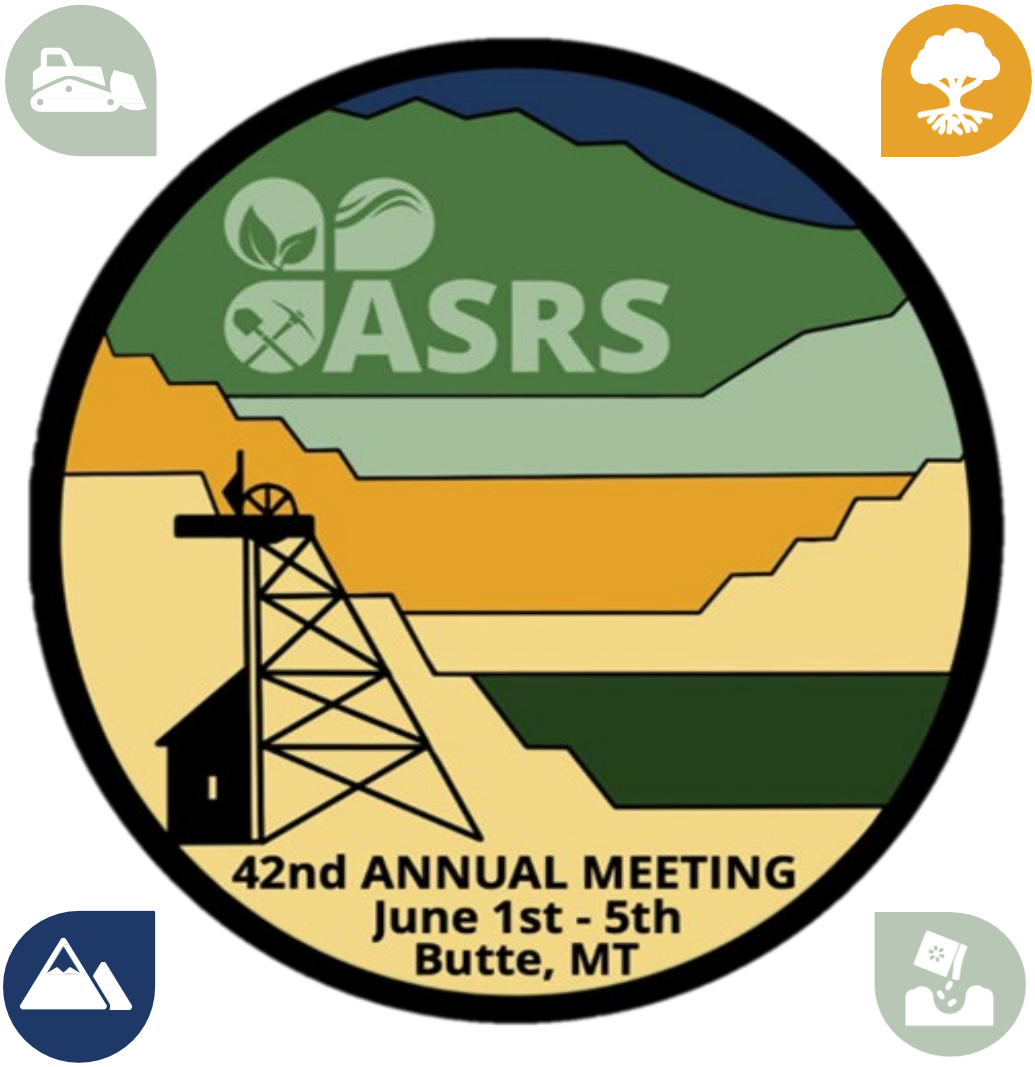

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Engineering/Construction Abstracts

GEOTECHNICAL and GEOPHYSICS – IS THERE A CONNECTION?

D. J. Barrick*[1] and C. A. Link[2], [1]*Montana Technological University*, *Butte, MT, USA*, [2]*Montana Technological University*, *Butte, MT, USA*.

Occasionally, in the field of Geotechnical Engineering, borehole data cannot be obtained because of environmentally sensitive soils, steep topography, or utilities. This dilemma frequently results in drilling boreholes at less-than-optimum locations to obtain desired subsurface geoengineering parameters for a project.

Enter geophysics. Commonly used geophysical equipment for characterizing the shallow subsurface is reasonably portable, allowing measurements to be made at sites inaccessible to a geotechnical drill rig. Two frequently used geophysical methods are seismic refraction and electrical resistivity. Seismic compression wave or shear wave refraction can provide 2-D layered solutions as well as velocity tomograms. Shear wave values may also be obtained via Multichannel Analysis of Surface Wave (MASW) in either 1-D or 2-D format. Electrical resistivity and induced polarization (IP) measurements are used to produce 2-D tomograms. Combining results from both methods can provide a less ambiguous interpretation of the subsurface, leading to improved decision-making.

Building on this approach, we have compiled a database containing seismic and resistivity/IP results along with standard geotechnical parameters for geomaterial types obtained from boreholes. We implemented a machine learning approach to map the relationship of geophysical inputs to various geotechnical parameters and material types, thus addressing the dilemma of not being able to acquire geotechnical data at challenging sites.

To date, the results are encouraging. Using a multi-layer perceptron (MLP) neural network and geotechnical data from over 100 boreholes and five American states, we achieved a correlation coefficient of over 0.7 by using network inputs of seismic p-wave velocity, electrical resistivity, seismic s-wave velocity, and IP to predict unconfined compressive strength (UCS), static Young's modulus, moist unit weight, and moisture content of variable soil and rock geologies.

Using another supervised classification machine learning model called Support Vector Machines (SVM), we were able to predict geology types ranging from clay/silt to sand/gravel, intermediate geomaterials (IGMs), and rock, with over 75% accuracy. Using these machine learning results, we constructed 2D profiles of geomaterial type and several geotechnical engineering parameters.

Key Words: Geotechnical, geophysics, machine learning

Tetra Tech abandoned mine land (AML) reclamation projects in the appalachian and mid-continent regions

E. E. Cavazza*, *Tetra Tech, Inc.*, *Pittsburgh, PA USA*.

In November 2021, the Bipartisan Infrastructure Law (BIL) (a.k.a. the Infrastructure Investment and Jobs Act (IIJA)) provided $11.3 billion in US Treasury funding over a 15-year period to address legacy coal AML and abandoned mine drainage (AMD) sites across the country. The funds are to be distributed in equal, annual amounts over a 15-year period to 23 states and one Indian Tribe based on the number of tons of coal historically produced in the state or tribe before August 3, 1977. For many of these states and the tribe, this results in significantly increased

funding for AML reclamation and exceeds their AML Program's resources. In order to obligate this funding to eligible AML projects, many states increased their use of and reliance upon consultants. Tetra Tech's OGA office in Pittsburgh, in response to various RFPs and RFQs, has entered into contracts with several State AML Programs and NGOs which have received AML grant funding to assist with project development, design, permitting and construction management. This presentation will highlight several of the AML projects that Tetra Tech is working on to support abandoned mine reclamation efforts in the Appalachian and Mid-Continent Regions of the country. These projects, which include both AML hazard abatement and mine drainage treatment, are located in the states of Pennsylvania, West Virginia, Ohio, Kentucky and Ohio, and are all being funded in whole or in part with AML funding derived from the Bipartisan Infrastructure Law (BIL).

Key Words: Abandoned Mine Lands**,** AML Reclamation, AMD Treatment

Proof of Concept: The Good Samaritan Pilot Program

J. Dillon*, *Crowley Fleck PLLP*, *Billings, Montana USA*.

In December of 2024, President Biden signed the Good Samaritan Remediation of Abandoned Hardrock Mines Act of 2024 into law. The Act is the culmination of a several-decade bipartisan effort to protect qualified "Good Samaritans" who wish to perform voluntary remediation activities and improve the environmental quality of abandoned hardrock mine sites. This presentation will cover the following: (1) a brief summary of the history of Good Samaritan efforts; (2) an overview of the Act and its contents; (3) the contours of the Good Samaritan pilot program, including the requirements that must be satisfied to be considered for a permit; and (4) the future of Good Samaritan legislation and its (potential) long-term effects.

Key Words: remediation good samaritan

Geomorphic Reclamation of the Abandoned McIntosh Uranium Open Pit Mine

H.J. Hutson*, *BRS, Inc.*, *Riverton, WY USA*.

The McIntosh abandoned open pit uranium mine was located in Fremont County, Wyoming. The Wyoming Abandoned Mine Land program (AML) along with their consultant, BRS, Inc. reclaimed the 500' deep open pit mine utilizing multiple techniques. The project required over 12 million cubic yards of excavation, backfill into over 200' of water, blasting well cemented sandstone highwalls, and evaporative dewatering. The 400 acre final design surface was constructed utilizing geomorphic grading techniques including Natural Regrade^{TM} software. Additional environmental enhancements include the establishment of a walk-in fishery, limber pine salvage and replanting, and application of specialized revegetation techniques. The project was completed over the course of 11 years in phases. The project was completed within 1% of the original project estimate. The presentation will include a summary of each phase's key aspects, challenges, and construction costs. The overall project successes will be discussed with an analysis of the performance of the final reclaimed geomorphic surface during a severe runoff event in 2023.

Key Words: Open Pit ReclamationGeomorphic ReclamationEvaporative Dewatering

Silver Bow Creek Greenway

Michael Browne*[1] and Dori Skrukrud[2], [1]*Pioneer Technical Services, Inc.*, *Helena, MT, USA*, [2]*City and County of Butte-Silver Bow*, *Butte, MT, USA*.

The Silver Bow Creek Greenway project encompasses the restoration of aquatic, riparian/wetland and upland ecosystems within the 23 miles of Silver Bow Creek stream corridor (headwaters to Clark Fork River), including the development and construction of a recreational trail along the corridor.
The superfund record of decision was structured such that Montana Department of Environmental Quality (DEQ) would conduct remediation to recreational standards while Montana Natural Resource Damage Program (NRDP) would conduct restoration to enhance the corridor to a more natural condition and provide public access to restored stream and floodplain. Greenway Service District (GSD) was formed in 1996 as an intergovernmental partnership between Silver Bow County and Deer Lodge County to facilitate the restoration component of the project. Since its inception, GSD has secured NRDP grants to facilitate restoration activities including tailings removal, fish barrier construction, habitat, securing private property and easements, and providing public access via the Greenway trail. To date, approximately half of the trail segments have been constructed. The next chapter of GSD is to complete the remaining trail segments, which will require securing additional funding, land transfers, and easements. Ultimately, the Greenway project creates a safe and enjoyable recreational experience for the public by providing access to the creek and its natural resources, allowing visitors to enjoy the beauty and ecological benefits of the restored area. It provides educational opportunities for the public to learn more about the natural environment and the importance of these restoration efforts. Most importantly, the Greenway will extend and complete the managed and controlled access through the entire corridor (institutional control mechanism), therefore protecting the investment made in remediation and restoration.

Key Words: Silver Bow Creek, Greenway, Recreational Trail

Transforming Butte: from the Parrott tailings to a resilience hub

S Coe*, M Terry, S Frazee, and J Vincent, *Water & Environmental Technologies*, *Butte, MT, USA*.

The Butte-Silver Bow community has received a $20 million Community Change Grant from the U.S. Environmental Protection Agency (EPA) to address environmental and climate justice challenges while fostering community resilience and development.
A key part of this initiative is the construction of a Community Resilience Hub on the reclaimed Parrot Tailings site. This site, previously contaminated with toxic mine waste, has been cleaned up, with nearly 650,000 cubic yards of contaminated soil removed and replaced with 720,000 cubic yards of clean material. This cleanup, completed in 2023, has improved groundwater quality and paved the way for new community projects.
The Community Resilience Hub will be a multifunctional facility focusing on health, education, arts, and cultural programming. It will be equipped with solar power, satellite communication, and modern amenities like an air filtration system, providing a safe and sustainable space for residents, especially during environmental crises. This project demonstrates the community's commitment to resilience and sustainability, addressing both immediate needs and long-term goals. The connection between the Parrot Tailings cleanup and the Resilience Hub showcases Butte's dedication to turning environmental challenges into opportunities for growth and development. The successful remediation of the Parrot Tailings site has mitigated a significant environmental hazard and created a foundation for the Community Resilience Hub, enhancing the community's capacity to adapt to climate change and other disruptions.
The presentation will highlight the collaborative efforts with local organizations and private partners, such as Montana Resources and Water & Environmental Technologies, which were instrumental in securing the grant and planning the project. Attendees will gain insights into the strategic planning, community engagement, and innovative approaches that have driven this initiative forward.
Join us to learn how the Butte Community Change Grant is revitalizing a historic site and setting

a benchmark for sustainable development and community resilience in the face of climate change.

Key Words: Parrot Resilience Cleanup

Grizzly Gulch Placer Mine Reclamation

Joel Pemble*, *RESPEC*, *Bozeman, MT, 59718*.

This oral presentation will explore the history, ownership, funding, and reclamation process of the abandoned Pretty Girl gold placer mine site located along Grizzly Gulch Drive, 3.5 miles southwest of Helena, Montana. The Grizzly Gulch watershed has experienced mining activities dating back to the late 1800s, with extensive mining at this site from 1980 until 2011, during which a large amount of material was removed. This activity obliterated Grizzly Creek, destroying the riparian area and disturbing water quality with increased sedimentation. Adjacent to Grizzly Gulch Drive, the site is unsafe for the public due to the steep slopes and large open pits of water.

The overarching goal of the project is to reclaim Grizzly Creek to a functional stream and floodplain, improving safety for the public using Grizzly Gulch Drive. The project is sponsored by the Lewis and Clark County Water Quality Protection District, with construction slated to begin in mid-February and end in early summer of 2025. The project design utilizes rock and drop structures along a channel formed by coir logs to help reflect the reference reach upstream of the site. The local conservation district is also involved with salvaging existing vegetation on the site.

The presentation will also highlight project permitting requirements and funding information from the Department of Natural Resources and Conservation (DNRC) Reclamation and Development Grants (RDG) Program and touch on the small miner's exemption bond. Ultimately, this project aims to deliver long-term environmental and community benefits after construction is complete.

Mitigation of the UPCC Rock Springs Nos. 3, 4, 7, and 8 mines below Interstate 80

R. Reed*, *BRS, Inc.*

The Rock Springs Coal Mining District is characterized by extensive underground coal mines. Numerous reclamation projects have been completed by the Wyoming Department of Environment Quality (DEQ), Abandoned Mine Land Division (AML) to address hazards posed by shallow underground mine workings. The Rock Springs Coal Mining District is located near and in Rock Springs, Wyoming in Sweetwater County. The historic coal mines were crucial for the development of the Union Pacific's transcontinental railway and development of the western United States.

The Union Pacific Coal Company Rock Springs Nos. 3, 4, 7, and 8 Mines are crossed by Interstate 80 between mile post 105-108[3]. Mine voids created by abandoned underground coal workings posed a risk to the critical infrastructure due to subsidence collapse. The Wyoming AML program responded by applying lessons learned on past projects to mitigate subsidence hazards by utilizing drilling and grouting techniques to stabilize underground mine voids. Special operating procedures and traffic controls were employed to ensure the safe completion of the work on the heavily trafficked section of Interstate 80.

The reclamation of Interstate 80 was a rewarding and challenging project for the Wyoming Abandoned Mine Land Program, and mitigated hazards due to past mining practices. The long-term benefits of this project was stabilization and mitigation of subsurface mine voids to prevent damage to critical public infrastructure.

Key Words: drilling and grouting, subsidence mitigation, interstate roadway

Post-wildfire site restoration in steep slope terrain

D. W. Evans, P.E.*, *IDR*, *Evergreen, CO, USA*.

Even the best mine site reclamation and restoration efforts can be quickly undone in areas subject to wildfires due to the aberrated site hydrology and resulting surface water flow. Post-wildfire site management issues become even more critical where steep slopes are present, especially across large areas where topography may limit active stormwater management. Work prior to and following a major wildfire at a mercury mine in Northern California will be summarized to highlight the mitigative value of planning prior to and post-wildfire to design and construct active preventative measures.

Key Words: Mine site reclamationWildfire mitigationStormwater management

International Abstracts

Evolving Landscapes: The Rising Importance of Land Reclamation in Response to Societal and Technological Shifts Since 1975

T. Richens*, *TCR Environmental Consulting Ltd.*, *Calgary, Alberta, Canada*.

This presentation will outline the connections between societal changes over the past 50 years and their potential impacts on our future as reclamation practitioners. Even with the global energy transition, our impact on the world cannot truly be understood if we don't recognize that almost everything in our lives links back to some sort of land disturbance. And where there's mining, there's reclamation.

Since 1975, the world's population has significantly increased, supported by massive technological shifts. These technological advances have increased the demand for certain raw materials that come from mining. The use of silicon in computers and cell phones and lithium for energy storage systems are examples of raw materials in greater demand today than in 1975. As the demand for greener options such as solar panels, wind turbines, concrete dams for hydroelectricity, electric cars, and batteries increases, so does the demand for mined raw materials and the subsequent reclamation of the land. The frequency and intensity of extreme weather events are also impacting today's society, as we have to rebuild entire communities and replace countless vehicles that would otherwise not need replacing.

Using publicly available statistics regarding population growth, housing development, vehicle registrations, cell phone and home computer purchases, and insured losses related to severe weather, this presentation will provide interesting and relevant information about the demand for the raw materials that come from our landscape that are necessary to build and produce these items on a mass scale. Reclamation of mines, quarries, and oil and gas facilities will continue well into the future due to increasing demand for the raw materials that come from them.

This presentation will serve as a reminder that our everyday choices, the technologies we rely on, and the quest for sustainable solutions are deeply intertwined with the responsible development of our natural resources and subsequent reclamation activities.

Key Words: reclamation, sustainability, technology

Assessment of Mining Activities Impacts on Ecosystem Services: A Case Study

M. Zhen*, *China University of Mining and Technology*, *Xuzhou, China*.

Ecosystem services (ES) around mining regions can change dramatically due to disruption and management of disrupted land, water, and air ecosystems existing prior to mining. For example, land topography, deforestation, water drainage and its contact with freshly exposed mined materials can change its quality and quantity. Localized temperature islands can develop due to temperature changes within a mining area due to changes in topography and spontaneous combustion of coal and coal waste materials. Based on the data developed for the periods 1995 and 2024 in the Huainan mining area, the author has developed changes in ecosystem services value due to mining activities. It has investigated the relationships between different ecosystem services as well as proportionate contributions for each service to the region's overall ecosystem service value. Ecosystem services included provisioning (such as food and raw coal), regulating (such as water purification and carbon sequestration), supporting (such as soil formation), and

cultural services (such as beauty and recreation). The results show that mining activities have resulted in significant changes to habitats, soil degradation, water contamination, and air quality degradation. Wide-ranging effects of ES degradation include decreased ecosystem resilience, heightened susceptibility to climate change, and a decline in the standard of living for communities that depend on these ES services. While ecosystem management and restoration efforts have shown some success in restoring soil stability and vegetation, the recovery of biodiversity and complex ecosystem functions remains incomplete. This case study highlights the need for sustainable mining practices and effective reclamation strategies to mitigate the long-term impacts on ES. By developing meaningful data on ES changes and their consequences as in this case study, stakeholders can better manage and prioritize ecosystem restoration and ensure the sustainable management of mining-affected landscapes.

Key Words: Ecosystem Services, Coal Mining, Sustainable Reclamation

Fifty years of environmental reclamation in Canada

Peter Beckett*, *Laurentian University*, *Sudbury, Ontario, Canada*.

The Canadian Land Reclamation Association was formed in 1975 in Guelph, Ontario, Canada with the Ontario Crop Conservation Council's recognition of the need for a national association focused on land reclamation. It has the current mandate of 'fostering collaboration among government, industry, and academia to enhance land and waterway reclamation efforts and promote environmental excellence from coast to coast' in Canada.. At present, in addition to CLRA National there are 6 Chapters representing Alberta, British Columbia, Ontario, Saskatchewan, Quebec and Atlantic Provinces. At national or provincial meetings, in webinars, or newsletters a wide range of reclamation topics are discussed including mining, gravel pits and quarries, forest and agricultural disturbances, coastal reclamation, waterways and wetland reclamation activities. There are student and excellence in reclamation awards at both the national and provincial levels. 'Canadian Reclamation is the official publication of the Canadian Land Reclamation Association and has been published twice a year since 2001. CLRA/ACRSD fosters cooperation between reclamation groups and individuals world wide.

Key Words: international reclamation, restoration, activities

Soil Abstracts

Gender mainstreaming

Gelito Inácio Franco Sululu*[1,2], José Eduardo Massanche[2,3], Celeste Albino Tembe[3,2], Rute Luís Chule[5,2], and PhD Almeida Meque Gomundanhe[2,1], [1]*Commonwealth Youth Climate Change Network*, *Lichinga City, Niassa Province, Mozambique*, [2]*Rovuma University*, *Lichinga City, Niassa Province, Mozambique*, [3]*WWF Mozambique*, *Lichinga City, Niassa Province, Mozambique*, [4]*WCS Mozambique*, *Lichinga City, Niassa Province, Mozambique*, [5]*UNICEF*, *Lichinga City, Niassa Province, Mozambique*.

