Soil

89249

Opportunities for forest slash-based biochar in abandoned mine land reclamation

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Biochar has great potential as a soil amendment for abandoned mine lands that have long-term problems with erosion, soil compaction, soil acidity and hazardous contaminants such as heavy metals. Yet, the availability of biochar for such remediation efforts is often limited or exceedingly high in cost. Ongoing efforts by the U.S. Forest Service to increase biochar production from forest slash offer synergistic opportunities to link forest fuels management with forest soil reclamation projects. Here we present on the emerging capability for biochar production from forest slash in the western U.S. and two associated biochar-based remediation projects underway in the Boise National Forest. These projects center upon surface additions of slash-based biochar and native seed mix. Treatments aim to improve soil structure, pH, water holding capacity, and ultimately the establishment of native vegetation on these otherwise barren, rocky soils left from historic mining activity. Results from these pilot studies will provide insight and guidance into viable avenues and methods for utilizing slash-based biochar applications to rejuvenate ecosystem services in disturbed and contaminated soils.
Keywords: Soil remediation, Seed establishment, Forest management

89581
nopref

Bunker Hill Complex, Ninemile Basin Remediation Progress Update
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Within Operable Unit 3 of the Upper Basin of the Bunker Hill Mining and Metallurgical Complex Superfund Site, Ninemile Basin is one of the largest loaders of heavy metals to the South Fork of the Coeur d'Alene River (SFCDR). The first mining claims were staked in 1884 and mining occurred off and on until the late 1970s. Throughout the years mines produced over 20 million ounces of silver, 700 million pounds of lead, and 650 million pounds of zinc from Ninemile Basin.
The Ninemile Basin is located north of Wallace, Idaho and is a tributary to the SFCDR. The basin is best described as having a narrow valley bottom with adjacent steep mountainous slopes typical of northern Idaho. The legacy waste rock piles within Ninemile Basin contain heavy metals, including lead and zinc, which are the primary contaminants of concern.
The Coeur d'Alene Trust began conducting work within Ninemile Basin in 2011. Initial remedial actions began in 2014 and will continue through 2026. The Coeur d'Alene Trust has completed, or is in the process of completing, remedial actions at six former mine sites along East Fork of Ninemile (EFNM) Creek and Ninemile Creek. These sites include the Interstate-Callahan (IC) Rock Dumps, Success Complex, Interstate Millsite, Tamarack Complex, Dayrock Complex, and Lower EFNM Creek. At the conclusion of remediation within the Ninemile Basin, over 1.45 million bank cubic yards of mine waste will be excavated and hauled to the EFNM Waste Consolidation Area, 102 acres revegetated, and approximately 14,600 lineal feet of EFNM and Ninemile Creeks reconstructed.
This presentation will provide an update to the IC Rock Dumps (presentation at Spokane Conference in 2016) and a remediation overview for each mine site including construction elements (waste excavation, stream reconstruction, and revegetation), challenges encountered, lessons learned along the way, and post remediation water quality updates.

Engineering/Construction

89281
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Competitive Interactions of American chestnut (*Castanea dentata)* during mine reclamation in Novel Ecosystems

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Trial plantings of American chestnut (*Castanea dentata*) are currently underway using reclaimed surface mines as reintroduction sites for hybrids bred for disease resistance to canker causing *Cryphonectria parasitica* (chestnut blight). Coalfields of the eastern US coincide with the species range, but little is known of its ecological interactions as it had largely been extirpated from the landscape by the 1940's. Non-native species such as *Lespedeza cuneata* (sericea lespedeza) have been planted extensively in the region for both agriculture and mine reclamation, and often dominate disturbed sites to form novel systems in place of native forests. We investigated the influence of herbaceous species on BC_2F_3 chestnut hybrid establishment and ectomycorrhizal (ECM) root colonization on three surface mines in eastern Tennessee that were restored using methods to avoid soil compaction. Hybrid chestnut growth, vegetation density, and species composition surrounding each seedling was assessed after eight growing seasons. ECM fungi present on root samples was quantified and identified by DNA sequencing of the ITS region. Sites differed significantly in herbaceous cover and seedling growth. Larger seedlings were found on the site that was comprised primarily of lespedeza. Average ECM colonization was similar across sites and groundcover vegetation diversity or sericea lespedeza did not influence ECM species richness. There was a difference in ECM community composition among the three sites with some fungi displaying subtle changes in species rank. Results suggest that in the absence of soil compaction, sericea lespedeza does not impede hybrid chestnut establishment or ECM root colonization in Appalachian afforestation projects.
Keywords: *Lespedeza cuneata*, FRA methods, mycorrhizal fungi

87586
oral

McDonald, PA Carbon Dioxide Mine Gas Investigation and Remediation
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On September 7th, 2021, the Office of Surface Mining Reclamation and Enforcement (OSMRE) was asked to provide technical assistance by the Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation (PADEP-BAMR) to investigate elevated CO_2 levels with low O_2 levels at a residence. The site was a single-family home on approximately one acre plot of land. The goal of this investigation was to remediate the indoor air quality.
Remediation would be considered successful if the O_2 levels remain above the minimum level required by the Mine Safety and Health Administration (MSHA); 19.5% by volume for 30 days. Long-term gas monitoring was discontinued on May 20, 2022. At that point, the O_2 levels remained above 19.5% for approximately 30 days (March 25 – April 14 and May 13 – 20, 2022).
It appears the combination of filling the mine void space with grouting, adding de-gas pipes (boreholes), and installing exhaust ventilation fans on the de-gas pipes provided new pathways for the CO_2 gas to ventilate to the atmosphere. This was effective at remediating the relatively large (approximately one acre) site. The key factor was the installation of the exhaust fans on the de-gas pipes. After the installation of the exhaust fans on the de-gas pipes, O_2 levels remained above 20%. It is hypothesized that the drilling and grouting alone wasn't as successful as it has been in the past due to the larger size of this property (i.e. more mine void space under the property).
This successful CO_2 gas remediation was unique, since historically PADEP-BAMR has completed many successful CO_2 gas remediation projects by only filling in the mine void space by way of boreholes with grouting and/or sealing cracks in a basement/garage at smaller sites approximately 0.5 acres.
Keywords: reclamation, innovations, monitoring

89408
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Tioga River restoration: a tale of active mine drainage treatment and consumptive use mitigation

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Coal was discovered in the Tioga River Watershed in 1792 and was mined significant during the 19th and 20th centuries, particularly around the village of Morris Run and the borough of Blossburg in Pennsylvania. The pollution impacts from this legacy mining stems mainly from six deep mine discharges that impact the Tioga River tributaries of Fall Brook, Morris Run, Coal Creek, and Bear Creek. Due to the adverse quality, high flows, and the compact area where the discharges are located, one centrally located active treatment plant was always the best avenue for treatment, but construction costs of this large plant were always the limiting factor. However, with the addition of funds entering from the Abandoned Mine Land Economic Revitalization (AMLER) Program and the Infrastructure Investment and Jobs Act, those construction cost limitations of a large active plant were negated. Consequently, the Susquehanna River Basin Commission (SRBC) was awarded a 2019 AMLER Grant for the design of an active plant that, when operating, will restore over 20-miles of the Tioga River, the Tioga section of the Army Corp of Engineers Tioga-Hammond Lake, and could offer nearly a billion-gallons of downstream consumptive use mitigation. In 2022, SRBC awarded a nearly $1.5 million contract to Kleinfelder Inc. for the design of the plant that will treat up to 15-MGD in split dual treatment trains each capable of treating 7.5-MGD. This presentation will describe the complexities of this centralized plant, particularly dealing with the capture and conveyance of each discharge, and the redundancy designed to ensure that high flows can be treated during significant precipitation events.
Keywords: mine drainage treatment, stream restoration, consumptive use mitigation

89226
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Soil/Site Disturbance and Challenges for Utility Scale Solar facilities in Virginia
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Development of utility scale solar (USS) in Virginia may disturb > 100,000 ha of land by 2033. Total disturbance ranges from < 20% to > 85% due to topsoil removal/return, cut/fill/grading operations, trenching, roads, structures, and stormwater conveyances and basins. Further disturbance, particularly compaction between panel runs, is likely during the 25 to 30-year lifetime, followed by another round of disturbance for removal of infrastructure. New VA regulations will require mitigation/remediation of impacts to >4 ha to prime farmlands or >20 ha of contiguous forest. Stakeholders are requesting native plant species, "pollinator friendly" assemblages, and/or improved pasture mixes for grazing. Strong soil variability under panel rows vs. middles/alleys leads to strong differentiation of vegetative species and cover. While no site-specific research on USS has occurred to date in the region, applicable work is available from surface mine reclamation and highway corridor revegetation studies. At this point in time, we recommend the following best management practices (BMP's) for USS: (1) Full transparency with respect to short, medium and long term impacts; (2) minimize soil disturbance wherever possible; (3) develop integrated revegetation strategies to meet both short-term erosion & sediment control (ESC) objectives and longer term management goals; (4) lime, P-fertilize and apply tillage to graded subsoils before topsoil return; (5) utilize direct-haul topsoil procedures when possible; (6) monitor soil/site recovery processes over time; (6) avoid acid-forming materials at all costs; (7) use conservative ESC and stormwater modeling procedures; (8) develop clear and well-expressed protocols for infrastructure removal and final post-closure landform remediation. We are also developing a larger range of site-specific BMP's.

Keywords: Solar farm, revegetation, runoff prediction

89238
oral

Management of acid producing materials for the Route 220 Project in Virginia
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Widening and relocation of U.S. Route 220 in western Virginia between 2018 and 2022 presented a significant challenge for management of potentially acid producing materials (APM). Over 700,000 m^3 of Devonian black shales were cut and filled, all directly adjacent to and upgradient of a perennial second order stream. Conventional acid-base-accounting (ABA) indicated that >75% could be net acid-forming (NNP < - 5.0 T/1000) and the original VDOT RFP criteria required that virtually all materials would need to be limed and compacted in fills. However, the criteria were complicated by (a) siderite and (b) low native soil/saprolite pH values (< 5.0) that in themselves amplified lime requirement. In cooperation with the successful design/build firm (Jacobs) and contractor (Faulconer), we sampled and tested over 300 more ABA samples (corrected for siderite) and developed a revised APM categorization scheme that indicated that approximately ~55 m^3 would be strongly acid forming and require liming+isolation, ~90,000 m^3 would require liming and compaction in place in fills, while the balance could be managed without liming. The subsequent ABA data were used to pre-designate various cut zones across the project corridor that would need specific identification of the APM as encountered. Critical to this determination was the development of a field screening system based on color, hardness, initial reaction to H_2O_2 and HCl, and the pH_{Fox} test to sort materials. All APM exposed in cuts was immediately surface-treated with 10 T/1000 of CCE limestone and then additional lime was added to cover soils as needed. Baseline water quality was assessed at 12 locations and then at 18 active locations for five years. While Fe, Mn and SC levels increased to a limited extent at several fill underdrains, pH and SC in the receiving stream was unaffected.

