AMERICAN SOCIETY OF RECLAMATION SCIENCES

ASRS/ARRI 2024 Abstracts

The 41st Annual Meeting of the American Society of Reclamation Sciences (ASRS) is June 2-6, 2024, in Knoxville, TN. This conference will focus on the research, technical, and regulatory issues associated with the land and water implications of anthropogenic land disturbances. It will provide a forum for the dissemination of information through presentation of research findings, field tours, and open discussion of public policy relating to the applied science of reclamation, rehabilitation, remediation, and restoration of areas disturbed by mining, oil and gas, conventional and alternative energy production, contaminated sites, agriculture, road construction, large-scale commercial development, and other disturbances to land and water resources.

Abstracts are organized by date and technical session.

Monday, JUNE 3, 2024

Plenary Session

Reclaiming Bloodroot: Appalachian Environmental History toward Regenerative Reclamation. Kathryn Newfont, *University of Kentucky, Lexington, KY.*

Known as *Gi-ga u-na-s-te-tlv* in Cherokee, "bloodroot" in local English, and *Sanguinaria Canadensis* in Latin nomenclature, a small plant native to the Appalachian forest understory is one of the first to unfurl springtime leaves and flowers. For generations Appalachian peoples have seen bloodroot as a sign of hope, renewal, and resilient life. They have looked to the plant as wisdom-keeper and healer.
In *Braiding Sweetgrass*, Robin Wall Kimmerer establishes the restorative power of a paradigm honoring plants as teachers. What happens if we use that paradigm to reclaim bloodroot? What might *Gi-ga u-na-s-te-tlv* and the humans who have long lived with and loved this plant have to teach about reclamation and regeneration? Using Kimmerer-inspired frameworks, and with a methodological emphasis on listening, this presentation will explore those questions through the lens of Appalachian environmental history.
Reclaiming bloodroot requires listening to Appalachian people who have long understood bloodroot as teacher. These knowledge keepers have worked with the little plant to introduce learners to the complexity and beauty of the Appalachian woods, which are among globe's most diverse temperate forests. They have asked bloodroot to highlight and to help protest immense costs of extractive destruction—destruction of those rich forests, of human lives and communities, of the very mountains and rivers that support both. Eastern Kentucky elder Daymon Morgan, for example, resisted mountaintop removal and taught resilience with this plant. Reclaiming bloodroot thus takes us directly into native mountain forests, into the hands of human elders, and into complicated environmental histories interweaving both. Reclaiming bloodroot can help us tally the losses, see the opportunities, and move toward more richly regenerative forms of reclamation.

The Division of Mineral & Geologic Resources - Focusing on Tennessee's Mineral and Resource Extraction Industry. Bryan Epperson - Director, *Tennessee Department of Environment & Conservation (TDEC) – Division of Mineral & Geologic Resources, Knoxville, TN, USA.*

Tennessee has unique and fascinating geology and a rich history of mining more and different kinds of mineral resources than any other state east of the Mississippi River, except North Carolina, dating back to the late 18th century. Because of the unique geology and the vast mineral resources in the state, it was necessary to create a division that focused on Tennessee's mineral and geologic resources and the existing programs in place to ensure the environmentally sound management, protection, and documentation of the state's mineral, land, and energy

resources. In 2022 the Division of Mineral & Geologic Resources (DMGR) was created for this purpose, and four tangential program areas were relocated from the Division of Water Resources to DMGR. While DMGR and these program areas focus on the protection of our environment, including water resources, they equally focus on the documentation of the state's mineral resources, the responsible extraction and protection of minerals, and the elimination of high priority health and safety hazards from past mining practices. DMGR must ensure that permittees have adequate support and expertise available when documenting the state's geologic resources, reclaiming abandoned mine lands, or developing mineral-extraction projects that further ensure the base materials necessary for construction, infrastructure, and commercial activities in Tennessee and nationwide while also ensuring the protection of Tennessee's vast water and land resources.

East Tennessee Geology and Mining: An Example of Geodiversity. Barry W. Miller, *Assistant State Geologist, Tennessee Department of Environment & Conservation – Division of Mineral & Geologic Resources – Geologic Survey, Knoxville, Tennessee, USA.*

Geodiversity is defined as the variety of geological features and earth materials and processes that shape a regional landscape. Earth materials include minerals, bedrock, sediments, fossils, soils, and water. Geologic features may include folds, faults, karst, and other geomorphic landforms that are influenced by various earth materials, particularly bedrock and water. Active geological and geomorphological processes such as tectonics, sediment transport, and soil formation characterize another aspect of geodiversity.

East Tennessee geodiversity is defined by its three geologic regions which basically correspond to its three physiographic provinces. The three regions from east to west are the Blue Ridge Mountains, the Valley and Ridge, and the Cumberland Mountains and Plateau physiographic provinces. The Blue Ridge region is underlain by folded and faulted Precambrian age igneous, metamorphic, and sedimentary bedrock such as basalt, granite, gneiss, slate, sandstone, and conglomerate. The Valley and Ridge region is underlain by primarily folded and faulted Paleozoic age sedimentary bedrock such as dolostone, limestone, shale, and sandstone. The Cumberland Mountains and Plateau region is underlain by moderately folded and faulted Paleozoic age sedimentary bedrock such as sandstone, conglomerate, shale, limestone, and coal. This diverse bedrock and geology also constrain the geomorphology and landscapes of the three provinces.

The geodiversity of East Tennessee's geologic regions extends to the source ore material for economic extraction. Tennessee has extracted more and different types of rocks and minerals than any other state east of the Mississippi River, except North Carolina, dating back to the late 18th century. The Blue Ridge province has produced iron (magnetite), manganese, granite, sand, gravel, gold, copper, sulfur, zinc, and barite. The Valley and Ridge province has produced limestone, dolostone, marble, zinc, and barite. The Cumberland Mountains and Plateau province has produced coal, oil, natural gas, and sandstone. The material extracted is controlled by the underlying geology.

The Tennessee Geological Survey plays a crucial role in understanding and managing Tennessee's geological, energy, and mineral resources. The Tennessee Geological Survey is the lineal descendant of the first Tennessee Geological Survey that was established in 1831. It is one of the oldest state geologic research organizations in the country. The survey advises other state agencies and federal and local organizations on matters relating to Tennessee geology.

Session 1 – ARRI: Forestry Reclamation in Appalachia

Assessment of American chestnut (*Castanea dentata*) hybrid stem count, growth, and surrounding vegetation on two reclaimed mines restored using The Forestry Reclamation Approach for soil amendment. Z. Griffith[1], R Homsher[1], J. Chapman[2], K. Gilland[2], and J.M Bauman*[3,4], [1]*Columbus State College*, *Delaware, OH, USA*, [2]*University of Wisconsin-Stout*, *Menomonie, WI, USA*, [3]*Tacoma Energy*, *Tacoma, WA, USA*, [4]*Western Washington University*, *Bellingham, WA, USA*.

Soil compaction and non-native species have been cited to inhibit tree survival and growth on reclaimed mine sites. To overcome this, recommendations outlined by the Forest Reclamation Approach have developed protocols such as deep-soil ripping and end-dumping to mitigate compaction. This is being coupled with the planting of native tree

species to encourage forest succession. Trial plantings of American chestnut (*Castanea dentata*) are currently underway using reclaimed surface mines as reintroduction sites for hybrids bred for disease resistance to chestnut blight. This study investigated chestnut growth, survival, and vegetation community composition from two Ohio sites that employed deep-soil ripping and end-dumping. After 13 years, chestnut stem counts varied on the two sites, the site that applied deep soil ripping had more surviving stems ($P<0.001$). However, when growth was compared, chestnuts growing in the end-dumped soils had larger DBH than those growing in deep ripped spoils ($P=0.005$). When soils were assessed, soils that were end-dumped were significantly higher in N, P, K, organic matter, and cation exchange capacity (all $P<0.05$), which may have been the overarching driver for growth. Vegetation also differed, ripped sites where chestnut was the dominate cover, species richness and diversity indices were significantly lower than sites with less chestnut stems. Threats from non-native species such as multifloral rose, lespedeza, and autumn olive will continue to be a management concern, however, increased canopy cover from native trees may discourage invasion and encourage succession to a diverse native forest over time.

Key Words: soil compaction, forest succession, vegetation

Pond-breeding amphibian response to the Forestry Reclamation Approach and wetland creation on legacy surface coal mines in the Central Appalachians. S Price*[1], L Sherman[1], J Newman[1], R Davenport[1], J Cox[1], J Larkin[2], and C Barton[1], [1]*Department of Forestry and Natural Resources, University of Kentucky*, [2]*Department of Biology, Indiana University of Pennsylvania*.

The Forestry Reclamation Approach (FRA) is a coal surface mine reclamation practice that enhances reforestation through soil decompaction, addition of coarse woody debris, and the planting of native trees and shrubs. Recently, wetland creation has been coupled with FRA at some locations to increase habitat availability for wildlife, including pond-breeding amphibians. Our objective was to evaluate the response of pond-breeding amphibians to the FRA by comparing species occupancy, richness and abundance across two FRA age-classes (younger FRA [2-5 year] and older FRA [8-11 year] reclaimed forests), traditionally reclaimed sites that were left to naturally regenerate after mining, and natural wetlands in mature, unmined forests in the Monongahela National Forest (West Virginia, USA). Using automated recording units and dipnet surveys, we documented 8 species in created wetlands within younger FRA forests, 8 species within older FRA forests, 7 species within traditionally reclaimed sites, and 7 species within mature, unmined forests. Using a multi-species occupancy model, we found that species richness and occupancy estimates did not differ across site types. Yet, Spotted Salamanders (*Ambystoma maculatum*) and Eastern Newts (*Notophthalmus viridescens*) had greatest estimated abundances in wetlands in the older FRA treatment. Additionally, we found that larger wetlands had greater abundances of Eastern Newts, Wood Frogs (*Lithobates sylvaticus*) and Green Frogs (*L. clamitans*) compared to smaller wetlands. Our results suggest that wetland creation and reforestation results in an increase in breeding sites and promotes microhabitat and microclimate conditions required by pond-breeding amphibians in Central Appalachian region.

Key Words: Forestry Reclamation Approach, amphibians, wetlands

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Reforesting Pennsylvania's Green Heart: The Continental Divide Reforestation Project . E Oliver*, *Green Forests Work*, *Lexington KY USA*.

In 2023, Green Forests Work began the process to reforest about 121.4 hectares of privately owned, legacy mined land in the heart of Pennsylvania. Using funding from NFWF, OTP, and other sources, the work will be completed by 2025 or 2026.
The land had been surface mined through the mid-1900s until about 1975. The last mining company went bankrupt in the 1970s and the land was left unreclaimed. Pennsylvania DEP performed the bond forfeiture reclamation in the early 1980s. As was standard reclamation practice at the time, emphasis was placed on compaction, herbaceous plants, and non-native trees and shrubs that grew well on drastically disturbed lands.
GFW will be reforesting the site using the ARRI Forestry Reclamation Approach and all native trees and shrubs.

Extensive work is being done to remove the invasive plants prior to loosening the soil by ripping. This presentation will discuss the planning that had to go into the projects as well and hurdles that needed to be crossed along the way. Drone imagery has been used throughout the project to monitor each step of the progress.

Key Words: ARRI, reforestation, reclamation

Session 1 – Bat Conservation and Mine Land Reclamation

Bat activity on high elevation reforested coal mines in the Monongahela National Forest, WV. B. Snyder*, C. Barton, M. Lacki, S. Price, and Z. Hackworth, *University of Kentucky, Department of Forestry and Natural Resources*, *Lexington, KY, USA*.

The Forestry Reclamation Approach (FRA) is a practical guide to reforesting surface mined lands. Bats, a group of mammals with declining populations, could benefit from mine reforestation. To determine if the FRA can provide suitable bat foraging habitat, we surveyed bat activity at created depressional wetlands on 1-year- old and 8-year-old FRA reforested lands (FRA1; FRA8), wetlands in naturally regenerating forest on traditionally reclaimed mined land (~40 years old; REGEN), and wetlands in mature forest not previously mined (MAT). We passively recorded echolocation calls for 12 nights across 16 sites between June and August 2021. We analyzed bat activity using the number of recordings, pulses, and feeding buzzes in conjunction with nocturnal insect abundance and biomass, microhabitat characteristics, and landscape characteristics via generalized linear mixed effects modeling. Both FRA1 and FRA8 had activity levels similar to MAT. REGEN had significantly greater foraging activity than the other three land classes, possibly due to its distance from roads and proximity to forest edges. Insect abundance and biomass were comparable across sites, indicating FRA practices do not hinder the establishment of a prey base for bats. Overall, bats are utilizing the restored mined land for foraging. Reforestation of mined lands, complemented with wetland creation, provides habitat that could benefit bat species conservation in Appalachia.

Key Words: acoustic monitoring, created wetlands, reforestation

Is this working? The effectiveness of current mitigating strategies for conserving use of abandoned mines by bats. R.E. Sherwin* and D.L. Waldien, *Christopher Newport University*.

Abandoned mine lands programs have long recognized the relationship of many species of bats with abandoned mines. As a result, AML programs typically mitigate for wildlife through the identification and protection of key roosting habitat using bat gates as the closure method. Mines which have not been identified as needing conservation, or in cases where important roosting habitat cannot be conserved (ex., structural instability), exclusions are recommended to ensure that no bats are roosting in underground features at time of closure. The legacy of AML programs includes safeguarding dangerous landscapes while also preserving subterranean bat habitat throughout North America. Important roosting habitat is typically identified prior to closure through surveys of mine workings searching for direct evidence of bat use and/or assessing type and quality of internal habitat from which to infer potential use by bats. While pre-closure surveys are standard, limited work is done at closure sites following reclamation. As a result, much of our understanding of bat responses to closure projects and gate installation is *ad hoc* and typically derived from casual and observational accounts collected outside of any standardized research design. This study presents our data collected over a minimum of 10 years in 6 reclaimed landscapes. We studied the behavioral responses of bats to gates, changes in colony size, and changes in patterns use of available roosting habitat within a landscape. We compared these data with those collected prior to reclamation. Gates included various construction materials, designs, and those with and without culvert stabilization. We found no evidence of wholesale rejection of gates for any type of roost use. It is quite possible that anecdotal accounts of site abandonment are a result of insufficient monitoring intensity or failure to identify critical mine roosts during pre-closure surveys. The most critical aspect of maintaining bat use in AML projects is the quality of the pre closure surveys using appropriate data collection tools and a focus on underground habitat within each

mine, rather than relying on presence of bats at time of survey as the sole indicator of habitat use.

Key Words: culvert bat-gate bat

Session 1 – Abandoned Mine Lands (AML): Programs and Projects

Federally funded coal abandoned mine land (AML) program overview. E. E. Cavazza*, *Tetra Tech, Inc.*, *Pittsburgh, PA USA*.

The federally funded Abandoned Mine Land (AML) Program was established under Title IV of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) and was originally authorized for 15 years. Funding for the AML Program was originally derived exclusively from fees on the active coal mining industry. There have been several extensions of the program and changes in the fees over the 46 years since SMCRA's passage. The industry derived fees were supplemented with US Treasury funding beginning in 2007. In 2016, the Abandoned Mine Land Economic Revitalization (AMLER) Program was first funded. And in 2021, the Bipartisan Infrastructure Law (BIL) extended the SMCRA Title IV AML Program through 2034 and also provided an additional $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. This presentation will cover some of the history of the AML Program, the shift from industry funding to US Treasury funding, the various current AML Programs and their requirements, and highlight some of the work that Tetra Tech is doing to support abandoned mine reclamation efforts nationwide.

Key Words: AML Funding, Federal AML Programs

Lessons from Ohio's year one of BIL funding. M. Lautzenheiser* and C. Kinney, *Ohio Department of Natural Resources, Division of Mineral Resources Management*, *New Philadelphia, Ohio, USA*.

