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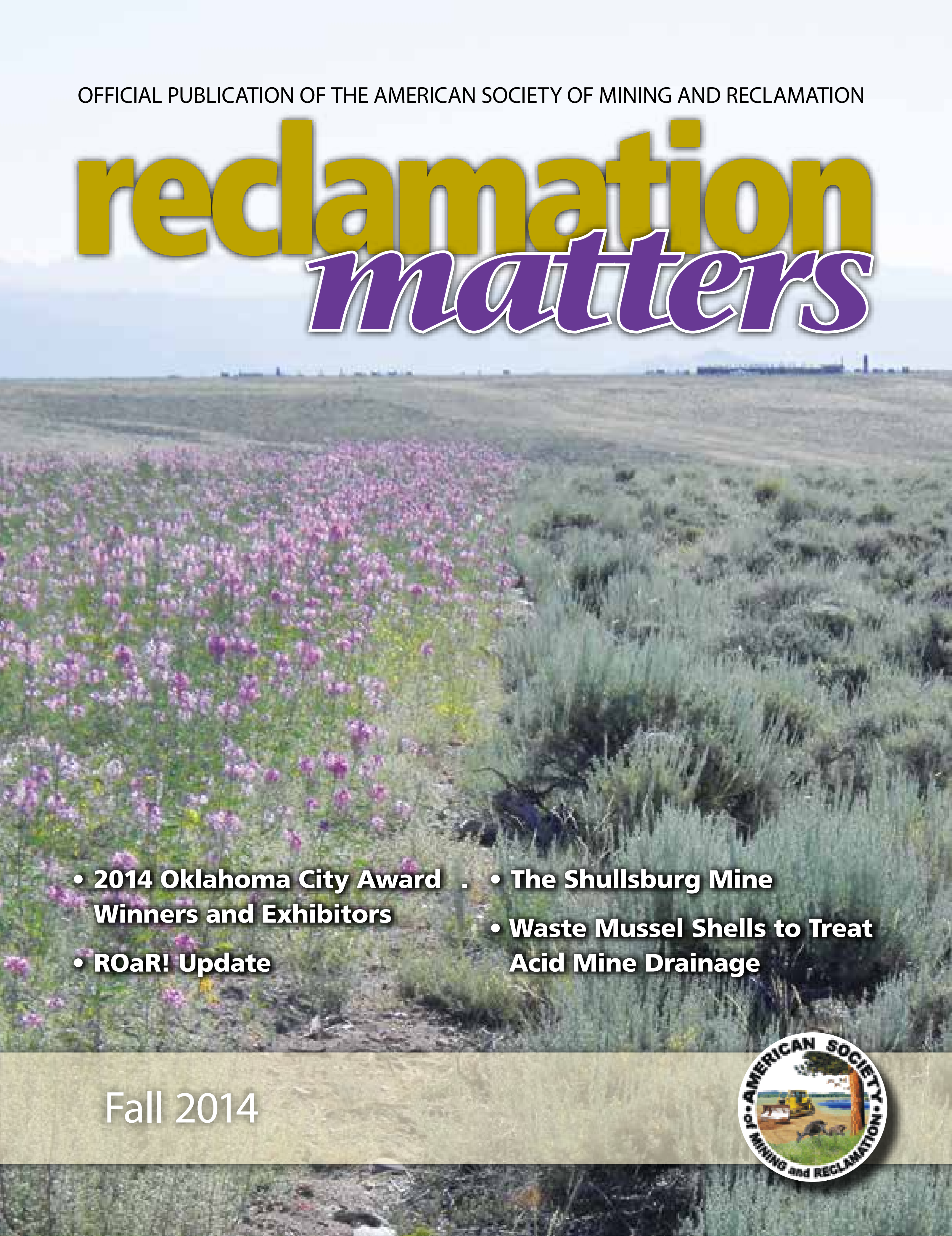
reclamation matters



- 2014 Oklahoma City Award Winners and Exhibitors
- ROaR! Update
- The Shullsburg Mine
- Waste Mussel Shells to Treat Acid Mine Drainage

Fall 2014

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It's Time to Deliver

By Joe Friedlander, North American Coal

"The greatest dangers to liberty lurk in insidious encroachment by men of zeal, well-meaning but without understanding."
Supreme Court Justice Louis Brandeis

I was left scratching my head when a previous Speaker of the House famously said on a Sunday talk show, "I believe in natural gas as a clean, cheap alternative to fossil fuels." Huh?

And I cringed recently when the EPA preemptively blocked future metals mining at Pebble Bay, Alaska. With no permit application submitted and no detailed plans developed, the EPA based their assessment on a preliminary notice the potential developers sent to the Securities and Exchange Commission. In the absence of published company mine plans, the agency developed its own mine plans – then found that disturbance would be so great that mining must be banned. They are now rethinking this ban and may impose restrictions instead.

What happened? This is what occurs when well-meaning people in authority speak and act without understanding all the facts. From seemingly small comments by national leaders to major agency actions affecting resource development, an ill-informed government will create poorly written and improperly interpreted laws and regulations. And Americans pay in every way, from restrictions on development and job growth to increased energy costs.

We can fix this. For more than 30 years ASMR, the American Society for Mining and Reclamation, has been the preeminent organization to advance knowledge of the art and science of disturbed land reclamation. When I joined in the early 1980s, land reclamation at surface mines was in its infancy. Using knowledge acquired through ASMR, hundreds of thousands of acres have been successfully reclaimed at the nation's coal mines.

Times change, and so do the issues. Concern over water quality has increased tremendously over the past several years, and companies are being asked to prove they can mine land and reclaim it successfully without impacting vital water resources.

Over the past few decades, reams of data have been collected about reclaimed land and water quality at mining operations, demonstrating successful use of the latest environmental protection technologies. And ASMR provides the best vehicle to share this information with policymakers, regulators, academics and the general public. Papers and presentations from annual ASMR meetings, as well as the ASMR online journal, are cited as sources of latest information on environmental protection and land reclamation.

Take action. Plan to attend and participate in the next ASMR annual meeting, to be held June 6-11, 2015 in Lexington, Kentucky. It's not too early to think about the valuable information you have that can be shared with others. A call for papers and presentations will come out this fall. The process has been made simple to encourage as many presentations as possible.

But it's up to you. As the President said last year in a speech highlighting the environment, "Push back on misinformation. Speak up for the facts." We've got the facts – we just need to speak up for them. It's time to deliver. ■

Catching up with University of Wyoming's Restoration Outreach and Research Club (ROaR!)

By Michael Curran, University of Wyoming

A group of ROaR! members teams up with Laramie River Conservation District to improve habitat quality and control erosion near the Laramie River.

ROaR! members Mary Poelman, Bree Lind, Michael Curran, Patricia McIlvena and Leticia Vareles take a break from removing trash and debris from Spring Creek. Over 350 pounds of trash were removed during this clean-up effort.

The Restoration Outreach and Research Club (ROaR!) at University of Wyoming is in for an exciting new year. During the 2013-2014 academic year, student participation in ROaR! was at an all-time high of 47 (17 graduate students and 30 undergraduate students). ROaR! is advised by Dr. Peter Stahl, director of the Wyoming Reclamation and Restoration Center and professor of Land Reclamation and Soil Ecology in University of Wyoming's Ecosystem Science and Management department. Many of Dr. Stahl's past students and former ROaR! members have gone on to have successful careers in the field of land reclamation. University of Wyoming alumni Chris Fare, who is now at Cloud Peak Energy, visited his alma mater this past April to discuss the issues of coal mine reclamation in northern Wyoming and to announce reclamation internship positions to ROaR! members. At the conclusion of this meeting, officer elections for the 2014-2015 academic year were held, with undergraduate students Jay Quintanilla and Olie Moss being voted president and vice-president, respectively. Graduate students Michael Curran and Casey Balthrop were voted treasurer and secretary.

As a student chapter of the American Society of Mining and Reclamation, ROaR! is constantly searching for new reclamation and restoration projects around

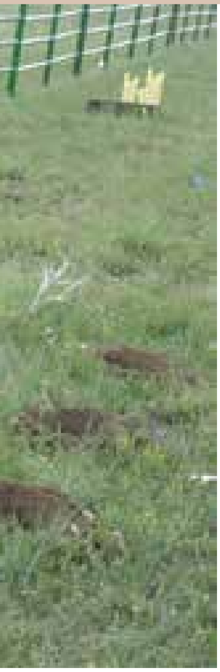
M.S. student and ROaR! member Seth Cude uses a power augur to provide holes for Casey Balthrop's research project. The holes would later be planted with sagebrush seedlings.

M.S. student and ROaR! member Seth Cude helps fellow M.S. student Casey Balthrop plant sagebrush seedlings in Douglas, WY as part of Casey's research project.

the Laramie, Wyo. community. Since its inception in 2010, ROaR! has worked closely with the Laramie River Conservation District (LRCD) and City of Laramie on multiple stream and river restoration projects in or near Laramie. In 2010, 2011, and 2012, ROaR! members worked to restore several banks of the Laramie River and in Fall 2013, Tony Hoch of the LRCD came to campus to acknowledge our efforts successfully improved habitat quality and reduced erosion along the Laramie River. In May 2014, a group of five ROaR! members and Dr. Stahl worked with the City of Laramie to remove over 350 pounds of trash from Spring Creek in Laramie, an area often used for recreational fishing. In addition to river and stream restoration and clean-up projects, ROaR! has actively been working with the City of Laramie to make access difficult for motorized vehicles and four-wheelers on public running and biking trails and has worked to remove trash and waste from these trails and adjacent areas. Besides working on these projects during 2013-2014, ROaR! joined forces with the Campus Sustainability Club, the Energy Resource Club, and the student farm at University of Wyoming to build a display in the campus library and host a film fest during Earth Week, which promoted ideas to increase responsible stewardship of our lands and environment.

Several students in ROaR! have individual projects involving reclamation and restoration. Graduate student Casey Balthrop recently planted over 690 Wyoming big sagebrush seedlings in the Douglas Core Habitat Area for greater sage-grouse, a species which is warranted but precluded under the Endangered Species Act. Casey's project is unique in that he collected seeds from sagebrush in the Douglas, Wyo., area as well as local soils before caring for them in a greenhouse. If successful, Casey's Masters of Science project may improve our ability to successfully reestablish sagebrush habitat for sage-grouse and other wildlife species in arid and semi-arid environments. Fellow graduate student, Rachana Giri Paudel, has been studying phytoremediation techniques to remove selenium from soils near a uranium mine outside of Douglas, Wyo. For her work, Rachana was recently awarded with the top student poster award at 2014's ASMR Meetings in Oklahoma City.

As ROaR! continues to increase in size, the future looks bright. Currently, ROaR! is working with the grounds crew at the University of Wyoming to beautify several courtyards around campus. The long-term plan for these courtyards is to use only native rangeland plants to create healthy insect and bird habitat as well as to be used as educational tools for courses with a plant identification component. Additionally, ROaR! continues to work with Laramie River Conservation District, City of Laramie, University of Wyoming, and other local businesses and groups. Recently, ROaR! was contacted about the potential of reclaiming several steep sites outside of Laramie, which are subject to extreme erosion after the Squirrel Creek fire burned through them last summer. ROaR! has also just begun communication with a limestone quarry south of Laramie and is hoping to provide expertise and man-power to a reclamation project associated with limestone mining. As the state of Wyoming con-



Sumi Pyakurel, Casey Balthrop, Calvin Strom, and Rachana Giri Paudel finish placing a cage over a set of plants to prevent grazing for Rachana's study on phytoremediation of selenium near the Cameco Uranium Mine in northeastern Wyoming.

tinues to be a leader in natural resource production, the need for restoration and reclamation will continue to grow. ROaR! is excited to welcome new members when the 2014-2015 academic year kicks off and we look forward to increasing the diversity and scope of restoration and reclamation projects we are involved with in the future. ■

WILD WOMEN OF RECLAMATION ARRIVE IN OKLAHOMA CITY

By Brenda K. Schladweiler, Michele Coleman, Cindy Adams

Wild Women of Reclamation (WWR) originated in Laramie in 2013 as a last minute idea of Brenda Schladweiler on Sunday evening of that conference week. Brenda is also a member of the Society of Range Management (SRM) and participates in the Wild Women of Range within that group.

"What a great idea to have a sister organization," was Brenda's thought. She checked out whether there would be any heartburn on the part of SRM to form such an organization within ASMR, of which there was none. Wild Women of Reclamation was BORN!

WWR was an integral part of the Monday agenda at the 2014 national meeting of the American Society of Mining and Reclamation. Participants met on Monday morning at a kickoff breakfast, a time slot to which they will continue to meet at future meetings. Brenda Schladweiler and Michele Coleman shared their career histories with the group through PowerPoint presentations, which showed some pictures of a much younger Brenda and Michele. Feedback from attendees indicated that they appreciated seeing *how it used to be* and, in many ways *how it still is.*

Front Row Left to Right: Rebecca Peer (St. Francis University); Cally Driessen (KC Harvey); Brenda Schladweiler (BKS Environmental); Ruth Anderson (Virginia Tech).