Mozambique is a poor country and the target of major tropical cyclones such as Gombe, Idai, Eloise, Kenneth, Shallane, Dineo, Freddy, Álvaro, Filipo, Gormane, El Nino, Olga and is currently being ravaged by the major tropical cyclone Chido. This is putting biodiversity in danger of extinction and putting the Mozambican population in a humanitarian crisis. Every rainy season Mozambique is hit by at least two or three tropical cyclones, causing human losses, the loss of millions of hectares of degraded land, the loss of biodiversity and the loss of public and private infrastructure. With the Youth Led Ocean Protect project, funded by the Sustainable Ocean Alliance and implemented by the Commonwealth Youth Climate Change Network in Mozambique, we have already restored more than two hundred hectares devastated by major tropical cyclones as a way of mitigating landslides or erosion (recovering low-lying land for agricultural production and environmental management), creating and formalising natural resource management committees, creation and formalisation of natural disaster risk management committees, creation of community agendas for the sustainable use of land and other natural resources, creation of agro-livestock associations (inclusion of marginalised women, girls and young people in the creation of self-employment through agricultural production and job creation through the green economy), mapping and micro-zoning of community lands,raising community awareness on retreating from flood-prone and landslide-prone areas, raising community awareness on the collection of plastic bags in the aquatic and terrestrial environment, including gender in decision-making on the sustainable use of land and other natural resources, and intensifying the practice of conservation agriculture to contribute to the reduction of hunger, chronic malnutrition and poverty. Our activities are being carried out in the villages of Ngoo, Chia and Mbueca in the Lake Niassa Partial Reserve, Mozambique.

Key Words: Climate Change, Peri-urban and Restoration

Sustainable soil erosion and sediment control in surface coal mines, USA semi-arid environment.

A Krzyszowska Waitkus*, *Environmental Consulting*, *Laramie, WY, USA*.

The major goal of the surface coal mine reclamation is to establish sustainable vegetation communities on a stable landscape without erosion and sedimentation. Erosionally stable slopes minimize production of sediment. According to state and federal rules, sediment cannot leave the surface coal mine permit boundary and cause an off-site impact. If this is a case, a notice of violation to the operator is issued by the federal and state agencies.
Sustainable conservation practices to reduce soil erosion in semi-arid environments include maintaining a vegetative cover, shortening slope lengths and steepness, increasing roughness of the area by tillage management, and roughening the area on a contour. Most important is permanent or temporary vegetation cover or cover crops that stabilize the soil surface and add nutrients to soil. Mulching, hydromulching, erosion control blankets, rock check dams, and addition of mycorrhizal inoculant help to prevent erosion and reduce sedimentation. Geomorphic approach to rebuild postmine topography over traditional approaches was proven to create the least amount of erosional features and sediment. Dust control due to erosional wind activities in

coal mining areas in semi-arid environments is achieved by establishing a vegetative cover, forming ridges and creating roughness of bare areas, forming shelter barriers, and using soil binders on roads and soil stabilizers on non-traffic areas.
Sedimentation following erosion requires different control techniques. Sedimentation control facilities require a pond or structure designed to capture runoff from disturbed areas that later allows sediment and suspended solids to be removed. Besides, sediment pond structures, other methods are implemented in the mine areas. All these measures are temporary such as silt and filter fences, straw bale barriers, rock riprap, gabions, wattles or filter socks. They can be removed when sedimentation processes are eliminated from the site. These sustainable methods are important for final approval of reclaimed land by the state and federal regulators for proposed future land uses according to permit commitments.

Key Words: surface mining, management erosion, sedimentation techniques

Final Pit Backfill and Spoil Regrade using a Dragline and Dozer

Allen Wellborn* and Gabe Johnson, *Navajo Transitional Energy Company*, *Decker, Montana 59025*.

The presentation will describe successfull final pit reclamation using the non traditional technique of Dragline spoil movement and dozer grading.

- Baseline information (Pre mine topography, Post mine topography, spoil quality)
- Design needs (drainage design and density, slope, aspect and backfill siting)
- Machine Software and File Design
- Permitting requirements (state, county and federal)
- Success monitoring (Post mine topography vs as built, cost and time savings, machine efficinecy comparison)
- Long term benefits

Included with the presentation will be explanations of the need for expedious dirt movement, cost savings, bond reduction and survey accuracy

Key Words: Spoil, Regrade, Reclamation

Effect of organic and inorganic soil amendments on zinc and lead availability in soils affected by historic mining activities

C.A. Baxter*[1] and G.S. Siemering[2], [1]*University of Wisconsin-Platteville*, *Platteville, WI, USA*, [2]*University of Wisconsin - Madison*, *Madison, WI, USA*.

Elevated zinc (Zn) and lead (Pb) in levels in soils are found throughout the historic mining district of southwestern Wisconsin, northwestern Illinois, and northeastern Iowa. Zinc phytotoxicity has been observed in these areas, and transport of soils through wind or water erosion increases risk of exposure to lead and other toxic heavy metals. A preliminary study conducted on contaminated soils from one of these sites indicated amendments that raised soil pH dramatically decreased zinc solubility. In 2018, a field experiment was established to determine the effect of selected treatments on remediation of zinc phytotoxicity. Twelve treatments consisting of three pH adjustment treatments (none, dry scrubber material, and pelletized lime) and four soil amendments (none, 500 ppm P, dairy manure compost at a rate of 67 Mg/ha, and a *Tricoderma* suspension applied at a rate of 1.68 kg/ha) were applied to 48 individual plots and seeded to grain sorghum (*sorghum bicolor*). Soil and plant material was collected in October 2018. Application of dry scrubber material significantly lowered 0.01M $CaCl_2$ extractable Zn in soils. Average above-ground biomass yields were greater in plots receiving P, compost, or *Tricoderma* suspension, but wide variability limited detection of

statistical significance. Treatment with *Tricoderma* suspension significantly increased Zn and iron concentration in plant tissues, indicating increased potential for phytoremediation of Zn contaminated soils.

Key Words: Zinc, sorghum, phytotoxicity

Soil health investigation of coversoil originating as biologically inert borrow

R. Prodgers*, *Bighorn Environmental Sciences*, *Dillon, MT, USA*.

Can biologically inert coversoil originating as deep borrow sustain flourishing revegetation? Do "soil-health" tests correlate with revegetation performance?
The Silver-Bow-Creek Superfund remediation of a riparian strip in southwest Montana, the headwaters of the Clark Fork River, plant hardiness zone 4a, was contaminated with mine waste in a flood more than 110 years ago. After removing 4.7 M m^3 of mine waste and building 389 km of new stream channel, biologically inert borrow was used as coversoil. Based on soil samples collected from among the fibrous roots of grasses up to 15 years old, coversoils fall short of nearby natural soils in some biological properties and exceeds others.

- Even with compost amendment of 2% OM in the upper four inches, organic matter content is one-sixth of reference soils.
- Active carbon is less than in reference soils.
- Nitrogen-mineralization lags, but it's progressing.
- CO_2 respiration rate falls between upland and riparian controls.
- The C:N ratio is tighter in coversoils, indicating more active organic matter.
- Water-stable aggregates are indiscriminate.

Stratified perennial canopy coverage for mile-long reaches in years of near-normal precipitation often exceeds 100%. Vigorous revegetation drives the soil foodweb. In turn, the soil foodweb drives primary productivity in a tight cycle. The action is in the rhizosphere, where root exudates sustain the microbial communities that implement nutrient cycling with little input from recalcitrant organic matter banked in the bulk soil.
One decade after seeding, revegetation is a soils map. Healthy revegetation denotes healthy soil. Of the "soil-health" quantifications applied here, CO_2 respiration, C:N ratio, and nitrogen mineralization correlate well with soil health. Active carbon is less so, whereas total organic matter is a poor indicator because recalcitrant compounds haven't accumulated. Water-stable aggregates are irrelevant.

Key Words: Nutrient cycling, rhizosphere.

Testing soil amendments to reduce lead bioaccessibility at bench- and field-scale

M. T. McDermott*[1], L. C. Nelis[1], C. Paul-Gorsline[1], R. Schoof[1], R. Orr[2], C. Kessel[2], R. Gordon[3], M. Arnold[4], S. Whitacre[5], and N. Basta[5], [1]*Ramboll Americas Engineering Solutions, Inc.*, *Seattle, WA, USA*, [2]*Teck American Incorporated*, *Spokane, WA, USA*, [3]*Confederated Tribes of the Colville Reservation*, *Nespelem, WA, USA*, [4]*G-Logics, an Atlas Geosciences NW Company*, *Issaquah, WA, USA*, [5]*The Ohio State University*, *Columbus, OH, USA*.

Abstract
A goal of many site remediations is to reduce human health impacts of mining-associated lead in soil. However, few soil remediation technologies can be applied to large areas without disturbance to vegetation and to people, and there are very few experimental tests of soil amendments under field conditions. Teck American Incorporated studied the efficacy of soil amendment applications to reduce soil lead bioaccessibility in northeastern Washington state,

under U.S. Environmental Protection Agency oversight, and in collaboration with public and private stakeholders. The project team first conducted bench-scale testing and then a field-scale experiment of soil amendment technologies that might reduce bioaccessible lead – lead that could harm human health - in soil at the impacted site. Therefore, we tested soil samples for total and bioaccessible lead, calculated as percent *in vitro* bioaccessible (%IVBA) lead, in addition to testing other heavy metals and soil nutrients. We tested five individual amendments and seven combinations of amendments in the laboratory experiment to select amendments for field application. Amendments that showed promise at the bench-scale level included compost, phosphate, and a mixture of phosphate and biochar. We applied these three amendments in a replicated field experiment with four field plots. Each plot had one subplot of each amendment and included one untreated control plot. We analyzed the soil from these field plots six times over two years to determine whether %IVBA lead changed over time. In the field experiment, no amendments significantly reduced %IVBA lead, but there was evidence that phosphate amendments may have influenced lead speciation under specific mineralogical conditions. Additionally, phosphate treated subplots had more vegetation cover and organic debris, which created a potential barrier to human contact with the soil surface. There remains a need for soil amendments that effectively reduce lead bioaccessibility under field conditions.

Key Words: soil remediation, phosphate, mineralogy

Use of Biochar as Soil Amendment to Improve Reclamation Success and Soil Resiliency

A. Hass*, R. Cantrell, and A. Chadband, *West Virginia State University*, *Institute WV 25113*.

Biochar, a charcoal like material composed mostly of stable organic carbon, can improve soil ecosystem services while mitigating adverse anthropogenic impacts. The use of fossil fuels led over the years to an increase in atmospheric carbon pool while poor agronomic practices led to depletion in soil organic carbon. Converting organic biomass to biochar and its use as soil amendment offer a dual opportunity of withdrawing carbon from the atmospheric pool while increasing soil organic carbon pool. The extent to which biochar improve soil attributes is soil, biochar production, feedstock, crop type and application rate dependent. Here we present results from a monitoring field study where the impact of land use of biochar as soil amendment is tested at sites of different soils and land management history. The sites, located at the Eastern Ohio Valley and at the Southern West Virginia coal field regions include three reclaimed mine sites and two agriculture lands. Commercially regionally produced mixed hardwood woodchips biochar was applied at 0 to 96 Mt ha^{-1}. Selected sites and treatments were instrumented with soil greenhouse gas monitoring system, and with soil moisture temperature and salinity sensors. Additionally, selected soil properties are tested annually. All sites were seeded with pasture mixture and crop yield is recorded every harvest cut. Initial results show significant increase and additive effect of biochar application rate and soil water content. Moisture, being the dominant growth-limiting factor on mine lands suggests that use of biochar can improve soil and site resiliency to extreme weather events, leading to successful reclamation and restoration of ecosystem services.

Key Words: Biochar, Soil amendment, Mine reclamation

On-site stabilization of elemental mercury

Caleb Fontenot* and Jon Miller, *Albemarle*, *Baton Rouge, Louisiana, USA*.

Elemental mercury (Hg^0) presents a challenge for on-site remediation of highly contaminated source materials. Commonly, materials bearing visible Hg^0 (beads) are solidified in-place via the use of cementitious materials and optional sulfide-based admixtures which have the primary effect of creating monolithic zones of a low permeability matrix with some ability to form less

soluble species of Hg where admixtures are employed.
MercLok™ P-640 has been developed by Albemarle to address environmental impacts from mercury contamination, including long-lasting sequestration of multiple species of mercury, including Hg^0, without the use of pozzolans. Several bench and field studies have been conducted to demonstrate such stabilization of Hg, including visible Hg^0 beads.
Cinders and soil from an industrial site contaminated with visible Hg^0 were treated with varying dosages of MercLok to evaluate the efficacy of sequestration. In the bench studies, leachable mercury was reduced in the soil and cinders by over 99% to an order of magnitude below the TCLP hazardous limit of 200 ug/L. Treated soil was further evaluated using the EPA 1314 up-flow percolation column method. The results showed that the cumulative mercury mass released from the treated soil was reduced by more than 90% compared to untreated soil, while eluate concentrations were reduced to below the MCL of 2 ug/L. Additionally, Hg^0 was no longer visible within the treated materials. Based on the dosages indicated by bench work, stockpiled cinders were treated on-site. Analytical samples collected from the stockpiled materials validated the bench study findings of leachability reductions over 99%.
Soils from an industrial site contaminated with visible Hg^0 were collected for bench study. Baseline soils were spiked with elemental Hg to evaluate performance in consideration of potential heterogeneous distribution within the stockpile. Following a post-treatment incubation period of 60 days, TCLP leachates were reduced to below the 200 ug/L limit for both the baseline and spiked soils and Hg^0 was no longer visible.
These studies demonstrate an alternative to soil solidification in that long-lasting stabilization of Hg^0 may be effected through direct interaction of the amendment with Hg^0 rather than encapsulation with pozzolans.

Key Words: Mercury, Stabilization, Leachate

Selenium Removal by Fast – Pyrolysis Waste Timber Biochar and Iron Modified Biochar for Phosphate Mine Reclamation

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The Western Phosphate Resource Area (WPRA) is a region within the Northern Rocky Mountain Range that is characterized by a sedimentary deposit of phosphorus rich ore. It contains approximately 30% of the United States phosphate reserves. The region has undergone intense mining for agricultural fertilizers and industrial products since its discovery. A byproduct of the ore mining is Middle-Waste shale that has elevated selenium causing the release, transport, and accumulation of selenium into the environment. Selenium is an oxyanion that typically exists in soils as a trace element (> 2 mg Se kg^{-1}), but in the reclaimed mining region in the WPRA, elevated Se concentrations (2.7 – 435 mg Se kg^{-1}) occur that are toxic to livestock, wildlife, and flora. Reclamation strategies include capping mine sites with clean topsoil, but the highly mobile oxidized species of selenium, selenite (Se^{4+}) and selenate (Se^{6+}), are transported into the topsoil, resulting in selenium concentrations that exceed action level criteria.
We are investigating the ability of biochar produced from onsite waste timber, such as slash piles, as a potential sorbent for selenium. Batch adsorption experiments were performed to measure the capabilities of three softwood biochars (two USFS fast pyrolysis and one commercial slow pyrolysis) and a modified USFS biochar (1% iron chloride) for selenite and selenate removal under differing concentrations, pH, and durations. Results showed that USFS fast pyrolysis biochars have a similar affinity for selenite removal as commercial slow pyrolysis biochar, but the former demonstrated a lesser ability to remove selenate. The iron modified biochar showed markedly higher capabilities for selenite and selenate removal, with removal measured as high as 1000 mg Se kg^{-1} and 175 mg Se kg^{-1}, respectively. Packed columns were used to simulate belowground processes and examine the ability of 2% biochar amendment to reduce selenium leaching from mine overburden. We hypothesize that iron modified biochar will

reduce selenium leaching to a greater degree than the unmodified biochar, particularly in the presence of competing ions, such as sulfate and phosphate.

Key Words: Selenium, biochar, phosphate mining

Bioavailability-based remediation of Pb-Contaminated mine land and urban soils using various biochars

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Select biochars have been shown to reduce the bioavailability of metals and metalloids such as arsenic (As), lead (Pb), cadmium (Cd) and zinc (Zn) in mine land and urban soils. The specific characteristics (e.g., elemental composition, pH, surface area, and cation exchange capacity) of biochar that immobilize heavy metals, however, remains largely unknown. Additionally, the ability of biochars to reduce metal bioaccessibility from incidental human ingestion in Pb-impacted mine land and urban soils require further investigation. Given these knowledge gaps, we aim to 1) identify key immobilization properties (physical and chemical) of multiple biochar sources to characterize their effectiveness and 2) evaluate the effectiveness of biochar to reduce Pb bioaccessibility through soil ingestion. Four biochar amendments derived from poultry litter, switch grass, biosolids produced at varying pyrolysis temperatures were selected for this study. The properties of each amendment, namely elemental composition (carbon, nitrogen, hydrogen and oxygen), ash content, surface area, porosity, and pH were characterized using multiple techniques. The biochar amendments were incorporated at a rate 1% w/w in Pb-contaminated soils sourced from a mine land in Blackwell, MO, a vacant urban lot in Cleveland, OH, and a naval base site in Kittery, ME. Following biochar incorporation, concentrations of bioaccessible Pb were assessed using USEPA method 1340 while phytoavailable Pb was determined using a 0.1M calcium chloride extraction. The findings on the effectiveness of biochar amendments in reducing phytoavailable and bioaccessible Pb and key biochar properties for Pb-immobilization will be discussed further.

Key Words: Bioaccessibility, phytoavailability, immobilization

Quantifying long-term persistence of biochar on reclaimed placer tailings in the Umatilla National Forest, Oregon

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At a placer tailings reclamation site in the Umatilla National Forest, Oregon, USA, revegetation efforts have found limited success due to low fertility and moisture availability in the soil. To address these issues, the US Forest Service established test plots of biochar, biosolids, and woodchips in late 2014. Biochar is expected to resist decomposition in the environment longer than non-pyrolyzed materials; however, exactly how long biochar persists in soil is not fully understood. Estimates of biochar residence times range from hundreds to thousands of years, though these are often produced from laboratory-based incubation experiments rather than field-based or in situ trials.

This experiment seeks to determine the amount of biochar remaining in soil samples collected from the surface (0-3 cm) and depth (3-12 cm) of these plots. Sample analysis was conducted by thermogravimetric, C/N Elemental Analyzer, and visNIR hyperspectral. Results from this experiment will be useful to assess the ostensible persistence of biochar in the environment.

Key Words: Biochar, reclamation, soil

Using Wastewood Biochar as a Potential Soil Amendment: An Underground Greenhouse Study

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Traditional soil amendments such as compost have come under scrutiny in recent years due to the presence of the emerging contaminant PFAs which has brought their continued use into question as an amendment source. Biochar, made from the pyrolysis of woody feedstock, has the potential to become another amendment source in the place of traditional compost due to it's rich abundance of organic carbon, its water retention potential, and its ability to neutralize acidic soils. Along with this, forests throughout the United States, especially in the Pacific Northwest, have many locations infested with standing dead timber that has little use besides being piled into slash piles and burned off with logging companies. Potential to turn this waste product into a viable source of soil amendment creates large avenues of growth within the biochar industry. The goal of this research is to analyze standing dead and deadfall timber as a new widely available source biochar and to see if the application of biochar on different land types, has any differential effects. To accomplish this, small scale testing was accomplished using an underground greenhouse on Montana Technological University's campus. While underground, variables related to water retention capability and overall biochar effectiveness were tested on soils that came in from a variety of different sources. The soil quality ranged from impacted soils of the Butte Westside Soils Operable Unit, background agricultural field samples from local sources in and around the Anaconda and Deer Lodge area, and fields with high yield biomass from around the Butte area.

Key Words: Biochar, Amendment, Greenhouse

Microbial community succession in recovering riparian zones

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Changes to macro flora and funaná are the primary focus of most restoration projects. However, the microbial biosphere is a fundamental part of all ecosystems. Further focus on restoring the underlying basal communities is necessary in improving ecological function. We observed two recovering sites on the Silver Bow Creek and Clark Fork River Complex (SBC/UCF) and examined their microbial communities. We observed their relationship with residual metal contamination and tracked microbial community successional.
Silver Bow Creek microbial communities exhibited spatially and temporally dynamic microbial consortiums. Integrating geochemical context suggested that ongoing habitat changes alter microbial assemblages. Soil communities in restored soils are dynamic. Even phytotoxic slickens soil contains a cultural able community. Our work is one step in the ongoing characterization of the recovering SBC/UCF ecosystem.

