Governing Unconventional Legacies: Lessons from the Coalbed Methane Boom in Wyoming[1]

K. B. Walsh* and J. H. Haggerty[2]

Abstract: Surface reclamation is a critical feature in the legacies of unconventional energy development. U.S. legal frameworks are in place to govern reclamation, but vary widely by state. While it is too early in the development cycle to assess the status of shale gas legacies, there are instructive case studies that draw attention to the challenges of governing reclamation. This paper explores land reclamation outcomes of the coalbed methane gas boom in the Powder River Basin of Wyoming and the ensuing issue of widespread well abandonment. We argue that the challenges associated with coalbed methane reclamation in the Powder River Basin track closely with what can be expected in the context of shale gas governance. Drawing on an extensive review of scientific literature on reclamation, policy analysis, and stakeholder interviews, we argue and specifically identify three key factors that have interfered with the effective definition, regulation and implementation of coalbed methane reclamation: (1) the absence of clear guidance from the scientific literature about what constitutes successful reclamation; (2) the complexity of both the jurisdictional environment and the oil and gas sector in the coalbed methane space; and (3) a lack of political will in the state of Wyoming to engage in pre-emptive environmental regulation. This paper aims to explore how these factors coalesce to make implementation of effective reclamation a highly complex governance challenge.

Key words: reclamation policy, coalbed methane, Wyoming

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1. Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017.

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Some thoughts on planting native tree species in mineland reforestation[1]

Mary Beth Adams[2]

Abstract: Successful reforestation of reclaimed minelands requires planting a variety of native tree species. The Forestry Reclamation Approach (FRA) recommends using a mixture of early successional and high value hardwood species to achieve ground cover/stabilization goals and to ensure economic value in the long run. Other considerations can perhaps be added as goals, including control of species diversity, reintroduction of native species extirpated by pathogens or mismanagement, increasing genetic integrity and ensuring important ecosystem services. In this talk, I discuss opportunities to use tree planting to address these and other goals. I will highlight opportunities particularly for incorporating American elm, American chestnut, and other species. Due to Dutch elm disease (DED), American elm can be rare in some landscapes. However there exist some DED- tolerant trees and research is ongoing to identify survivor trees which may be resistant to the disease. In 2013 and 2014, DED-tolerant seedlings were planted at 14 sites in the Appalachian coal fields from Alabama to Pennsylvania. Elevations ranged from 220 m to more than 900 m, and sites included FRA sites, legacy mine sites (sites that had previously been reclaimed under SMCRA between 1992-2005), and AML (abandoned mine land) and bond forfeiture lands. Survival, diameter, and height were measured on 7 of these sites over the first 2 growing seasons following establishment. Survival after 2 years on most of the sites exceeded 75% with one exception, that being a site with significant browsing by deer and elk, where survival dropped to 65%. After two years, the average height of the DED-tolerant American elm seedlings was 61.6 cm, and was nearly identical to that of yellow poplar, another early successional species. Nor were there large differences between the 2 species in vigor class or survival.

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Stand Level Nutrient and Carbon Content Across One Rotation of Loblolly Pine Plantations on a Reclaimed Surface Mine[1]

H.Z. Angel[2*], J.S. Priest, J.P. Stovall, B.P. Oswald, Y. Weng, and H.M. Williams

Abstract. Understanding temporal changes in nutrients and carbon (C) in aboveground tree biomass over many years can provide information regarding ecosystem recovery following a disturbance. Loblolly pine (*Pinus taeda*) trees growing on reclaimed mined lands in east Texas exhibit similar productivity compared to unmined lands. However, it is unclear how carbon and nutrients in aboveground components affect growth rates or differ from forests on undisturbed land. Numerous studies have previously assessed loblolly pine aboveground biomass, C, and nutrient contents; however, similar data have not been collected on mined lands for loblolly pine in the Gulf States region. Using a chronosequence approach, we investigated C, N, Ca, Mg, K, and P contents for first rotation loblolly pine growing on reclaimed mined lands in east Texas over a 32 year period. Elemental contents were analyzed using a CN analyzer and ICP, and results were then scaled using previously published allometric relationships for these stands to an individual tree and stand level basis by three tissue components (foliage, branches, and stem wood). Generally, stands on mined lands followed similar trends in nutrient and carbon contents to values reported in the literature for stands on unmined land.

Additional Key Words: Biomass productivity, carbon sequestration, tree age sequence

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Surface and Subsurface Tillage Effects on Soil Properties and Tree Growth at an East Texas Lignite Surface Mine[1]

H.Z. Angel[2*], H.M. Williams, and J.P. Stovall

Abstract. Luminant has planted over 38.7 million trees on its reclaimed lignite surface mine operations in Texas since 1974. For decades, the use of improved reclamation techniques on Luminant's mined lands have resulted in quality reclamation with over 31,160 hectares reclaimed to forests, wildlife habitat, and pastures with productivity levels similar to that found on undisturbed lands. Development of new reclamation methodologies offers opportunities to further improve productivity potential of planted trees at Luminant's Martin Lake Oak Hill Mine in east Texas. The conventional haulback or 'truck-shovel' reclamation method uses haul trucks for the selective transport and placement of oxidized overburden to serve as the reforestation growth medium. Overburden transport and placement can also be accomplished using tractor pulled scraper pans; however, there is a lack of information regarding the effects of scraper pans on mine soil compaction and tree growth. To address the potential compacting effects of scraper pans, four soil tillage techniques (n=5) were implemented in August 2015: 1) no tillage (control); 2) disking (30-35 cm depth); 3) single ripping (90 cm depth) and disking (30-35 cm depth); and, 4) cross ripping (90 cm depth) and disking (30-35 cm depth). Soil physical and chemical properties were investigated at 0-30, 30-60, and 60-90 cm. Vegetative response was measured for the winter cover crop in May 2015 and for loblolly pine (*Pinus taeda*) tree seedlings in October 2016 after one growing season. Aboveground biomass production of the winter cover crop was higher for the ripped treatments. When compared to control plots, tillage significantly decreased soil bulk density at 0-30 cm and increased tree seedling survival. Cross ripping was superior in terms of lowering bulk density at all three depths and increasing tree seedling volume index. Above and belowground biomass of loblolly pine seedlings followed similar trends.

Additional Key Words: Reclamation, soil, compaction, bulk density, vegetative response

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High Sulfate Mining Wastewater Treatment by Two-Stage Chemical Precipitation Process [1]

K. Banerjee, H. Kronebusch*, and S. Muddasani[2]

Abstract: A treatment process was developed to treat high sulfate wastewaters for sulfate removal to less than 100 mg/l. The treatment system is comprised of a two-stage chemical precipitation process. The first stage uses a one-time addition of seed material and sludge recirculation to reduce sulfate to less than 1,800 mg/L. The second stage process precipitates sulfate as a highly insoluble calcium sulfoaluminate mineral known as Ettringite. The sludge from the second stage is treated to recover the aluminum from the Ettringite solids as aluminum hydroxide which is reused in the Ettringite precipitation process. Two methods of treatment can be employed for Ettringite destruction and aluminum hydroxide recovery; either by using hydrochloric acid and solid/liquid separation equipment or by using sulfuric acid and solid/solid separation equipment. A pilot study (4 m^3/hr design flow) was conducted on gold mine wastewater in South Africa to evaluate the performance of both processes. The impacts of sludge recirculation ratio and chemical dosages were investigated. Dissolved sulfate and total aluminum were analyzed by Ion Chromatography (IC) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS) methods respectively. Using X-ray diffraction (XRD) and X-ray fluorescence (XRF) methods, the characteristics of the Ettringite and recovered aluminum hydroxide solids were determined. Pilot study results and chemical consumption along with preliminary operating and capital cost will be presented and discussed for the proposed processes.

Additional Key Words: Ettringite, Aluminum Recovery, Gypsum Desaturation.

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Ecological Restoration on the Mower Tract within the Monongahela National Forest, WV [1]

Chris Barton[2*], Shane Jones[3], Scott Eggerud[4], Todd Kuntz[3], Anna Branduzzi[3], and Patrick Angel[4]

Abstract: Green Forests Work in partnership with the US Forest Service, Appalachian Regional Reforestation Initiative, West Virginia Division of Natural Resources, NRCS Plant Materials Center, and the Central Appalachian Spruce Restoration Initiative has implemented an ecological restoration project on 2,600 acres of mine impacted land in the Monongahela National Forest. The project is located on Cheat Mountain, which traverses the entire length of central Randolph County, WV. This high elevation site was historically a red spruce-northern hardwood ecosystem prior to mining and logging activities. The red spruce ecosystem of the Central Appalachians is characterized by exceptionally high biodiversity and is a priority for conservation and restoration. The project area (Mower Tract) was mined for coal in the 1970s. During reclamation the site was returned to approximate original contour and planted with non-native trees and grasses. Restoration activities were initiated in 2009 to reduce impacts from the mining and to restore the red spruce ecosystem. A holistic suite of restoration strategies including soil decompaction, wetland restoration, woody debris loading, and planting of native trees and shrubs have been employed. To date, this partnership has performed restoration activities in over 500 acres of the watershed, created over 400 vernal pools/wetlands, and planted over 250,000 native trees and shrubs. Objectives achieved through implementation of this project will minimize impacts from past mining activities and help conserve and ensure long-term viability of the important plant and animal species associated with this high elevation forest and associated wetland communities.

Additional Key Words: Forestry Reclamation Approach, vernal wetlands, red spruce

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[3.] Shane Jones, Wildlife Biologist, Todd Kuntz, Forest Technician, and Anna Branduzzi, Forest Technician, Monongahela National Forest, USDA Forest Service, Bartow, WV 29420.

[4.] Scott Eggerud, Forester, OSMRE, Ona, WV 25545; and Patrick Angel, Soil Scientist, OSMRE, London, KY 40741.

A FIELD DEMONSTRATION OF AN ALTERNATIVE COAL WASTE DISPOSAL TECHNOLOGY – GEOCHEMICAL FINDINGS[1]

P. T. Behum, L. Lefticariu, and Y. P. Chugh

Abstract: The objective of this study was to develop alternate management practices for coal refuse disposal which will minimize the release of sulfate (SO_4) and chloride (Cl) into surface water discharge. It was designed to provide confidence to mine operators to develop and implement innovative concepts for engineered waste disposal at coal mines. Field-scale kinetic testing (leaching columns) was employed to investigate whether co-disposal of coarse and fine coal refuse will provide an improved geochemical environment necessary to minimize total dissolved solids (TDS) in refuse area discharge, while maintaining adequate geotechnical stability. The impact of alkaline addition (moderate additions of ground limestone to the coarse and fine coal refuse blend) was also investigated as a means of increasing both the geotechnical stability and the buffering capacity of the simulated co-disposed waste fill. The primary purpose of this paper is to present our geochemical findings. Nineteen months of field testing was conducted at an active Southern Illinois mine site using duplicate 100-gallon leach columns [oval, polycarbonate, stock tanks 113.4 cm (52.5 inches) long by 94 cm (37 inches) wide by 53.3 cm (21 inches) tall] containing three compacted refuse blends. Two columns contained coarse refuse, representing the existing practice (the control), two columns contained a fine and coarse coal refuse blend (simulating co-disposal) and two columns contained blended refuse with 10% (by volume) ground limestone. We found that the mobility of sulfate was significantly lower in leachate derived from columns composed of the compacted blend of coarse and fine refuse as compared to compacted coarse refuse alone. Additional improvements in leachate chemistry were observed in columns simulating blended refuse with limestone addition. In this experiment, Cl was extracted at a considerably higher degree than S. The counter ion Na was also elevated in column leachate, but could have also been derived from cation exchange (with Ca) in abundant clays associated with the run-of-mine (ROM) coal in the region. Kinetic testing revealed a rapid decline in bicarbonate (HCO_3) concentration as compared to sulfate (SO_4) concentrations suggesting that either carbonate weathering rates far exceeded the sulfide rates or that alkalinity-producing minerals were passivated (coated with mineral precipitates), thereby limiting carbonate dissolution. In the course of leach testing higher pH conditions in columns simulating the two co-disposal options may have enhanced precipitation of oxy-sulfate minerals such as K- and Na-jarosite, minerals which can sequester both Fe and S. Both of these sulfate minerals were predicted to form during the late leaching period (> 7 months) in geochemical models. Modeling also indicated that Fe hydroxides will form within the columns at higher pH (> 6) during early leach testing (< 7 months) and may have combined with jarosite to limit the mobility of Fe. This research was conducted partial support from the Illinois Clean Coal Institute.

Additional Key Words: Sulfate, chloride, TDS, co-disposal, coal refuse, alkaline addition.

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Tree seedling survival after planting under varying treatments on reclaimed mine land[1]

Patrick J. Boleman* and Rebecca M. Swab[2]

Abstract: Reforestation of previously mined lands is essential for improving ecosystem services and restoring forest ecosystems in the Appalachian region of the United States. At *the Wilds*, a conservation and research facility in southeast Ohio, forests historically dominated the landscape. Reclamation of the previously strip mined land occurred in the mid to late 1900s. Initial reclamation involved reforestation, however after federal regulations in the 1970s reclamation primarily involved grassland establishment. Reforestation projects in these grassland areas have had limited success due to factors such as soil compaction, low nutrient availability, and competition from invasive grasses. To increase tree seedling survival rate, an experiment was designed to test multiple planting treatments: fertilization, Terra-Sorb® root dip, post-planting herbicide application, and a control. In the spring of 2016, roughly 5,000 tree seedlings were planted representing five native hardwood species. By October of 2016, white oaks (*Quercus alba*) had the highest survival rates for the species planted while tulip poplar (*Liriodendron tulipifera*) had the lowest. Survival rates also varied by treatment method with fertilized plots showing the highest survival (94.8%) and herbicide plots having the lowest (88.1%). Both tree species and treatment method were shown to have a significant effect on seedling survival rates. Survival results from treatment methods were unexpected as they run contrary to contemporary tree planting protocol, where sites are typically not fertilized at establishment and are often sprayed with herbicide to reduce vegetative competition. Herbivory was observed to be higher in plots with less vegetative cover, thus reducing seedling survival rates. This suggests herbicide application could have increased mortality through increasing herbivory. Further investigations will survey mortality by herbivory to determine if treatment method affects herbivory and survival. The results from this study will help guide future reforestation projects at *the Wilds* and on other reclaimed mine lands in the Appalachians.

Additional Key Words: Reforestation

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3D Modeling of the Sand Coulee Basin Abandoned Mine Lands

Kristin M. Brown*

Abstract: This case study describes the process of creating 3D models in order to make regulatory decisions. Belt and Sand Coulee are two towns with acid mine drainage issues from abandoned mine lands. They are located in the Sand Coulee Basin of the Great Falls coal field in Montana. Montana Department of Environmental Quality (DEQ) Abandoned Mine Lands program is currently working on water treatment options for the acid mine drainage (AMD) from the abandoned mines and has already installed a system to bring clean drinking water to the town of Sand Coulee. Earth Vision modeling software created by Dynamic Graphics was used to build the model. LIDAR, satellite imagery, drilling logs as well as USGS geologic maps and reports were used to create the input files for the 3D model. The completed 3D model will help Montana DEQ better understand the mine pools, hydrologic systems, and geologic setting causing the AMD. This in turn will aid the DEQ in making water treatment choices for the acid mine drainage.

Additional Key Words: Acid Mine Drainage, Hydrology, Water Treatment.

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Competition among understory plants varies depending on reclamation soil and fertilization[1]

Jennifer Buss*, Kyle Stratechuk, and Brad Pinno[2]

Abstract: Following oil sands mining, the main land management goal is to establish a functioning boreal forest ecosystem, including the understory plant community. One of the challenges with restoring the understory is the presence of invasive species that compete with desirable native species for resources. In a greenhouse study, we looked at the growth of 2 native understory species (*Galium boreale* and *Vicia americana*) and an invasive species (*Matricaria perforata*). These species were grown with either intra or interspecific neighbors across 3 common land reclamation soils (upland forest, peat based, and a layering of the two) and a nitrogen fertilizer treatment (with and without). When grown by itself *V. americana* growth did not differ among soil or fertilizer treatments, likely due to its ability to fix nitrogen. However, growth of *M. perforata* was directly related to soil nitrogen with the greatest growth on the upland soil and with fertilization. Growth of *G. boreale* was less than the other species and it also had the highest mortality in the nitrogen poor peat soil. When grown with interspecific competition, the proportion of *M. perforata* to *V. americana* biomass increased with soil nitrogen. Overall, nitrogen fertilization had the biggest impact on *M. perforata*, an invasive species, which had the largest increase in above ground biomass with fertilization and shifted the competition balance of nitrogen rich soils from favoring *V. americana* to *M. perforata*. Operationally, care should be taken when applying fertilizer to reclamation areas, as it may have an unwanted positive effect on growth for invasive plants at the expense of native species. This work will help in the development of site and soil specific fertilization and seeding prescriptions which help to meet the goal of establishing a native understory plant community.

Additional Key Words: *Matricaria perforata*, *Galium boreale*, *Vicia americana*, forest floor-mineral mix, peat- mineral mix.

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Reclamation Experiments on the Allegheny Front: The Push for Bio-Energy, Habitat, and Timber[1]

Bart Caterino*[2], Jamie Schuler, Shawn Grushecky, Jeff Skousen

Abstract: Six hectares of multi-purpose reforestation plantings were established on a surface coal mine near Mt. Storm, Grant County, West Virginia. The site was prepared in accordance with the Appalachian Regional Reforestation Initiative (ARRI) Forestry Reclamation Approach (FRA). Three hectares were planted with mixed timber species (northern red oak, sugar maple, red maple, black cherry, and red spruce). The remaining three hectares were planted with shrub willow for bio-energy, nut producers (hybrid chestnut, hybrid hazelnut, Allegheny chinquapin,) for bio-fuel production, sugar maple for sap production and white pine for screening provenances ranging from Georgia to Pennsylvania. After two growing seasons, biomass has been quantified for the willow crop, while seedling survival has been monitored for the other objectives. The project objective was to establish tree cover that incorporated both short-term products (bio-energy feedstocks) as well as long-term timber species to improve soil and water conditions, increase carbon pooling, and produce valuable crops. We have created a demonstration area that highlights various species and deployment strategies. The intent is that our model will lead to increased reforestation of abandoned mine lands and foster new employment opportunities for West Virginia.

Additional Key Words: reforestation, short rotation coppice, carbon capture

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Sludge Impact on the Stabilization of the Fire Road Mine in New Brunswick[1]

M. Coleman*, K.D. Phinney[2]

The approximately 120 ha backfilled coal mine cut, located near Fredericton, New Brunswick, Canada, has been a source of acid rock drainage since the mid 1980's. The approximately 20 m mine cut was backfilled with run of mine sandstone rock containing iron sulphides, principally pyrite in the range of 1 to 2 wt.%. Lime neutralization of acidic drainage has been continuously ongoing to prevent discharge of approximately 200m^3/a of untreated surface and ground water into the environment. Various reclamation schemes have been considered over the years, but engineering studies indicated either impracticalities associated with maintaining a flooded site or excessively high costs for an engineered cover while not necessarily eliminating the need for continuing drainage treatment operations.

Annual hydrated lime demand for water treatment has decreased from approximately 2000 t/a in the 1990's to less than 250 t/a today, primarily due to exhaustion of reactive sulphides in the unsaturated (vadose) zone. The periodic dredging of treatment ponds and ultimate disposal of the aluminum/iron-rich treatment sludge into the backfilled cut has shown no adverse effects on acid generation and may be acting as a source of residual alkalinity and as a "sealant," somewhat reducing the rate of acid generation. Detailed analysis of twenty years of mine water chemistry has indicated that the impact is negligible on the overall acidity of the mine water. In situ neutralization of generated acidity, due to reaction of acid with alkaline mineralization, has been the major contributor to the decrease in acidity over the years. Levels of trace metals in the drainage, from the area, have and are expected to remain at low concentrations during and subsequent to stabilization of the site.

Additional Key Words: lime neutralization sludge, acid mine drainage

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Communicating Maintenance of Acid Mine Drainage Treatment Projects in Ohio[1]

S.D.L. Cornwell*[2]

Abstract: Ohio Department of Natural Resources Mineral Resources Management (ODNR-MRM) manages State AML funds and contracts with local watershed partners to monitor and maintain active and passive AMD treatment projects in Southeast Ohio. The ability to share maintenance data with ODNR-MRM between different types of organizations was identified as a critical need to efficiently address project performance issues, broken project components, and create a shared historical record of maintenance activities. Chemical monitoring already occurs according annual monitoring plans in project discharges and in the receiving stream channels to assure that water quality improvements are maintained. Water Quality data is entered into the Ohio Watershed Data website: www.watersheddata.com by watershed partners and is accessible for public viewing. Regular maintenance is performed in accordance to annual maintenance plans to assure that project components stay in working order. To facilitate data sharing between watershed partners, a Maintenance Tracker was created by the Ohio University Voinovich School and added to the Ohio Watershed Data website. The Maintenance Tracker is only accessible by watershed partners with a username and password. Data is organized by watershed and electronic forms are available for individual projects. For each project a detailed User Manual and Inspection Form are available on the Maintenance Tracker to provide specific information about project operation and project components. Watershed partners have the capability to "flag" entries in the electronic form, which automatically sends an email alerting the appropriate project officer with ODNR-MRM. Once maintenance issues are addressed, the form can be marked as "inactive" and a record still exists in the database. Records are searchable by project, date, and keyword and data can easily be exported into Excel. The Maintenance Tracker has streamlined communication between watershed partners and created a place to store important historical data regarding the operations and maintenance of individual projects.

Additional Key Words: passive treatment, active treatment

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A GEOCHEMICAL KINETICS MODULE FOR AMDTreat TO ESTIMATE THE EFFECTS OF AERATION ON RATES OF DECARBONATION AND IRON OXIDATION[1]

Charles A. Cravotta III[*], Brent Means, and Bill Arthur[2]

Abstract: A new PHREEQC "kinetics tool" has been developed for the AMDTreat computer program that utilizes established rate equations for gas exchange and pH-dependent oxidation of dissolved ferrous iron (aqueous Fe(II)). The kinetic model accurately simulates the interdependent effects of CO_2 outgassing (decarbonation), O_2 ingassing, and pH on Fe(II) oxidation rates for net-alkaline or net-acidic mine drainage. A first-order asymptotic rate law is used to simulate the rates of CO_2 outgassing and O_2 ingassing, which result as the dissolved gases in groundwater that is retained in ponds or wetlands gradually equilibrate with the atmosphere or undergo rapid exchange due to aggressive pre-aeration or other forms of aeration. Aeration promotes CO_2 outgassing, thereby increasing pH and the rate of Fe(II) oxidation. The rate of Fe(II) oxidation is estimated by using the combined homogeneous and heterogeneous rate laws plus a generalized microbial oxidation rate, which becomes relevant at low pH (< 5). The homogeneous rate law indicates the rate of Fe(II) oxidation increases 100-fold when pH increases by 1 unit at pH 5-8 and dissolved O_2 concentration is constant. The additional heterogeneous rate law quantifies the potential catalytic effects of suspended Fe(III)-oxide particles on Fe(II) oxidation and, thus, permits the evaluation of sludge recirculation on iron-removal efficiency. From pH 2.8 to approximately pH 5, Fe(II) oxidation rates are negatively correlated with pH and proportional to the concentration of iron-oxidizing bacteria. Temperature correction is applied to the gas solubility and gas-exchange rates and to the Fe(II) oxidation rate constants. The kinetics tool permits a user of AMDTreat to select among a range of values for the O_2 ingassing and CO_2 outgassing rates, the iron oxidation rate constants, the concentration of Fe(III) in recirculated solids, and the "most probable number" of iron-oxidizing microbes. The selectable gas-exchange rates generally correspond to specific aeration technologies that may be incorporated at passive and active treatment facilities. Each technology has different potential costs for installation and operation, which are computed by AMDTreat, depending on the size and/or number of aeration technologies and energy usage. The kinetic simulations for the specified initial water quality and treatment conditions indicate changes in the pH, dissolved iron, alkalinity, and other solute concentrations remaining in treated effluent at progressive elapsed times (retention time), plus the cumulative quantity of precipitated solids produced by treatment. AMDTreat uses this information to compute the estimated volume and associated cost for removal of the resultant sludge, which contains the precipitated solids.