With the passage of the Infrastructure Investment and Jobs Act (known as BIL) on November 15th, 2021, a historic investment was made towards cleaning up legacy pollution from pre-law coal mining. Ohio has had a mining reclamation program since 1972, and currently the Division of Mineral Resources Management has a robust abandoned mine land reclamation program. The BIL funding provided numerous opportunities for both successful and challenging projects. We will review how Ohio implemented our first year of BIL funding, specifically discussing organizational challenges and program successes.

BIL funding allowed us to quickly implement projects due in part to having shovel-ready AML projects that our staff had partially developed. We will discuss the impact of having a robust eAMLIS collection process and staff who stagger project development into multiple phases. In addition, we will discuss our partnerships with large land-owning entities, and the how the size and scale of reclamation projects has changed with BIL funding. Finally, we will review the successful addition of project capacity by working with private consultants through an RFQ/SOQ process that has put out more than $10 million in contracts within the first year.

Lessons can also be learned from the challenges of rapidly scaling up a program. Staffing a program that is changing so quickly is difficult. We will share the way our program is looking towards a long-term staffing plan to balance project development staff with the technical staff needed to get projects to completion. In addition, we will discuss what happens when staff change roles and positions within a program, and how to ensure continuity and not have information loss when staff leave. Finally, we will discuss how we're remodeling our program to address not only complaints but be proactive in seeking out and developing the highest-priority AML issues in our state.

Key Words: BIL Program, Management, Consulting

Construction of a subsurface fire wall on the Rock Springs No. 9 mine. H.J. Hutson*, *BRS, Inc.*, *Riverton, WY USA*.

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, Abandoned Mine Land Program (AML) to address hazards posed by underground coal mines. Rock Springs Coal Mining District is located near 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 Rock Springs No. 9 mine is crossed by a utility corridor containing 3 high pressure interstate gas and petroleum pipelines. The mine voids are as shallow as 30' from the surface and posed a risk to the critical infrastructure due to subsidence collapse. In addition, a large underground mine fire to the south of the corridor had begun to burn beneath the pipelines. In 2020 and 2023, the Wyoming AML program responded by utilizing drilling and grouting techniques to stabilize shallow underground mine voids to mitigate subsidence hazards, extinguish the fire beneath the gas pipelines, and prevent the spread of the fire to the north through the mine workings.
However, drilling and grouting techniques could not address the un-mined coal barrier pillar left near outcrop by past mining. Excavation and construction of a sub-surface firewall was completed in 2023 to prevent the mine fire from burning through the shallow un-mined coal toward the pipeline corridor and spreading to the north.
The reclamation of the Rock Springs No. 9 Mine utility corridor was a rewarding and challenging project for the Wyoming Abandoned Mine Land Program, and mitigated hazards due to past mining practices through the use of multiple methods. The long term benefits of this project to the include preventing the spread of underground coal mine fire and final stabilization and mitigation of mine voids to prevent damage to critical public infrastructure.

Key Words: mine fire, subsidence, firewall

Session 2 – Forest and Rangeland Restoration

Mountain rangelands: large-scale, open-range, small ruminant production on reclaimed surface mines in Appalachia. H.Z. Angel*[1], K.M. Andries[2], F.W. Harrelson[2], N.L. Haan[1], J. Lay[3], and P.N. Angel[4], [1]*University of Kentucky*, *Lexington, KY, USA*, [2]*Morehead State University*, *Morehead, KY, USA*, [3]*Kentucky State University*, *Frankfort, KY, USA*, [4]*Southeast Kentucky Sheep Producers Association*, *London, KY, USA*.

Central Appalachia has hosted large-scale surface coal mine operations for much of the last century, resulting in large-scale grassland and shrub habitat. Soil compaction and aggressive non-native vegetative cover on reclaimed mined land can complicate reforestation and present challenges for grazing cattle livestock. Thus, small ruminant grazing systems may offer a more suitable land use for the following reasons: 1) Sheep and goats specifically target plants (e.g., Sericea lespedeza, autumn olive) that are invasive and not palatable for cattle; 2) small ruminants are better adapted to the rocky and steep terrain on Appalachian surface mines; and 3) professional herders may provide management oversight and protection from predators where fencing infrastructure is not feasible. Here, we report on preliminary results of a small-ruminant grazing project on a 3,200-acre reclaimed surface mine site in eastern Kentucky over the summer of 2023 (May 12-July 16), conducted as a 'proof-of-concept' demonstration. A total of 159 Katahdin sheep were introduced with a full-time herder who lived on-site. Animal health parameters were measured during the start and end of the project including hoof conditions, Body Condition (BC) Score (related to body energy reserves), and FAMACHA (F) Score (related to anemia). The hoof conditions for 77% of sheep stayed the same or improved during the project whereas hoof conditions worsened for 23% of sheep. The F Score stayed the same or improved by one point over the course of the project for 91% of the ewes. The BC Score improved or stayed the same for 92% of the sheep (28 scores stayed the same and 51 scores improved by one point). Our proof-of-concept study suggests that leveraging these underutilized grassland mine sites for small ruminant grazing presents an opportunity for sustainable economic development in the region. Ongoing work will address the potentially positive impacts of grazing systems on soil structure and fertility. All animal procedures were approved by the Morehead State University IACUC committee (protocol 22-11-02).

Key Words: coal mines, grazing, sheep

Only 5% of mining disturbed forest successfully reclaimed in the Amazon for the past three decades. Wu Xiao*[1,2], Tingting He[1], and Wenqi Chen[1], [1]*School of Public Affairs, Zhejiang University*, *Hangzhou, Zhejiang, China*, [2]*Institute of Land Reclamation and Ecological Restoration, China University of Mining and Technology, Beijing*, *Beijing, Beijing, China*.

The vast Amazonian rainforest, a critical carbon sink and biodiversity hotspot, is facing mounting threats from mining activities. Despite its ecological importance, a clear understanding of mining-induced deforestation and its carbon impact remains elusive. To address this gap, we utilized high-resolution satellite data to map deforestation and restoration efforts due to mining over a 30-year period, allowing us to estimate changes in forest carbon storage. Our results reveal a grim picture: by 2020, mining had claimed a staggering 2,427.61 km² of Amazonian forest, a rate six times higher than at the turn of the 20th century. Moreover, mining is venturing deeper into older, taller forests (average age 41.08 years, height 6.97 m), jeopardizing high-conservation-value areas and triggering a carbon loss of 34.99 Tg C. Compared to natural regeneration and agroforestry, which can recover up to 77% and 61% of original carbon stocks, respectively, mining presents a far more persistent threat. This stark difference stems from the devastating impact of topsoil stripping, hindering vegetation regrowth. Indeed, only a meager 5.1% of mined areas have achieved effective restoration to their pre-mining state. Our findings underscore the alarming extent of mining-induced deforestation in the Amazon and the formidable challenges associated with post-mining restoration. Emphasizing these realities is paramount for ensuring the sustainable management of this irreplaceable ecosystem.

Key Words: Mining disturbance, remote sensing, change detection

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Identifying metrics of ecosystem recovery on reclaimed minesites in eastern hardwood forests. I Kennedy*[1], J Franklin[1], D Buckley[1], and K Sena[2], [1]*University of Tennessee*, *Knoxville, TN, USA*, [2]*University of Kentucky*, *Lexington, KY, USA*.

Determining metrics for the recovery of ecosystem health and function on reclaimed sites is an important step in standardizing assessment of the reclamation process. We examined seven potential metrics that can estimate a wide range of ecosystem functions such as carbon sequestration, water provisioning, and wildlife habitat. Variables included soil density and water infiltration, insect biomass, aboveground and belowground carbon biomass, decomposition rate, and canopy coverage. Each variable chosen was hypothesized to estimate recovery of ecosystem health and function by showing a strong relationship with time since reclamation. Sites were selected and sampled on a chrono-sequence up to 30 years post-disturbance, using age classes of 0-5, 6-10, 1-15, 16-29 and 30+ years, with 3 sites in each age class. Sampling was replicated on clear-cut timber harvest sites for comparison between disturbance types. Additionally, control sites were selected based on minimal human disturbance within the last 50 years. A 1/10-acre plot was established on each site, overstory was measured, and remaining variables were sampled on 3 sub-plots within each plot. Sampling of insect biomass and decomposition rate required two trips to each site and experienced relatively high rates of sample loss as a result of wildlife activity. All plots were established, and all data collected between June and September of 2022. Results have indicated that aboveground biomass, infiltration rate, canopy cover up to a certain age, and belowground biomass at a certain depth, all display a significant change over time. This implies their potential for use as metrics of ecosystem recovery which have great value as a tool for communication and as a quantitative assessment of reclamation success in present and future reclamation projects.

Key Words: monitoring, reforestation

Session 2 – Reclamation Sciences: Broader Conversations

From mining reclamation to reclamation sciences: expanding the scope and influence of ASRS. R.W. Nairn*[1] and J.A. LaBar[2], [1]*The University of Oklahoma*, *Norman, OK, USA*, [2]*Oklahoma State University*, *Stillwater, OK, USA*.

The focus of the American Society of Reclamation Sciences (ASRS) has appropriately changed in response to industry, regulatory, and technical needs since its initial inception more than 50 years ago. In 2020, the Society purposefully expanded its scope (and name) beyond mining reclamation to "reclamation sciences", a term meant to encompass the ubiquitous need for effective and sustainable reclamation practices to address any anthropogenic or naturally induced land or water disturbance. During society-wide discussions of the proposed name change, the experience and expertise of Society members in coal and hard-rock mining reclamation was argued to be widely applicable to oil and gas extraction, sand and gravel mining, transportation infrastructure, urban development, hydroelectric projects, brownfield redevelopment, and other related efforts. Environmental responses to natural disasters (e.g., floods, landslides, severe weather events) were also deemed to fall under the purview of ASRS members. The expansion in scope was designed to diversify and increase Society membership, attracting various industrial and disciplinary partners. Review of recent national meeting session and presentation topics indicates that these efforts are works in progress. Several actions are proposed to further expand and enhance these efforts. First, the Society must coordinate efforts with the multitude of related professional organizations, representing a substantial pool of new members and meeting attendees. Second, targeted co-hosting of annual meetings must continue, with an emphasis on expanding base membership. Third, the Society should develop and promote white papers, fact sheets, technical notes, web pages, videos, and related content, targeted to non-technical audiences, including policy and decision makers. Fourth, in today's technocentric world, a current and continuously updated social media presence is required. Fifth, the Society needs to continue to enhance and expand engagement for students and early career professionals and become the go-to professional organization for reclamation scientists.

Key Words: engagement, service, growth

ASRS-II: Reclamation Without Borders. Brenda Schladweiler*[1] and Y. Paul Chugh[2], [1]*BKS Environmental Associates, Inc.*, *Gillette, Wyoming, USA*, [2]*Southern Illinois University*, *Carbondale, Illinois, USA*.

Drastically disturbed lands result from a wide variety of natural and man-made factors including industrial disturbances associated with extractive industries. World demand for biproducts of these extractive resources continue to increase which will result in increased disturbance to various biomes throughout the world, including North America. For example, the need for electronic manufacturing and battery storage of energy requires rare earths and critical minerals such as lithium.

The American Society of Reclamation Sciences (ASRS) was established in the 1970's in the United States of America because of the passage of the federal Surface Mining Control and Reclamation Act of 1977 or SMCRA. Since those early days, this Society addresses a wide variety of drastically disturbed lands including hard rock mining (including rare earths and lithium), oil and gas activity, as well as surface coal mining in both the western and eastern United States. Much knowledge has been acquired over the last 40 plus years of ASRS's existence. This initiative will describe current reclamation practices with a focus on the lessons learned over this time for reclamation in different ecosystems throughout the United States.

Key Words: International, Historical Knowledge, Best Management Practices

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Reclaiming Communities through National Service. April Elkins Badtke*, Patricia Silva, and John Michael Aurednik, *Stewards Individual Placements*, *Beckley WV USA*.

The OSMRE AmeriCorps VISTA Team was founded to address the socioeconomic repercussions of environmental degradation related to pre-regulatory mining. AmeriCorps VISTA projects were hosted in eight Appalachian states (A.L., KY, MD, OH, PA, TN, VA, WV). In comparison to the national average, this region has a poverty rate of 17.20% or 110.20% percent higher than the national average, according to the Appalachian Regional Commission (www.arc.gov). In 2006, the Office of Surface Mining Reclamation and Enforcement (OSMRE) estimated that more than three million people in Appalachia lived within one mile of Abandoned Mine Lands (AML). The Code of Federal

Regulations defines abandoned Mine Lands as "un-reclaimed" coal-mined lands that existed before August 3, 1977, and for which there is no continuing reclamation responsibility. Environmental health concerns include abandoned surface and groundwater pollution and sediment-clogged streams. Community well-being concerns include high obesity rates, poor overall health, a profound distrust of government, and cultural resignation to poverty. Incentives for business relocation have dwindled, property values have plunged, populations have diminished, and the region struggles with insufficient sewage and infrastructure and a faltering economy. Still, it maintains a strong sense of local community and abundant natural resources.

OSMRE VISTA projects focus on identifying resources and funding to grow and sustain economic development programming. At the same time, it also brings awareness through community engagement to environmental factors' impact on human and community wellbeing. Due to the unique characteristics of each of these communities, these projects employ aspects of all the core goals to build capacity and sustain community initiatives over time. The At-Risk Ecosystems strategic plan objective will be the primary performance measure, looking closely at individuals receiving education or training around environmental stewardship as well as the capacity building and leverage strategic plan objective, primarily tracking increased knowledge of environmental stewardship and related outreach and public events centered on the dissemination of this information. Secondary project data related to economic development through employment will also be considered by measuring individual job readiness improvement.

Key Words: Community, OSMRE, reclamation

Session 2 – Abandoned Mine Lands (AML) 2: Programs and Projects

The Banning/West Newton Coal Logistics Coal Refuse Pile Reclamation Project Rostraver Township, Westmoreland County, Pennsylvania. E. E. Cavazza*, *Tetra Tech, Inc.*, *Pittsburgh, PA USA*.

Tetra Tech was selected by the Pennsylvania Department of Environmental Protection (PADEP) in August 2023 to prepare design plans and specifications and to obtain all required permits for the Banning/West Newton Coal Logistics (Banning/WNCL) Coal Refuse Pile Reclamation Project. The abandoned bond forfeiture site was originally part of the Banning #4 underground mine in Rostraver Township, Westmoreland County, PA. Tetra Tech completed an alternatives analysis for the Banning/WNCL site in November 2022. The analysis included the evaluation of three reclamation alternatives.

- The potential for removal of the fine coal refuse (FCR) from the site.
- Evaluation of several materials to stabilize and reduce the moisture content of the FCR on the site to improve the mechanical stability of the material.
- Evaluation of the removal of the FCR from the site by slurrying the FCR before pumping it to an adjacent abandoned underground mine.

Based on the work completed, Tetra Tech recommended developing a final project design based on Alternative 2, stabilizing the FCR with an imported material and reincorporating the stabilized FCR back into the final site grading plan due to a higher certainty of success. This alternative was approved by PADEP and is the basis for the current project design.

The planned reclamation strategy is to excavate the FCR and sludge contained in the slurry impoundments and mix it with appropriate amounts of coarse coal refuse (CCR) and an additive (such as quicklime or alkaline ash) to dry and stabilize the material. Once stabilized, the admixture will be incorporated back into the pile during grading. Specific project objectives include decertifying the jurisdictional dams on the site; demolishing the remaining mine buildings from the Banning No. 4 mine; regrading the site to stable slopes, revegetating the site, mitigating acid mine drainage (AMD) to the extent practicable, and maximizing the surface area at the top of the regraded/reclaimed refuse pile to facilitate the planned future solar development.