Back Row Left to Right: Michele Coleman (NB Power); Leah Oxenford (University of Oklahoma); Taya Zoubareva (St. Francis University); Margaret Dunn (Stream Restoration Inc.); Zenah Orndorff (Virginia Tech); Jennifer Franklin (University of Tennessee); Amanda Taylor (QEP Energy Company); Cindy Adams (BKS Environmental); Samantha Day (University of Wyoming); KeriAnne Pritchett (Cascade Earth Sciences).

To keep the fire going throughout the coming year, the group was divided into more experienced individuals (greater than five years in their career), vs. less experienced (less than five years). One person from each group was paired with one from the other group. Those mentors and proteges were then given the assignment to keep in touch with each other throughout the coming year. Having that support network is important for both sides. Unfortunately, those not able to attend the OKC meeting were not able to participate in this aspect of WWR. Perhaps something can be arranged at future meetings.

Two special events were planned for the following year, in addition to the mentoring group. First, your favorite photo of *my worst field day* will be submitted by November 1, 2014 for compilation and judging by the whole group, including the 2013 and 2014 WWR attendees. Results will be available in January. Second, *my favorite wildflower photo* will be submitted by group members on or before April 15, 2015 and voted on. If sufficient time allows, the 12 most popular photos will be compiled into a calendar and sold as a fundraiser at the Lexington meetings in June 2015.

Michele Coleman and Cindy Adams have agreed to plan for future events of the WWR, including the Lexington meeting. Thank you Michele and Cindy. Stay tuned for information from them.

Soon after the Oklahoma meeting, Amanda Taylor, with QEP in Vernal, who attended the 2014 breakfast meeting, was tragically killed in a rafting accident. She will be sorely missed by her WWR mentor from Virginia Tech, as well as those who knew her through ASMR and outside the society. ■

Paul Eger

2014 Reclamationist of the Year Award

Our recipient of the 2014 Reclamationist of the Year Award is Paul Eger. Eger has been involved in acid mine drainage and mine reclamation for over 30 years. He has been a member of ASMR for 20 years and served on the NEC from 2006-2009, and also served as President in 2007. He received his B.S. in chemical engineering from the University of Rochester and has completed additional graduate education in chemical engineering and environmental health from the University of Minnesota.

His career includes working for the Minnesota Department of Natural Resources, Green Horizons Environmental Consultants, Golder Associates, Global Minerals Engineering in Hibbing, MN. He has published over 90 articles in the area of acid mine drainage and mine reclamation. He has received numerous awards including the Interstate Technology Regulatory Council Team Award, four annual awards for effective teamwork from the State of Minnesota, and the Henry Krumb Lecturer Award from the Society of Mining Engineers.

His early career concentrated on metal leaching in mine drainage and in recent years has involved the development of cost-effective and environmentally safe reclamation using waste products, such as municipal solid waste compost, paper processing waste and dredge material from

Lake Superior. His work with bio-solids for reclaiming coarse taconite tailings has led to the development of a best management practice which has been used to accelerate soil development on over 33,500 acres of taconite tailing wastes in Minnesota. ■

James Gusek

2014 ASMR Richard and Lela Barnhisel Reclamation Researcher of the Year

The Richard and Lela M. Barnhisel Reclamation Research of the Year Award recipient is Jim Gusek. Gusek has 40 years of wide-ranging experience in mining related projects, with a focus in environmental and geotechnical disciplines. He received his B.S. in Mining Engineering from Colorado School of Mines in Golden, CO.

During his career, he has worked as a private consultant, and for a variety of firms, including the U.S. Army Corps of Engineers; Consolidation Coal Co., McElroy Mine, WV; D'Appolonia Consulting Engineers, Inc.; Resource Management Consultants Inc.; Gormley Consultants Inc.; Golder Associates Inc.; and Sovereign Consulting Inc. He is a recognized international authority in the passive treatment of mine drainage. One of his passive treatment projects received several awards for engineering excellence, including the 1998 Grand Conceptor Award from the Colorado Chapter of the American Consulting Engineers Council (ACEC), as well as an honor award at the national level of the ACEC. He has also received the American Society of Mining and Reclamation Reclamationist of the Year Award for his outstanding and thorough evaluation and planning of mined land reclamation projects.

He has recently co-invented an innovative technology which uses engineered foam to deliver and apply site-specifically selected materials to mitigate acid rock drainage. He has authored or co-authored 58 publications and has made numerous technical presen-

tations at the ASMR annual conferences as well as at other meetings, workshops and training seminars. He is known for his generous time as a mentor and has helped many young engineers and scientists during his career. ■

Wayne Erickson

2014 Pioneer in Reclamation Award

The Pioneer in Reclamation Award goes to Wayne Erickson. Erickson has worked in the field of mine land reclamation for 34 years. He worked as a reclamation technician at the Edna Mine in Oak Creek, CO; an environmental specialist, Southwestern Division Office in Gallup, NM; a general environmental supervisor, McKinley Coal Mine, Gallup, NM; an environmental services unit manager, Pittsburgh & Midway Coal Mining Co., Englewood, CO; senior environmental engineer, Pittsburgh & Midway Coal Mining Co., Englewood, CO and owner and principal environmental scientist, Habitat Management, Inc., Englewood, CO.

His career definitely demonstrates his broad background in industry and as a consultant (since 1995). His outstanding efforts in the formation of the Western Alkaline Coal Mining Working Group resulted in EPA proposing and obtaining approval of a special subcategory of the law relating to sediment transport on arid western reclaimed lands. In November 2009, EPA approved the revised NPDES application for the McKinley Mine. The establishment of this subcategory provides legal footing for the final reclamation bond release of mined lands in arid and semi-arid lands where naturally occurring sediment loads would have otherwise been prohibited.

Without this subcategory, the 0.5 ml/L effluent standard would prohibit removal of sediment ponds and prevent bond release. ■

Margaret Dunn

2014 William Plass Award

Our recipient of the 2014 William T. Plass Award is Margaret Dunn. Dunn has been involved in numerous aspects of mineral extraction, mine water chemistry, and reclamation for over 30 years. She received a B.S. in Geology from Florida State University, a M.S. in Geology from Virginia Polytechnic Institute and State University, and is a Registered Professional Geologist in Pennsylvania. She worked for King Coal Company as a geologist; CDS Associates, Inc., served as president for 2 years; co-founder and president of Stream Restoration Inc.; co-founder and president of BioMost, Inc.; and is also presently associated with Leonardo Technologies, Inc. as the senior geologist.

She is a life member of ASMR and served as President in 2004. She is also a member of the American Institute of Professional Geologists and Society of Mining, Metallurgy and Exploration. She has provided testimony to the U.S. House of Representatives Subcommittee on Energy and Mineral Resources on the *Opportunity to Improve the Lives of Many by the Restoration of Watersheds Impacted by Abandoned Mines* and to the Pennsylvania House Environmental Resources and Energy Committee on *Growing Greener: A Program for All Pennsylvania.*

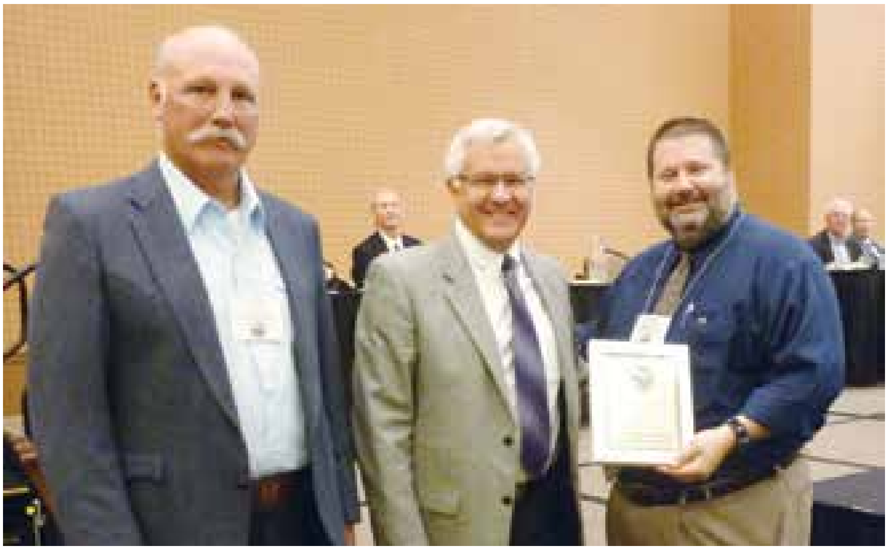
She has authored or co-authored over 40 papers. She has received 23 awards from local, state, regional, and national entities. Her most recent recognition was the recipient of the *Pennsylvania Abandoned Mine Land Conference Mayfly Award* for leadership in watershed restoration and stewardship. Her nominator described Margaret as a person who strives to make a positive impact upon

the world around her and to help other (particularly young people) to do the same.

"She is a role model and an inspiration to those involved in mine reclamation and stream/ecological restoration… Her motto 'Get it Done' is the epitome of her character with achievements to validate it." ■

ASMR Special Award: Wyoming Abandoned Mine Land Program

The Wyoming Abandoned Mine Land Program of the Wyoming Department of Environmental Quality has an outstanding program dealing with issues of abandoned mine lands. They supported mine land reclamation research through the Abandoned Coal Mine Reclamation Research Program, through the Office of Research at the University of Wyoming for nearly a decade. However, this recognition is granted based upon the implementation of the Natural Regrade™ technology to compliment geomorphic surface mine reclamation design efforts and the implementation of those designs during field construction. The specific project cited in the nomination is the Lionkol Project located within a historic coal mining district in Sweetwater County, Wyo., which had been intensively disturbed and impacted by underground mining beginning in the early 1900s, through the 1940s and then followed by open pit mining in the early 1970s. In addition to AML funding, it was supported by the City of Rock Springs and the BLM. The Lionkol Project fully implemented new methods in geomorphic mine land reclamation to achieve a sustainable landscape which blended with the native topography and provides long-term erosional stability. The mayor of Rock Springs stated, "many of the technology advances developed during mitigation and abatement work in Rock Springs and Sweetwater County will benefit future OSM mine land reclamation work throughout the United States." ■



Receiving the award are: Alan Edwards, Administrator, WYAML, and Bill Locke, Program Manager, WYAML.

Scholarship Recipients

MS Scholarship Michael Curran.

PhD Scholarship Ben Uster.

Presentation Winners

Oral First Place Jessica Brumley.

Oral Second Place Kenton Sena.

Oral Third Place Rebecca Peer.

Poster Winners

Poster First Place Graduate Rachana Paudel.

Poster Second Place Graduate Seth Cude.

Poster First Place Undergrad Ruth Anderson.

Poster Second Place Undergrad Taya Zoubareva.

Congratulations to all winners!

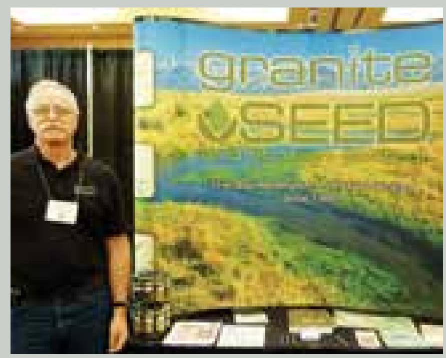
ACZ Labs - Mike McDonough

Biomost - Tim Danehy and Cliff Denholm

Enercon - Mike Fitter

Foam Concepts - Marcus Anderson

Forrest Keeling - Mike Thompson



Granite Seed - Daryle Bennett

Habitat Management - Rio Franzman

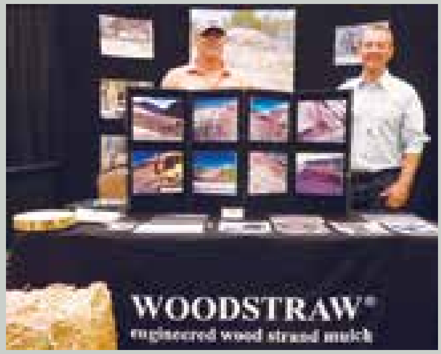
JRW Bioremediation - Mike Sieczkowski

Office of Surface Mining - Steve Felch

Office of Surface Mining, Mid-Continent - Brandon Schneider and Larry Emmons

OK Oil & Gas - Madeline Dillner

Pacific Intermountain Distribution - Bill and Eric Krippaehne



Woodstraw - Gus Connelly and Trent Jones


Profile - Adam Popenhagen


Rocky Mountain Bioproducts - Tom Bowman


Skelly and Loy - Terry Schmidt


Sovereign Consulting - Tyler Chatriand


Truax - Jim Truax and Jim Christianson

Keeton Industries - Mike Moore

Voss Signs

Pennington - Jay Vonder Haar

The Shullsburg Mine:

An Upper Mississippi Valley Zinc-Lead District Reclamation Case Study

By Tom Hunt, Applied Ecol. Services

Animal sentinels detect risks to humans by providing advance warning of a danger, particularly in the context of environmental hazards. Sentinels are more susceptible to a particular hazard than humans in the same environment. Plants and animals have long been noted to display signs of impending hazards or evidence of environmental degradation. The classic example is the canary in the coal mine. Coal miners brought canaries into coal mines as an early-warning signal for toxic gases such as carbon monoxide. Since the birds displayed symptoms before the miners, the miners had a chance to escape or don personal protective equipment.[1]

Indicator species are sentinel organisms whose presence, absence, or relative well-being in a given environment is indicative of the health of its ecosystem as a whole. For example, oysters and mussels have been extensively used as bio-monitors in marine and estuarine environments. Various biotic indices are used to help determine fresh water quality and are based on the diversity and abundance of a suite of aquatic organisms.[2] Terrestrial organisms such as birds are sometimes used to help determine the extent to which ecological systems are displaying deleterious anthropogenic influences as a result of changing land use, principally loss of habitat. Simplification, fragmentation, isolation, and pollution among other factors result from land use decisions.