Additional Key Words: Mine water treatment, PHREEQC, geochemical model, cost analysis

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[1.] Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

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Hydrological and Geophysical Methods to Investigate Streamflow Losses and Restoration Strategies in Abandoned Mine Lands of Schuylkill River Watershed, Pennsylvania, USA, 2012-2015 [1]

Charles A. Cravotta III[*], Laura Sherrod, Daniel G. Galeone, Wayne G. Lehman, Terry E. Ackman, and Alexa Kramer[2]

Abstract: Longitudinal discharge and water-quality campaigns (seepage runs) were combined with surface-geophysical surveys, hyporheic-temperature profiling, and watershed-scale hydrological monitoring to evaluate the locations, magnitude, and impact of stream water losses from the West Creek subbasin of the West West Branch Schuylkill River into the underground Oak Hill Mine complex that extends beneath the watershed divide. Contaminated discharge from the Oak Hill Boreholes to the West Branch Schuylkill River was sustained during low-flow conditions and correlated to streamflow lost through the West Creek streambed. During high-flow conditions, streamflow was transmitted throughout West Creek; however, during low-flow conditions, all streamflow from the perennial headwaters was lost within the 300-to-600-m "upper reach" where an 1889 mine map indicated steeply dipping coalbeds underlie the channel. During low-flow conditions, the channel within the "intermediate reach" 700-to-1650-m downstream gained groundwater seepage with higher pH and specific conductance than upstream; however, all streamflow 1650-to-2050-m downstream was lost to underlying mines. Electrical resistivity and electromagnetic conductivity surveys indicated conductive zones beneath the upper reach, where flow loss occurred, and through the intermediate reach, where gains and losses occurred. Temperature probes at 0.085-m depth within the hyporheic zone of the intermediate segment indicated potential fluxes ranging from -0.53×10^{-5} m/s (upward) during dry conditions to 2.1×10^{-5} m/s (downward) during flowing conditions. Cumulative streamflow lost from West Creek during seepage runs averaged 53.4 L/s, which equates to 19.3 percent of the daily average discharge from the Oak Hill Boreholes and a downward flux of 1.70×10^{-5} m/s across the 2.1-km-by-1.5-m West Creek stream-channel area.

Additional Key Words: Legacy Coal Mining, Surface Geophysics, Surface-water Hydrology, Infiltration

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Growth Rates of Hardwood Trees Nine Years after Reclamation in Response to Substrates and Amendments[1]

K. Dallaire, L. Wilson-Kokes, P. Emerson, C. Delong, C. Thomas, and J. Skousen[2]

Abstract: To promote successful reforestation on mined lands, the Appalachian Reforestation Initiative supports the Forestry Reclamation Approach (FRA). The first step of the FRA is to create a suitable rooting medium. Growth media plots for reforestation studies were established at the Birch River Mine in Webster County, WV to assess the effects of mulch and hydroseeding treatments on the growth of twelve hardwood species on gray and brown sandstone. In 2006, a 5-ha plot was constructed with half having 1.5 m of brown sandstone placed at the surface and other half with 1.5 m of gray sandstone. Bark mulch was applied to the center of the plot covering both brown and gray substrates and the ends of the 5-ha plot were hydroseeded, resulting in eight treatment combinations. Twelve hardwood tree species were transplanted across the plot in spring 2007. Tree volume data and soil samples were collected each year and growth rates over 9 years were compared for all trees species combined, as well as selected species in all treatments. For brown vs gray mine soils (including mulch and hydroseed treatments), brown mine soils had growth rates for all trees combined of 1,675 $cm^3\ year^{-1}$ vs 1,041 $cm^3\ year^{-1}$ for gray mine soils. For the brown mine soil areas, mulched areas had significantly higher growth rates for all trees combined than brown non-mulched areas (2,369 vs 986 $cm^3\ year^{-1}$, respectively). For hydroseeding, all trees combined had significantly higher growth rates in the brown hydroseeded treatments than non-hydroseeded areas (2,109 vs 1,246 $cm^3\ year^{-1}$). In gray sandstone mine soils, mulch treatments resulted in significant increases in growth over non-mulched treatments for all species combined (1,881 vs 200 $cm^3\ year^{-1}$) and growth rates for all tree species combined were significantly higher on the gray hydroseeded treatments compared to the gray non-hydroseeded treatments (1,131 vs 951 $cm^3\ year^{-1}$. Amendments such as bark mulch and hydroseeding can improve the growth rates of trees on both brown and gray sandstone and should be used when planting trees for mined land reforestation.

Additional Key Words: gray sandstone, brown sandstone, hydroseeding, mulch, reforestation

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Development of International Standards for Mine Reclamation[1]

W. Lee Daniels* and Steven Carpenter[2]

Abstract: In 2012, the International Standards Organization (ISO) reactivated Technical Committee (TC) 82 – Mining, which deals with development of standards for many aspects of mining machinery, processes and safety. In the USA, participation in the ISO standards process is formally administered by the American National Standards Institute (ANSI) which subsequently formed Technical Advisory Group (TAG) 82 to manage appropriate input and advice on new mining standards. The activities of TAG 82 are managed under contract by the Canadian Standards Association (CSA), but all formal votes on new ISO standard proposals are placed by ANSI. In 2014, a new proposal for the development of standards for mine reclamation was promoted by South Korea and accepted by TC 82 with South Korea as the lead country (Secretariat). This activity is managed by Subcommittee (SC) 7 and various working groups (WG) that are authorized over time. To date, SC-7 has reviewed and accepted proposals to form two working groups, Mine Reclamation Terminology (WG-1; Lead – South Korea) and Mine Reclamation Management Planning (WG-2; Lead - Canada). Other proposals for standards for abandoned mine land reclamation and mine water monitoring are being considered. The overall ISO standard development process requires input from all interested and affected stakeholders and advances via consensus from all voting countries along a sequential five-step review and approval process. The two WGs described above are currently in the initial phase of standard development. Development and adoption of any international reclamation standards raises issues of (a) neutrality with respect to existing national/state regulations, (b) applicability to highly variable and site-specific climatic/geologic/mining/socio-political conditions, (c) avoidance of specifying technologies, and (d) potential effects on innovation and development of new reclamation technologies and strategies. Compliance with any adopted final ISO standards is voluntary.

Additional Keywords: ISO Standard, Mine Planning, Mining Terminology, Abandoned Mined Lands.

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Mine Reclamation Applications of a New Water Budget Model: Wetbud[1]

W. Lee Daniels*, G. Richard Whittecar, Tess Thompson, Zach Agioutantis, Stephen Stone[2]

Abstract: The development of accurate water budgets is essential for the appropriate design of created wetlands on formerly surface mined areas and also has applications to other permitting needs such as evapotranspiration and runoff predictions. The primary goal of this interdisciplinary research program has been the development and validation of a new set of wetland water budget procedures which are collectively known as "Wetbud". The model estimates wetland water budgets using available weather data and site-specific topographic, soil and geohydrologic data, coupled with mass balance mathematics. Wetbud can be run in its basic form where wetland topography, soil parameters and groundwater flux are simplified, or in the advanced form, where these parameters are included in a more complex approach via integration of the MODFLOW package, a free 3D program that was developed by the United States Geological Survey. Both versions can also include overbank flow hydrology sources and the advanced form can also model sloping and irregular topography. The program downloads weather data from the nearest applicable station and selects appropriate wet-normal-dry (W-N-D) years following a modest user data clean-up step. Wetbud then automatically calculates evapotranspiration for any input year via Thornthwaite (monthly) or Penman (daily) methods. Wetbud also has the ability to utilize existing short-term (e.g. 6 to 9 months) groundwater data from an upgradient well to simulate longer-term groundwater level inputs for the selected W-N-D years. In addition, Wetbud features a "Wizard" version that comes pre-loaded with 14 pre-selected weather data sets for all areas of Virginia that can develop a simple monthly water budget in less than 15 minutes – a feature that could be expanded anywhere geographically with historic weather data. Wetbud is now available for public use as freeware from www.landrehab.org/WETBUD and runs in Windows environment.

Additional Keywords: Wetland creation, design tool, evapotranspiration, runoff.

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Effect of Grading on Productivity of High-Value Tree Species in Appalachian Surface Mines[1]

Wesley T. Dement[2*], John M. Lhotka[2], Christopher D. Barton[2], and Jeffrey W. Stringer[2]

Abstract: Surface coal mining has disturbed more than one million acres of Appalachian forest. Reclamation employed in compliance with federal regulations often compacts substitute soil material (spoil) and inhibits tree growth. In 1996, University of Kentucky researchers established an experiment on the since renamed Starfire Mine in eastern Kentucky. The study established nine reclamation cells to investigate the effects of soil compaction on tree growth and survival and develop guidelines regarding site preparation and tree species compatible with mine reforestation. The study evaluated three spoil grading treatments: 1) no grading (loose-dump); 2) graded with one equipment pass (strike-off); and 3) multi-pass grading resulting in uniform surface appearance (compacted). Treatments were planted with six native tree species. Nineteen growing seasons following planting, differences in survival and growth were compared among species and treatment. Survival ranged from 3.8% for black walnut in compacted spoil to 87 % for white ash in the loose-dump treatment. Analysis of overstory tree height data revealed significantly larger mean overstory heights for all species in the loose-dump and strike-off treatments versus the compacted treatment with the exception of black walnut. Mean overstory heights were not significantly different between loose-dump and strike-off treatments. Long-term data indicate the benefit of low compaction grading for reforestation of Appalachian surface mines. Data further suggest that strike-off sites may support tree survival and growth as well as sites where end-dumping practices leave spoil uncompacted. The strike-off reforestation treatments exhibit generally uniform topography that may facilitate efficient application of silvicultural treatments and timber harvesting, making this a promising approach for reclamation of Appalachia's surface mines.

Additional Key Words: Forestry Reclamation Approach, hardwood forests, compaction

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Metals got you Down? A Look at Effective Mining-Influenced Water Treatments

P. J. Dugan*, D.M. Hartsough[1], and H. Schuster[2]

Abstract: Background: Historic and present day mining activities continue to adversely impact surface and groundwater quality. But you can also get metal-impacted water from any excavation into sulfur-bearing rock during creation of roadways, especially when deep enough to be below the zone of active weathering. Roadways in regions where pyritic material becomes exposed can also result in a long-term source of metal contamination. Metal-impacted discharges can persist as contaminant sources for many decades. Significant efforts have been undertaken to evaluate reactive amendments for ex situ remediation of metal-contaminated soil and surface water. Reductions in aqueous metal concentrations can be achieved by: (1) oxidation, (2) adsorption, (3) entrapment of metals in crystal lattices and, (4) precipitation/co-precipitation.
Approach/Activities: Manganese (Mn) and Iron (Fe) are common constituents found in net alkaline and net acidic mining discharges. Typically, Fe is removed by adding a chemical that increases pH (e.g., sodium hydroxide, lime, soda ash). Mn removal requires higher pH (e.g., >9.5) to precipitate dissolved Mn which may lead to the creation of treated water that exceeds regulatory discharge pH limits. High pH values may also lead to the resolubilization of aluminum, an element under increasingly close scrutiny. Permanganates have been widely used for decades for Mn and Fe removal in drinking water and wastewater applications. Recent permanganate product innovations have resulted in two technologies for metal treatment: 1) Permanganate Tablets for passive year-round removal of Mn and Fe in net alkaline mine drainages and 2) Alkaline Permanganate for coupled Mn/Fe removal with pH adjustment for net acidic waste streams. Reactive capping technologies have also proven beneficial in reducing the bioavailability of dissolved metal contaminants after road cut activities.
Results: Experimental research and field efforts have proven the benefits of using a variety of adsorbents and reactive amendments for in situ and ex situ capping approaches. For example, environmentally benign resins have been used for ex situ capping for slope stabilization, soil retention, and remediation in road cuts and slag piles. In addition, thin layers of reactive components have been used as part of a reactive capping. By incorporating a thin layer of pH adjusting compound into a reactive capping technology the bioavailability and mobility of metal contaminants is decreased, the required cap thickness is decreased and by the addition of reactive amendments there is reclamation and remediation of soils and runoff. Promising results from field-scale efforts where permanganate tablets, alkaline permanganate and the reactive capping technology PennzSuppress will be presented where Mn and Fe were successfully removed and pH adjusting amendments were incorporated into a reactive cap to meet regulatory discharge limits.

Additional Key Words: Acid Mine Drainage, Reactive Capping, Permanganate

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Preventing Acid Rock Drainage Can Source Control Really Be Successful?[1]

P. Eger[2]

Abstract: Acid rock drainage is one of the mining industries' most serious environmental problems. Although the ability to predict problematic drainage has improved, a method to prevent its' formation has been elusive. If the natural acid neutralization potential of the waste exceeds the acid production potential, the drainage should be net neutral. Adding alkaline material appeared to be an easy way to adjust neutralization potential in waste storage areas. While this approach was effective in laboratory tests, large scale implementation had generally been ineffective. Borrowing an addition technique from the gold industry, a small scale pilot was conducted with an acid producing Archean Greenstone which had a sulfur content of 0.63% and an NP/AP ratio of 0.4. Magnesium rich limestone (dolostone) was added to increase the NP/AP ratio. Two addition rates were used which increased the NP/AP ratio to 1.4 and 3.4. After about 3 years the pH in the control tank dropped precipitously from around 7 to less than 5.5 over the course of the summer. The pH continued to drop and currently appears relatively stable at around 4.0. In contrast, both treated tanks continue to have pH > 7 after 15 years after treatment.

Additional Key Words: alkaline addition, sulfate, pH control, mitigation

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Water Treatment: Planning for Forever, New Options

D.T. Eyde* and D.A. Baker

Abstract: We have reached the conclusion that there will be an upward trend in investments in water infrastructure and treatment. This same trend may hold for increased investment in the treatment and disposal of water and effluents. One of the largest ongoing expenses during the life cycle of a mining operation in the coal fields of the southeastern U.S. is the treatment of effluents that can leave an operation. Southern Coal Corporation and 26 affiliated mining companies are under an EPA consent decree that requires the companies to make comprehensive upgrades to their coal mining and processing operations to prevent discharges of polluted wastewater from their mines in Appalachia. The estimated cost of these measures is $5 million. Coal mining operations may soon face in-perpetuity effluent treatment with affiliated bonding requirements. This will require new more efficient and less costly long term treatment technologies. More importantly, these treatment requirements will continue past the economic recovery of coal at a mining operation. Meeting this challenge is one of the more difficult for the minerals industry. Natural zeolites with their exceptional ion-exchange and sorption properties may represent a part of the solution. Their effectiveness as shown by numerous studies, have confirmed their excellent performance on the removal of metal cations from wastewaters. They have advantages over other materials because they are cheap, they exhibit excellent selectivity for different cations at low temperatures, which is accompanied with a release of non-toxic exchangeable cations (K^+, Na^+, Ca^{2+} and Mg^{2+}) to the environment. They can also reduce AMD. Several case studies confirmed, and US government lab testing (USGS, EPA) and examining the viability of their use under field conditions. New treatment technologies using compact bio-reactors and bio-films on zeolite media show real promise as a long-term passive system supplementing or replacing current treatment technologies.

Keywords: effluents, discharges, ion exchange, zeolites, in-perpetuity, bonding, water treatment, bio-reactors, bio-films, AMD

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Sulfate Removal in Biochemical Reactors and Scrubbers Treating Neutral Low-Metal Concentration Mine Influenced Water (MIW)[1]

Guadalupe Fattore[2], James Gusek[3], Thomas Clark[4], and Lee Josselyn[3]

Abstract: Sulfate and metals are commonly found in mining influenced water (MIW). A biochemical reactor (BCR) is an established technology that can remove sulfate and metals. Three organic mixtures were bench-tested to decrease sulfate concentration in a circumneutral pH MIW containing low metal concentrations. As it was of interest to charge the BCRs with organics that could be sourced regionally, organic mixtures included various proportions of wood pellets, oat straw, and biochar and, as an inoculum, manure. The inorganic fraction of the mixture included limestone-dolomite. The BCRs were operated for a total of 180 days. Additionally, three inorganic materials were evaluated as a means of scrubbing excess hydrogen sulfide/sulfide ion from the BCR effluents. The scrubber reactors or sulfide polishing units (SPUs) were charged with native soil from the site, zero valent iron (ZVI) or magnetite and operated in series to a single BCR. Median MIW influent contained about 3000 mg/L of sulfate and very low concentrations of metals and the flow rate was varied from 144 to 500 mL/day, corresponding to BCR hydraulic retention times of less than 38 days. All BCRs demonstrated similar removal rates of 1.3 to 1.5 mol $SO_{4\text{-}2}/m^3$ day. SPUs were operated to remove dissolved sulfide from the BCR effluent, but they behaved as an extended BCR unit. It appeared that dissolved organic carbon in the BCR effluents continued to promote sulfate-reducing microbial activity in the SPUs where the inorganic materials functioned as a solid support for the microbial community. In fact, somewhat higher rates of reduction were achieved in the scrubber units using non-lignocellulosic support materials: 1.9 and 2.2 mol SO_4^{-2}/ m^3-day in SPU-1 (native soil) and SPU-2 (ZVI), respectively. Magnetite was not an effective media for sulfate removal. Sulfate removal efficiencies in the BCRs varied: 56% (BCR-1), 58% (BCR-2), and 68% (BCR-3). Sulfate percent removal in the SPUs was 35% (SPU-1 paired with BCR-2) and 37% (SPU-2 paired with BCR-1). Novel reactor charging configurations in single units may therefore be much more effective and efficient than approaches exclusively using lignocellulosic or inert supports. It was also noted that sulfate reducing microbial populations were still increasing at reactor termination.

Additional Key Words: BCR; Sulfate; Organic Mixture

Optional Data: Project Location: Lat. *Confidential*, Long. *Confidential*

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Zinc and Nickel Sorption and Desorption Using a Mixed Algae Community Collected from a Mine Drainage Passive Treatment System[1]

E.E. Fielding* and R.W. Nairn[2]

Abstract: Algae communities populate ponds in passive treatment systems (PTS) naturally, but their role in water quality dynamics is not well understood. Algae are capable of sorbing metals from contaminated waters, but it is uncertain how much of the sorbed metals will remain after the death and decomposition of the algal detritus. If algae are capable of retaining some of the sorbed metals even after decomposition, then the naturally growing communities may benefit overall PTS performance. Algae and water from the final polishing unit of the Mayer Ranch PTS at the Tar Creek Superfund Site of the Tri-State Lead-Zinc Mining District (Oklahoma, Kansas and Missouri) was collected for a sorption and desorption experiment. Concentrations of both zinc and nickel (0.5 mg/L, 2.0 mg/L, 5.0 mg/L, 10 mg/L, and 20 mg/L) were added to the PTS water to determine the magnitude and extent of possible sorption. Algae and the solution were tested for metal concentrations after a five-day period. Light was then removed by covering the vessels and they were placed at 0°C to promote algal death. Immediately after return to room temperature, and after a period of time provided for decomposition, both the algae and solution were tested for metal concentrations. All samples were centrifuged at 3000 rpm for five minutes to separate the algae from the supernatant for testing purposes. The algae were dried at 50°C for 15 hours, then powdered. Analyses were completed using acid digestion and Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES). It was hypothesized that sorption of both zinc and nickel by the naturally occurring mixed-algae community will occur and algal metal concentrations will decrease after decomposition of the detritus.

Additional Key Words: Langmuir and Freundlich isotherms, absorption, adsorption

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Subsidence wetland formation and transition in the high ground water table coal mining areas[1]

Y.H. Fu*, Z.Q.Hu, X.M. Dong, Q.Y. Wang and W.Xiao[2]

Abstract: The total amount of coal production and consumption in China is keeping on the top of the world. The coal mine resources has played and still plays an important role in the economic development, however, the mining activities impacts the eco-environment severely. In the coal mining area with high water level, the problem is even more seriously, the mining activities due to the land subsidence and caused water logging, large areas of farmland and construction land merged into water, the farmers lost their farmland and houses. The land reclamation and ecological restoration has been started in China since 1980s, as food production is always essential in these areas, farmland is the first choice for the restoration. However, only 50%~70% of the subsidence arears could be reclaimed into farmland because of topsoil shortage and technical restrictions; therefore, the water area will continue to expand with the mining activities. The subsidence wetland caused by mining activities which is different with the natural wetland, which has not been defined clearly in the former research, this paper has studied its connotation and its location in the wetland classification system. According to the mining subsidence theory, the forming reasons of the topography and hydrography of the subsidence wetland and the feature of soil and vegetation have been analyzed. In addition, the mining disturb to the landscape does not happen once, but happens gradually in accordance with the mining schedule and geological situation and the subsidence wetland forms dynamically. Other anthropogenic factors of the subsidence wetland are including the reclamation, wetland restoration, and spontaneous farming activities, and the wetland transition in the coal mining areas with high ground water level is drastic. Take a coal mine site in Shandong Province as an example, this paper has examined and analyzed the dynamic patterns of wetland transition based on the high-resolution Landsat TM (Thematic Mapper) data from 1985, 1995, 2005, 2010, and 2015. The result shows that the wetland increased 210% in the study areas, mostly transited from farmland and construction land. The wetland transition can dramatically affect the eco-environment in these areas. Wetland is one of the three most important ecosystems, and considered as the lung of the earth. The new formed subsidence wetland could be a harm or benefit of the eco-environment. The mining caused subsidence wetland has changed the terrestrial ecosystem into terrestrial-aquatic ecosystem, with rational planning and proper restoration, it could alleviate mining impact to the ecosystem, enhance the ecological service function, landscape diversity and resistance ability, furthermore, optimize the social, economy and ecological benefit during the ecosystem succession in coal mining areas, and meanwhile supplement the wetland quantity in China which declined 11.46% in the recent 20 years.

Additional Key Words: reclamation; restoration; eco-environment.