Keywords: Potential acidity, acid base accounting, water quality

89276
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Gills Creek, Columbia, SC, reclamation enhancement project following 1000-year flood event impacts

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The Gills Creek Watershed (GCW) in Columbia, SC, is an impaired urban watershed that was severely impacted by a 1000-year flood in October 2015, when over 46 cm (18") of rainfall fell in 24 hours causing the breaching of at least 6 dams, extensive property damage and loss of life. The watershed is 19,500 ha (75 mi^2), has over 110 miles of stream, a population >111,000 and is 55.8% urban land; the highest percentage of urban land of any watershed in SC. Prior to the flood, the waters were impaired and continue to be with E. coli, Pb, Hg and low DO, and the GCW had impacts attributable to urbanization such as advanced streambank erosion, wetland filling and impervious surfaces causing increased runoff. One severely flood impacted stream stretch, but which also was ditched, had severely eroded stream banks, and all prior floodplain areas filled and covered with impermeable asphalt, was partially reclaimed by the GCW Association with §319 Grants from EPA administered through the state agency, DHEC, City of Columbia funds and GCWA funds. The nearly $1 million dollar project enhanced 261 m (856 ft) of stream banks with measures including: 1) two large infiltration/bio-retention basins allowing infiltration to groundwater and slower release as base flow; 2) mini infiltration basins; 3) boulder placement along bank to reduce sediment loads from upstream, 4) boulder placement at bank toe to reduce slope pitch; 5) daylighting of stormwater pipes to rip rapped flow channels, 6) removal of asphalt stormwater discharge flumes and replacement with step boulders creating a series of small waterfalls to aerate water (increase DO), and 7) geolifts for enhanced vegetation. Native plants will replace invasive and non-native species along reclaimed stream. Monitoring is on-going but decreased erosion, increased sediment capture, and increased wildlife observed.
Keywords: restoration, floodway, TMDL

87593
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Superfund Remediation at Tar Creek
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The Quapaw Nation was the first tribe in the nation to assume the lead over an EPA Superfund site. The Tar Creek Superfund Site is in Northeast Oklahoma, and is a former lead and zinc mine. Closed in the 1960's, Tar Creek was listed on the National Priorities List in 1983. Since that time, more than 35 teragrams of mine tailings have been identified, and the 100 square kilometer site is undergoing active remediation and restoration. Working with landowners, EPA, and state officials, the Nation determines the best approach on a site-by-site basis, so the remediated site can be returned to productive use.
Keywords: CERCLA, Remediation, Restoration

89271
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Engineering the Nature of Change: A Presidential Dream Course on Nature-Based Solutions
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Transferring the passion of reclamation practitioners to academia presents challenges. Even in community-engaged and service-learning coursework, and in research, laboratory, and field classes, only the instructor's perspective is provided. Recognizing these challenges, the University of Oklahoma (OU) began the Presidential Dream Course program in 2004. The call for proposals for these courses asks "What sort of classes would OU faculty members devise if money were no object? They would bring in the best guest lecturers in their fields to stimulate interest and inspire students to delve more deeply." A Dream Course entitled "Engineering the Nature of Change" was taught in spring 2023. The course examined the premise that solving our many environmental challenges requires a revolution in our thinking of the relationship between humanity and the planet. The class was designed to explore ecological engineering, Engineering With Nature, natural infrastructure, and nature-based solutions. The course enrolled nearly 30 students from five academic majors. With funding provided by the Office of the Senior Vice President and Provost, five Distinguished Speakers were brought to campus. Speakers provided class guest lectures prompting conversations on specific topics. Well-publicized and well-attended evening Public Lectures were live-streamed and recorded. Speakers included representatives from the U.S. Army Corps of Engineers, White House Office of Science and Technology Policy, the private sector, and academia. Topics included Engineering With Nature and resilient infrastructure, the National Nature Assessment, passive treatment form and function, the circular economy, and an historical accounting of ecological engineering over the past 50 years. Substantial on and off campus community interest led to an extraordinary experience for both enrolled students and a much broader audience.

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Landform design in mine reclamation: is this the future?
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The practice of landform design in mine reclamation is gaining momentum as an alternative to traditional reclamation techniques which can result in highly stylized and engineered analogues for natural systems. Rigid geometric shapes, uniform slopes, and the use of non-native materials are common design features which certainly are not representative of the natural world. Conversely, landform reclamation borrows from the surrounding landscape to create a reclaimed surface that is similar to nearby undisturbed areas. The features of a particular landscape reflect how it has evolved over time and will continue to evolve based on the prevailing climatological and environmental processes unique to the area. The reclaimed mining landscape must incorporate features that reflect this evolutionary history if reclamation is to be stable and self-sustaining. Using the surrounding landscape as a guide, landform reclamation embodies the architect Louis Sullivan's famous axiom, *"form follows function."* Our planet is comprised of dynamic and evolving landscapes which hold clues for how reclaimed mine sites will perform over time. We have the tools to begin to make predictions about how these sites will evolve, thereby providing opportunity to enhance our stewardship of these reclaimed lands. Today's presentation examines why the mining community should consider adopting landform design principles as the standard for future mine reclamation.
Keywords: geomorphology, landscape, stability

Soil

89289
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Anthropogenic versus geogenic source determination of heavy metals in residential soils potentially impacted by metal smelting
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Smelting releases heavy metals (HM) into the environment and HM pollution is hazardous due to its effects on human health and the environment. Determination of soil background concentrations (those representing geogenic material) is necessary to assess potential risks associated with HM exposure. Here, data will be presented from thousands of soil samples collected from an urban residential environment (Site) to evaluate potential HM impact from nearby copper smelting. Chemistry of potentially impacted Site soils is compared with geogenic and mine-related sources. Due to the geologic/geochemical complexity of the Site, standard statistical methods are not sufficient to unravel anthropogenic and geogenic signatures in Site soils. This is partly due to incomplete characterization of mining-related potential source endmembers and the similarity between the geogenic and mining-derived soil components, both of which are elevated in arsenic, lead, copper, iron, and zinc. To distinguish geogenic from anthropogenic sources, we employ a multi-faceted approach utilizing machine learning (ML) tools (commonly applied in data science, but only recently regularly applied in environmental geochemistry) and myriad data types to recover a defensible background dataset. ML techniques are implemented to identify the most important data features controlling background and mining-related chemical characteristics. Preliminary results indicate that incorporation of ML tools with standard statistical techniques and other geochemical characterization data (e.g., chemistry, lithology, mineralogy) are invaluable to establishing background datasets and should be applied at other similarly complex sites. This multifaceted toolkit can build confidence in risk assessments, land-use planning, and environmental management practices.
Keywords: Geochemistry, Smelting, Arsenic

89827
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Innovations and advancements to Enhanced Weathering
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Beyond the progressive vast and intense emissions reduction strategies, forecasted climate scenarios reveal that huge amounts of CO_2 need to be removed from the atmosphere to avert climate warming above the dangerous levels of 1.5°C. Several Negative Emission Technologies (NET) have been proposed and research efforts to enhance its range of carbon drawdown efficiency, costs, environmental influence, etc. are being intensified. Examples of such NETs include Ocean fertilization and afforestation/Reforestation (which are organic pathways) as well as enhanced weathering and mineral carbonation (which are inorganic pathways). Of interest for this study is enhanced weathering (EW) and the innovative advancement in its knowledge. Based on reviews and research findings, here, we show EW's potential carbon dioxide removal (CDR), nutrient replenishment, and soil improvement. Its reaction rates can be accelerated by increasing the reaction temperature, decreasing the particle size and high surface area, increasing the pressure, modulate the solution chemistry through a catalyst; which could be organic or organic additives, and hypothetically biologically (such as microorganisms and bacteria). We identified up-to-date research gaps and innovative advancements necessary to maximize the potential of EW, such as its quantification, managerial demands, comprehensive knowledge, geomicrobiology, climate-based limitations, beneficial influence, and the possibility of re-emissions. Also, we argue that EW is most suitable for forest soil in tropical regions and a perfect strategy for efficient land use. Its implications for marginal lands and the reclamation of post-mining sites were discussed. For a comprehensive pathway of both organic and inorganic carbon removal and other beneficial influence of EW, we recommend the combination of different NETs.
Keywords: Negative Emission Technologies (NETs), inorganic and organic carbon

89291
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Microbes in mine reclamation: Bioecology, biofertilizers, bioeconomy
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Microorganisms play an important role in restoring degraded land, improving nutrient and carbon cycles, and soil structure, suppressing plant diseases and supporting plant productivity. The term microbiome refers to a community of microorganisms –bacteria, fungi, algae, and protozoa – that live and interact together in a defined environment. Microbiome research is generating efficient microbiome-based solutions for plant protection, fertilization, stress alleviation and plant health, while promoting biodiversity and sustainability. When applied to mine reclamation, these reduce costs related to sourcing and transporting large volumes of external capping materials and/or soils. Phytostablization is the use of plant roots to absorb pollutants from the soil and retain them within the rhizosphere, with metal mobility reduced by precipitation around plant roots, root sorption, metal valence reduction and metal complexation. The objective for successful phytostablization is the long-term succession of a plant community achieved through the promotion of soil development processes, microbial diversity, and restoration of soil ecosystem functions producing self-sustainability. While reactive organic amendments such as biosolids and compost can support short-term plant establishment, long-term growth and recruitment of revegetated plant species require systematic development of soil properties and production of a functional technosol. The current state of this approach is reviewed and a demonstration case is presented where this approach was used during reclamation of dispersed tailings of an abandoned gold mine. Implications for broader community revitalization via the bioeconomy will be discussed regarding the potential to support both climate change mitigation and adaptation, and Sustainable Development Goals.
Keywords: Microbes, PRPR, AMPs

89255
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Hydraulic Mines and Process Based Restoration: Pilot project at Grizzly Creek Diggins
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Hydraulic mine remediation requires fuels reduction from the surrounding forested areas, on-site erosion control and organic soil amendments to be successful. Hydraulic mine impacted lands are highly erosive landscapes with drought-, insect-, and disease-stressed vegetation that are often avoided during traditional forest health restoration projects. Restoring these sites with Process-Based Restoration involves using erosion control techniques from more arid regions and utilization of a forest by-product, biochar. Amending the soil with biochar reduces soil temperature, increases soil moisture potential and soil carbon, improves water quality, and reduces off-site sediment loads. Process-Based Restoration works with nature to heal nature and can result in returning mine-scarred landscapes to greater hydrologically functional watersheds and address the ongoing legacy impacts of the California Gold Rush.
Keywords: Biochar, Hydraulic Mine, Sediment

87913
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Using organic amendments to restore abandoned mine sites in northeastern Oregon
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There are thousands of abandoned mine land (AML) sites in the U.S. that need to be restored to reduce wind and water erosion, provide wildlife forage, shade streams, and improve productivity. Coupled with this is the need to dispose of waste wood from local timber operations or biosolids from wastewater treatment facilities. The use of these organic byproducts is an opportunity to increase soil cover, improve soil quality, and could be a way to decrease restoration costs. In northeastern Oregon, we used biochar, biosolids, and wood chips, alone and in combination, applied to gold dredgings capped with 10 cm of loam and, after 40 years, having little native vegetation. Plots were replicated three times and seeded with native grasses and a forb. After two growing seasons, plots with all three amendments had the greatest plant cover, improved nutrient available, and greater soil moisture. The abundant woody biomass available on National Forests that border many AMLs are an opportunity to create and use biochar or wood chips locally. In addition, many water reclamation facilities have an excess of biosolids that can contribute nutrients to AML restoration. Local creation and use of organic amendments for non-contaminated mine sites make this strategy both affordable and effective.
Keywords: Biochar, biosolids, wood chips

89384
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Limiting factors to restore abandoned mine lands with woody biochar
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Mining is a man-made disturbance that causes long-term impacts on the ecosystems. These impacts vary from landscape, to soil, water streams, air pollution, wildlife habitat, biodiversity, and human health to the surrounding communities. Mining activities started in the United States of America in 1848 with the gold rush in the West leaving behind a mining legacy of thousands of abandoned mine lands, considered health, safety and environmental hazards. Biochar has high potential for a wide variety of applications. It presents an opportunity to promote forest management in areas with high risk for wildland fire while using low value biomass for biochar production. Biochar has potential applications in mine site reclamation, soil and water remediation, for enhancing soil health, and decreasing heavy metals bioavailability.
Biochar for mine restoration has not been adopted and applied extensively in the US in spite of the benefits that it provides. Limiting factors are policy and regulations limiting production, high cost of transportation from the mill to the site, high cost of biochar per ton, and still developing biochar markets. We address limiting factors to use biochar and provide valuable information to facilitate its application on restoration of mining sites using biochar alone, or in combination with other organic amendments.
Keywords: Biochar, abandoned mine lands, restoration