The indicator species concept has been criticized because individual species do not necessarily reflect trends in other co-occurring species. Individual species within a ground nesting guild may give little information about the abundance or diversity of other like species that may have different life cycle requirements. On the other hand, examination at the overall guild level as opposed to the individual species level may mask the decline of species within a guild.[3]

Habitat assemblages are community-level ecological indicators that over the long term help detect and assess changes in populations and associated habitats. Habitat assemblages of birds, such as grassland birds, are categories of functional groups based on habitat preferences that are likely to show a measurable relationship between anthropogenic disturbances and species richness and abundance.[3]

Declines in populations of many species of grassland birds in North America have been more dramatic than those of forests and other biomes. Most grassland species both breed and winter on the continent so it is thought the declines are a function of land use decisions and related processes. The principal culprit is thought to be conversion of grasslands to cropland and associated management practices. Some agricultural land use and farming practices such as perennial pastures and CRP may be favorable to grassland birds if managed appropriately.[4]

Figure 1 highlights the role that forages play in providing adequate breeding bird habitat. Not only does well managed pasture play an important role in erosion control, it provides critical substitute habitat for the grassland wildlife that evolved with North American grasslands. The graph shows changes in row crop acres (green) and forage acres (blue) in the Great Lakes and North Central region (Minnesota, Iowa, Illinois, Indiana, Wisconsin, Michigan, Ohio, Pennsylvania, and New York). The red line charts a typical response of a grassland bird species (western Meadowlark) to changing habitat conditions over the years 1965 to 1990 (data taken from Breeding Bird Survey results in Wisconsin).[5]

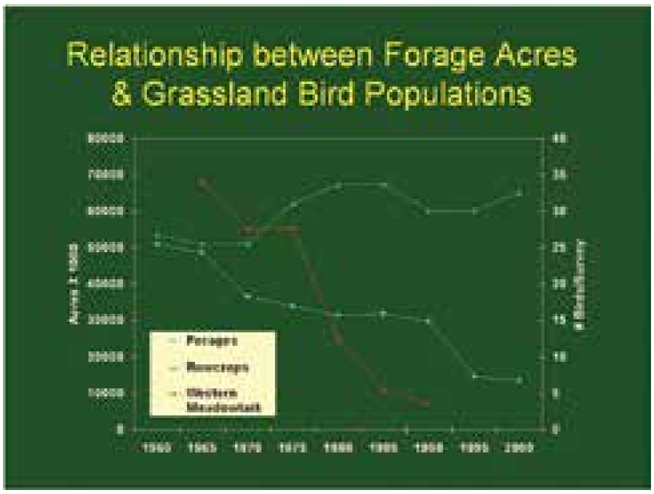


Figure 1. Relationship between forage acres, row crops, and western Meadowlark.

While agriculture has had an extensive impact on the loss and/or degradation of grasslands and associative wetlands, other land uses such as mining pose impacts on habitats including grasslands. Like agriculture, there are approaches and practices related to mining that are favorable to the restoration of habitat which renders the impacts temporary as opposed to irreversible. Temporary impacts from mining can result from an approved post mining land use designation for wildlife, a well conceived reclamation plan designed for a particular habitat assemblage, and the implementation and monitoring of the reclamation plan. This case study tells a story of resource recovery of matters both mineral and feather.

The Shullsburg mine site is located in southwestern Wisconsin, which is part of the western upland physiographic region and lies within the unglaciated part of the state known as the Driftless Area. It is characterized by deeply-dissected, broad-rolling hilltops punctuated with occasional prominent topographic mounds that rise more than 300 feet. Galena dolomite of Ordovician age underlies a mosaic of productive soils in the orders Mollisols and Alfisols. St. Peter sandstone underlies the dolomite, and the topographic mounds are capped by Maquoketa shale and Niagara dolomite. The Pecatonica and Fever Rivers along with their tributaries constitute the dendritic drainage pattern. The climate is continental. The winters are long, cold, and snowy while the summers are warm with periodic occurrences of hot humid weather. The elevation is 1,019 feet, the mean annual temperature is 47° F, average annual rainfall is 36 inches, and average annual snowfall is 42 inches.[6] [13]

Prior to European settlement the area was dominated by prairies and savanna which is now part of an ecological landscape called the Southwest Savanna. Once upon a time dry prairies on the hilltops graded into mesic prairies, oak savannas, and oak woodlands downslope. The valleys were mixed hardwoods including oak, maple and elm. Relict pine stands still occur on bedrock outcrops along some stream systems. More than 70 percent of the current land cover is agriculture though farms are increasingly parceled for residential and recreational land use. A pressing conservation concern is the precipitous decline of grassland birds such as Henslow's sparrow, loggerhead shrike, greater prairie chicken, and Bell's vireo.[7]

The earliest known miners in the area were Ho-Chunk, Fox, and Sauk Indians though Nicholas Perrot is credited with the discovery of lead around 1690. Float galena cubes were found at village and burial sites. Lead was used for net bobs, boat stones, ornaments, and later ammunition when the use of firearms became common. Historical reports document mining, smelting, and trade of lead by tribes in the region as early as 1709.[8]

The absence of Pleistocene sediments in the Upper Mississippi Valley Zinc/Lead region, shown in Figure 2, made it easy for early prospectors and miners to work exposed placer and crevice deposits of lead ore with a pick and shovel.[9] [10] Circa 1820, Jesse Shull (hence Shullsburg) and a few other Americans, under the protection of the U.S. Army, were the first known white pioneers to extract ore in the vicinity of the present mine site. Early miners worked their digs or shallow pits by a method known as suckering. The digs and associated spoil piles produced pock-marked hillsides once common in southwestern Wisconsin. These digs along with primitive dwellings of the early miners were responsible for the State's nickname, the Badger State.[9] [11]

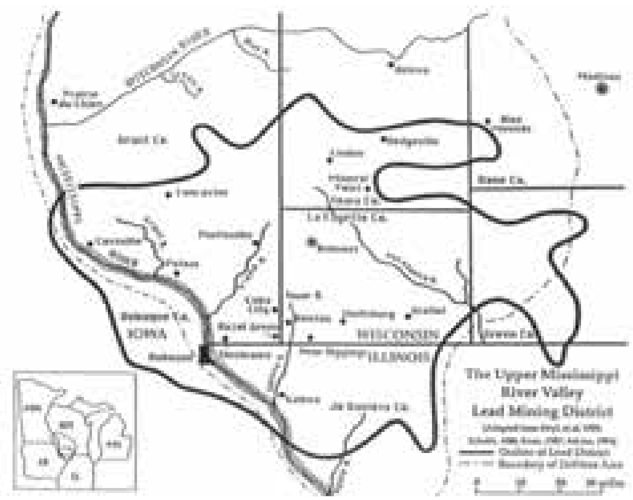


Figure 2. Map illustrating the boundaries of the Upper Mississippi River Valley Lead Mining District and the Driftless area.

The District was ranked seventh nationally in lead production until the late 1950s. When the Shullsburg mining unit closed in October 1979, lead and zinc production came to a halt. Until then, southwestern Wisconsin was the oldest continuously producing lead-zinc district in the nation. Geologists estimate the remaining resources to be greater than the total ore removed.[9]

The District, which includes parts of adjacent Iowa and Illinois, is important in the history of economic geology because it is the type area for the class of carbonate-hosted base-metal deposits known as Mississippi Valley-type (MVT) deposits. Zinc ore, primarily sphalerite and minor amounts of smithsonite, was found below the lead veins and was concentrated in the pitch-and-flat deposits in which the shaly Decorah carbonates were dissolved and replaced by sphalerite, pyrite, and marcasite, along with calcite and/or barite as gangue minerals. The pitches were dipping fractures in the Galena carbonates, formed above the flat deposits, resulting from subsidence caused by dissolution of the Decorah. The pitches were commonly mineralized. The zinc deposits were deeper than the lead veins and required larger-scale mining operations, including high-capacity pumps for dewatering.[12]

Figure 3. The Shullsburg Mine site as shown in an aerial oblique taken in 1964.

Figure 4. The Shullsburg Mine tailings mound prior to reclamation.

The early mills used mechanical separation methods such as shaker tables to concentrate the ore, and later mills used the more efficient flotation process. Early "jig tailings" were sometimes reprocessed years later by flotation mills to recover more metal. From the 1940s to the end of mining in 1978, the number of mines decreased, and the size of operations grew larger and more mechanized. Large mining companies such as Eagle-Picher and New Jersey Zinc initiated aggressive exploration programs, opened new mines, and expanded older mines such as Shullsburg shown in Figure 3 during a peak period of production. Hoisting shafts were replaced by inclined shafts, which allowed for truck haulage from the working face to the mill. Adjacent deposits were connected by horizontal drifts, and large complexes such as Shullsburg resulted, where one could drive several miles underground before reaching the extent of the mine workings. A mining company commonly mined ore from several headings in different mines and hauled the ore to a central mill for processing.[12]

Figure 4 illustrates the look of legacy tailings mounds scattered across the landscape after the closure of the District. Figure 4 depicts the Shullsburg Mine tailings mound prior to reclamation.

The original permit application (circa 1977) for the Shullsburg mine designated the post-mining land use for the site as general wildlife habitat. Post-mining activities were directed to that end either directly or indirectly. Today, the majority of the mine site (~75 acres), excluding access and maintenance roads, has been reclaimed to wildlife habitat and for minimal non-consumptive use such as education.[14]

By 1985, Applied Ecological Services (AES) began implementing a Land Reclamation and Environmental Monitoring Program for the Shullsburg mine unit. The Shullsburg unit once served as a mill site for processing ore from a shaft mine and later an incline portal after the shaft caught fire and burned. Both the shaft and portal are now closed and sealed in accordance with regulatory requirements. Ore fed the mill from more than 30 miles of underground workings. When the mine closed, merchantable byproducts (chat or jig tailings and some flotation tailings) were sold for a limited period of time. The tailings were marketed with limited success as agricultural lime. Jig tails, on the other hand, were robustly sold for seal coating macadam over the course of approximately 15 years. Flotation tails were left in place to be vegetatively stabilized.[14]

Prior to seeding, the slopes were regraded from 1.5:1 to 2.5-3:1 to improve conditions for vegetation establishment. Additionally, physical and chemical analyses of tailings and topdressing materials informed recommendations for soil amend-

Figure 5. The Shullsburg Tailings Mound post reclamation. Dry prairie grassland dominates the tailings mound slope with prairie switchgrass and little bluestem. Smooth brome, a non-native, is an introduced component of the plant community.

ments to ensure successful revegetation. Seeding occurred in the fall of 1985 and in the spring seasons of 1987 and 1988. Seed mixes were formulated according to soil moisture conditions and wind exposure. Commonly used species included big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), prairie switchgrass (*Panicum virgatum*), and Canada wild rye (*Elymus canadensis*) among others. After the jig tailings pile was completely removed in 2002, the entire reclaimed mine site was mechanically and vegetatively stabilized and native prairie vegetation dominated the reclaimed slopes as shown in Figure 5. However, smooth brome grass (*Bromus inermis*), introduced by another company on the eastern half of the south slope, has become a co-dominant throughout the site.[14]

Pursuant to Wisconsin mining codes and statutes, reclamation of a mine site must address long-term monitoring and care activities to be implemented at the site during a 20-year care period. As shown in Figure 6 the long-term monitoring and care period commences upon issuance of the Certificate of Completion (COC) by Wisconsin Department of Natural Resources, the regulatory authority. Inspiration Development Corporation, current owner of the Shullsburg mine unit, has recently been issued a COC from the WDNR. During the long-term care period, the fully reclaimed mine site provides:

- A closed mine site with secured perimeter.
- A vegetatively stabilized tailings mound.
- Grassland, wetland and surrounding forest/savanna habitat which provides diverse wildlife habitat.
- An aesthetically pleasing naturalized landscape for educational use.