Key Words: Restoration, Microorganisms, Phytotoxic

Chemical Compatibility of Lake Dredge for Abandoned Mine Land Reclamation Borrow Material

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Planned abandoned mine reclamation projects in Ohio suffer from a common problem, the availability of local borrow material. In Rush Creek, Perry County, Ohio, an approximately thirteen acre abandoned coal mine reclamation projects is planned for construction in late 2025. Planning to date includes use of lake dredge from nearby Buckeye Lake as part of the borrow material to re-soil the site. This is a new practice in the state. Buckeye Lake was constructed in

the place of a historic swamp as a canal feed lake. It is less than ten feet deep and requires frequent dredging to maintain recreational uses. Storage of lake dredge is a land management challenge and diversion to land reclamation is seen as a potential solution. This study presents commercial TCLP and neutral leaching results alongside neutral and acid leaching experimental results when the lake dredge is mixed with mine spoil from the site prior to leaching. Lake dredge was mixed in different proportions with mine spoil and leached with DI or HCl in triplicate, mixed for 24 hours, then allowed to settled for 24 hours. The resulting eluent was filtered then tested for N and P and over a dozen metals and metalloids including Fe, Al, Mn, As, Ba, Cd, Cr, Cu, and Zn. TCLP and neutral leaching results suggest that the lake dredge material contains leachable metals and that pH is a key control on leachability, particularly controlling the concentrations of As, Ba, Cr, and Pb leached. The results of leaching tests of lake dredge mixed with mine spoil are forthcoming.

Key Words: land reclamation, mine spoil

From Remediation to Restoration: a Tar Creek Story[1]

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The Tri-State Mining District once spanned the Midwest corners of the four states: Arkansas, Kansas, Missouri, and Oklahoma. From the late 1800's until approximately 1970, this district was a significant lead and zinc ore source. Mining and milling operations in the area produced over 500 million tons of waste, including coarse tailings (chat) and fine tailings. One of the four mining areas within the district is Tar Creek, located in Northeast Oklahoma and within the boundaries of the Quapaw Nation reservation. Tar Creek was added to the National Priorities List in 1983 due to contamination concerns. Since cleanup efforts began in 2013 (under Operable Unit 4), around 8.5 million tons of waste have been removed, and approximately 722 acres have been remediated. One notable project at Tar Creek is the Howe Interim Measure (IM), situated along Tar Creek south of the Oklahoma-Kansas border. This project has been instrumental in testing passive water treatment methods and the success of revegetation efforts. Once a chat pile that stood roughly 200 feet tall, the site has been significantly reduced, with 300,000 tons of source material removed to a repository and 271,000 tons of marketable chat transferred to a processing facility. As part of the Howe IM project and for the proposed presentation, representatives from Quapaw Nation will detail the creation of two sediment traps, two sediment canals, and one acre constructed wetlands. Currently, the Quapaw Nation is partnering with Oklahoma University to monitor these passive water treatment systems. Additionally, the Quapaw Nation has planted 8,000 native plants, including Black Willow, Button Bush, Horsetail Reed, and Coontail, along the traps, canals, and wetlands. The Howe site is in an interim state until full cleanup can begin, and in the meantime, these passive treatments offer sustainable solutions for managing contaminated sediment in Tar Creek.

Key Words: CERCLA EPA

Evaluation of multiple sediment amendments at a mercury contaminated reservoir using bench top microcosm treatability testing

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The Black Butte Mercury Mine Superfund site in Lane County, Oregon, has contributed mercury contamination to the downstream Cottage Grove Reservoir (CGR). Seasonal water level fluctuations, lowering the reservoir from November through February, expose sediments to the atmosphere which appears to enhance mercury methylation in the seasonally inundated sediments relative to sediments that stay submerged all year long. Methylmercury is the species most relevant to food web uptake that results in elevated fish tissue, a key risk driver for this site.

To address this, EPA Region 10 and CDM Smith conducted a bench-scale treatability study to assess the efficacy of sediment amendments in a series of bench top microcosms.
The study was designed in multiple phases to assess the performance of amendments with multiple sediment types from the reservoir. The amendments were selected based on published studies demonstrating their performance in sequestering mercury and consist of a variety of engineered, activated carbon, and biochar amendments. In the first phase, seven amendments were tested under anaerobic conditions in sealed microcosms containing sediment and surface water collected from one location in the seasonally inundated zone, incubated for 3 weeks. The second phase replicated the first phase but focused on the top three performing amendments based on the results from the first phase. The second phase involved testing different sediment locations in the reservoir with varying incubation period (2, 3, and 4 weeks). All mesocosms, including controls, were conducted in triplicate and were agitated ever 2 to 3 days.
This presentation will discuss the performance of the seven amendments on seasonally inundated sediments from CGR, focusing on the top three amendments tested across various sediment locations. The findings will inform the design of future field-scale pilot studies and guide long-term remediation strategies for mercury-contaminated sediments.

Key Words: Mercury, treatability, sediment

Lessons learned from over 400 years of practitioner experience in Wyoming

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Wyoming is the leader of reclamation in the United States as evidenced by a comparison of reclamation awards received among ASRS, OSMRE, and the IMCC versus other states. Wyoming is also a leader in wildlife conservation, especiallly as it pertains to the sage-grouse. In 2022, the Sage-grouse Implementation Team in Wyoming requested individuals from the Wyoming Mining Association, Petroleum Association of Wyoming, Wyoming Game and Fish Department, Bureau of Land Management, County Commissioners, Wyoming Oil and Gas Conservation Commission, Wyoming Department of Environmental Quality, and other NGOs to form a State-wide "Reclamation Task Force". Subsequently, nine white papers from reclamation practitioners were received from reclamation practitioners working in mining, oil and gas, and the Wyoming Department of Transportation. The authors of these white papers combined for a total of 187 years combined experience in reclamation. Upon vetting the white papers, Abnova Ecological Solutions received funding from numerous Sage-grouse Local Working Groups in Wyoming to conduct a state-wide survey. At present, 16 survey respondents with over 200 years combined experience have responded to the survey. Combining practitioner expertise from white papers and survey respondents has highlighted commonalities which nearly all practitioners (practicing independently) have found useful and a framework to guide reclamation from planning, implementation, monitoring, and completion is expected to be delivered to the State of Wyoming in March 2025. This talk will highlight lessons learned from four centuries of combined experience.

Key Words: expert knowledge, practitioner experience, knowledge sharing

Turning polluting mine wastes into earth materials - a nature-based appraoch to achieve sustainable ecological rehabilitation

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Mine wastes, such as tailings are largely toxic polymineral mixtures generated from extracting minute amounts of base and precious metals from ores of various and declining grades. So far, about 1950 tailings storage facilities have been declared, among which about 20% are within 5 km of proteced areas of important nature. Meanwhile, about 10 billion m3 railings have been added to the current liability every year. Conventional cover method by using topsoil excavated from natural

landscapes is infeasible, ineffective and unsustainable in the rehabilitation of toxic tailings containing abundant reactive minerals. Through last 15 years of knowledge discovery and field scaling up of concept proofs, we have dmeonstrated that tailings can be turned into earth resources (e.g., soil or Technosol, quasi-sedimentary rocks) to be used in engineering land horizons and landforms, supporting sustainable vegetation estbalishment and ecological shifts. These have been achieved by placing tailings within the framework of pedogenesis, in which bio-chemical weathering of unstable minerals could be harnessed and enhacned within field feasible engineering context (i.e., ecological engineering). The present talk aims to illustrate the conceptual processes, by using research evidence on Cu-Pb-Zn tailings, Fe-ore tailings and bauxite residue.

Key Words: Tailings, ecological engineering, pedogenesis

Evaluation of sorbent application methods for mercury control in a contaminated reservoir in San Jose, California

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Mercury is recognized as an important contaminant with the potential to cause negative health effects in humans and wildlife. California's long history of gold and mercury mining has led to statewide efforts to remediate widespread mercury contamination. This study examined the use of a sulfurized activated carbon sorbent, MerSorb, to remediate mercury-contaminated aquatic sediments from Guadalupe Reservoir, San Jose, CA located near the historic New Almaden mercury mine. Twelve 2-liter experimental chambers with minimally disturbed profundal sediment and overlaying hypolimnetic water were incubated for 20 days under oxic conditions followed by 30 days under anoxic conditions. Triplicate sets of chambers assessed different sorbent application approaches including direct sediment application, suspended treatment bag, flow through treatment, and a no-treatment control. Under oxic conditions, all sorbent treatments had significantly lower average concentrations of total mercury (treatment bag 5.5-18.7 ng/L, sediment application 1.9-18.9 ng/L flow through 2.3-26.4 ng/L) and methylmercury (treatment bag 0.06-0.18 ng/L, sediment application 0.05-0.14 ng/L, flow through 0.07-0.10 ng/L) compared to the control (11.3-27.6 ng/L, 0.16-0.31 ng/L). Under anoxic conditions, sediment application resulted in the lowest total mercury concentrations (~1.8 ng/L), while the sediment application and treatment bag both resulted in low methylmercury concentrations (~0.1 ng/L). The flow through treatments experienced an anoxic release of total mercury (~22.6 ng/L) and methylmercury (~8. 6 ng/L), potentially related to the development of a biofilm during the oxic phase and its decay in the anoxic phase resulting in low oxidation-reduction potential in water (~ -100 mV). All treatments had higher average sulfate concentrations in chamber water (treatment bag 35 mg/L, sediment application 80 mg/L, flow through 68 mg/L) than the control (12 mg/L), indicating that pre-rinsed MerSorb was still a source of sulfate to these batch incubations. The results of this study inform the use of sorbents for aquatic mercury remediation, highlighting that a sediment application or suspended treatment bag may be effective, though questions remain about efficacy under conditions of low oxidation-reduction potential.

Key Words: sorbent methylmercury sediment

Characterization of a Mining District Superfund Site Butte West Side Soils Operable Unit Remedial Investigation

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The West Side Soils Operable Unit 13 (WSSOU) of the Silver Bow Creek/Butte Area Superfund Site in Butte, Montana consists of an abandoned silver and manganese district to the west/northwest of the City of Butte covering 6,500 acres and containing 100 abandoned mines

and hundreds of smaller exploration claims. CDM Smith and others conducted remedial investigation (RI) sampling from 2019 through 2022, which includes approximately 4,900 surface soil and mine waste samples, 280 subsurface samples within mine dumps using a direct-push rig, over 100 surface water and sediment locations during multiple seasons, 40 pore water samples, and groundwater samples from 40 private residences. The sampling effort also included both surface and subsurface background soil sampling.

Solid soil and mine waste samples were analyzed with combinations of various metrics including pH and lithology, x-ray fluorescence (XRF) and/or laboratory metals, for arsenic and lead bioavailability, modified synthetic precipitation leaching procedure, and acid-base-accounting. Water samples were analyzed for metals and common ions. Sample locations and field data were collected using tablets and ESRI applications. Analytical data, field data, and observations were evaluated with lidar aerial and topographic data in ArcGIS on an individual mine basis. The results of the study were presented in an RI report published in November 2024. Overall, this presentation will discuss the array of results obtained and how they were used to characterize the nature and extent of contamination, fate and transport, risk assessments, and to inform the feasibility study. Various analyses and conclusions will be presented including mine disturbance extents, AutoCAD Civil 3D modeling of mine waste volumes, XRF to laboratory regressions, geology and geochemistry, degree of acid generation and leachability, bioavailability of arsenic and lead, surface water and groundwater interactions, phytotoxicity, stream habitat, and background sampling.

Key Words: Sampling, leachability, XRF

Technology Abstracts

PFAS Regulations and Methods Update for Environmental Professionals

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The EPA is rapidly increasing regulations involving PFAS that are impacting the environmental professional community. For example, on September 6, 2022, the EPA announced a proposed rule to designate Perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonic acid (PFOS) as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)—*also known as Superfund*. As applied within the context of the EPA's *Strategic Roadmap for PFAS*, such a designation will significantly affect solid waste management protocols in several ways. Of note, landfills will be required to monitor for PFAS in onsite ground water, they must consider monitoring PFAS emissions from waste incineration or leachate evaporators, and there will be a need to monitor incoming waste (such as AFFF impacted soil) for PFAS prior to acceptance. The EPA has also proposed that six PFAS be regulated under the Safe Drinking Water Act (SDWA) with associated Maximum Contaminant Levels (MCLs). To maintain compliance with these new requirements, it is imperative that environmental professionals be current in their understanding of available analytical methodologies for quantifying PFAS. This presentation will outline the available PFAS analytical methodologies and the best way to incorporate them into new and existing testing/monitoring practices. We will also examine historical PFAS methodology such as the use of "Modified" 537 for non-potable matrices and see if that data is comparable with newly released non potable methods. We will specifically focus on EPA 1633, D8421, TOPS Analysis, TOF, and AOF.

Key Words: PFAS, Technology, Methodology

Understanding Seismic Imaging for Mine Reclamation: Insights and Innovations from Geophysical Investigations of Abandoned Mines

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Abandoned mine sites present a wide array of technical challenges for proper and effective reclamation. When planning to mitigate or reclaim these sites, it's essential to understand what lies beneath the surface, including the underground workings, the amount of material that needs to be removed or treated, and the site's geotechnical stability. However, capturing this information can be difficult and or expensive. The series of studies presented here explores how seismic imaging techniques—methods that use sound waves to create images of underground structures—can help address these challenges. By employing both active and passive seismic methods, we can effectively map out old mine workings and assess the condition of the surrounding rock and waste materials. We discuss various seismic techniques, from traditional methods to newer approaches, through the lens of several case studies that highlight the practical challenges encountered during mine closure. These examples illustrate how seismic imaging can provide valuable insights for reclaiming abandoned mines and managing tailings or waste rock storage facilities. In conclusion, we propose a framework that integrates these geophysical methods into mine closure planning, offering a promising path forward for environmental remediation efforts in the mining sector.

Key Words: Geophysics, Geotechnical, Reclamation

Using Geospatial and Geostatistical Models Created with Leapfrog Works to Inform Remediation Design at a Historical Smelter Site in Butte, Montana

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The Butte Reduction Works (BRW) Smelter Area Mine Waste Remediation and Contaminated Groundwater Hydraulic Control Site (Site) is located in Butte, Montana. Historically, the Site included several different smelting infrastructures, and the operations left behind a complex distribution of materials including slag, tailings and other waste, demolition debris, foundations, and other historical structures. The Site remediation requires the removal of waste within a 275-foot average width "removal corridor" along the southern portion of the Site. Silver Bow Creek will then be rerouted from its current path on the northern portion of the Site into a reconstructed floodplain within the excavated area. To support the remedial design and better understand the Site and the data gathered over decades of soil characterization efforts, Pioneer Technical Services developed a three-dimensional geospatial and geostatistical model. The model is used to estimate waste extents to inform the design of the excavation surface. This presentation provides an overview of how geospatial and geostatistical models produce an interactive and three-dimensional visual aid that can help engineers and scientists solve the mysteries presented by historical mine processing sites. The modeling programs deliver a platform to visualize and better understand how site geology, hydrology, historical infrastructure, and contaminant sources interact. This presentation provides an overview of how the Leapfrog Works software was used to create a robust conceptual site model that was integrated into the remedial design for the Site.

Key Words: Technology, GIS, Mine Waste Reclamation

Development of Image Datasets and Image Analysis Workflows for Efficient Monitoring of Restored Environments

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Reclamation and restoration efforts around Butte, MT have been proceeding for several decades. Long-term monitoring of the restored sites is performed by technicians manually inspecting the completed sites. Because the total area of land needing to be monitored continues to increase, most sites are evaluated for invasive species, erosion, and other negative changes at a rate of once every four years. To increase both the efficiency of site evaluations and consistency of evaluation metrics, I propose that drone-based imaging technology should occur at least once per year to create tiled image sets of the restoration sites at a resolution sufficient to extract meaningful data. My research focus is to create image analysis workflows that will be used to process drone-derived image datasets. To begin this effort, one dataset was collected using "real-world images" and the second dataset is being generated as "synthetic images" using Blender, an open-source 3D rendering software. The real-world images have been collected and the files are stored on the iNaturalist website. Student researchers uploaded images of plants in the Butte area and an emphasis was placed on including images with a top-down point of view to be relevant for analyzing images collected via low, absolute altitude drones. The synthetic image dataset leverages photorealistic 3D plant models to populate virtual environments. Scattering systems were developed in Blender to allow for the randomization of plant placement while also working within user-defined constraints such as the density and clumping of individual plants as well as both alpha and beta measures of plant species biodiversity. Python scripts were used within Blender to automate the image generation process and to control environment lighting and background appearance. For image analysis, Python scripts will extract feature data such as ground cover classification using segmentation and plant identification using object classification.

Key Words: image analysis, synthetic data, virtual environments

Characterizing underground coal mine and fire surface hazards via geomorphic analysis using remote and ground-based techniques

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Abandoned underground coal mines and coal fires pose significant hazards to the built and natural world. Due to vegetation growth and continuous landform evolution, mining infrastructure such as adits, shafts, underground excavations, and access roads are frequently lost and buried over time. Uncertainty regarding the location of historic coal mine infrastructure hinders reclamation efforts and poses significant risks to public safety. Identifying historic mine features in the Grand Hogback coalfield, located west of Glenwood Springs, Colorado, is further complicated by steep topography prone to landslides and mudslides that drastically alter the landscape. Mine openings and access roads, carved into the terrain, may further destabilize slopes. While subsidence is indicative of underground voids, removal of subsurface support, and differential settlement of fill material, the spatial relationship between these surficial features and subsurface consolidation processes is commonly ill-defined. Integrating geomorphic analysis with remote sensing and multi-source ground-based monitoring techniques can be used to identify coal mining infrastructure and characterize the dynamic nature of hazards associated with abandoned underground coal mines, facilitating enhanced decision-making for strategic hazard management and mitigation. Furthermore, designing effective extinguishing methods for underground coal mine fires requires a comprehensive understanding of the subsurface fire extent and architecture, a challenge exacerbated by unknown mine excavations and openings. LiDAR collected in 2016 across the Grand Hogback region was used to generate high-resolution topographic parameters, including elevation, slope, roughness, curvature, and aspect. A geomorphic analysis was then employed to discern surface patterns and processes due to mine infrastructure deterioration, subsidence, and slope movement. Incorporating mining records, field observations, and aerial imagery, enables the mapping of historic infrastructure, supporting a systematic evaluation of hazard formation and evolution while aiding accurate georeferencing of underground excavations for further incorporation into mitigation design.

Key Words: LiDAR, GIS, Colorado

Developing a mine-focused risk layer for the conterminous U.S.

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Lands in the United States are home to tens of thousands of active and abandoned mines whose by-products (mines waste and tailings) can contain potentially hazardous and toxic materials. The U.S. Geological Survey (USGS) has developed a “decision-support tool” focused on mined lands, inclusive of those with critical mineral resources, designed to assist Department of Interior and other land managers in prioritizing areas for targeted management actions. While the tool utilizes published datasets to spatially display mine locations and landscape and environmental characteristics, there remains a need to aggregate these data into a relevant risk framework. To address this gap, we have built upon a USGS initiative in California that devised a methodology to assess the relative risk of various mineral deposit types to human and ecological receptors by expanding these metrics to the conterminous U.S. (CONUS). However, representing complex processes at such a large scale comes with challenges around data availability, accuracy, and completeness. These risk metrics incorporate the most complete mine data available and are developed with the flexibility to improve as more comprehensive datasets are released. A wide range of national environmental and demographic datasets have been leveraged in conjunction

with established geoenvironmental models for a range of mineral deposit types to identify areas that may be vulnerable to physical and chemical hazards. Additionally, to quantify risks, human and environmental health thresholds, as well as sensitive species, drinking water sources, and at-risk communities have been identified and incorporated. The final layer summarizes risk into HUC12 watersheds, demonstrating potential human and aquatic health effects as related to mining activities. This talk will showcase the challenges, strategies, and outcomes of processing this risk layer, and will include the caveats that users should consider when leveraging this risk information.

Key Words: mined lands, decision support, gis

Using Remotely Sensed Imagery to Characterize the Historic Bentonite Mining Area Near Belle Fourche, South Dakota, to develop an ecological restoration roadmap

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Mining of bentonitic clays northwest of Belle Fourche, South Dakota, began during the 1920s and continues today. The Cretaceous Belle Fourche Shale bentonite mining is characterized by shallow pits where the overburden is removed and piled elsewhere to uncover the bentonite beds, which are mined. The regional mining has produced a landscape of isolated ponds due to the impermeability of Belle Fourche shale and mounded waste, with little to no soil development and limited vegetation. The United States Bureau of Land Management and the Center for Sustainable Solutions at the South Dakota School of Mines have initiated a project to characterize baseline conditions and identify barriers to ecological and hydrologic function restoration to develop a remediation plan. To accomplish this, we have initiated a field-based and remotely sensed approach for characterization. We have used USDA half-meter NAIP infrared imagery and partnered with the South Dakota Wing of the Civil Air Patrol to fly a fixed-wing drone with a multi-spectral camera to produce high-resolution imagery (9 cm pixel) that can be used for identification of water bodies, soils, geology, vegetation (type) to help identify unique strata in the defined study area. Additional field sampling based on spectral differentiation of soils was conducted, electrical conductivity, temperature, and pH were measured, and qualitative observations were recorded. Initial results broke down the study area into water, vegetation, and spectrally distinct bare ground (differentiated as dark, medium, and bright). Initial imagery analysis shows riparian development along certain mine pits but is absent in others. In contrast, the potential vegetation and possible soil development are evident in undisturbed locations and erosional flow paths, though not in other strata. Initial results suggest that where ecological processes have been established, we see increased productivity, implying that facilitating these processes may be a pathway for restoration.