89228
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Campus as a Reclamation Classroom: A case study in urban reclamation from Lexington, KY, USA
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As an urban campus, the University of Kentucky campus presents opportunities for hands-on research and teaching in urban reclamation and greening. This talk reports on a project on UK's campus that I initiated as a service- and research-learning project for my lower level honors seminar on Restoration Ecology. Our project site was a landscape strip on either side of a central campus street, immediately adjacent to the building where the class meets. Other than mature cherrybark oak trees, this landscape strip was unvegetated and had experienced significant erosion. To restore the site, we partnered with UK's Grounds and Campus Planning units to 1) reduce soil compaction with a pneumatic tilling system, and 2) develop and implement a planting plan to revegetate the area with native understory plants. For research purposes, we also implemented a biochar/no-biochar treatment and a shrubs/no-shrub treatment. We collected data on infiltration, compaction, and soil chemistry; these analyses will be repeated periodically over time to test for any effects of intervention on these soil physical and chemical outcomes. Pedagogically, this project was successful regardless of ecological outcomes. Students remarked that the project gave them a chance to apply concepts we had discussed in class in a practical or real-world context. Others commented on the value of just getting their hands dirty, or of doing something that they felt would leave a meaningful positive impact on the campus and the community. Every campus has its spaces in need of a little extra TLC—I conclude with an invitation to explore opportunities for implementing restoration and reclamation projects in your own campus and community spaces.
Keywords: urban restoration, undergraduate education, experiential education

88548
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Reclaiming the WVU farm woodlot for economic development in Morgantown, WV
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The WVU Woodlot is part of the WVU Animal Science Farm located one-mile northeast of Morgantown, WV, and is about 100 acres in size. A 15-ac underground mine is located within this woodlot and includes a dangerous 40-high highwall, spoil piles, unsafe protruding rocks, and hazardous subsidence cracks and holes that open down into the mine. In this 100-acre woodlot, a series of popular, but uncontrolled mountain biking and hiking trails have been created and some of the trails come within a few feet of subsidence holes/cracks.
This project will remediate numerous dangerous, legacy coal mining features on the WVU Woodlot, a property heavily utilized by the public as an urban woodland park and by WVU for research and education. The work proposed here will reclaim the site and create a flat area on which a commercial composting operation will be built. The composting facility will used by WVU and the city of Morgantown that will provide job training and workforce development, as well as create a value-added product from organic waste. Adjacent to the composting operation, a series of greenhouses will be constructed where WVU students and Veterans from the Welcome Home Project can produce and sell local food. Another section of the reclaimed area will provide a more user-friendly public trailhead, with an outdoor education center to support WVU teaching at the woodlot property. At present, a coal operator has agreed to conduct the mining and reclamation process, and other partners in this project include the Coalfield Development Corporation, the Office of the President of West Virginia University (WVU), the WVU Office of Sustainability, WVU Davis College, the City of Morgantown, Mountain Harvest Farm, ABJ LLC, the Preston Growers Association, and the Outdoor Education Development Collaborative.
Keywords: Abandoned mine lands, composting facility, greenhouse production

89821
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Assessing health risks at a Soviet-era mercury mine: validation of X-ray Fluorescence (XRF) for humanitarian intervention in the Kyrgyz Republic

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Khaidarkan town in Batken Province, Kyrgyzstan is home to one of the world's largest and last primary mercury mines and smelters. Doctors without Borders (MSF) and the Ministry of Health (MOH) of Kyrgyzstan identified elevated rates of non-communicable diseases (NCD) in Batken, citing heavy metals as a likely factor. TerraGraphics International Foundation (TIFO) partnered with MSF and MOH to conduct a human health risk assessment to investigate heavy metal exposures. Relying on hand-held X-ray fluorescence (XRF) for soil screening enabled the team to collect hundreds of data points at a fraction of the cost of bench-scale methods. Real-time vapor mercury readings were also taken using a Lumex at soil surface to guide screening activities. To establish a site-specific mercury conversion factor between XRF and Atomic Absorption Spectrometry (AAS), soil samples were analyzed by XRF in three stages: *in situ*, *ex situ-bulk*, and *ex situ-sieved*. The *ex situ*-sieved samples were also analyzed by AAS. Results indicate that *in situ* XRF readings can be used as a qualitative tool for screening, and a conversion factor of 1.7 was most appropriate for converting *ex situ*-bulk/*ex situ*-sieved to AAS mercury results. XRF, Lumex, and AAS results identified arsenic and antimony, not mercury, as significant contributors to human health risk. Arsenic and antimony soil contamination was identified as a significant route of exposure, especially for young children. Local vegetables grown in contaminated soils were also a significant risk for this group. Results from XRF and AAS were used to inform risk intervention activities. The XRF-AAS comparison validates the use of XRF as a rapid, cost-effective monitoring tool for mercury soil contamination.
Keywords: risk assessment, environmental health, applied science

89829
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Mercury Contamination in Huancavelica, Peru: Community Engagement to Assessment and Remediation

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Huancavelica, Peru is among the world's most mercury-contaminated cities due to 400 years of cinnabar mining and refining associated with the nearby Santa Bárbara mine. Located southeast of Lima at 12,000 ft. in the Andes, Huancavelica is the capitol of its namesake department, which is the poorest in Peru. Several assessments using community-based participatory research have identified mercury two orders of magnitude above risk-based screening levels in earthen walls and floors in 75% of the homes studied. This extrapolates to about 3,800 homes that could be contaminated above risk-based screening levels. The contamination is likely due to historic emissions of both vapor and dust from refining cinnabar in the city. Local surface soil is contaminated with mercury and other heavy metals, and such soil has been used as construction material for over half the homes in the city. Mercury concentrations in wall and floor material, as well as indoor vapor, are above USEPA and World Health Organization standards for chronic exposure and in many cases above USEPA interim removal action levels. Since 2009, community members have been engaged in research design and conduct, educational initiatives, and a remedial action pilot study. The pilot study consisted of encapsulating contaminated walls and floors to reduce both vapor and contaminated dust in the homes Vapor concentrations decreased on average approximately 60% after completing the remedial action. In addition, encapsulation of heavy metal-contaminated earthen materials significantly decreased the risk of exposure through incidental ingestion of contaminated dust, which also contains arsenic and lead above screening levels. Stucco walls and concrete floors are moderately inexpensive and are a culturally relevant remedy.
Keywords: mercury, Peru, residential

Technology

87665
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Discovery of Australian native hyperaccumulator plants for developing phytoremediation applications
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High concentrations of trace elements in soils are a widespread environmental problem in Australia, with thousands of contaminated mine sites unremediated. One option for developing new remediation approaches is to identify and utilise plants that accumulate trace metals. In particular, hyperaccumulator plants have the unique ability to concentrate certain metals or metal(loids) to extremely high concentrations in their biomass and identifying new species of hyperaccumulators is essential for applications that make use of the unique properties of these plants. To date, just 11 manganese (Mn) and three nickel (Ni) hyperaccumulator species are known from the whole of Australia. However, we suspect that Australia is probably rich in hyperaccumulator plants that remain undiscovered given its highly diverse flora (>20 000 species) coupled with its range of mineral resources and soil types. The aim of this research is to discover new Australian hyperaccumulator plants using non- destructive X-ray Fluorescence (XRF) scanning of herbarium specimens (targeting >10 000 species) at the Queensland Herbarium. The results of the XRF scanning revealed >50 new hyperaccumulator species for different elements (Mn, Co, Ni, Zn) in the Proteaceae, Cunoniaceae, Celastraceae, Myrtaceae, Apocynaceae, Phyllanthaceae, Salicaceae, Crassulaceae and Symplocaceae families. The species *G. fragrantissima* (Myrtaceae) was found to be a multi-element hyperaccumulator of Mn, Co, Ni and Zn, whereas *D. cunninghamii* (Celastraceae) is a Mn hyperaccumulator reaching up to >3 Wt. % Mn in its leaves. Australian native hyperaccumulator plants have an optimum fit for the local climate and geochemical conditions for developing phytoremediation applications on mineral wastes.
Keywords: hyperaccumulators, nickel, manganese

89253
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Appalachian STEM Enrichment Academy Online and In Person K-12 Curriculum
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The Appalachian STEM Enrichment Academy provides virtual hands-on STEM learning opportunities and career track development for K-12 students throughout Appalachia Ohio and beyond. The Academy platform provides hands-on activities and online lessons and resources and is available 24/7/365. It can be utilized by teachers, after school groups, summer camps, families, and students to access unique resources to encourage the next generation of lifelong STEM learners who will be equipped with the knowledge needed to tackle emerging challenges in our world. Lessons follow a "5E instructional model" which facilitates topical connections through engagement, exploration, explanation, elaboration, and evaluation. The online platform delivers these programs remotely, while fostering an appreciation for reclamation science, among other topics. The Academy provides career tracks in specific substantive areas including water. energy, environmental remediation, technology, and sustainability. Learning modalities include a blending of seminars, interactive online sessions, hands-on learning activities-many of which can be carried out with items found at home, career videos, and student sharing via their online postings, videos, and social media interaction. In-person classroom presentations can be provided as well upon request and dependent on available resources.
Funding for the ASEA is provided by the Voinovich School of Leadership and Public Service, the PORTSfuture Program funded by the US Department of Energy Office of Environmental Management, the American Electric Power Foundation of the Columbus Foundation, and Constellation. The Academy is free and open to the public for use from any internet-abled device at home or on the go.
Keywords: education, outreach

88021
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Missouri's Land Reclamation Information System (LRIS)
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Abstract: Missouri has approximately 16,187 hectares of permitted industrial and metallic minerals mine sites. The development of the Land Reclamation Information System (LRIS) involved at least a 10-year commitment to bring the interactive mapping system to service for public viewing and electronic permitting for mine operators. LRIS involved countless hours to improve the environmental permitting process initiated from stakeholder requests. It provides enhancements to the program's data collection, improved mapping accuracy, and transparency to the public. Regulated entities are able to easily manage mining permits. For mine operators who utilize LRIS to submit a permit renewal or amendment application, the permit issuance process is quick. In most cases, permit renewals are received and issued in the same business day. Mine operators are also able to apply for permit modifications and bond releases where they are able to use the interactive mapping tools to select and/or edit the designated area being applied for. The interactive map allows mine operators to determine accurate hectares, post-mining land uses, and auto-calculations of permit fees and bonding rates. Upon permit issuance via LRIS, all information is available for viewing online to the associated mine operator(s). One of the unique features of LRIS is an interactive map viewer of all the mine sites in Missouri for viewing by the general public, local, state, and federal governments to determine the location of mine sites along with contact and permit information. The interactive map viewer is located at:
https://modnr.maps.arcgis.com/apps/webappviewer/index.html?id=9ce9dbcc86a04cd78cd5554799155ac2
Keywords: Electronic Permitting, Interactive, Map Viewer

Vegetation

89284
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Screening native/indigenous species for tolerance to Pb/Zn/Cu tailings and using image-based analysis as a new assessment approach
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Screening of plant species for tolerance to the extreme characterstics of mine tailings should be considered to achieve successful revegetation strategy. Assessment typically involves destructive sampling and time-consuming and expensive chemical analyses. This pot experiment aimed to screening locally available rich-carbon waste byproducts for their potential to support cultivation of ecologically viable native species on Pb/Zn/Cu tailings and the use of image analysis and computer vision to assess plant response and tolerance. Substrates prepared by treating tailings with different amendments including: biosolids, compost, charcoal, woodchips, and sawdust. Several native and prairie grasses and forbs were planted in the potted substrates and photographed weekly using side-view and top-view raspberry pi cameras attached to a portable computer. Temporal plant trait data were then extracted from the images using an open source platform called PlantCV. To allow phenotypic attributes to be analyzed, first, a pipeline was developed to segment plant material out of the background. Plant responses were then quantified using shape parameters (16 measurable outputs) and color (hue and intensity). Phenotypic data revealed significant differences between species in their responses to stress induced by tailings, indicating some species more tolerant than others, and in assessing amendment strategies. Amendments significantly impacted these responses, especially the color traits, indicating alteration in metal and nutrient availability, which manifests in leaves. Correlations of the PlantCV results with the end of experiment destructive testing will be discussed to demonstrate potential for more efficient assessment of revegetation efforts for mine impacted sites and other remediation and restoration efforts.
Keywords: Phenotyping, Computer Vision, Metal Stress