The presentation covers the background of the project, work completed to date, and the current design and permitting status including the anticipated project construction schedule and estimated project construction cost.

Key Words: Coal Refuse, Slurry, Reclamation

Carissa Gold Mine: Making an Abandoned Mine into a State Park. B. Drake*[1] and G. Robson[2], [1]*RESPEC*, *Cheyenne, Wyoming, US*, [2]*Wyoming Deparment of Environmental Quality, Abandoned Mine Lands Division*, *Lander, Wyoming, US*.

Wyoming's largest gold boom occurred in the late 1800s to early 1900s in the South Pass Mining district. Prospectors flocked to the State intending to find riches beneath the unique geology located in this district. The boom peaked with the Carissa Gold Mine, the largest gold operation in the State at this time. Over time it became apparent that the operation of the mine and mill were not profitable, and operations were shut down. Left behind were the historic remnants of 20th-century mining operations. In 2003, the State of Wyoming purchased the property with the intent to create a State Park to display this rich history. However, to achieve this goal, a large undertaking was required to ensure the public's safety when visiting the site. The Wyoming Department of Environmental Quality, Abandoned Mine Lands Division (WDEQ/AML) in coordination with State Parks, hired RESPEC to perform an environmental assessment and evaluation of the site to prioritize the dangerous features present and to provide recommendations on mitigation techniques. Over nearly two decades, dozens of projects were undertaken to mitigate hazards including the cleanup of dangerous mine-related chemicals (i.e. cyanide, arsenic), mine opening safeguarding, tailings encapsulation, structural stabilization, and overall site improvements to create a State Park that sees thousands of visitors each year. Today, the Carissa Gold Mine is an educational and cultural resource for Wyoming's youth on its mining history, and a unique tourist destination displaying a time once forgotten. The entirety of the AML's 18 years of work is a testament to the program's intentions to protect and inform the public and was achieved with the collaboration between multiple parties including WDEQ/AML, the State of Wyoming, Wyoming State Parks, Wyoming State Historic Preservation Office, and multiple Wyoming contractors and consultants who performed the work.

Key Words: AML, Reclamation, Mitigation

Strategic Planning Tools for Abandoned Mine Void Subsidence Mitigation. Melissa Bautz* and David Hibbard, *Brierley Associates*, *Denver, CO 80222*.

This presentation covers planning methodologies used to categorize and implement consistent, repeatable approaches to investigate and mitigate underground coal mine subsidence risk. This planning strategy offers a transparent and repeatable mechanism for communities to leverage sound prioritization of resources while minimizing public impacts. A comprehensive subsurface mine mitigation project involves many considerations, such as overburden rock and soil material, historic mining methods, underground mine conditions, mine geometry, groundwater conditions, overlying infrastructure, and land uses. Mechanisms for defensible decisions to prioritize abandoned mine voidfill mitigation projects include 1) collection of comprehensive baseline data, 2) a consistent, codified decision-making process, and 3) enhanced technical guidance.
By developing criteria for proactive investigation and mitigation, identifying site-specific characteristics during the planning phase, forging relationships with stakeholders, complying with OSMRE problem type prioritization, and implementing a wide range of technical expertise, AML programs can effectively and consistently investigate and mitigate subsidence in areas of infrastructure. This approach can enable proactive, logical allocation of funding resources, planning and design of future construction projects, and reduction of potential subsidence hazards to impacted infrastructure.
Topics to be discussed include specific planning criteria that can be customized to suit unique situations, building community relationships, using GIS tools, identifying mitigation strategies and techniques, and verification of project effectiveness (QA/QC).

Key Words: AML, GIS, Partnerships

Session 3 – Reclaiming Soils in Appalachia

Harnessing biosolids to reclaim mine lands: Case studies from Appalachia. R Cherwinski* and S Liebl, *Denali*.

Over several decades, Denali has worked with landowners and mine operators to reclaim thousands of acres of mine lands in Appalachia using organic residuals. The residuals have primarily been biosolids sourced from large municipalities. This work has been a tremendoussuccess and shows the potential of using biosolids to improve water quality, establish vegetative cover, create and maintain wildlife habitat, and improve the economic value of mine lands in the Eastern United States, of which there are hundreds of thousands of acres.

From the point of view of municipalities and recycling organizations, mine lands are exceptional outlets for large amounts of organic residuals due to state and federal regulators typically allowing application rates of biosolids in excess of typical agronomic rates. The reasons for this include: the need to introduce large amounts of organic matter to restore soil health where topsoil has been almost entirely removed; the need to correct soil and water pH; and the negligible negative impact of pollutants due to the relatively short window of application.

Denali's two case studies on this subject are land reclamation at a surface coal mine in Western Pennsylvania and a copper mine in Southeast Tennessee.

Key Words: Vegetation, soil health, biosolids

On The Use of Biochar as Soil Amendment. Amir Hass* and Robert Cantrell, *West Virginia State University*, *Institute WV 25113*.

Biochar, a charcoal-like material is emerging as a go-to soil amendment to improve soil productivity quality and health at different scales and land uses. Produced from biomass through pyrolysis process (i.e. thermal-decomposition of organic material under oxygen-limited environment), biochar is a highly porous, solid, and stable carbon-rich material. As such, incorporating biochar in soil has the potential to improve soil porosity and water holding capacity; increase soil organic matter content and reduce soil bulk density; enhance soil sorption and exchange capacity; and to improve soil pH and nutrient content. The extent to which biochar does improve intended soil and site performances is a bit more complicated and dependent on biochar characteristics, which in turn dependent on feedstock source (e.g. animal waste, herbaceous, woody biomass, etc.), production conditions (e.g. peak temperature, hold time, etc.), and final grading and/or co-mixing/inoculation. Its impact is further dependent on its application rate (and mode of application), soil transition and inherent properties (e.g. organic matter content and pH, texture and mineralogy, respectively, etc.) and site characteristics; and on the target crop/cover vegetation. In this talk we will discuss biochar history, production, and properties (and manipulation thereof); and provide insight as for managing expectation with respect to its impact on soil properties, production, and health.

Key Words: Soil carbon, greenhouse gasses, organic matter

Classification and land use potentials of two reclaimed mine soils in Virginia. H.Z. Angel*[1], W.L. Daniels[2], R.D. Stewart[2], Z.W. Orndorff[2], D.K. Johnson[3], and J.M. Galbraith[2], [1]*University of Kentucky*, *Lexington, KY, USA*, [2]*Virginia Polytechnic Institute and State University*, *Blacksburg, VA, USA*, [3]*East Tennessee State University*, *Johnson City, TN, USA*.

Post-mining land use potentials depend on resulting mine soil properties and subsequent integrated classification and land use interpretation guidance. Here, we discuss the current classification of two different mine soils (coal

and mineral sands) in Virginia using the 12th edition of USA *Soil Taxonomy*. We also discuss how their land use interpretations are improved through the new proposed order for anthropogenic soils (Artesols). For the 25+ year-old Appalachian coal mine soil pedons studied, rock type was either dominantly one type (100% sandstone or siltstone) or mixed but did not influence family level particle-size and reaction class (pH). Despite the differences in rock type (parent material), taxonomic placement did not vary among most of the pedons observed but did accurately represent pedogenic pathways (^Bw horizon formation) at the great group level. Therefore, current mine soil series level concepts based primarily on parent material type may pose challenges for highly variable or recently constructed mined lands that are undergoing rapid transformations within a few years' time. Following reclamation of mineral sands mine soils (upper Coastal Plain), unique features were observed related to a combination of sedimentation into basins followed by heavy grading such as contrasting textural materials, very thick cloddy and platy structures, and one or more densic contacts. Several pedons had undergone significant pedogenesis indicated by ^Bw (cambic) diagnostic horizons, while other pedons lacked significant subsoil pedogenesis, likely due to the presence of densic materials via grading. Since the depth to first densic contact varied widely among pedons, it is crucial to recognize and properly categorize a range of different depth classes to densic materials, ideally at the family level. For either of the mine soils studied here, Artesols conveys their anthropogenic nature at the highest level (order), thus enabling other relevant taxa important for land use interpretations at lower levels (great group and subgroup). Given this new order, there is an opportunity to build new taxa related to the specific disturbance type and its associated limitations (e.g., poor internal drainage, mechanical compaction, topsoil over spoils) over time.

Key Words: coal mining, mineral sands mining, Soil Taxonomy

Session 3 – Mercury Site Remediation

Mercury mine site remediation using a novel powder product. Stephen McCord*, *McCord Environmental*, *Davis, CA, USA*.

Mercury (Hg) was mined extensively in California's Coast Range from the 1850's to 1970's and used in gold mine sites in the Sierra Nevada and elsewhere. Mercury mined today is applied at an artisanal scale to amalgamate gold in several developing countries. Mercury ore processing facilities and artisanal gold mining sites release mercury in multiple forms, which creates source contamination that is problematic to remediate. Aside from mine sites themselves, naturally Hg-enriched watersheds in mining regions tend to produce Hg-contaminated waterbodies that significantly exceed safe use criteria.
Remediation of Hg-contaminated mine sites and waterbodies are challenging because of remote site conditions, complex Hg speciation/transformation processes, and multiple routes of Hg transport and exposure.
Commensurate with those challenges, remediation projects need to be multi-pronged—addressing site hydrology, soil erosion, leaching, transpiration, degradation, vegetation uptake, downstream impacts and more. Stabilization of mercury source areas is often the initial step to remediation of diffuse contaminated media.
MercLok™ P-640 (MercLok), a proprietary powder-format remediation product developed by Albemarle's bromine technologies group as an Hg treatment technology, was applied to Hg-contaminated calcines at two abandoned Hg mine sites in northern California. The purpose for the projects was to evaluate the product's efficacy in rendering such contaminated materials less hazardous and thereby reducing remediation project costs. Non-amended and amended calcines and their leachates were analyzed for Hg content and related conditions. Samples from one site were tested in contained buckets over a five-month period. Sampling indicated that the amendments effectively reduced leachability below the soluble leachate limit, thereby reducing the estimated remediation project costs. Full-scale remediation was implemented at the other site, consisting of MercLok application to a calcines pile and additional hydrologic controls to minimize run-on, erosion, and runoff.

Key Words: mercury, mining, leachate

Use of MercLok™ P-640 to reduce elemental mercury beads and remediate highly contaminated mining wastes. C. Fontenot*, J. Miller, and K. Pingree, *Albemarle*.

MercLok™ P-640, a mercury treatment technology, has been developed by Albemarle to address environmental impacts from mercury contamination. The product is an amendment for the in-situ remediation of mercury-contaminated mining, chlor-alkali, munitions and other manufacturing sites. MercLok is designed to capture and sequester multiple species of mercury, including elemental mercury, reducing diffusion into groundwater and surface water.

Albemarle conducted a pilot study using MercLok at an abandoned mercury mine site in California. For the five-month pilot study, layers of unamended (controls) and MercLok-amended calcines were arranged in open-top container "reactors" representing two alternative application techniques and various dosages. Rainwater was allowed to enter the reactors to simulate natural leaching of mercury. The leachate was sampled monthly and analyzed for total mercury, dissolved mercury, and methylmercury. Calcine solids were analyzed at the beginning and end of the exposure/leaching period for total and leachable mercury. Analytical results from rainwater leachate and acid-based leaching tests demonstrate MercLok reduced total mercury leaching by up to 99% and reduced methylmercury in leachate by 75%. MercLok also reduced the leachability of mercury from the calcine materials to below hazardous solid waste classification limits.

To evaluate the capture and sequestration of elemental mercury, MercLok, water, and elemental mercury beads were placed into sealed bottle reactors and agitated over several days. Each day the samples were visually inspected for the presence of mercury beads. At the conclusion of the study, no beads were visible within the samples. Analysis by USEPA method 7473 indicated that the solid MercLok portion of the sample contained the majority of the mass of mercury added to each reactor, though elemental mercury was not visible within the amendment matrix. Additionally, the TCLP (Toxicity Characteristic Leaching Procedure) analysis of the filter cakes from each reactor was only able to extract a maximum of 0.002% of the total mercury mass at the lowest dosage of MercLok, which was below TCLP criteria.

These findings demonstrate an effective stabilization approach for calcine and other mercury-impacted waste materials, as well as a treatment option for wastes containing elemental mercury beads.

Key Words: mercury, calcine, leachate

Application of a polymeric equilibrium-based passive sampler for methylmercury to measure a sediment porewater depth profile. J Damond*[1], U Ghosh[1], and C Gilmour[2], [1]*University of Maryland, Baltimore County,*, *Baltimore, MD, USA*, [2]*Smithsonian Environmental Research Center*, *Edgewater, MD, USA*.

Porewater methylmercury (MeHg) profiles are essential to determine the risk of uptake into the aquatic food web and are an important parameter for targeting and assessing a sediment remedy. However, current sampling methods are incredibly difficult due to the transformative, redox-sensitive nature of MeHg and often low detection in aqueous matrices. The passive sampling device presented in this work facilitates the measurement of this porewater profile at a fine spatial scale, offering a robust, easy-to-use alternative. Our passive sampler (PS) is an agarose gel polymer embedded with activated carbon (ag+AC). Throughout deployment, the aqueous MeHg equilibrates with the embedded AC adsorbent, which within a month can be analyzed to produce a time-averaged concentration. The sampler material was designed to target equilibrium partitioning behavior that mimicked most sediments, so that it can detect porewater levels across a range of sediment chemistries. Here, we used the ag+AC samplers to measure a porewater profile at a 0.5 cm resolution in sediments from multiple sources. We were able to locate beneath the sediment-water interface where the porewater MeHg reached its peak. Further, the location of this peak corresponded to the changing sulfate and sulfide profiles that were measured alongside, providing an indication of the microbial activity responsible for MeHg production. With this information, we can better

understand and quantify how mercury responds to biogeochemical conditions and changes. This is especially advantageous when designing and assessing sediment treatments, for the effectiveness of a remedy – such as a sand, adsorbent, or reactive cap – is impacted by the biogeochemistry of the sediment.

Key Words: passive sampling, methylmercury, depth profiling

Session 3 - Urban Restoration

Restoring University Drive: An urban campus restoration story. K Sena*, C Samuelson, and H Dockery, *Lewis Honors College, University of Kentucky*, *Lexington, KY, USA*.

While the scope and severity of ecological degradation often does not appear as extreme in urban areas as in areas influenced by mining or other similar activities, a degraded urban landscape can reduce ecological and human health. Furthermore, given that urban areas are characterized by dense human population, urban ecosystems that are not flourishing represent a missed opportunity for human-environment reconciliation. The University of Kentucky (UKy) campus is situated in Lexington, KY, a midsized US city with a 2020 population of 320,000. As an urban campus, UKy grounds experience pressure from urban development, including construction and maintenance of facilities and infrastructure, and high levels of foot and vehicular traffic. These pressures were obvious along University Drive, a central avenue through campus: landscape beds between the sidewalk and the street along University Drive used to be a regularly mowed turfgrass understory underneath a row of mature cherrybark oak trees. However, new building construction in the mid-2010s altered hydrology and understory light conditions, reducing plant cover and driving sheet and rill erosion. By 2022, soils on these sites were devegetated, highly degraded subsoils with exposed gravel and construction debris. To arrest soil erosion, UKy Grounds mulched the sites with fresh wood chips in spring 2022. We established an experimental restoration project on these sites in Fall 2022 to evaluate the effects of pneumatic tillage and biochar addition on infiltration, compaction, and growth and survival of planted sedges and shrubs. By the end of the first growing season, soil strength had decreased consistently ($p < 0.10$) in all treatment plots (but not the control), while infiltration had increased across treatment and control plots, compared to pre-intervention data. First-year survival of planted sedges was low, but survival of planted shrubs was high. Further research will be necessary to evaluate the effects of these interventions over time, but these initial results suggest that mulch addition alone improved infiltration, and that mulch + tillage had additive benefits for reducing soil compaction.