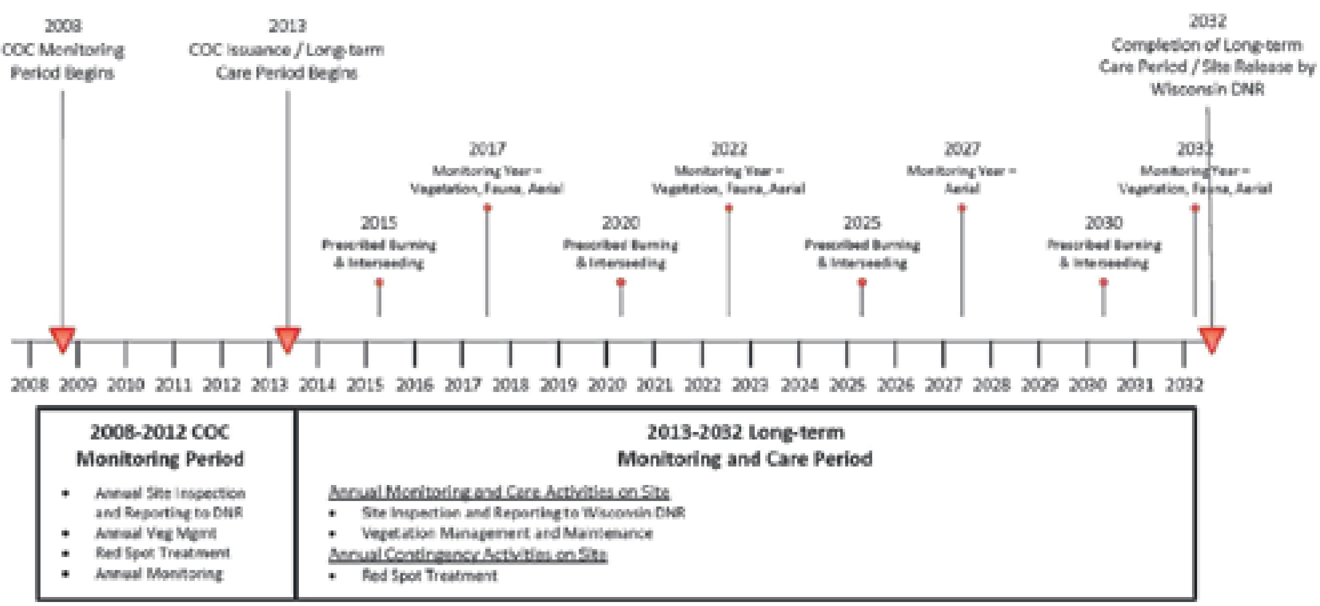


Figure 6. Shullsburg Mine Certificate of Completion and Long-term Care Timeline.

Figure 7. Avian sample points depicted within the Shullsburg Mine long-term care area.

- Ingress / egress for maintenance and inspection.

All animals require basic needs: food, water, rest, travel lanes, places to escape weather and predation, places for reproduction and rearing young, and enough space and resources to support a viable breeding population. Based on the existing onsite resources, native faunal assemblages of SW Wisconsin, and information about preferred species, AES prepared a Wildlife Habitat Management Plan (WHMP) that will ensure compliance with the Long-term Care specifications. The WHMP will assure that the Shullsburg mine site contributes more fully to the natural heritage of Lafayette County and the state of Wisconsin.[14]

During the past three decades, the land cover at the Shullsburg mine site has functioned as 'wildlife habitat.' The mosaic of prairie grassland, old fields, isolated wetlands, and forested spaces present throughout the site provides valuable cover, foraging, breeding, and critical overwintering habitat for a variety of birds, mammals, and other wildlife. Habitat types of special interest on the site are remnant oak savanna and grassland which are of regional ecological concern and provides habitat for unique plants and animals, especially grassland birds.

In accordance with the WHMP, scheduled surveys are ongoing to determine baseline wildlife diversity, abundance, and distribution throughout the site. An avian survey, sample points are depicted in Figure 7, was included as part of the approved WHMP.

Breeding bird data was collected in 2014 using unlimited-distance point count surveys following the USGS Breeding Bird Survey Protocol. Points were placed approximately 200 meters apart and in strategic locations to best capture the habitat diversity of the site.

Grassland habitat dominates the land cover (approximately 60 percent). Therefore, four of the eight onsite point count locations were located either entirely or largely within grassland habitats as shown in Figure 7.

A modified version of Reynolds bird *survey methodology* was also conducted on June 6th, 2014.[15] This survey method is designed to identify individual male territories and, therefore, aids in providing detailed abundance and distribution data.

Henslow's sparrows were observed at each grassland point (Figure 8). Since this is a Wisconsin State-threatened species, territory mapping was done on June 6th to better understand both the abundance and distribution of this population.

As illustrated in the AES wildlife biologist's field notes in Figure 9, a total of seven individual male Henslow's sparrows were observed maintaining separate territories on and around the tailings mound/grassland habitat.[16]

Figure 8. **Adult male Henslow's sparrow maintaining his territory on the east slope of the tailings mound on site. Photo taken July 6th, 2014, by Michael McGraw.**

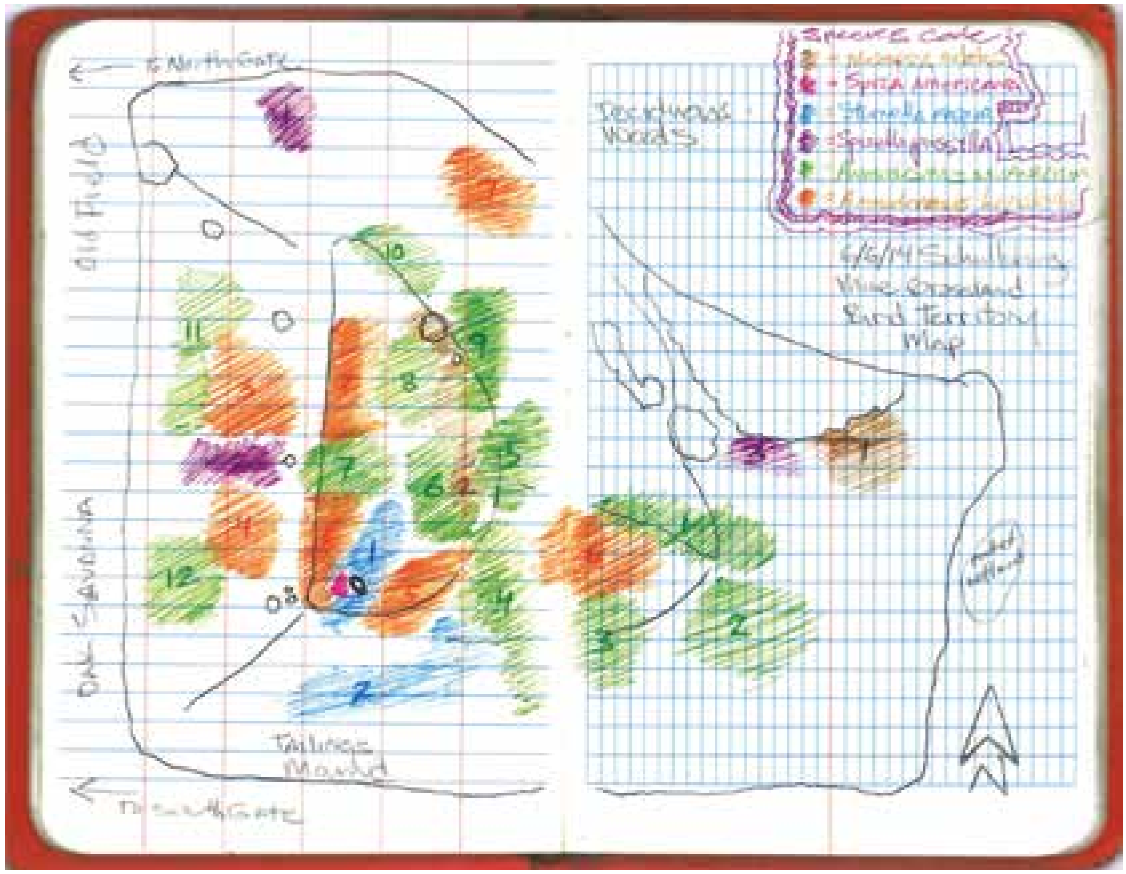


Figure 9. Field notebook illustrating relative locations of grassland birds at the Shullsburg mine site (Michael McGraw). The birds include: song sparrow, Dickcissel, Eastern meadowlark, field sparrow, grasshopper sparrow, and Henslow's sparrow.

Henslow's Sparrow (*Ammodramus henslowii*), a state threatened species in Wisconsin and considered a pressing conservation concern has suffered significant declines in many parts of its breeding range. It is an obligate grassland nester.

Management Guidelines: The U.S. population of this rare species has declined >68 percent from 1966-1991. The Wisconsin population has dropped an average of 5 percent per year. This habitat specialist has suffered from the loss of a mosaic of patchy areas within tall, dense grassland vegetation. Henslow's sparrow ranked highest in the Wisconsin Grassland Bird Study's ranking of birds of management and conservation concern in the state. The control of woody vegetation is critical. And, because this species requires dense litter layers, it benefits directly from management that promotes short burning rotations. Burning should not occur more often than once in 3 years. Patch burning is preferable.[17]

The reclaimed habitat at the Shullsburg site is suited to the Henslow's sparrow. However, there are no guarantees that the Henslow's sparrow will remain a viable population at the Shullsburg Mine site. Seven territories covering 33 acres were observed with an average territory size of approximately 1-2 acres which is consistent with previously observed data. Data also indicate large grasslands are needed to support persistent populations of this species. A persistent problem on smaller sites has been brood parasitism.[16]

If the presence of Henslow's sparrow and associative species is an indicator of ecological health then the long-term reclamation outcome for the Shullsburg Mine site is promising. The site will require diligent monitoring, management, and maintenance, but one can't help but think the recovery of the natural and cultural heritage of the Upper Mississippi River Valley District is a story with continuing possibilities.

Special thanks to Inspiration Development Corporation, Jim Schelhorn, retired, and John Foster for their support. And, thanks to Ry Thompson and Mike McGraw, outstanding AES ecologists, for their many contributions and energetic field work. As my former mentor, Cotton Mather, used to say, "There is no substitute for the field."

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Waste Mussel Shells to Treat Acid Mine Drainage: A New Zealand Initiative

By Benjamin Uster[1], Dave Trumm[2], James Pope[2], Paul Weber[3], Aisling D. O'Sullivan[1], Chris Weisener[4], Zach A. Diloreto[4]

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Introduction

Mine-influenced water (MIW), commonly referred to as acid mine drainage, is a significant environmental issue in New Zealand. Even though MIW geochemistry specific to New Zealand geology and climatic regimes has been extensively studied, little passive treatment remediation work has been fulfilled to date apart from a few small-scale trial systems (Trumm 2007; Weber et al. 2008; Trumm et al. 2008; Pope et al. 2010; Trumm and Watts 2010). The majority of acidic MIW in New Zealand occurs on the West Coast of the South Island of New Zealand where the main coal fields are located. The topography of the West Coast makes remediation efforts challenging as most of the mining sites are remotely located on high plateaus and are surrounded by thick native temperate rainforests established on steep slopes (Fig. 1). This tough topography combined with a harsh climate, dominated by low temperatures with an annual mean of about 9°C and annual precipitation of 6 meters per year, results in high MIW flows and limited space for reclamation (Davies et al. 2011). In addition, the remote mine locations associated with a low overall population results in a contamination largely hidden from the public view.

Other political reasons explaining the lack of remediation include the absence of a specific MIW reclamation fund (no Superfund or Abandoned Mine Land financing plan exist in New Zealand), a vague regulation and a poor enforcement policy. Neither the Resource Management Act nor the Australian and New Zealand Guidelines for fresh and marine water quality (MfE 1991; ANZECC 2000) specifically addresses MIW issues and most of the legislative and executive work is left to the regional environmental authorities.

Fig. 1: A typical abandoned mine adit on the West Coast of New Zealand. The MIW is strongly acidic (pH <3) with elevated concentrations of iron (>100 mg/L) and aluminum (>40 mg/L). *(credit: Dave Trumm)*

To date, passive remediation work consisted of small- to medium-scale pilot studies and treatment trials. These have been completed and funded by mining companies and by government research programs, including the Ministry of Business, Innovation and Employment, the Coal Association of New Zealand, and the University of Canterbury. Since 2006 several lab- and field-based studies have been conducted using waste mussel shells in MIW passive treatment systems. This article provides an overview of this research and its outcomes.

Mussel shells in New Zealand

The green-lipped mussel (*Perna canaliculus*), also known as the New Zealand Mussel, is an endemic shellfish occurring all around New Zealand's coasts (Fig. 2). With more than 95,000 tonnes produced in 2011, representing a total value of more than NZ$200 million, it is the greatest national seafood product both in terms of volume and value (New Zealand Aquaculture Farm Facts 2012). As the vast majority of the mussels are locally sold and exported overseas in a half shell frozen format, a significant volume of waste shells are produced every month. Although, other disposal methods such as agricultural field spreads and storm water management systems exist, most of the seafood wastes (e.g. mussel and oyster shells, fish bones, etc.) are currently disposed of in landfills, costing in some instance more than NZ$200/tonne for disposal.