Key Words: BentoniteDroneSouth Dakota

Use of digital technologies and GIS to improve reclamation monitoring and reporting

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Sound monitoring plans are a critical component to tracking progress of reclamation. Traditional methodologies are time-, cost-, and labor-intense and result in cumbersome reports which are not easily understood and not inherently tied to space. In 2014, researchers at the University of Wyoming, University of Canterbury, and State and Federal Government partners began utilizing

handheld cameras equipped with GPS units to collect permanent image record with built-in spatial information with a state-of-the-art sampling design called Balanced Acceptance Sampling. This led to the creation of the first ever spatially explicit dashboard system to report monitoring data to stakeholders in a visually easy-to-understand manner. In the past decade, we've solved route optimization algorithms and have advanced our techniques by using cell phone cameras, GIS apps, and drones. This talk will explain concepts related to environmental monitoring as it pertains to reclamation and highlight benefits of spatially balanced sampling designs. It will also give a history of the use of image-based monitoring and spatially-explicit dashboards for reclamation to current day, with examples of state-of-the-art cell phone apps used to monitor well pads and pipelines. Attendees should expect to leave the talk understanding sampling concepts, benefits of image-based monitoring, dashboard concepts, and how the combination of all three leads to cost-, time-, and labor-savings while leveraging the ability for multiple stakeholders to improve decision management on their reclamation projects.

Key Words: decision management, dashboards, optimization

Artifical Intelligence - A Primer and Potential Applications to Land Reclamation

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While a receent report from Accenture suggests executives believe 75% of businesses are at risk of going out of business within 5 years if they do not up their ability to incorporate artificial intelligence (AI), the US Census Bureau believes only ~5% of businesses are currently using AI. The goal of this talk is to give a primer on AI -- explaining what it is and what it is not along with a brief history and where we are today. Differences between machine learning and AI will be highlighted and the three types of AI (Artificial Narrow Intelligence, Artifical General Intelligence, Artifical Super Intelligence) will be explained. Common uses of AI will be discussed along with open source and subscription based AI platforms. After completing a primer on AI, the second half of this talk will give examples of how AI is being used to improve reclamation monitoring and improve management strategies with specific examples from oil and gas fields in Wyoming. Some of the algorithms to be discussed will include those which can; (1) detect anomalies, (2) find causes based on results, (3) cluster, or group, sites together, (4) find similarities, (5) recognize objects of interest, (6) make predictions, (7) improve decision making.

Key Words: machine learning, reclamation, decision making

CDM Smith Sky Wave remote sensing and machine learning technologies for site investigations and monitoring

D.P. Wilson*, A. Reicks, B.V. Brown, and A.M. Kopale, *CDM Smith*.

CDM Smith continues to refine and develop remote sensing and machine learning technologies for use in a variety of efforts. For example, at the City of Jacksonville Gold Merit Pope Place Ash Disposal Site, Sky Wave at CDM Smith has successfully employed multispectral sensors mounted on drones, combined with advanced machine learning algorithms, to accurately determine tree species and monitor restoration success. This innovative approach allows for high-resolution data collection and analysis, providing detailed insights into the health and diversity of the vegetation. The integration of these technologies has enabled efficient and precise monitoring, and ensured the effectiveness of restoration efforts and contributing to the overall environmental sustainability of the site. This study highlights the potential of drone-based multispectral imaging and machine learning in ecological restoration projects. Other case studies will be explored, such as recent successful field planning and data collection for Ohio DNR’s Abandoned Mine Lands Reclamation Program, as well as ongoing wetland and stream mapping

for various types of clients across the United States.

Key Words: remote sensing, machine learning, drones

Discovery of Australian native hyperaccumulator plants for developing phytoremediation applications

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High concentrations of trace elements in soils are a widespread environmental problem in Australia, with thousands of contaminated mine sites unremediated. One option for developing new remediation approaches is to identify and utilize plants that accumulate trace metals. In particular, hyperaccumulator plants have the unique ability to concentrate certain metals or metal(loids) to extremely high concentrations in their biomass and identifying new species of hyperaccumulators is essential for applications that make use of the unique properties of these plants. To date, just eleven manganese (Mn) and three nickel (Ni) hyperaccumulator species are known from the whole of Australia. However, we suspect that Australia is probably rich in hyperaccumulator plants that remain undiscovered given its highly diverse flora (>20 000 species) coupled with its range of mineral resources and soil types. The aim of this research is to discover new Australian hyperaccumulator plants using non- destructive X-ray Fluorescence (XRF) scanning of herbarium specimens (targeting >10 000 species) at the Queensland Herbarium. The results of the XRF scanning revealed >50 new hyperaccumulator species for different elements (Mn, Co, Ni, Zn) in the Proteaceae, Cunoniaceae, Celastraceae, Myrtaceae, Apocynaceae, Phyllanthaceae, Salicaceae, Crassulaceae and Symplocaceae families. The species *G. fragrantissima* (Myrtaceae) was found to be a multi-element hyperaccumulator of Mn, Co, Ni and Zn, whereas *D. cunninghamii* (Celastraceae) is a Mn hyperaccumulator reaching up to >3 Wt. % Mn in its leaves. Australian native hyperaccumulator plants have an optimum fit for the local climate and geochemical conditions for developing phytoremediation applications on mineral wastes.

Key Words: hyperaccumulators, nickel, manganese

Automatic Quantification of Dissolved Copper in Remote Acid Mine Drainage Sites

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We present a case study for an automated continuous-monitoring system for dissolved copper using the Hummingbird™ platform developed by Fluid Photonics Corporation. Containing sulfuric acid and dissolved metals,[2] acid mine drainage (AMD) is treated using a multistage settling-pond system in which chemical additives are dosed at each pond to precipitate specific metals in targeted locations.[3] Copper is an economically critical metal that is relatively abundant in AMD, providing potential economic value. [4] An analytical procedure in which modified sodium diethyldithiocarbamate produces a yellow colorimetric response in the presence of copper(II) ions

[2] Acid Mine Drainage. https://www.usgs.gov/publications/acid-mine-drainage . Retrieved 2/2/2025.
[3] Kefeni, KK, Msagati, TAM, and BB Mamba. Acid mine drainage: Prevention, treatment options, and resource recovery: A review. *J. Clean. Prod.* **2017**, 151(10), 475-493. DOI: https://doi.org/10.1016/j.jclepro.2017.03.082.
[4] US adds copper to critical raw materials list.https://www.mining-technology.com/news/us-government-adds-copper-to-critical-materials-list/. Retrieved 2/7/2025.

has been used for many years to determine copper ion concentrations in water[5] and in foods, biologicals, and pharmaceuticals.[6] Our research focuses on validating a reagent formulation for copper quantification in AMD using the Hummingbird™ platform, a novel continuous monitoring system that is designed for use in such a multistage settling-pond system to enhance copper recovery. The Hummingbird™ platform's versatile features can be used to automate and deploy the photochemical detection and quantification of dissolved metals on a microscale. The platform can monitor copper concentration in AMD from a range of 20-20,000 ppm. We present data on the effects of pH, temperature, and the presence of other metal cations on accuracy and precision in the field. The Hummingbird™ platform can be deployed within active water treatment systems to provide real-time monitoring data for dissolved copper concentrations. Modern process control systems can use these monitoring data to respond instantly to changes in operating conditions by adjusting the dosage of chemical additives. The large data sets resulting from the Hummingbird™ platform's continuous data collection will also provide new insights into seasonal and event-driven changes in settling-pond systems.

Key Words: Water Testing, Process Control

[5] Noll, CA and LD Betz. Determination of Copper Ion by Modified Sodium Diethyldithiocarbamate Procedure. *Anal. Chem*. **1952,** 24(12), 1894-1895. DOI: 10.1021/ac60072a008.

[6] Uddin, MN, Shah, NM, Hossain, MA, and MM Islam. Copper and Mercury in Food, Biological, and Pharmaceutical Samples: Spectrophotometric Estimation as $Cu(DDTC)_2$. *Am. J. Anal. Chem.* **2014**, 5, 838-850. DOI: http://dx.doi.org/10.4236/ajac.2014.513093.

Vegetation Abstracts

Importing the Forestry Reclamation Approach to Northern Minnesota: an American Society of Reclamation Sciences Technology Transfer Success Story

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For decades, the Forestry Reclamation Approach (FRA) has been either under development or used in practice in the coalfields of Appalachia. Although a recognized reclamation approach under the Surface Mining Control and Reclamation Act (SMCRA), and developed by a broad alliance of federal, state and mining industry researchers through the Appalachian Regional Reforestation Initiative, the practice is not widely recognized outside of U.S. Office of Surface Mining Reclamation and Enforcement jurisdictions, even in native forest ecoregions where mining has been practiced for the better part of the last century. The FRA thus may provide value by importing and, where necessary, adapting the approach to reclamation in the Northern Forest region of the iron mining states of Minnesota and Michigan. Two projects were advanced to improve understanding of the applicability of FRA to reclamation in Minnesota:

- A comparative survey of mined areas and stockpiles with tree plantings (either intentional plantings or successional ingrowth of tree species) and traditional grass and forb reclamation areas. Areas were selected that had undergone approximately 10, 5, and 2-3 years of growing seasons for comparison, along with older sites that were planted with trees that pre-date the reclamation rules in Minnesota.
- A pilot project, "Project Greenwood", which seeks to demonstrate the application of FRA on a variety of iron mining substrates and with varying surface preparations. A planting of 17,000 tree seedlings is being tested. Results will be compared for cost of implementation and surveys of site stability, vegetative cover, species richness, and percent cover by species and stratum in the herbaceous, shrub, and tree layers.The comparative survey and pilot project had broad industry and community support and will serve as a potential demonstration toward recognition of FRA as a reclamation approach in the region.

Key Words: reforestation, ecological restoration, forestry

Coversoil attributes and influence on vegetation cover on reclaimed areas of the Continental Mine

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Reclamation has been completed on rock disposal sites, facility sites, and other areas surrounding the Berkeley Pit and Continental Mine between 1990 and 2019, although most of the current reclamation work has been completed since 2017. WESTECH Environmental Services, Inc. (WESTECH) conducted monitoring in 2021 and 2022 to assess reclamation on these sites. Data from these areas have been evaluated to assess the influence of coversoil attributes on vegetation growth; in particular, WESTECH assessed the following coversoil attributes influence on vegetation growth: thickness, pH, percent organic matter, and metals. As individual attributes, coversoil thickness and percent organic matter had relatively limited effects on perennial grass cover, with no significant difference in grass cover on areas with < 10 inches of coversoil compared to areas with > 20 inches of coversoil, and < 0.5% organic matter compared to 1.0-1.5% organic matter. Likewise, perennial grass cover was not significantly different at pH levels between 5.5 and > 7.5; although perennial grass cover was less at pH levels < 5.5. Similarly, in most cases, total metals (measured by a Total Metal Index (TMI) in mg/kg

calculated as the sum of As + Cu + Zn) had relatively limited effect on perennial grass cover. The only single factor that significantly affected perennial grass cover was reclamation age; areas with < 3 growing seasons had lower perennial grass cover than areas with ≥ 3 growing seasons. Although single coversoil factors did not significantly affect perennial grass cover, the interaction of coversoil thickness and percent organic matter may result in more perennial grass cover; however, there are few areas in currently reclaimed areas with very thin coversoil and very low organic matter and this interaction could not be fully explored with existing data.

Key Words: coversoil vegetation metals

Restoring And Revegetating a Floodplain Contaminated With Mine Waste Near Butte, Montana

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Over 15 years, the Montana Department of Environmental Quality removed 4.7 M m^3 of mine waste and contaminated dirt and revegetated 688 ha remediating and restoring Silver Bow Creek for a Superfund cleanup in southwest Montana. Chief contaminants were Cu, Zn, and As in acidic mine waste. After removing contamination and building 38 Km of new stream channel, clean fill served as coversoil for revegetation initiated through seeding and transplanting.
The revegetation effort matched plants to each important habitat, the physical and chemical elements of the plant's environment and most importantly soil particle size and moisture regime. Revegetation survived droughts, floods, herbivores, soil salts, and noxious weeds.
Lessons include:

- Removing ~95% of contamination and fixing ensuing visible impairment is more cost-effective than removing ~99.5% with inevitable over-removal. This project was completed using about two-thirds of the allotted funding.
- Flooding is more often an agent of restoration than destruction, leading to increased habitat and vegetational diversity. Bringing the floodplain back to design specifications, promotes cookie-cutter revegetation.
- Perennial plant cover and species composition equilibrate beginning about four years after seedling emergence and transplanting. After the initial shakeout in species composition, changes are slow at upland and subirrigated sites but faster in wetlands, where waterfowl and shorebirds continually bring in plant propagules.
- Properly implemented revegetation is a soils map. Underachieving revegetation usually indicates residual contamination or other edaphic limitation.
- Seeding a component of inoculated legumes can double primary production driving the soil foodweb, which promotes soil genesis.
- For diversity, shrub seed was a better investment than forb ("flower") seed because shrubs increased over time while forbs declined.
- Species richness *decreased* over time except in wetlands.
- Monitoring identified the best species to seed and transplant in the next reach.

Key Words: Riparian, contamination, habitats

Rodents and cheatgrass limit bitterbrush establishment in Colorado mountain shrublands

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Reclamation in mountain shrubland habitats is often challenging due to limited establishment of key shrub species. Enhancing strategies for establishing shrub species from seed can reduce costs and increase reclamation success. This study investigated factors limiting the seedling establishment of two foundational mountain shrub species in western North America: antelope bitterbrush (*Purshia tridentata*) and mountain mahogany (*Cercocarpus montanus*).
We conducted a factorial experiment across four sites in Colorado to evaluate the relative influence of three key factors: cheatgrass (*Bromus tectorum*) competition, rodent activity, and insect damage. Treatments included rodent exclusion cages, insecticide application, and cheatgrass manipulation (addition/removal). Shrub seeds were planted in fall 2023 and fall 2024 with data collection occurring in spring and summer 2024. Preliminary results highlight the substantial impact of rodent activity on bitterbrush establishment and reveal significant interactions between rodent exclusion and cheatgrass treatments, indicating that both factors inhibit early seedling survival.
These findings underscore the importance of integrated management approaches to improve shrub establishment in reclamation efforts. Specifically, addressing cheatgrass invasion and mitigating rodent impacts are likely critical for enhancing shrub recruitment success. Ongoing monitoring during the 2025 growing season will further elucidate these dynamics and refine recommendations for land managers and reclamation professionals aiming to restore mountain shrublands effectively.

Key Words: EstablishmentShrubsReclamation

Recovery rates of native plants around Butte, MT: Phytomining feasibility

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Standard mining practices of the past have left valuable, critical minerals remaining within mine waste dumps or tailings piles. Phytoremediation, or the use of plants to uptake and store heavy metals and other potential contaminants, has grown in popularity for these sites. A new technology, phytomining, is being developed that not only offers the benefits of phytoremediation but also allows a new pathway to extract and generate revenue from these untouched critical minerals. Certain plants have been identified as hyperaccumulators, or plants that have the ability to bioaccumulate a high level of certain minerals or elements in their plant tissue. This study is exploring eighteen different species of plants that are native to Butte, Montana to examine and test their hyperaccumulation capabilities. Testing is currently being conducted with controlled growth of these identified plants using growing mediums of standard control soil and mine waste collected from local sources, composed of elements such as manganese and zinc. The growing is being carried out in two locations, with one duplication in the Native Plant Program's greenhouse on Montana Tech's campus and the other duplication in the Orphan Boy underground mine, where an area of the mine has been modified to become a greenhouse to demonstrate the feasibility of using inactive mine areas for remediation technology activities. After the growing and harvesting of these species, the plant tissue will be digested and analyzed to determine their recovery rates. The feasibility of planting these species at larger sites will then be found, followed by the optimization of milling procedures for extraction of the critical minerals.

Ecosystem service monitoring at Silver Bow Creek Conservation Area

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Silver Bow Creek in Butte, Montana was designated a superfund site in 1983, following years of contamination from mining, milling, and smelting in the area. The Silver Bow Creek Conservation Area (SBCCA) remediation and end land use project is a component of remedial actions required by the Butte Priority Soils Operable Unit (BPSOU) Consent Decree. There is contamination of soil, surface water, groundwater, and stormwater in Butte, which is relatively stable, except during stormwater surges when it can be mobilized and carried downstream. To achieve the project's stormwater management goals, Atlantic Richfield is integrating nature-based solutions (NBS) which will also create high-quality habitats and community open spaces for recreation. These include bio-sequestration, adding native plants, and creating stormwater treatment ponds and wetlands within a 160-acre urban greenway in the heart of the town.
As a voluntary addition to the project, Atlantic Richfield committed to a long-term ecosystem services monitoring program to quantify how remediation improves ecosystem services, biodiversity, and socioeconomic indicators such as tourism. Our initial surveys, conducted from 2022-2024, monitor baseline conditions prior to construction for remediation. We paired traditional field monitoring with audio recording, temperature sensors, and environmental DNA (eDNA) collection to survey and quantify ecosystem services in the remediation sites and a reference site. At baseline, the remediation sites had more anthropogenic noise pollution, higher average temperatures, and less biodiversity than the reference site. After remediation, we will document changes in our measured ecosystem services, provide advice for adaptive management, and report successes and lessons learned to make the next NBS remediation project even better.

Key Words: Nature-based Solutions, eDNA, biodiversity

Edge Effects in a Mining-Fragmented Grassland Impact Plant Survival and Growth, but Not Seed Production or Seeding Rates

Taleigh Adrian* and Robert W. Pal, *Montana Technological University*.

Habitat fragmentation poses a significant threat to vegetation biodiversity and habitat connectivity. The resulting increase in edge habitat from fragmentation can alter environmental conditions and ecological processes. This study examines the influence of edge effects on plant reproductive fitness, particularly plant survival, growth, seed production, and seeding rate. This study took place in a fragmented intermontane grassland landscape located in the West Side Soils Operable Unit of the Superfund site in Butte, Montana that is extensively impacted by anthropogenic influences, particularly mining. Field surveys were conducted to collect data on plant species' presence, growth form, seed production, and seeding rate within a network of 116 habitat fragments. The study focused on two native plant species, one pollinated by wind and one pollinated by insects. This study found several impacts due to edge effects; plant survival and growth was impacted by fragmentation while seed production and seeding rates were not. These findings provide valuable insights into the ecological dynamics of fragmented grassland landscapes and can inform restoration and conservation strategies aimed at mitigating the negative impacts of habitat fragmentation by mining on plant diversity and ecosystem function.

Key Words: Habitat Fragmentation, Mining, Native Plants

Restoration Technique Impacts Vegetative Cover, Species Richness, and Native Plant Growth Whereas Slope Impacts Cryptogrammic Crust Cover

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Restoration method selection is crucial in determining vegetative establishment and survival. Technique dictates current and future site conditions and the eventual vegetative community. We examined vegetative cover and cryptogrammic crust growth at three sites remediated using "rough and loose" and "scrape" techniques in the Butte Superfund Area. Both techniques decreased non-native species cover and increased native species richness. However, the rough and loose technique performed better by decreasing non-native species richness while increasing overall native species richness and native grass cover. Both techniques encouraged some plant growth, but the rough and loose technique performed better by increasing the growth of native shrubs and grasses. Cryptogrammic crust was influenced by site specific factors, primarily slope. Our findings suggest that a rough and loose reconfiguration and careful control of site slopes are the most effective restoration approach for optimizing plant communities.

Key Words: soil, slope restoration, rough and loose

Practical approaches to climate resilience in reclamation projects

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The goal of this presentation is to provide reclamation planners with a range of practical approaches for incorporating climate resilience into projects.

Primary regulatory drivers and policies (both Federal and State) for incorporating climate resilience into reclamation plans will be presented. The distinction between planning for climate impacts on a project (i.e. adaptation) and planning for climate impacts from a project (i.e. mitigation) will be discussed. Information will be focused on soil, vegetation, and water as three key components of reclamation success.

In the context of climate resilience, the following topics will be addressed: site characterization to inform reclamation planning; soil characterization, conservation, and amendment; revegetation species selection and diversification; and water availability, demand management, and diversion. Aspects of reclamation which rely on the relationships among soil, vegetation, and water (e.g. carbon sequestration and riparian shade corridors) will be examined.

Seed availability is a critical issue facing reclamation planners. In cooperation with Granite Seed Company, insights will be provided into the impacts of climate on seed availability (commercially grown and native wildland harvest); working with seed vendors to navigate seed mix alterations due to seed market conditions and supply variability; and designing diversity into seed mixes to accomplish reclamation goals, restore wildlife habitat, and improve climate resilience for reclaimed sites.

Strategies for effective monitoring and adaptive management will be described. Finally, practical resources for reclamation planners and a selection of current research and development efforts related to climate resilience for soil, vegetation, and water will be presented.