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Assessing How Hydrologic Isolation of Coal Mine Spoils Affects Streamflow Mechanisms and Water Chemistry Using Open Source Wireless Technology[1]

S.G. Fulton*, J. Dowd, A. Thompson, and C. Rhett Jackson[2]

Abstract: High freshwater salinity (usually measured as total dissolved solids, TDS) is toxic for many fish and macroinvertebrates, particularly species in fresh water (highly dilute) streams. Salinity levels are often the strongest indicators of stream degradation below surface coal mining and valley fill (SCM/VF) operations throughout central Appalachia. The negative environmental effects of elevated stream salinity appear to be cumulative and long-term. Unfortunately, there are no standard technologies to cost-effectively control TDS loadings to streams at remote mine sites. However, a promising experimental technology to remedy this called "hydrologic isolation" (HI) was implemented at a SCM/VF site in Magoffin County, KY. The HI method was designed to maintain water quality and quantity downstream from SCM/VF operations by minimizing groundwater contact with high TDS-producing overburden. Our project goal is to evaluate the effectiveness of this HI methodology. We will identify and characterize the source water contributions to streamflow using salinity measurements (conductivity, a proxy for TDS) to determine how HI affects surface water-groundwater interactions and identify the dominant hydrologic flowpaths contributing to streamflow in mined watersheds. We have developed an inexpensive open source wireless sensor network to continuously monitor and live-stream weather, streamflow, and groundwater and surface water physical and chemical data. We pair continuous rainfall data with continuous discharge and flow-weighted conductivity to evaluate the seasonal relationship between rainfall-runoff and streamflow and conductivity levels. Our sensor data will be compared to surface water and groundwater grab samples and *in situ* data collected monthly and analyzed in the laboratory. End-member mixing analyses will be used to quantify contributions to stormflow from different streamflow generation mechanisms. The wireless sensor technology will be described and preliminary results will be presented.

Additional Key Words: salinity, total dissolved solids, conductivity, source water identification, end-member mixing analysis.

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Geochemical Controls on Limestone Utilization in Abandoned Mine Land Reclamation

P. A. Giri*, [1], B. Tracy[2], and G. A. Olyphant[1]

Abstract: The effectiveness of limestone in acid mine drainage (AMD) treatment is often underrated due to its tendency to lose efficiency over time. Acidic waters promote dissolution of limestone, thereby generating alkalinity. However, native metals also tend to precipitate. Precipitation of oxides, sulfates, and salts can form coatings on the limestone which act as chemical barriers, reducing the buffering capacity and inhibiting alkalinity generation. These interactions are highly dependent on the site-specific influent pH and mineral acidity, which fluctuate with the seasonal discharge. A fundamental approach to perceiving the long-term behavior of complex conditions within limestone-based treatments is to employ physio-chemical models which simulate the progression of rates over time and space. We present the first approximation to a fully coupled model for simulating chemical reactions between limestone and AMD in passive limestone treatment systems. A coupled model is developed in PHREEQC simulating conditions in either oxic or anoxic drains, over long time frames. Particularly, emphasis is placed on the modeling of reactive limestone surface area and drain porosity. Mineral reactions and iron redox reactions are modeled kinetically, and the loss of reactive limestone surface area and drain porosity are directly coupled to the formation of iron and aluminum precipitates. Decadal simulations are conducted and compared with historical chemistry data from an operating anoxic limestone drain in Indiana. The model successfully reproduced many characteristics observed in the field including reductions in acidity and aqueous metals and increased alkalinity over a time-span of 15 years, despite formation of oxides. Application of the model can be a valuable strategy in assessing feasibility, and forecasting long-term performance at other sites slated for reclamation. As modeling such as ours allows consideration and comparison of various design characteristics including length, cross-sectional area, velocity, and grain size, it may be useful in optimizing drain performance.

Additional Key Words: reactive transport modeling, armoring, kinetics, passive AMD treatment, limestone drains

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Woods-run Chips as a Filter Sock Matrixl[1]

S. T. Grushecky* and L. McDonald[2]

Abstract: The use of filter socks for controlling sediment movement has become a standard BMP associated with oil and gas site development activities. One of the sediment and erosion control products to come into wide use in oil and gas development is the filter sock. Filter socks are a type of contained filter berm typically constructed of a biodegradable mesh tube filled with a filtering media. Federal standards specify composted filter media that has been certified using the U.S. Composting Council's Test Methods and Parameters (USCC 2010).

The specified use of composted materials during the construction of filter socks has created inefficiencies during well site construction. Typically, during clearing and grubbing of a well pad site, discarded trees and tree tops are chipped on site and temporarily stockpiled. Then, composted chips are hauled on to well sites and used to fill filter socks during erosion and sediment control measures installation. The use of the woods-run chips created on site, instead of hauling composted chips from supply yards, could reduce energy/capital costs, truck traffic, and disposal costs for woody material generated on site.

The primary objective of this research project is to compare the effectiveness of woods-run material versus traditionally composted wood chips in controlling sediment transport as well as other chemical and biological parameters. Preliminary results indicate minimal difference in the moisture content or piece size distribution of composted versus woods-run material or in K, Ca, Mg, P, pH, and NO_3^- levels between matrix types. Moreover, both woods-run and seasoned wood chips both filter >90% of total suspended solids during preliminary testing. These results suggest that the use of composted wood chips as a filter medium may not be necessary during oil and gas site development activities.

Additional Key Words: Compost, Sediment, Oil, Gas, Development.

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A Pathway to Walk-Away? – 30 Year Old Technology to Suppress Acid Rock Drainage Revisited[1]

James Gusek[2]

Abstract: Patented controlled-release bactericide pellets formulated in the 1980s, coupled with surface-applied bactericide, were used at dozens of acid rock drainage (ARD) prone sites across the USA and internationally. In the late-1990s, usage of this technology virtually ceased when the sole vendor of the bactericide products closed its doors. The primary goal of these products was facilitating revegetation on acid generating mine wastes; decreasing ARD flow, metals/acidity loading, and sulfate were secondary benefits. At the time, state agencies and mining companies alike viewed bactericide applications as temporary remedies. In hindsight, were they right? This paper considers available data for selected sites to assess the long-term conditions two or more decades after bactericide applications. The paper also examines several promising 21st century technologies that might capitalize on this earlier work and be combined with bactericides to fashion a practical "Pathway to Walk-Away" for mining companies and government agencies which are saddled with ARD treatment in perpetuity.

Additional Key Words: Bactericides, Case Studies, ProMac, Probiotic Organic Passivation

Optional Data: Project Locations:
Lat. 37.79°N, Long. 81.26°W
Lat. 45.45°N, Long. 80.87°W
Lat. 41.09°N, Long. 79.98°W
Lat. 37.07° N, Long. 82.71 W
Lat. 39.32° N, Long. 80.34° W
Lat. 38.93° N, Long. 79.96° W
Lat. 39.2° N, Long. 106.4° W
Lat. 40.86° N, Long. 78.86° W

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Advancements in Iron Terrace Design for Metal Mine Sites[1]

James Gusek[2], Lee Josselyn, and Eric Wolaver

Abstract: Volunteer iron terrace formations associated with coal mine sites are well-documented in the literature but relatively little has been published regarding iron terraces in metal mining terrain. Iron terraces might be considered a subset of aerobic wetlands that appear to remove iron without macrophytes/plants and open water surfaces. Microbial mechanisms appear to be important. The influence of organic carbon such as leaf litter and other natural cellulolytic material on first-order iron removal kinetics is somewhat uncertain. Early work at understanding the mechanisms in iron terraces (aka terraced iron formations -TIFs) in Eastern US coal mine ARD originated at Penn State but iron terraces have been studied by the USGS at metal mining sites in the western US in the Rocky Mountains and by others in the Iberian pyrite belt in Spain. This paper examines iron terraces/TIFs from a process engineering perspective as applied to passively treating iron-bearing metal mine drainage as a first step in a multi-unit treatment system that may include biochemical reactors, aerobic polishing wetlands, and manganese removal beds.

Additional Key Words: Ferricrete; Ferrous Iron; Organic Dehydration; TIFs

Optional Data: Project Locations: Lat. Multiple°N, Long. Multiple°W

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Establishment of Hybrid Poplar on a Reclaimed Mine Site in Southern West Virginia[1]

A. Hass*, R.S. Zalesny Jr., and D. Patel[2]

Abstract: Short-rotation woody crops (SRWC) can grow on marginal and disturbed lands that are otherwise not suitable for agriculture. Such land-use diminishes competition for current agronomic land by the biomass industry while increasing the overall productive land inventory. Surface mining is a prime example of such lands, where the reclaimed mine lands are rarely suitable for agronomic practices. Incorporating SRWC systems as a viable post mine land use alternative increases the potential for biomass production and restoration of natural resources. Moreover, SRWCs may provide an economic stimulus to revitalize local economies, counterbalancing the financial impact of the declining coal industry. A phyto-recurrent selection study was established to study the suitability of different hybrid poplar genotypes to surface-mined lands in the southern coalfield of West Virginia. Sixty different hybrid poplar genotypes belonging to seven genomic groups were planted at a recently-reclaimed mine site near Marmet, WV (phyto-recurrent selection cycle 1). After the first growing season (126 days after planting), clonal survival ranged from 19 to 100%, that of genomic groups ranged from 56 to 100%, and stand-level mean survival was 75%. On average, height and diameter were nearly six times greater for the six most-productive genotypes relative to their least-productive counterparts. Height ranged from 6.6 cm [(*P. trichocarpa* × *P. deltoides*) × *P. deltoides* 'NC13470'] to 38.3 cm (*P. nigra* × *P. suaveolens* subsp. *maximowiczii* 'NM2') and the stand-level mean was 23.1 cm, while diameter went from 0.6 mm ('NC13470') to 3.6 mm ('NM2') with a mean of 2.3 mm. In May 2015, cycle 2 was established, consisting of 32 of the original 60 genotypes. Those data are currently being summarized and will be presented at the conference. Results from both growing seasons will be integrated to evaluate survival and growth of the different clones and as a viable potential plant material for establishment of SRWC on such sites.

Additional keywords: biomass, short-rotation woody crops, phytotechnologies, Populus, post mining land use, reforestation

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The Maelstrom Oxidizer - Astonishing Aeration System[1]

Jeff Hayden[2] and Jim Oliver[3]

The Maelstrom Oxidizer (MO), although invented in the 90's, has been insignificantly marketed and utilized until recently. In the fall of 2015, the patent and rights were purchased and Somerset Environmental Solutions (SES) was formed. This remarkable technology supplies oxygen to raw water in the most effective way possible at the lowest cost and smallest footprint of any other technology available. Most water treatment specialists understand the benefits of adding oxygen to raw water, but because the MO can super-saturate water with oxygen in an incredibly short period of time, many things can be accomplished over and above the norm. Chemical used to cause heavy metals to precipitate can be dramatically reduced or eliminated and some other interesting findings have occurred. This paper illustrates some case study work done to show actual field results and unexpected findings. The MO has proven successful in its effect on pH, Fe, Mn, Al, CO2 removal and phosphate and ammonia reduction. The MO often increases Dissolved Oxygen dramatically in a very short period of time, usually less than one minute. The MO uses relatively low horsepower and is exceptionally efficient. Efficiency can be rated in pounds of oxygen transferred per horsepower hour. An efficient (standard) aerator is rated at 3 pounds per horsepower hour. The Maelstrom Oxidizer has efficiency in excess of 22 pounds per horsepower hour. Operating costs are ten times less than conventional aerators and is easier to maintain – there are no moving parts except for the blower. The Maelstrom Oxidizer is the most cost effective apparatus for transfer of oxygen into liquids to oxidize and precipitate metals, convert sulfite to sulfate or to outgas carbon dioxide.

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[1] Oral paper presented at the 2017 Joint Conference, National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: April 9 - 13, 2017.

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[3] Jim Oliver, VP of Operations Somerset Environmental Solutions, former owner of Environmental Solutions, Patent and Rights to technology.

The Complicated Role of CO_2 in Mine Drainage Treatment[1]

Robert S Hedin and Benjamin C Hedin[2]

Abstract: Mine waters often contain high concentrations of carbon dioxide. In lime treatment systems CO_2 reacts with CaO or $Ca(OH)_2$ to form calcite ($CaCO_3$) resulting is inefficient use of lime. To counter this inefficiency, mine water is often aerated prior to lime addition so that calcite formation is minimized. In passive treatment systems the degassing of net alkaline water raises pH which can promote Fe and Mn oxidation reactions. However, degassing CO_2 does not always increase treatment efficiency. The passive treatment of acid waters with limestone often involves limestone and relies on calcite dissolution which is increased by CO_2. We will present field and experimental data from two sites where the differential management of CO_2 has affected alkalinity generation. Both systems treat acidic water with oxic limestone beds. The influent to the Fall Brook limestone bed is pre-aerated and the system produces 50-60 mg/L net alkalinity. Alkalinity-generating experiments show that the system would discharge about 150 mg/L net alkalinity if the CO_2 was preserved. The influent to the Woodlands limestone bed is not aerated and the system produces 200 mg/L net alkalinity. Alkalinity generating experiments show that if the Woodlands influent was aerated, alkalinity generation would decrease to 125 mg/L. The results can explain variability in the alkalinity generation of existing passive systems, suggest easy ways to increase the alkalinity generation of poorly performing limestone beds, and provide new guidance for the handling of water in passive systems.

Additional Key Words: calcite dissolution; passive treatment.

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2. Robert Hedin, Hedin Environmental, Pittsburgh, PA, 15228; Benjamin Hedin, Department of Geological and Environmental Sciences, University of Pittsburgh, Pittsburgh, PA (student).

Production of an Iron Oxide Product from Mine Water: 15 Year Report [1]

Robert S Hedin [2]

Abstract: The precipitation of iron under oxidized conditions at pH 3-8 results in iron oxyhydroxide minerals that can have valuable pigmentary and chemical characteristics. In northern Appalachia there are numerous large flows of Fe-contaminated discharges that when treated passively yield large quantities of iron oxides. Iron oxide is a commodity that is valued as an earth-tone pigment, a raw material for ferrite production, and as a sorbent/reactant in water and soil remediation applications. Hedin Environmental has been producing iron oxide from mine discharges and treatment systems for 15 years. Sales over the period have totaled 4,700 tons (solid) with 92% for pigment and 8% for chemical reactivity applications. Recently HE has been working with various partners to advance chemical reactivity applications. Beneficial uses for phosphate control, contaminated soil remediation, hydrogen sulfide treatment, and selenium control have been demonstrated. The presentation will describe the chemical characteristics of iron solids that form in mine water treatment systems, the applications that have been realized over the last 15 years, and opportunities for the future.

Additional Key Words: iron oxide, resource recovery

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2. Hedin Environmental, Pittsburgh, PA, 15228.

Groundwater Modeling Used to Design of a Tailings Impoundment Removal near Yellowstone National Park[1]

T. H. Henderson* and M. W. Borduin[2]

By the late 1960s, Soda Butte Creek was considered the most polluted stream entering Yellowstone National Park. A significant portion of the pollution was coming from the McLaren Tailings impoundment, constructed in the channel and floodplain of Soda Butte Creek near the community of Cooke City, Montana. The majority of the tailings impoundment was saturated with metals-contaminated groundwater. Following the 1988 Yellowstone fires, the site was designated an Emergency Response Action Site by the Environmental Protection Agency due concerns with flooding and a tailings release to Soda Butte Creek and the National Park. To remove the impoundment, the Montana AML program was faced with excavating tailings to depths of 35 feet below ground surface and up to 30 feet below the water table in the impoundment. A confined aquifer system was directly beneath the impoundment and contained groundwater under artesian conditions. Extensive hydrological and modeling investigations were conducted to design the water management portion of the project. A three-dimensional groundwater flow model was developed to evaluate well locations, required groundwater extraction rates, dewatering timeframes, seasonal pumping schedules, and alternate management strategies. A critical insight gained through this work was that the construction dewatering and water treatment efforts would be best achieved by pumping the aquifer system underlying the impoundment instead of extracting water directly from the tailings. The modeling work was tested by the installation of a 17-well dewatering system, groundwater pumping rates exceeding 800 gallons per minute and complete excavation of the tailings impoundment. The successful design and operation of the dewatering system resulted in project completion one year ahead of schedule. Project innovations have been recognized by awards given by the American Council of Engineering Companies and the National Association of Abandoned Mine Land Programs.

Additional Key Words: Construction dewatering, mine reclamation, numerical modeling.

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Utilizing an Unmanned Aerial System and a High Resolution Multi-Spectral Sensor to Evaluate Ecosystem Health and Predict Surface Water Quality[1]

B.K. Holzbauer-Schweitzer* and R.W. Nairn[2]

Abstract: This study is focused in the Grand Lake O' the Cherokees watershed in northeastern Oklahoma, upstream of the Grand Lake reservoir formed by Pensacola Dam, a hydroelectric power installation. The lake receives metals-contaminated waters from the abandoned Tri-State Lead-Zinc Mining District of Oklahoma, Kansas and Missouri and is also heavily impacted by nutrient runoff due to agricultural and urban development contributing to eutrophication and significant algal blooms. Addressing these problems higher in the watershed will help to minimize water and sediment quality problems. An ATI AgBot Unmanned Aerial System (UAS) will be used in conjunction with a MicaSense RedEdge sensor to collect multispectral reflectance data in shallow, slow moving, surface drainages, allowing for estimation of chlorophyll concentrations and other water quality parameters. The spatial data paired with *in-situ* field verification will allow for data validation and strengthening of water quality and land use models. This research will attempt to find areas of most concern and suggest remediation and/or restoration efforts (e.g., land reclamation, passive treatment, contour cropping, riparian buffer restoration, and other low impact development best management practices). Even further, the data generated by the UAS may be able to be used to evaluate habitat quality (through Normalized Difference Vegetation Indices, Species Richness/Diversity, Stream Power Indices, etc.).

Additional Key Words: Chlorophyll, Habitat Assessment, Best Management Practices

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Applying landforming to reclamation: A case study in Central Appalachia [1]

L.C. Hopkinson*, J.D. Quaranta, J. Hause, J. Lorimer, R. Park, and I. Santos[2]

Abstract: One reclamation technique, geomorphic landform design, may offer opportunities to improve aspects of mine reclamation in Central Appalachia. The approach designs landforms in a steady-state, mature condition and considers long-term climatic conditions, soil types, slopes, and vegetation. While applied successfully in semi-arid regions of the United States as well as in Spain, Canada, and Australia, geomorphic reclamation has not yet been applied in Central Appalachia. This work describes a case study where landforming techniques are being applied to a coarse coal refuse pile in West Virginia. The reclamation design includes four geomorphic watersheds that radially drain the pile. Each watershed has one central draining channel and compound slope profiles. The watersheds are connected by conventional bench slopes that also have surface drains. The intent is to reduce infiltration rates which will decrease water quality treatment costs at the site. Cut and fill volumes (approximately 250,000 yd^3) are comparable to those of more conventional designs, and all hillslopes are at 2:1 (H:V) or less. If proven successful, the technique can be part of a cost-effective solution to improve water quality at active and future refuse facilities, abandoned mine lands, bond forfeiture sites, landfills, and major earthmoving activities within the region.

Additional Key Words: geomorphic landform design

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[1] Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

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New Soil Reconstruction Method for Reclaiming Subsided Land with Yellow River Sediments[1]

Zhenqi Hu[2]

Abstract: Coal is the most important energy in China. Most of coal mines use underground mining, which produce a lot of subsided land. As large population in China, the conflict between farmland and coal mining is very serious. Therefore, farmland reclamation of subsided land has become the focus of research activities. This paper introduces the shortage of current subsidence reclamation filled with some filling materials. A new reconstruction method for reclaiming subsided land with Yellow River Sediments was developed.

Additional Key Words: Subsidence land reclamation, soil reconstruction, Yellow river sediments.

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Restoration Techniques to Increase Survival and Vigor of Wyoming Big Sagebrush Seedlings[1]

A.P. Jacobs*, P.D. Stahl[2]

Abstract: Loss of shrub species in semi-arid systems reduces ecosystem function and causes abiotic resources to be re-distributed to, and monopolized by, competition from native and non-native plant species. Low water availability in dryland soils hinders shrub establishment and survival, and is the largest bottleneck of successful restoration in these disturbed environments. Our study focused on the efficacy of mechanically suppressing herbaceous species to reduce competitive pressures and increase the survival and reproductive value of transplanted shrub seedlings. We measured the effects of polypropylene fabric mulch and sod removal on 10,900 Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle & A.W. Young) seedlings outplanted into two sites burned in different years (1986, 2012) in eastern Wyoming, USA. We transplanted seedlings in spring 2015 and monitored over two growing seasons (2015-2017). Two years post-planting, mean survivorship of sagebrush treated with 1m2 sod removal (65% ±6) was up to one-fold higher than other treatments ($p=0.0392$). 1 m^2 polypropylene fabric dramatically increased the above-ground volume (cm^3) of sagebrush canopy (up to 2400%; $p<0.0001$) and was the only treatment with a significant percentage of seedhead (60%; $p<0.0001$) produced by individual transplants. Sites outplanted with sagebrush 3-years post fire experienced higher rates of transplant survivorship, canopy volume, and seedhead production across all treatments ($p=0.0299$). Combining techniques of outplanting and mulching, in a timely manner following wildfire, can increase the survival, growth, and seedhead production of foundational shrubs in semi-arid environments. These findings can be useful for the successful restoration of ecosystem function in sagebrush steppe systems.

Additional Key Words: Competition, Disturbance, Ecosystem Function, Outplant, Sagebrush, Wildfire.

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Revegetation success at several Montana sites using soil amendments[1]

S.R. Jennings*[2]

Abstract:

Remediation of metal enriched soil, overburden, subsoil, and waste using amendments is an evolving low cost technology for mitigating water quality and vegetation impacts at legacy mine and smelter sites. Revegetation of mine sites is often technically difficult and costly due to local shortages of high quality growth media and presence of inhibitory rootzone conditions on site. Combination of elevated metals, low pH, and low fertility create challenging conditions for seeding and planting as well as serving as a source for metal leaching to shallow groundwater. Furthermore, risk-based action levels for soil cleanups for human health protection may require removals of contamination for human health considerations leaving behind residual subsoil with elevated metals and a shortage of organic matter. Short and long-term monitoring at several reclaimed sites was performed and provides examples of soil remediation efficacy and validation of risk reduction targets. Soil amendment prescriptions will be presented with examples of field implementation, revegetation success, and post-reclamation soil assessment. Plant community demographics, soil chemical characteristics, and remedial decision making under the Superfund law will be discussed using sites from Western Montana. Typical soil amendments applied include lime, compost, and fertilizer. Results show companion reductions in metal mobility and increased soil fertility at sites with robust vegetation while sites with poorer vegetation outcomes show persistent limitations due to metals, pH, and fertility.

Additional Key Words: phytotoxicity, metal mobility, soil remediation

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[2] Stuart R. Jennings, KC Harvey Environmental, LLC, Bozeman, MT.

Field Predictors for TDS Generation Potential from Appalachian Mine Spoils[1]

D.K. Johnson*, W.L. Daniels and C.E. Zipper[2]

Surface mining for coal in the Central Appalachians contributes total dissolved solids (TDS) to headwater streams, especially below larger mines and associated valley fills as rainwater percolates through blasted mine spoils. The objective of this study was to characterize the TDS generation potential of a range of surface soils and associated geologic strata from the Central Appalachian coalfields and to relate those properties to simple field indicators, such as color or rock type. We hypothesized that these indicators could accurately predict TDS generation potential. Thirty-three vertical weathering sequences were sampled from eight surface mines throughout the Central Appalachian coalfields, for a total of 204 individual samples. No differences were found among sites in overall saturated paste specific conductance (SC; used as a proxy for TDS) levels, but significant geochemical differences existed among samples. Surficial soils and sandstones were yellowish-brown in color and much lower in SC, compared to underlying grayish to black sandstones, shales, and mudstones. Samples generating exothermic reactions with 30% H_2O_2 produced higher SC levels. In conclusion, the mine spoils studied varied widely in TDS generation potential. The simple field indicators presented here, such as color, weathering status, rock type, and H_2O_2 reaction can provide valuable guidance for identifying TDS risk in the field which would greatly improve operator's ability to actively minimize TDS release. We recommend using soils and weathered, yellowish-brown sandstone layers as a source of low TDS spoils whenever possible. Underlying unweathered bedrock layers should be treated as "potentially high TDS spoils". The H_2O_2 field test is useful for identification of TDS risk. Particularly high risk spoils include gray to black mudstones and shales, coals, and coal associated shales, mudstones, and clays directly associated with coal seams. We recommend hydrologically isolating these spoils using techniques similar to those used historically for acid-forming materials.