89292
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Influence of native mycorrhizal fungi inoculation and co-application of biochar and biosolids on eco-restoration of Pb/Zn/Cu tailings: five-year study
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The symbiotic relationship between plants and arbuscular mycorrhizal fungi (AMF) may greatly enhance eco-restoration of mine tailings due to the provision of several ecosystem services linked to AMF-plant interactions. Inoculating prairie plants with their specific native AMF strains was found to significantly drive native diversity and richness and inhibit non-native growth during grassland restorations. This pot experiment aimed to investigate the interactive effect of AMF isolated from prairie lands and co-application of BC and BS on long-term prairie growth in mine tailings. The Pb/Zn/Cu tailings were collected from an impoundment located in Viburnum, MO, US. Two different mixtures of native AMF species were isolated from contrasting prairie environments: low-nutrient sandy soils around the Great Lakes and high-nutrient soils in Kansas and Missouri. Seasonal plant responses and temporal dynamics of tailings physicochemical and nutrient/metal bioavailability were assessed over a 5-year growth period. At the end of each growing season, soil pore water (SPW) samples were extracted using Rhizon samplers inserted in each pot. Physicochemical parameters (pH, EC, DOC) and available concentrations of nutrients and metals were determined in collected SPW. Inoculation with AMF significantly enhanced the long-term plant growth and fecundity compared to sterilized BS and BC treatments. Synergistic effects of AMF and BC were observed with temporal reduction in metal availability compared to sterilized treatments or treatments with no BC. In addition, the two AMF mixtures exhibited different impacts on plant growth responses and metal availability. Pilot-scale trials are underway to assess the interactions between prairie plants and native AMF in mine eco-restoration.
Keywords: Phytostabilization, Arbuscular mycorrhizal fungi, Revegetation

89282
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Seed Mix Design and Implementation – A Practitioner's Guide for Successful Reclamation
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Reclamation in arid and semi-arid lands poses significant challenges. This talk presents a practitioner's approach to effective seeding. Topics covered include selecting the appropriate mix of reclamation species, choosing carrier agents, multi-hopper box use, seed bed preparation, timing of seeding, seeding equipment, rates of seeding and selecting (or not!) amendments.
Keywords: Seed, Equipment, Amendments

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Reclamation Monitoring and Management: Metrics, Key Performance Indicators, and Dashboards for Projects Across their Life Spans

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Land reclamation and ecological restoration are forms of 'assisted succession'. Understanding successional concepts within a given ecosystem is helpful to gauge how a project is performing since reclamation was initiated. Vegetation characteristics will change over the life span of a given project and hence it follows that monitoring strategies should change with the successional pathway of the project. In this talk we will identify metrics (those things which can be measured) and key performance indicators (KPIs - metrics which are critically indicative of project success or failure) within reclamation projects and give examples of how these can change over time. As KPIs change over time, the intensity, methods, and tools for monitoring these metrics should also change throughout a project's life span. We will demonstrate techniques to keep statistical validity of monitoring programs across time, while also optimizing data collection at different stages of reclamation in order to best inform decision making. Examples of when and how certain tools, methods, and personnel can be incorporated into a long-term monitoring program will be shown. Next, concepts regarding dashboards (data communication tools) will be discussed and examples will be presented. We will demonstrate how these project management concepts perform within a database management framework along with examples of utilizing other data sources (e.g., climate information) to assist with decision making. Finally, specific examples of how these efforts can be used to satisfy multiple regulatory requirements and multiple stakeholders will be shown. Attendees will leave equipped with monitoring concepts and reporting strategies to make informed decisions within a project management framework, across reclamation sites.
Keywords: environmental monitoring, dashboards, decision management

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Monitoring Strategies for Reclamation Programs Involving Multiple Sites
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Monitoring reclamation efforts from energy development is critical for regulatory compliance, to assess site performance, and to inform management actions. While the importance of collecting useful information in timely and cost-effective manners at individual sites is recognized, little work has been done to address efficient methods to monitor and report findings for entire reclamation programs. It is common for large numbers of individual sites requiring reclamation to fall under the umbrella of one company or agency. Upstream oil and gas companies may have hundreds of well pads with varying reclamation status within an individual field, while midstream companies may have thousands of miles of pipeline right-of-way to reclaim across ecological and ownership boundaries. Even with efficient site-level monitoring, obtaining valuable and useful data across all sites requiring monitoring may be impractical and too costly to implement. In this talk, we discuss methods to categorize individual sites into groups, or panels, for purposes of improving program-wide monitoring efforts. A method which is particularly useful to monitor entire reclamation programs is called a rotating panel design. This method is used to conduct statistically valid field sampling across spatial and temporal schedules, resulting in major time and cost-savings without sacrificing monitoring quality. Examples of implementing rotating panel designs will be given with specific emphasis on natural gas fields. These methods will result in robust, reliable data collection which can feed into a database management framework accompanied by a dashboard system to provide rapid assessment for management decisions. While our focus will be on natural gas fields, instances where rotating panel designs are effective for other development projects will be explained.
Keywords: environmental monitoring, rotating panel design, decision management

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Reclamation of an urban limestone barrens
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Ijams Nature Center (a 501(c)(3) organization) provides education and recreational opportunities on 127 ha within the city of Knoxville, Tennessee. Pockets of former industrial land are found within the forested natural area, including the site of a former agricultural lime packing facility that includes a 1 ha basin with heavily compacted alkaline soils (pH 8.0-8.4) and widespread disturbance from recreational use. The sparse vegetation included native plant species characteristic of the relatively uncommon limestone barrens ecosystem. A reference site with similar soil chemistry (pH 7.6) and limestone barrens indicator species was located within 2.5 km. Compared to the reference site, the reclamation site was lower in soil organic matter and bryophyte cover, had a greater percentage of bare ground and invasive species cover, lower overstory basal area and diversity, and a very slow infiltration rate. Soil compaction could not be alleviated due to a cave system below the site. Objectives were to increase soil organic matter and vegetative cover to slow water flow, monitor recovery of the native plant community, and provide a working classroom. Fencing was placed to discourage bicycle and foot traffic, brush wattles were placed on steep slopes to slow water movement, and invasive species were removed. Vegetative cover was assessed in 2018, 2020, and 2023. Over the first two years bare ground had dropped from 36 to 23%, and bryophyte cover increased from 12 to 21%, compared to 47% on the reference site. In late summer of 2020 herbaceous cover was similar to that of the reference site and the average number of species per $1m^2$ plot increased from 5 to 8, compared to 13 species per $1m^2$ on the reference site. Natural recovery of vegetation is occurring relatively quickly.
Keywords: Natural revegetation, alkaline soil, tree establishment

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Loblolly Pine Survival and Growth on a Mineral Sands Mine
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Mineral sands mining in southeastern Virginia results in compacted, variably textured soils with low fertility and pH. Loblolly pine (*Pinus taeda*) is a common timber species in the southeastern United States that is well-adapted to these conditions and tolerates periodic poor drainage. Loblolly pine plantations generally require minimal inputs by landowners and may be a favored post-mining land use. In 2013, we initiated a study on a reclaimed mine in SE Virginia to assess the effects of fertilizer (F), weed control (WC), and fertilizer+weed control (WCF) treatments on *P. taeda* growth and survival. Seedlings were planted in January 2013 and treatments were applied the first two growing seasons (GS). Trees in F/WCF treatments were fertilized in March 2013 and June 2014 with 56 kg/ha N as urea, 12.3 kg/ha N as DAP, 28 kg/ha P as DAP, and 56 kg/ha K as potash. Fertilized trees also received 114.3 kg/ha granulated trace minerals in June 2014. In March and June 2013, and June 2014, 1% glyphosate was applied to WC/WCF treatments. Trees were thinned after the 10^{th} GS. After ten GS, overall mean survival was 75.4%, and mean survival excluding thinned trees was 68.3%. Survival was highest in the check (C) treatment (82.7%) and lowest in the F treatment (46.7%; $p = 0.013$). Trees in the WCF treatment had the greatest ten-year mean height (13.3 ± 2.4 cm), ground line diameter (GLD, 25.5 ± 4.4 cm), and diameter at breast height (DBH, 18.4 ± 2.9 cm). While not significant, basal area (11.3 ± 3.3 m^2/plot) and tree volume (62.2 ± 10.3 m^3/plot) were both nominally highest in the WCF treatment. Growth was initially slow, but by the eighth GS, height had exceeded that of comparable loblolly pines on undisturbed southeastern Virginia soils. Our findings show that the combination of weed control and fertilizer was the most effective treatment for *P. taeda* growth and this crop could be an economic option for landowners.
Keywords: Silviculture

89260
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Listening to the noise: what's in your data besides data?
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Reclamation depends upon data. The quality and acceptability of reclamation depends upon the comparison between baseline and reclaimed datasets. It is imperative that the people who plan monitoring, people who collect data, and people who evaluate that data understand exactly what the data is and what it is not. All data includes errors. There is no way to eliminate errors entirely. Keeping the errors to within an acceptable range, and recognizing unusual effects when they come up, makes data analysis possible.
Regular training and clear operating procedures can minimize human error. Continuity and consistency will ensure that reclamation data, often collected years or decades later, is legitimately comparable to baseline.

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Mulching and Soil Depressions for Revegetation of Oil and Gas Wells in Arid Ecosystems
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Surface mulching and soil depressions (e.g., pitting) have long been tools for ecosystem restoration. Although these techniques can improve plant establishment, they are not commonly used in oil and gas well pad reclamation, and in cases where they have been used, their effects have varied due to treatment and site factors. To better understand the application of these techniques, we first performed a review of scientific literature related to oil and gas reclamation practices in the intermountain west, which revealed that only 9% of studies evaluated mulching and 3% soil shaping/depressions. Second, we performed field studies on oil and gas wellpads in the Uinta Basin, UT, in cooperation with federal agencies (BLM, USFWS) and industry practitioners. At six locations representing a spectrum of plant community types, we compared the outcome of seeding in plots receiving surface mulching, soil depressions, artificial plant shelters, or no treatments. Regardless of seedmix or site, both mulching and soil depressions (but not shelters) increased plant density in all years except those with extremely low precipitation. Whether seeded plants benefitted more from mulching or soil depressions varied by site and year, but when used together, the effect of these tactics were additive. At several locations, mulching resulted in fewer non-native weedy species than did soil depressions, and it proved more beneficial than integrated compost where they were tested side by side at one site. In a comparison of inexpensive, locally-sourced woodchips to commercial cedar mulch, we found that the benefits of both products were equal, suggesting that affordable, effective mulch options may be readily available. This research provides new evidence that both surface mulching and soil depressions can benefit plant establishment for oil and gas reclamation in the arid west.
Keywords: mulch, pitting, revegetation