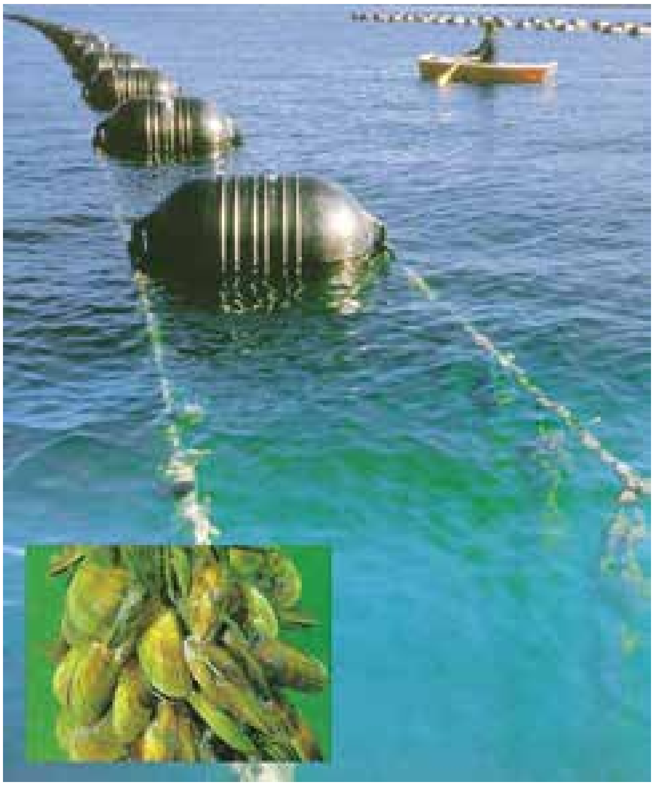

Fig. 2: An example of the New Zealand Mussel long-line farming system in the Marlborough Sounds, New Zealand.

A passive bioreactor for MIW treatment often consists of an engineered basin filled with a mixture of organic materials such as compost, wood chips, manure, etc., and an alkalinity generating material (usually limestone). These systems utilize sulfate-reducing bacteria (SRB) and other decomposer microorganisms present in the organic mixture to degrade the substrate and chemically reduce the sulfate presents in the MIW to produce hydrogen sulfide and bicarbonate alkalinity. The hydrogen sulfide molecules then react with the dissolved metals also present in the MIW and precipitate as insoluble metal sulfides and hydroxysulfates. The main purpose of the limestone is to provide additional alkalinity through calcium carbonate dissolution. Other terms for these bioreactors include compost reactors, vertical flow wetlands or sulfate-reducing bioreactors.

Using waste mussel shells to treat acidic MIW

Because of its relative cheap price (NZ$25-30/tonne) and the fact that it can often be sourced close to a mine site (NZ$20-30/tonne transport), limestone is commonly the main alkalinity generation material used in passive treatment systems for acidic MIW. Limestone with a purity of more than 90 wt percent $CaCO_3$ is usually used in MIW passive treatment. Similarly, mussel shells are comprised of 90 to 95 wt percent $CaCO_3$, making this material an excellent potential alkalinity source for treatment systems (Fig. 3). The structure of the shells is comprised of three layers: an inner layer consisting of aragonite (a natural polymorph of calcite), a mid-layer containing both aragonite and calcite interbedded with protein molecules, and an outer layer made of chitin, a form of polysaccharide containing nitrogen (e.g. *periostracum*) (Fig. 4). The average composition of minerals in the shells is approximately 90 percent calcite and 10 percent aragonite (Hutchinson and O'Sullivan 2008). The shell material also contains up to 10 wt percent of organic matter (including seaweed, mussel meat remnants and organic matter within the shell). This organic matter as well as the nitrogen present within the shells provides an ideal source of labile carbon and nutrients readily available for the microbial community that operates in a bioreactor system.

In 2006, researchers from Solid Energy New Zealand Ltd. undertook trials using waste mussel shells as a source of alkalinity to neutralize acid mine drainage from a waste rock dump. This first trial consisted of a single 40 m^2 pond filled with 10 tonnes of shells and covered by 250 tonnes of acid-producing overburden. A control pond filled with a similar quantity of acid-producing overburden was set up adjacent to the trial pond. After a 10-month trial period, the pH in the control pond was 3.3, but was up to 6.7 in the pond containing mussel shells. Similarly, acidity was 350.3 mg/L $CaCO_3$ equivalent in the control pond and only 1.9 mg/L $CaCO_3$ equivalent in the pond with shells. Dissolved iron and aluminum concentrations were respectively 97.7 percent and 99.1 percent lower in the mussel shell pond. This work, the first of its kind, demonstrated that mussel shells could be a simple solution for the treatment of acidic MIW (Weber et al. 2008).

These promising results initiated multiple lab and field-based studies focusing either on: (1) using mussel shell as a replacement for limestone in a substrate mixture containing other organic

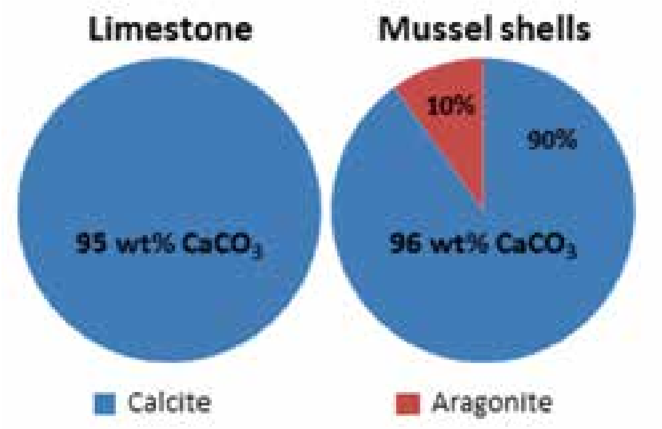

Fig. 3: Mineralogical composition of limestone and mussel shells showing the total content of calcium carbonate (wt percent of dry sample) and the relative abundance of calcite and aragonite.

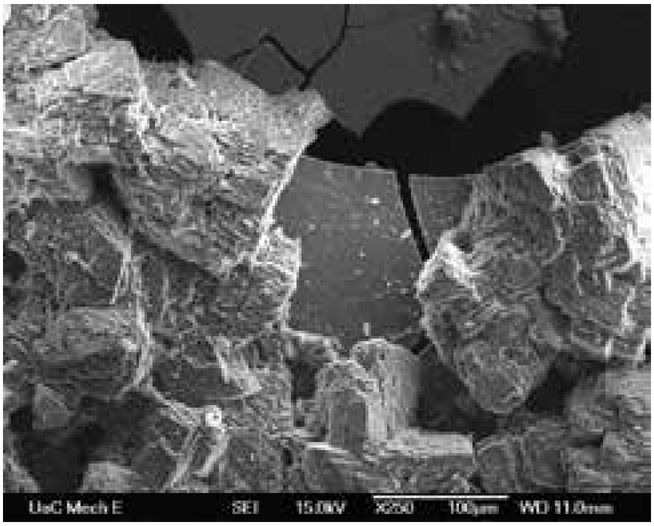

Fig. : A scanning electron microscope image of mussel shell fragments after 16 weeks of treatment. The layered texture is typical of these shells. *(credit: Jenna Hutchinson)*

materials; or (2) using mussel shell as a sole reactive substrate material. Separated studies have looked at optimizing the amount of mussel shells and/or limestone to be incorporated in the reactive substrate, while others have investigated parameters like reactor shapes and sizes, flow design (downward flow versus upward flow), hydraulic retention times (HRT), and loading rates (McCauley et al. 2009; Uster et al. 2013; Trumm and Ball 2014; Uster et al. 2014).

Mussel shells as a replacement for limestone

Taken together, the results indicate that mussel shells perform better than limestone in terms of alkalinity generation. In a recent study, alkalinity generation rates between 60 and 113 percent higher were obtained when mussel shells were used instead of limestone

Fig. 5: Upward flow sulfate-reducing bioreactors comparing mussel shells and limestone at the University of Canterbury. *(credit: Benjamin Uster)*

(Uster et al. 2014) (Fig. 5). The most probable reason explaining this result is a faster dissolution rate for the shells compared to the limestone. Indeed, different properties including mineralogy (e.g. calcite vs. aragonite), reactive surface area, grain size, and calcium carbonate content may explain this difference in reactivity. Cubillas et al. (2005) demonstrated that the BET surface-area of mussel shells increased by 80 percent during dissolution compared to only 30 percent for pure calcite. These authors also showed that the dissolution of aragonite was less affected by mineral armoring than the dissolution of calcite. It is also possible that the nitrogen present within the proteins in the shells may have helped the microbial community and contributed to the total alkalinity generation via SRB neutralization. Mussel shells also outperformed limestone in terms of metal removal. Apart from aluminum for which removal efficiencies are comparable, bioreactors containing mussel shells removed 3 to 5 percent more iron, copper, nickel, and zinc compared to similar systems with limestone. Manganese removal was up to 40 percent higher in the reactors containing the shells. Sulfate removal rates reported in these studies are comparable to values found in the literature and the use of mussel shells does not seem to result in a better sulfate removal (McCauley et al. 2009; Uster et al. 2014).

Mussel shells as a sole substrate material

When used as a single substrate material, mussel shells not only provide a good source of alkalinity, but also afford the organic matter and a solid matrix, both required for a bacterial community to thrive. Even though the long-term performance of these reactors that contain only mussel shells is largely unknown, the results obtained to date indicate that there is enough organic matter associated with the shells to establish reducing conditions conducive to sulfate reduction and metal-sulfide precipitation (Trumm and Ball 2014). In addition, the mussel shells, even if partially crushed, will maintain a high porosity while affording a greater surface area than the limestone (Weber et al. 2015).

A downward flow field-scale bioreactor constructed by Solid Energy New Zealand Ltd at the Stockton coal mine on the West Coast of New Zealand successfully treated MIW for over 1,000 days (Crombie et al. 2011). The downward flow configuration resulted in a series of distinct layers sequestrating metals in diverse forms (Fig. 6). Briefly, an upper layer consisting of iron (oxy) hydroxide precipitates is followed by an aluminum hydroxide layer overlying a bottom layer in which metals like nickel and zinc are removed as metal-sulfides. This metal removal sequence basically followed the redox (Eh) and the pH gradients, with redox measurements changing from oxidizing conditions at the top of the reactor (iron layer) to reducing conditions within and below the aluminum layer. The pH increased with depth from less than three in the influent to values above seven in the bottom metal-sulfide layer. The overall metal removal was up to 96-99 percent (Diloreto et al. 2014; Weisener et al. 2015). Because of the downward flow design, the oxidizing zone is likely to migrate downward as the mussel shells are dissolved. This could ultimately lead to the remobilization of the metal-sulfide precipitates when the entire system becomes oxidized. Further long-term researches, as well as appropriate waste management techniques, are needed in order to prevent the leaching of heavy metals when a treatment system reaches the end of its life. Alternatively, a periodic supplementation of fresh shells could potentially maintain the reducing conditions, thus rendering the metal storage capacity permanent.

Fig. 6: Three distinct layers forming in a downward flow treatment system containing only mussel shells at Stockton Mine. The top layer (brown-orange) is a mixture of sediments and iron oxyhydroxides, the mid (white) layer contains aluminum hydroxides and the bottom (gray-black) layer is made of undissolved mussel shells and metal-sulfide precipitates. *(credit: Paul Weber)*

Another study currently underway is investigating a series of three upward flow bioreactors (Fig. 7). These were built to prevent the formation of these separated metal-specific layers. Preliminary results indicate that reducing conditions are well established and maintained through the entire bioreactor system and that most metals (including iron) are removed as sulfide (Trumm and Ball 2014; Trumm et al. 2015). This type of construction in series also reduces the risk of failure due to short-circuiting.

Fig. 7: A train of upward flow in series bioreactors containing only mussel shells. *(credit: Dave Trumm)*

Conclusion

Overall, these studies have demonstrated that mussel shells are a simple, sustainable, and effective alternative to limestone and that their use in passive treatment systems is a potential new pathway for this material currently considered a waste product. So far, all the studies conducted using these shells showed that they yield a greater alkalinity generation and resulted in a better metal removal when compared to limestone. Additionally, it has now been demonstrated that these shells can be used as a single substrate material in a bioreactor system. A recent study using life cycle assessment compared the environmental impacts of several active and passive treatment options, including a mussel shell bioreactor. The results indicated that the gravity-fed mussel shells passive treatment system was the least environmentally damaging option (Hengen et al. 2014).

These promising results have encouraged people in other countries such as Australia to consider reusing some of their own seafood wastes, such as oyster shells, in acidic MIW passive treatment. In New Zealand, several mining companies have now installed operating treatment systems using these shells and the data arising from these systems will provide valuable information in regards to operational performance and longevity. In the next few years, it is expected that more systems, including full-scale systems, will be built using this technology.