Additional Key Words: Specific conductance, weathering, overburden, coal, peroxide, color.

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Regeneration dynamics of seedling origin aspen: Working towards resiliency in forest restoration

C. M. King* and S. M. Landhäusser[2]

Abstract: Aspen (*Populus tremuloides* Michx.) is a foundational tree species, native to large areas of North America. The resilience of aspen forests can be attributed to the species' ability to regenerate vegetatively after aboveground disturbance, where new shoots can be produced from its large clonal root system and from retained stumps. More recently, aspen of seedling origin has been planted on many boreal forest reclamation sites. In this situation seedlings are genetically independent and have self-reliant root systems. It is unclear how these seedling origin aspen stands will respond to aboveground disturbance, and whether they provide enough suckering to successfully regenerate to forests via clonal propagation. Our research aims to understand the extent of clonal regeneration in 8 to 12-year-old aspen trees, and to determine how this is related to disturbance type, planting density, and root system characteristics. Selected aspen trees were cut at either 0 cm or 25 cm stump height, left standing but with their roots severed, or were left as an untreated controls (n=80). The type and amount of regeneration for each tree was assessed at the end of the summer. In 2016 all remaining trees (n~1700) were removed from the sites, and regeneration was assessed. Trees cut at 0 cm produced on average 7.5 suckers per individual root system compared to 2.5 suckers in the 25 cm cut and severed root treatments. Small diameter trees produced more stump sprouts than large diameter trees. In 2016, trees planted at a lower density and possessing larger individual root systems produced more suckers than smaller diameter, higher density stands. The results indicate that stands originating from planted aspen seedlings have the ability to recover from disturbance, but this is dependent on individual root system size and planting density, suggesting that individual root systems maintain independence and are competing for resources.

Technical Sessions: Reforestation or Reclamation Success

Additional Key Words: Reclamation, clonal management, forest management

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[1] Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

[2] Carolyn M. King, Renewable Resources, University of Alberta, Edmonton, AB, Canada (student); Simon M. Landhäusser, Professor, Renewable Resources, University of Alberta, Edmonton, AB, Canada.

What Happens to a Mine after Mining?
Making Mine Land Reclamation More of a Community Asset[1]

Michael C. Korb, P.E.[2]

Abstract:

A mine is only a temporary use of the land. The operation of a mine may last a few years or several decades. A mine is closed when it is depleted or isn't profitable. Abandoned mine lands (AML) are reclaimed when funding's available.

Active mine regulators require mine closure plans reclaimed to a specific post-mining land use. Restoring to pre-mining land use has historically been easiest and cheapest to permit. AML priorities have focused on reclamation of hazards. In both cases, mine sites are usually returned to their pre-mine uses, usually wildlife habitat or forestry, which often doesn't benefit communities.

Mine-closure plans are seldom creative. I attempted a revised reclamation plan with a water-filled pit for recreation in the 1980s. Regulatory agencies were not enthused and that plan has become a legend that is still talked about. In the state AML program, we did some "innovative" reclamation, but one department secretary described our role as "filling holes."

In recent years, regulators have looked more kindly on imaginative land uses, and AML projects began reclaiming the energy of communities affected by legacy coal mining. 1990 and 2006 SMCRA amendments created set-aside allowances for abandoned mine drainage treatment. Most recently, the 2016 Federal Appropriations bill included a $90 million pilot project for economic development on AML.

The pilot program projects are a good start for making AML more of a community asset. Projects could and should include tourism, recreation, museums; industrial development, research or education centers; gardens, parks, fish farms, agriculture; and mine water district heating.

This presentation will look at and discuss some of the pilot projects in progress, some past projects here and in other countries, and will touch on some "out-of-the-box" ideas for making mine closure and AML projects more sustainable and more of a community asset.

Additional Key Words: mine closure, abandoned mines, geothermal, tourism, economic development, tourism, recreation.

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Relationship between aqueous and sediment chemistry and biological recovery across a gradient of acid mine drainage impairment[1]

N.A. Kruse*, S. Damdinbal, and D.L. Lopez[2]

Abstract: Acid mine drainage, a product from pyrite weathering in coal mining regions, has caused destructive changes in water chemistry, sediment chemistry, and biological communities in streams worldwide. This study focused on correlations between water and sediment chemistry and its impact on benthic macroinvertebrates in the coal mined areas of four coal-mined watersheds in southern Ohio, Leading Creek, Monday Creek, Raccoon Creek, and Sunday Creek watersheds. They have all been severely, moderately, and lightly impacted by acid mine drainage. Sediment chemistry analysis was completed at 32 sites across a gradient of biological impairment, as indicated by macroinvertebrate multimetric index scores, in addition to historic data analysis of water chemistry, sediment chemistry, and aquatic biology. Aqueous and sediment chemistry were compared with biological impairment to determine which chemical stressors had the largest impact on the biological community. The study results suggest that contaminants including acidity, Al, Fe, and Mn in the water column and sediment metals namely, As, Ca, Cu, Fe, and Mn are the most likely stressors to impede macroinvertebrate recovery. While previous research has shown little influence of sediment chemistry on macroinvertebrate health, this study has shown correlations between biological impairment and elevated sediment metals that should be investigated further.

Additional Key Words: macroinvertebrate, coal mine, geochemistry

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Development of a low-cost remote water quality monitoring system in acid mine drainage impaired watersheds[1]

N.A. Kruse*, G.G. Ogallo, H. Kruse[2]

Abstract: The efficiency of watershed management and acid mine drainage (AMD) treatment depends on the frequency of monitoring water quality. Remote water quality monitoring can improve watershed management by collected ongoing data in difficult to reach or infrequently visited locations. However, this is often very costly and difficult to implement. This study focused on designing and building a low-cost remote water quality monitoring system and deploying it in an AMD impaired stream. System development was achieved by integrating low cost computing technology, power management, monitoring sensors, and 'disruption tolerant networking' (DTN). DTN is a communications protocol that supports data transfer even in regions with either no cellular coverage or unreliable coverage. The test system was used to measure pH, specific conductivity, and temperature at 15 minute intervals. The composite system is made up of three main components which include the data acquisition node, communication module, and the cloud database. The data acquisition node is made up of the sensor nodes which include pH, conductivity and temperature sensors, a credit-card sized computer, and microcontroller powered by a solar panel. Data was transmitted using a data mule (computer or smart phone that automatically transfers data from the computer) and was then uploaded to cloud storage. A side-by-side test between the low cost water quality monitoring system and a reference YSI 600 XLM sonde was conducted to demonstrate the effectiveness of the low cost system.

Additional Key Words: geochemistry, sensors, acid mine drainage treatment

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Evolution of Trace Metal Removal Products in Field-scale Vertical Flow Bioreactors

J.A. LaBar* and R.W. Nairn[2]

Abstract: A passive treatment system, including two parallel vertical flow bioreactors (VFBR), was constructed in 2008 to treat net-alkaline ferruginous mine drainage in the Tar Creek Superfund Site in northeastern Oklahoma. The VFBR were installed to remove trace metals through a variety of mechanisms, including adsorption, carbonate precipitation, organic complexation, and sulfide precipitation. Substrate samples from the VFBR were collected in 2010 and 2014 and subjected to sequential extraction procedures to determine the final products of trace metal removal. Trace metals that were examined included Cd, Co, Fe, Mn, Ni, Pb, and Zn. Average total concentrations of Cd, Co, Fe, Mn, Ni, Pb, and Zn were 1.4, 6.9, 2.3, 2.3, 5.8, 2.3, and 4.1 times greater in 2014 than in 2010, respectively. Comparison of results from the two sampling episodes demonstrated an evolution in the final products, from less stable constituents in 2010 to more stable constituents in 2014. Higher percentages of all seven trace metals were found in the exchangeable fraction in 2010 than in 2014, while higher percentages were found in the organic/sulfide fraction in 2014 than in 2010. Adsorption played an important role in trace metal removal in the first two years of operation of the VFBR, but by the end of six years of operation, sulfide precipitation became the primary method of Cd, Co, Fe, Ni, Pb, and Zn removal. Removal of Mn was dominated by adsorption and carbonate precipitation in the first two years, but by the end of six years organic complexation accounted for nearly a third of Mn removal. With the exception of Mn, the majority of trace metals are being retained as insoluble sulfides in the mature VFBR.

Additional Key Words: Bacterial sulfate reduction, sulfide precipitation, sequential extractions

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2. Julie A. LaBar, Environmental Engineering Postdoctoral Fellow, Center for Watershed Restoration and Service, Department of Engineering, Saint Francis University, Loretto, PA 15940; Robert W. Nairn, Viersen Family Foundation Presidential Professor, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK 73019.

Utilization of Extractable Soil Test Sulfate as an Indicator for Acid Producing Pyritic Sulfur[1]

David. J. Lang* and K. Keith Crouse[2]

Abstract: Overburdens in the Mississippi Embayment are mined for lignite in Mississippi, Louisiana, and Texas. Similar Eocene deposits are mined for lignite in Wyoming, Montana, and North Dakota. These are unconsolidated sediment layers that are unoxidized gray materials and may be suitable inclusion as final respread. Variable amounts of pyritic sulfur may be present in these overburdens selected for reclamation that can be difficult to predict from visual characterizations. Generally, red oxidized materials contain little pyritic S, so these are favored as suitable topsoil substitutes. Standard agricultural soil testing determines exchangeable potassium (K) and phosphorus and extractable potassium (K), but neither pH nor the predicted lime requirement provides an indication of potentially oxidizable sulfur. Normal agricultural soils contain 50 to 200 mg kg^{-1} extractable sulfate depending upon seasonal sulfur mineralization stages and it can vary by extractant utilized (Bray, Mehlich, Lancaster, etc.). The Mississippi Soil Testing laboratory routinely utilizes the Lancaster solution to determine agricultural fertilizer and lime recommendations. It determines most of its parameters by Inductively Coupled Plasma Spectroscopy including Ca, Mg, P, K, Na, Zn, Mn, and SO_4-S, though Mn and SO_4-S are not routinely reported. Since 2005, all samples from reclamation research in Mississippi have had SO_4-S and Mn reported. Samples with known pyritic-S levels of 0.05 (A) to 0.16% (B) were found in some gray unoxidized materials not suitable for topsoil replacement utilization. These were mixed with various portions of suitable red oxidized materials with 0.00 % pyritic-S and tested for extractable sulfate and incubated in the greenhouse for 12 months. Extractactable S from B (high pyritic S) was 500 to 1000 mg kg^{-1} initially and 150 to 180 mg kg^{-1} SO_4-S from the low pyritic-S site (A). Apparent pH remained high (7.2 to 7.8) at site A, but it declined to 4.6 to 5.1 in the higher pyritic-S materials. Economical utilization of routine agricultural soil testing provides a viable initial screening tool prior to expenditure of scare resources for expensive overburden testing procedures.

Additional Key Words: Oxidizable Sulfur, Initial Screening Tool

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Metal Reclamation Units (MRUs Wetlands in a Box) for AMD and Nutrient Cycling [1]

C. Lennox [2]

Abstract: Metal Reclamations Units (MRUs) are passive, modular, scalable, rapidly deployed wetland bioreactors. The biofilm which grows upon the support matrix inside the MRUs is self-selecting and determined by the introduced pollutants and how they are attenuated throughout the treatment process. MRUs use multiple stepped waterfalls (1-750 Lpm), which decrease short circuiting, increase gravity precipitation to the bottom sludge vault, and engender 3 periodic and efficient gas exchanges per MRU. These gas exchanges speed the oxidation or reduction process by de-gassing biotic/abiotic products and swapping them for preferenced gases in the open or closed MRU. The metabolic pathways that develop and change through attenuation represent all three microbial domains and are the MRUs work force. MRUs also support a diverse array of breeding micro and macro fauna, functioning as vernal ponds when buried to the lid and the treated flow surpasses sensitivity thresholds. Currently, our systems function as tertiary treatment at six sites removing Mn and Al, pH<7, where residual Fe and Al are captured to below 0.35 mg/L and Mn is removed at rates up to 200+grams/m2/day to achieve TMDLs (3, 4). At another site, raw treatment of dissolved Fe, pH <5.5 max to 3.2> minimum, demonstrated rates up to 4kg/day of Fe captured using two MRUs Mk1.5s in series, residence 20-25 minutes, flow 280 Lpm (5). Replications show that nutrient additives which consider biofilm ecological needs increase biological remediation of metals. Concerning aquaculture, an MRU which receives diverted leachate from grow rooms recycles the intentional over-nitrification of P and K almost indefinitely, while nitrate is produced from the aquaponic nitrifier dynamic. The highly diverse and aerobic ecosystem in the MRUs function as integrated pest managers, limiting the dangers of pathogens, pests, and metal toxicity from uncycled fertigation water in closed loop environments.

Keywords: biofilm, natural attenuation, aquaponics

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2. Colin Lennox is a field scientist, inventor, and CEO of EcoIslands LLC.
3. C. Lennox. Biofilm Remediation of Al, Fe, and Mn Using "Microchip Wetland" Metal Removal Units (MRUs). 2015 West Virginia Mine Drainage TaskForce Symposium. Abstract. http://www.slideshare.net/ColinLennox/biofilm-remediation-of-aluminum-iron-and-manganese-using-microchip-wetland-metal-removal-units- mrus
4. C. Lennox. http://www.slideshare.net/ColinLennox/mn-bio-ox-webinar-aug-2016-68494783?qid=3df4e899-926c-4ffa-af59-a5ff7aed8c55&v=&b=&from_search=1
5. C. Lennox. http://www.slideshare.net/ColinLennox/total-fe-removal-552-f32-ph-present

A Case Study Evaluating Effluent Quality Following Chemical and Electrochemical Precipitation for Metals Removal from Acid Mine Drainage Water[1]

B. J. Lesikar, Ph.D., P.E.*, D.J. Kovalcik, and C.J. Villela[2]

Abstract: Treatment of acid mine drainage water streams is critical to meeting water quality goals in mining regions. A case study was conducted on mine water series of treatability tests on acid mine drainage water, specifically for the reduction in metals and water clarification. Testing included conventional chemical precipitation using calcium hydroxide and sodium hydroxide, independently, for metals precipitation. BakerCorp's patented electrocoagulation system (EC) was tested for metal precipitation. The EC results were compared to conventional chemical precipitation using calcium hydroxide and sodium hydroxide. The conventional chemical precipitation raised the pH of the acid mine drainage water to a neutral pH level using calcium hydroxide and sodium hydroxide, respectively. The EC treatment investigated influent pH ranges, treatment flow rates, and post treatment pH ranges for the precipitation of metals in the acid mine drainage water. The conventional chemical injection did reduce metal concentrations in the acid mine drainage water, confirmed by a third party NELAC certified analytical laboratory. Specifically, aluminum and iron concentrations were reduced to <0.1 mg/L and <0.02 mg/L, respectively. After conventional chemical precipitation was completed and solids separation was conducted the conductivity of the acid mine drainage water increased from the original raw water. The EC system did reduce metal concentrations in the acid mine drainage water, confirmed by a third party NELAC certified analytical laboratory. The EC treatment was able to reduce aluminum and iron concentrations to the same effluent levels of the conventional chemical injection process. Results conclude the EC treatment process has the ability to reduce metals concentrations to lower levels compared to conventional chemical precipitation. Metals include, but not limited to: manganese, nickel, silicon, and zinc. The conductivity of the effluent water decreased compared to the influent raw water, whereas conventional chemical precipitation increased the effluent conductivity.

Additional Key Words: Chemical coagulation, Electrocoagulation, Total Dissolved Solids, Iron, Aluminum, manganese, nickel, zinc.

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Geocoding Locations of Historic Reclamation Research Sites using Google Earth[1]

R. Li[2]

Abstract: The American Society of Mining and Reclamation (ASMR) has been publishing conference proceedings and journal articles on land reclamation and the protection of soil and water resources. Much of the technical work presented in the ASMR conferences and journals contain specific mining sites or localities that are associated with geographic locations. However, the geographic contexts of these articles were often not directly available or geotagged. This deficiency affects the abilities of related professionals to explore the technical reclamation knowledge in terms of its geographic background. Therefore, it is critical to develop quality-assured geographic reference to the papers published by the ASMR. This study used Google Earth and ArcGIS software to create a series of placemarks that link past ASMR technical articles to the actual locations. These placemarks can be freely distributed and integrated into the website for web map display.

Additional Key Words: ASMR; geotagging; ArcGIS; placemark

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2. Ruopu Li, Assistant Professor, Department of Geography and Environmental Resources, Southern Illinois University, Carbondale, IL 62901.

Reclassification of the Upper Little Juniata River Based on Continuous In-Stream Monitoring[1]

S. Long, W. Strosnider[2], and J. Eckenrode[3]

As mandated by the Municipal Separate Storm Sewer System (MS4) program, municipalities are required to execute a storm water management program aimed at protecting, preserving, and improving existing streams by minimizing the impacts of runoff. The Little Juniata River; tributary to the Juniata River in the Susquehanna River and Chesapeake Bay watersheds, is situated in a designated, urbanized region and subject to possible high pollution concentrations via runoff during storm events. The Little Juniata is currently classified as a "Trout Stocked Fishery" with intent of upgrading to a "Class A, Wild Brown Trout Stream" per the PA Fish and Boat Commission expected recommendations. Additionally, there is a potential of High Quality Coldwater Fishery (HQCWF) designation from PA Department of Environmental Protection. Due to geographic location and surrounding land use, concerns of pollutants infiltrating the watershed during storm events could impair the stream, inhibiting the Little Juniata from attaining HQCWF designation. The intent of this study is to compile a comprehensive synopsis of the upper Little Juniata River by monitoring several locations along its reach. Continuous instream monitoring devices combined with portable samplers are relied upon for consistent data available in 15 minute increments as well as collection of water samples during normal flow and storm events. Thorough analysis of physical and chemical attributes attained via monitoring will supply a sound indication of the quality of the stream with its current designation as impaired, thus influencing river designation.

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2. William Strosnider, Professor, Engineering Associate Professor Environmental Engineering, Loretto, PA, 15947; Stefan T Long, Student, Environmental Engineering, Saint Francis University, Loretto, PA 15947.

3. James Eckenrode, Watershed Specialist, Blair County Conservation District, Hollidaysburg, PA 16648.

Unmanned Aerial Vehicle (UAV) Survey for Year-End Mining Reclamation Estimation

M.S. Maguire[1]

Abstract: Mine operators routinely take stock of their mining assets at the end of the year for reserve estimation and financial reporting. The timing of this activity can be very challenging. Data must be compiled as close to year-end as possible to ensure accurate reporting and forecasting for budget models. In addition to calculating stockpile volumes, future reclamation activity must be evaluated for Asset Retirement Obligations (ARO) and budget estimations. These data are typically captured through aerial or terrestrial survey to obtain high resolution aerial photography and topographic information. The advent of Unmanned Aerial Vehicle (UAV) technology has created another means for capturing this information and offers advantages over traditional survey methods. UAVs can be deployed at mine sites with minimal setup, short flight times, and quick turnaround of topographic data for volumetric calculations. This presentation will provide an overview of the hardware and software tools, mapping products, and data processing techniques for determining ARO metrics. A case study of UAV survey work completed for several mining sites in Somerset County, Pennsylvania will be presented, which will highlight project successes and considerations for future improvement.

Additional Key Words: Drone, Topography, Mapping, Stockpile, Volumetric

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Understanding Storm Response of AMD Impacted Streams

Z. I. Martin*, N. Kruse

Abstract: Limited biological recovery in acid mine drainage (AMD) impacted streams may be due in part to a flushing response caused by rainfall events due to the transport of accumulated AMD reaction products that go partially untreated, causing a decline in water quality of the stream. This study examines the changing geochemical environment during precipitation events in the Hewett Fork watershed, in Athens County, Ohio. Three sampling sites along Hewett Fork were selected to deploy data logging equipment to log water chemistry. The most impaired site, HF129, was situated just downstream of an active treatment system discharge; here the data logger collected depth, temperature, and conductivity. The next site downstream, HF090, is where some biological recovery can be found, and the furthest downstream site, HF039, is where the stream meets both chemical and biological metrics. At the latter two sites the data loggers recorded pH, temperature, conductivity, total dissolved solids, and oxidation-reduction potential. During large storms, water samples were collected once an hour for 24 to 48 hours using auto-samplers at HF090 and HF039. The collected samples were then analyzed for total acidity, total alkalinity, sulfate, and a large suite of cations, including Al, Fe, and Mn. Flow measurements were collected during various flow regimes to help correlate the discharge to measured water depth. The results suggest that storm events occurring under high flow conditions are more critical to the chemical conditions than expected. While storm events during the low flow of summer did not lead to episodic degradation of water quality. Inputs from downstream tributaries and groundwater sources within the watershed are shown to be contributing additional alkalinity during storm events, which may buffer the storm effect during low flow conditions of summer. This study supports the importance of measuring the variation of chemistry during storm events.

Additional Key Words: Episodic events, Auto-samplers, Rainfall, Flushing response

Reclamation of Refuse Piles using Fluidized Bed Combustion Ash in the Blacklick Creek Watershed, Pennsylvania[1]

G.L. Aaron*, R. Martin, and G. Greenfield[2]

Abstract: Refuse piles from abandoned, pre-SMCRA underground mining operations have been a major source of acid mine drainage in the Blacklick Creek watershed located in Cambria County, Pennsylvania. Beginning in 1988, five of the largest refuse piles in the watershed were permitted for refuse reprocessing. The refuse was to be removed, screened, and hauled to a nearby fluidized bed combustion (FBC) power plant, specifically designed to burn coal refuse. At the FBC power plant, ground lime is injected into the boiler to aid in air pollution control by removing sulfur dioxide. The FBC ash would then be returned to the site and mixed along with the reject refuse material. As a result of the lime addition in the combustion process the FBC ash that encapsulates the reject material is alkaline and has a low permeability resulting in reduced water infiltration and acidity generation. The sites are revegetated once all combustible refuse is removed and ash placement is completed. Of the five refuse piles, two have been fully reclaimed and three are still in the process of removing refuse or placing ash. As of 2015 more than seven million metric tons of refuse has been reprocessed from the five sites. A total of twenty three individual discharges are being monitored on the five sites. As refuse reprocessing has been progressing there has been a substantial reduction in the loadings of pollutants to Blacklick Creek watershed. Prior to reclamation the total average acidity loading from the twenty three discharges was 4,826 kilograms per day. After reclamation was fully or partially completed the total average acidity loading is now 204 kilograms per day. The water quality of the immediate receiving streams had been net acidic for several decades since the refuse piles first were placed, but is now consistently or intermittently net alkaline.