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The effects of root enhancement seed technologies and timing of seeding on Wyoming big sagebrush establishment
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Sagebrush (*Artemesia tridentata ssp. wyomingensis)* is an integral component of the sagebrush steppe landscape across the West as it provides habitat and forage to many iconic species. Establishing sagebrush is essential to successful reclamation in the sagebrush steppe. However, this can be difficult to do by seed as sagebrush tends to establish episodically during infrequent years with high spring precipitation. We have been developing a possible approach to increase sagebrush restoration success in the form of "root enhancement" seed technologies. These are targeted treatments for sagebrush seed designed to enhance root growth – and therefore drought tolerance – early in the first growing season. We have conducted iterative lab trials looking at the effects of these technologies on root and shoot length and dry biomass and have identified a few promising technologies that increased root length and root biomass. We then tested these at reclamations of varying ages in central Wyoming. Our field results have been mixed. No seed technology that we have tested has significantly increased survival overall, but we have demonstrated that some seed technologies increase mid-season survival, indicating some benefit to the seedlings. We have consistently found that regardless of seed technology, reclamation age plays an important role in sagebrush establishment. Fresh reclamations have the lowest emergence and highest survival rates, while older reclamations have higher emergence and lower survival rates. One year old reclamations have an ideal balance of emergence and survival and seeding at that time could be an alternative strategy to improve success. Our research suggests that these seed technologies and appropriate timing of seeding could be a viable pathway to improving sagebrush restoration success and are worthy of continued research.
Keywords: Establishment, emergence

89262
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Native grassland revegetation on a utility scale solar development in South Texas
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Utility-scale solar energy development is known to cause disturbance during the installation phase of construction. This causes a challenge to native grasslands which have been steadily decreasing across the United States, affecting the habitat of countless wildlife and pollinator species. To combat this growing issue, we initiated a study evaluating 4 different native seed mixes, 2 planting techniques, and 2 planting sequences to find the most appropriate methods to restore native grassland within utility scale solar developments. Our study site is 7.02 MWh (20ac) (8.1ha) experimental area within a 260 MWh (1800ac) (728.4ha) mix solar-wind development in Bee County, Texas. Treatments are replicated 5 times creating 80-0.25ac research plots. To estimate cover, I modified a pin frame to have pins enter from the side of the frame at 5 cm, 30 cm, 60 cm, and 100 cm; each pin has 10 – 10 cm sections corresponding to the 10 traditional pins. When looking at only the species included in the seed mix, seed mix significantly ($F_{[3,64]}$=4.43, P=0.0068) affected the percent cover at height one. With the low and mid diversity seed mixes averaging 24% coverage and the high and non-seeded treatments averaging 11-13% coverage. Coverage in the high diversity mixes is predicted to be lower due to a decreased percent composition of species present in all 3 seed mixes; added diversity tends to dilute species that establish and create cover. Interactions of seeding date and technique with seed mix were not significant. This can lead us to conclude that if there is good site preparation and a well-established seed mix, planting efforts can be successful.
Keywords: Restoration, seeding, foliar cover

89280
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A Practitioners Perspective: Integration of Balance Accepted Sampling, Nadir Photography and the SamplePoint Platform into an AML Reclamation Monitoring Program

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Vegetation monitoring is critical to assess outcomes of reclamation efforts associated with Abandoned Mine Lands. Traditional transect-based monitoring systems are time consuming and costly to implement, which often leads to an insufficient number of sample points to appropriately characterize a site, let alone the variation of performance across larger sites. Tetra Tech has worked with Dr. Curran of Abnova Ecological Solutions to design and implement a new reclamation monitoring system for the Wyoming Abandoned Mine Land Program, utilizing a balance accepted sampling (BAS) approach to distribute sample locations across sites, ground-based nadir image capture at the sample locations, and the photo plot sample platform, SamplePoint, to analyze the images collected. The marriage of these components in our monitoring system has allowed us to collect substantially more statistically valid vegetation/ground cover data, per unit of field time, than would be possible from traditional transect-based approaches. This talk will highlight the architecture of the monitoring system, equipment and staffing needs to implement it, lessons learned during implementation, and the programmatic opportunities that are manifesting due to its implementation, such as development of data-driven analysis and decision management system to improve reclamation approaches and performance within the program.
Keywords: Abandoned Mine Lands, SamplePoint, Balance Accepted Sampling

89229
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Urban Reforestation as Reclamation: Exploring opportunities for reclamation in an urban context

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Given that the human population is becoming more concentrated in urban areas, both in the US and globally, mitigating the negative ecological effects of urbanization is critical. The Lexington-Fayette Urban County Government (LFUCG) has conducted an annual reforestation project within the city since 1999, establishing over twenty discrete planted forest sites, but their ecological structure and function have not been assessed. In 2020, we collected a suite of ecosystem data from twenty Reforest the Bluegrass sites to evaluate whether planted trees developed forest structure and function over time. Trees and shrubs were surveyed in fixed radius plots. Understory non-woody plants were tallied by percent groundcover within the overstory plots. Finally, reforested riparian sites were evaluated for effects of reforestation on stream-water quality. Overstory trees were primarily native species that had been planted as part of the Reforest the Bluegrass program, but the shrub layer was dominated by invasive species such as Amur honeysuckle and Callery pear, especially in older sites. Furthermore, the understory plant community shifted from dominance by grasses in recently planted sites to dominance by forbs in older sites. Increasing invasive species importance was associated with reduced understory species richness. These observations underscore the key role of invasive species in structuring plant communities in urban forests, particularly in planted urban forests. Finally, water quality improved in some planted sites as streamwater passed through the reforested riparian areas. While macroinvertebrate community data were inconclusive, improved water quality in some sites suggests that riparian reforestation could help alleviate some of the water quality impacts of urbanization.
Keywords: urban forests, forest ecology, community forestry

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The Icing on the Cake – Revegetation on the Flat Creek Iron Mountain Mine Superfund Site
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At the end of the long Superfund process, it is critical to establish the permanent vegetation needed to provide site stability and erosion control as well as to kickstart the habitat restoration process. The history of the Iron Mountain Mine Superfund project will be reviewed along with a focused look at the revegetation approach used on the OU2 (streamside) portion of the restoration. The methodology and successful results of the applications will be examined in depth.
Keywords: revegetation, streamside, erosioncontrol

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Native wetland restoration projects in the tongue river valley of the powder river basin.
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Abstract
The presentation will review the various wetland projects NTEC has completed or has in progress outlining the following:

- Baseline information (vegetation, hydrologic function, wildlife)
- Remediation needs (exclusion, seeding/planting, noxious weed control, physical structure removal, enhanced dirt work, channel reconstruction)
- Remediation practices relative to: noxious weed control, undesired grazing, hydrologic function, fluvial efficiency, and wildlife habitat.
- Permitting requirements (state, county and federal)
- Success monitoring (vegetation and hydrologic function)
- Long term benefits

Included with the presentation will be explanations of the need for native wetland restoration, and its benefits to a whole ecosystem. Additional items covered will be success and failure photos, seeding techniques, technique applications for other projects, and project management details.
Keywords: wetlands, restoration, vegetation

Water

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Effect of water chemistry and time on the sustainable reuse of recovered iron oxides as phosphate sorbents
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Sustainable treatment of mine drainage must consider the economic and environmental impact of treatment processes including the fate of the mine drainage (MD) treatment residual solids. Disposition and disposal of these solids can be costly and have a large environmental footprint. Thus, finding ways to reuse these solids can help improve the economic and environmental sustainability of treatment systems. The surface chemistry and large surface area per unit mass of iron oxide (FeOOH) solids make these materials an ideal sorbent for phosphate (PO_4), possibly giving these treatment residuals a beneficial reuse. These materials and similar industrial byproducts (e.g., fly ash) have been evaluated for this purpose by several authors. However, limited research has been performed to analyze 1) how different MD water chemistries affect the resulting FeOOH mineralogy and PO_4 sorption capacity and 2) how these FeOOH solids change in situ over time and any resulting effects on PO_4 sorption capacity and possible metals desorption. This research analyzed FeOOH from net-alkaline hard-rock MD passive treatment systems (PTS) (Tar Creek Superfund Site) and from net-acidic coal MD discharges and net-alkaline coal MD PTS (Arkoma Basin). Preliminary data shows that more amorphous forms of FeOOH (ferrihydrite and poorly-ordered goethite) are found near discharges where precipitates were the freshest while more mature materials found in PTS demonstrated greater crystallinity. All samples have a large sorption capacity for PO_4 (≈90 mg/g). Although the FeOOH from hard-rock MD PTS had higher metals concentrations than FeOOH formed in coal MD discharges, minimal desorption of metals was found over time in all samples. Management and disposal of these solids can be costly, however reuse of these solids as a PO_4 sorbent may be an economically and environmentally sustainable alternative.

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The Role of Retention Basins in Alleviating Post-Mining Streams TDS Levels
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Surface coal mining in the Appalachian Region leaves highly disturbed landscapes of impaired capacity to provide ecosystem services. One of the long-lasting and persistent impacts on stream water quality is total dissolved solids (TDS), frequently exceeding ecoregion benchmark levels. Recent studies documented the high TDS levels in mining-affected streams and the slow recovery to baseline levels to persist long after completion of mining operations and reclamation; with revised prediction of recovery time rates exceeding four decades. In this study, we highlight the temporal and spatial impact of retention basins, located downstream from the disturbed area, on TDS stream water levels in previously reclaimed mountaintop-removal valley-fill operations. Data from an intensively monitored paired-watershed study and three additional watersheds are presented. Stream water TDS levels are monitored on a 15 min intervals at selected locations along the stream - at the toe of the valley-fill and above and below existing retention basins. A system dynamic modeling approach is used to conceptualize the role of the retention basins and to simulate their role in attenuating stream water TDS levels. The study is aimed at establishing a tool enabling the sizing and positioning of such retention basins to achieve desired TDS levels based on minimal data input. Empirical results from the field monitoring stations and the conceptual model and applications will be discussed. The overall hypothesis is that if properly sized and positioned, sediment ponds can be designed with long-term function in mind to be used as TDS mitigating retention basin systems, contributing to mitigating mining impact on stream-water quality long after completing their initially intend role of trapping and retaining sediments during the active mining and reclamation stages.
Keywords: Water quality, specific conductance

89264
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Observe, Orient, Decide, Act: Using the OODA Loop in long-term water management during mine closure and reclamation
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Long-term water management during closure and reclamation requires ongoing evaluation of existing treatment processes for performance and efficiency as mine and process water quantity and quality change over time. This presentation describes decision-making strategies around long-term water management, using the OODA Loop as a model for continuous evaluation. The DeLamar Mine in Idaho is presented as a case study.

Evaluation should address regulatory requirements and anticipated future changes to regulations or existing permits, operational needs, capacity of the owner/operator to change existing systems, capital and operating costs of existing and updated systems, and best available technology including lessons learned from industry. This presentation examines the process of evaluating existing water management and treatment processes, tracking regulatory drivers, selecting candidate strategies, and developing cost comparisons.

Approval of changes to long-term water management requires effective coordination with regulatory agencies. Coordination strategies are described, with an emphasis on understanding agency perspectives and goals, using agency guidance on best management practices, and developing demonstration studies to support agency acceptance.