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Long-term Forest and Soil Development on Southern Appalachian Coal Mines

By Jennifer Franklin and Jan Frouz, University of Tennessee

Reclamation techniques have changed greatly in the southern Appalachian coalfields over the past 50 years. Although some research into forest reclamation was undertaken as early as the 1920s, very little reclamation was carried out on mined sites in this region before the 1960s. Large scale mine reforestation in Tennessee began in the late 1950s when the Tennessee Valley Authority planted thousands of acres of pine seedlings on abandoned mine sites. Tree survival on these sites was highly variable as many of the overburden materials had chemistry unsuitable for native trees. Therefore, research was undertaken to select tree and herbaceous species and soil amendments for reforestation. In the 1970s reclamation practitioners adopted soil compaction and planting of aggressive, non-native ground covers as a reliable way to minimize erosion on steep slopes. Tree planting fell out of favor, as attempts to establish trees on mine sites reclaimed in this manner often resulted in high mortality and poor growth due to both soil conditions (Burger and Fannon, 2009) the aggressive nature of the herbaceous cover (Conrad et al., 2002).

Over the past 10 years there has been a growing interest in the eastern United States in returning disturbed land to productive forest. Much of the Appalachian region consists of steep terrain with shallow soils unsuitable for farming. But this region does support hardwood and mixed pine-hardwood forests known for its high biodiversity and which are among the most productive forests in the country. It is now known that soil compaction results in reduced growth and survival of planted tree seedlings (Zipper et al., 2011). In West Virginia, Skousen and others (Skousen et al., 2006) found that native Appalachian hardwood trees were able to establish on portions of those mines reclaimed prior to current regulations and therefore without soil compaction or seeding of herbaceous vegetation, while seeded areas supported only sparse tree cover several decades after reclamation.

New guidelines outlined by the Forest Reclamation Approach (Burger et al., 2005) recommend the placement of at least four feet of minimally compacted medium for tree growth, and seeding with non-competitive ground covers. Although mining and material placement methods differ between the 1950s and today, older mine sites with un-compacted soils may have enough similarities with contemporary sites to be helpful in predicting long-term forest development under new Forest Reclamation Approach guidelines. We located some early reclamation research plots that had been planted with pine, and compared these with areas that were allowed to revegetate naturally to determine how tree planting had influenced the development of vegetation and communities of soil organisms. Because the goal of reclamation is to speed ecosystem development, we compared forest productivity and soil processes on these sites to those of the adjacent, minimally disturbed hardwood forest.

Figure 1. Original pine research plot planted in 1957, photographed in 1963 *(From Kring, 1967, reprinted with permission).*

Study Sites

Three sites were selected in northeastern Tennessee and one in southern Kentucky. All were mined for coal in the late 1950s, planted with various species of pine trees between 1957 and 1965 (Figure 1), and had a well-documented record of land use since mining with minimal forest management activity. Information on reclamation treatments and soil characteristics at the time of tree planting was obtained from original research notes and publications (Kring, 1967; Thompson et al., 1984). Details on mining

Figure 2. Mature hardwood forest on loose spoil of an un-reclaimed, pre-SMCRA coal mine.

Figure 3. Un-mined mature hardwood forest.

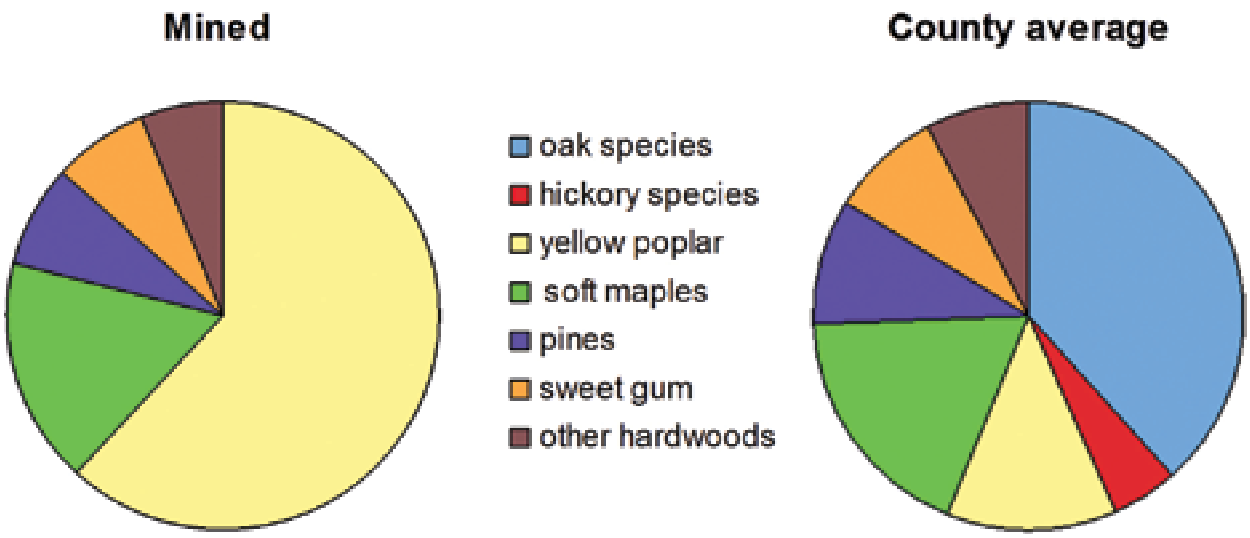

Figure 4. Composition of overstory on previously mined areas (percent basal area) compared to similar-aged stands in the same county (Morgan County, TN, from FIA data).

methods and material placement were not available, but all sites showed the remains of a pit and steep out-slopes, which are characteristic topographic features of sites where spoils were loosely dumped and minimal reclamation followed coal extraction. Based on original research notes and with the help of researchers involved in initial planting of research plots, we selected locations within the original research plots, adjacent mined areas that had no vegetation planted, and nearby un-mined areas. Three plots were placed in each area at each site. An additional 10 plots in Tennessee were selected on mined, un-reclaimed areas of similar age to measure overstory composition and productivity.

We surveyed overstory and perennial understory vegetation, and measured soil respiration using an infrared gas analyzer fitted with a soil CO_2 flux chamber (IRGA, Model LI-6400, Li-cor Biosciences, Lincoln, NB). In each plot, four 18-cm deep cores were collected and divided into top, middle and bottom sections, each 6 cm thick. These were returned to the lab and used to measure soil carbon, nitrogen and phosphorus, root biomass, microbial respiration, and soil invertebrates. Litter bags were left in the field for two months then collected to determine decomposition rate. Dominant tulip poplar (*Liriodendron tulipifera*) on the 10 additional overstory plots were cored and aged, and site index was estimated from published site index curves (Beck, 1962).

Development of Forest Vegetation

Nearly 50 years after mining, a highly productive native hardwood forest had developed on un-reclaimed areas with an overstory dominated by tulip poplar (Figure 2). Site index is commonly used in forestry as a measure of forest productivity and is primarily related to soil factors. Average site index of tulip poplar on mined sites was 106 ft at an index age of 50, compared with an average site index for this species and region of 87 ft. Basal area averaged 29.4 m^2 ha^{-1}, compared with an average of 24.7 m^2 ha^{-1} reported for eastern Tennessee in 1999 (Schweitzer, 2000). However, tree species

Table 1. Most common understory vegetation (average number of stems per acre).

	Un-mined	Un-reclaimed	Planted with pine
Tree seedlings			
Red maple	8816	361	5800
Black cherry	580	464	464
Northern red oak	928	412	1237
Non-native perennials			
Chinese yam	3866	129	1933
Japanese honeysuckle	0	9898	4640
Native perennials			
Clubmoss	17	31	0
Greenbrier	1276	851	2552
Perennial grasses	928	1160	2320
Poison ivy	0	16871	296
Rattlesnake plantain	8081	0	9976
Virginia creeper	284	722	1134

composition in mined areas differed from that of the adjacent un-mined area, which was dominated by chestnut oak (*Quercus michauxii*) and scarlet oak (*Quercus coccinea*) (Figure 3). Other un-mined stands in the same county, that are of the same age, are also dominated by oaks (Figure 4). A diverse understory had developed on mined areas, and like the overstory, differed in species composition from the adjacent un-mined forest (Table 1). Poison ivy and Japanese honeysuckle, common species of early-successional forests, were still abundant in the heavily shaded understory of mined areas, while other species characteristic of mature forests, such as ferns, were becoming established (Figure 5).

The planted pine were declining, hastened by an outbreak of Southern pine beetle around 1996. Natural succession of pine to hardwood was occurring over many of these pine-planted areas and pine was being replaced primarily with red maple. Red maple dominated the overstory and sapling layer, as well as the seedlings of overstory trees in the un-mined and pine-planted areas (Table 1). However fewer oak seedlings were found in the un-reclaimed area than in either the planted pine, or adjacent un-mined forest. The understory in the un-reclaimed area was also diverse and differed from other areas sampled. Rattlesnake plantain is commonly found in natural pine forests and was abundant in un-mined and pine-planted areas, likely colonizing from the surrounding forest. Very little poison ivy and Japanese honeysuckle was present in un-mined areas, but prevalent in mined areas. Although vegetation differed somewhat between locations, differences between un-mined, pine planted and un-reclaimed areas were equally important drivers of forest community composition.

Soil Development

Following mining time is needed for soil processes to become re-established. Colonization by microorganisms, invertebrates, and plant roots help to re-establish nutrient cycling on newly reclaimed sites. In the un-mined forest, the surface was covered by a litter and fermentation layer one to two inches thick, under which was the mineral horizon (Figure 6). The soil surface of pine sites was very similar, with a litter layer of pine needles. In un-reclaimed sites, which were dominated by hardwood, ¼ inch or less of litter covered the soil surface. Earthworm activity was very visible in the un-reclaimed area, and soil mixing had moved carbon and nitrogen from the surface to deeper soil layers. Earthworms were found in the mined areas, but not in un-mined areas, and may have been introduced through tree planting.

Much of the soil function had recovered on the mine sites. All classes of invertebrates found in the un-mined soils were also found in the mined areas. Microbial respiration rates, and total soil C and N were also similar between mined and un-mined sites. The native soils in this area are predominantly Ultisols, which are highly weathered and low in both total and plant-available P. Some mine soils in this region have a high iron content, which further reduces the availability of P (Daniels and Amos, 1985). But here, mined sites had a larger stock of P than un-mined reference sites, which may have helped promote tree growth. High rates of hardwood growth on un-reclaimed sites may have contributed to soil respiration rates, which were much greater than in areas planted with pine. While most soil parameters on mined areas were similar to the un-mined forest after 50 years of development, root biomass and decomposition rate are recovering more slowly and were still only half that of un-mined soils.

Summary and Conclusions

Results show that while planting of pine had some long-term effects on forest development, there was no evidence that it accelerated the development of forest soils or productivity on these sites. Both natural succession and the planting of tree seedlings in ungraded spoil resulted in the development of a forest ecosystem after 50 years which was, in many aspects, comparable to the un-mined forest. There were more similarities than differences between planted-pine and un-reclaimed sites after 50 years, which is in agreement with European studies indicating that differences between reclaimed and un-reclaimed sites decrease over time (Frouz et al., 2008). Rapid forest development on these sites was undoubtedly facilitated by their relatively small size which accelerated natural

Figure 5. Diverse, naturally regenerated understory beneath a hardwood canopy.

Figure 6. Thin layer of litter on un-reclaimed areas.

succession, and the narrow, linear shape of the disturbance left all parts of the site in close proximity to intact forest.

These results demonstrate the potential for highly productive forest to develop on loosely placed overburden on Appalachian coal mines, as is recommended by the Forest Reclamation Approach. Species such as earthworms that may be introduced through reclamation activities, and invasive species such as Japanese honeysuckle that colonize newly reclaimed sites may be very persistent and influence the development of the forest community for many decades. Additional research is underway to identify species for reclamation plantings that speed the recovery of native forests and soil processes, reduce colonization by invasive species, but have little long-term influence on the development of the forest community.

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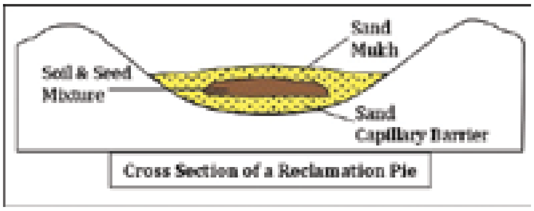
A New Technique May Improve Reclamation in Disturbed Arid Landscapes

By Seth Cude, University of Wyoming



In any desert, low precipitation is one of the greatest challenges facing reclamation. In the Wamsutter, Wyo. oil and gas fields, this is exacerbated not only by saline/sodic soils and significant compaction, but from most precipitation coming as snow which blows off of the bare, flat and very windy sites before plants can use it. With over 4,000 wells and more than 60,000 acres of disturbance, extensive snow fencing is cost prohibitive.

A new reclamation technique developed at the University of Wyoming seeks to address this problem with an innovative approach. Working with consultant Mark Ankeny and Associate Professor Jay Norton, Seth Cude, a master's degree candidate, has shown shallow pits with sand in the pits can capture snow on a flat windy location and retain the water for plants.