Additional Key Words: None

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Labware Evaluation for Selenium Sorption Experiments

R.K. McGrail* and L.M. McDonald

Abstract: Selenium (Se) is an essential trace element that is toxic at small concentrations. The United States Environmental Protection Agency has established a maximum concentration of 50 µg L^{-1}in drinking water and 5 µg L^{-1} as a chronic life criterion. Environmentally relevant concentrations are very low — 0.02 µg L^{-1} in freshwater, 0.08 µg L^{-1} in saltwater and 0.01-2 mg/kg in soil. Therefore, labware must be carefully chosen in order to prevent changes in sample composition over time as a result of interactions between sample and container. Our objective was to assess four materials (glass, silanized glass, Teflon, and polypropylene) for use in Se sorption studies. All glass containers were acid washed in a two stage acid bath for 24 hours per stage. Varying selenium stock solutions (0, 10, 25, and 50 µg L^{-1}) were prepared in 0.1 M NaCl and delivered to each container. Samples were sealed and allowed to equilibrate for 6, 12, 24, or 48 hours to evaluate the ability of the material to suitably hold samples for sorption studies. ANCOVA was conducted on blank corrected samples as the acid used in analyses contains trace amounts of selenium. Results were statistically significant at concentrations of 25 and 50 µg L^{-1} with p-values of 0.0018 and 0.0001. Within each model, silanized glass corresponded to the smallest slope with 0.03, 0.04 and 0.06 at concentrations of 10, 25, and 50 µg L^{-1} respectively. In sorption studies, silanized glassware is recommended as it enhances sample integrity through limited losses to the material itself.

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[2.] Rebecca K. McGrail, Graduate Research Assistant, West Virginia University, Morgantown, WV 26505 (student); Louis M. McDonald, Professor, Plant and Soil Sciences, West Virginia University, Morgantown, WV 26505.

EFFECTIVE MODIFICATIONS TO THE DESIGN AND APPLICATION OF CONSTRUCTED WETLANDS AND LIMESTONE BEDS[1]

Brent Means* and Malcolm Crittenden[2]

Abstract: Constructed wetlands and limestone beds have been used to treat mine drainage for many years. Both treatment systems have undergone an evolution of design changes to address issues that degrade treatment performance. Recent modifications have been made to the design and application of these technologies to optimize treatment performance and maintenance requirements. This paper reviews the modifications used to optimize treatment and provides the performance of numerous modified wetlands and limestone beds. Ponds are the technology of choice to oxidize and settle iron from net alkaline mine drainage; however, ponds struggle with achieving effluent standards for electrostatically stable solutions containing iron colloids. Ponds use gravitational settling as the primary removal mechanism, which is ineffective if the mass of the colloid is small enough where electrostatic repulsive forces dominate over gravitational forces. Wetlands were placed after ponds at several treatment sites to cleanse the water of colloidal iron to concentrations as low as 0.07 mg/L. The authors hypothesize wetlands remove iron colloids through an electrostatic attraction between colloidal iron and vegetation. An empirical-based sizing methodology was developed that accounted for the annual vegetative growth cycle to ensure removal during winter months. This application of wetland technology can help achieve strict total iron effluent criteria and replace the use of organic polymers in both active and passive treatment scenarios. Limestone beds are used to passively treat acidic mine drainage. Accumulation of metal hydroxide sludge within the bed is a major operation and maintenance issue that degrades treatment and leads to hydraulic failure. Engineering solutions, such as flushing systems, have been historically used to remove sludge. As an alternative to engineering solutions, the authors modified the basic design of a limestone bed to promote periodic sludge maintenance using excavators. The bed is designed to pond water above on top of the limestone in areas that are hydraulically plugged with sludge. This visual cue is used to perform targeted rehabilitation long before effluent quality degrades. Plugged areas are mechanically agitated or replaced to restore flow. More than ten of these systems have been constructed over the past decade.

Additional Key Words: Mine water treatment, Passive Treatment

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The Appalachian stream syndrome: complex local conditions and regional metacommunity degradation caused by the accumulation of multiple stressors[1]

E. R. Merriam* and J. T. Petty[2]

Abstract: We surveyed 170 streams throughout the mountaintop-mining region of West Virginia to characterize local (i.e., chemical degradation) and regional (i.e., metacommunity processes) controls over aquatic resource degradation. We first characterized and quantified the relative contribution of specific land use activities to regional chemical degradation. We then used a series of modeling techniques to test the hypothesis that local (observed water quality) and neighborhood (predicted water quality within a 5km buffer) conditions combine to control macroinvertebrate assemblages through alteration of metacommunity structure (organism tolerance) and processes (dispersal). We identified 3 important dimensions of variation in water chemistry associated with contemporary surface mining (elevated dominant ions, sulfate, alkalinity, and selenium), abandoned mine lands and coal geology (elevated trace metals), and residential development (elevated sodium and chloride). Development-related chemistries were predicted to be the most prevalent on the landscape; however, the combination of all 3 sources of pollutants resulted in complex contaminant mixtures, particularly in larger streams. Local conditions (i.e., habitat and water chemistry) were the dominant driver of community composition, with development-related chemistries having the strongest effect on state-adopted indices of biotic integrity (i.e., West Virginia Stream Condition Index). However, mining-related chemical degradation was strongly related to the loss of sensitive taxa (e.g., EPT richness). The accumulation of mining- and development-related degradation at the neighborhood-scale further acted to decrease the occurrence and abundance of moderately sensitive and poor dispersing taxa and to facilitate the proliferation of tolerant taxa. Thus, aquatic resource degradation within this region can be attributed to the accumulation of contaminants from multiple land use activities that degrade aquatic communities through disruption of large-scale metacommunity processes. Future management will require a multi-stressor approach that addresses both local and neighborhood effects of current and future land use and mitigation activities.

Additional Key Words:

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[2.] School of Natural Resources, West Virginia University.

POLLUTION LOADING TRACKING TO CHARACTERIZE SUCCESS OF AN ANOXIC LIMESTONE DRAIN INSTALLATION ON LAMBERT'S RUN, SOUTHWESTERN PENNSYLVANIA[1]

Hannah E. Patton*, Lydia G. Mignogna*, Kevin Tomkowski*, Joshua Vinglish*, Kelsea J. Palmer, Morgan C. Whited, Malcom Crittenden, Greg Shustrick, William H.J. Strosnider[2]

Abstract: Mining has been an integral part of the history of Western Pennsylvania since the 1700s when the first bituminous coal mines opened. An unfortunate byproduct of this extensive mining history is the occurrence of acid mine drainage (AMD) in local watersheds. The Lambert's Run AMD treatment system, located in Somerset County, is the result of an AMD-affected artesian well discharging directly into a wetland that empties into Lamberts Run, a tributary of the Stonycreek River. The discharge is characterized as having pH of around 3 and little to no alkalinity. This site has been monitored for years by the Pennsylvania Department of Environmental Protection as well as the Somerset County Conservation District prior to installing an Anoxic Limestone Drain (ALD) to treat the discharge. Currently, pollution loading tracking studies are being completed in order to characterize the success of the ALD treatment system and to determine other significant sources of AMD in Lamberts Run. According to the pollution loading strategies completed, the pH of discharge has increased to over 5 and alkalinity to over 30 mg/L. Thus far, the data suggests that the system as it stands may not be enough to fully remediate Lambert's Run. The ALD was always envisioned as a first step to remediate this water resource and further work may be necessary for a return to suitable water quality.

Additional Key Words: alkalinity, iron, passive treatment, pyrite, specific conductivity, total metals concentration

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Survival and Growth of Woody Plants on Four Reclaimed Mine Sites

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Abstract: Reforestation plantings usually include tree species that dominate the forest canopy, namely, oaks, maples, cherry, poplars, and pines. Planting of understory woody species, however, is less common in reforestation efforts despite their importance in forest ecosystems. In this study, the survival, health, and growth of 20 species of mast- and fruit-producing shrubs and small trees were evaluated to better understand their suitability for reclamation plantings. Seedlings were planted in graded overburden material between 2008 and 2010 on four reclaimed surface coal mines in WV. The selected sites were reclaimed using conventional methods. The experiment was a completely randomized block design with four replications per site. At each site, four blocks measuring 4,160 m^2, two east-facing and two west-facing, were established. Each block was comprised of 20 plots (one plot per species), and within each plot 25 individuals of the selected species were planted on 2.4 x 2.4 m spacing. Initial data on survival, growth, and health of these species was collected in 2008 on two sites and 2010 on two other sites. Survival, growth, and health of these species were measured again in 2015 and 2016 to determine individual species performance over time. Overall, shrub species had higher survival percentages than tree species. Species that performed well with ≥50% survival were Washington hawthorn (*Crataegus phaenopyrum,* 62% survival and 1 m avg. height), black chokeberry (*Aronia melanocarpa,* 59% survival and 0.8 m avg. height), nannyberry (*Viburnum lentago,* 56% survival and 0.9 m avg. height), black cherry (*Prunus serotina,* 55% survival and 2.5 m avg. height), and gray dogwood (*Cornus racemosa,* 54% survival and 1 m avg. height). These species would be good candidates for inclusion in reforestation plantings on reclaimed mines. Species that did not perform well in this study included pawpaw (*Asimina triloba,* 9% survival and 0.06 m avg. height), flowering dogwood (*Cornus florida,* 10% survival and 0.1 m avg. height), blueberry (*Vaccinium corymbosum,* 27% survival, 0.2 m avg. height), elderberry (*Sambucus canadensis,* 30% survival and 1 m avg. height), and persimmon (*Diospyros virginiana,* 38% survival and 0.5 m avg. height). Due to the ≤50% survival percentages achieved by these species in this study, they are less suited for reclamation.

Additional Key Words: shrubs, small trees, West Virginia

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Why Aren't All Mine Reclamationists Considered Ecological Engineers?[1]

R.W. Nairn and William H.J. Strosnider[2]

Abstract: The science of mine reclamation has advanced considerably in the past 40 years since passage of the Surface Mine Control and Reclamation Act. Implementation of innovative reclamation strategies on permitted and abandoned coal mines has provided benefit to both human health and the environment. A 2016 proposed rule by the U.S. Environmental Protection Agency provides for similar post-mining requirements on hard rock mines. Successful reclamation often results in self-sustaining ecosystems, albeit ones that may include introduced species and similar (but not identical) structure and function of the original landscape. Restoration, as opposed to reclamation, has been described as the return of an ecosystem to an approximation of its original condition prior to disturbance. Therefore, an inherent disconnect exists between the not dissimilar professional communities of practicing reclamationists and restoration ecologists. Ecological engineering, defined as the design of sustainable ecosystems that integrate human society with the natural environment for the benefit of both, may bridge the gap between these communities. Through the marriage of ecosystem ecology, with a focus on biogeochemical cycling, energetics, and resilience, and engineering design, ecological engineers build functioning ecosystems. They also recognize that natural infrastructure, through conservation of intact natural ecosystems and/or creation of ecologically engineered ecosystems, provides services critical to economic and social well-being. In comparison to traditional "gray" infrastructure, natural or "green" infrastructure has proven to be more resilient and adaptable to major global environmental drivers, including growing and shifting human populations, increasing climate variability and change, water scarcity and degradation, and changes in energy production and consumption patterns. Several mining reclamation case studies in southern Great Plains and northern Appalachian watersheds provide meaningful illustrations of the role of ecological engineering applications in practice, demonstrating the need for a basic change in our global approach to multifaceted food, energy, and water challenges.

Additional key words: natural infrastructure, passive treatment systems, ecosystem ecology, engineering design

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Challenges of Designing and Building a Passive Treatment System with Limited Topography, Hydraulic Head, and Available Land Area [1]

R.W. Nairn, T. Danehy, C. Neely, R. Dutnell, B. Page, N. Shepherd, D. Cates and B. Stanila[2]

Abstract: Mine waters at the Tar Creek Superfund Site, part of the Tri-State Lead-Zinc Mining District of Oklahoma, Kansas and Missouri, are characterized as net alkaline with elevated Fe, Zn, Pb, Cd and As concentrations. Successful passive treatment of these waters has been demonstrated when adequate land area, appropriate topography and satisfactory hydraulic head differences are available. In southeast Commerce, Oklahoma, artesian-flowing collapse features were filled in 2006 as part of a land reclamation project, which resulted in distributed upwelling of mine water. These seeps were captured in subsurface drains and discharged untreated to the headwaters of an unnamed tributary to Tar Creek. Consequently, mine waters no longer daylighted on site and instead were maintained at a depth of 3-4 feet below grade. Existing site surface elevation differences were minimal (~ five feet) and potential land area for construction was limited to ~2.5 acres held by a single cooperative landowner. In addition, the site is near schools, residences, and light industrial operations. Mine waters were pH 6 with 300 mg/L alkalinity, 134 mg/L Fe, 10 mg/L Zn, 60 ug/L Pb, 30 ug/L Cd, 40 ug/L As and >2000 mg/L sulfate with volumetric discharge rates of ~100 gpm. A four-process unit passive treatment system was designed and constructed to address these waters, consisting of an oxidation pond (OP), surface flow wetland (SFW), vertical flow bioreactor (VFBR) and final polishing unit (FPU). Innovative design aspects included shared design surface water elevations across units, use of z-piling and baffle curtains to extend hydraulic retention times and direct flows, solar-powered floating aeration devices (in the OP and FPU) and odor control (for the VFBR outlet), and nuisance mammal control strategies. During construction, unmapped mine shafts were encountered, leading to substantial uncontrolled flows into the OP and impacting other nearby artesian discharges. It is anticipated that successful passive treatment of the Southeast Commerce mine waters will lead to ecological recovery of the unnamed tributary.

Additional key words: oxidation pond, vertical flow bioreactor, solar-powered aeration, float-mix aerators, Tar Creek Superfund Site, mine drainage

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Passive Treatment of Highly Contaminated Iron-Rich Acid Mine Drainage[1]

C.M. Neculita*, T.V. Rakotonimaro, B. Bussière, T. Genty, and G.J. Zagury[2]

Abstract: Highly contaminated iron-rich (> 0.5 g L^{-1} Fe) acid mine drainage (AMD) is often generated on closed and abandoned mine sites. Efficient treatment of such quality AMD is sometimes achieved by using passive multi-unit systems. The reactivity and hydraulics of these units are challenging because they deteriorate over time. The DAS (dispersed alkalinity substrate) units, consisting of coarse organic matrix (wood chips) and neutralizing materials (calcite, magnesia) seem appropriate for the passive treatment of iron-rich AMD. Likewise, the use of a mixed treatment system comprised of passive biochemical reactors (PBRs - wood waste-based and constructed wetlands) appears to be suitable. The present paper comparatively evaluates the performance of laboratory and two field treatment systems. Firstly, laboratory batch and column testing was performed over a 2-year period, using DAS-calcite, DAS-dolomite or DAS-wood ash with the aim of iron pretreatment, prior to sulfate removal by PBR, followed by a final polishing unit. The performance of this laboratory treatment system was then compared to a field pilot tri-unit (two PBRs separated by a wood-ash unit) system, which was installed on Lorraine rehabilitated mine site and monitored over a 5-year period. Results showed better efficiency (up to 99% Fe removal) during laboratory testing, using two DAS-wood ash pretreatment units, relative to the field pilot (76% Fe removal). Moreover, laboratory testing showed that the hydraulic and clogging issues, often encountered in field passive treatment systems, were limited. On East-Sullivan, a second rehabilitated mine site, a 14-year monitoring data of a mixed treatment system showed the progressive improvement of water quality over time. Iron concentration decreased down to 98%, while regulation requirements (Fe <3mg/L) are respected in most of the discharge locations. Further studies are still required for the efficient design of performant multi-step systems for the passive treatment of iron-rich AMD.

Additional Key Words: multi-unit systems, passive biochemical reactors, dispersed alkalinity substrates.

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Soil changes during stockpiling and after reclamation at three Wyoming natural gas production areas[1]

J. B. Norton* and C.F. Strom[2]

Abstract: Successful reclamation following typical soil salvage, stockpiling, and respreading practices at natural gas wells is often hindered by salt-affected soils, weed invasions, and slow plant establishment. Study sites were established pre-disturbance at nine planned natural gas well pads at the Wamsutter, Jonah, and Pinedale Anticline production areas. Soil physical, chemical, and biological properties in the top 15 cm were tracked for eight years, from predisturbance, through stockpiling, immediately after reclamation, and one, two, and eight years afterward. Cover by planted native species was recorded each season. Results indicate that soil organic carbon (C) content dropped from around 1.8 to about 0.8%. Total soil nitrogen (N) dropped by a similar magnitude, from around 0.15 to around 0.11%, while salt and clay contents increased. Soil C and N were conserved in deep, dry stockpiles then rapidly decomposed following respreading. Native vegetation began to become established at some of the study sites and soil C and N did concentrations were variable but increasing during the sampling period. Although total N dropped, plant-available N increased following respreading of salvaged and stockpiled soils. The results suggests that deep stockpiling may not lead to detrimental changes in semiarid areas, and that there is a need for practices that conserve N mineralized from organic matter during the reclamation process.

Additional Key Words: semiarid, sagebrush-steppe vegetation, Aridisols, soil organic matter, salt-affected soils.

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Effects of Alternative Liming Strategies on Leachate Quality and Soil Morphology of Acid-Forming Dredge Materials[1]

Zenah Orndorff*, W. Lee Daniels, Sara Klopf, and Abbey Wick[2]

Abstract: Over 200 M m^3 of dredge materials are removed annually in the USA from a wide array of source environments. Since 2001, > 750,000 m^3 of fresh- and salt-water source dredge materials have been placed and converted to agricultural uses at an upland utilization facility (Weanack Land LLLP) in Charles City County, Virginia. All materials accepted for placement at Weanack must pass a rigorous screening protocol that includes an assessment of their acid-forming potential. To date, we have screened approximately 20 different potential dredge materials and found that approximately 1/3 of the saline source materials contain significant levels of potential acidity. To determine best management practices for one material (Cox Creek; H_2O_2 potential acidity-PPA = -10 Mg CCE per 1000 Mg material; Total S = 1.31%; CCE = 7.13%), we conducted a series of lab (reported to ASMR in 2011) and long-term field experiments. In the field, two lime application methods were tested (bulk-blending and layering; both at 12.5 Mg CCE per 1000 Mg) against an unlimed control treatment. Three zero-tension lysimeters were installed under each plot to monitor pH, EC and metal content of leachates. The pH of both the bulk-blended lime and layered treatments remained between 4.4 and 5.5 over the first four years (2010-2014), but the pH of the leachates under the non-limed control plots dropped to 3.7 after two year, before slowly rising again to approximately 4.2. The initial EC of the leachate samples (6 to 17 dS m^{-1}) indicated an issue with soluble salts across all treatments, but all fell to < 4 dS m^{-1} by the end of the five year monitoring period. The salts initially originated from entrained chlorides, but were enhanced by sulfates over time as sulfides reacted and were neutralized. High levels of Fe (> 10 mg L^{-1}) and Mn (> 100 mg L^{-1}) leached from the non-limed and layered lime treatments in the field, but were significantly lower in the bulk-blended lime treatment. Net sulfuricization processes were noted by the white sulfate salt crust on the soil surface and prominent jarosite mottles with depth in all plots over the first two growing seasons. More recent (2016) soil pit investigations confirmed that jarosite was still present in subsoil horizons, but was no longer as prominent. The exact nature of the phytotoxicity was not directly determined, but we assume that is was due to a combination of (a) very high levels of soluble salts the first two seasons combined with (b) high soil heat levels due to the black color of the exposed surface materials. Finally, for this particular material (Cox Creek saline dredge) the PPA technique for estimating potential acidity was superior to a more conventional acid-base-accounting approach based on Total-S and CCE determinations.

Additional Keywords: Acid sulfate soils, potential acidity, revegetation, jarosite, phytotoxicity, soluble salts.

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IRON TRANSPORT AND REMOVAL DYNAMICS IN THE OXIDATIVE UNITS OF A PASSIVE TREATMENT SYSTEM: A FIVE-YEAR PERFORMANCE EVALUATION[1]

L.R. Oxenford and R. W. Nairn[2]

Abstract: Performance evaluation of the preliminary oxidative units of the Mayer Ranch Passive Treatment System (Tar Creek Superfund Site, Commerce OK) reveals an average removal of 17.5 g $m^{-2}day^{-1}$ iron oxyhydroxides within Cell 1 (73% removal efficiency; 26,905 kg/year), 95% (33,547 kg/year) for the three oxidative units, and 99% (33,696 kg/year) for the system over five years of operation (2009-2013). Performance nearly meets design expectations of 20 g $m^{-2}day^{-1}$ iron for Cell 1, and the average iron export of 0.51±0.43 mg/L from Cell 6 is satisfactorily below the 1 mg/L guideline for iron loading of surface waters. However, the oxidative unit demonstrates variability in removal efficiency based on seasonality and storm events which impact iron oxidation and sedimentation mechanisms. Cell 1 demonstrates attenuated removal efficiency in December through February with an average water temp = 6.5°C, yet removal inefficiency is mitigated by the surface flow wetlands (cells 2N/2S) in design series. Storm events transport a significant amount of iron oxides in excess of standard operational baseline values ($p = 0.05$; t test), yet the amount transported does not correlate to rainfall intensity. Any rainstorm with an intensity greater than 0.25 cm/hr mobilizes iron oxides for transport due to disruption to the settling of iron flocs rather than the resuspension of sequestered materials. The high frequency of low intensity rain events (0.25-0.99 cm/hr; 6 per month on average) has the largest contribution to iron mass loadings due to storm-induced transport dynamics in comparison to the total mass transport induced by moderate (1.00-2.99 cm/hr; 1 per month), high (2.00-2.99 cm/hr; 1 per month), and extreme (>3.00 cm/hr; 2 per month) events combined. Iron accumulation within the oxidative unit was found to lack bathymetric uniformity as removal and deposition of material has been measured in the initial section of the cell rather than being distributed uniformly. Accumulation and characterization of the physical properties of iron oxyhydroxides from discrete core samples yield bulk phase properties for goethite, with low crystallinity (<20% in Cell 1, <70% Cells 2N/2S), low organic matter (<4%), and average particle size of 11-19 microns (hydrated via laser diffraction). A reduction in the design hydraulic retention time of Cell 1 was confirmed (7.7 days design; 5.4 days in 2015) via rhodamine tracer study.

Additional Key Words: iron oxidation, solids transport and accumulation, Tar Creek

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SEASONAL STORM-INDUCED METAL TRANSPORT DYNAMICS BETWEEN OXIDATIVE PASSIVE TREATMENT CELLS[1]

L.R. Oxenford and R. W. Nairn[2]

Abstract: Iron oxidation, hydrolysis, and sedimentation are key processes promoted in passive treatment of net alkaline mine waters to remove iron from mine drainage. Oxidation cells are sized based on an area-adjusted mass removal rate of 20 g m^{-2} day^{-1} with a layout that maximizes the hydraulic retention time. Although the chemical composition and hydrology of the mine water is characterized over time as part of system evaluations, the frequency and intensity of storm events have not typically been considered. The purpose of this study was to determine if the metals transport by individual, seasonal, and annual rainfall events is significant with respect to the total amount of metals transported in the discharge of individual treatment cells. Total metals transport from a preliminary oxidation cell (Cell 1), surface flow wetland cells (Cells 2N/2S), and from the final polishing wetland (Cell 6) of the Mayer Ranch Passive Treatment System were characterized over a three-year period (2011-2013) based on rainfall intensity. Autosamplers installed at the effluent of each cell collected time-incremented total metals samples when the rainfall intensity exceeded 0.250 cm/hour over 30 hours. Storms were classified based on intensity as Low (0.25-0.99 cm/hr), Moderate (1.00-1.99 cm/hr), High (2.00-2.99 cm/hr), and Extreme (>3.00 cm/hr). Laboratory determination of total metals (EPA methods 3050 and 6010), produced a series of transport curves for the mass export of total metals including Fe, Zn, Cd, Ni, As, and Pb based on seasonally adjusted flow rates 450 gpm average system influent). Iron transport above baseline (without rainfall disturbance) for individual storm events was significant at all locations indicating that rainfall disturbance does mobilize iron, yet the amount of iron transported does not correlate to rainfall intensity. This suggests solids settling disruption rather than stored materials resuspension as the possible mechanism for total metals storm transport. Storm induced iron transport was at its greatest during spring rain events due to the frequency of storm events rather than their intensity. However, final effluent concentrations for the system were not impacted.