Key Words: pneumatic tillage, biochar, urban restoration

Botanical index of the reclamation of an urban limestone barrens. D. R. Holdridge* and J. A. Franklin, *School of Natural Resources, University of Tennessee*, *Knoxville, TN, USA*.

The Urban Wilderness in South Knoxville, Tennessee spans over 400 ha and 100 km of trails and greenways, providing outdoor recreational and educational opportunities to the metropolitan area. Many of the most notable attractions in the area were once severely degraded lands left abandoned after decades of mineral extraction. The Crag, owned and managed by Ijams Nature Center (a 501(c)(3) organization), was previously a quarry where limestone was harvested and packed for agricultural use. Today the site is heavily trafficked for rock climbing, mountain biking, and hiking. Past and present use have led to heavy compaction on the soils in the 1 ha basin. These soils are highly alkaline given the exposure of the underlying limestone geology, and support a sparse native plant community of species that are indicative of limestone barrens an uncommon ecotype in this region. Significant efforts began in 2018 to reclaim this area to support the natural establishment of a native limestone barrensecosystem. Fixed radius plots were established both at The Crag and a nearby reference site which was largely undisturbed and boasted similar soil and plant characteristics. A timed sampling protocol has been used monthly for one year in order to catalog the species and percent cover of herbaceous plants present on six plots: 3 at The Crag and 3 at the reference site. The Shannon Index was used to compare diversity between the two sites,

along with a comparison of native and invasive species abundance, species which dominate ground cover, and frequency of barren indicator species. So far, 14 species have been recorded at The Crag while 16 species were recorded at the reference site, with 9 species recorded at both sites. A greater number of invasive species were found at the Crag, which must be accounted for when interpreting diversity index results.

Key Words: Quarry, urban, establishment

Riparian Repairing: Effects of conservation efforts on microbial communities and soil characteristics. C. R. Samuelson*[1], H. Dockery[1], K. Pham[2], L. Moe[2], and K. Sena[1], [1]*Lewis Honors College, University of Kentucky*, *Lexington, KY, USA*, [2]*Plant and Soil Sciences, University of Kentucky*, *Lexington, KY, USA*.

Urban environmental management is a growing field of study due to the increased risks of climate change and from greater awareness of anthropogenic impact. However, the dominant urban management practice is mowing, which reduces biodiversity and compacts soil. Alongside this, urban development places extreme stress on streams, thus managers and planners are increasingly interested in alleviating urban effects on streams. Riparian buffer zones have been proven to improve water quality and reduce nitrates in rural, agricultural settings, but there is not much research about their impact regarding environmental contaminants, soil characteristics, and microbial communities in urban areas. To better understand the benefits of riparian buffer zones, this study looks at soil compaction, infiltration, chemistry, and microbial communities across 10 sites in Lexington, KY. At each site, compaction and infiltration were measured and soil samples were collected. Soil samples were split between soil fertility measurements and 16s rRNA microbial sequencing. Riparian buffer zones had statistically significant lower compaction ($1.07 * 10^6$ Pa, $1.40 * 10^6$ Pa) and statistically significant higher infiltration (9.76 L/hr, 4.88 L/hr) than mowed zones. Soil organic matter (5.18%, 4.27%) and potassium (226.52 mg/kg, 328.96 mg/kg) differed significantly between riparian buffer and mowed zones, while total nitrogen, phosphorous, pH, and Shannon alpha diversity had no significant differences ($p < 0.05$). Age was shown to be correlated with soil characteristics and Shannon alpha diversity in riparian buffer zones but had no impact on mowed zones. Both the riparian buffer and mowed zones are dominated by the phyla of Proteobacteria (Pseudomonadota), Verrucomicrobia (Verrucomicrobiota), Acidobacteria (Acidobacteriota), and Actinobacteria (Actinomycetota). Compared to mowed zones, riparian buffer zones improved desirable soil characteristics related to urban environmental management.

Key Words: mowed, urban, restoration

Session 4 – Soils and Vegetation

Soil stockpile age does not impact vegetation establishment in a cold, arid natural gas field. M Curran*[1], J Sorenson[2], and T Robinson[3], [1]*Abnova Ecological Solutions*, *Cheyenne, WY, USA*, [2]*Jonah Energy*, *Pinedale, WY, USA*, [3]*University of Wyoming*, *Laramie, WY, USA*.

Land reclamation is critical to ensure surface disturbance associated with natural gas development is not permanent. Soil management is critical to reclamation success, especially in arid environments. Typically, natural gas well pad construction involves stripping topsoil to allow for equipment to be on level ground and placing it into a stockpile. After well pad construction, soil is respread and seeded to initiate interim reclamation. Previous research has shown soil disturbance during natural gas well pad construction and subsequent reclamation in cold, arid environments is highest at the stripping and respreading phases, with minimal soil activity occurring during the stockpile phase. Other research has shown that additional soil disturbances after reclamation is initiated may exacerbate soil damage, limiting revegetation potential. Here, we examine soil stockpiles which are 1-7 years old in the Jonah Infill natural gas field for vegetation emergence and vegetation cover using an image analysis software called SamplePoint. In a ten-week greenhouse experiment, we found vegetation cover across stockpile age-classes increased uniformly during the study period but that there was no significant difference in rate of vegetation cover increase or percent vegetation cover over time. These findings suggest it may be better to keep soil stockpiled in

cold, arid natural gas fields when it is uncertain if additional construction activities will be required on a well pad location rather than respreading soil with a chance that redisturbance is necessary.

Key Words: soil stockpile, revegetation, arid environment

Session 4 – Metals in Freshwater Systems

Implications on Periphyton as a Relevant Methylation Source in Mercury Contaminated Aquatic Ecosystems and its Potential Use as a Passive Sampler. S Dent*, *Steve Dent*.

Challenges associated with mercury contaminated sites arise from the large variety of chemical species and conditions that manifest from mining mercury ores, historical processing of gold and silver, and other industrial operations such as Chlor-Alkali plant operation and mercury chemical product manufacturing. In aquatic ecosystems, ionic mercury can be biochemically transformed into methylmercury, the organic form of the metal that partitions into biotic tissue and subsequently biomagnified. The mechanisms that control methylation and bioaccumulation rates are complex and site specific. It can be quite challenging to adequately delineate exactly where methylmercury is formed and how it interacts with and biomagnifies up into the food web. It is also difficult to understand long term exposure mechanisms, as there currently a lack of options for reliable methylmercury passive samplers. Recent understanding has grown on the roll of inorganic mercury sequestration and mercury methylation within the biofilms of periphyton within aquatic ecosystems, a complex community of photosynthetic algae, bacteria, fungi, and invertebrates that can cover various sediment, plant, cobbles, and other underwater objects. In the right conditions, methylmercury formation within periphyton biofilm can be a potential missing link as a relevant source to the base of the food-web that is independent of sediment production, the most common zone targeted for evaluation. Considering it is a media that can grow quickly, has an affinity for sequestering inorganic mercury, and comes into equilibrium within the water column, it has potential to be used as a passive sampling tool to help identify source inputs into riverine systems. This presentation explores periphyton as a media to both identify key methylmercury sources in contaminated aquatic ecosystems and its potential for use as a passive sampling tool through a number of case studies from around the United States.

Key Words: mercury, methylmercury, periphyton

Trace Metal Bioaccumulation in Planted Vegetation of a Mine Drainage Passive Treatment System and Potential Ecological Risk. O. J. Mitchell*[1,2], L. H. Olson[1,2], and R. W. Nairn[1,2], [1]*Civil Engineering and Environmental Science at the University of Oklahoma (CEES OU)*, *Norman, OK, USA*, [2]*Center for Restoration of Ecosystems and Watersheds (CREW)*, *Norman, OK, USA*.

Legacy impacts of the historic Tri-State Lead-Zinc Mining District (Missouri, Kansas, and Oklahoma) include elevated trace metal concentrations in various environmental media. The ecologically engineered Mayer Ranch Passive Treatment System (PTS), installed in 2008, addresses artesian mine water sources, retaining more than 90% of targeted contaminants via various biogeochemical mechanisms in 10 process units. The design included two parallel vegetated surface-flow wetlands. After excessively high water levels in 2019 resulted in vegetation loss, one wetland was replanted in 2020 with common cattail (*Typha latifolia*) and the other was left unplanted. Water quality has been monitored for 15 years, but limited evaluation of ecological processes has occurred. This research investigated the role of phytoextraction (plant uptake of trace metals) and resulting potential risk. Water, soil, root, rhizome, and shoot biomass were collected from the replanted wetland and analyzed for trace metals. Estimated ingestion rates and resulting hazard quotients (HQs) were used to assess potential risk to muskrats (*Ondatra zibethica*). Effluent water quality data indicated that both wetlands effectively retained Cd, Fe, Pb, and Zn from the water. However, in comparison to annual mass retention, presence of cattails showed little effect. Soil and cattail roots, rhizomes, and shoots showed elevated levels of Cd, Fe, Pb, and Zn, with the greatest biomass concentrations in the roots. HQs for muskrats consuming shoots and rhizomes were elevated for Cd (27), Fe (298), Pb (6), and Zn

(13). This potential risk to wildlife should be considered when emergent vegetation is included in mine water PTS design.

Key Words: Passive Treatment System, Phytoextraction, Ecological Risk

The Use of Terrestrial Laser Scanning to Assess the Mobilization Erosion of Contaminated Sediment Creekbank Soil in Oak Ridge, Tennessee. T Musante*[1], M Mayes[2], K Lowe[2], and A Johs[2], [1]*University of Tennessee*, *Knoxville, Tennessee, USA*, [2]*Oak Ridge National Laboratory Environmental Sciences Division*, *Oak Ridge, Tennessee, USA*.

The town of Oak Ridge in eastern Tennessee, USA is contaminated with mercury due to cold war era activities at the US Department of Energy's Y-12 plant. Large amounts (11 million kilograms) of metallic mercury were used to separate lithium isotopes to produce thermonuclear weapons. By the end of lithium isotope separation activities in 1963, a total of around 128,000 kg of Hg was unintentionally discharged into the headwaters of East Fork Poplar Creek (EFPC), which are located within the Y-12 plant. 85% of this discharge was incorporated into floodplain soils along EFPC. Currently, continued erosion of creekbank soils gradually adds more mercury into the EFPC. The first step to accomplishing remediation of this mercury is assessing how much soil is being eroded and to determine how much mercury is entering EFPC. In the past, this has been accomplished using conventional methods, such as erosion pins and an enhanced erosion mesh. More recently, we started the transition to using a terrestrial laser scanner (TLS) that uses Light Detection and Ranging (LiDAR) technology. This scanner is deployed at streambanks of concern, and over time, scans of the same sites are compared to previous scans using registration software, and a volume difference is calculated between scans to quantify erosion. Using the LiDAR scanner is challenging due to high amounts of vegetation, and overhanging soils on the streambanks. We are also adding additional georeferencing into the LiDAR scan registration workflow to improve the ability to match exact scan locations over time. Other variables such as bank height, stream velocity, and soils and sediment composition will be utilized to assess dominant erosional processes and accurately quantify erosion. Preliminary results show between 0-0.79 m^3 of soil loss detected by LiDAR, and 0-6.92 m^3 of soil loss detected by erosion pins over a 6-month period.

Key Words: LiDAR, Erosion, Mercury

Session 4 – Understanding and Mitigating Acid Drainage

Investigation acidic discharges at the Monahan abandoned mine lands site, Kansas. P Behum*[1], M Spence[2], J Arruda[3], R Johnson[2], and C Kiser[1], [1]*Office of Surface Mining Reclamation and Enforcement*, *Alton, IL, USA*, [2]*Kansas Department of Health and Environment*, *Pittsburg, KS, USA*, [3]*Pittsburg State University*, *Pittsburg KS, USA*, [4]*Kansas Department of Health and Environment*, *Pittsburg KS, USA*, [5]*Office of Surface Mining Reclamation and Enforcement*, *Alton, IL, USA*.

The Surface Mining Section of the Kansas Dept. of Health and Environment (KDH&E) & U.S Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) conducted a remediation project of a coal mine waste facility on the Monahan Outdoor Education Center. The Monahan Refuse Disposal Area is an 80-acre site in Crawford County Kansas, approximately 1 mile north and 1.5 miles east of Cherokee, Kansas. This pre-SMCRA site was both a surface and underground mine and coal processing facility, which was subsequently donated to the Pittsburg State University (PSU), Pittsburg, Kansas. Acid mine drainage (AMD) is discharging from the former coal refuse pile. Prior to AMD remediation a hydrologic baseline study by KDH&E, PSU,and OSMRE evaluated AMD sources. Dilution was determined to be necessary with alkalinity-bearing water from a large final pit impoundment with an average combined flow of average 17.7 GPM estimated by a weir installation. Engineering tests were performed on a dilution water/AMD mix at a 1:1 ratio. This mixing experiment suggested that acidity derived from dissolved metals and pH will yield a calculated acidity of 442 mg/L. A conceptual design was completed in 2018 by the OSMRE/KDHE team that proposed remediation using a passive treatment system (PTS) which was designed and constructed in 2023 by KDHE contractors. The PTS employs: 1) dilution to lower the acidity and metal content, 2) low

pH iron oxidation, 3) treatment by a vertical flow pond (VFP), 4) precipitation of metals in an oxidation pond and aerobic wetland, and 4) secondary dilution with alkaline water added near the system outlet. Jar tests suggest 160 mg/L calcium carbonate equivalent alkalinity will be generated by the VFP. The secondary dilution water source should provide and estimated 62 mg/L calcium carbonate equivalent additional alkalinity. Initial results of system operation will also be presented.

Key Words: Vertical flow pond, oxidation pond and aerobic wetland

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Management of acid-forming sediments at the Stafford Airport expansion project in Virginia. W.L. Daniels*, *Virginia Tech*, *Blacksburg, VA, USA*.

Construction in sulfidic Coastal Plain sediments at the Stafford Regional Airport (SRAP) in the early 2000's generated > 150 ha of acid sulfate soil (ASS: pH < 3.5) with local water quality impacts. The project area was one of the largest non-mining ASS impacts in North America and remediated via application of high rates of lime and biosolids. Between 2021-2023, SRAP completed an extension that disturbed another 850 K CY. The bid contract specified VDOT testing protocols (based on PA DOT criteria) that required complete isolation and bulk liming of with net neutralization potential (NNP) of < -5 g/kg (T/1000 T) calcium carbonate equivalent (CCE). Due to the highly weathered nature of the soil mantle (Ultisols), significant portions of the upper weathered zone failed this criterion along with ~ 1/3 of the underlying sediments. Virginia Tech worked with consultants (Talbert & Bright, DEA & TerraScience) to develop a hybrid classification based on segregating potential ASS materials into three different categories with differential handling, isolation and management. Initial lab analyses of drill core samples indicated that most problematic materials (NNP < -30 T/1000T) were relatively thin (< 3 m thick), associated with adjacent non-ASS materials, and the upper weathered mantle was depleted of S. Materials were evaluated onsite daily by depth, color/unique stratigraphic features, and 30% H_2O_2 reaction to identify problematic materials with follow-up lab confirmation. The majority of surface weathered materials were placed with liming only required for their final revegetation. A large portion of the underlying acid-forming materials were moved with adjacent strata such that their blended NNP was > -5 T/1000 T, were bulk limed at varying rates to achieve NNP > 0, and compacted into conventional fills. Problematic materials (pH < 4.5 and/or NNP < -5; ~150 K CY) were isolated, bulk limed at 1.5 x NNP deficit, compacted in place and isolated from infiltration and groundwater. Total lime utilization was 2400 T CCE, much lower than the original VDOT criteria would have required. While not monitored rigorously, adverse water quality impacts have not been noted to date. Similar but smaller (< 100 K CY) projects are currently occurring throughout the region, many without any direct mitigation or oversight.

