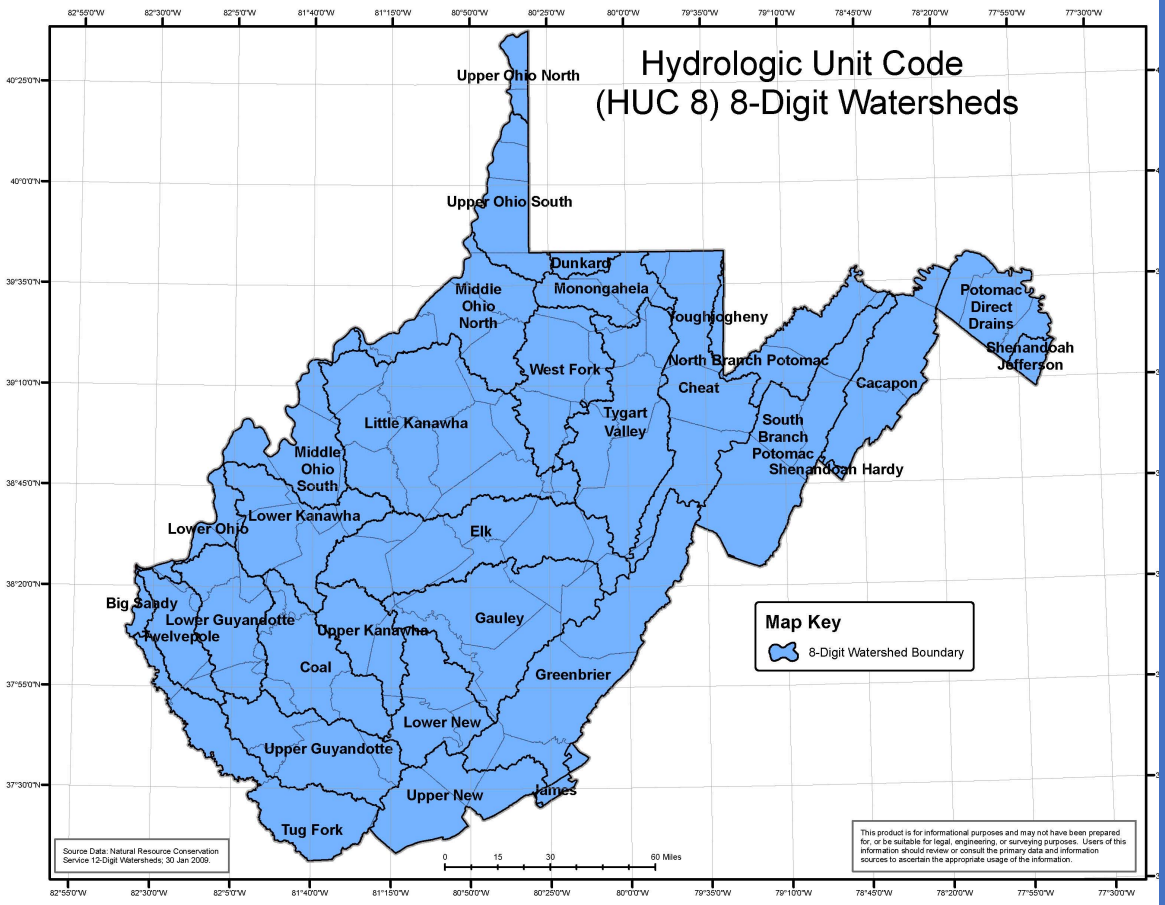
32 watersheds divided according to hydrologic unit codes (HUC-8) that contribute to the Chesapeake Bay and the Gulf of Mexico

The waters west of the eastern continental divide flow into the Ohio River

The eastern continental divide also changes the course of five of our eastern rivers towards the Potomac River

A few streams in the southeastern corner of the state flow towards the James River

Multiple smaller subbasins within WV have severe degradation due to AMD (HUC 10,12,14)



- WV HUC 8 Watersheds

National Mine Land Reclamation Center

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Objectives

In 1988 Congress recognized the need for an organization to specifically address the outstanding reclamation problems and authorized formation of the National Mine Land Reclamation Center (NMLRC).

The NMLRC has become an internationally-recognized leader in the area of acid mine drainage (AMD). Among technologies initiated, refined or demonstrated by the NMLRC, the following are now in practice within the industry, state and federal agencies:

- Alkaline amendment *Quantitative AMD prediction method
- Pneumatic and slurry placement of alkaline coal ash in underground mines
- Selective spoil handling * Remining
- Passive AMD treatment systems for watershed restoration
- Use of coal ash and steel slag barriers

The NMLRC has worked with numerous groups throughout WV to address AMD and install passive treatment systems

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Slide photo is of the North Portal at the Mars Portals site; this heavily polluted AMD water is now treated as part of the Mars Portal Passive Treatment project

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Watershed Scale Restoration

- Multiple subbasins within WV that have severe degradation due to AMD (HUC 10,12,14)
- Historically we have treated single sources of AMD due to funding restrictions
- Recently we've been able to tackle a few projects that are on a larger scale and take entire watersheds into consideration
- Now, with BIL funding, these projects are more of a reality than a vision