Key Words: climate resilience, revegetation

Repurposing Woody Debris via Fuel Reduction Practices to Enhance Hillside Stability and Soil Seedbank Recovery

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Woody debris is a fundamental component of forest ecosystems, playing a crucial role in enhancing productivity and functionality. Additionally, it is widely accepted as a hydrogeological component capable of regulating runoff, promoting soil infiltration, and supporting forest structure, nutrient availability, as well as carbon and nitrogen cycling.
Our study site is located near the Mount Haggin Wildlife Management Area on the southeastern side of Sugarloaf Mountain, an area classified as "*moonscape conditions*" due to historic smelter emissions that began impacting the landscape early as 1902. Extensive habitat loss, combined with soil profile and harsh semi-arid conditions, has limited natural regeneration and recovery. During our research we found the lack of woody debris has contributed to homogenous site conditions, intensifying precipitation events such as runoff, sheet and rill erosion. These interacting and influential factors are hindering key recovery objectives, including hillside stabilization and revegetation.
Our goal was to utilize the notion of woody debris as a fundamental catalyst for initiating early pre-seral forest succession, by repurposing fuel load reduction practices to a designed steep slope remedy using a novel bioengineering technique known as modified brush layers. We installed 295 so called modified brush layers (MBLs) at the study site.
Initial results from this research indicate that MBLs have an immediate positive impact on key objectives by enhancing soil moisture and sediment retention. This, in turn, is found to significantly improve soil seedbank propagation and increases vascular plant growth compared to control sites without MBLs as a treatment.
We conclude current results suggest slope is no longer a limiting factor for vascular plant growth and emergence. A previous study simulating broadcast seeding found that vascular plant growth and emergence decline significantly as slope degree increases. The results of this study support a significant and positive correlation to hillside stability and revegetation, regardless of slope degree. This bioengineering technique not only accelerates ecological succession but also fosters the development of a self-sustaining forest habitat, contributing to the long-term success of restoration based ecological outcomes.

Key Words: steep slope, bioengineering, revegetation

A landscape-scale assessment of mining and restoration activities in the Appalachian region

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Surface mining and ensuing reclamation and restoration have varied spatially and temporally as new science improves methods. Consequently, tracking the success of mining reclamation and restoration is difficult due to the dynamic nature of these activities. We provide a spatiotemporal landscape-scale assessment of biotic and abiotic properties within known mine sites of the Eastern United States Appalachian region to identify knowledge gaps and inform management planning. We compiled all known spatial mining footprints from state, government, and published sources. Using Landsat remotely sensed data (1985-2023), we identified important milestones of vegetation condition, including loss, persistence, change, and planting/forest recovery. We evaluated probabilistic changes in elevation and landform types by comparing historical, photogrammetry elevation data and recent lidar elevation data. Lastly, we compared changes to headwaters affected by valley fills resulting from mountaintop removal and other mining practices. We identified 19,984 km-2 of mining activity (all known active, inactive, abandoned, and legacy surface mines based on 38 sources and 60 datasets) and footprint subunits

denoting estimated years of vegetation loss. In addition to annual summaries of vegetation change, we identified grassland and barren land persistence which may inform future management actions for legacy and abandoned mines. Estimates of where and when trees were planted indicate progress toward forest recovery. Changes in terrain, landforms, and miles of headwaters altered by valley fills may improve our understanding of the effects of surface mining on watershed health. The compilation of data and employed methods are intended to support continued research and management efforts to improve public safety/health, reclamation/restoration efforts, and identification of potentially degraded environmental conditions affecting regional biodiversity.

Key Words: *forest recovery, hydrology/landforms, remote sensing*

Investigating the phytoextraction potential and metals uptake for willow species in the Rocky Mountains

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The Rocky Mountains have an extensive history of material extraction in various forms, this has left many areas within the Rocky Mountains with high levels of contamination, and in some cases, Rare Earth Elements (REEs). Willows, a common species implemented in riparian restoration, have been under research for their ability to uptake metals and REEs. Further, understanding uptake rates of willows in REE rich environments will help us understand the potential for recovery of REEs that would otherwise be lost. As technology continues to progress, rare earth elements are becoming more valuable, finding new methods of recovering neglected sources is valuable information. In this project, I am looking at the potential use of phytoremediators in a streambank setting to aid in extraction of trace Rare Earth Elements (REEs). The goal is to analyze the rate of REE uptake in willow species from contaminated soil and water.

Key Words: Phytoextraction, Resource-recovery, Remediation

Recovery of vegetation after relieving soil compaction on a reclaimed surface mine

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Heavy soil compaction and planting of aggressive non-native grass and forb species were common on reclaimed coal mines in the eastern U.S. resulting in a non-native grass and brush ecosystem, hindering natural succession to a native forest. We tested the effect of subsoiling on one such 11 ha site in Claiborne County, TN, that was reclaimed between 2003 and 2005. Initial vegetation was measured, and the site was subsoiled in winter of 2016. Two areas were delineated based on soils and topography, then planted with different mixtures of tree and shrub seedlings at a density of 1851 stems/ha. Permanent plots were established, trees were monitored in 2017 and 2018, and all woody stems were inventoried in 2023. Average tree survival after 2 growing seasons was 68%, however by 2023 survival dropped to 50% for Pinus echinata, 9-15% for oaks (Quercus spp.), and only 2% for American chestnut (Castanaea dentata). While Pinus seedlings had an average DBH of 9.3 cm, DBH of the 3 oak species averaged between 2.9 and 3.7 cm, and nearly one-third had not reached a height of 1.37m. Stems of volunteer overstory species outnumbered those of planted species, and density of overstory species was 1163 stems/ha. Browse damage was high on green ash (Fraxinus pennsylvanica) and several shrub species while fewer than 18% of oaks showed browse damage in 2023. The four shrub species maintained or increased in stem density. Six years after treatment many non-native species persist but plant diversity is high and a successional sequence typical of southeastern ecosystems has been restored.

Key Words: reforestation, seedling establishment

Possible ecological indicators of ecosystem function around mining areas using soil, water and biological characteristics: a case study

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In response to a new restoration emphasis on ecosystem services, ecological Indicators (EI) are being extensively researched to detect changes in ecological systems from environmental stressors. Many of We think that the EI being considered are assessed at the landscape scale and may not be sensitive enough to reflect short-term changes, or to adequately describe ecosystem function at the project, or site scale. Furthermore, some EI may spatially change with time further reducing their long-term usefulness. We hypothesize that soil physical and chemical properties, site physical characteristics, and species planted are the primary variables affecting ecosystem function. Therefore, we hypothesize that an attempt should be made to identify EI using professionally accepted and readily quantifiable and relevant site-scale indices in disturbed soils such as soil quality index (SQI), and net primary productivity (NPP), that can be compared to reference values. These can be used along with landscape-scale indicators such as the water quality index (WQI), water pollution index (WPI), and index of biotic integrity (IBI) to track long-term changes in ecosystem function. A case study of a watershed that includes reclaimed surface mines is used to research the hypothesis. Through systematic data developed prior to mining, post- mining and post-ecological restoration, the authors analyze the potential for developing such indicators and future directions for such research. Such indicators will continue to evolve with scientific advancements in plant biology, bio-informatics, and AI.

Key Words: ecosystem services, reclamation assessment

Micronutrient enabled establishment of native grasses and reduced invasive plant prevalence through novel fertilization strategies emphasizing soil health

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Every plant species has unique nutrient requirements including weeds. Site disturbance may inadvertently create soil nutrient levels suitable to weed growth through use of low quality soil or heavy nitrogen fertilization during reclamation. Seeded species, and especially late successional perennial grasses common to revegetation seed mixes, thrive in high quality soils rarely available at reclamation sites. The practice of seeding late successional species into soils not suited to their development often results in the growth of persistent invasive plants rather than the seeded species. Novel fertilization strategies have been developed to emphasize micronutrient fertility and to promote the growth of common seeded species. Field research has shown that soil micronutrient levels are critically important to establishing perennial grasses required at many revegetation projects. Subsequent greenhouse testing suggests that micronutrient fertilization allows for better establishment of seeded species and reduced time to germination. Results from several western U.S. sites will be presented showing the beneficial response of common reclamation species to these novel fertilization strategies at sites impacted by cheatgrass (*Bromus tectorum*), spotted knapweed (*Centaurea stoebe*), Russian knapweed (*Rhaponticum repens*) and others. With augmented fertility, perennial grasses can outcompete weedy invaders under edaphic conditions designed to mimic late successional grasslands. Rapid establishment of deep-rooted native perennial species is associated with improved infiltration slope stability, organic matter accumulation and reduced maintenance costs.

Key Words: revegetation, cheatgrass, spotted knapweed

Assessing impacts of engineered soil amendment and erosion control materials on mine cover system design and implementation

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Mine covers in cold regions are difficult to establish due to often poor local materials for a cover growth medium and harsh climate conditions. We examined the effectiveness of surface amendments for mine cover establishment on a low organic content, coarse, till soil from a northern Canadian mine site and their impact on ecohydrological functions. We tested two manufactured products: an engineered soil amendment and a flexible growth medium. We tested the effects of these amendments on vegetation establishment, surface erosion, runoff rates, infiltration, and percolation.

Testing was carried out at the Multi-purpOse Slope Testing (MOST) Facility at the University of Saskatchewan. Three test slopes were constructed. Two of the slopes had amendments applied and the third was left as a bare cover control. Slopes were seeded with herbaceous vegetation local to northern British Columbia. Controlled experiments were conducted on the slopes in frozen and unfrozen states. We mimicked a Dfb mid elevation climate regime (Koppen-Geiger climate classification) and the slopes underwent a six month growing season. After the growing season, a winter period was simulated, and the slopes were frozen down to -5 °C for 3 weeks. The experiment concluded with a simulated spring runoff event where 326 mm snow water equivalent was applied to the frozen slopes and allowed to run off over a two-week period.

Our results show that the amendments increased rates of vegetation establishment with the amended slope's vegetation reaching more developed growth stages 1-2 weeks in advance of the control slopes. Amended slopes were also found to have improved canopy coverage relative to the control slopes. We observed no surface erosion on the amended slopes while the control slopes saw 1.4kg/m^2 of soil erosion over the six-month growing season. The amended slopes also showed higher levels of soil moisture retention (75-85% of precipitation inputs retained) whereas the control slope saw only 68% input retention, owing to higher runoff rates on the non-amended slope. Our results suggest that these soil amendments could be a useful way to help rapidly stabilize mine covers at the time of construction by controlling surface erosion and providing improved growing conditions for vegetation establishment on poor soils.

Key Words: *mine cover systems vegetation establishment ecohydrology*

Establishment of a Native Vegetation Cover at Sweetwater Mine Site: Evaluation of Waste Byproducts and Mycorrhizal-Assisted Ecorestoration

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Success of revegetation of mine soils strongly depends on the effectiveness of the amendment strategies to support adequate plant growth while stimulating microbial processes and soil revitalization leading eventually to a self-sustaining ecosystem. The aim of this field study is to stimulate establishment of adequate vegetation cover and diverse community of targeted native/prairie plants, promoting sustainable ecological restoration and soil development. Established test plots aimed at investigating amendment-assisted enhanced revegetation at Sweetwater Mine Site, Reynolds County, MO. Eighteen test plots were installed examining the synergistic benefits of combining manure as a rich organic amendment combined with locally available rich-carbon waste by-products such as biochar and woodchips and inoculation with native isolates of arbuscular mycorrhizal fungi (AMF). To neutralize the high acidity associated with this site, lime was also incorporated. In Spring 2023, the treated test plots were seeded with

diverse native and prairie species mix representing different successional stages (i.e., early, mid, and late-successional species). The second-year plant growth responses were monitored, and soil were sampled in September-October 2024. Surveys were conducted using 1 × 1 m quadrat method. Plant indexes of percent cover, native richness and diversity were calculated. Compared to untreated soil, higher values of desired plant growth indexes were stimulated by the soil treatments supporting growth of highly conservative species that were absent in the untreated soil. Mycorrhizal inoculation played a significant role promoting higher diversity and richness indexes of native species in the corresponding plots. Soil chemical and biological analyses are underway to be correlated with plant responses revealing key factors driving shifting in plant communities.

Key Words: Arbuscular mycorrhizal fungi, Mine tailings ecorestoration, Native and prairie plants

Arbuscular mycorrhizal fungi combined with biosolids and biochar sustained phytostabilization and enhanced soil properties of mine tailings

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Employing innovative revegetation strategies can significantly enhance plant growth on mine tailings while stimulating ecosystem restoration and soil building. This long-term greenhouse experiment aimed to examine the role of arbuscular mycorrhizal fungi (AMF) and locally available rich carbon amendments for their potential to support sustainable cultivation of ecologically viable plants on legacy mine tailings while stimulating soil productivity and function and restoring ecosystem services. Soil was collected from a Pb/Zn/Cu tailings impoundment located in Viburnum, MO, USA. Substrates prepared by treating the top layer (10 cm) of soil with different amendments including locally available biosolids as a primary amendment, alone or combined with biochar and native isolates of AMF, while the bottom layer (10 cm) left as untreated soil. During a 7-year sustained growth period, impact of amendments on nutrient/metal leachability and availability was seasonally assessed. At the end of the experiment, the impact of amendments on agronomic and microbial properties was also assessed. Most notably, phospholipid fatty acid analysis (PLFA) was performed. Treatment combinations revealed significant differences in their impact on soil agronomic and geochemical properties. The findings strongly indicate that AMF plays a critical role in the establishment of soil microbial communities, particularly linked to carbon and nutrient cycling, progressing with depth into deeper, unamended tailings layers. Furthermore, the pattern of microbial community abundance indicates that roots of AMF-inoculated plants act as vectors of microbial community development and carbon sequestration, especially in severely impaired mine soils that do not traditionally support plant growth. These results strongly suggest the development of long-term productivity and ecosystem services at untreated depths as a result of surface-level amended revegetation with important implication for agroecosystem restoration on highly degraded mine soils.

Key Words: Arbuscular mycorrhizal fungi, Soil building, Phospholipid fatty acid (PLFA)

Water Abstracts

Novel Hydrologic and Geochemical Baseline Assessments for Closure Planning at Golden Sunlight Mine, Montana

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Golden Sunlight Mine (GSM) is re-evaluating baseline hydrologic and geochemical conditions to determine whether perpetual active treatment is needed for closure planning. A hydrologic baseline assessment was done, which required compiling, reviewing, and correcting water-level data from 289 wells. A novel water-level modeling approach was used to differentiate between natural and anthropogenic influences on groundwater levels, resulting in the analysis and flagging of 16,755 water-level measurements as representing either natural conditions, mine pumping, non-mine pumping, mine infiltration at the land application disposal (LAD) area, or leakage from a mine facility. High-quality data were used to develop pre-mining and 2024 potentiometric maps.

LifeCycleGeo performed a multivariate statistical analysis to differentiate mine-impacted and natural water-quality footprints, including natural acid-rock drainage (ARD), at GSM. The trend analysis and potentiometric maps provide a geologic and hydrologic interpretation for the water-quality trends. The "v" shape of contours east of the pit coincide with a landslide slump fault that created a groundwater trough. Wells with natural ARD follow along the trough centerline through Quaternary alluvium and Tertiary debris flows. A breccia pipe at the open pit is believed to be the source of the natural ARD signature. During mining operations, dewatering has created a cone of depression, which has prevented mine ARD water from migrating into the trough. The updated hydrologic and geochemical baseline assessment may be used to reduce the water-quality footprint that requires water management in future closure.

Status of abandoned mine lands managed by the BLM Butte Field Office, southwest Montana

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Southwest Montana has been mined extensively since the mid-19th century. Early mining practices occurred with little regard for the health of the environment, resulting in impacted soils and waters. The Bureau of Land Management's (BLM) Abandoned Mine Lands program addresses physical safety and environmental hazards associated with hard rock mines on BLM lands. Within the boundaries of the BLM Butte Field Office, eleven mine waste repositories have been constructed to consolidate and contain waste from nearby mines and mill sites. Repositories are concentrated in the Marysville District around the Marysville Stock, ~20 miles NW of Helena, and in the Colorado and High Ore Districts, ~5-10 miles SW of Jefferson City. The geology around the Jefferson City area includes mineralization related to the Late Cretaceous Boulder Batholith (73-76 Ma) and Elkhorn Mountains Volcanics (82-85 Ma).

BLM-managed repositories are located on both public and private land and many sites are managed jointly by the BLM and the Montana Department of Environmental Quality in coordination with private landowners. Upon identification of a contaminated site, efforts are made to identify parties responsible for contamination. In many instances, this is not possible and work is completed using Federal and State funds. Reclamation of mine waste and restoration at project and ecosystem scales can be expensive and difficult. Long-term monitoring and maintenance costs compound with initial repository and facility construction costs. A multi-disciplinary approach with input from a broad spectrum of resource specialists is needed to

achieve a desired outcome. While BLM's efforts to remediate mine waste on federal land are laudable, there are always opportunities to improve existing sites, ensure remedies remain effective, and address other locations of concern as funding and staffing allow. Recent interest in mine waste as a resource may change the way these problems are looked at in the future.

Key Words: Abandoned mine lands, repository, monitoring

Long-Term (10-year) Effects of Mine Spoil Weathering on Leachate Quality

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The Appalachian region of the United States has extensive areas of former surface mines in various stages of closure and reclamation that continue to pose water quality compliance issues. Coal surface mining byproducts include large amounts of relatively unweathered rock spoils, used as topsoil substitutes or placed into adjacent head of hollow fills to accommodate swell and maintain landform stability. As these newly exposed rock materials weather and leach, they release total dissolved solids (TDS) into local runoff and seepage, impacting receiving streams. Prediction of leachate quality from laboratory columns has been well-studied and informative but usually short-duration and don't replicate seasonal trends commonly observed in actual valley fill drainage and stormwater release points. In 2012 we initiated a mesocosm weathering experiment with sandstone rock spoil from southwestern Virginia to quantify seasonal trends in pH, specific conductance (SC), cations/metals, sulfate, and bicarbonate. The same spoils were also subjected to column leaching trials. Rock spoil (< 50 cm; ~30% fines) was loaded into three ~1.5 m^3 tanks, kept unvegetated, and exposed to ambient rainfall. Resulting leachates were collected and analyzed through May 2022. Initial mean SC exceeded 2000 uS/cm and eventually stabilized below 350 uS/cm, but seasonal increases in SC were observed every winter, which we attribute to the accumulation of weathering products (e.g. sulfates) on spoil surfaces over dry summer months and release in winter. Overall, total mean sediment loss was 2.95 mg/kg of spoil. Initial selenium concentrations were approximately 90 ug/L, but after 1 month dropped and remained below 5 ug/L through the study, even during winter seasonal peaks. This mesocosm leaching study was able to capture the observed seasonal behavior of leachate quality from coal surface mines, however these data indicate that the matching laboratory column studies were relatively accurate predictors of initial peak vs. long-term SC.

Key Words: Mine spoil, water quality, coal surface mining

Coal mine drainage and the Interagency Coal Mine Drainage Geochemical Database: Legacy pollution as a future energy resource

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Coal mine drainage (CMD) is frequently a large volume wastewater stream, particularly in Appalachia (USA), that can contain elevated metal concentrations including critical minerals such as Co, Ni, Mn, and rare earth elements (REEs). CMD has been targeted for remediation efforts to protect human and environmental health. An example of these efforts is the development of the U.S. Geological Survey's Science-based Hazard Assessment and Restoration of Mined Lands Decision Support Tool GIS-based application. Additionally, coal mine drainage and associated solid precipitates are currently being investigated as potential resources of critical minerals as a means to help develop a more secure domestic resource. Refining understanding of site-specific environmental characteristics that explain the chemistry of CMD, such as time since mining, hydrological source area and variability, and source rock geological and mineralogical controls, is warranted to enable more efficient targeting of sites for remediation and resource recovery. In this study, we measured the geochemistry at six untreated CMD sites in the

anthracite coal region of northeastern Pennsylvania, USA. Throughout 2024 we sampled and compiled historical data spanning 60 years (1965-2025). Preliminary findings indicate that loads of REEs are currently discharged to the environment at a rate on the order of kilograms per day, are highly dependent on CMD flow, and have generally decreased over the decades since mining ceased. These local results are interpreted in the context of the greater Interagency Coal Mine Drainage Geochemical Database (ICMDGD) with perspective toward the utility of the ICMDGD in evaluating restoration and resource potential. This database represents a compilation of CMD geochemistry data across Appalachia and is a new collaboration between U.S. Geological Survey, Department of Energy, and Office of Surface Mining Reclamation and Enforcement partners.

Key Words: critical minerals, rare earth elements, wastewater

Where are the fish? Evolving metal-related risks in an ecosystem impacted by a century of mining

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A legacy of metals mining has historically impaired the ecological health of the Clark Fork Basin (Montana, USA). Since the Superfund designation in 1983, large stretches of the Clark Fork River and its tributaries have been restored, leading to improvements in water quality and fish populations. However, in the last decade, nearly all three-year-old or younger brown trout have been absent from the uppermost reaches of the Clark Fork River. This decline in population was coincident with many changes to the management of mine waste, including the start of a new discharge of treated mine-wastewater. When this mine-wastewater is discharged outside the summer months, it enriches the river with a mixture of solutes that may alter metal toxicity or induce new risks to fish populations. We evaluated flow-normalized trends in metal(loid) (arsenic, cadmium, copper, lead, zinc) concentrations and loads across four sites in the Clark Fork Basin with varying degrees of restoration, exposure to active and historical mine wastes, and fish population histories using the Weighted Regressions on Time, Discharge, and Season (WRTDS) model. Preliminary results suggest that annual average concentrations of most metal(loid)s have declined over nearly 30 years, with the largest declines at restored sites and smallest declines at unrestored sites. Additional analyses will evaluate risks associated with metal(loid) concentrations in recent years, such as trends in metal bioavailability during periods when fish populations are vulnerable (e.g., May and June for juvenile brown trout). We will also present plans for future data collection to address knowledge gaps identified by the trend analysis. Results produced from this work will help us understand the effects of historic and active mine mitigation on fish populations in the Clark Fork Basin.