The technique was tested on two plugged and abandoned well pad sites near Wamsutter, Wyo. Treatments included controls where no pitting was done, only pitting, and pitting with sand. At each site, small pits were dug (approx. 15 cm deep) and on half of the pits coarse sand was used as a capillary barrier and mulch. Coarse sand acted to reduce water loss by helping to lessen upward water movement through evaporation and decrease surface runoff from compacted clay soil materials. Typically these sites have clay soil materials on the surface that tend to crust due to the sodium-induced dispersion of soil materials. But the sand mulch moderates the crust, thereby increasing infiltration and reducing the energy required for plant seedling emergence.

At both test sites, the control plots with no pits and no sand performed poorly and were representative of growth seen with standard reclamation practices. At one of the test sites, plots with only pits performed very poorly when sand was not applied as mulch. At the other test site, pitting showed some plant growth. But when the pits were filled with sand at both sites, grass emergence was significantly increased over control areas and areas with pitting alone.

While these treatments were administered by hand, it would not be difficult to imagine a mechanized process to pit, seed and spread sand across a site. For sites where pitting alone is sufficient, roughing up a site before seeding would facilitate favorable microclimates and snow capture.

These two trials were small, roughly 20 m^2 each, and have only been in the field for one season so uncertainty remains around long term survival and continued snow capture (some pits have filled in slightly). But this technique offers a potentially significant improvement over current reclamation practices on drastically disturbed arid lands. ■

Snow and moisture was present in all pits on both sides in winter.

Grass emergence on May 29, 2014 in a sand mulch and capillary barrier treatment.

Bridging the Gaps among Science, Practice and Policy

By Michael Curran, University of Wyoming

While still young and growing, the field of restoration ecology and the practice of land reclamation have undergone rapid advancements in recent decades, at least in part due to increased land disturbance associated with natural resource extraction (Suding, 2011). However, knowledge of land reclamation efforts at a large scale is limited because many of these efforts have been done by industry and often times have not been made available to the public or scientific community (Aronson et al., 1995; Hild et al., 2009). Many of the natural resources which are extracted from the land provide tangible benefits and, as we continue to need these resources, continued land disturbances are inevitable. Therefore, it is imperative that knowledge from scientific studies and the reclamation experiences of the industry on large areas over long time periods be communicated to improve our ability to achieve successful land reclamation and increase our knowledge of best management practices.

The Wyoming Reclamation and Restoration Center (WRRC) at University of Wyoming began collaboration with BP America Production Company (BP) and Conservation, Seeding, and Restoration Inc. (CSR) in 2011 to create a large reclamation database. The database originally contained data from BP oil and natural gas well pads on federally owned Bureau of Land Management (BLM) land in three areas in southern Wyoming: Wamsutter, Jonah Infill natural gas field, and Moxa Arch. Using reclamation practice data (e.g., seed mixes, soil amendments, herbicide treatment) combined with reclamation results data (i.e., vegetation monitoring) and binary data to determine whether or not well pads pass regulatory criteria set forth by different BLM field offices and Wyoming Department of Environmental quality, the initial goal of the database was to identify best management

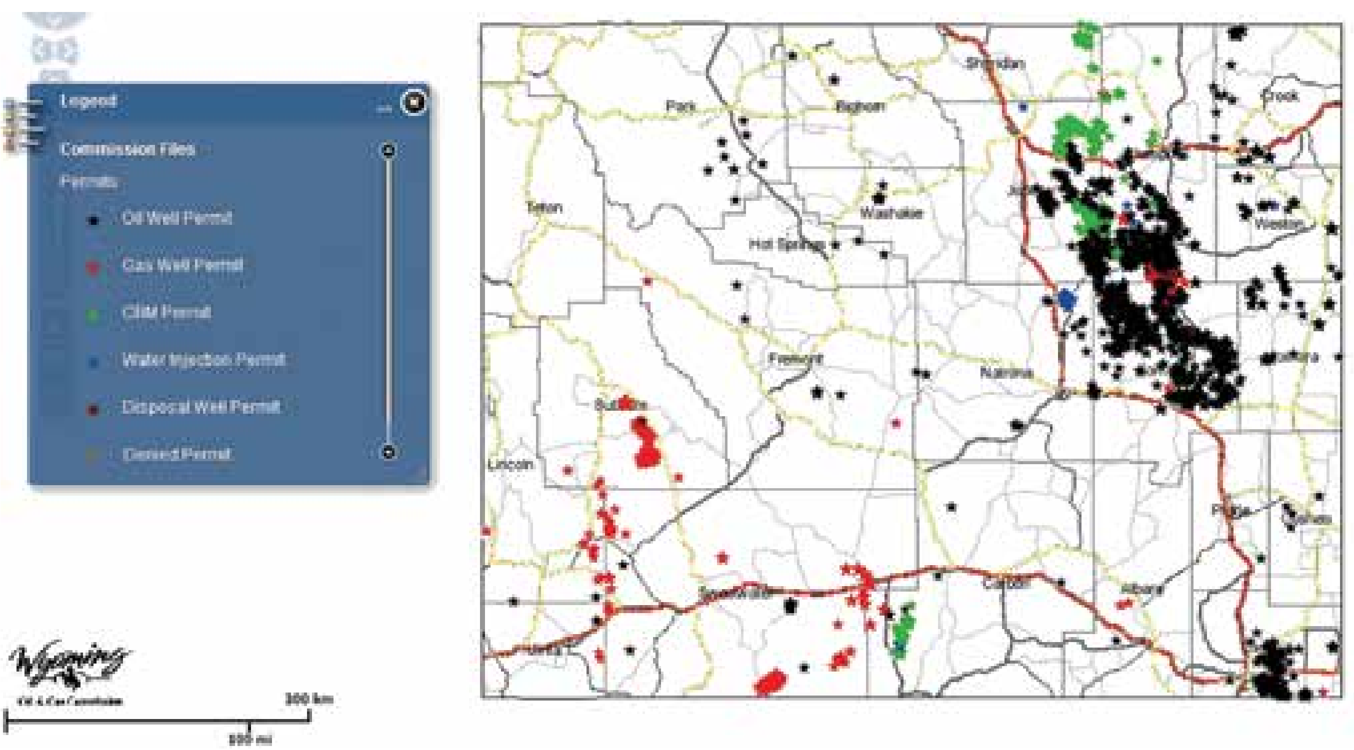


Photo 1. A map of Wyoming depicting areas where permits have been granted to drill for oil, natural gas and coal-bed methane, created by Wyoming Oil and Gas Conservation Commission.

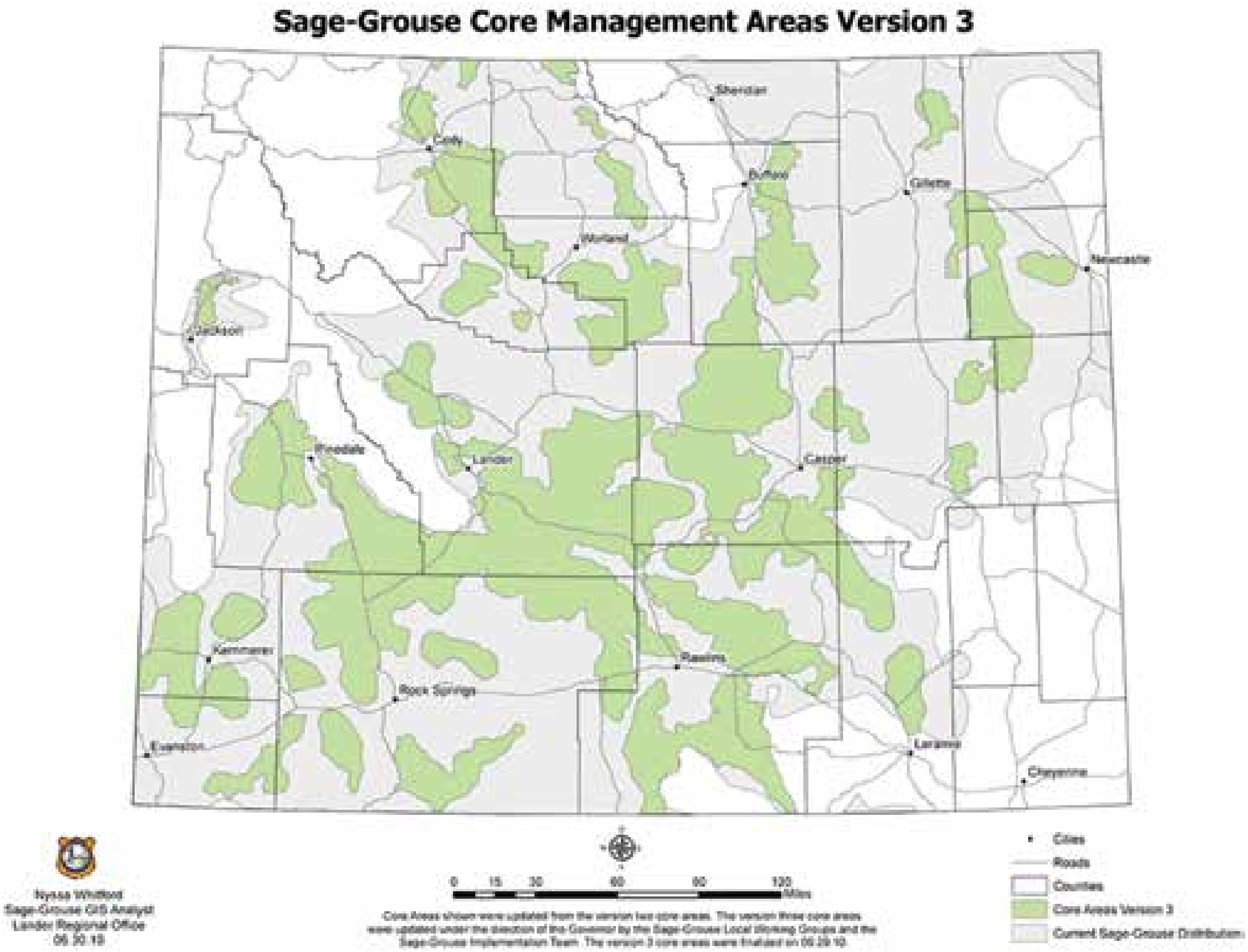


Photo 2. A map of Greater sage grouse distributions and core habitat areas in Wyoming, created by Nyssa Whitford of Wyoming Game and Fish Department. Notice how closely sage grouse habitat aligns with areas where oil, natural gas and coal-bed methane development are occurring.

practices which lead to successful land reclamation in arid and semi-arid climates in southern Wyoming (Curran et al., 2013). Several factors interfered with our ability to reach this goal including: successful land reclamation lacks clear definition, monitoring techniques and monitoring timing vary among fields and across years, and data quality is suspect. These factors will be discussed later in this article.

Since the inception of the database, the United States Fish and Wildlife Service (USFWS) and Wyoming Game and Fish Department (WGFD) have expressed interest in using data housed in the WRRC reclamation database to quantify land reclamation efforts and to determine how lands disturbed by oil and natural gas development have recovered after reclamation (Photos 1 and 2). The reason for this is because the greater sage-grouse (Centrocercus urophasianus), a ground-dwelling bird species found in sagebrush-steppe habitats of the Rocky Mountains, is being considered as an endangered species under the Endangered Species Act of 1973 and the final decision to list the bird is due in 2015. Core habitat areas for the greater sage-grouse in Wyoming often overlap or fall in close proximity to areas where natural resources, especially natural gas, are abundant and extractable. The Policy for Evaluating Conservation Efforts when Making a Listing Decision (PECE) clause of the Endangered Species Act requires land reclamation and habitat restoration to be considered when making listing decisions, as land reclamation and habitat restoration may reduce threats to species which are negatively impacted by development (USFWS 2003).

After discussion with the USFWS and WGFD, the WRRC has worked closely with the Petroleum Association of Wyoming (PAW) to increase the scope of the reclamation database. With the help of PAW, over a dozen operating companies have shared data or agreed in principle to share data with WRRC to expand

Photo 3. Cattle are often rotated through the Jonah Infill natural gas field in southwestern Wyoming and have free access to graze on newly reclaimed well pads and undisturbed land between them. Only several isolated studies have assessed the impact of controlled grazing on newly reclaimed oil and natural gas well pads.

Photo 4. The edge of a well pad seeded with Rocky Mountain Bee Plant, a native forb species, runs into an undisturbed patch of sagebrush in the Pinedale Anticline natural gas field. Although Rocky Mountain Bee Plant appears to do an excellent job of attracting pollinators, the advantages of using this plant as an early succession species have not been quantified.

Photo 5. A wild horse and his mother are caught grazing on a well pad in the Pinedale Anticline natural gas field in southwestern Wyoming. More studies would be helpful for managers to make decisions about when to allow these species on reclaimed areas.

the reclamation database. A thorough literature review suggests the WRRC reclamation database is the largest database in the fields of restoration ecology and land reclamation. Although still ongoing, analyses of data from additional operating companies and regulatory agencies is difficult due to aforementioned issues faced with analyses. As the project moves forward, the academic and scientific community could serve as an objective third party and help practitioners and regulatory agencies define goals and determine 'successful land reclamation', which will improve our ability to measure success, and ultimately to increase our ability to implement management practices that lead to reclamation success across a variety of sites.