Key Words: Acid sulfate soils, potential acidity, liming requirement

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Treating mine drainage in batch: greater efficiency and cost savings. Travis Tasker*[1], Ben Roman[1], James Eckenrode[1], Nicole Himes[1], Henry Warner[1], Buck Neely[2], Cliff Denholm[3], William Strosnider[4], Julie LaBar[5], and Tim Danehy[2], [1]*Saint Francis University*, *Loretto, PA, USA*, [2]*BioMost, Inc.*, *Mars, PA, USA*, [3]*Stream Restoration Inc.*, *Slippery Rock, PA, USA*, [4]*University of South Carolina*, *Georgetown, SC, USA*, [5]*Oklahoma State University*, *Stillwater, OK, USA*.

Mine drainage (MD) treatment systems are often designed to operate in flowthrough where MD continuously flows into and out of a basin filled with limestone. However, these systems are often prone to short circuiting and clogging. In the work herein, we hypothesize that a batch operating limestone treatment system (BOLTS) can overcome some of these challenges by treating MD in batch for a set hydraulic retention time (HRT), thereby producing higher acidity removal rates than a typical auto flushing vertical flow pond (AFVFP) operating in flowthrough. To test this hypothesis, influent and effluent acidity concentrations were monitored for a passive treatment system near Puritan, PA when operated with different treatment configurations (i.e., flow-through or batch treatment mode) and theoretical HRTs (i.e., 4.5 or 9-hour). In all experiments, the limestone treatment system achieved greater treatment efficiency per limestone volume when operating in batch versus flowthrough treatment mode. For example, at a 9-hour theoretical HRT, the net acidity of the MD decreased from 341 mg/L to -26.2 mg/L in

the BOLTS and from 267 to 71.5 mg/L in the AFVFP. At a 4.5-hour theoretical HRT, the net acidity decreased from 302 mg/L to -11.8 mg/L in the BOLTS and from 303 mg/L to 183 mg/L in the AFVFP. HRT and net acidities were used to calculate surface area normalized acidity removal rates for both treatment configurations. Based on the removal rates, a BOLTS would require 5,945 short tons (i.e., 6,553 tonnes) of limestone to treat the MD while an AFVFP would require 11,679 short tons (i.e., 12,873 tonnes). Overall, these results suggest that batch systems can have higher treatment efficiency than AFVFPs for a given quantity of stone. This can result in an initial reduction of design size or an increase in system longevity.

Key Words: mine drainage treatment

Session 5 – Biodiversity and Ecology

Reclamation of natural gas well pads and pipeline right-of-ways to create biodiversity hotspots and ecological corridors. M Curran*, *Abnova Ecological Solutions*, *Cheyenne, WY, USA*.

While the debate between reclamation, restoration, rehabilitation, and remediation has festered for decades, a new definition was posed for 'ecological reclamation' in 2022. Gerwing and others suggest 'ecological reclamation' is “the process of assisting the recovery of severely degraded ecosystems to benefit native biota through the establishment of habitats, populations, communities, or ecosystems that are similar, but not necessarily identical to surrounding and naturally occurring ecosystems.” There are many benefits associated with the use of native plants. Recent research from the Jonah Infill and Pinedale Anticline natural gas fields suggests early successional native vegetaton communities on reclaimed natural gas well pads contain significantly higher amounts of pollinators and other invertebrate species than reference ecosystems which are predominantly composed of decadent, old-growth stands of sagebrush. More recently, we examined pipeline right-of-way reclamation for insects and found similar results with clear evidence that reclamation efforts which result in diverse native plant communities host more insects than those which are dominated by non-native or lack vegetative diversity. Insects are useful indicators of reclamation success because they provide numerous ecosystem services and respond quickly to environmental change. Our results suggest if upstream and midstream operators in natural gas fields coordinate on reclamation efforts and goals with an emphasis on establishment of native vegetation communities, a network of biodiversity hotspots (well pads) and ecological corridors (rights-of-way) is possible.

Key Words: insects, pollinators, biodiversity

Red Spruce Restoration and Ash Protection on the Appalachian Trail. Matt Drury*, *Appalachian Trail Conservancy*, *Asheville, NC, USA*.

The Appalachian National Scenic Trail traverses a landscape which contains a wide range of altitudes, latitudes, and ecosystems; it is the largest ecological corridor in the Eastern United States. Some of these ecosystems are globally imperiled and are at risk in the face of climate change, are in poor health due to past management practices, or are under threat from forest pests and pathogens. In the Southern Region, the Appalachian Trail Conservancy has been performing ecological restoration activities on globally imperiled (G1) Southern Appalachian Spruce-fir forests. These efforts include installing different size canopy gaps with differing light conditions on the Roan Massif and Unaka Mountain to find the best methods for spruce release and recruitment. Research and methodology for treatments and data collection were developed in partnership with Western Carolina University and Virigina Tech and the results will help inform management of landscape scale spruce restoration activities in advance of the pending USFS Region 8 National Environmental Policy Act compliance for spruce-fir restoration. The Appalachian Trail Conservancy has also engaged in spruce restoration at Whitetop Mountain in Virginia. Another substantial forest health initiative is Appalachian Trail Conservancy’s Save Our Ashes program, which protects ash trees against the emerald ash borer. Save Our Ashes has strategically treated 875 ash trees in Tennessee, North Carolina, and Georgia, as well has hundreds of trees in New England. The primary objective of this program is to keep these trees

alive on the landscape for future reintroduction efforts in the Southern Appalachians.

Key Words: spruce, ash, restoration

Future Restoration Priorities based on 50 Years of Lessons Learned in the NJ Meadowlands. T Doss*, *NJSEA Meadowlands Research & Restoration Institute*.

The New Jersey Meadowlands are one of the largest contiguous blocks of open space located within the highly developed landscape of the New York City metropolitan area.

In 1962, it was stated that "The Hackensack Meadows are not at the present time of significance to fish or wildlife… productivity of the meadows has all but been destroyed." However, after 50 years of active preservation, protection, remediation and restoration, this urban wildland now supports a diversity of flora and fauna and provides critical ecosystem functions including nutrient cycling and flood storage.

But what have we learned from this past half-century of efforts? And what are future restoration strategies and priorities, given climate change and sea level rise uncertainties? This presentation will review past remediation and restoration efforts, and then turn a deeper focus on what we've learned from these projects, and how we'll be applying those lessons to continue in our efforts to protect and preserve this important urban habitat.

Key Words: Wetlands, restoration

Session 5 – Uranium Mine Reclamation

Novel approaches to dryland reclamation enhance vegetation and soil stability at a former uranium mine. K.D. Eckhoff*[1,2], R.K. Mann[1], S. Munson[3], K. Walton-Day[4], J.E. Hinck[5], and M.C. Duniway[1], [1]*US Geological Survey, Southwest Biological Science Center*, *Moab, UT*, [2]*Northern Arizona University*, *Flagstaff, AZ*, [3]*US Geological Survey, Southwest Biological Science Center*, *Flagstaff, AZ*, [4]*US Geological Survey, Colorado Water Science Center*, *Lakewood, CO*, [5]*Natural Hazards Mission Area*, *Reston, VA*.

Mining activities provide much needed mineral resources but can have negative effects on vegetation and soils in dryland regions. To understand how these negative impacts can be mitigated during reclamation, we compared traditional revegetation approaches to new approaches that may influence plant establishment and soil stabilization, therefore improving reclamation outcomes. We utilized the reclamation of the Kanab North Mine in the greater Grand Canyon, Arizona ecosystem to test the effectiveness of traditional treatments (practices historically performed in the region) of drillseeding a non-native plant species seed mix versus novel treatments of a native plant species seed mix and using artificial nurse plants (Con-Mods) with broadcast seeding. We measured plant establishment and composition, soil surface cover, and dust emissions for the first five years of reclamation. We also tested the application of biological soil crust (BSC) inoculum as a split-plot factor on plant and BSC establishment, soil surface cover, and soil stability. Results showed that plant cover and establishment increased in all treatments and consisted mostly of annual unseeded non-native forbs. Con-Mods significantly increased cover of total, graminoid, and native plant species, and native seed mix increased woody, native, perennial, and seeded species cover. Spacing between perennial plants decreased with time in all treatments, but traditional drillseeded non-native seed mix remained higher than novel treatments. Dust emissions decreased with time and increasing plant cover but were not affected by seeding mix or method. BSC inoculation increased the level of soil development with Con-Mods but not drillseed. Though soil stability increased over time, BSC inoculation resulted in only a small increase in stability, with Con-Mods resulting in higher stability than drillseed. Overall, novel approaches to reclamation (Con-Mods and native seed mix) were more effective overall than traditional methods, increasing plant cover, permitting BSC establishment, and promoting soil stability after uranium mine reclamation.

Key Words: Dryland reclamation, revegetation, soil stability

Shirley Basin Investigative Geotechnical Drilling Design and Construction. C Sloan* and M Gentry, *Herrera Environmental Consultants Inc.*, *Casper, WY, United States*.

Addressing the challenges posed by variable soil conditions on uranium mining waste piles in the Shirley Basin of Wyoming is crucial for successful vegetation establishment during reclamation. To achieve this, a comprehensive understanding of the site's soil resources, both surface and subgrade, is essential for restoring these lands to have less erodible surface and more suitable habitat for sage grouse and other wildlife. The overarching goal for reclamation in Shirley Basin is to effectively reclaim the area and mitigate potential future hazards to public health and the environment from acid-forming materials, and radioactive mine waste from historic abandoned uranium mine sites. Additionally, prioritizing the reduction of sediment deposition into the Little Medicine Bow River is paramount. The combined use of Carlson Natural Regrade ™ and SIBERIA ™ modeling software will lay the groundwork for a stable and sustainable approach to site regrading; however, successful revegetation is key to ensuring long-term environmental health and viability.
To optimize vegetation establishment after regrading in the Shirley Basin, we leverage past soil analyses while integrating innovative strategies into current designs. This holistic approach enhances our grasp of site limitations related to soil textures, characteristics, and quantities, providing a comprehensive understanding of historical mining and reclamation practices. By adopting diverse perspectives, we ensure thorough exploration of available options to procure the requisite soil media for sustainable reclamation efforts. Our multifaceted approach entails refining prior investigation methodologies, studying successful vegetative reclamation in adjacent areas, quantifying the volume of suitable cover soil for desirable species establishment, landform specific seed mix designs and tailoring our analysis to grasp the design's most impacted areas. This includes delineating zones with heightened radioactive material levels, particularly in areas slated for excavation per the design plan.
This presentation will discuss the soil investigation process and results which are expected to yield a more comprehensive understanding of the subsurface materials at the site, which will be used to further improve planning and reclamation design at the Shirley Basin

Key Words: Soils Modeling, Geomorphic Reclamation, Abandoned Uranium Mines

Enhancing geomorphic reclamation through 3d soil modeling: insights from an abandoned uranium mine in Wyoming. S Cude*, *Rockwell Science*, *Lexington, Kentucky, USA*.

A 3-dimensional soil model was constructed based on data from 110 drillholes spanning the 74-hectare area of the Shirley Basin 500 pile abandoned Uranium mine in Wyoming. This model was instrumental in estimating the volumes and spatial distribution of suitable growth medium available on-site for geomorphic reclamation. Soil samples underwent comprehensive laboratory analysis for important parameters, while pH, electrical conductivity (EC), and radiation levels were measured in the field. The modeling process accounted for soil texture differentials throughout the entirety of the site, reaching depths of up to 14 meters. Within 39 identified cut areas critical for the geomorphic reclamation design, soil suitability assessments were performed at 1.5-meter depth intervals. The classification process categorized over 1,000,000 cubic meters of material, with approximately 25% deemed suitable as growth medium. This classification was based on texture, pH, EC, Acid/Base Potential, and metal content analysis, and a confidence classification was applied to mitigate the risk of overestimation due to low drillhole density. Recommendations for soil amendments were made based on soil textures and fertility tests to enhance the soil's ability to support plant growth. The spatial modeling of material suitability significantly enhanced the planning and design phases of the substantial earthmoving project required to restore the abandoned Uranium mine to its natural landscape contours, facilitating its transformation into a functional ecosystem.

Key Words: Soils Modeling, Geomorphic Reclamation, Abandoned Uranium Mines

Session 5 – Mitigating Acid Mine Drainage

Sandy Creek restoration - the tale of two acid mine drainage treatment systems. B Fancher*, *State of West Virginia*, *Philippi, WV, USA*.

The Sandy Creek watershed, spanning approximately 23,387.6 hectares across Barbour, Taylor, and Preston Counties in West Virginia (WV), faces degradation from Title IV and Title V coal mining as defined by the Surface Mining Control and Reclamation Act (SMCRA). These activities contribute 49.5 percent of all acidity loading (4,229.75 kg/day) to Tygart Lake and Tygart Valley River. In response, the WV Department of Environmental Protection's (WVDEP) Office of Special Reclamation (OSR) initiated the design of three AMD treatment systems in 2016 to rectify the impaired streams.
By 2017, OSR had retrofitted F&M Coal Co. in the headwaters of Left Fork Sandy Creek to ensure consistent AMD treatment. The outdated treatment, utilizing anhydrous ammonia and small settling ponds, was replaced with High-Density Lime Slurry System (HDLSS) and larger settling ponds. This retrofitting aimed to meet water quality standards under the National Pollutant Discharge Elimination System (NPDES) Permitting program and was completed in 2020. Groundwork for AMD treatment within Left Fork Little Sandy Creek (LFLS Creek) and Maple Run watersheds commenced in 2016 after legislative revisions to the state's water quality standards. WVDEP received USEPA approval for a watershed-based NPDES Permitting Variance in 2018. Construction of an in-stream doser using the HDLSS on LFLS Creek and a Hydrated Lime Mechanical Feed System along Maple Run concluded in 2019. Before 2016, no efforts made to improve the water quality or stream ecology of Sandy Creek had worked due to the overwhelming amount of AMD. Upon completion of all water treatment systems, the previously depressed pH approached near neutrality, allowing the migration of fish species upstream. Fish and benthic macroinvertebrate surveys in 2021 and 2023 demonstrated increased diversity and richness. Similar positive results were observed below the F&M Coal permits in Left Fork Sandy Creek.
Utilizing AMD treatment systems, the Sandy Creek watershed has made significant strides in achieving long-term ecological restoration goals outlined in the Watershed-based Variance. While 22.85 km of Sandy Creek and Little Sandy Creek have begun to experience relief from the long-term AMD problem, evidence now shows improved water quality and the return of aquatic life in the region.

Key Words: Acid Mine Drainage, High-Density Lime Slurry Treatment, Ecological Restoration

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Use and regeneration of hydrochar as a metal sorbent from acid mine drainage. S. Jamshidifard and N. Kruse Daniels*, *Ohio University*, *Athens, Ohio, USA*.

Hydrochar is a material, akin to biochar, that is made from organic materials and can be used for a variety of applications including water treatment and land amendment. Compared to biochar, hydrochar is produced at lower temperature in the presence of water. As part of a larger project that aims to find innovative ways to divert food and organic wastes, we explored use of hydrochar created from anaerobic digestate from food waste and septage, processed using hydrothermal carbonization between 180°C and 260°C for 30 minutes. In previous work by our team, we have shown hydrochar to be an effective sorbent for Zn, Cu, and Cd in pH 4 lab-created mine water, with sorption percentage increasing with increasing processing temperature. Here, we explore using different solvents for desorbing metals from the hydrochar to explore different applications that may allow for regeneration of the solvent or desorption to allow for land application of the spent hydrochar. Several solvents including EDTA, nitric acid, KCl, and deionized water were tested for two rounds of sorption/desorption. The third round of sorption was much less effective than the first two and different solvents were more selective for different metals. SEM imagery shows a change in surface structure of the hydrochar through the rounds of treatment that may be indicative of reduced efficacy.