Key Words: metals mining water quality

Natural Acid Rock Drainage: Examples from Montana

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Investigations of natural acid rock drainage (NARD) in mineralized but unmined landscapes can provide insights into processes controlling sulfide mineral oxidation and transport of solutes in waters downstream of active or abandoned mines. Furthermore, case studies of NARD may help constrain what pre-mining (baseline) water quality was like for projects where no such data exist. This presentation will outline the geology and geochemistry of three examples of NARD from Montana: 1) the Judith Mountains; 2) the Mt. Evans area of the Anaconda Range; and 3) the Tobacco Root Mountains. Despite contrasting topography and geologic setting, all three locations are characterized by stream pH values in the range of 2.5 to 4.5, with very high

concentrations of sulfate and trace elements, including Al, Cd, Co, Cu, F, Fe, Mn, Ni, REE, and Zn. Concentrations of toxic metals near the headwaters are well in excess of regulatory standards for protection of aquatic life. Further downstream, trace metals attenuate due to dilution and adsorption onto hydrous Al, Fe, and Mn oxides on the stream bed. Rock glaciers locally exacerbate NARD by increasing sulfide-mineral surface area, which speeds up the rate of chemical weathering. In late summer, melting periglacial ice can supply cold, acidic, and metal-laden water to alpine catchments that otherwise would experience a decrease in streamflow and metal loading at this time of year. This phenomenon, which has recently been documented in the Austrian and Swiss Alps, may be due in part to human-caused climate change.

Key Words: Geochemistry, trace metals, NARD

Performance of a passive treatment system over 30 years in Tennessee

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A passive treatment system consisting of an Anoxic Limestone Drain (ALD) with approximately 6,000 tons of limestone, two basins, and two wetland cells was constructed at a reclaimed surface mine in east central Tennessee in 1995. The system was originally designed for a flow rate of 200 gallons per minute to treat total iron concentrations of 100 mg/L and meet permit effluent limits. The system performed remarkably well for approximately 15 years. Several years following construction, the flow rates peaked at more than double the design flow which stressed the passive treatment system, but the discharge water quality targets continued to be met. In 1999/2000, a supplemental ALD system was designed and constructed to address high flow periods. In 2009, sludge cleanout was performed at the primary basin of the original passive treatment system. The sludge management was successful with nearly all the sludge removed from the primary basin resulting in restored retention and settling capacity for the passive treatment system. Sludge was contained in the Geotubes, dried, and subsequently sold for beneficial reuse and recycling in the paint pigment industry. In 2010, National Pollutant Discharge Elimination System (NPDES) effluent limits for manganese were lowered requiring upgrades to the treatment systems. The 1995 treatment system was hydraulically connected to the 2000 treatment system, manganese removal beds were installed, and additional settling capacity provided. The final effluent has met all NPDES discharge limits including new manganese effluent limits since completion of construction upgrades in 2012. In the last decade, the system has been sampled regularly and maintenance has been performed including wetland vegetation management to minimize manganese release during summer conditions.

Key Words: manganese passive treatment

Metagenomic and Geochemical Insights into Silver Bow Creek Microbial Ecology

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Aqueous metals are pervasive contaminants associated with historical mining. We produced and examined nineteen metagenomes from a recovering creek to examine copper and arsenic contamination's effects on aquatic microbial genomic profiles. We incorporated metagenomic datasets with concurrently collected geochemical context into multivariate models to examine correlations between stream geochemistry and microbial functional potential. Integrating the metagenomes with full geochemical profiles emphasized that even low copper and arsenic concentrations shape microbial ecology and that seasonal shifts in metal bioavailability are relevant controls on basal communities.

Key Words: metagenome, copper, bioavailability

How to test PFAS in complex matrices

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For more than a decade, the landscape of Per- and Polyfluoroalkyl Substances (PFAS) has been constantly evolving. With an ever-increasing number of compounds classified as PFAS, what can we do to keep up with potential environmental testing requirements?
Starting with the development and publication of drinking water methods under the Environmental Protection Agency (EPA) Unregulated Contaminants Monitoring Rule (UCMR) in 2013 and an additional method in 2019, the world of PFAS testing expanded at an exponential rate. Most recently, a targeted method, including 40 PFAS was developed, validated, and finalized, as EPA 1633A.
In addition to targeted analysis, several methods for an overarching "total" PFAS concentration have been developed. Incorporating different technologies and methodologies to get us closer to a total PFAS concentration. Several commercially available methods and emerging methods will be discussed, comparing the types of matrices applicable and the type of PFAS data generated. This includes potential strengths and weaknesses in each method as well as potential challenges with the methods from a laboratory point of view

Key Words: PFAS, Analytical testing, EPA Method 1633

TDS Mitigation in Mining Affected Streams Using In-Stream Reservoirs

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Mountaintop removal valley fill surface coal mining operations (MTR-VF) are a source of high levels of Total Dissolved Solids (TDS) that continue to degrade water quality in the Central Appalachian region decades after reclamation. Stream water baseflow (fed by MTR-VF leaching) exceeds ecoregion TDS benchmark levels, leading to adverse effects on downstream ecosystems. Inasmuch as no effective mitigation measures are currently available, recent observations from a paired-watershed study shows promise for a potential solution. Namely, using in-stream reservoirs recharged by a surplus of seasonal low-TDS runoff to mitigate the MTR-VF baseflow effect on stream water TDS levels. The proposed mechanism is that surface runoff of low TDS level displaces the reservoir volume, diluting and decreasing its MTR-VF baseflow-dominant TDS level. The recovery of downstream TDS to MTR-VF baseflow levels, upon cessation of surface runoff, depends in-turn on the reservoir buffering capacity – the ability of its recharged low TDS waters to resist the high TDS levels of the incoming baseflow. In this study, a lab-scale drainage basin model system was fabricated and used to simulate the in-stream reservoir effect on downstream TDS. In-stream TDS was monitored up- and downstream from the reservoir and the delayed-response of the downstream TDS back to baseflow level was recorded. The simulation was conducted under different scenarios using different reservoir volumes, TDS levels, runoff volume, and combinations thereof. Results were compared to theoretical mass-balance mixing models in a combined effort to further elucidate the mechanisms and factors governing the observed phenomenon. Results demonstrate a multi-parameter dependence of the reservoir buffering effect, indicating an avenue for implementation at other high TDS-affected streams tailored to their individual constraints.

Key Words: Valley-fill, Total Dissolved Solids, Stream water quality

Evaluating Urban Stream Restoration Success: Water quality, macroinvertebrate surveys, and eDNA

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Urban streams are significantly impaired systems. Urban streamflow is altered by impermeable surfaces, which rapidly shed water during rain events, rather than permitting precipitation to infiltrate into soil, or remain in storage in association with wetlands or vegetation. Urban stream-water quality is also impaired by a suite of pollutants including sanitary sewer overflows, sediment, industrial effluent, and lawn applications. While urban streams have been the target of billions of dollars worth of restoration efforts, the efficacy of these efforts remains uncertain. This project was initiated to evaluate whether riparian reforestation and stream reconstruction efforts in seven urban streams in Lexington, KY, have influenced stream health. Our study assessed water quality using a standard chemical analyte panel, as well as macroinvertebrate community composition using standard survey techniques and a novel eDNA-based metabarcoding approach. Our results show that stream restoration efforts have significantly improved water quality in several study streams, yet have had no effect in others. For example, nitrate concentrations were reduced by as much as 50% between upstream and downstream sampling locations in one stream, but were similar between upstream and downstream locations in two other streams. In contrast, macroinvertebrate community composition assessed by conventional survey methods shows no significant difference between upstream and downstream communities, suggesting that stream restoration efforts have not ameliorated stream impairment sufficiently to support biotic recovery. Finally, macroinvertebrate community composition and structure as assessed by metabarcoding of eDNA is currently under analysis, but preliminary results suggest that this will be a promising approach to assess stream health recovery after restoration. Overall, stream restoration activities can be successful at improving some stream health outcomes, but are unlikely to be able to drive full recovery unless they are undertaken as part of a more holistic watershed-scale restoration effort.

Key Words: reforestation, riparian buffer, urban ecosystems

Reducing Design Uncertainty with Comparative Numerical Groundwater Modeling at a Former Smelter Site in Butte, Montana

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Hydraulic control and capture systems present unique and potentially expensive design challenges at many remedial sites. At the Butte Reduction Works (BRW) Smelter Area Mine Waste Remediation and Contaminated Groundwater Hydraulic Control Site (Site) in Butte, Montana, control of groundwater is a required portion of the remedy to prevent the flux of contaminants from groundwater to surface water. Additionally, Site remedial action will include dewatering and removal of saturated waste. Development of a fit-for-purpose Groundwater Modeling System (GMS) numerical model of groundwater flow at the Site allowed a comparative analysis of hydraulic capture and dewatering design alternatives and helped to constrain design uncertainties around hydraulic capture flows and dewatering flows. This presentation will provide an overview of available data, selection of modeling approach, summary of model calibration techniques, and describe comparative modeling scenarios used to inform the remedial design at the Site. The calibrated model allows rapid quantification of proposed design changes, simulations of groundwater and surface water interaction, and a visual aid to help engineers understand groundwater behavior in potential design outcomes. The presentation will discuss appropriate modeling approaches given data limitations and describe uncertainties inherent in the modeling. Modeled design scenarios and interpretation of numerical

model outputs associated with the scenarios will help illustrate the utility of this modeling approach to inform design decisions.

Key Words: Groundwater, Modeling, Water Treatment

Rare Earth Element Occurrences in Acidic Mine Drainage in Montana

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The demand for Rare Earth Elements (REE) continues to grow as new technologies emerge, but access to these elements is limited. With very few active REE mining operations, the United States currently does not have the domestic supply to meet the demand, causing the US to look to foreign sources. The demand has sparked the search for domestic REE's in unconventional deposits. Mine waste is being explored as a viable secondary source of REEs. Montana is home to several active and thousands of inactive mines that may be suitable targets for secondary REE exploration. For this poster, we analyzed acid mine drainage (AMD) water produced from active and inactive mines. This poster will report on samples from prominent Montana mine sites and mining areas such as the Berkeley Pit, the Great Falls Coal Field, and the Neihart mining district. Total recoverable and dissolved aqueous samples were analyzed at West Virginia University (WVU). REE's were detected in every sample; however, concentrations varied depending on the waste source and sites. Concentrations trended higher from sites with acidic conditions (<4.0 pH) while more neutral sites had lower concentrations. Sites identified as viable sources of REE's will be targeted for more intensive sampling to determine economic viability. Many of the abandoned mines across Montana have been left to decay, polluting the natural environment around them. The presence of REEs could provide an economic incentive and resources to remediate these sites.

Key Words: Water, Rare Earth Elements, Acid Mine Drainage

Using statistical models to identify drivers of change

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Resilient management strategies require tools that disentangle complex ecological systems to identify key drivers of change. Stepwise statistical modeling, in conjunction with population- and community-level analyses, can tackle large datasets to evaluate key drivers of change, thereby improving management strategies. Here, I will present two case studies demonstrating that statistical modeling applies to both naturally occurring and human-disturbed ecosystems at the macro and microscopic scale. In the first study, stepwise statistical modeling with population metrics was used to assess naturally occurring environmental drivers of butterfly population dynamics in a subalpine ecosystem to determine the drivers of population growth for a species at varying life stages. During the developmental life stages of the butterfly species, temperature determined future population growth, but for a similar species population growth was driven by snow cover and temperature during the overwintering life stage. These conflicting results highlight the nuance in efficiently managing species, communities, and ecosystems and the need to focus efforts strategically. The second case study applied stepwise statistical modeling and community analyses to assess how a suite of water quality analytes influenced the microbial community in a human-disturbed system. The outcomes of this research identified analytes that shaped a favorable native microbial community for the effective operation of a large-scale in situ bioreactor. These case studies highlight the value of statistical modeling tools to identify specific drivers of ecological change and develop targeted management strategies to mitigate their effects

and optimize an ecosystem to achieve treatment goals. The application of this approach has the potential to inform public and private sector work and evaluate interdisciplinary questions for efficient and effective management.

Key Words: Applied quantitative ecology, Stepwise statistical modeling

Transport, fate, and exposure to selenium from the Elk Valley British Columbia, Canada coal mines into ecosystems of the upper Columbia River Basin, United States

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The U.S. Geological Survey was directed congress to monitor and investigate the transboundary impacts of Canadian mines on waters of the United States. Koocanusa Reservoir, part of the upper Columbia River Basin, is located on the international border between northwestern Montana and British Columbia (BC) Canada. The reservoir receives mine wastes discharged from a globally significant metallurgical coal mine complex located in the Elk River, BC. Selenium is an essential micronutrient necessary for life, but excess concentrations can cause deformities, oxidative stress, and mortality in vulnerable egg-laying species. To gain insight into this issue we began a series of studies to better understand how total selenium concentrations change in space and time and to what degree the bioaccumulation of selenium into the food web poses a risk to aquatic and terrestrial wildlife. Loads of total selenium (in water) discharged from the Elk River into Koocanusa Reservoir have increased 443% since 1984. Over 95% of the selenium entering Koocanusa Reservoir is from the Elk River despite the fact the Elk River contributes < 30% of the water entering the reservoir. Decades long increasing trends in selenium concentrations are observed for over 575 km of the river system from Sparwood, BC to the Washington State/BC border near the confluence with the Columbia River. Elk River mines contribute potentially 67% of the load entering the US at the Washington State/BC border. Selenium concentrations in fish tissue exceed aquatic life standards throughout the Kootenai River Basin in Montana and Idaho. Additionally, selenium concentrations are increasing in tree swallows, an insectivorous bird that feeds along the river corridor. Long-range transport of selenium suggests potential risks to wildlife may extend into the US portion of the upper Columbia River Basin.

Key Words: Elk River Valley, selenium, ecology

Navigating PFAS Challenges in NPDES Permit Renewals

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As the U.S. Environmental Protection Agency (EPA) expands its regulatory oversight on per- and polyfluoroalkyl substances (PFAS) in wastewater, industrial facilities with upcoming National Pollutant Discharge Elimination System (NPDES) permit renewals face increasing challenges. Preliminary Effluent Guidelines Program Plan 16 underscores the EPA's commitment to studying PFAS discharges across industries, signaling a shift toward stricter monitoring and potential effluent limits. While many states have yet to establish enforceable PFAS discharge thresholds, the inclusion of EPA Method 1633 for monitoring in state-issued permits is becoming more prevalent.

To help clients navigate these evolving requirements, we implemented a proactive PFAS investigation and mitigation strategy for a facility which had documented PFAS contamination

and an upcoming NPDES permit renewal. Our approach included site-specific PFAS sampling, source identification, and wastewater fate-and-transport modeling. By engaging with regulators early and developing a targeted mitigation plan—including source control measures and potential treatment options—we positioned the client to address future compliance requirements before they became a mandatory requirement from the regulatory agency and this preventive should help with upcoming NPDES permit challenges.
Our result demonstrates that early intervention minimized regulatory uncertainty and likely reduced the risk of extended costly corrective actions. As EPA and States expand their PFAS oversight, industrial facilities should adopt a reclamation-driven approach to wastewater management. By embedding reclamation science principles into site investigations and mitigation planning, industrial sites can navigate PFAS-related permitting challenges while improving environmental stewardship and operational resilience.

Key Words: PFAS NPDES Mitigation

CASE STUDY: Design and Implementation of the Dream Mountain Passive Treatment System - Northern West Virginia

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Abstract: This case study highlights the design and construction of a large-scale passive treatment system in Preston County, West Virginia. The Dream Mountain Passive Treatment System was implemented for the Friends of the Cheat (local watershed group) on property owned by a hunting preserve / game ranch and discharges into Muddy Creek (a tributary of the Cheat River). Prior to the start of the current Dream Mountain Passive Treatment System, the site had experienced several failed attempts to treat portions the impacted mine water. The current passive treatment system addresses a relatively high flow, acidic discharge that combines waters which emanate from multiple pre-law abandoned underground coal mine entries. The design water quantity and quality data (avg / design) for the Dream Mountain Passive Treatment System are: flowrate (469 / 950) L/m *[(124 / 251) gallons per minute]*, pH 2.9, acidity (423 / 625) mg/L as $CaCO_3$, dissolved metals concentrations of iron (20 / 26) mg/L, aluminum (31 / 41) mg/L, and manganese (2 / 4) mg/L. Site specific constraints regarding the allotted and available construction area, property owner interests, permitting challenges, and funding allocations all played roles in the challenges encountered with the design and construction of this system. The Dream Mountain Passive Treatment System utilizes treatment technologies that include: two Auto-Flushing Vertical Flow Ponds (AFVFPs) in series; two Settling Ponds (SPs); a Jennings-Type Vertical Flow Pond (JVFP); and a Final Polishing Pond. The treatment system was officially placed online in spring of 2024. This presentation will also provide a preliminary evaluation of the system's performance from available sampling events conducted from project completion through present day.

Key Words: Acid Mine Drainage (AMD), Auto-Flushing Vertical Flow Pond (AFVFP), Jennings-type Vertical Flow Pond (JVFP)

Comparison of Pollutant Removal Rates for Three Limestone-Only Autoflushing Vertical Flow Ponds

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Performance analysis of mine drainage passive treatment systems in Pennsylvania was completed to better understand the removal rate of acid load within limestone-only autoflushing vertical flow ponds (AFVFPs). The passive, automatic flushing function of these ponds with rapid and gradual fill/flush cycle settings as well as the installation of telemetry systems paired with as-built measurements provide a unique ability to observe acid load removal per volume of

limestone in a full-scale operational system. The three sites compared in this study were the Neal Run system (Indiana Co., PA), the Oven Run B system (Somerset Co., PA), and the Muscavitch system (Washington Co., PA). All three sites have AFVFPs containing ≥ 90% CaCO3. Neal Run and Oven Run B contain AASHTO #1 while Muscavitch contains AASHTO #3. Water quality treated by the Neal Run, Oven Run B and Muscavitch AFVFPs include influent acidity concentration ranges of 3,279-5,363 mg/L CaCO3, 217-599 mg/L CaCO3 and 153-350 mg/L CaCO3, respectively. Metal concentrations removed will also be presented. Acid load removal rates were observed to be 79-351 g/d/tonne (Neal Run), 15-30 g/day/tonne (Oven Run B) and 46-115 g/day/tonne (Muscavitch). Acid load removal rates were observed to vary at the same site between gradual and rapid addition (filling) of the mine drainage, with rapid fill cycles appearing to provide more acid load removal per ton of limestone. The acid load removal rates seen in these AFVFPs will allow designers to consider the inclusion of limestone-only autoflushing vertical flow ponds with holding ponds and to adjust sizing criteria and flush cycles with respect to the raw water quality.

Key Words: passive treatment system sizing, AMD treatment, auto-flushing limestone bed

Field Calibration of PHREEQ-N-AMDTreat Input Parameters

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This study evaluates the applicability of PHREEQ-N-AMDTreat, a geochemical modeling tool, for designing and optimizing passive water treatment systems. Previous studies have estimated the sorbent mass, a critical user-defined parameter, by modeling metal precipitation and coating of different limestone sizes. However, the accuracy and reliability of these inputs remain uncertain due to limited field validation. This study evaluates the accuracy of simulated biofouling scenarios from the original PHREEQ-N-AMDTreat publication by comparing them with field-collected data from an operational passive treatment system. The system components being studied consist of an automatic flushing limestone-only vertical flow pond and a settling pond. Monitoring data from each treatment component were incorporated into the model, and sorbent mass variables were iteratively adjusted until the model's output most closely reflected the measured quantities. The adjusted sorbent mass values were then evaluated against theoretical methods for quantifying sorbent accumulation: (1) the model's internal calculation of total precipitated solids per component and (2) the observed change in contaminant load through the system. This comparison aims to establish a framework for improving sorbent mass quantity selection, particularly for non-expert users. Findings from this study provide insight into the practical limitations of PHREEQ-N-AMDTreat and suggest refinements for its application in passive treatment system design.