Additional Key Words: iron oxidation, lead-zinc mine drainage, total metals transport

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Quantifying Hydraulic Conductivity in Mine Drainage Passive Treatment System Vertical Flow Bioreactors[1]

B. J. Page* and R.W. Nairn[2]

Abstract: Passive treatment systems (PTS) are cost effective treatment technologies that are designed to use relatively little fossil fuels and natural physicochemical and biological processes for the treatment of AMD. One of the key components of PTS are vertical flow bioreactors (VFBRs). VFBRs typically include waste organic materials as microbial substrates overlying rock drainage layers. They utilize the dissolution of limestone to generate alkalinity for neutralization of excess protons and promote sulfate-reducing bacteria in the organic layer for additional alkalinity generation and trace metal removal as sulfides. However, long-term operation and maintenance issues in PTS include decreased hydraulic conductivity in VFBRs. Decreased hydraulic conductivity leads to either water by-passing the cell or decreased treatment efficiencies. This research focused on quantifying the hydraulic conductivity and characterizing the organic layer in VFBRs of multiple passive treatment systems with the intention of developing plans for extending the lives of the treatment systems. VFBRs at the Mayer Ranch, Hartshorne, and Red Oak PTS of Oklahoma were selected for this study. This research used four different methods to estimate hydraulic conductivity in VFBRs that have been in operation for 8-15 years. Hydraulic conductivity was compared against several different treatment media characteristics. The hydraulic conductivity measurements ranged from $9.93x10^{-3}$ to $1.74x10^{-5}$ cm/s. A comparison of the hydraulic conductivity and the treatment media characteristics indicated a trend that as porosity increased the hydraulic conductivity decreased. The comparison of the different methods found that site variables dictated that certain methods may be more viable than others. The results helped to characterize the treatment media and quantified the hydraulic conductivity of VFBRs.

Additional Key Words: VFBR, hydraulic conductivity, Mayer Ranch, Passive Treatment

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Coupling Technical Assistance with Student Service Learning in Mine Water Reclamation[1]

K.J. Green[2], M. H. Whited[3], W.H.J. Strosnider[4]

Abstract: The Saint Francis University (SFU) Center for Watershed Research and Service was established in 2012 with the mission to meet technical, labor and volunteer needs of local watershed restoration organizations. The Center has recently developed a stem of this relationship to help our regional organizations in their efforts to monitor and improve local waterways by providing the design, construction and installation of weirs. The Center has also begun work on quarterly sampling for pollutant loading studies in Quemahoning Creek and Lamberts Run of Somerset County as well as Brubaker Run in Clearfield County. The strong backs of undergraduate students are welcomed to provide this service and their hands-on experience with these waterways and treatment systems involved provides knowledge and valuable experience beyond the classroom. This service learning and technical student/professor assistance concept has begun to expand into a relationship where guided students have monitored a treatment system awaiting retrofitting, started preliminary designs, and have participated in treatment system audits. This presentation will go into the details of how the program is being run and funded as well as how you could use this model to help your organization, firm, or students. We will specifically be talking about the successes in the 2016-2017 academic year and future plans for reclamation in Western Pennsylvania.

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1. Oral presentation to be given at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: What's Next for Reclamation, April 9-13 2017.

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POLLUTION LOADING TRACKING TO CHARACTERIZE SUCCESS OF AN ANOXIC LIMESTONE DRAIN INSTALLATION ON LAMBERT'S RUN, SOUTHWESTERN PENNSYLVANIA[1]

Hannah E. Patton*, Lydia G. Mignogna, Kevin Tomkowski, Joshua Vinglish, Kelsea J. Palmer, Morgan C. Whited[2], Malcom Crittenden, Greg Shustrick, William H.J. Strosnider[2]

Abstract: Mining has been an integral part of the history of Western Pennsylvania since the 1700s when the first bituminous coal mines opened. An unfortunate byproduct of this extensive mining history is the occurrence of acid mine drainage (AMD) in local watersheds. The Lambert's Run AMD treatment system, located in Somerset County, is the result of an AMD-affected artesian well discharging directly into a wetland that empties into Lamberts Run, a tributary of the Stonycreek River. The discharge is characterized as having pH of around 3 and little to no alkalinity. This site has been monitored for years by the Pennsylvania Department of Environmental Protection as well as the Somerset County Conservation District prior to installing an Anoxic Limestone Drain (ALD) to treat the discharge. Currently, pollution loading tracking studies are being completed in order to characterize the success of the ALD treatment system and to determine other significant sources of AMD in Lamberts Run. According to the pollution loading strategies completed, the pH of discharge has increased to over 5 and alkalinity to over 30 mg/L. Thus far, the data suggests that the system as it stands may not be enough to fully remediate Lambert's Run. The ALD was always envisioned as a first step to remediate this water resource and further work may be necessary for a return to suitable water quality.

Additional Key Words: alkalinity, iron, passive treatment, pyrite, specific conductivity, total metals concentration

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1 Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: What's Next for Reclamation? April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

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Geomorphic Reclamation and Landscape Heterogeneity: A landscape approach to quantify geomorphic stability and vegetation community diversity

Amanda Pennino[1], Kurt Fleisher[1], Karen Vaughan[2], Kristina Hufford[2], Thijs Kelleners[2], Jay Norton[2], Peter Stahl[3], Calvin Strom[3]

Abstract: Mining across the Rocky Mountain West has led to drastic land alteration. The industry provides vital contributions to the economy of Wyoming, but requires sustainable reclamation in a challenging semi-arid climate. Traditional reclamation rebuilds the landscape by creating long, uniform slopes and terraces. An alternative practice is geomorphic reclamation which has gained popularity for its heightened attention to constructing natural drainages and topography to the restored landscape. Geomorphic designs incorporate the natural geomorphology of the landscape, emphasizing drainages and complex topographies. Two surface mines in Wyoming reclaimed nearly a decade ago by the Wyoming Department of Environmental Quality (DEQ), Abandoned Mine Lands group (AML); present a unique opportunity to compare both methods of reclamation and study the environmental outcomes of geomorphic principals where water and vegetation establishment is a limiting factor. Our proposed efficiency assessments of traditional and geomorphic reclamation methods include remote sensing and field surveys of wildlife habitat and vegetation cover, density and diversity. Additionally, we will make comparisons of erosional susceptibility between sites through hydrological modeling applications, plant growth capacity through differences in soil health parameters and an assessment of topographic diversity. Presented data will report results of remote sensing analysis to determine landscape-scale differences in topographic and vegetative diversity between traditional and geomorphic sites. Landscape-scale data will be combined with field surveys to evaluate the extent to which geomorphic reclamation improves plant-available water storage and increases vegetative diversity.

Additional Key Words: erosion modeling, restoration ecology, mine reclamation, soil quality

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Seasonal Recharge and Groundwater Storage in a Below Drainage Mine-pool

E Perry*, T. Gray, H. Trexler and S. Poborsky

Abstract: Seasonal recharge and groundwater storage characteristics were determined for a below drainage mine-pool complex in western Pennsylvania. The mine-pool generates three discharges that are among the largest pollution sources in the Blacklick Creek watershed. The Pennsylvania Dept. of Environmental Protection is planning to control the discharges in a combined treatment facility. The mine-pool includes three individual, but hydrologically connected, flooded and abandoned underground coal mines. Mine-pool recharge was found to be seasonally dependent, typically ranging from a low of about 1.9 L/Ha-min in late summer through fall to about 4.7 L/Ha-min in spring. This information was used in developing a management plan that reduces mine-pool hydraulic head by controlled pumping, and eliminates existing pollutional discharges to the receiving stream. Weir and transducer measurements were collected at existing mine decant points for over 18 months and analyzed to provide expected monthly pumping, storage and treatment requirements. A full record of reliable discharge could not be acquired for one subpool. Recharge properties were estimated for this subpool based on geologic and mining conditions, and behavior of adjacent subpools. The mine-pool is at long term steady state conditions, and the discharge rate is considered equivalent to the recharge rate. The management plan includes a provision to reduce mine-pool head and maintain sufficient in-mine storage to capture 30 days of peak seasonal recharge. The two principal mines in the complex require hydraulic head reduction of about 9.8 and 15.5 meters to provide 30 day storage of 190 and 511 million liters, respectively. The management plan also includes disposal of treatment sludge by injection into the mine-pool at locations that are unlikely to recirculate to mine water extraction pumps. Pump specifications and a conventional chemical treatment plant will be designed to accommodate seasonal variation in mine-pool hydrology.

Additional Key Words: stage storage, design flow, sludge disposal.

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Cluster planting: a new prescription for enhancing structural diversity in reclaimed boreal forest[1]

Brad Pinno*, Amanda Schoonmaker, Robert Albricht[2]

Abstract: Tree planting is an important step in forest re-establishment after land reclamation in the boreal forest. Trembling aspen (*Populus tremuloides*) normally regenerates after disturbance through root suckering but this regeneration mechanism is not viable on completely reconstructed sites. Therefore, planting aspen is often required but it remains to be seen what the optimal planting patterns are. For example, is it better for aspen growth and understory plant community development to have a regular distribution of trees or a clustered distribution with localized patches of high density and low density trees? Widely spaced trees may have greater maximum growth potential but individually they are more susceptible to reduced growth from intense competition and take many years to reach canopy closure resulting in "open" reclamation sites. Clustered trees, on the other hand, may have the ability to "capture the site" and reach canopy closure sooner thereby reducing vegetative competition at the risk of reduced growth from intraspecific competition between trees. Building off of past research examining the spatial distribution of naturally regenerating aspen stands and the benefits of high density planting for the development of crown closure, we tested the impacts of planting aspen in clusters of 4, 10 and 20 trees at an internal spacing of 0.25 to 0.5 m compared to a conventional planting prescription of 2,500 regularly spaced stems per ha on an industrial reclamation area in the oil sands region of Alberta, Canada. Initial first year results indicate the largest clusters reduced total vegetation competition, driven by a reduction in forb cover, and tree growth increased with clustering compared to the conventional planting prescription. This cluster planting approach also has the potential to increase the site level diversity by creating both closed canopy and open areas within a single reclamation area without increasing overall planting costs.

Additional Key Words: Reclamation, oil sands, trembling aspen, vegetation competition

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Upland forest development in a reconstructed watershed after oil sands mining in northern Alberta, Canada[1]

Brad Pinno*, Fran Leishman, Ruth Errington, Morgane Merlin, and Simon Landhäusser[2]

Abstract: The goal of land reclamation after oil sands mining in northern Alberta is to re-establish functioning forest ecosystems. At the Sandhill Fen watershed reclamation research site, we studied initial upland forest development, i.e. tree growth and associated understory plant community composition, in response to different reclamation soil types (coarse vs fine textured) and to different tree planting densities (0, 5,000 and 10,000 stems per ha) over the course of five years. Height growth of trees (trembling aspen, jack pine, and white spruce) was greater on fine textured soils and this difference is increasing over time. There was no immediate impact of planting density on tree growth but by year 5 crown closure has almost been achieved in the highest planting densities so we expect more significant ecosystem changes after this time to be related to tree density. Understory species richness and total understory leaf area was greater on fine textured reclamation soils but by year 5 there was no difference in total plant cover (average 65%) between soil types. However, there were differences in plant community composition with coarse textured soils having greater bryophyte cover and lower forb cover than fine textured soils. There was also a tendency for understory plant cover to increase with tree density. In this water limited environment, of particular importance is the partitioning of water between upland forests and lowland bogs and fens with leaf are (i.e. tree species and density) and soil type being major drivers of this relationship. This work on upland forest development will contribute to the development of sustainable and integrated reclamation landscapes.

Additional Key Words: Reclamation, understory plant community, trembling aspen, jack pine

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North Branch Potomac River Mine Pool Assessment Study

N.D. Pointon* and J. Felbinger[1]

Abstract: A thorough understanding of the hydrologic and technical issues surrounding the flooding of underground mines is essential to the protection of the environment in the Appalachian Region. If the consequences of mining are not predicted accurately and the management of resulting mine pools is not implemented properly, the public will ultimately pay the price through decreased water resources, uses and potentially the cost for water treatment. For this reason, a clear and accurate characterization of mine pools is critical to formulate sound management programs. Utilizing water balance equations and groundwater flow principles, this study attempts to characterize several mine pools in a geologic and topographic basin within the North Branch Potomac River watershed.

The study area includes 12 underground mine sites in 2 coal seams. The mines are a combination of abandoned, active and inactive underground mines that are flooded to different extents. These mine pools are currently managed by coal companies or a state agency. Water from the mines is currently pumped and/or collected then treated and discharged to the surface, or maintained at an elevation below surface drainage. Without pool management, many existing mine pools located in both West Virginia and Maryland have the potential to leak and/or discharge into the North Branch Potomac River. Accompanying this leakage is a risk for increased total dissolved solids with accompanying metal concentrations and precipitants to the river.

Additional Key Words: underground mines, water storage, water balance

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Cost-effective Strategies for the restoration of large disturbances[1]

David Polster[2]

Abstract: Ecological restoration is defined internationally as the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (SER 2004). This suggests that the best we can do is to help (process of assisting) what will happen naturally. But how can we help? The first step is to define what might be preventing recovery (the filters). Polster (2015) lists eight abiotic and six biotic filters that might be limiting the recovery of the ecosystem. On industrially disturbed sites (mines, well sites, etc.) compaction and steep slopes are the most common abiotic filters while competition (with seeded grasses and legumes) and herbivory (with hyper-abundant ungulates) are the most common biotic filters. Restoration strategies that avoid creation of these filters and assist the recovery of the degraded ecosystem is the most cost-effective way of restoring large disturbances (Polster 2016). Since these are relatively simple problems, the solutions are similarly simple. Steep slopes can be dealt with by regrading and compaction can be addressed by making the restoration area "rough and loose" (Polster 2015). Since rough and loose ground reduces the risk of erosion by allowing rainwater and snowmelt to soak into the ground, there is no need for grass and legume seeding (traditionally used to control erosion). Without a competing grass and legume cover, herbivory is less of a problem. Adding woody debris to the rough and loose ground can help control erosion and enhance the establishment of biota (Craig et al. 2014; Vinge and Pyper 2012). By using a waste material to enhance recovery, the use of woody debris provides an excellent way to assist the recovery of disturbed sites. This paper explores the use of natural processes to let nature do the work of restoring drastically disturbed sites.

Craig, M.D., A.H. Grigg, R.J. Hobbs and G.E. St. J. Hardy. 2014. Does coarse woody debris density and volume influence the terrestrial vertebrate community in restored bauxite mines? Forest Ecology and Management 318 (2014) 142-150.

Polster, D.F. 2015. Effective strategies for the reclamation of large mines. Proceedings of the Mine Closure 2015 conference. A.B. Fourie, M. Tibbett, L. Sawatsky, and D. van Zyl (eds.). Vancouver, BC

Polster, D.F. 2016. Cost-effective Strategies for the Restoration of Large Disturbances. Paper presented at the B.C. Technical and Research Committee on Reclamation, BC Mine Reclamation Symposium. Penticton, B.C. September 19-22, 2016.

SER, 2004. The SER Primer on Ecological Restoration. Version 2. October 2004. Science and Policy Working Group, October 2004. Society for Ecological Restoration International. Washington DC. Accessed Dec. 14, 2016 (http://www.ser.org/page/SERDocuments).

Vinge, T. and M. Pyper. 2012. Managing woody materials on industrial sites: Meeting economic, ecological and forest health goals through a collaborative approach. Department of Renewable Resources, University of Alberta, Edmonton, Alberta. 32 pp.

Additional Key Words: Natural processes, succession, cost-effective.

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NATURAL PROCESSES FOR THE RESTORATION OF LARGE MINES

David Polster[1]

Abstract: Natural processes have been restoring natural disturbances (landslides, volcanic eruptions, floods, earthquakes, glaciation, etc) for hundreds of millions of years. By understanding how these systems operate we can use them to restore major mines and other significant disturbances. The first step in developing an effective natural process based system for the restoration of a disturbed site is to identify the filters (or constraints) that are preventing the natural recovery. Polster (2015) identified eight abiotic filters and six biotic filters that operate at disturbed sites. At most mines abiotic filters such as steep slopes, compacted substrates, adverse textures, low nutrients, and in some cases adverse chemical properties are preventing recovery. Biotic filters such as excess herbivory, competition with seeded grasses and legumes and a lack of suitable seed availability may also occur at mine sites. This paper presents strategies for addressing these filters that are based on how natural systems address them. By using natural processes as a model for restoration of large disturbances the cost savings of getting natural processes to do the work can be enjoyed. Examples are drawn from the author's experience.

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Detecting the Presence of Coal Mining Impacts by Predicting Acid Mine Drainage Impacted Streams Using Aerial Imagery[1]

S.C. Porter, J.R. Bowman*, and S.A. Miller[2]

Abstract: Coal mining leaves an environmental legacy in Appalachia; the process is disruptive to ecosystems and incurs both chemical and physical changes that alter water and habitat quality in receiving water bodies. To attempt to restore impacted streams, treatment systems are necessary. Before systems can be designed and deployed, an intensive and costly series of field work is performed to find, identify, assess and plan for acid mine drainage (AMD) restoration. If the identification can be accomplished by using remotely sensed data, then the cost and time of preparing a treatment plan is drastically decreased. Four-band aerial imagery collected by Woolpert for five counties in Appalachia Ohio and water quality data from Ohio University's Database (www.watersheddata.com) were employed for this study. A data set was established in a GIS system based on AMD-impacted (8,065 pixels) versus non-AMD impacted (3,747 pixels) sites using pH, Fe, and Al values. Custom software written in Python was deployed to calculate and retrieve values from the imagery. The analysis was performed via an iPython notebook (scipy, pandas, sklearn). The analysis process involved structuring the data, descriptive statistics, hypothesis testing to determine if AMD and non-AMD impacted streams appear to be from different populations, and then applying machine learning algorithms to see if AMD can be successfully classified. From the infrared band, the Mann-Whitney U test was run, which yielded a U of 13,921,607(p=0.000) indicating that infrared values for AMD and non-AMD are from different populations. For all five of the machine learning classification attempts, a random sample of 25% was used to fit each model (training set), then the other 75% was used to test the predictions as the testing set. Machine learning algorithms were able to correctly classify 70-75% of all sampled pixels, with many of the misclassifications explainable from the same few water bodies.

Additional Key Words: Appalachia, Python, GIS, machine learning.

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The Impacts of Acid Mine Drainage Remediation Projects on Water Quality, Aquatic Macroinvertebrate, and Fish Populations in the Deckers Creek Watershed, Monongalia and Preston Counties, West Virginia[1]

N. P. Revetta*[2]

Abstract: In 2007, Friends of Deckers Creek began installing active and passive acid mine drainage (AMD) remediation projects on abandoned mine lands throughout the Deckers Creek watershed in Monongalia and Preston Counties, West Virginia. These projects have reduced the loading of heavy metals and acidity entering nearby streams, successfully improving the water quality and habitat for fish and macroinvertebrates. As a result, the abundance and diversity of the aquatic biota has improved in several reaches of the Deckers Creek mainstem as well as one major tributary. In 2002, Friends of Deckers Creek began tracking trends in water quality quarterly along thirteen sampling sites throughout the watershed from the thalweg of the stream; these sites include nine along the Deckers Creek mainstem and four tributaries. In 2007, Friends of Deckers Creek began sampling fish and macroinvertebrate populations at these thirteen sites annually. Fish populations were analyzed utilizing a backpack electroshocker along a 100m representative reach and macroinvertebrates populations were analyzed following the protocol described in the West Virginia Stream Condition Index. As the number of AMD remediation projects continues to increase, so does the abundance and diversity of the fish and macroinvertebrate populations. Despite these positive trends, the Deckers Creek mainstem and many of its tributaries are still on the EPA's 303(d) list of impaired streams due to additional mine discharges that still require remediation.

Additional Key Words:

[1.] Oral presentation at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***The Impacts of Acid Mine Drainage Remediation Projects on Water Quality, Aquatic Macroinvertebrate, and Fish Populations in the Deckers Creek Watershed, Monongalia and Preston Counties, West Virginia*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

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Practical Outfall Mine Water Treatment Applications– Challenges and Solutions[1]

D. Bess, J. Ceslovnik, B. Riley* [2]

Abstract: This paper will address practical examples of outfall and discharge water treatment programs for the mining industry. Examples will focus on the reduction of manganese, aluminum, iron, and TSS. The before state in each case study will include the starting conditions and unique challenges and concerns prior to treatment program application.

Additional Key Words: manganese, aluminum, iron, TSS, chemical reduction

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1. Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

2. Danny Bess – Director of Corporate Accounts, Global Mining and Mineral Processing – Nalco Water; Jon Ceslovnik – Sales Engineer, Global Mining and Mineral Processing – Nalco Water; Ben Riley, Senior Marketing Manager – Water Solutions, Global Mining and Mineral Processing – Nalco Water, 1601 W. Diehl Road, Naperville IL 60563.

Conservation of Northern Long-eared Bat Habitat at an Aggregate Mine in Westmoreland County, Pennsylvania[1]

C.D. Rockey[2]

Abstract: In April 2015, the northern long-eared bat (*Myotis septentrionalis*) or NLEB, a small bat common to the eastern United States, was listed by U.S. Fish and Wildlife Service (USFWS) as "Threatened with a 4(d) rule" under the Endangered Species Act. It is the opinion of USFWS that impact to habitats within a 0.25-mile buffer around any cave or mine known to be used by NLEB during the hibernation period can lead to "harm" of the NLEB, and an Incidental Take Permit should be sought by the project proponent. In August 2016, Lehigh Hanson proposed to expand its Wagner (limestone) Quarry, located in Westmoreland County, Pennsylvania. The expansion will require disturbance of the land surface in an area that overlaps with two known presence buffers for NLEB. As a result, Hanson contracted CEC to assist in their coordination with USFWS and the Pennsylvania Game Commission. While the project is ongoing, this presentation will discuss the measures taken to mitigate potential impacts to the NLEB, including minimization of the project's footprint, seasonal restrictions to tree clearing, and the installation of artificial roosting structures within the buffers.

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[1]Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017.

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A REVIEW OF PASSIVE TREATMENT TECHNOLOGY[1]

Jeff Skousen[2], Carl Zipper[3], Arthur Rose[4], Paul Ziemkiewicz[2], Robert Nairn[5], Louis McDonald[2] and Robert Kleinmann[6]

Abstract Many hundreds of passive treatment systems have been constructed to treat acid and alkaline mine drainage in Eastern US over the past 20 years, and many continue to be built. Our knowledge of the various passive processes has greatly increased over the years. An extensive review of passive treatment by the above authors is in press in Mine Water and the Environment. The current presentation summarizes some of the developments discussed in the published review. Technologies discussed are aerobic wetlands, anaerobic wetlands, vertical flow wetlands, Mn removal beds, bioreactors, anoxic limestone drains, open limestone channels, limestone leach beds including flushing, steel slag leach beds, diversion wells, limestone sand and low-pH Fe removal. Design parameters, maintenance, problems and effectiveness are summarized, based on about 180 literature citations. The behavior of various types of organic matter is evaluated.