An opportunity exists at the DeLamar Mine to optimize the existing water management approach for drainage from an adit which averages over 10 million gallons per year. The adit is dewatered continuously using a pumping station, with dewatering volumes reporting to an onsite water treatment plant where they are commingled and treated with other mine and process water sources. This presentation examines long-term management of the adit dewatering volumes using the OODA Loop and supports the 2023 ASRS site tour of the DeLamar Mine.
Keywords: Long-term water management, DeLamar Mine

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Remedial Action Effectiveness at the Bunker Hill Superfund Site.
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The Successor Coeur d'Alene Custodial and Work Trust (Coeur d'Alene Trust) manages and funds investigations and remediation of impacted sites in the Bunker Hill Mining and Metallurgical Superfund Site (Bunker Hill Superfund Site) located in North Idaho. Bunker Hill is one of the largest Superfund sites in the United States and encompasses the Upper and Lower Basins of the Coeur d'Alene River, Coeur d'Alene Lake, and a portion of the Spokane River. Metal-laden waste originating from historic mine and mill sites in the Upper Basin migrated into soil, groundwater, surface water, and sediment throughout Bunker Hill Superfund Site. The Coeur d'Alene Trust recently assisted EPA to update the approach to the Basin Environmental Monitoring Plan (BEMP) that defines how remedial action (RA) effectiveness monitoring should be conducted site-wide.
The Coeur d'Alene Trust works cooperatively with EPA to successfully prioritize work and perform RAs. As part of the RAs, the Coeur d'Alene Trust conducts monitoring to evaluate effectiveness in relation to the goals and objectives of the project consistent with the BEMP, which includes baseline and port-RA monitoring. Due to the size and complexity of the Bunker Hill Superfund Site, the RA effectiveness monitoring has been divided into three geographically based tiers: site-wide, area-wide, and site-specific. Site-wide RA effectiveness monitoring is geographically the largest tier and focuses on the entire Bunker Hill Superfund Site. The area-wide tier encompasses multiple RA sites and surrounding area (e.g., within watersheds). Site-specific is the smallest tier and focuses on the goals and objectives of an individual RA. REFER TO EMAIL TO DUSTIN WASLEY.
Keywords: water monitoring; sediment sampling; remedial action effectiveness

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Floodplain reconnection stream restoration increases water and nutrient retention
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Extensive floodplain reconnection stream restoration has been completed in rural Western Pennsylvania as a stream and wetland mitigation bank primarily for impacts of the shale gas industry. Prior to restoration, while the streams were of moderate quality and typical for the region, they showed signs of legacy land uses. Stream channels were incised and flowed along one lateral edge of the valley and showed evidence of head cutting and erosion. Restoration regraded and reconstructed both the channel and the floodplain, creating a broad, wetland floodplain with a shallow, sinuous stream channel flowing through it. The stream channels allow for inundation of the floodplain and their gradient is designed to avoid erosion except in large storm events. Restoration and reference streams were selected in three size classes – primary headwaters, headwaters and wading streams. Reference streams represent high quality regional streams. Three years of monitoring data suggest that the restoration projects improve water retention, sediment retention, and nutrient retention on the sites. There is a significant reduction in hydrologic response to precipitation post restoration, significantly higher sediment nutrient concentrations in restored versus reference streams, and significantly lower solids concentrations in restored versus reference streams. Since restoration affects site soils, carbon was evaluated. TOC varied by season and site, but not by restoration status and large woody debris was not significantly different between sites or restoration status. Variability between sites suggests the approaches that would be most effective for future applications of this restoration method. Monitoring has suggested that water level, periods of wetland inundation, perennial nature of flow, and solids analyses could act as parameters for measuring successful restoration.
Keywords: wetland, transient water storage

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Making the case for urban stream restoration and urban stream channel management
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Athens, Ohio, the home of Ohio University, sits on the Hocking River. In the 1970's amid multiple floods of the University campus, the Army Corps of Engineers rerouted the river into an engineered channel to direct floodwater through town quickly and avoid further flooding of campus. Athens is situated in the foothills of the Appalachians and is characterized by steep sided valleys and rolling hills. The relocation of the river has led to further development on the floodplain as the primary flat land in the area. The engineered channel is managed with mowing and dredging; the Hock Hocking Bike Path is a popular multi-use path built on the levy. The main urban tributary of the Hocking River in Athens, Coates Run, is confined in a partially natural, partially hardened channel amid significant floodplain development. Coates Run floods frequently, damaging businesses and restricting access to a main road, despite recent improvements to stormwater conveyance. Monitoring and evaluation suggest that changing the mowing frequency of the channelize area of the Hocking River could save money, improve pollinator habitat, and, with appropriate planting, encourage native species without threatening flood water conveyance. Water level monitoring and storm observations in Coates Run suggests that increased storm intensity, increased impervious surfaces, and physical restrictions and debris reduce channel capacity leading to increased flooding. These studies support integrated management of ecological engineering approaches to urban stormwater management. The traditional approach taken currently of quickly conveying floodwaters away from the city are not being effective for both ecological quality and flood protection, while increasing water retention through green infrastructure and, where possible, floodplain connection could improve outcomes for the city.
Keywords: flood, stormwater, green infrastructure

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Beyond reclamation and remediation, next steps in a recovered watershed
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Raccoon Creek Watershed is a 684 square mile watershed that drains 6 counties in southern Ohio. It has nearly 50,000 acres of abandoned underground and surface mines and was designated as Limited Resource Water by the Ohio Environmental Protection Agency in the 1990's. Beginning in the late 90's, there has been significant investment in reclamation and remediation throughout the watershed totaling approximately $20 million dollars over the time period. Projects have included land reclamation of abandoned strip pits and coal processing areas, treatment wetlands, a vertical flow reactor, numerous steel slag leach beds, and a lime doser. In 2017 and 2018, the Ohio Environmental Protection Agency performed a comprehensive TMDL study on the watershed, whereas previous studies had only assessed portions of the large watershed. Based on these data, the OEPA has re-designated the stream reaches from the town of Vinton at river mile 40 to the backwaters of the Ohio River as Exceptional Warm Water Habitat, and the remainder of the mainstem of the stream as Warm Water Habitat. The redesignation of the creek has opened new opportunities in the watershed. The transition from Exceptional Warm Water Habitat to Warm Water Habitat is at a low head dam that restricts fish passage. Removal of the low head dam is a priority, but community and landowner resistance will not allow the project to proceed. A recent evaluation suggests that much of the creek and the main tributary, Little Raccoon Creek, would meet state criteria for a state Wild, Scenic, or Recreational River. The new growth in funding for abandoned mine lands opens possibilities for further recovery, economic development through outdoor recreation and education, and engagement with the community on the improvements and continued maintenance of the recovered stream.
Keywords: scenic river, recreation, low head dam

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Efficacy of activated MgO, metakaolinite and their composite on the treatment of real acid mine drainage: A comparative study

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Acid mine drainage is a bio-recalcitrant wastewater matrix that poses notorious effect to terrestrial and aquatic ecosystems including other environmental compartments. This is mainly due to its acidic as well as elevated concentrations of Fe, Al, Mn and SO_4^{2-}. In essence, acid mine drainage requires to be contained and managed or treated before releasing to the receiving environment. This will then improve the integrity of the receiving environment and its capability to foster life. In this study, a comparison of activated MgO, metakaolinite and their composite on the removal of heavy and trace metals from acid mine drainage was evaluated. Advanced modern analytical instruments were used to underpin the results. Specifically, the effects of contact time and different dosages (activated MgO, metakaolinite and their composites) were determined through batch experiments. These experiments were done at 60 mins at a 10g/500mL solid–liquid (S/L) ratios, equilibrated and their capacity to neutralize acidity and reduce levels of inorganic contaminants in metalliferous effluents. The study results revealed that the pH of the solutions increased post contacting the activated MgO, metakaolinite and their composite. The levels of inorganic contaminants in metalliferous effluents were also observed to reduce after applying the activated MgO, metakaolinite and their composite. The treatment efficacy demonstrated the following performances order composite ≥ activated MgO ≥ metakaolinite. This study further concludes that polishing or complementary technique might need to be coupled to further enhance the performance of the system.
Keywords: Acid mine drainage; activated MgO; composite; metakaolinite; metal removals

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Nature-Based Solutions Linking Reclamation to Remediation and Restoration on Derelict Mining Sites

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Reclamation of mined lands and waters often does not lead to adequate ecological restoration, which is confounded at sites requiring remediation of hazardous materials. Despite decarbonization efforts, the global transition to a renewable energy economy requires continued mining. Nature-based solutions (NBS), recognizing the inherent interdependencies of humanity and nature, are key to building a sustainable future. Much can be learned from NBS applications at mine sites. The Tar Creek (Kansas-Oklahoma, USA) watershed of the Tri-State Lead-Zinc Mining District is a test bed to explore linking reclamation, remediation, and restoration on over 100 km^2 of degraded land contaminated by mining wastes. Artesian flowing mine waters, along with waste leachate and runoff, contribute elevated ecotoxic metals concentrations to receiving streams. Land reclamation activities have been ongoing for decades, with substantial initial efforts focused on soil removal in residential locations. Remediation of source materials has increased dramatically in the past decade, led by the Quapaw Nation, and has resulted in the return of previously derelict lands to agricultural use. Two full-scale mine water passive treatment systems, led by the University of Oklahoma, were installed to address selected source waters. They produce 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 richness and abundance, as well as the return of North American beaver and river otter. Although ecological restoration is implied by these reclamation and remediation activities, it is not an implicit goal of these efforts. New guidelines may provide a framework for coordinated restoration efforts.

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A hybrid and stepwise approach using a combination of MgO-NPs and a series of constructed wetland planted with *Vetiveria zizanioides* for the treatment of acid mine drainage

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An efficient, environmentally friendly and low cost hybrid approach was duly developed for the treatment of acid mine drainage (AMD). The hybrid approach combined a nano-and-biotic system operating in a step-wise modular. Specifically, the treatment chains were made up of different stages of which, stage 1 focused on activated magnesite for the neutralisation of AMD and stage 2 focused on the polishing of product water using a series of constructed wetland (CWs) planted with *Veteveria zizanioides*. In stage 1, raw AMD was treated with magnesite at a ratio of 1:100 (1g/100 mL), at 500 rpm, and 1 h of hydraulic retention time (HRT) whilst in stage 2, the pre-treated water was explicitly fed into the phytoremediation system for polishing of product water using a series of CWs planted with *Vetiveria zizanioides* in subsurface vertical flow (SSVF-CW), free water surface flow (FWS-CW) and subsurface horizontal flow (SSHF-CW) mode. In this stage, the product samples were characterised every 24 h per 5 days' interval for a period of 30 days. The feed and product sludge and plants were characterised using the state-of-art analytical techniques. Overall, the removal efficiency of chemicals species registered the following sequence, Fe (99.8%) ≥ Al (99.5%) ≥ Mn (99.24%) ≥ Zn (98.36%) ≥ Cu (97.38%) ≥ Ni (97.7%) ≥ SO_4^{2-} (80.59%). The electrical conductivity (EC) recorded ≥ 86%. The pH was observed to increase from 2.9 to 10.2. Thenceforth, the substrate, grass and external factors played a huge role in residual chemical species removal. The PH REdox EQuilibrium (in C language) (PHREEQC) geochemical model confirm that metals existed as di-and-trivalent complexes in solution.
Keywords: Acid mine drainage, hybrid approach, MgO-nanoparticles

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Early water quality changes from stream and wetland restoration in former agriculture land
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The Stream and Wetlands Foundation of Ohio has restored an 80 acre portion of the historical Bloody Run Swamp in Licking County, Ohio. The site was tiled for drainage and is surrounded by drainage ditches conveying water to Bloody Run and the South Fork Licking River. The watershed is impaired by nutrient and sediment enrichment. The restoration project included restoring the levies between the drainage network and adjacent fields, raising grade to retain water in the restored wetland, breaking tiles, and constructing a stream channel flowing through the north end of the wetland and infilling the ditch that previously flowed along the north end of the site. The stream conveys the majority of the flow on the north end of the site, with overflow in the remnants of the north ditch. Ohio University measured hourly water level, and biweekly nutrient and solids concentrations and flow prior to restoration (Spring-Summer 2022) and during the construction period (Fall 2022). When correlated with antecedent precipitation index, the response of water level to precipitation was less during construction than prior to construction, suggesting that more water is being retained in the site as construction proceeds. Nitrogen concentrations were significantly lower during construction than prior to construction, in concert with a reduction in nitrite and nitrate, but a significant increase in ammonia. No significant change in phosphorous was measured. Total dissolve and total solids were lower during construction than prior to construction. These data support this method of combined stream and wetland restoration for nitrogen and solids reduction and transient water storage. Further monitoring is continuing in 2023 as the project is completed.
Keywords: nutrients, natural channel design, watershed management

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Genomics application for optimization of constructed wetland treatment systems for oil sands process-affected water