Key Words: Acid Mine Drainage (AMD), Auto-Flushing Vertical Flow Pond (AFVFP)

Where are the fish: A paradox of declining fish populations and improving insect communities in a mine-impacted ecosystem

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The Upper Clark Fork Basin, Montana, is affected by historic and active metals mining and has been receiving large-scale ecosystem restoration since its designation as a superfund site in 1983. Restoration efforts aim to improve ecological conditions by reducing exposure to various metal(loid) sources across the landscape. However, restoration and mitigation efforts themselves may consequently change exposure risks over space and time. Since restoration began, dissolved metal(loid) concentrations in water have decreased and invertebrate communities have improved such that between 2019 and 2023 an index of biotic integrity suggested that all sites are unimpaired or slightly impaired. Despite this and other measures of restoration success, there is a

decrease of nearly all three-year-old or younger brown trout in the uppermost reaches of the Clark Fork River. Additionally, metal concentrations in caddisfly tissues persist at levels exceeding fish toxicity thresholds from the river's headwaters to 140 miles downstream. Here, we plan to compare a 30-year record of metal(loid) concentrations in caddisfly tissues to richness of taxa less often studied in ecosystem dynamics. This will fill a significant data gap that exists regarding how metal(loid) concentrations affect a broader range of taxa, including new taxa repopulating the Upper Clark Fork, which may support a substantial portion of fish diets. This will allow us to understand the impact of metal(loid)s on a larger scale and motivate future sampling efforts in the Upper Clark Fork River Basin to understand metal(loid) concentrations and accumulation within food webs.

Key Words: Metals Invertebrates Fish Restoration

Effect of Fermentation Conditions on the Performance of Microbial Cellulose Membranes for Filtration Applications

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Access to safe drinking water remains a global challenge, and membrane filtration offers a reliable solution for contaminant removal from water. However, high production costs and membrane fouling limit its widespread use. This study employs response surface methodology (RSM), using a face-centered central composite design, to optimize microbial cellulose (MC) membrane formation from kombucha fermentation for water filtration. The effects of temperature (25–35°C), inoculum mass (1.5–2.5% w/v), and fermentation time (8–16 days) on membrane properties were evaluated. After harvesting, membranes were treated with 0.1M NaOH to remove impurities and extracellular polymeric substances (EPS). Flux tests were performed in a filtration apparatus to assess the permeability of the membranes under different operating conditions. Results indicate that fermentation time significantly affects membrane thickness and permeability. Longer fermentation time (16 days, 35°C) produced thicker membranes (8.8 mm) with lower permeability (56.2 $L/m^2 \cdot h \cdot bar$), while shorter fermentation time (8 days, 25°C) yielded thinner, more permeable membranes (432.4 $L/m^2 \cdot h \cdot bar$). Increased inoculum mass led to thicker membranes, reducing water flux. Interaction effects between fermentation time and inoculum mass were evident, with higher inoculum dosages at prolonged fermentation times leading to depletion of available carbon sources, thus altering membrane properties. Optimization of fermentation conditions is crucial for balancing microbial growth and carbon availability to achieve desirable membrane properties. Findings highlight fermentation time as the most influential factor and provide insights for scaling MC membranes as a cost-effective, sustainable filtration solution. Future work will focus on conducting exposure tests to evaluate the longevity of the membranes and monitoring changes in performance over extended periods.

Key Words: Membrane permeability, Fermentation optimization, Water flux

Predicting settling pond hydrology and chemistry from extreme weather and operations using GoldSim

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Settling ponds are crucial for mine water treatment, improving water quality through the sedimentation of heavy metals and supporting regulatory compliance. However, changes to climate, influent chemistry, surface and groundwater sources, or operations can significantly impact pond efficacy and effluent chemistry, posing potential risks to operators, landowners, and the environment. GoldSim, a proprietary software that provides a robust and adaptable framework for graphically representing and dynamically modeling intricately engineered

systems, offers the ability to evaluate risks associated with these potential perturbations, and predict system responses to future variable conditions.

Here, we present a GoldSim model simulating water and chemical constituent transport in a complicated hydrological system based on previously developed models for real settling ponds. The model integrates key processes such as precipitation, evaporation, surface water flows, recirculation, and groundwater interaction, and is combined with geochemical data to conduct a mass balance analysis. We will demonstrate how to use the model with the Monte-Carlo method to better quantify hydrological and geochemical risks associated with 1) unknown input and output rates of water, 2) extreme weather events, and 3) changes to the routing and recirculation of pond water. Results will primarily focus on heavy metals that tend to attenuate in pond settling systems, as well as other constituents considered to be more inert. This approach can be employed beyond settling pond systems for broader pre- and post-mine water resource management, including the operations of tailings storage facilities, assessment of heap leach pad drainage, and the hydraulic and chemical evolution of pit lakes.

Key Words: Goldsim, Wetlands, Climate

Recent changes in the Berkeley Pit water quality

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The water quality in the Berkeley Pit (Butte MT) has changed substantially over the past 15 years. The Berkeley Pit began filling with water in 1983 after the Anaconda Mining Company suspended operations. From the late 1980's through 2012 the Berkeley Pit water quality changed very little with pH of 2.5 to 3.1, >10,000 mg/L total dissolved solids (TDS), <0.5 mg/L dissolved oxygen (DO) at depth, >200 mg/L Fe, and high concentrations of Al, Zn, Mn, Cu, Cd, and As. Safety concerns prevented monitoring between 2012 and 2017. When monitoring resumed in 2017, the water quality had changed significantly with pH >4, <10 mg/L Fe and As, and >6 mg/L DO at depth. The cause for these changes is attributable to (1) a copper recovery operation that removed Cu from the water and returned soluble Fe to the pit, and (2) the disposal of lime-treatment sludge into the pit. The water quality of the pit has continued to change since 2017, although to a lesser degree than the pre-2012 to post-2017 change. This water quality change is somewhat obscured by the apparent semiannual turnover of the pit water, which often results in inconsistent trends between individual measurements. However, the overall trends indicate that the pH has changed from just above 4.0 to routinely near or above 4.5, and the DO has changed from >6 to <3.5 mg/L at depth. Along with these chemical changes, the biology of the pit has also changed significantly in recent years with visually apparent algae blooms beginning in the summer of 2021 and continuing since that time.

Key Words: Berkeley Pit lake

Watershed and reservoir geochemistry: A case study in the San Juan River watershed with applications to the Kootenai River and Clark River watersheds

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Studies have demonstrated that rivers and reservoirs in watersheds affected by mining have complicated metals geochemistry because of the potential for multiple source inputs. Studying water and sediments entering rivers and reservoirs supports a better understanding of the location and extent of risk to aquatic and human health. The San Juan River watershed in the Four Corners Region, USA has widely varying potential sources of metals including events like the

Gold King Mine spill in 2015. Additionally, the watershed has numerous oil and gas production sites, natural uranium deposits, uranium mines and mills, coal mines, coal fired power plants, urban regions, livestock, and agricultural land. A study sources of aluminum, arsenic, and lead in tributaries to the San Juan River identified numerous tributaries that input these elements along the river's extent. Analysis of strontium, lead, and sulfur isotopes indicated that water sources are associated with the local geology and oil and gas from different river sections in the area. Sediment was studied from three reservoirs in the San Juan River watershed, Aztec Drinking Water Reservoir #1 (ADWR), receiving water from the Animas River, Farmington Lake (FL) and the San Juan Generating Station Reservoir (SJGSR), both receiving water from the San Juan River. Sediment from the ADWR showed evidence of uranium milling upstream while FL and SJGSR did not show evidence of mining or milling. The techniques used in the San Juan River watershed study are applicable to both the Kootenai River (KR) and Clark Fork River (CFR) watersheds. Preliminary implementation of these techniques in KR and CFR watersheds will be presented.

Key Words: geochemistry, watershed, reservoir

Reclamation of Coal Combustion Residuals Impoundments using calcium polysulfide

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Coal Combustion Residuals Impoundments (CCR) associated with coal-fired power plants are characterized by heavy metals, hardness, alkalinity, chemical oxygen demand (COD), sulfate, chloride, and low pH. The leachate from the ash contaminates the ground water and the surface water resource, posing a serious threat to the public health and the ecosystem. Thus, the reclamation of CCR impoundments is crucial to safeguard the health of the environmental recipients. This study aims to use calcium polysulfide (CaSx) as an efficient, less toxic, and cost-effective chemical compound to treat CCRs. CaSx has a large surface area and reactive sites that facilitate strong binding with the contaminants, immobilizing them and preventing their leaching into the groundwater. The impoundments wastewater was collected from an active coal-fired plant in the U.S. Jar test operation was carried out to optimize different parameters including pH, CaSx dosage, and the fly ash mixing ratio. As a starting point, the operation was carried out at pH 2.92 (the natural pH of CaSx) and pH 7.01 at CaSx dosage of 2 to 10% (w/w). In both cases, CaSx induced flocculation; however, it raised the final pH of the mixture; an increase in the pH was directly proportional (R^2= 0.99) to the CaSx dosage. Interestingly, even low dosage (2%) of CaSx elevated the pH to 8.51 (for initial pH 7.01) and 8.23 (for initial pH 2.92). It provides a clue that CaSx may lack carbonate alkalinity. A metal analysis is underway to ascertain the effect of pH change on the metal removal efficiency. Future experiments also include evaluating and optimizing slurry mix design to achieve high treatment efficiency and matrix stability to avoid leaching.

Key Words: Coal Combustion Residuals Impoundments (CCR); Calcium Polysulfide; Reclamation, Stabilization, Leaching

Microbial Zinc metabolism in a recovering stream

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Silver Bow Creek (SBC) near Butte, MT is recovering from historic metals (e.g. Cu, Cd, Zn) contamination. Zinc contamination in aquatic ecosystems contributes to metal bioaccumulation

with substantial impact on ecosystems. In this study, we generated and analyzed 16 metagenomes from the creek to explore how anthropogenic zinc contamination influences microbial functional profiles. These metagenomes were sourced from sediments samples, providing insight into the microbial communities present in this environment.
We identified 3461 Zn related genes across the area. These genes are grouped into distinct gene families based on diverse functional characteristics including carboxypeptidase, dehydrogenase, large subunit ribosomal proteins, oxireductase, small subunit ribosomal proteins, Zn binding, Zn finger protein, Zn metalloprotease, Zn permease, Zn resistance, and Zn uptake. Each potentially might play a role in maintaining cellular Zn regulation and mitigating its toxicity. By combining these metagenomic profiles with detailed geochemical data, we will develop a multivariant model to explore the relationships between chemistry and microbial functional capabilities. Seasonal fluctuation and locations may alter the genetic makeup of microbial communities as observed in SBC copper resistomes. It is found that metal-induced stress impacts the composition and functional potential of microbial communities (Helfrich *et al.,* 2024). Like Cu, it is anticipated that Zn profiles would display both spatial and temporal variability. This study is designed to help determine the specific pathways and mechanisms through which microbes adapt to Zn stress, particularly in relation to metal resistance genes and detoxification processes. Moreover, these findings will be useful for the development of robust strategies to help manage, remediate and restore the ecosystem.

Key Words: Zinc, Microbial activity, Geo-bio-chemistry

Food web selenium accumulation could impact fish in a recovering aquatic ecosystem

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After the discharge of treated Berkeley Pit water into Silver Bow and Blacktail Creeks began in September 2019, aqueous selenium levels can reach 3–5 µg/L which is over the limit of 1µg/L in natural waters. Although these concentrations are low, selenium can biomagnify in food chain components such as macrophytes and invertebrates (Hamilton, 2004). Macrophytes take up selenium from the water, insects and small fish feeding on these plants accumulate high selenium concentrations, increasing the risk of toxicity in the fish. Selenium accumulates in higher quantity in various fish tissues such as the muscle, liver, and kidney tissues when the concentration exceeds the optimum level, exerting negative impact on the health of fish and cause toxicities (Hilton et al. 1980). Given the possibility for long-term environmental impacts, ongoing monitoring is important to evaluate selenium bioaccumulation in the food chain and its effects on fish health.
This research aims to measure selenium concentrations in the fish food web. Samples were collected from the creek every three months at sites from Blacktail Creek in Thompson Park to Garrison on the Upper Clark Fork, from May 2024 - February 2025, both above and below Warm Springs Pond, to capture spatial and seasonal variations in selenium distribution. After acid digestion, selenium was measured using Inductively coupled plasma mass spectrometry (ICP-MS). Selenium analyses of water samples will also be carried out to help predict selenium accumulation in the fish. Additionally, the geochemistry of the creek from 2024 will be examined to understand how it influences selenium bioavailability. It is anticipated that this study will provide insight into selenium transfer in the aquatic environment and its impact on the fish populations.

Key Words: Upper Clark Fork Silver Bow Creek Metalloid-bioaccumulation

Development and optimization of a novel reactor for remediating acid mine drainage using natural substrates

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This paper discusses the development, optimization, and performance of an innovative reactor designed for the passive treatment of acid mine drainage (AMD) using natural substrates. AMD is a widespread environmental concern caused by effluents from mining operations, characterized by acidic water and elevated levels of dissolved toxic ions and heavy metals. The presence of AMD poses significant risks to ecosystems and environmental integrity, potentially leading to the ecological devastation of watersheds and the pollution of surface water bodies. In this study, state-of-the-art analytical techniques and instruments, including Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDS), X-ray Fluorescence (XRF), and X-ray Diffraction (XRD), were employed for the characterization of materials. Ion Chromatography was utilized to determine anions such as sulfate ($SO4^{2+}$), while Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) were used for the analysis of metals and metal ions.
The results demonstrated effective removal of metal content (Fe^{3}+, Mn^{2+}, Cr^{2+}, Cu^{2+}, Ni^{2+}, Pb^{2}+, Al^{3+}, and Zn^{2+}) and anions from AMD matrices, achieving high removal efficiencies. This novel technique has proven to be effective in treating AMD generated from mining activities. The proposed reactor offers significant benefits to the mining industry by providing an affordable wastewater treatment technology characterized by low operational costs and minimal energy consumption. Furthermore, the potential for recycling and reusing AMD water in mining operations presents additional opportunities for cost reduction

Key Words: Acid Mine Drainage Natural Substrates Passive Treatment

Hydrologic Controls on Nutrient Retention in a Restored Wetland

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Wetland restoration and construction are key elements to aquatic restoration and mitigation projects. In many regions, wetland loss has occurred with agricultural and urban development, limiting the nutrient and sediment retention and water storage in the landscape. In this study, pre- and post-construction water quality and water level measurements characterize the changes in nutrient retention from a wetland restoration project in Bell Run-South Fork Licking watershed in Eastern Ohio. The 80-acre wetland restoration project converted previously farmed land back to the pre-settlement wetland land use, a portion of the historic Bloody Run Swamp. The restored parcel sits amongst agricultural fields; the subwatershed drains through tile drains and agricultural ditches to Bloody Run, then to the South Fork of the Licking River. The wetland construction was completed by the Stream and Wetlands Foundation and included removal of drainage tile, repair of berms surrounding the field and those on surrounding parcels, development of hummock and tussock microtopography, construction of a natural channel design channel to replace the ditch on the north end of the site, and planting of native wetland plants. Results suggest that nitrogen loading reduced from pre- to post-construction conditions, while phosphorous loadings increased from pre- to post-construction due to the release of legacy nutrients. The hydrology of the pre- and post-construction monitoring periods varied and the dynamic nature of nutrient export from the site was evident. High flow time periods appear to be critical for nutrient export from the site and further monitoring during high flow conditions can further our understanding of the function of restored wetland ecosystems. In the summer of 2024, extreme drought conditions occurred throughout the region, and the effects on wetland

hydrology and nutrient retention of the drought are still being studied.

Key Words: wetland mitigation, nitrogen, phosphorus

The Use of Hydrochar as an Amendment in Bioreactors for Acid Mine Drainage

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This study is based on batch bioreactor experiment to investigate the effectiveness of using hydrochar to promote the growth of sulfate-reducing bacteria in acid mine drainage treatment, with a primary focus on copper, zinc, and cadmium removal. It introduces a novel technique that emphasizes the use of passive biological treatment processes over chemical treatment utilizing various organic substrates such as cow manure, maple woodchips, and cornflour acquired from a local granary blended with hydrochar produced from food waste and septage; diverting these wastes from landfill. Bioreactor trials were performed with 0%, 5%, 10%, and 20% of hydrochar by volume in the bioreactor substrate. Bioreactors were operated 98 days, and water quality parameters are analyzed periodically by extracting eluent with a syringe. After operation, 16s rRNA sequencing was used to determine the presence of sulfate reducing bacteria of bioreactors. From the results, bioreactors without hydrochar content in Batch 2 more effectively raised solution pH and reduced metal concentrations, with removal percentages of Cu (89-100%), Zn (97-100%), Cd (100%), and sulfate (50-100%), following the removal trend of Cd > Zn > Cu. Statistical analysis result demonstrates no significant influence of hydrochar concentration on metal removal ($p > 0.05$), but time has a significant effect ($p < 0.05$), indicating that removal effectiveness improves with time regardless of hydrochar quantity. The presence of sulfate-reducing bacteria was confirmed across all bioreactors, with the species *Desulfovibrio* and *Desulfitobacterium* being the most abundant.

Key Words: Sulfate reduction, DNA sequencing, waste diversion

High Resolution Stormwater Monitoring: Study Design, Outcomes, and Lessons Learned from Contrasting Three Hydrologic Studies in The Western United States

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Understanding short-term stormwater discharge and storm-influenced water quality in stream systems is often crucial for site characterization, offering key insights into hydrologic flow regimes, water quality changes, mass flux, hyporheic interactions, and even morphological evolution within stream reaches. High-resolution monitoring (i.e., real-time flow tracking and water quality sampling) of storm-affected stream discharge provides data to support physical and geochemical analyses of stormwater events. There are many approaches for monitoring surface water behavior and capturing stormwater data. Integrating automated equipment, telemetry, and other digital tools can enhance data collection, though success depends on understanding both technical and logistical factors. For example, calibrating automated monitoring equipment typically requires development of rating curves of characteristic surface water flows and/or developing hydrologic models prior to (or during) study implementation. In addition, traditional methods—such as reconnaissance, site selection, and physical observation—often yield valuable data to support characterization efforts. The specific study questions, site characteristics, available personnel, budget, health and safety, and data needs can all affect study design, effort, and success.

We present the results of three similar yet distinct stormwater monitoring projects, contrasting approaches based on physical stream behavior, study design, technical execution, logistics, and cost. The study sites, located in the western United States—west-central Montana, the southern

Coast Range of California, and the western Cascade Range in central Oregon—represent diverse montane and fluvial valley stream systems related to historical mining activity. Each site posed unique challenges, including variations in stream morphology, biotic influences, and precipitation patterns, as well as logistical considerations like site access, equipment durability, natural interferences, and study duration.
Although the studies employed different methods to meet their respective objectives, the collective observations revealed common lessons learned, offering valuable insights for future study designs.

Key Words: High-Resolution Flow Tracking, Surface Water Monitoring, Automated Data Collection

The EBR: Biological Selenium Removal without Production of Troublesome Se Species and Complex Post-Treatment

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Selenium (Se) is a naturally occurring metal with an elevated prevalence in the Earth's crust in Western North America and Appalachia. Historical and modern mining practices expose mineralized Se, allowing for its weathering and release into water bodies.
WesTech partnered with a North American mining client to demonstrate the Electro-Biochemical Reactor (EBR) technology for selenium removal from site waters. The EBR system uses an innovative approach to biotreatments by decoupling the electron provision from organic carbon metabolism. The electrons are provided to the bioreactor directly, using a low applied potential at milli-Amp current levels. The directly supplied electrons are readily available to the microbes in a consistent manner without the metabolic energy expenditure.
The mine waters are currently treated with reverse osmosis (RO) system, removing total selenium from 160 $\mu g\ L^{-1}$ to less than 5 $\mu g\ L^{-1}$ in the permeate while concentrating selenium four-fold in the reject stream.
The six-month pilot demonstrated an average total selenium removal rate of 99.3%, reducing the reverse osmosis reject concentrations of 650 $\mu g\ L^{-1}$ to less than 5 $\mu g\ L^{-1}$. The nutrient requirement was low, reducing operating expenses and limiting the excess biogrowth production often experienced with conventional bioreactors. The post-treatment requirement was significantly reduced because of the low bioreactor BOD levels, low phosphorus, and low turbidity. The final system design produces no liquid waste streams.
Selenium speciation results, collected throughout the pilot across steady-state and stress-testing phases, showed that the predominant species in the RO concentrate stream was selenate. The pilot system produced, on average, 4.5 $\mu g\ L^{-1}$ selenate and 1.0 $\mu g\ L^{-1}$ selenite, with non-detectable levels ($<0.15\ \mu g\ L^{-1}$) of methylseleninic acid, selenomethionine, and selenocyanate. This paper will describe the pilot system configuration, testwork program, granular results, and full-scale system design considerations.

Key Words: bio-treatment, electro-biochemical reactor, speciation

Insights and lessons learned from launching new mine land reforestation program

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In 2023, the Cumberland River Compact launched a mine land reforestation initiative in the Cumberland River basin focused on restoring landscapes degraded by coal mining activities. This presentation will detail the foundational steps taken to launch the reforestation program, highlight the lessons learned in overcoming challenges, and offer a framework for other organizations aiming to reforest post-mining landscapes. As an education and recruitment tool,

attendees at the Compact's presentation will gain insights from a boots-on-the-ground practitioner into the strategic planning, outreach, and adaptation needed in order to scale a successful reforestation program.