Key Words: Cu, Cd, Zn

NPDES Compliance with Passive Treatment for Acid, Iron, Manganese, and Aluminum-bearing AMD - A Four Year Performance Evaluation. T Danehy*, D Guy, R Mahony, C Neely, and D Clayton, *BioMost, Inc.*, *Mars, PA, USA*.

A multi-stage passive treatment system was installed in November 2019 to treat an acidic, iron, manganese, and aluminum-bearing postmining discharge at a completed surface coal mine site in Washington County, Pennsylvania. The Pennsylvania Department of Environmental Protection set National Pollutant Discharge Elimination System (NPDES) effluent limits including maintaining the pH between 6.0 and 9.0, alkalinity greater than acidity, and monthly average metal concentrations of no more than 3.0 mg/L iron, 2.0 mg/L manganese, and 2.0 mg/L aluminum. The system was designed to treat an average flow of 30 liters per minute (lpm) (8 gallons per minute (gpm)) with a maximum design flow of 45 lpm (12 gpm) and a daily load of up to 12.7 kg (28.1 lb) acidity, 1.2 kg (2.6 lb) iron, 2.5 kg (5.6 lb) manganese, and 1.5 kg (3.2 lb) aluminum. The actual average and maximum flow rates have been 45 lpm (12 gpm) and 231 lpm (61 gpm), respectively. The maximum daily influent pollutant load has reached up to 60.9 kg (134.2 lb) acidity, 3.6 kg (7.9 lb) iron, 9.5 kg (21.0 lb) manganese, and 3.9 kg (8.6 lb) aluminum. Despite a maximum flow five times and maximum daily pollutant loads over three times higher than expected, the system has been able to achieve regular NPDES compliance for four years with few exceptions. Performance of various components including a limestone-only auto-flushing vertical flow pond (AFVFP a/k/a drainable limestone bed), settling pond, Jennings-type vertical flow pond (JVFP), and horizontal flow limestone bed (HFLB a/k/a manganese removal bed), will be compared with design criteria and other known performance metrics. Notably, an average manganese removal rate of 5 g per tonne of limestone within the AFVFP (0.01 lb manganese per short ton) has been quantified.

Key Words: Mining, AMD, Treatment

Session 6 – Remediation and Restoration

From Remediation to Restoration: A Tar Creek Story. Summer King*, *Quapaw Nation*, *Quapaw, OK, USA*.

The Quapaw Nation continues to conduct superfund remediation at the Tar Creek Superfund Site in northeastern Oklahoma, a large former lead and zinc mining disctrict. Many new remediation projects are starting to include constructed wetlands near impacted waterways and other measures to control sediment until final remediation. Completion of remediation activities is also allowing more lands to become available for restoration. These large-scale restoration projects present a new set of challenges the Nation is working to overcome, including funding, logistics, supply, and completion of restoration activities.

Key Words: Superfund, remediation, restoration

Nature-based solutions linking reclamation, environmental remediation, ecological restoration, and sustainable resource extraction. R.W. Nairn*, D.M. Dorman, J.I. McCann, L.H. Olson, H.N. Seago, C.M. Morgan, N.L. Shepherd, and R.C. Knox, *The University of Oklahoma*, *Norman, OK, USA*.

In response to the unprecedented environmental challenges of the 21st century, proposed solutions incorporating the terms “nature” and “natural” have become ubiquitous in the scientific literature and the popular press. Some relevant recent terms include nature-based solutions (NBS), natural infrastructure (NI), and nature and nature-based features (NNBF). The role of NBS and related efforts is especially relevant in the mining sector, as the global transition to a renewable energy economy requires continued resource extraction, despite decarbonization efforts. Reclamation of mined lands and waters is especially difficult at sites requiring remediation of hazardous materials. In addition, successful reclamation often does not lead to acceptable ecological restoration. NBS, which inherently recognizes the interdependencies of humanity and nature, may be key to linking reclamation, environmental remediation, ecological restoration, and sustainable resource extraction. Much can be learned from existing NBS applications at derelict mine sites. The Tar Creek (Kansas-Oklahoma, USA) watershed of the abandoned Tri-State

Lead-Zinc Mining District is a test bed exploring the links between reclamation, remediation, restoration, and potential future resource extraction. Remediation of source materials has increased dramatically in the past decade and has resulted in the reclamation of previously derelict lands to agricultural uses. Two full-scale mine water passive treatment systems have been installed, producing circumneutral pH, net alkaline effluents containing ecotoxic metals concentrations meeting in-stream water quality criteria. The receiving stream has demonstrated substantial water quality improvement and ecological recovery, with documented increases in both fish species, as well as the return of North American beaver and river otter. Potential for resource recovery from both passive treatment residual solids and the remaining abandoned mining wastes is being explored. By taking a nature-based solutions approach, legacy mine sites may be able to be restored to functioning ecological systems while closing the resource recovery loop.

Key Words: ecological engineering, Engineering With Nature, natural infrastructure

Session 6 – Engineering and Construction

Use of industrial residuals and earthworks in the reclamation of abandoned aggregate pits. Peter Beckett*[1], Jonathan Lavigne[2], Marc Hebert[3], Graeme Spiers[1], Nathan Basiliko[2], Olivia Baudet[3], and Roch Rochon[3], [1]*Laurentian University*, *Sudbury, Ontario, Canada*, [2]*Lakehead University*, *Thunder Bay, Ontario, Canada*, [3]*College Boreal*, *Sudbury, Ontario, Canada*.

Many industries generate byproducts rich in organic matter, plant essential nutrients, with elevated buffering capacity. Indeed, alternative soil conditioners, such as lime-stabilised municipal biosolids (LSMB), pulp mill sludge (PMS) and biomass boiler fly ash (BBFA) are industrial products which have successfully amended soils. In the Sudbury area, a low volume application of LSMB (20t/ha) successfully alleviated metal and acid toxicity in industrially damaged soil while significantly improving native biodiversity and recruitment. The benefits of industrial residuals may also be extended to any lands with poor, droughty, coarse textured soils, such as aggregate pits. In a greenhouse study, our results suggest that Trembling Aspen (*Populus tremuloides*) and Yellow Birch (*Betula alleghaniensis*) seedlings planted or sown in aggregate soil is strongly dependent on improvements to soil physical structure rather than purely chemical enhancements. In contrast, the buffering capacity of LSMB and BBFA appear to generate temporary nutrient deficient conditions in soils already neutral to alkaline, which had clear deleterious effects on seedling outcome (leaf discoloration, stunted growth). Incorporating neutral, nutrient rich PMS to gravel soil at a high-volume (290t/ha) significantly improved long-term moisture retention, soil structure, and in turn root growth, resistance to drought, and overall seedling health. Following a 20-week monitoring period, we found only initial spikes of nitrate and orthophosphate leaching whereas metals were not found at harmful concentrations. However, a holistic approach is required to achieve a more complete restoration. At a borrow pit, we are investigating applying residuals in conjunction with a “Rough and Loose” surface treatment and functional trait-based species selection approaches. In an ongoing trial, using a functional approach, we have selected species both native to the area and with physiological traits which promote biological soil health (high production of nutrient rich litter) and rapid establishment of vegetative cover (tall species able to spread vegetatively.

Key Words: soil amendments native species restoration

Progress and prospect of coal mined land reclamation in China. Zhenqi Hu* and Zhen Mao, *China University of Mining and Technology*, *XUzhou,Jiangsu, China*.

Coal is the most important energy resource. The output of coal in China is over 50% of total coal output in the world. With the excavation of coal, a lot of land were destroyed. Thus, coal mined land reclamation is the focus of research activities. This paper introduced progress of mined land reclamation in China. Idea and regulation change on mined land reclamation in recent years was introduced first. Then, the main technology of land reclamation related to surface coal mining and underground coal mining were presented in this paper. Finally, this paper gave

some prospection on the technology of coal mined land reclamation in China.

Key Words: Mined land reclamation, reclamation technology, subsidence land reclamation

Poster Session

Land cover accounting of appalachian surface mines. D.J. Putnam*, R.H. Wynne, and V.A. Thomas, *Virginia Tech, Forest Resources and Environmental Conservation*, *Blacksburg,VA,United States*.

The Appalachian mountain region is faced with the environmental impact of surface mining which threatens its endemic biodiversity. These activities can alter the natural terrain, creating novel plateau-like features with poor soil conditions. Despite the Surface Mining Control and Reclamation Act's (SMCRA) reclamation requirements, many mined lands lack permanent native vegetation or are dominated by the exotic invasive autumn olive (*Elaeagnus umbellata*).
We employed remote sensing techniques to categorize and quantify the land cover of former mine sites in Appalachia. Using Sentinel-2 satellite images from 2019 to 2021, we applied the Continuous Change Detection and Classification (CCDC) algorithm to fit harmonic regression coefficients to annual phenology. Our classification method integrated 2021 monthly image composites and CCDC coefficients in a gradient-boosted random forest classifier, trained and validated on >1,200 photo-interpreted sample points representing nine land cover classes. The classification achieved an overall accuracy of 92%, with the lowest per-class producer's and user's accuracies being 83% and 86%, respectively. For autumn olive, these accuracies were 93% and 90%. Key spectral indices like the Normalized Burn Ratio 2 (NBR2) and the Shortwave Infrared 1 band were significant contributors to the classification. Image availability during leaf onset months (April, March, June) notably improved classification performance. Our analysis revealed that grass was the dominant land cover class on reclaimed mine lands, accounting for 27% of mined area (13,195 ha), followed by deciduous forest, autumn olive, developed land, and shrub/scrub.
Subseqent research will include the examination of relationships between time since disturbance and land cover, and spatial adjacency of land cover; particularly for grass and autumn olive. Further work will explore lidar canopy metrics and spectral recovery metrics, offering crucial insights into the state of mine reclamation in Appalachia for regulators, mining firms, and community action groups.

Key Words: Google earth engine, time series, machine learning

Preserving the Past, Nurturing the Future: Inorganic Fertilizers and the Role of Phosphorus and Potassium in Native Prairie Restoration. K Hays*, D. B. Arnall, L Goodman, R Sharry, J Derrick, and Samuel Akin, *Oklahoma State University*, *Stillwater, OK, USA*.

Phosphorus (P) and potassium (K) are macronutrients required to sustain plant growth and reproduction. They are commonly applied as inorganic fertilizer by farmers worldwide for their crops but these nutrients are also important for the development and sustainment of native grassland systems. Much of the Great Plains region has been used as farmland or grazing land. These practices can disturb natural nutrient cycling by removing nutrients without adequate replacement. Current literature regarding nitrogen (N) application in rangelands has largely focused on the production of biomass and its relation to carbon (C) cycling, but little research exists regarding the application of P and K in rangeland systems. This study evaluates the effects of inorganic fertility application on soil and plant communities in the southern Great Plains region. This experiment was placed on disturbed prairie soils in central Oklahoma. N, P, and K were added as urea, 0-46-0, and 0-0-60 at 67 lbs/ac, 57 lbs/ac, and 57 lbs/ac respectively. Soil sample analysis included macronutrients, micronutrients, texture, pH, and EC. Forage sample analysis looked at nutrient uptake and total N and total C. Currently, ample literature is available for nitrogen application on native grasslands but the response to P and K is unclear. This study looks to understand native prairie responses to immobile nutrients better and assist in native prairie restoration in the future.

Key Words: Rangelands, Immobile Nutrients, Inorganic Fertilizer

Thin Section Petrographic Optical Analysis of Sandstones from the Central Appalachian Coalfields. D Johnson*[1], W Daniels[2], and K Eriksson[2], [1]*East Tennessee State University*, *Johnson City, TN, USA*, [2]*Virginia Polytechnic Institute & State University*, *Blacksburg, VA, USA*.

Geologic strata within the same vertical mining column often contain drastically different geochemical properties that influence their release of total dissolved solids (TDS) following mining disturbance. This study was conducted to compare thin section petrographic optical analysis of sandstone samples to a variety of field- and lab-based geochemical tests. Fourteen sandstone samples were collected from five vertical weathering sequences on coal surface mines in the Central Appalachian coalfields. Thin sections were prepared for each sample and stained to aid in the analysis of porosity, ferruginous carbonate, and calcite. Detailed mineralogy was determined via 300 to 400 point counts for each sample. The reaction of each sample to 30% H_2O_2 was recorded as producing or not producing heat and the reaction of each sample to 5% HCl was recorded as causing effervescence or no effervescence reaction. Saturated paste pH was measured after crushing the samples to less than two millimeters. Results were contrasted using non-parametric Kruskal-Wallis one-way analysis of variance test. Significant differences ($p < 0.05$) were found in H_2O_2 reactions across different concentrations of chlorite, sillimanite cement, and kaolinite cement, HCl reactions across different concentrations of potassium feldspar, and saturated paste pH across different concentrations of monocrystalline quartz. The fourteen samples analyzed were generally quartz-rich subarkoses or sublitharenites. Quartz was the most common framework grain, but feldspars were also abundant, occurring as plagioclase, orthoclase, and microcline, and were often replaced by kaolinite. Carbonate and siderite cements were rare, but oxidation was evident in some samples. Microcline and plagioclase were found to be weathering much more than chlorite and muscovite. Feldspars and other non-carbonate minerals seemed to contribute significantly to neutralization potentials. Overall, thin section optical analysis of sandstones provided valuable insights into variations of their geochemical properties and to their relative potential to produce TDS.

Key Words: field indicators, pH, mineralogy

Sulfate-reducing bioreactor for acid mine drainage treatment using hydrochar as an amendment. A. Marma*, B. Madden, and N. Kruse Daniels, *Ohio University*, *Athens, Ohio, USA*.

As part of a larger project identifying innovative strategies to divert food and organic waste, we are investigating approaches to using hydrochar for treatment of low-iron acid mine drainage with a focus on removing Zn, Cu, and Cd. Hydrochar is a material akin to biochar, but produced at lower temperatures in the presence of water through hydrothermal carbonization. Batch-scale bioreactors are in progress to test the effect on metal removal of hydrochar addition to bioreactors. Bioreactor substrates were chosen to divert food, agricultural, and organic waste from the local system and include cow manure, maple wood chips, and cornflour from a local granary. These are tested with and without the addition of 5% w/w of hydrochar produced from anaerobic digestate of food waste and septage at 260°C for 30 minutes. Pre-treatment metal, sulfate, and COD concentrations alongside ORP, pH, and conductivity in the lab-created mine water were analyzed and are retested after 1, 2, 4, and 7 days of operation and weekly thereafter for 9 weeks or until values stabilize. After operation ceases, genetic analysis of the substrate will be used to characterize the bacterial community in the reactors. This bench-scale test will inform design of future column tests.

Key Words: Cu, Cd, Zn

Effects of forest reclamation on avian occupancy, species richness, and abundance within Appalachian reclaimed surface mines. M Varias*[1], R Davenport[1], C Barton[1], J Cox[1], L Sherman[1], J Larkin[2], T Fearer[3,4], and S Price[1], [1]*Department of Forestry and Natural Resources, University of Kentucky*, [2]*Department of Biology, Indiana University*

of Pennsylvania, [3]*American Bird Conservancy*, [4]*Appalachian Mountains Joint Venture*.