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Bitumen extraction processes from surface oil sands mining produce large volumes of oil sands process-affected water (OSPW) (currently exceeding one billion m^3), accumulated in tailings ponds. OSPW consists of several major classes of contaminants, in particular a major contributor responsible for the toxicity of OSPW is a broad family of organic compounds called naphthenic acids (NAs). Constructed wetland treatment systems (CWTS) are one of the few nature-based passive management strategies that are feasible to reduce the toxicity of OSPW because they are cost effective, scalable, and can treat large volumes of wastewater. Increasing our understanding of how these systems operate to treat industrial water is needed to enhance efficacy, particularly in northern environments with cold winters and short summers. CWTS use naturally occurring microbes and wetland plants to target the reduction of OSPW toxicity. However, the conditions to establish optimal wetland community to degrade NAs and detoxify OSPW contaminants are not well understood. We will apply genomic-based methods to inform the efficacy of CWTS using mesocosm-scale and in-situ scale CWTS by identifying optimal conditions for NA biodegradation; understanding associated genes and mechanisms with biodegradation of NAs; developing new genomics-based tools and passive sampler methods to monitor concentrations of NAs and other OSPW contaminants; and developing CWTS that optimize the effectiveness of wetland design in the treatment of NAs and other contaminants in OSPW. This project will provide insight on the mechanisms of plant interactions to facilitate the development of a 'green' robust cost-effective system for remediating OSPW, while guiding CWTS development. Preliminary results from mesocosm-scale experiments will be presented at the talk.
Keywords: remediation, mesocosms, naphthenic acid

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Watershed-based strategy for treating acid mine drainage discharges
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Most mine drainage treatment approaches rely on treating the water at or near the point of discharge using active and passive systems suited for the site and water conditions. While these systems are generally effective, they do little to ameliorate receiving streams that often carry significant pollutant loads. We propose that addressing regulated, point source discharges, is *not* the best strategy for restoring stream miles. This is particularly true where unregulated discharges provide the bulk of stream pollution. Strategies relying solely on treatment of regulated discharges often result in no benefit to stream recovery.
Muddy Creek is a large, impaired stream in northern West Virginia, which receives hundreds of acid mine drainage point source discharges from abandoned and bond-forfeited mine sites. The West Virginia Department of Environmental Protection (WVDEP) has spent millions of dollars treating many point source discharges in the Muddy Creek watershed with chemical and passive systems. However, Muddy Creek remained impaired because over 95% of the iron and acidity loads came from dozens of abandoned mines. In 2015, the WVDEP planned the construction of a large chemical treatment plant on Muddy Creek that began operation in 2018 (costing roughly $10M to build with $530,000 annual operating costs). After four years of operation, the project resulted in restoration of 3.2 miles of Muddy Creek and an additional 16 miles of the Cheat River and Cheat Lake; both of which are now productive game fisheries.
Keywords: abandoned mine lands, acid mine drainage, mine water discharges

Wildlife

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Risks of biointrusion: small mammal and insect implications on isolated waste cover systems
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There is increasing interest from a regulatory perspective to quantify the impact of small mammal and insect biointrusion on reclaimed cover systems, yet there remains a general lack of research into these effects and how to model them. Great emphasis is placed on the characterization of hydraulic and geotechnical properties of earthen cover materials. However, available literature indicates that the creation of macropores by rooting vegetation and animal burrows significantly affect hydraulic properties of covers within a few years of implementation. Burrowing animals can affect cover performance by creating preferential pathways affecting percolation rates, exposing waste materials through castings, introducing waste material into the food chain by ingestion, and disturbing soil structure which may encourage erosion.
Current models that attempt to describe vegetation biointrusion have shown that field evapotranspiration (ET) rates are lower, hydrologic conductivity (Ks) increased, and water infiltration increased significantly with frequent rainfall at high intensity in areas of increased biointrusion. Though vegetation and animal biointrusion may work synergistically, models must be able to quantify animal biointrusion individually, as burrows are far more variable than rooting vegetation. Burrows range in width, depth, and density according to species, generally ranging from badgers and larger predators to termites and ants. A qualified ecologist/wildlife biologist should be involved in engineering design and hydraulic modeling of cover systems to conduct risk assessment of biointrusion. The risk assessment considers the plants, animals, and insects expected to inhabit the reclaimed cover system, quantifies the characteristics of the types of burrows they establish, and proffers findings on whether the anticipated biointrusion could significantly impact cover performance.

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Ecological Restoration for Insect Conservation within Natural Gas Fields
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Land reclamation and ecological restoration are required to mitigate land surface disturbances associated with natural gas extraction in the western United States. Traditional focus on these lands has been to stabilize soil to prevent erosion, though more recently, there has been an emphasis on restoring ecosystem services. Insects provide numerous ecosystem services and can be considered indicators of success for ecological restoration projects. It has been suggested that creating spatial and temporal mosaics of flowering plants will be necessary for pollinator conservation. This talk will examine two recent studies from the Pinedale Anticline and Jonah Infill natural gas fields in Sublette County, WY suggesting ecological restoration can play a significant role in insect conservation. Implications of this research will be highlighted and suggestions for developing wildlife friendly reclamation and restoration plans will be made. Furthermore, challenges related to seed availability as it relates to wildlife conservation and ecosystem restoration will be discussed.
Keywords: pollinators, ecosystem services, biodiversity

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Concurrent Vegetation and Wildlife Mapping Assists Reclaimed Desired Plant Community (RDPC) Planning
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Cedar Creek has been implementing concurrent baseline biological and reclamation planning studies for multiple projects in Nevada to support permitting efforts, including the National Environmental Protection Act (NEPA). Project sizes have ranged between 1,000 acres and over 200,000 acres. Cedar Creek designed a concurrent field data collection program that combines reclamation-specific data collection with multiple agency requirements for vegetation, grazing allotment, soil, and wildlife baseline assessment needs. The concurrent design reduces costs through concurrent data collection. Our design approach overlays Ecological Site Description data (ESDs) across topographical and elevational data, GAP wildlife habitat mapping, previous RDPC, and wildlife data to create field polygons in which to collect specific data. Field data is collected in a nested design to enable landscape-level characterization along with and finer-scale quantitative data. Reporting and other data presentation are organized and formatted to be used directly in permitting documents, creating consistency between permitting, operational and reclamation plans. We also found that wildlife presence/absence could be more precisely mapped using concurrently collected vegetation data. Merging biological baseline and reclamation characterization programs can benefit projects from permitting initiation through final closure.
Keywords: NEPA, RDPC, reclamation

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Sage-Grouse R & R
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The sagebrush steppe ecosystem is the largest interconnected habitat type in North America. It covers 165 million acres in 11 western states and one Canadian province, and is home to hundreds of obligate wildlife species that rely upon the ecosystem's health and vigor, including the greater sage-grouse (Centrocercus urophasianus). Sage-grouse habitat fragmentation and population declines across the sagebrush steppe have been so severe in the last half a century that the species has been designated as a candidate for listing under the Endangered Species Act. An endangered species listing could have the potential to severely impact Wyoming's two most iconic industries, agriculture and energy development.
Current population estimates of 425,000 breeding individuals show a staggering decline from the historical population estimate of 16 million. A wide variety of factors ranging from; disease, energy development, habitat fragmentation, invasive species encroachment, mining, wildfires, and urbanization has caused sage-grouse population declines that may best be described as death by a thousand cuts – could the solution be a million stitches?
In 2019, Governor Mark Gordon strengthened Wyoming's Sage-Grouse Core Area Management Strategy by adding habitat restoration and enhancement as a conservation priority (Exec. Order No. 2019-3). AML identified this Executive Order as an opportunity to maximize reclamation outcomes by setting goals to establish functional sage-grouse breeding, brood rearing, and nesting habitats on large-scale geomorphic reclamation projects. AML's goal of designing and building sage-grouse breeding habitat, known as leks, on large-scale geomorphic projects is a lofty goal that requires an innovative reclamation approach. This approach is aimed at achieving the objectives identified within the Governor's Executive Order, with the additional goal of expanding the greater sage-grouse range.
Keywords: Sage-Grouse, Reclamation, Restoration

Technology

87801
poster

Evaluating technologies for mining-influenced water (MIW) treatment: Information and data needs

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Numerous technologies are available for treatment of mining-influenced water (MIW) at abandoned mining sites. Case studies examining both established and recently developed technologies for treating MIW are reported in conference proceedings, reports, or journal articles. Studies range in terms of size, duration, and purpose, from bench-scale proof-of-concept testing to field pilot-scale testing conducted over a few months to years-long, full-scale field deployments. In evaluating whether a treatment is suitable for a site requiring remediation, data and information from case studies are examined, including what elements are treatable, the efficiency of the treatment, the concentrations and flows able to be treated, the volume of waste material generated, waste disposal requirements, necessary site requirements (e.g., land space required, available energy source) and costs. In examining various technologies across case studies documenting performance for six months or more in field-scale systems treating MIW from hardrock mining sites, the level of detail reported for some technologies was found to be inadequate for determining its use and transferability to a site different from the locations where the case studies were conducted. Information and data deemed necessary to be reported from case studies will be discussed along with how such data and information contribute to assessing technology transferability.
Keywords: technology transfer, choosing technologies, abandoned mine sites

Vegetation

89275
poster

Restoring Riparian Forests Using Assisted Migration as a Climate Change Adaption Strategy
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Assisted migration can accelerate tree migration by deliberately moving species poleward to overcome land use barriers and climatic factors that inhibit natural recruitment. However, there are concerns over aggressive growth or maladaptation due to soil factors. Beneficial symbionts such as ectomycorrhizal (ECM) fungi aid in tree establishment but this relationship may be impeded when transferred into new soil microbiomes. The objective of this study is to assess the survival of tree genotypes and the interactions of ECM fungi during assisted population migration. Western Washington (WA) tree stock was compared to California (CA) and Oregon (OR). Douglas-fir (*Pseudotsuga menziesii*), Shore pine (*Pinus contorta*), and Garry oak (*Quercus garryana*) were planted within an upland forest in Western Washington (100 per genotype, 900 seedlings total). Seedlings were evaluated under two environmental conditions: irrigated and non-irrigated. After the first year, shore pine had the highest growth and survival of all seedlings ($P<0.05$), and genotypes were similar when irrigated. However, under drought conditions, WA and OR had greater growth and survival than the CA shore pine genotype ($P<0.05$). No differences existed among the Douglas-fir genotypes when irrigated, however, CA and OR Douglas-firs outperformed WA Douglas-fir under drought conditions ($P<0.05$). Regarding Garry oaks, OR and WA had higher growth and survival than CA stock when irrigated, but the WA Garry oaks were superior to both CA and OR genotypes under drought conditions ($P<0.05$). ECM colonization was higher when irrigated ($P<0.05$) and molecular protocols are being used to describe fungal communities per genotype. The results will provide land managers with data that can contribute to climate adaptation protocols for future forest restoration projects.
Keywords: reclamation, assisting gene flow, ectomycorrhizal fungi

89285
poster

Assessing indicators of ecosystem recovery on reclaimed minesites in eastern hardwood forests

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It is important to be able to standardize the assessment of the recovery of ecosystem health and function on reclaimed sites. We tested 7 potential indicators that can estimate a wide range of ecosystem services such as carbon sequestration, water provisioning, and wildlife habitat. Each chosen variable was hypothesized to estimate recovery of ecosystem health and function by showing a strong relationship with time since reclamation. Variables included soil density and water infiltration, insect biomass, aboveground and belowground carbon biomass, decomposition rate, and canopy coverage. Sites were chosen 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. For comparison between disturbance types, the sampling was replicated on clear-cut timber harvest sites. In addition, control sites were selected based on minimal human disturbance within the last 50 years. On each site overstory was measured on a 1/10 acre plot, and the remaining variables were sampled on 3 sub-plots within each plot between June and September of 2022. Sampling of insect biomass and decomposition rate required two trips to each site, and had a relatively high rate of sample loss as a result of wildlife activity. Data is being analyzed to identify easily testable metrics of ecosystem function, which have great value as a tool for communication and as a quantitative assessment of reclamation success in present and future reclamation projects.
Keywords: monitoring, reforestation