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[1] Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

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[5.] Robert Nairn, Professor, Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK 73019;

[6.]Robert Kleinmann, Environmental Geologist, HDR, Inc., Pittsburgh, PA 15217.

Georeferencing of American Society of Mining and Reclamation Proceedings: A New Tool and Patterns in Reclamation Research

Ashley Rovder, Zach Shoff, David Madl, Staci Wolfe, Stefan Long, William Strosnider, and Peter Smyntek

Abstract: The Saint Francis University Center for Watershed Research & Service georeferenced the American Society of Mining and Reclamation conference proceedings from 1998 to 2007. This project was undertaken in the context of our Research-Learning structure. Small teams of undergraduate students overseen by professor and postdoc mentors executed the work. Google Earth and Earth Point were applied to allow broader analysis options. Trends have been noted between meeting location and the location of research projects. Aside from that, an easily accessible database has been created that should allow for easy location of the sites of past research, perhaps opening the door for sites to be revisited for follow-on research topics such as long term successional or passive treatment performance studies.

Additional Key words: geolocation

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Yields and Ethanol Production Potential of Switchgrass and Miscanthus on Reclaimed Mine Lands

S. Scagline, J. Skousen, and T. Griggs

Abstract Herbaceous species like switchgrass (*Panicum virgatum* L.) and Miscanthus (*Miscanthus x giganteus*) have been proposed as potential cellulosic crops to meet bioenergy fuel goals. Both are warm season grasses and show potential for biomass production on marginal lands and reclaimed mine lands in the eastern USA. The objectives of this study were to determine yields, theoretical ethanol yield (TEY, L Mg^{-1}), and theoretical ethanol production (TEP, L ha^{-1}) of these two grasses grown at the Alton, WV, mined site. Alton was reclaimed in 1985 with less than 15 cm of topsoil thickness replaced over mixed overburden. An herbaceous ground cover was maintained at the site for 25 years before two cultivars of switchgrass (Kanlow and BoMaster) and two varieties of Miscanthus (Public and Private) were planted in herbicided plots in 2010. Both species established and after 6 yrs. produced 13.9 and 11.7 Mg ha^{-1} DM for Private Miscanthus and Kanlow switchgrass, respectively. Carbohydrate analyses to estimate TEY were done using near-infrared reflectance spectroscopy (NIRS). Pentose sugars (C5) were significantly greater in switchgrass therefore TEYs were significantly higher for switchgrass (479 L Mg^{-1}) compared to Miscanthus (467 L Mg^{-1}). But when TEYs were multiplied by biomass yields, Miscanthus TEP was significantly greater than switchgrass TEP (5,802 vs 4,275 L ha^{-1}). Kanlow and BoMaster TEPs were similar, but Private was significantly greater than Public TEPs. The results show that both species can produce high yields and good quality feedstock on reclaimed mined lands.

Keywords: Bioenergy crops, BoMaster, Forage analysis, Kanlow, Land reclamation, Ligno-cellulosic traits, Near-infrared reflectance spectroscopy, Revegetation, Theoretical ethanol yield

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Groundwater tracing in mine pools above the Cabin Creek oilfield in Kanawha County, West Virginia[1]

Andrew Schaer[2]

Abstract. The saline aquifers of the Kanawha River Valley and hydrocarbons of Cabin Creek oilfield represent an upwelling of deep fluids in Kanawha County, WV. Just south of the city of Charleston these deep fluids intersect shallow mine pool aquifers in various coal beds of the Kanawha Formation. The West Virginia Department of Environmental Protection and the Office of Surface Mining Reclamation and Enforcement conducted ground water sampling of mine pools and other groundwater sources around the historic Cabin Creek oilfield. Chemical analyses of the mine pools and flow-path interpretation show an interaction and mixing of acid mine drainage, alkaline mine drainage and deep source brines and hydrocarbons of considerable complexity. Using cation and anion ratios and trace element tracing, a set of geochemical maps of this area was produced. This analysis helped segregate and identify deep and shallow ground water and surface water sources in this rather unique geohydrologic system.

Additional Key Words: Mine Pools, Acid Mine Drainage, Brine

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[2]Andrew Schaer is a Geologist with the West Virginia Department of Environmental Protection, Charleston, WV 25304.

Water quality and biotic condition in mining-influenced Appalachian headwater streams: an overview of a long-term study[1]

S.H. Schoenholtz, E.A. Boehme, D. Drover, R.A. Pence, D.J. Soucek, A.J. Timpano, R. Vander Vorste, K.M. Whitmore, and C.E. Zipper[2]

Abstract: Water quality and biotic condition in central Appalachian headwater streams influenced by coal mining can be affected by multiple factors, including elevated levels of total dissolved solids (TDS). This presentation will summarize completed and ongoing, collaborative studies of the relationship between water quality and biotic condition in 28 Appalachian coalfield headwater streams since 2008. Study streams affected by varying extents of mining were selected with the intent of isolating effects of TDS while minimizing potential influence by other known stressors (e.g., impaired habitat). Six of the study streams are in a reference condition. Specific conductance (SC), a surrogate for TDS, was recorded at 15- to 30-minute intervals using automated loggers from October 2011 to present. Water samples were obtained periodically and analyzed for TDS, major ions, and trace elements. Benthic macroinvertebrate communities were assessed in all study streams using semi-quantitative methods and quantitatively in 15 of these streams. Carbon processing was assessed by evaluating leaf-litter breakdown rates during an 8-month period. Water quality measures were analyzed for seasonal variability; benthic macroinvertebrate community structure and leaf-litter breakdown rates were analyzed to determine relationships to water quality. Components of aquatic macroinvertebrate communities showed consistent sensitivity to increases in SC. We also observed strong seasonal patterns of SC along with variance of aquatic macroinvertebrate community structure within and among seasons of sampling.

Additional Key Words: Total dissolved solids, specific conductance, aquatic macroinvertebrates, mining impacts

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[1.] Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

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Acid Mine Drainage Water Testing and Metals Analysis at Morris Creek, WV[1]

Logan Cox and Juliana Serafin[2*]

Abstract: Acid mine drainage (AMD) is generated by abandoned mines and negatively affects bodies of water across the nation. Morris Creek is one of these bodies of water in Montgomery, West Virginia. The Morris Creek Watershed Association has worked with the WV Department of Environmental Protection to implement a limestone bed remediation treatment. This research conducted Water Quality Index (WQI) testing and Atomic Absorption (AA) analysis of metals on water samples collected at several different points in the treatment system. The WQI testing includes temperature, pH, turbidity, total solids, dissolved oxygen, biochemical oxygen demand, phosphates, nitrate, and fecal coliform (Johnson, Holmquist, & Redding, Water Quality With Vernier, 2007). The hypothesis of this study is that Water Quality Index (WQI) testing and metal ion concentrations are related, mainly through the correlation between dissolved oxygen levels and metal (Fe and Ca) concentrations. The results show that the hypothesis is supported.

Additional Key Words: AMD, water quality testing, metals analysis.

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Assessing the benefits of at source vs. in stream AMD treatment: Implications for managing water liabilities under the WVDEP's Bond Forfeiture Program[i]

Michael P. Sheehan[ii] Paul F. Ziemkiewicz[iii]

Abstract: The Cheat River in northern West Virginia was impaired by historic acid mine drainage. Restoration efforts since 1995 have improved the Cheat River fishery but Muddy Creek remained a significant source of AMD, reducing fishery potential. The West Virginia Department of Environmental Protection's Office of Special Reclamation (OSR) was obliged to treat several bond forfeiture sites within the Muddy Creek watershed at significant cost but, since the majority of acid load resulted from numerous, abandoned mine land (AML) discharges no improvements in stream water quality were realized.

OSR currently has nine active treatment sites, one passive treatment system, and three treatment systems yet to be constructed. Although a majority of the treatment sites were constructed between 2004 and 2006 OSR had been treating AMD in this drainage as early as 1995. To date the OSR has spent over $3.4 million in construction cost including modifications to the T&T treatment site and approximately $10 million in O&M cost, or roughly $648 thousand on an annual basis, and OSR now manages 10 NPDES outlets.

Since the majority of the AMD comes from AML sites in the Martin Creek sub watershed. The previous NPDES permitting structure resulted in OSR discharging compliant water into "dead" streams. To remedy this, OSR is pursuing an NPDES permitting structure that will allow for in-stream treatment in lieu of treating at-source.

Earlier analysis conducted by the West Virginia University Water Research Institute (WRI) indicated that, whereas the money spent on at source AMD treatment had no beneficial effect, significant stream recovery would result if those funds were applied to an in stream treatment strategy. In October 2015 OSR and WRI initiated a study to evaluate the benefits of in stream vs. at source AMD treatment. The project demonstrated significant cost savings and increased environmental benefit by applying in-stream lime dosers at strategic locations within the stream system rather than using lime dosers to treat individual sources. By utilizing portable dosers and placing them at strategic locations within the Martin Creek watershed we identified optimal locations for permanent installation of in-stream dosers. Results of the first year of the project are presented.

Additional Key Words: Stream restoration, NPDES

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[i] Oral paper presented at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What's Next for Reclamation?*** April 9 - 13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61821.

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The Effects of *Castor canadensis* (North American Beaver) Repopulation on a Mine Drainage Impacted Stream[1]

N.L. Shepherd and R.W. Nairn[2]

Abstract: An unnamed tributary to Tar Creek (Ottawa County, OK) impacted by metal-laden mine drainage for over 30 years was repopulated *by Castor canadensis* in 2014. By the end of 2014, the majority of the tributary length was transformed into a series of impoundments due to beaver dams. The tributary is one mile long and fed by two continuous mine drainage discharge points and runoff. The first mine drainage source is the headwaters of the stream, discharging ~100 gpm; the second is located 0.4 miles downstream discharging ~160 gpm to the stream. In 2008, a passive treatment system was constructed to treat the second discharge point, improving stream quality for the remaining length of the tributary. This study investigated three aspects: (1) retention of metals due to the presence of dams, (2) metal mobilization during dam destruction creating a high velocity flush and (3) hydrologic and habitat alterations due to the presence of dams using tracer studies and rapid habitat assessments. Metal concentrations decreased at the outflow of the beaver impounded water at all dams compared to the inflow concentrations. The most significant concentration decreases occurred at the dam nearest the headwaters of the tributary (67% Cd, 38% Fe, 17%Pb, and 23% Zn). Metal mobilization occurred when dams were destroyed, showing an increase in concentration of Cd, Fe, Pb, and Zn one hour after dam destruction. Conservative tracer studies showed the presence of beaver dams doubled the mean retention time of water, taking 182 hours compared to a mean retention time of 92 hours without beaver dams.

Additional key words: Tar Creek Superfund Site, passive treatment, tracer study

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2. Nicholas L. Shepherd, Graduate Research Assistant (Student), and Robert W. Nairn, Viersen Family Foundation Presidential Professor, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK 73019.

Evaluation of Risk Posed by Trace Metals in Soils of a Mining-Impacted Agricultural Watershed

A.L. Sikora* and R.W. Nairn[2]

Abstract: The Elm Creek watershed, located in Ottawa County in northeastern Oklahoma, is situated to the west and south of the Tar Creek Superfund Site, part of the historic Tri-State Lead-Zinc Mining District. Trace metals contamination has been documented in Elm Creek. However, questions remain about broader impacts in the Elm Creek watershed. Elm Creek watershed properties purchased by the Grand River Dam Authority (GRDA), a public power provider, are designated to be used as offsite mitigation for fish and wildlife impacts under the Pensacola Dam hydropower license under the Federal Energy Regulatory Commission. Surface soil samples were taken from the site to evaluate lead, zinc, cadmium, and other metals concentrations to allow estimation of ecotoxic risk. Samples were obtained from Elm Creek stream terraces and upland environments. Moisture content, loss-on-ignition, and particle size for each sample were determined. Three metals analysis protocols were compared. A handheld field portable x-ray fluorescence (XRF) spectrometer was used *in-situ* for analysis of metals concentrations (USEPA Method 6200). Collected samples were homogenized and pulverized in the laboratory and re-tested using the field portable XRF. Samples were also analyzed for metals via microwave-assisted hot HNO_3 digestion (EPA 3051) followed by inductively coupled plasma-optical emission spectrometry (ICP-OES) analyses (EPA 6010). The results of this study will influence long-term land use in the watershed.

Additional Key Words: XRF, ICP-OES, wetlands development, bottomland hardwood forests

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EFFECTS OF LONGWALL MINING ON AQUATIC RESOURCES AT THE BAILEY MINE IN SOUTHWESTERN PENNSYLVANIA

J.M. Silvis, M.L. Shema*, and M.R. Haibach

Abstract: Since 2005, longwall coal mine operators in Pennsylvania (US) have been required to collect extensive hydrologic and biological data to document pre- and post-mining conditions of streams and wetlands overlying the subsidence control plan areas. This study analyzed biological data collected during the time period of 2005 through 2016 from 40 km of streams and 3.3 hectares of wetland that traverse the 19.3 km^2 study area. Hydrologic analysis suggested that there are variable degrees of change to headwater stream flows immediately following mining; however, the majority of the effects are reversible through stream flow intervention (i.e., mitigation). Biological assessments showed that greater than 95% of assessed stream length has maintained its ability to support benthic macroinvertebrate communities following mining and subsequent intervention. Comparisons of the benthic macroinvertebrate community metrics showed that the biological community in 48 of the 50 sample sites is being maintained or restored. The effectiveness of intervention was further substantiated by the similarity in recovery times between streams having no intervention (median = 2.1 years, 95^{th} percentile = 4.9 years) and streams with intervention, when recovery times were measured from the date of the intervention (median = 1.7 years, 95^{th} percentile = 4.7 years). Changes to individual wetlands were observed between the pre- and post-mining assessments, but cumulatively a net gain of 7% in wetland acreage was realized. Hydrologic assessments were used to infer whether there was a potential that streams had been affected by mining; however, the ultimate test of stream recovery is based on biological metrics that establish the relative quality of the biological communities following mining. Overall, the aquatic life use of streams is being maintained within the Bailey Mine's subsidence control plan areas.

Additional Key Words: Stream, Recovery, Benthic Macroinvertebrate, Wetland

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Exploration of a Multi-Sensor Approach for the Detection and Mapping of Coal Seam Fires in the United States [1]

A. J. Sivitskis* and J. Richards [2]

Coal fires, which are widespread and generally under-reported, pose a threat to both human and environmental health that can result in a further loss of resources and large economic cost. Traditional mapping and monitoring of coal fires within the US has primarily relied on field based or airborne data collection. Studies in other major coal producing nations (particularly China and India) have demonstrated the effectiveness of using remotely sensed satellite data to identify problematic coal fires. The Office of Surface Mining Reclamation and Enforcement (OSMRE) is currently investigating the use of such remote sensing techniques to enhance the mapping and monitoring of coal mine fires within the United States.

Here we present a multi-sensor approach to mapping surface thermal anomalies relating to coal mine fires. By employing multispectral imagery from ASTER, Landsat, and World View, we have attempted to detect the extent and surface expression of coal fires at the Wise Hill, South Canyon, and IHI #3 fire sites in Colorado. These spaceborne sensors observe wavelengths outside of the visible spectrum allowing for the detection of thermal anomalies. Preliminary results indicate a positive correlation between remotely sensed products and ground based survey data. The implementation of this remote sensing method could assist current monitoring efforts of fires throughout the nation, as well as provide updated information on historical fire data.

Additional Key Words: Remote Sensing, ASTER, Landsat, World View.

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2. Alexander J. Sivitskis, AmeriCorps Member – GIS and Remote Sensing, Office of Surface Mining Reclamation and Enforcement, Denver, C0; Julia Richards, AmeriCorps Member – GIS and Remote Sensing, Office of Surface Mining Reclamation and Enforcement, Denver, CO.

Mass Transport Controls on Aluminum Removal in Limestone-Based Treatment Systems

Charles Spellman Jr[1], David Madl, Arthur Rose, Edward Zovinka, Joel Bandstra, William Strosnider

Abstract: Limestone dissolution is an essential process in a wide variety of acid mine drainage (AMD) treatment technologies. Although calcite dissolution rates have been well characterized under laboratory conditions, application of lab-based rate laws to field-scale treatment systems appear to systematically over-predict treatment effectiveness. This difference parallels the widely documented discrepancy between lab and field rates ―even after accounting for temperature and solution chemistry―for alumino-silicate minerals where explanatory factors include mineralogical impurities, complex surface geometries, surface armoring by secondary mineral formation, and biological influences. While all of these factors may play a role in AMD treatment effectiveness, it is also possible for limestone dissolution to be rate limited by mass transport. To assess the possible influence of mass transport on rates of limestone-based AMD treatment we have measured rates of limestone dissolution and metals removal for two systems―one in the field and one in the lab―both treating aluminum-dominated AMD. Focusing on aluminum-dominated AMD allows mass transport effects to be isolated from other complicating factors. The field system consisted of an open limestone channel treating an AMD discharge with an average acidity of 61.4 mg/L as $CaCO_3$ equivalent, pH 3.46, Al 7.3 mg/L, Fe 0.49 mg/L, and Mn 0.71 mg/L. The lab system consisted of a limestone column reactor with an influent solution of pH 3.3 and Al 20 mg/L. Both systems removed Al and increased pH even though effluent pH never exceeded 4.8. Both Al removal and Ca addition rates varied with volumetric flow rate in a manner consistent with mass transport limited dissolution. Moreover, removal of Al at low pH suggests a mass transport mechanism for precipitation of aluminum hydroxide. A geochemical model will be presented to synthesize the lab and field results as well as to draw out lessons for limestone-based AMD treatment system design.

Additional Key words:

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1. Charles Spellman, and David Madl, Undergraduate Environmental Engineering Students, Saint Francis University, Loretto, PA.; Arthur Rose, Emeritus Professor, Penn State University Department of Geoscience; Edward Zovinka, Professor, Saint Francis University Chemistry Department. Loretto, PA.; William Strosnider & Joel Bandstra, Associate Professors, Saint Francis University Environmental Engineering Department. Loretto, PA.

Drone Imagery Acquisition to Perform Volumetric Analysis for Landscape Mapping[1]

M. P. Strager[2], P. Kinder, J. A. Kimmet, and A. Hentz

Abstract: This poster presentation focuses on the use of drone imagery for mapping and modeling the volume of disturbed land features. We demonstrate the use of imagery collected at two sites: a forest biomass site and a mine overburden site. The drone we used for our analysis was a simple DJI Fantom 3 drone mounted with a SLR camera system. The flight planning included both north-south and east-west path lines to assure 80% over and endlap of ground features. An RTK global positioning system was integrated into the flight planning to capture targets from the drone and use in creating an image orthophoto. Software included a combination of Agisoft, Pix4D, and FUSION. We were able to create volumetric estimates accurate to within 8% of a more traditional terrestrial laser system also used at the sites. Along with the methodology the poster will highlight the utility of the approach to demonstrate how to capture large footprint features at a fraction of the time and cost from traditional sampling. In addition, the planning and effectiveness of this approach will be discussed for helping future considerations in using this technology.

Additional Key Words: 3D modeling, Processing, Othophotos, Biomass, Overburden

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Native vegetation in reclamation: improving habitat and ecosystem function through using prairie species in mine land reclamation [1]

R.M. Swab, N. Lorenz, S. Byrd, and R. Dick[2]

Abstract: In the Appalachian region, coal mining has impacted 600,000 hectares historically. While a return to forest would be a preferable postmining land use, due to the difficulty and higher costs of reforestation, many sites are reclaimed into non-native grasslands. The typical seed mix for these grasslands is low diversity and consists of exotic, cool season grasses and forbs. For this study, we combined several species in standard reclamation mixes with prairie species native to North America to create a higher diversity planting on three mine sites in southeastern Ohio. Vegetation and soil microbial properties were assessed within two years after site establishment. Results were encouraging. The mix that included native plants met reclamation standards of ground cover two years after planting, indicating these alternative mixes can be successful. The first year species richness and diversity were higher in native planted areas when compared with traditional, the second year they were equal between treatments. Soil beta-Glucosidase activities tended to be lower or higher in the native planted areas, in contrast to soil organic matter, which was generally higher under native prairie mix. Microbial biomass, Actinobacteria, and gram negative bacteria estimated by ester-linked Fatty acid methyl esters occasionally appeared to be higher under native prairie mix indicating that the experimental mix may have a positive effect on soil microbial biomass after almost two years of establishment. Incorporating hardy native prairie plants into reclamation seed mixes can increase the value of the ecosystem for pollinators and wildlife, and potentially improve soil conditions more quickly than non-native plantings alone.

Additional Key Words: native plants; prairie restoration; soil beta-Glucosidase activity; soil microbial community composition and biomass.

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Phosphorus, Iron and Trace Metal Interactions at the Sediment Layer-Water Column Interface: The Role of Recovered Mine Drainage Residuals[1]

Zepei Tang* and Robert W. Nairn[2]

Abstract: In this research, the goal was to understand the nutrient and metal cycling processes at the sediment layer-water column interface in a large terminal reservoir, with impacts from various environmental parameters (such as algae blooms and mixing) and to investigate the feasibility to use recovered mine drainage residuals (MDRs) for phosphorus (P) release control. The study site was the Grand Lake o' the Cherokees, Oklahoma, as it has both elevated metals concentrations from the Tri-State Lead-Zinc Mining District and elevated nutrient concentrations from agriculture run-off, resulting in eutrophication and substantial algae blooms. There are three hypotheses: 1) algae blooms impact P distribution between the water column and sediments; 2) mixing/bioturbation can increase P concentrations in the water column and decrease the net P sink in sediment; 3) MDRs can perform as P-sorbing products to decrease bioavailable P concentrations in the water column. Field characterization studies have been done to collect *in-situ* water quality data (pH, DO, SC, T, turbidity, alkalinity, etc.) as well as water and sediment samples for nutrient and trace metal analyses. A laboratory bench-top preliminary experiment was designed to identify the ideal MDR type, dose, and reaction time for optimal P-sorbtion performance. A greenhouse microcosm experiments will test different control parameters on P distribution in the system. A pond mesocosm experiment will examine the pilot-scale feasibility of MDR in a real-world condition. It is expected that the results will show that MDRs can be used to control P release in the water column; therefore, future engineering designs can be provided for addressing eutrophication in lakes.

Additional Key Words: AMD, MDR, phosphorus release control

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Passive Treatment of Sulfate from Mine-Influenced Water[1]

Robert C Thomas* and James S. Bays[2]

Abstract: A passive treatment system pilot study was set-up at a confidential mine site in the south Midwestern United States. The mine site has a mine-influenced water seep interception system at the base of reclaimed mine waste rock dumps. The main contaminant of concern is sulfate with concentrations ranging from 1,000 to 2,000 mg/L. A field-based pilot study was conducted at the site to test the efficacy of using a biochemical reactor (BCR)-based system coupled to a novel sulfide precipitation cell (SPC) to reduce sulfate to sulfide and then remove the sulfide through the precipitation of iron sulfides. The pilot consisted of six arrays with each array containing a single BCR unit hydraulically connected to a SPC unit. The substrate recipe for the BCRs was varied slightly between units and two units were actively fed a liquid organic carbon supplement. Substrates tested in the SPC units for sulfide removal included various types of magnetite waste rock and ore, siderite, and zero-valent iron (ZVI).