Lands mined for coal in southern Appalachia suffer from soil compaction, acidity, and an overgrowth of invasive species, creating barriers to water infiltration and increasing runoff into the Cumberland River basin of Tennessee and Kentucky. The Compact's reforestation program provides long-term ecological and hydrological benefits, and is designed to support aquatic life, reduce soil compaction, create wildlife habitats, and possibly reduce downstream flooding events. Additionally, the initiative seeks to engage local contractors, ensuring that Appalachian communities benefit from this restoration work.

As with any startup of complex and unique nature, the Compact faced significant challenges in building the mine land reforestation program. Barriers have included securing privately owned land, establishing partnerships, and navigating trust within local communities. However, with the guidance of the Office of Surface Mining Reclamation and Enforcement and the Appalachian Regional Reforestation Initiative, the Compact's nascent program has successfully restored 42 acres in its first year and 80 acres in its second, planting a total of 77,725 native seedlings using the Forestry Reclamation Approach (FRA). Key partners, including The Nature Conservancy, Green Forests Work, the Kentucky and Tennessee Department of Forestry, and Kentucky Fish and Wildlife, have been instrumental in the success of the program.

Key Words: Planning, Reclamation, Education

Remote sensing methods to identify culverts impairing fish passage

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Culverts may impair fish passage, limiting access to spawning grounds or headwaters habitat. Several key mechanisms can lead to fish passage limitation through culverts: the slope of the culvert, the drop between the downstream end of the culvert and the stream, and the culvert material. We engaged with stakeholders in the Lake Erie basin of Ohio and reviewed NPS-IS (Non-point Source Implimentation Strategy) reports to identify known barriers to fish passage as a validation data set. We then developed a method to prioritize and identify culverts that were impairing fish passage using LiDAR and aerial imagery data. The statewide culvert database does not include sufficient data to determine if a culvert is impairing fish passage by itself. Culverts in high quality watersheds were first selected for those on perennial or intermittent streams. Based on the state database, culvert openness ratio was then calculated; a low openness ratio may lead to impairment of fish passage. Aerial imagery and LiDAR were used to calculate the average slope from the streambed upstream of the culvert to downstream of the culvert. A high average slope suggests either a high slope culvert or disconnection at the downstream end; both impair fish passage. The data in the Lake Erie basin had natural breaks that suggested that sites with high slope (>10%) and sites with moderate slope (4-10%) should be evaluated in the field for further characterization for potential removal or replacement projects.

Key Words: LiDAR, stream restoration, aerial imagery

Assessing Methylmercury in Sediments at Varying Depths: A Case Study in Methylation Dynamics

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Mercury contaminated sites pose unique challenge as compared to other metal contaminated sites due to the complex nature of mercury transformations. Unlike other metals that have direct exposure risks, mercury can build up within the food web to concentrations above the EPA guideline for consumption, which is often the risk driver for cleanup rather than direct exposure. This occurs based on site specific conditions that can facilitate the conversion of inorganic mercury to the bioavailable organic species, methylmercury. The challenge with mercury contaminated sediment sites is that small increases in sediment methylmercury can greatly exacerbate mercury uptake in upper trophic level fish species. This phenomena of mercury methylation is not just controlled by site specific conditions, but also specific depths within the sediment, typically at the boundary of oxic/anoxic conditions. Methylmercury generated near the sediment surface can impact surface water concentrations, and subsequent food web uptake. This talk focuses on a sediment mercury methylation evaluation done at various depths within a tidally influenced creek, Wappinger Creek, New York. This system has the added complexity of a daily tidal swing that exposes, then floods, soft shoal sediments. The data shows that shallow sediment, near the sediment water surface, can be more prone to mercury methylation than deeper sediments, with significant differences between depths. There are some exceptions throughout the site however, which is potentially linked to the hydrodynamic nature of daily dewatering and flooding of tidal sediments, with subsequent oxidation of surface sediments during periods of exposure. This presentation is geared toward site investigators challenged with the complexity of mercury contaminated sediment sites, in particular those that are tidally influenced, with a discussion on optimizing methylmercury evaluations.

Key Words: Sediment mercury methylation

Manganese Speciation in Anaerobic, Organic-Matter-Rich Wetland Environments

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Manganese (Mn) is a nearly ubiquitous heavy metal that acts as an essential nutrient for plants and animals. Environments can easily reach toxic Mn concentrations as organisms require only extremely small concentrations. 20% of US water systems are shown to have Mn that exceed current maximum Mn drinking water concentrations at 300 µg/L as set by the US EPA. The concern of this project is the unpredictable nature of Mn concentrations that occur in the high organic carbon, anaerobic conditions observed in wetlands due to environmental parameters such as pH and redox conditions. Mn speciation is vital to understanding this as Mn may exist in several oxidation states that strongly impact behavior. Under anaerobic conditions, soluble Mn(II) and insoluble Mn(IV) are present, with Mn(II) as the dominating species. 1L batch reactors with spent mushroom compost and ~0.5 mg/L of Mn at a 4:1 liquid:solid ratio were created and allowed to incubate until anaerobic conditions were achieved. Oxygen and pH were then manipulated by bubbling air back into the reactors and using dilute acid (sulfuric) and base (sodium hydroxide) solutions, respectively. They were sampled twice weekly and analyzed for pH, temperature, dissolved oxygen, redox potential, and conductivity, as well as total Mn and Mn(II). Mn(II) concentrations were determined by filtering aliquots of samples taken from the batch-reactors. Mn(IV) concentrations were determined after subtracting Mn(II) from total Mn. The results we obtain by studying the behavior of Mn speciation as water quality conditions change aim to determine what impacts Mn retention and/or release. These results will help us ascertain new ways to effectively and consistently decrease toxic Mn concentrations in wetland environments and drinking water resources.

Key Words: Water treatment, water resources

Residuals from passive treatment system process units close the loop on resource recovery

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Passive treatment is an accepted water quality improvement practice at legacy and active mining sites. Properly designed and sized passive treatment systems (PTS) effectively retain problematic constituents. Retained solid types vary based on which physical, biogeochemical, and microbiological mechanisms are promoted in given process units, but are most often oxides, hydroxides, or sulfides. System design and size are based on empirically derived areal or volumetric removal rates and given design lifetimes. Therefore, PTS require periodic removal of accumulated treatment residuals. Recovery and reuse of these residuals or their selected components may promote a circular economy and offset maintenance costs. This study examined the potential for resource recovery in several long-term PTS receiving coal or hard rock mine waters in Oklahoma, USA. PTS influent waters were either naturally net alkaline (lead-zinc mines) or rendered net alkaline by anoxic limestone drains (coal mines). In addition to analysis of a robust water quality data set, residual solids were examined from oxidative and reductive process units. Solid samples were analyzed physically, chemically, and microbiologically to examine three resource recovery options: trace metal recovery, rare earth element (REE) or critical mineral recovery, or bulk reuse as sorbents. Oxidative residuals, primarily ferrihydrite or goethite, were found to be effective anionic sorbents. However, residual age, inferred from accumulated depth, dictated potential effectiveness. Reductive residuals (exogenous organic substrates) were found to contain galena, sphalerite, pyrite, and other metal sulfide forms, as well as the greatest concentrations of economically important REE and critical mineral concentrations, including yttrium, lanthanum, cerium, and neodymium. Natural infrastructure like mine water PTS may serve as demonstrable links between environmental remediation, ecological restoration, and the global transition to a renewable energy economy. By closing the resource recovery loop, benefits beyond water quality improvement may be realized.

Key Words: sorbents, critical minerals, circular economy

Evaluation of Legacy Gold Mining in South Carolina

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Open-pit gold mines have left a legacy of clean-up issues in McCormick and Chesterfield counties in South Carolina from historical mining methods such as the use of sodium cyanide. Two such sites, the Brewer and Barite Hill Mines, are on the federal Superfund list which make them priority cleanup sites. Many of these legacy sites may be part of current or proposed gold mining operations as previously mined gold-bearing ore bodies are being permitted and reworked under current technology, e.g., Haile Gold Mine in Lancaster County which also has an historical aspect. In addition, legacy areas may be part of the overall tourism industry in South Carolina, e.g., Heritage Gold Mine Park. Areas of more serious cleanup are under the direction of the Environmental Protection Agency (EPA), and, along with other stakeholders have worked over decades to address environmental issues.

The South Carolina Mining Act and Regulations were promulgated in 1975. Three separate permits were issued and combined for the Haile Gold Mine described earlier under this act. The latest modification application was received by State regulators in 2019. After a lengthy review of three years, the Department of Health and Environmental Control (DHEC) approved this mine-operating permit. Concerns for such newer mining include: larger surface pits that impact

surface and groundwater, disruption of wetlands, and construction of tailing ponds. These are especially concerning to nearby towns who must balance the economic benefits with potential environmental impacts.
Combining federal authority under Superfund, as well as state authority under the state mining laws, can be challenging. Several states in the eastern and western United States deal with this. New mining technology and ways to mitigate impact have changed drastically since the early days of gold mining in South Carolina. However, concerns on acid drainage and metal contamination are still issues both with legacy sites and current permitted areas. Federal and state regulators work with all stakeholders for operation and cleanup.

Key Words: Gold Mining, Acid Mine Drainage, Legacy Sites

Using Hydrology, Water Quality, Soils, and Vegetation to Evaluate Wetland Condition and Effects on Trace Metals in Natural and Treatment Wetlands in the Tar Creek Watershed

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Natural and treatment wetlands have been shown to improve water quality on mining impacted lands using biogeochemical and microbiological processes as well as providing ancillary ecosystem services including wildlife habitat and stormwater control. Wetlands are defined and evaluated through indicators such as hydrology, water quality, hydrophytic vegetation, and hydric soils. In the Tar Creek Superfund Site, part of the historic Tri-State Lead-Zinc Mining District in Oklahoma, Kansas, and Missouri, treatment wetlands have been successfully incorporated into holistic multi-cell passive treatment systems to remove trace metals from net-alkaline, artesian flowing mine drainage. Incidental wetlands have also developed adjacent to the creek and near untreated mine drainage seeps throughout this watershed. This study compares the effectiveness of treatment wetlands and incidental wetlands in removing trace metals from surface water and determines which indicators of wetland condition correlate with effective removal of trace metals in mining-impacted wetlands. This study also determines which indicators of wetland condition correlate with a greater wetland vegetative structure in mining-impacted wetlands in order to develop site-specific recommendations for water quality improvement. Ten wetland sites in the Tar Creek watershed were included in this study, which represent various hydrologic regimes, water quality, vegetative communities, and substrate composition. Water quality analyses were conducted at the inlet and outlet of the sites, including three treatment wetlands and seven incidental wetlands, to determine the change in trace metal concentrations. Vegetative surveys were conducted to identify species richness, Simpson's index, and Pielou's index. Soils analyses were conducted to determine organic matter content, particle size distribution, total recoverable metal concentrations, and bioavailable nutrient supply rates using Plant-Root Simulator Probes. These results are then compared to evaluate the relationship between wetland indicators and the water quality improvement function of these wetlands as they relate to the influent water quality and the structure of the wetlands.

Key Words: Wetland Metals Vegetation

River and floodplain restoration on formerly mined lands

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River channel and floodplain placer and gravel mining has impacted thousands of miles of stream channels, including habitats for imperiled and keystone species such as salmon and steelhead throughout the Pacific Northwest. Despite the past impacts, these sites often provide a unique opportunity for restoration of natural processes and habitats following the cessation of mining. In some areas, legacy gravel ponds or tailings piles have, paradoxically, prevented more permanent impacts such as housing, highways, or commercial development. These sites provide an opportunity to restore important river and floodplain functions including floodplain

connectivity, creation of off-channel fish habitat, wetlands creation, restoration of native vegetation communities, and resumed natural channel migration processes. These projects also frequently have multiple societal benefits that go beyond river restoration, including providing recreational amenities, fishing opportunities, and public education. Inter-Fluve and other river restoration practitioners are actively restoring formerly mined channels and floodplains throughout the PNW. This work builds on decades of river restoration design and implementation by interdisciplinary teams of engineers, fluvial geomorphologists, and biologists. Inter-Fluve's experience dates back to the early 1990s with the creation of the "Handbook for Reclamation of Placer Mined Stream Environments in Western Montana" (Inter-Fluve 1991 for US EPA). Since this time, our understanding of stream ecological processes and the practice of river restoration design has evolved, lending new insights and considerations to this work. This presentation will describe the current state of the practice using numerous past and on-going project examples by a range of public and private entities including local, state and federal agencies, non-profits, hydropower companies, and Native American Tribes. The talk will describe various design approaches, challenges with grading and water management, risk considerations, and methods for maximizing ecological functions. Areas of future work opportunities and new directions will be described.

Key Words: SalmonFloodplainRestoration

Wildfire Ash Effects on Source Water Quality and Treatability

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Wildfires often accelerate post-fire erosion and increase turbidity, resulting in shifts in surface water quality. Forested watersheds provide potable water supplies for billions of people around the world. Understanding the properties of wildfire ash that drive particle stability, downstream mobilization in aquatic systems and the effects on drinking water treatment are crucial for effective post-fire management and treatment of water sources. Wildfire ash samples were collected from 2020 Oregon and California fires and compared to unburned soils. To understand the impacts of wildfire ash particles on source water quality and drinking water treatment, two studies were conducted: 1) ash effects on water quality effects and particle stability, and 2) conventional coagulation treatability of wildfire ash particles. Particle size, specific surface area, pH, electrical conductivity, turbidity, alkalinity, zeta potential, dissolved organic carbon (DOC), and nutrients were analyzed. Analysis of solids showed lighter colored ash (white and gray), indicative of greater combustion temperatures, had higher pH, electrical conductivity, specific surface area, zeta potential, and smaller particle size than darker ash (dark gray and black) and unburned soils. In water, wildfire ash increased the pH and released more phosphorus, nitrogen, and organic carbon than unburned soils. White wildfire ash produced the highest turbidity, 1199±464.2 NTU, but particles settled faster compared to low-temperature ash. The greater density of high-temperature ashes may account for the faster settling, while the greater DOC and lower density of low-temperature ash particles may explain the slower settling. Among all ash-water mixtures, white ash showed the highest zeta potential (-27.4±7.80 mV) suggesting higher particle stability. The treatability evaluation showed that white wildfire ash had elevated settled water turbidity even at a high alum dose (80 mg/L). High raw water turbidity, pH and zeta potential might have resulted in lower particle removal. pH adjustment of ash-water mixtures resulted in significantly lower settled water turbidity and DOC at an alum dose of 20 mg/L implying post-fire source water may be treated with conventional processes if pH is adjusted.

Key Words: wildfire, water quality, water treatment

Wildlife Abstracts

A 10-year review of Chinook and Sockeye Salmon conservation initiatives within the Skokomish Watershed in Washington State

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The North Fork of the Skokomish River (NFSR) located on the Olympic Peninsula of Washington State was significantly impacted two hydroelectric dams that were constructed in 1926 and 1930. The Cushman Dams resulted in two reservoirs with pen stocks that diverted water out of the river and directly to the powerhouse for electricity generation. The fish barrier combined with loss of flow resulted in the extirpation of Chinook (*Oncorhynchus tshawytscha*) and Sockeye Salmon (*O. nerka*) from NFSK. The Federal Energy Regulatory Commission relicensed both dams in 2010 to Tacoma Power, which included settlement agreements specifying mandatory improvements to instream flows, native salmonid populations via hatchery production, safe fish passage above and below dams, and wildlife habitat within the Skokomish Basin. Hatcheries were constructed and fish passage projects were completed in 2014 with the goal of reintroducing Chinook and Sockeye salmon to the Skokomish Watershed. After 10-years, recent data has been analyzed to determine the best management practices. For Spring Chinook salmon, annual hatchery production goals of 375,000 yearlings and subyearlings have been achieved. Data suggests that adult returns and productivity are two times higher when Spring Chinook salmon are released as yearlings. Though returns to the hatchery has not yet reached a self-sustaining population, 2024 data suggest significant increases in Chinook adults naturally spawning in the river. Regarding the Sockeye Salmon program, the 2 million annual juvenile production goal has been consistently attained. Varying release strategies (river and lake) employing different age classes (parr, smolts, sub-yearlings and yearlings) have been employed. Both lake and river releases of smolts are trending toward the required release-to-adult survival rate for a self-sustaining population. This talk will conclude with engineering methods coupled with habitat efforts employed to promote safe, timely, and effective fish passage with access to historic NFSR spawning and rearing habitat.

Key Words: salmon recovery, reintroduction

The Use of Waterfowl Nesting Structures in Remediated Areas as an Educational and Research Tool

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The nation’s largest and most complex mining-related environmental remediation and restoration project is located squarely within a major waterfowl migration corridor of the Pacific Flyway. This means the area is ecologically connected on a continental scale, spanning from the northern Arctic to South America. The Clark Fork Valley and its surrounding areas have served as important nesting and overwintering habitats for waterfowl for millennia. However, waterfowl have received the least attention and consideration during the planning and execution of the remediation, likely due to a cultural preference for habitat reclamation and restoration with a focus on big game and trout.

Additionally, what is likely the largest wetland creation project in Montana’s history is unfolding as millions of cubic yards of metals-contaminated sediment are being removed from the Clark Fork River’s floodplain. Our work focuses on bringing these issues to the forefront of the cleanup while educating the public about the area's significance and the role of remediation in supporting waterfowl along the flyway. We achieve this through educational programs that incorporate hands-on construction of waterfowl nesting structures, which are then placed in these

newly created wetlands. These structures not only raise awareness but also serve as both a restoration tool and a resource for research.

We tailor our programming to school children ranging from elementary to high school, incorporating biology and ecology as well as vocational training, as all three skill sets are crucial for the future of remediation and restoration.

CREATING RECLAMATION AND RESTORATION PLANS WITH AN EMPHASIS ON ESTABLISHING TERRESTRIAL FOOD WEBS

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Land reclamation and ecological restoration are critical to mitigate land surface disturbances associated with natural (e.g., wildfire) and anthropogenic (e.g., oil, gas, mining) activities. Environmental challenges associated with reclamation and restoration in Colorado and Wyoming include short growing seasons, poor soil conditions, low and unpredictable precipitation, and issues with seed quality and availability. Social challenges include lack of knowledge sharing and unclear targets of success during goal setting and planning phases of reclamation and restoration. For example, oil and gas operators may be required to achieve 70% relative ground cover for storm water permit goals and different targets to satisfy Bureau of Land Management regulatory criteria. Little emphasis has been placed on establishing a full suite of ecosystem services when tailoring reclamation and restoration plans. Insects, the most diverse and abundant group of animals on Earth, provide more ecosystem services than other animals but are often overlooked in wildlife studies. While many recognize insects for the roles as pollinators, less emphasis has been placed on the role of insects in terrestrial food webs (e.g., they are the primary source of protein for ~96% of terrestrial birds). Recent research from Wyoming oil and natural gas fields shows that deliberate reclamation plans to establish forbs and native plant diversity can result in significant increases of insect diversity and abundance. Additionally, new information about forbs and insects in the sage-grouse diet is being conglomerated. This talk will demonstrate how to create reclamation, and restoration plans for ecosystem services, with an emphasis on establishing terrestrial food webs. Examples will include real data sets from several oil and gas fields across Wyoming and Colorado with direct connection to sage-grouse diet.

Key Words: sage-grouse, insects, plant-insect interactions

Understanding Species as Method for Improved Wildlife Mitigation

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Industrial landscapes often stand in conflict with ecological conservation; the remedies for which regularly unfold as revisionism in trial-and-error scenarios that can be frustrating for industry managers, especially when trying to meet environmental standards. Wildlife mortalities attributed to industry are emblematic of this struggle. This work looks at the role that speciation plays to improve the efficacy of active and post-industrial landscapes. Acute and chronic health effects of various chemical contaminants to wildlife are well-documented across numerous laboratory and in-field studies. For waterbird species, the impacts of acid metalliferous water (AMW), characteristic of reclamation sites, are a particular focus in which dermal exposure and ingestion have been identified to cause direct mortality and may reduce long-term fitness (Isanhart et al. 2011). Acid mine waterbodies, known as ‘pit lakes,’ are a result of historical and ongoing open-pit mining that can be hot spots for exposure to metals and other contaminants, especially for waterbird species that may use these waterbodies as stop-overs areas along migration routes. The Berkeley Pit, in Butte, Montana, is likely one of the most intensively monitored pit lakes on the planet, especially for waterbird activity. The unique, geochemistry and

extensive size of the Pit, in addition to its geographic location along the eastern edge of the Pacific Flyway, make this acid mine waterbody a novel, in-field laboratory for scientists and resource managers to quantify waterbird populations and evaluate risks and mitigation strategies. As a result of systematic waterbird observations on the Pit over a six-year period (2018 – 2023), we identified 54 taxa, 18 of which have at least species had at least one known mortality on the Pit. This study examined the annual distribution of the different species and assessed which ones were most at risk of mortality when exposed to AMW. These results provide baseline information essential for effective management and conservation of species exposed to anthropogenic landscapes and associated contaminants.

Key Words: Species, waterbirds, conservation