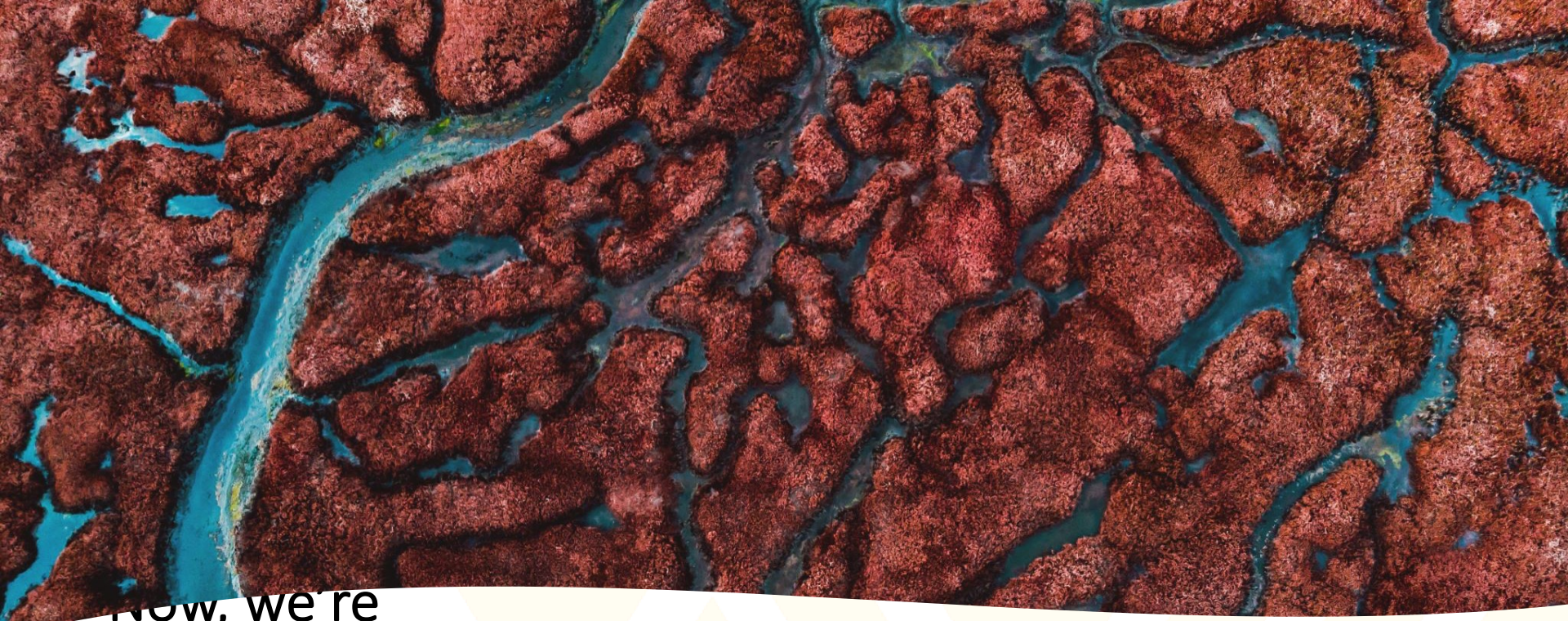
Muddy Creek Treatment Facility

Watershed Scale Restoration and REE/CM Production

Historically AMD treatment in WV has resulted in sludge handling and disposal issues

This has been viewed as a highly **negative by-product** of AMD treatment

Do we bury it, move it off-site, or landfill it?



Now, we're starting to recognize AMD by-products as an opportunity!

- The Critical Materials and Rare Earth Element team at WVU have developed methods to extract these materials out of AMD
- Instead of an unwanted by-product, our sludge now has the opportunity to be transformed into something of value

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However, there are some Disadvantages of Sourcing REE/CM from AMD

- Low concentrations
- Requires collection from many sites
- Need to manage upstream supply chain
- Quality control: moisture, grade

Yet, there are Numerous Advantages

- Often already permitted sites, no delays due to permitting
- Easy to quantify yield, minimal exploration cost
- Environmentally beneficial, the byproduct is clean water
- Solid wastes are non-hazardous
- Distributes jobs and benefits across broad areas
- Incentivizes treatment of legacy AMD discharges
- Uniform feedstock, across mines and sectors
- Attractive economics – offset of treatment cost

Now, it's an opportunity!

- The NMLRC has identified multiple watersheds in WV that would benefit from large-scale restoration projects
- Many of these projects have the potential for REE/CM production

- Watershed scale AMD treatment strategies are efficient
  - Lower cost
  - High watershed benefit-TMDL compliance
- Large, consolidated AMD treatment plants are better for REE/CM recovery
  - Feedstock and product quality control
  - Logistics, infrastructure

Conclusions

- Countless WV watersheds have been negatively impacted by legacy coal mining issues; these issues persist despite efforts from industry, state, higher education, and grassroots groups
- Historically there has only been an opportunity to treat AMD discharges as a single source due to funding constraints
- With the additional $140 million per year invested in the AML program, WV now has an opportunity to treat AMD via large-scale centralized systems
- REE/CM extraction can be built into the design plans for these large systems; offsetting costs and reducing negative by-products