Seepage water flow rate was set to test the hydraulic residence time (HRT) in the BCR unit. Flow rates varied to test a 3-day, 6-day, 9-day, and 12-day HRT. The combined BCR and SPC treatment system removed up to 50% of the influent sulfate relative to the effluent without any supplemental carbon. Greater percent removal was achieved with slower flow rates (i.e., longer residence in the substrate), though based on the moles of sulfate removed per day per volume of substrate, an 8-9 day residence time was optimal for this system. Variations in the BCR substrate recipe did not have a big impact on performance. By adding supplemental carbon, sulfate removal rates approached 100%. The SPC substrate recipe impacted removal performance; ZVI performed best. However, the ZVI substrate resulted in significant cementation which could diminish permeability over time.

Additional Key Words: sulfide precipitation cell (SPC), zero-valent iron (ZVI), biochemical reactor (BCR).

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Flight 93 National Memorial Reforestation Project

M.C. Tyree[1]*, J. Larkin[1], S. Eggerud[2], P. Angel[2], M. French[3]

Abstract: The Flight 93 National Memorial is located in Somerset Co, PA. Starting spring 2012, the National Park Service and Office of Surface Mining Reclamation and Enforcement teamed with others to reforest sections of the reclaimed mineland using native woody trees and shrubs. The purpose of the monitoring project was to evaluate reforestation success and provide data to drive future management decisions. Specifically, this work aims to: 1) Determine survival and establishment success for each woody species planted in each of the four planting phases; 2) evaluate level of deer browse by for each phase; 3) describe competing vegetation across each of the planting phases; and 4) test whether planting position impacts plant growth. One hundred eighteen 0.04 ha permanent, fixed radius plots were established across the planting phases. Species, height, ground-line diameter, vigor class, deer browse, and planting position were determined for each woody plant within the plot. Of the 74,219 trees (1,891 trees/ha) planted, overall survival of planted trees and shrubs was above 55%. Quaking aspen, locust species, and pitch pine consistently performed well with eastern hemlock, sugar maple, and red maple demonstrating the poorest survival and growth. Deer browse was extremely low with 97% of all seedlings showing no sign of deer browse and only 3% being classified as low impact. We found a significant ($P = 0.006$) interaction between plant group (coniferous, deciduous tree, shrub) and planting location. In both coniferous and deciduous tree species. Average height was greater in plants located on the tops of the ripping mounds relative to the middle or bottom locations; however, there was no effect of planting location on shrub height. Early findings will provide baseline data for future comparison as the stands mature, as well as, allow for site-specific decisions on species selection and planting guidelines.

Additional Key Words:

[1.] Indiana University of Pennsylvania, Department of Biology
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[3.] The American Chestnut Foundation

A Seasonal Comparison of the Passive Abandoned Coal Mine Remediation System at Wingfield Pines[1]

M. Valkanas* and N. Trun[2]

Abandon mine drainage (AMD) in Pennsylvania results in a significant amount of mine pollution entering local watersheds. One solution used to lower the contaminant levels is passive remediation in which contaminants are removed through a series of settling ponds and a wetland. Wingfield Pines, in Bridgeville, PA, contains a passive remediation system that was constructed in 2009. It consists of an aeration pond, four settling ponds and wetlands before water is diverted back into Chartier's Creek, which is part of the Ohio River watershed.

Mixed water and soil samples were taken from the beginning of each pond, the end of the remediation system and just before the water flows back into Chartier's Creek in April 2015, July 2015, October 2015, and January 2016. The samples were centrifuged and separated, and the water was sent to an independent lab for water chemistry analysis of aluminum, barium, copper, lead, zinc, manganese, iron, strontium, nickel, arsenic, cadmium, and selenium levels by ICP-AES and sulfate levels by IC. DNA was extracted from the soil samples and was tagged with a unique 16S *rRNA* Illumina PCR tag (http://www.earthmicrobiome.org). The amplified 16S *rRNA* fragments of the chromosomal DNA were analyzed by high-throughput sequencing using MiSeq. The data (~2.7 million sequences) was quality filtered and analyzed using python and Qiime programs (Caporaso, 2010). The data show a variety of differences including spikes in different metal levels (1 site in summer, a different site in fall) as well as the type and relative abundance of bacteria communities present. Proteobacteria were most prevalent year round, though prevalence at the Class level varied. Cyanobacteria were only high in the summer. The bacterial communities at the beginning of the remediation change dramatically throughout the year, while the end of the remediation remains fairly constant. The results suggest that the remediation effectiveness and bacterial richness at Wingfield Pines changes, depending on the time of year and contaminate levels.

Additional Key Words: AMD Passive Treatment; Bacterial AMD communities; microbiome analysis; water quality analysis; Wingfield Pines; alkaline mine drainage

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[2] Michelle Valkanas, Department of Biological Sciences, Duquesne University, Pittsburgh, PA 15282 (graduate student); Nancy Trun, Associate Professor, Department of Biological Sciences, Duquesne University, Pittsburgh, PA 15282.

A Feasibility Study for the Automated Monitoring and Control of Mine Water Discharges

Christopher Vass* and Aaron Noble[1]

Abstract: The chemical treatment of mine-influenced waters is a longstanding environmental challenge for many coal operators, particularly in Central Appalachia. Mining conditions in this region present several unique obstacles to meeting NPDES effluent limits. Outlets are often located in remote areas with challenging terrain where conditions do not facilitate the implementation of large-scale commercial treatment systems. Maintenance and monitoring of these systems is often laborious, expensive, and time consuming, as environmental technicians are often used to visit outlets on a periodic basis. When combined with the lower effluent limits imposed by increased regulatory scrutiny, this treatment method can lead to the discharge of non- compliant water and high regulatory costs. As an alternative solution, ongoing research at West Virginia University is addressing the design and development of automated protocols for the treatment and monitoring of mine water discharges. In particular, the current presentation describes a pH control strategy based on machine learning algorithms. During this research project, a bench-scale pond treatment system was constructed, and a machine learning controller was implemented to administer alkaline material to adjust the outlet pH to a desired set point. Results from these tests showed that, when optimized, the machine learning approach provides a robust control strategy that can overcome multiple simultaneous disturbances while maintaining the outflow pH within a strict tolerance. Following the successful laboratory test campaign, this system was implemented at an active AMD treatment site, to further prove the advantages of this technology in a realistic setting. Preliminary results from this test campaign will be discussed.

Additional Key Words: Acid Mine Drainage, Adaptive Neuro fuzzy Inference Systems

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Carbon Dioxide: A Global Problem in Search of a Rational Global Solution[1]

Kimery C. Vories[2]

Abstract: This paper focuses on the facts concerning rising carbon dioxide levels in relation to fossil fuel utilization and its impacts upon global climate, the global economy, and the world population. Factors essential to understanding potential solutions to the problem include: the global nature of CO_2 emissions; the global impacts of fuel consumption; the importance of global electrical power supply; the actual ability of renewables to replace fossil fuels; the length of time for renewables to significantly reduce carbon emissions; assessment of other solutions that could impact CO_2 emissions; and impacts to the world population and human standards of living necessary to reduce carbon emissions. It contrasts: (1) the impacts of current popular notions in the media and the US regulatory community that fossil fuels are an "evil" that must be prohibited and that renewables actually have the potential to replace fossil fuels in the near term versus (2) the utilization of common sense to assess how to best use and advance currently available science and technology. It focuses on the need for rational global solutions that recognize the international trends in national electrification, the huge infrastructure changes necessary to reduce carbon emissions, and the highly unsubstantiated predictions of massive conversions to renewables. It highlights best available control technology (BACT) that could reduce the man made contribution of carbon dioxide in the atmosphere in a way that does not bankrupt the global economy and jeopardize the global population.

Additional Key Words: Carbon Emissions, World Population, Fossil Fuels, Coal Utilization, Electric Power Generation

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Local Government Entities in Improving AMD Impaired Waters[1]

Donna Wagner[2], David Thomas, Ernest Fuller, Donald Hedge[3]

Abstract: For many years in Pennsylvania, watershed groups and other locally based conservation groups have been working on addressing non-point sources of pollution. Local townships have always been a great partner in these endeavors, if a group can get them onboard. In many cases a partnership between a watershed group and this type of local government entity can be vital to getting a project completed because the township can supply equipment and manpower. It is rare though to have a township take the lead in the restoration of a watershed but Broad Top Township in Pennsylvania is an example of a government entity that has as one of their priorities to restore abandoned mine drainage (AMD) affected streams in their jurisdiction.

Broad Top Township is a very rural township located in Bedford County, PA. They have a very progressive and unique approach for dealing with non-point source sources in their township including AMD, sewage, and illegal dumping. Not only do they work at acquiring funding for projects but they also do their own construction.

Work the township has completed has enabled one stream to be moved from being impaired to attaining on the Pennsylvania 2014 Integrated Water Quality Monitoring and Assessment Report. Another stream may follow in the near future. Broad Top Township is considered a role model in demonstrating what a township can do to improve local water quality and they have met with others to show what they have accomplished. This presentation will demonstrate what a very involved township can do to address nonpoint source pollution with an emphasis on AMD pollution.

Additional Key Words: Abandoned Mine Drainage (AMD), passive treatment systems, Broad Top Township.

[1.] Oral presentation at the 2017 National Meeting of the American Society of Mining and Reclamation, Morgantown, WV: ***What'sNext for Reclamation?*** April 9-13, 2017. Published by ASMR, 1305 Weathervane Dr. Champaign, IL 61921.

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Bond release verification requirements for successful reclamation at Wyoming surface coal mines[1]

Anna Krzyszowska Waitkus[2]

Abstract: A reclamation bond must be submitted and updated periodically by all coal mines permittee to secure the performance of reclamation obligations. Approximately, 40% of coal in the US is produced by the state of Wyoming. The State of Wyoming Land Quality Division (WLQD) of the Department of Environmental Quality (DEQ), administers Wyoming's coal regulatory program. WLQD together with coal industry, government, and consultant representatives established a set of criteria and performance standards that have to be verified before a reclamation bond can be released. In Wyoming, four bond release phases (Area Bond, Phase 1, 2, and 3) for surface coal mines indicate the completion of various reclamation processes. Bond release verification criteria for an Area Bond include backfilling and regrading of the mined out area according to the approved plan. Bond release verification criteria for Phase 1 consist of reconstruction of stream channels and soil application. Completion of Phase 2 verification criteria involve an ocular approval of vegetation establishment and erosional stability and construction of permanent water impoundments. Phase 3 verification criteria include the accomplishment of revegetation success, tree replacement, and mitigation of wetlands. Major performance standards to meet the post mining land use pertain to backfill material quality approval, roads and structure removal, wildlife habitat restoration, surface and ground water quantity and quality evaluation. Examples of the bond release criteria and performance standards verification that occur through field inspections and annual reports will be discussed. The Bond Release Geodatabase (a GIS/GPS approach) was developed for a large surface coal mine to support the tracking of areas that satisfied criteria and performance standards for the incremental bond release. The Bond Release Geodatabase is a highly effective method that significantly reduces the time needed to track bond release progress, reach agreement between operator and regulator, and improve the state inspector's ability to assess reclamation adequacy and progress.

Additional Key Words: phases reclamation, performance standards, bond release geodatabase

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Three Year Performance Evaluation of a Sulfate Reducing BioReactor for Mine Water Treatment in PA: Sulfate Removal, Sulfide Control, and TDS Reduction[1]

William J Walker, PhD[1]

Abstract: A sulfate reducing bioreactor system was designed and constructed in 2014 to remove sulfate in alkaline mine water to 250 mg/L sulfate prior to discharge. The design elements were previously described and consist of a metals removal circuit, carbon feed circuit and twin bioreactors bedded with large cobbles and seeded with sulfate reducing bacteria but containing no additional carbon source. Biochemical performance to date has shown that sulfate reduction approaches 1500 mmol SO4 $m^{-3/}$day using ethanol, molasses or molasses plus ethylene glycol. After 3 years of operation, influent sulfate of 2800 mg/L is reduced to concentrations ranging from only 24 to 400 mg/L depending primarily on ambient temperature. Effluent metal concentrations were decreased to <1 mg/L Fe and <0.2 mg/L Mn. Effluent residuals such as sulfide (dissolved and gaseous) are removed using an additional iron bed circuit where removal of sulfide from 15 mg/L to <0.20 mg/L occurs with a 30 second contact time. Concerns over elevated TDS (via Osmotic Pressure) have led to testing passive methods for reducing salt in the effluent. To date, several zero valent iron powders have been used in different treatment system configurations to reduce effluent TDS by 35 to 60%.

Additional Key Words: SRB, bioreactors, AMD, sulfate reducing bacteria, mine waster, Osmotic Pressure, TDS, Zero Valent Iron

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2. William J Walker, PhD, Senior Geochemist, Sovereign Consulting, 3100 Airport Road, Seattle, WA 98134.

A Drainable Limestone Bed Constructed in a Botanic Garden[1]

G. R. Watzlaf*, R. S. Hedin, and B. C. Hedin[2]

Abstract: A drainable limestone bed (DLB) was constructed on property that is being developed into the Pittsburgh Botanic Garden. Mine drainage discharged at a rate of up to 40 L min^{-1} with a pH of 3.3 containing 143 mg L^{-1} of acidity and 16 mg L^{-1} of dissolved aluminum. A vertical-walled, concrete tank (30.5 m by 6.1 m by 1.5 m deep) was constructed and filled with 408 tonnes of limestone. A concrete tank approach was used to minimize impacts on the surrounding vegetation within a developing area of the Garden. Effluent water quality is consistently very good with a pH of 6.7, over 200 mg L^{-1} of alkalinity and less than 1 mg L^{-1} of aluminum. The treated water discharges into what is now called the Lotus Pond which is now stocked with trout, bass and bluegill. This pond has become a focal point in the developing PBG. Aluminum solids are flushed from the DLB (approximately weekly) and directed to a separate pond. Testing during flushing found that over 70% of the accumulated aluminum solids were removed from the DLB during each flush. The DLB has been effectively treating water for over 3.5 years and based on water quality data should not require major maintenance (cleaning the limestone) for several years.

Additional Key Words: Mine drainage, passive treatment, aluminum removal, Pittsburgh Botanic Garden, flushing effectiveness.

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[2] George R. Watzlaf, Environmental Engineer; Robert S. Hedin, Ecologist; and Benjamin C. Hedin, Environmental Scientist, Hedin Environmental, Pittsburgh, PA 15228.

Transforming Abandoned Mine Lands into a Botanic Garden[1]

G. R. Watzlaf*, R. S. Hedin, B. C. Hedin, K. Kaiser and R. L Beam[2]

Abstract: The Pittsburgh Botanic Garden (PBG) is being developed on 186 ha of abandoned mine land. Underground mining occurred on the property in the early 1900s and surface mining occurred along the outcrop in the 1930s and 40s. Reclamation and remediation of this property is ongoing in four major project areas: the Woodlands Lotus Pond passive treatment system, a passive treatment system in the Kentucky Hollow area, the Abandoned Mine Land Economic Revitalization (AMLER) Pilot Program, and Remining/Reclamation. A drainable limestone bed (DLB) has been constructed in the Woodlands area that has very effectively treated mine drainage (40 L min^{-1}, pH 3.3, 16 mg L^{-1} aluminum) for the past 3.5 years. The treated water is of such good quality (pH 6.7, 200 mg L^{-1} alkalinity, < 1 mg L^{-1} of aluminum) that it discharges into what is now called the Lotus Pond which has become a focal point in the developing PBG and is stocked with fish. A newly funded project will treat two mine discharges in the Kentucky Hollow area using DLBs to treat this low pH, high aluminum water. The PBG received a grant from the Abandoned Mine Land Economic Revitalization (AMLER) Pilot Program to address many abandoned mine land issues on the site: over 3 km of unreclaimed highwalls, subsidence prone areas, vertical openings up to 3 m deep, additional mine drainage discharges and refuse piles. In an effort to clean up water and reclaim the land on another part of the site, over 10 ha are being remined. Some of the remining area (1.3 ha) has been reclaimed using the ARRI tree planting method, which is consistent with the vision of the PBG. These reclamation and remediation projects will be discussed and the challenges to proceed in a manner consistent with the development of a botanic garden.

Additional Key Words: Mine drainage, passive treatment, drainable limestone bed, mine reclamation, highwalls, subsidence, remining, Pittsburgh Botanic Garden.

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Seasonal recovery of an Appalachian stream affected by acid mine drainage and municipal wastewater

Morgan Whited*, John Gaughan, Sawyer Rensel, Justin Hugo, William H.J. Strosnidier, Peter M. Smyntek[1,2]

Abstract: Contamination of waterways by acid mine drainage (AMD) and municipal wastewater (MWW) still affects many communities both regionally and across the world. Despite the fact that these two common sources of rural water pollution frequently co-occur, their interaction and combined effects have not been thoroughly examined in the field. A monitoring-based field study was undertaken to evaluate the combined water quality impacts of AMD and MWW in Bradley Run, a second-order Appalachian stream near Gallitzin, PA, and investigate the resilience of the stream ecosystem. Clear differences in metal and nutrient concentrations and aquatic macroinvertebrate community composition were observed between sites upstream and downstream from the AMD and MWW inputs. This indicated that these pollutant sources significantly decreased water quality within the stream, particularly during low-flow conditions in the autumn when they comprised a significant source of water to the stream. However, substantial removal of aluminum and phosphate was observed, suggesting a rapid interaction between these key pollutants within the AMD and MWW, respectively. In addition, during high-flow conditions in the spring, higher water quality was observed along with recovery of the aquatic macroinvertebrate communities. This may indicate that small streams may be resilient and ready to recover if AMD and MWW pollutant inputs are simultaneously reduced since their combined effects may be less harmful than either one on its own.

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Seasonal recovery of an Appalachian stream affected by acid mine drainage and municipal wastewater

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Selenium Dynamics in Mining-Influenced Headwater Streams of Central Appalachia[1]

K.M. Whitmore[*], S.H. Schoenholtz, C.E. Zipper, D.J. Soucek[2]

Surface coal-mining is a source of selenium (Se) contamination in streams of the Appalachian coalfields. Selenium dynamics in aquatic systems are complex and largely controlled by site-specific factors, but have been understudied in Appalachian headwater streams. In this study, we evaluated the degree and dynamics of Se enrichment and bioaccumulation in headwater streams influenced by coal-mining. Based on Se concentrations in macroinvertebrates collected from 23 headwater streams, nine sites were selected for further study: three reference streams with no history of coal-mining, and six streams influenced by coal mining. Mining-influenced streams were further separated into “high-Se” and “low-Se” streams based on macroinvertebrate tissue Se concentrations. Water-column, sediment, biofilm, leaf detritus, and prey and predator macroinvertebrates were collected and analyzed for Se concentration during two sample periods, Sept. - Oct. 2015 and Feb.-March 2016. Selenium concentrations in all media were found to be elevated in mining-influenced over reference streams and in high-Se over low-Se streams. Selenium dynamics, enrichment in particulate media (sediment, biofilm and leaf detritus) and trophic transfer of Se to prey from particulate media and to predators from prey, did not exhibit major differences among streams of differing Se levels. Water column Se concentrations were predicative of Se concentrations in macroinvertebrate tissues. Findings from this study indicate headwater streams influenced by coal-mining play a significant role in the introduction of elevated Se concentrations into the aquatic food-chain.

Additional Key Words: macroinvertebrates, trace element, enrichment, bioaccumulation

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[2.] Kriddie M Whitmore, Graduate Student, Department of Forest Resources and Environmental Conservation; Stephen H. Schoenholtz, Director, Virginia Water Resources Research Center; and Carl E. Zipper, Professor, Department of Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, and David J. Soucek, Ecotoxicologist, Illinois Natural History Survey, Champaign, IL 61820.

Objectives and Design Solutions of a 1000-year Evapotranspiration-Capillary Surface Barrier System[1]

Z. Fred Zhang* and D.M. Wellman[2]

Abstract: Surface barriers (covers) have been used to isolate mine waste and restore mine lands. The design objectives and hence solutions vary depending on numerous factors such as waste type and hazardousness, hydrogeological conditions, vegetation, climate, and the environmental elements of concern. For radioactive waste sites at the semiarid Hanford Site in southeastern Washington State, a series of objectives was set to meet or exceed Resource Conservation and Recovery Act criteria, function in a semiarid to subhumid climate, limit drainage through the silt to less than 0.5 mm yr^{-1}, limit runoff, minimize erosion, minimize biotic intrusion, have a design life of 1000 years, and be maintenance free. To achieve these objectives, a package of design solutions was developed to

- isolate waste using a multi-component and multi-layered surface barrier system;
- immobilize the underlying contaminants by nearly eliminating drainage;
- manage precipitation and drainage with a store-and-release natural ecological system and by including a capillary break and a coated asphalt concrete layer;
- control wind- and water-induced soil erosion with vegetation and pea gravel;
- inhibit animal, vegetation, and human intrusion with a riprap layer and a coated asphalt concrete layer;
- protect the functional part of the barrier system against damage using side slopes;
- eliminate the impacts of material degradation using only natural stable materials (e.g., soil, sand, and rock);
- reduce gas release from the waste and oxygen ingress into the waste with a coated asphalt concrete layer.

A demonstrative Prototype Hanford Barrier (PHB) was constructed in 1994 and has been tested under stressed and natural conditions for over two decades. PHB performance demonstrated that the barrier satisfied nearly all key objectives. The above solutions can be modified for sites containing other types of wastes, e.g., uranium mill tailings (UMTs), mine tailings or mine lands, and hazardous waste landfills. Depending on the hazardousness of the waste sites, the intrusion prevention layer could be thinned or removed. The coated asphalt concrete layer or a modified version can be used to prevent the release of radon gas from the UMTs or reduce the ingress of water and oxygen into the mine tailings, and hence reduce acid mine drainage generation. The silt loam storage layer probably can also be thinned, depending the maximum allowed drainage rate from the barrier and the minimum thickness needed for normal growth of vegetation.

Additional Key Words: Surface Cover; Mine Land; Reclamation; Tailings; Geotechnical

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Water Quality and Freshwater Mussel Status in Mining-Influenced Virginia-Tennessee Rivers[1]

C.E. Zipper, B. Beaty, J.W. Jones, C. Lott, and R. Stewart [2]

Abstract: The Clinch and Powell Rivers of southwestern Virginia and northeastern Tennessee support diverse aquatic communities that include imperiled species of fish and freshwater mussels. Forty-five mussel species, including at least 20 federally endangered species, are extant in these two rivers despite the surface coal mining that has affected water quality in both rivers. Freshwater mussel communities have declined in sections of both rivers over multiple decades, while total dissolved solids (TDS), an indicator of mining influence, has increased in concentration over those time periods. In both rivers, mussel community declines have been most severe in the river sections where TDS-concentration increases have been greatest. In laboratory bioassays, *Villosa iris* juveniles were exposed to waters with environmentally relevant major ion concentrations, but no impairments of survival or growth were observed. In an effort to identify water contaminants responsible for mussel decline, an intensive water monitoring program is being conducted in the Clinch River and at one location in a mining- and urban-influenced tributary, the Guest River. First-year results indicate that total dissolved solids, specific conductance, several major ions (K^+, Na^+, and SO_4^{2-}), and several metals (total Cu, Fe, Mn, Ni, and Sr) are elevated in the Clinch River reach that has experienced severe mussel declines, relative to other river sections; and are even greater in the Guest River relative to the Clinch River mainstem. Trace metals, polycyclic aromatic hydrocarbons, and major ions have been identified as potential stressors that may be contributing, either individually or synergistically, to mussel declines; but cause and effect relationships and current environmental exposures are poorly understood.

Additional Key Words: aquatic ecology; conductivity; major ions; metals.

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