What is Reclamation Success?

Wyoming is a unique state in that roughly half of the surface area is owned by the federal government. While land reclamation goals on privately owned land are determined by the property owner, land reclamation on federally owned USDI Bureau of Land Management (BLM) surfaces is regulated by the BLM field office or interagency office with jurisdiction of a given area as well as the Wyoming Department of Environmental Quality's (WDEQ) Storm Water Pollution Prevention Plan (SWPPP). The Society for Ecological Restoration International (SERI) has put together a list of nine attributes that should be measured to assess restoration success, most of which deal with ecosystem functionality, resiliency, structure, and composition (for the complete list see SERI Primer, 2004 or Ruiz-Jaen and Aide, 2005). While these measurements were agreed on by a large group of members of the scientific community, reclamation or restoration success are defined by regulatory agencies and policy-makers with jurisdiction over specific areas of land in a more practical sense. Queries from the Curran et al. (2013) database revealed major discrepancies among regulatory agencies. Reclamation success criteria of BLM field offices and interagency offices in Wyoming vary greatly and generally focus on vegetative structure and soil protection characteristics relative to adjacent, undisturbed sites, whereas WDEQ SWPPP criteria emphasize erosion control by requiring reclaimed sites to have 70 percent or greater ground cover compared to an undisturbed reference site.

Two natural gas fields in southwestern Wyoming, the Jonah Infill and the Moxa Arch, which are regulated by adjacent BLM field offices (Pinedale BLM field office/Jonah Interagency Office and Kemmerer BLM field office respectively) have very different criteria for reclamation success. Well pads in Jonah Infill are required to meet criteria for ground cover, total absence of noxious/invasive weeds, erosion control, shrub and forb cover, shrub, forb and grass richness, and plant vigor (BLM 2006), whereas well pads in the Moxa Arch are only required to meet criteria for ground cover, minimal noxious/invasive weeds, and soil stability

(BLM, 2007). Queries using reclamation monitoring data show 0 of 116 (0 percent) BP well pads in the Jonah Infill natural gas field of southwestern Wyoming passing Jonah Interagency Office (BLM, Wyoming Game and Fish Department, WDEQ, and Wyoming Department of Agriculture) criteria in 2011. However, 67 of 116 (58 percent) well pads passed WDEQ's SWPPP criteria (BP has since sold their assets in this field and confidentiality agreements are still underway with the new contractor, which is why more recent data are not shown). In the Moxa Arch natural gas field of southwestern Wyoming, 317 of 630 (50 percent) BP well pads passed Kemmerer BLM reclamation criteria, while 340 of 630 (54 percent) well pads passed WDEQ SWPPP criteria. Queries to evaluate Jonah Interagency Office versus Kemmerer BLM standards were conducted and revealed that all 317 well pads passing Kemmerer BLM requirements in Moxa Arch would be considered failures against the Jonah Interagency Office criteria. But 63 of 116 (54 percent) well pads in Jonah would be considered successful against Kemmerer BLM criteria in 2011 (Curran et al., 2013).

The vast difference between reclamation success criteria among BLM field offices and between BLM and WDEQ are problematic for multiple reasons. Determining and setting a goal or target for success is a critical component in the initial stages of land reclamation planning (Allen et al., 1997; Dickens and Suding 2013, Ehrenfeld 2000). Major discrepancies among regulatory agencies may result in confusion, additional work, and possible increase costs for operating companies and reclamation practitioners who are responsible for land in multiple areas. Additionally, major differences in reclamation success criteria may also result in problems when decisions need to be made using reclamation information (Photos 3 to 7). For example, as the USFWS nears their listing decision of the greater sage grouse, it would be ideal and most cost-efficient if BLM and WDEQ criteria could be used to indicate whether or not suitable sage grouse habitat has been restored.

BLM lands often aim to have multiple uses including energy development, recreation, cultural and aesthetic value, grazing, and wildlife habitat. Since climate, soil characteristics, historic vegetation communities, below-ground resources, human activity (e.g., grazing management and recreation) and wildlife species vary across spatial scales, it should not be necessary to standardize reclamation success across wide spatial scales. Reference sites are effective in determining practical goals for restoration efforts (Aronson et al., 1995; SERI Primer, 2004). In areas where energy development occurs and sustaining wildlife populations is critical (e.g., for recreational, cultural, aesthetic, or to comply with the Endangered Species Act, etc.), it makes sense to use reference sites or known habitat traits to compare reclamation results to determine success and failure rate of reclamation practices. In this case, it may be imperative that reclamation ecologists communicate with wildlife biologists, practitioners, and policy-makers/regulatory agencies to prioritize land reclamation goals aiming at habitat restoration (Smith et al., 2014). In areas where sustaining wildlife populations is not critical, but grazing, recreation, and other cultural values are important land-uses, land reclamation goals may be different and areas under reclamation may be judged against reference sites known to be suitable for these activities. In most cases, multiple land uses are desired and a balanced set of land reclamation goals and success standards should be incorporated into reclamation planning from the start to satisfy needs for multiple uses. While setting up reclamation goals and defining standards for reclamation success are necessary at the beginning of reclamation planning, they should be adaptable and it is important that monitoring reclaimed areas is performed in a manner to allow sufficient assessment.

Monitoring

Monitoring reclamation sites is essential to track progress, rate success, and adjust reclamation plans in the future. While monitoring is a critical aspect to management, it can often become costly and may not always adequately measure correct attributes to determine whether a site is successfully or unsuccessfully reclaimed. Currently, on BLM lands in Wyoming, reclaimed well pads can be monitored in different ways so long as monitoring protocol is in compliance with BLM Technical Reference 1734-4: Sampling Vegetation Attributes (BLM, 1999). The use of different monitoring techniques by different operators and practitioners can create difficulty in data analysis and in determining what practices are leading to successful reclamation. In addition to the use of different techniques, different individuals are often set out to monitor well pads and pipelines in large oil and gas fields independently of one another. This may lead to serious errors when analyzing datasets due to observer bias and human error. Additionally, timing of monitoring varies from year to year and often among practitioners and operating companies. Timing of monitoring is critical, especially in areas like Wyoming which have short growing seasons and varied precipitation which may result in many species having very short windows where they can be successfully identified. When combined, these factors confound the ability to identify trends in reclamation and inhibit the ability to be confident in assessment of reclamation success. For example, the same well pad was monitored by two different individuals four days apart in the Jonah Infill natural gas field in 2008 and the results showed drastic discrepancies between species richness, species present on site, ground cover percent, and weed presence. These differences could be due to differences in observer plant taxonomy skills, differences in timing, or because the observers may have monitored different areas of the pad (Photo 8). The scientific community should continue to aim

Photo 6. University of Wyoming graduate student Michael Curran and a group of wild horses gather near a leak in a water pipe on a natural gas well pad in Pinedale, Wyoming. It seems as though certain features of these pads may attract animal species to them in arid and semi-arid environments.

Photo 7. A group of Pronghorn Antelope graze fresh vegetation along a pipeline in Pinedale, Wyoming. The impacts of wildlife species grazing on newly reclaimed sites has not been greatly studied.

Photo 8. University of Wyoming graduate student Samantha Day instructs a group in soil monitoring at a 2013 Wyoming Reclamation and Restoration Center workshop.

to improve monitoring techniques so they become efficient, reliable, and cost-effective (Cagney et al., 2011).

Cagney et al. (2011) propose the idea that image-based monitoring may be more effective than many traditional techniques in rangeland environments. Not only does image-based monitoring provide a permanent record, it also can reduce observer bias by allowing one person to examine images taken over time by different people, and can reduce time spent in the field and cost of labor. After working through datasets from over a dozen operating companies, I am convinced that image-based monitoring should be incorporated into large-scale monitoring plans in rangelands and areas where vegetation is low-growing. The use of image-based monitoring would allow for the data analyst to go back and re-analyze images on well pads where data is suspect or questionable. Additionally, image-based monitoring would allow for improved communication and relations between operating companies, practitioners, and regulatory agencies. For example, in 2012 (a drought year in Wyoming), one operating company was confident enough in their monitoring effort to submit seven well pads to BLM to have them signed off as successfully reclaimed in early May. However, by the time paperwork was processed and sites were able to be ground-proofed by BLM in late June, no forb species were identified and all sites were considered failures. Being a warm, dry year, it is very possible that forb species were present and flowering in early May but could have senesced and been unidentifiable in late June. Images with geo-tags on them would be able to prove the existence of forb species and could potentially lessen the need for BLM to ground-proof sites in a very short window after receiving initial requests from operating companies.

While there are many positives to image-based monitoring, there are several questions the scientific community should continue to study which could benefit operating companies, practitioners and reclamation contracting companies and regulatory agencies. Some of these questions include: How intense should monitoring efforts be? When should monitoring take place? What should be monitored/measured? Currently, the WRRC are working to address these questions. By monitoring sites at different intensities, we hope to determine the adequate sample size to describe vegetation on a well pad as well as ways to randomly select points to use for monitoring. Using historic climate data from Oak Ridge National Laboratory's DAYMET database, we are working to figure out how temperature and precipitation are influencing plant phenology to aid in making better decisions about when to monitor sites. The question of what to monitor and measure is a difficult one and may be dictated by desired land use. For example, if the desired land use is to provide sage grouse habitat, studies by wildlife biologists determining habitat requirements for sage grouse should be incorporated into the monitoring plan. When no local sage grouse population exists but where livestock grazing is desired, focus should be placed on the presence of suitable ground cover, erosion control, and lack of noxious and invasive weed species. Ultimately, vegetation monitoring is the way that reclamation success is evaluated and the scientific community should recommend practical ways to evaluate reclamation success.

Conclusion

The field of land reclamation and restoration ecology are still new and offer plenty of exciting opportunities. As land disturbance continues to increase, our ability to successfully reclaim these disturbances will continue to be very important. While a reclamation database created by the WRRC highlights many areas where gaps occur between data from practitioners, operating companies, and regulatory agencies, it is not sufficient to simply point out problems. The scientific community should feel a strong obligation to improve monitoring techniques and enhance the ability to analyze large-scale reclamation efforts and to determine reclamation success. While scientists continue to study land reclamation, they must strive to provide practical and efficient tools and practices for the industry and regulatory agencies to apply. Additionally, it will be important for reclamation/restoration ecologists to adopt procedures from experts in other fields. Right now, the sage grouse is a major topic of concern for reclamation ecologists, wildlife biologists, operating companies, practitioners, policy-makers and the general public in Wyoming. But as we move forward and as land disturbances continue to occur across space we should be prepared to face new challenges and work with our friends on the practice and regulatory side of things to provide new solutions.

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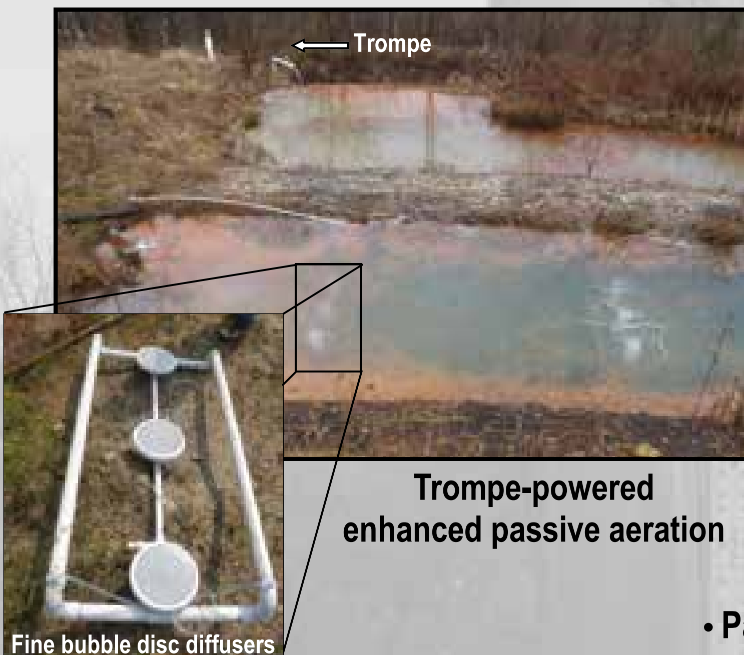

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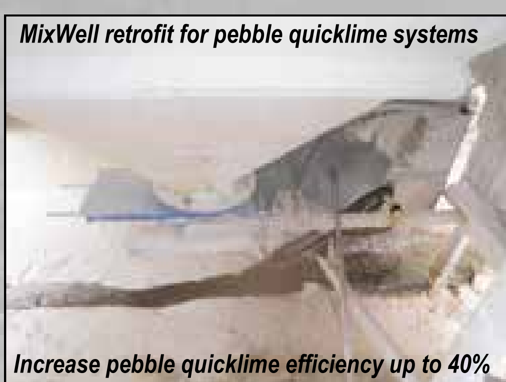

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