89287
poster

Impact of Riverbank Lupine (*Lupinus rivularis*) on Grand Fir (*Abies grandis*) Ectomycorrhizal Symbioses

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Lupine (*Lupinus rivularis*) is used in the revegetation of coarse sediments surrounding the Elwha basin in Washington State due to its ability to improve soil conditions. Previous research illustrated that seeding lupine with conifers increased growth and foliar nitrogen, however, decreased ectomycorrhizal (ECM) root colonization, an important symbiosis for conifers used in restoration. We hypothesized the observed decrease in ECM may be due to lupine increasing soil nitrogen, negating the need for a fungal symbiont. To investigate this, we explored the interaction between lupine and ECM colonization of grand fir (*Abies grandis*) in both a field and greenhouse experiment. In the field we surveyed for a correlation between lupine and conifer growth and ECM colonization. No correlation between lupine cover and conifer growth was detected, however, ECM colonization was negatively correlated with lupine cover ($P<0.05$). In the greenhouse we investigated growth and ECM colonization of grand fir under the following treatments: 1) synthetic nitrogen, 2) N-fixing lupine, 3) non-N fixing forbs, and 4) a control. We found that growth did not differ among treatments, however, ECM colonization decreased within the nitrogen treatment ($P<0.05$) but not the lupine treatment. Additionally, conifers growing within the lupine and competition treatments had more foliar nitrogen than in the nitrogen or control treatments ($P<0.05$). The greenhouse study illustrated that N fertilizer reduced ECM colonization, not lupine, which may indicate other factors influencing fungal colonization in the field. Our results show that fertilizer may negatively impact ECM and companion plantings with native species help with the retention of N in coarse soils.
Keywords: companion planting, nutrient retention, restoration

89259
poster

New Tools for Making Science-Based Decisions for Oil and Gas Reclamation
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Oil and gas development is widespread on public land in the intermountain west, having a footprint of nearly 1.5 million acres, all of which is or will be undergoing surface reclamation to meet standards set by the governing land management agencies. However, in water- and nutrient-limited regions, revegetation on reclaimed well pads often fails to resemble target plant communities in adjacent reference areas even after decades of recovery, which underscores a need for effective tactics, accessible information, and decision-making tools for carrying out reclamation. Our team harnessed the expertise of oil and gas reclamation specialists and compiled a broad set of literature to create two substantial new tools to aid practitioners in developing successful surface reclamation strategies. First, we created a searchable online bibliography, which includes summaries of 290 products relevant to oil and gas reclamation standards, monitoring, or practices. The bibliography includes not only published scientific literature but also information available from the management community, such as project reports, manuals, and conference proceedings. Second, we created an extensive report to supplement the BLM's Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development (The "Gold Book"). The new report provides detailed guidance for planning oil and gas reclamation, including how to: identify relevant reclamation standards, select appropriate reclamation practices, and conduct effective monitoring to evaluate reclamation outcomes in light of site-specific goals. Both the online bibliography and the new reclamation report are forthcoming, and will offer up-to-date, science-based tools for the management and practitioner communities that can help streamline and amplify our efforts to create desirable, stable outcomes on retired oil and gas well pads.
Keywords: decision tool, oil and gas

Water

89240
poster

Evaluation of the use of manure-based biochar for zinc retention at the Tar Creek Superfund Site
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Chicken manure-based biochar was placed as sorptive media to retain Zn at two locations in the Tar Creek Superfund Site in northeastern Oklahoma from June to December 2022. The first area, an artesian-flowing seep at the Central Mill Repository (Repository), had low (approximately 6 LPM) but consistent flow throughout the experiment. The second location, the mine waste-impacted bed of Elm Creek near its headwaters, was impacted by severe drought during the study. Limited flow in Elm Creek led to ponding on the downstream end of the installation, which increased concentrations of K, Cl^-, and PO_4^{3-} by approximately 240, 137, and 8600 times the upstream concentrations, respectively, and decreased dissolved oxygen to 10% of the upstream concentration in the weeks following installation. Increased ion concentrations were also observed at the downstream end of the Repository installation, but the continuous flow spread the load of exchangeable ions over time. An average of 33% of the influent Zn was retained at the Repository, but Zn was exported from the Elm Creek installation. Initial equilibrium geochemical modeling of the Repository data using PHREEQC indicated that Zn sorption to precipitated iron oxyhydroxides was unlikely. Analysis of the spent biochar, along with unused biochar and iron oxyhydroxide solids collected from the Repository, was performed to determine likely Zn retention mechanisms. The in-stream placement in Elm Creek did not lead to effective Zn removal in the surface water and caused concerns about possible impacts to downstream ecosystems from increased nutrient concentrations and decreased dissolved oxygen. However, the low, consistent flow at the Repository and its disconnection from larger surface water bodies make it an area of continued interest for possible Zn removal via sorptive media.
Keywords: PHREEQC, iron oxyhydroxides, mine waste

89283
poster

Hydrology and biogeochemistry of legacy sediment riparian ecosystems
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Little is known about emerging riparian ecosystems that may become established in exposed legacy sediment deposits after reservoir depletion. A longitudinal study of the hydrology and biogeochemistry of a legacy sediment emergent riparian ecosystem is being conducted at Lake Frances on the Illinois River of eastern Oklahoma. Research objectives are to: 1) quantify hydrologic storage within the subsurface, 2) determine pools and flux mechanisms of several major constituents (e.g. C, N, P, S, Mg, Fe, Pb, Na, and Si) within soils, groundwater, and surface waters throughout the legacy sediment riparian ecosystem, and 3) demonstrate the potential of legacy sediments in emerging riparian zones to provide ecosystem services as nature-based solutions. Initial soil and surface water samples have been collected from throughout the site to provide a framework to identify potential controls on nutrient fluxes and controlling factors (e.g., sediment particle size, presence of metal oxides or organic matter). Following data collection and analysis, mesocosm experiments are planned to model the effects of emerging riparian ecosystems on sediment deposition, nutrient cycling, and soil moisture retention during hydrologic extremes. The role of legacy sediment deposits on watershed hydrology and the extent of legacy sediment effects on retention or release of specific constituents to surface waters decades after reservoir depletion will be elucidated.
Keywords: Hydrology, Biogeochemical cycles, Legacy sediment

89244
poster

Combined stream and wetland restoration on agricultural ground: Bloody Run, Ohio
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Bloody Run is a tributary to the South Licking River in Licking County, Ohio. Land use is primarily agricultural in this watershed (Bell Run-South Fork Licking River). In 2020, the Stream and Wetlands Foundation of Ohio acquired an 82-acre parcel of tile-drained farmland on which it restored the field to wetland conditions in late 2022. Two ditches drain the field, one on the north border and one on the south, before merging with Bloody Run to the east. To accommodate the flow-through wetland, the straight, northern ditch was reconstructed to meander through the wetland and will be reconnected to Bloody Run in early 2023. The goal of this project is to assess the impacts of combined stream and wetland restoration on water quality in Bloody Run by comparing pre-construction and post-construction conditions and nutrient retention capacities. Chemical and sediment data was gathered prior to wetland construction at several points in the drainage ditches and downstream Bloody Run, representing a baseline of data for pre-treatment conditions. After the restored northern channel is reconnected, water and sediment samples will be taken from seven sampling sites in the stream and wetland and analyzed for nutrient concentration. The site is expected to retain more nutrients and water during high flow time periods than pre-construction conditions. Further research objectives will be to determine hydrology in the old and new north channel, including the effects of storm events on hydrology, and to quantify erosion rates in the old channel as a result of restoration. Parameters of the study include field measurements (pH, specific conductivity, dissolved oxygen, etc.) and chemical analytes from water and sediment grab samples (nitrates, orthophosphates, total organic carbon, etc.). The post-construction study period will be on-going until summer 2025.
Keywords: channel reconnection, sediment, nutrient retention

89274
poster

Engineering With Nature to Develop Socially Sustainable Nature-Based Solutions: Natural Infrastructure to Address Complex Environmental Challenges

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Solving complex environmental problems requires a revolution in thinking of the relationship between humanity and the Earth. Twentieth-century solutions – based on "gray" infrastructure driven by fossil fuels – cannot sustainably address the complexity and interrelatedness of the 21st century problems we face. Nature-based solutions, based on renewable energies and recognizing the inherent, yet oft-neglected, interdependencies of humanity and nature, hold promise for building a sustainable future. Natural infrastructure approaches to some of Oklahoma's most intractable water challenges have been the focus of teaching and research for many years at the Center for Restoration of Ecosystems and Watersheds (CREW) at the University of Oklahoma. CREW conducts research focusing on Ecological Engineering (the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both) along with related areas of inquiry including Engineering With Nature (the intentional alignment of natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits through collaboration), natural infrastructure, green infrastructure, natural and nature-based features, and nature-based solutions based on the idea that sustainable solutions require working with natural ecological, hydrological, and biogeochemical processes and not against them. Research efforts include passive treatment of trace metals-contaminated mine waters, addressing emerging contaminants through treatment wetlands to support indirect potable reuse of municipal wastewater, amelioration of excess nutrient problems and degraded habitat through riparian conservation easements, urban stormwater low impact development best management practices, and reservoir enhancement through wetland restoration.

89286
poster

Physical classification of iron oxyhydroxide treatment residuals for reuse in stormwater treatment
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Iron oxyhydroxides are a solid residual produced in the passive treatment of metals-contaminated mine drainage. Unaddressed, the accumulation of this material in oxidation ponds and other process units shortens the lifespan of passive treatment systems. Finding effective options to encourage removal and beneficial reuse of iron oxyhydroxide residual solids is becoming increasingly important to maintain these essential water quality improvement systems. Iron oxyhydroxide residuals have been shown to be particularly effective at sorbing phosphorus and therefore have potential for reuse in stormwater treatment media. In this laboratory study, iron oxyhydroxide samples were collected from two alkaline hard rock mine drainage passive treatment systems, an alkaline coal mine drainage passive treatment system, and two acidic coal mine natural drainage sites. Iron oxide materials were characterized by particle size, particle density, and bulk density following standard geotechnical methods. Hydraulic conductivity was estimated using falling head permeability tests for both the pure iron oxyhydroxide residuals as well as residuals amended with various percentages of clean sand. Simulated stormwater flow-through tests determined the likely water quality improvement effectiveness of the iron oxyhydroxide amended media. The results of this research are intended to aid in the design of a pilot system for the treatment of stormwater using iron oxyhydroxide residuals from passive treatment systems. Further work on this topic will include final designs, prototyping, implementation, and monitoring of the stormwater treatment design.
Keywords: urban runoff, phosphorus, sorption

Wildlife

89290
poster

Do Beaver Dam Analogs (BDAs) reproduce the biodiversity and water filtration ecosystem services provided by beavers?
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Ecosystem engineers, or species that significantly modify their environment to suit their needs, profoundly affect biodiversity and landscape heterogeneity. North American beaver (Castor canadensis) is an allogenic ecosystem engineer that alters ecosystems through dam construction, facilitating various ecosystem services, particularly in arid environments. Beaver dam analogs (BDAs) are increasingly used across the western U.S. to restore ecosystem function and stream health when beavers are extirpated from a system. Our research question is: **Do BDAs reproduce the biodiversity and water filtration ecosystem services provided by beavers?** If BDAs promote biodiversity and filter water at equivalent levels, we predict observing higher species richness and lower pathogen loading in beaver and BDA reaches compared to control reaches. Using a Before-After-Control-Impact (BACI) design, we will collect eDNA and water quality measures at ten points within a control reach (little to no beaver), a natural beaver dam reach, and a BDA stream reach. With eDNA, we plan to retrieve biodiversity metrics via amphibian presence/absence, the relative abundance of amphibians, sensitive species of invertebrate presence, and E. coli loads. Our results will provide insight into the efficacy of an increasingly commonly-used stream restoration technique.
Keywords: Beaver, amphibians, eDNA