Surface coal mining and subsequent reclamation efforts transform the ecological characteristics of natural landscapes, often altering the habitat and distribution of native wildlife. The Forestry Reclamation Approach (FRA) is a coal mine reclamation method that emphasizes best management practices in forestry. These practices have demonstrated success in establishing native forests and accelerating natural succession on both active and legacy coal mines; however, no studies have empirically examined the effects of the FRA on bird communities. Our study aimed to assess how FRA implementation has influenced the occurrence, species composition and abundance of distinctive avian nesting habitat guilds (i.e., mature forest, early successional, and generalists). Additionally, we sought to assess the prevalence of known avian indicator species of the native forest land cover within FRA forests. We conducted point count surveys in high-elevation, red spruce-northern hardwood (RS-NH) forests in the Appalachian Mountains of eastern West Virginia. We examined differences in avian species richness, and species abundance between four treatment types: 1) younger FRA forest (2-5 yr), 2) older FRA forest (8-11 yr), 3) naturally regenerated forest on mineland (>40 yr), and 4) unmined mature forest (>100 yr). We found that both FRA treatments had a higher species richness and occupancy of early successional breeding birds compared to the naturally regenerated and mature forest treatments. Furthermore, the FRA breeding bird community included all the avian indicator species expected to inhabit an early successional RS-NH forest. Treatment type had similar effects on species-specific abundance estimates, with mature forest species maintaining higher abundance in non-FRA and mature forest sites, and disturbed habitat species having higher abundance in younger and older FRA treatments. These results suggest that after approximately one decade, legacy mines reclaimed using the FRA are progressing toward a native RS-NH forest that supports associated forest bird communities.

Key Words: birds Forestry Reclamation Approach Red Spruce

Prediction of Suspended Sediment Load using Artificial Intelligence from Data Integrity test through Genetic Algorithm. Chidubem Damian Dibie*, *University of Johannesburg*, *Johannesburg, Guateng, South Africa*.

ANN models are known to give good outcomes with regards to reproduction and extreme forecast of occasions independent of the interaction to the extent that there are adequate verifiable information which the AI procedure can mimic. Nonetheless, the cycle can be changed to such an extent that the ANN model could in fact give improved results; Genetic Algorithm Calculation Method in WinGAmma programming was used in dissecting the dataset to choose the most important combination of parameters from the dataset through information respectability test by isolating information with commotion which will create better execution of the ANN model and the result was contrasted and the ordinary ANN model which used every parameters in the dataset and the GA-ANN model outperformed the ANN model with all parameters which goes on to show the GA procedure is entirely solid and a welcome strategy in choosing input parameters for the ideal presentation of the ANN model in reproduction and expectation of occasions. . The event simulated in this work is the Daily suspended sediment load with several input variables ranging from present and antecedent parameters of Discharge, Sediment Discharge and Suspended Sediment load of Shiroro dam in Nigeria. Although the result of the ANN model with all 7 input variables was satisfactory, but the GA-ANN model gave a much better result with lesser but more relevant input variables as selected by the GA technique.

Key Words: Artificial Neural Network (ANN)Genetic Algorithm (GA), nodes

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Film Festival

Solutions for Sagebrush: Restoring an Iconic Western Landscape. AML Native Plants Project and The Nature Conservancy in Wyoming. Maggie Eshleman[1] and Corinna Riginos[1], [1]*The Nature Conservancy in Wyoming, WY, USA.*
The Nature Conservancy in Wyoming is pioneering innovative native seed technology to enhance reclamation and restoration outcomes in the Sagebrush Steppe. The seed technology project is a collaborative project supported by

restoration scientists at the Nature Conservancy, the Wyoming Department of Environmental Quality Abandoned Mine Lands Division, the Bureau of Land Management Abandoned Mine Land Program, the Office of Surface Mining Reclamation and Enforcement, and the Wyoming Mining Natural Resource Foundation. The mission of this effort is to improve sagebrush obligate wildlife habitat by re-establishing native plant communities on Abandoned Mine Land projects. Despite challenges unlocking successful Wyoming Big Sagebrush Seed Technologies, our team is enthusiastic about applying lessons learned to improve establishment of key native forbs, crucial for the life cycle of the imperiled Greater Sage-Grouse. This initiative aims to foster biodiversity, ecological resilience, and the overall health of the Sagebrush Steppe ecosystem.

Restoring Fish Passage in Maine. Marian Orlousky[1], Peter Ruksznis[2], and Steve Tatko[3], [1]*Appalachian Trail Conservancy, USA,* [2]*Maine Department of Marine Resources, Maine, USA, and* [3]*Appalachian Mountain Club, Maine, USA.*
The Appalachian Trail Conservancy (ATC), in collaboration with longtime conservation partner the Appalachian Mountain Club (AMC), remove one of the final remaining fish passage barriers in the Maine woods. Restoring stream connectivity allows the federally endangered Atlantic salmon and brook trout to swim freely upstream to spawn. It also benefits all who live, work, and play in the A.T. landscape.

Key Words: Salmon, Passage, Spawn, Connectivity, Barrier

Saving Sagebrush – Our Wyoming. AML Native Plants Project and The Institute for Applied Ecology – Sagebrush in Prisons Project. Steven McKnight[1] and BJ Klophaus[1], *Wyoming Public Broadcasting, WY, USA.*
The Sagebrush in Prisons Project, operational at the Wyoming Honor Farm since 2019, involves incarcerated adults in cultivating around thirty thousand native seedlings annually. Collaborative partners include the Wyoming Department of Corrections, Wyoming Department of Environmental Quality Abandoned Mine Lands Division, Bureau of Land Management Abandoned Mine Land Program, Office of Surface Mining Reclamation and Enforcement, and the Institute for Applied Ecology. Participants contribute to native seed collection, seedling production, and planting on reclamation projects in Wyoming's sagebrush steppe ecosystem. Throughout the growing season, an immersive experiential education on sagebrush steppe ecology fosters a direct connection between participants and the ecosystem they actively preserve and restore.

Saving the Southern Appalachian Red Spruce Forest. Connor McBane[1], Laura Belleville[1], and Brittany Phillips[2], [1]*Appalachian Trail Conservancy, USA and* [2]*US Forest Service, Marion, VA, USA.*
A relic of the last Ice Age that thrives in colder temperatures, the red spruce was once a mainstay of the eastern North American forest from the southern Appalachians to coastal Canada. Widespread logging in the 19th and early 20th centuries cut its historic range in half. This made the remaining forests vulnerable to wildfires. Today, red spruce in the southern Appalachians exist mostly on the highest mountaintops, forming dark green “sky islands.” The Appalachian Trail Conservancy (ATC) is working with partners including the Southern Appalachian Spruce Restoration Initiative to preserve the red spruce forest. In addition to providing an unforgettable experience for A.T. visitors, the red spruce trees are the center of a complex ecosystem that several endangered species rely upon for their survival.

Key Words: Red spruce, Appalachian, Forest, Restoration

Wednesday, JUNE 5, 2024

Session 7 – Technology for Reclamation Planning and Monitoring

Long-term monitoring strategies for ecological reclamation programs using spatially balanced rotating panel designs. M Curran*[1], B Robertson[2], and T Robinson[3], [1]*Abnova Ecological Solutions*, *Cheyenne, WY, USA*, [2]*University of Canterbury*, *Christchurch, NZ*, [3]*University of Wyoming*, *Laramie, WY, USA*.

Monitoring reclamation efforts is critical for regulatory compliance, to assess site performance, and to inform management actions. It is not uncommon for a single company, agency, or landowner to be responsible for monitoring many locations over multiple years. For example, oil and gas exploration and production companies may be required to monitor hundreds or thousands of well pads over decades or molre. Midstream companies may be require to monitor hundreds of miles of pipeline right-of-way reclamation efforts. Due to time, cost, and other logistical constraints it is unlikely that every location would be capable of being monitored every year. However, there is inherent risk in not developing a strategy for the entire asset -- for example, weed issues may not be recognized in certain sections of a field or wildlife habitat stipulations may be unmet. We have developed a novel method utilizing spatially balanced sampling designs and constrained clustering algorithms to create neighborhoods of well pads and pipelines to ensure solid spatial coverage is acheived across an entire asset. Then, using a rotating panel design system, we can ensure entire assets are covered over time. In our talk, we will give specific examples from a well pad system containing >300 well pads across 198,000 miles as well as a pipeline right-of-way system in Pinedale, Wyoming.

Key Words: environmental monitoring, sampling efficiency, reclamation compliance

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Using a construction-grade drone to map stream and wetland restoration sites. L. Kijek*, C. Mollick, N. Kruse Daniels, S. Teas, and N. Sullivan, *Ohio University*, *Athens, Ohio, USA*.

Functional stream and wetland restoration projects rely, in part, on floodplain connection and wetland inundation. Microtopography within wetland restoration projects can support development of a diverse plant, macroinvertebrate, and amphibian communities. Periods of inundation of wetlands can be used as a metric of successful wetland restoration, but detailed topographic surveys can be time consuming and challenging given the terrain, access, and saturation. In this work, we deployed a Skydio 2 drone, designed for construction mapping and inspection, with 6 on board cameras, to map several stream and wetland restoration sites during the leaf off winter season. At one, a 24 ha (80 acre) former-agricultural field-turned-stream and wetland, mapping was done over two field days, a total of approximately 4 hours of flight time. Operation on a single day was limited by battery life, particulary when wind speeds were higher. At several smaller floodplain reconnection stream and wetland restoration projects, mapping was more challenging due to tree canopy bordering the project, despite conflict avoidance technology built into the drone. To map these sites, several shorter flights were programmed and later combined into a single file. The photos taken, alongside their metadata, are stitched together to create a TIN which is then converted to a DEM that can be used in GIS applications to determine periods of inundation, alongside other metrics.

Key Words: Skydio, DEM, GIS

Employing machine learning and UAS for effective autumn olive treatment on reclaimed surface mines. S. Keane*[1,2], P. Kinder[1,2], M. Strager[1,2], and W. Veselka[1,2], [1]*West Virginia University*, *Morgantown, WV, USA*, [2]*Natural Resource Analysis Center*, *Morgantown, WV, USA*.

This research introduces an innovative approach for managing the invasive autumn olive (*Elaeagnus umbellata*) on reclaimed surface mines. The pervasive spread of autumn olive poses a significant ecological challenge which necessitates a more effective and efficient management strategy. This study employs machine learning and unmanned aerial systems (UAS) to enhance detection and treatment. Specifically, a convolutional neural network (CNN) model was developed to accurately identify autumn olive from UAS mounted multispectral imagery. The model's predictions will then be integrated with a UAS equipped with a precision spraying mechanism for herbicide application. The anticipated outcome is a significantly improved method of autumn olive management, offering higher accuracy, efficiency, and reduced ecological impact on desired and native species. This research holds promise for surface mine reclamation, providing a scalable and transferable solution for controlling invasive species

and post-mine land management.

Key Words: autumn olive, convolutional neural network, unmanned aerial systems

Session 7 – Reclamation in Diverse Settings

A River Runs Through It Restoration of a Highly Contaminated Site in Central New Jersey. W Young*, *University of Pennsylvania*, *Philadelphia, PA, USA*.

Cornell-Dubilier Electronics, Inc. manufactured electronics parts at a 26-acre facility in South Plainfield from 1936 to 1962, after which it was converted to an industrial park. PCBs and solvents were used in the manufacturing process, and the company disposed of PCB-contaminated materials and other hazardous waste at the facility, contaminating the soil, groundwater, and nearby areas, including Bound Brook. In 1998, EPA added the site to the National Priorities List and has been cleaning it up in phases.
Once it has been remediated, land must be returned to some state of native ecosystem. This law applies to many state and federal projects. Since every single square foot of land and riverbed was excavated and removed, entire riparian systems had to be rebuilt from scratch.
Using specialized equipment like Marsh Master® and Trillion no-till seeder, restoration commenced as soon as the site was signed off as clean by federal authorities. Ecological restoration is a cost-effective, nature-based tool that enhances resilience, supports local biodiversity, and supplies multiple ecosystem goods and services. The following native habitats were created according to their proper hydrological regimes:
Upland forest
Riparian forest
Emergent zones
Scrub shrub habitat
Lower and Upper shoreline zones
Extensive fencing was installed to deter native herbivores like Canada geese and white-tailed deer.
From 2019 to 2023, 1,823 trees and 1,019 shrubs had 86% survival, 580 Willow live stakes had 73% survival, and 17,900 two-inch plugs had about 90% survival. Bill will report on three years of extensive monitoring and annual reporting.
The entire river and floodplain was rebuilt to its former alignment and flow and flooding regimen. This paper will review the progress and findings of two restoration phases along the Bound Brook, the river that runs through the site.

Key Words: ecological restoration wetlands

Solar-farm grass establishment on the edge of the Mississippi Delta. William Stark*, B. R. Stewart, and J. D. McCurdy, *Mississippi State University*, *Mississippi State, MS, USA*.

Solar farms represent a new area in field of reclamation. When these sites are built, existing vegetation is removed, and the site is often leveled or configured to maximize energy production. Vegetation is this re-established. To date there is a paucity of research on these sites. Early sites used flat panels in which very little light reached the ground surface beneath the panels. More modern sites have panels that pivot in response to sun angle and have more space between rows of panels in which vegetation needs to be established. Criteria for vegetation include, rapid establishment, low cost, low maintenance, low growing, and the ability to crowd out weeds. An experiment on a solar farm near Greenwood, MS was established to examine both warm and cool season grasses for their use under solar panels. The warm season grasses centipedegrass (*Eremachloa ophiroides*), buffalograss (*Bueteloa dactyloides*), carpetgrass (*Axonapus fissifolius*), and bermudagrass (Cyanodon dactylon); and cool season grasses tall fescue (*Festuca arundinacea*), fine fescue (*Festuca spp.)* and annual ryegrass (*Lolium multiflorum*) as well as mixtures of carpetgrass and tall fescue, centipedegrass and tall fescue and bermudagrass, tall fescue and annual ryegrass were

planted in the summer of 2024. The experiment was a randomized complete block design with 4 replications. The warm season grasses were planted on August 6 and the cool season grasses were planted October 3. A profound summer drought limited the establishment of the warm season species but fall rains allowed for good establishment of the cool season species. Data on surface coverage and species have been collected.

Key Words: carpetgrass, centipedegrass, fescue

Session 7 – Hydrologic Applications for Reclamation Challenges

Metal Loads Accounting at a Legacy Mine Site: The Tar Creek Watershed, Oklahoma, USA. J.I. McCann* and R.W. Nairn, *Center for Restoration of Ecosystems and Watersheds, University of Oklahoma*, *Norman, OK, USA*.

Because of their hydrologic and geochemical complexity, managers of legacy sites must use available and limited funding efficiently. Characterization efforts are important for determination of locations where remedial actions will maximize benefits to ecological and human health. This study serves as an exploratory examination of Tar Creek, a second-order stream in the legacy Tri-State Lead-Zinc Mining District of northeastern Oklahoma and southeastern Kansas, to determine which reaches may be most affected by non-point source metal contamination. Water quality in the Tar Creek watershed is impacted by artesian discharges of circum-neutral pH mine water flowing from underground mine workings, runoff and leachate from mine wastes in large piles on the surrounding ground surface, and mine wastes washed into the stream channels. Data evaluated for this study included in-stream concentrations and flow measurements at multiple locations used to calculate trace metal loads. These loads were then used to determine potential areas of interest for further study to examine diffuse contaminant transport and determine trends that may be related to remedial activities within the watershed. Recent data were also compared to data collected from 2004 to 2010 to evaluate impacts from remedial work in intervening years. Although metal loads increase sharply in areas where mine drainage discharges enter Tar Creek, there are also substantial in-stream metal loads not associated with point sources, suggesting impacts from mine waste. In some sections of Tar Creek, differences between the measured downstream loads and the contributing loads (the sum of loads at the upstream location and the contributing tributaries) exceeded loads from point-source discharges, suggesting that non-point sources are the principal origin of trace metals in that reach of Tar Creek. Diffuse and tributary loads varied seasonally with fluctuations in mine pool elevation and precipitation. Future remedial efforts should be driven by holistic metals load accounting efforts.

Key Words: mine waste, mine drainage, diffuse pollution

Treatment and reclamation planning in Rehobeth, Rush Creek, Ohio. N. Kruse Daniels*, J. Bowman, and R.G. Riefler, *Ohio University*, *Athens, Ohio, USA*.

Rush Creek Watershed in Perry County, Ohio, has extensive pre-law and post-law surface and underground coal mining. The extent and severity abandoned mine land issues in the watershed meant that at pre-Bipartisan Infrastructure Law (BIL) funding levels, treatment and reclamation was beyond the scope of the state's Abandoned Mine Land program. Private landowners and local philanthropists initiated investigation of potential treatment projects prior to BIL and investigations were funded by Brownfields funds. With BIL, treatment and reclamation plans that were developed through these investigations are now becoming reality. In Rehobeth, the tributary to Rush Creek that contributes the most acidity to the mainstem, there are many sources of acid mine drainage (AMD), including multiple abandoned strip pits in Perry State Forest. To plan treatment in this complex watershed, collaborative planning is underway. Ohio Department of Natural Resources AML program is planning surface reclamation in Perry State Forest, while Ohio University is planning treatment scenarios further downstream, and Office of Surface Mines is providing advice about alternative active treatment systems. Treatment planning will be presented based on changing monitored water chemistry over time, scenarios of outcomes from reclamation projects, and challenges to do with site size, topography, and mining history. Outcomes, collaboration, and lessons

learned will be shared to inform other planning efforts.

Key Words: Coal mining, collaborative planning, active treatment

Fill type and hold time impacts to limestone-only automatic-flushing vertical flow pond performance. C. A. Neely*, T. P. Danehy, D. A. Guy, and R. M. Mahony, *BioMost, Inc.*, *Mars, PA, USA*.

The Oven Run B Passive Treatment System, located in Somerset County, Pennsylvania was rehabilitated in summer 2022 and includes three limestone-only Automatic-Flushing Vertical Flow Ponds (AFVFP) that can be operated in multiple configurations. A common operation mode of AFVFPs includes gradual filling over a 24-hour period with a rapid drain once per day yielding an average retention time of 12 hours. A more recent advancement includes a holding pond that is used to rapidly fill the AFVFP and achieve actual specified hold time. The rapid fill and drain method is referred to as Batch Operated Limestone Treatment System or BOLTS. This study, conducted from November 2023 to January 2024, evaluates the daily acid load reductions observed during 4 different tests (24-hour gradual fill/12-hour average hold, 12-hour hold, 9-hour hold, and 6-hour hold). Each test condition was allowed to run for 2 weeks prior to sampling with no instances of overflow or flow-through mode being observed. Results show the following daily acid load reductions: 24-hour gradual fill/12-hour average hold 90.0 kg (198.4 lb); 12-hour hold 104.8 kg (231.1 lb); 9-hour hold 113.9 kg (251.1 lb); and 6-hour hold 103.4 kg (227.9 lb). This corresponds to acid load reduction percentages of 62.3%, 78.3%, 68.8%, 68.0% respectively. These results show that by using the BOLTS configuration you can treat significantly more water to a higher level of acid load reduction than you can achieve with the conventional 24-hour gradual fill/12-hour average hold mode of operation. For example, the 6-hour hold (8-hour total cycle time including one-hour fill and one-hour drain) sits empty for 16 hours of the day during these tests, however if operated in BOLTS configuration the same quantity of limestone would be able to treat 3 batches of water in a 24-hour period. Thereby, tripling the daily acid load neutralization potential from 103.4 kg (227.9 lb) to 310.2 kg (683.7lb). Alternatively, designers could also use this data to help size systems more economically by reducing the quantity of limestone by 66.6% while maintaining 5.7% greater acidity load reduction than a conventional 24-hour gradual fill/12-hour average hold mode of operation.

Key Words: Passive Treatment Sizing

Session 8 – Technology for Reclamation Planning and Monitoring 2

Use of Telemetry at a Passive Treatment System to Monitor Flow, pH, and Water Level. Daniel Guy*, Timothy Danehy, Cody Neely, Logan Hauck, and Ryan Mahony, *BioMost, Inc.*

Passive treatment systems are essential for mitigating the environmental impact of abandoned mine drainage. The rehabilitation of the Oven Run B passive treatment system located in Somerset County, Pennsylvania, USA, included the installation of a solar-powered telemetry system to allow remote monitoring of pH, flow, and water elevation. Acid-neutralization is monitored using pH meters positioned after each of the two limestone-based treatment stages within the system. Flow measurement, being fundamental for understanding the overall performance of the system, is monitored utilizing an ultrasonic flow meter in conjunction with a 1.5 foot H-Flume at the system influent. Radar meters are used to track the water level in the three limestone-only Automatic Flushing Vertical Flow Pond (AFVFPs) to ensure that the programmable the fill and drain valves are working as intended. In addition to monitoring system performance during normal operation, the telemetry system has been instrumental in the evaluation of the system components during recent testing and optimization of the Batch Operated Limestone Treatment System (BOLTS). This optimization has included monitoring the impacts of various AFVFP hold times. The water level measurements have documented that the BOLTS did not enter flow-through mode, thus ensuring that the impacts of hold time are not affected by short-circuiting. These water level measurements have also been used in conjunction with the flow monitoring to assess the effective void space within the limestone and monitor for infiltration and exfiltration. Use of a telemetry system to record pH, flow, and water elevation at the Oven Run B

passive treatment site has helped to provide a better understanding of individual treatment component function while optimizing system performance.

Key Words: AMD, Solar Powered

Spatially explicit dashboards as a tool to enhance project management and decision making in reclamation. M Curran*, *Abnova Ecological Solutions*, *Cheyenne, WY, USA*.

Reclamation of disturbed lands is a challenging task. Proper project management is helpful to assist outcomes and satisfy multiple stakeholders. Soil handling and management, proper seed mix selection and installation, weed management, wildlife management, and erosion control are all factors involved with initial planning. Monitoring efforts often focus on regulatory criteria and do not always excel in letting operators doing reclamation how well their seed mixes performed or if areas are being utilized by wildlife. Additionally, reports are often generated long after field data collection and are cumbersome and overly complicated. We have developed a spatially explicit dashboard system using geo-tagged imagery and agnostic data collection techniques to easily view various aspects of reclamation outcomes. Examples of how this tool can be useful to project managers, agencies, scientists, and others involved with reclamation projects will be given. While many intracies and complexities were involved in developing our tool, it is easy to use and simple to understand. Ultimately, giving project managers and various stakeholders the ability to visualize information in a spatially explicit manner ought to improve the ability to make management decisions and better understand how their assets are performing both within and outside existing regulatory frameworks.

Key Words: project management, GIS, decision making

Session 8 – International Perspectives

A short history of changes in reclamation of Central Appalachian coal mined lands over the last 45 years. L. Daniels*[1] and J. Skousen[2], [1]*Virginia Tech*, *Blacksburg, Virginia, USA*, [2]*West Virginia University*, *Morgantown, West Virginia, USA*.

Passage of the federal Surface Mining Control and Reclamation Act (1977) drove major changes in mine operating and closure practices throughout the central Appalachian (KY/VA/WVA) coalfields. Many of the essential underlying practices (e.g. valley fill construction and acid-base-accounting) had been developed earlier in WV and KY, but implementation of new requirements to return most lands to approximate original contour (AOC) with associated excess spoil disposal valley fills led to both short- and long-term unanticipated consequences, including a progression towards larger multi-seam and mountaintop mining projects. Mandatory identification and isolation of acid-forming materials greatly improved revegetation success (particularly with topsoil substitutes) and overall water quality with respect to pH and metals. However, bulk mixing of net alkaline and acidic strata into valley fills led to long-term and continuing issues with net release of total dissolved solids (TDS), particularly for Se. In addition to potential acidity control, it was quickly realized that heavy mine soil compaction was a major factor limiting revegetation success, particularly for woody species. Initially, revegetation focused on establishment of herbaceous grass/legume stands and conifer plantings. However, common use of highly competitive species (e.g. tall fescue and sericea lespedeza) inhibited tree growth, particularly native hardwoods. By the mid-1990's, preferred reclamation protocols had been transformed by the Appalachian Regional Reforestation Initiative (ARRI) to moderate soil pH, minimize or remediate compaction, and minimize herbaceous competition for native hardwood plantings. While much smaller in total areal impact, stabilization and reclamation of coal refuse (gob) was much more challenging, particularly with respect to long-term water quality implications. Today surface mining is rapidly declining, but we are seeing increased emphasis on various "mine land repurposing" programs including refuse reprocessing, solar development, recreation and other mixed-use redevelopment efforts.

Key Words: SMCRA Central Appalachia revegetation

Community engagement as a key requirement for integrated mine closure. Coal mines in South Africa a Case Study. Jessica Pryor and Lerato Ratsoenyane*, *Digby Wells Environmental*, *Johannesburg, South Africa*.

Development of social closure plans (SCPs) require meaningful input from external and internal stakeholders to ensure concerns and opportunities in reclamation are adequately addressed. Post closure opportunities are often decided at a management level where prepopulated ideas of what reclamation should look like are determined. Reclamation is no longer focused solely on the post mining land use but on the risks and opportunities for the stakeholder within and surrounding the operation. Reclamation should be viewed as a consultative process not developed in boardrooms based on environmental permitting requirements but integrated with all levels of external and internal stakeholders. Environmental standards and liabilities contextualize opportunities for future land use but buy-in from stakeholders defines a mine's legacy.
Engagement is required with:

- **Government authorities** to share mine closure vision and objectives are aligned to national legislation and international best practice.
- **Internal management, workforce and unions** to record potential negative impacts and risks while gathering input into management actions.
- **Communities and business** within the mine's area of influence to determine economic impacts, expectations and potential partnerships for development.

Case Study: Integrated closure approach to Thungela's mine collieries. Work streams for social transitioning to closure include gap analysis, risk assessment, social baseline, economic modelling, establishment of mine closure committees, development of closure criteria as well as integration of social indicators into existing closure and reclamation plans. Incorporation of stakeholder engagement feedback loops throughout the process.
Engagement approaches need to be carefully workshopped with each mine to ensure local knowledge and risks are shared ahead of any discussions. Closure is rarely a topic management want to discuss, conscious of any backlash or protests this could trigger. Proactive engagements and preemptive planning can serve to sensitize all stakeholders to the timing of planned closure and integrate inputs into the transition phases. Thereby mitigating the element of surprise when the mine eventually reaches closure.

Key Words: social transition, social closure plan, stakeholder engagement, workforce, unions, communities, liabilities, commitments, closure vision

Coal Mine Closure Practices in China: An Overview. Li Jing*[1], Y. Paul Chugh[2], and Hu Zhengi[1], [1]*China University of Mining and Technology*, *Beijing, China*, [2]*Southern Illinois University*, *Carbondale, Illinois, USA*.

China's energy resources can be characterized as rich coal, poor oil and very little gas. Therefore, coal plays an important role in China's energy production and consumption. The raw coal production increased to 4.71 billion mt in 2023 while the number of operating coal mines continued to decrease. The coal industry is striving to consolidate under pressures for resource conservation, higher productivity, increased profitability, and improved safety and environment. Over the last decade, China has closed a large number of mines with the number of operating coal mines falling dropping from 24,300 in 2005, 14,000 in 2012, and 4,300 in 2023. Therefore, mine closure has evolved into a very important issue. Based on available data from the Energy Bureau of the National Development and Reform Commission of China, this paper will present the regional distribution of closing mines, mine closure planning and processes to deal with potential ecological risks. Guidelines for mine closure planning and monitoring have been developed and incorporated into policy implementation for mine closure for pre-mining and active operating mines. The paper will also present successful case histories of underground waste management practices, ecological restoration, abandoned mined-land utilization and community development in different areas of China. Finally, the paper will identify need for mine closure research and specific research areas that should be focused in.

Key Words: Mine closure, Practices, Research areas, China

Session 8 – Hydrologic Applications for Reclamation Challenges 2

A Study of Groundwater Conditions within the Abandoned Underground Coal Mines of Hanna, Wyoming. Joel James*, David Hibbard, and Alex Schlattmann, *Brierley Associates*, *Denver, CO United States*.

Beginning in 1890, subsurface coal extraction in Hanna, Wyoming supplied vital fuel to the Trans-Continental Railroad. Coal extraction in the Hanna area ended in 2012, making for a staggering 122 years of continuous production mining. During this production, the expansive subsurface mines, operated primarily by the Union Pacific Coal Company, were developed beneath the present-day Town of Hanna.
The depths of these coal mines vary in depths ranging from visible surface outcrops to substantial depth of approximately 370 meters at its deepest point under the town and surrounding area. A crucial aspect of maintaining these mines was the continuous dewatering process, which was necessary to ensure safe and workable conditions for miners. This prolonged dewatering led to a substantial alteration of the local groundwater regime, transforming it into a pseudo-state, distinct from its natural condition.
In present-day Hanna, where the majority of the abandoned subsurface mine workings still exist pose unique hydrogeological challenges. Many of the abandoned mines have become fully submerged as the groundwater regime attempts to achieve equilibrium. With the aquifer characteristics altered due to abandoned subsurface mine workings, the local groundwater regime displays hydrogeologic anomalies, inconsistent with conventional principles of groundwater hydrology. Select regions of the area now reside over aquifers that are subjected to artificial artesian head pressures, along with an uncharacteristically shallow water table.
This presentation aims to delve into the complex hydrogeologic impacts of Hanna's long-standing coal mining legacy. It will explore historical data, past mitigation efforts, and ongoing strategies to manage fluctuating groundwater levels. By examining these challenges, we aim to understand the broader implications and develop effective solutions for managing altered aquifer characteristics in post-mining landscapes.

Key Words: Historic Mining Groundwater Abandoned Mine Lands

Upper He Creek hydraulic and hydrogeologic control solutions in east central Tennessee. T. W. Schmidt*, *Earthres Group, Inc.*, *Pipersville, PA, USA*.

An area surface mine in east central Tennessee completed coal removal activities in 1992 in the upper He Creek watershed. Following land reclamation and grading in 1993, the backfill water level increased and mine impacted water discharged near the perimeter of the permitted areas.
A dewatering well was drilled in the backfill and a pump was installed in late 1993 to manage the discharge. Due to the effectiveness of the initial dewatering well, additional dewatering wells were added. Throughout the year, the water level in the backfill varied by more than 10 meters, introducing oxygen to the backfill where contact with pyritic material was possible.
An upper He Creek water balance study was conducted in 2013 to measure and assess all aspects of the site water balance. The results indicated 20.5% recharge, 33.6% runoff, and 45.9% evapotranspiration occurred from rainfall events during the 2013 study period.
The water balance identified recirculation loss to recharge of the pumped water. To reduce recirculation, a hydraulic control plan was developed and executed from 2014 to 2017 to extend piping, line selected channels, and remove basins. Hydraulic controls were installed from 2014 to 2017 to reduce potential recharge to the backfill. The water balance also identified areas where surface watershed runoff could be collected and routed directly to the receiving streams and locations where basins constructed in backfill areas could be removed. These hydraulic controls were installed from 2014 to 2017 to reduce rainfall recharge to the backfill.
From 2017 through 2020, the focus shifted to hydrogeologic controls. An electrical resistivity (ER) survey was

conducted to assess potential areas where groundwater may be preferentially entering the site. The ER survey determined that preventive pumping could be an option for reducing clean groundwater flow into the backfill. However, a cost benefit analysis indicated limited benefit, and preventive pumping was not pursued.
In the timeframe 2020 through 2023, activities focused on hydrogeologic controls including increased dewatering capacity to reduce variability in backfill water levels. Two new high-capacity wells were installed in 2023 to manage backfill water levels and reduce opportunities for oxygen introduction.

Key Words: hydrology, hydrogeology, dewatering