OFFICIAL PUBLICATION OF THE AMERICAN SOCIETY OF MINING AND RECLAMATION

reclamation *matters*

Selecting Tree Species for Reforestation of Appalachian Mined Land

Passive Treatment of Coal-Mine Drainage by a Sulfate-reducing Bioreactor in the Illinois Coal Basin

Abandoned Mine Drainage Remediation Efforts in the West Branch Susquehanna Watershed in Northcentral Pennsylvania

Spring 2013

2013 Joint Conference issue

AMERICAN SOCIETY of MINING and RECLAMATION

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contents

Choose Wisely

By Bruce Buchanan, ASMR President

In my early reforestation days, I became good friends with the owner of a family operated sawmill in the Lincoln National Forest. Members of the family would fell the trees and bring them to the mill site. My friend operated the large circular saw that would rough cut the logs. The first few cuts were rounded planks, mostly of bark, that were cut into short lengths and sold for firewood. The main products were boards of various sizes that would be hauled away every few weeks on a flat bed. These boards went to a finish mill and were later sold at lumber yards.

Some customers went directly to the sawmill to buy lumber, but most would buy from a retail lumber yard. Each bought lumber because they were going to build something; maybe a barn, a shed, a deck, a dog house, an outhouse or even a home. Some built fences, wagons, teeter-totters, swings and one customer even made wood sculptures. The point being, boards were purchased for a purpose and the use was as varied as the customer.

Now, some 40 years later, I think about that old sawmill and lessons learned. In a sense, as a youth, we went to the sawmill (school) to get our boards (education). Because of choices, our education came to us in different forms, sizes and shapes. For many, this education came from the school of experience and for others, the school of hard knocks. For some, it came formally from a trade school or university. Whatever the case, we made choices and from these choices we gained an education, skills and experiences…resulting in a career. We became scientists, professors, managers, owners, partners, technicians and presidents. We worked hard and each built something just a little different. The remarkable part of all this…we had the freedom to choose and to build whatever we wanted. With some, a choice was made and what we started was never changed. In contrast, there were those that made changes along the way. Some of us had starts, stops, do-overs and once in a while an "oops!" Sometimes the changes were small, sometimes great, sometimes planned and sometimes unplanned.

I believe what seemed to be small incidents or insignificant decisions at the time were in fact the events and decisions that often had the greatest influence on what we "built". I also believe, along the way, we were influenced to a great extent by our mentors and tutors who we regarded as examples. Simply put, we are the product of choices (big or small) and the examples we chose to follow. Early in my childhood, my father taught me I could become anything I wanted…my mind was like a garden and it was my choice as to what I would grow. My mother taught me to enjoy what I chose and whatever I did, to do it well.

As this year's president of ASMR, my message to those early in their career would be to select carefully from the sawmill and choose wisely as to what you build. Fences and sheds are easy; homes and sculptures are hard – they take more time but have greater value. Do not be afraid of change, include mentors in your building…these "older examples" are valuable resources. To those in the middle of their career, my advice is to just keep on building, remodeling when needed and make change a positive experience. It isn't what happens to us that counts; it is how we deal with it. To those closer to the end of a career, if there ever is an end, the building may be built but we are the mentors, we are the examples and our contribution is sharing, teaching and helping.

This year as we attend the National Meeting in Laramie, Wyoming, I hope we all come with the purposes of building and sharing. ■

Trust Others and Throw the Ball!

By Jeff Skousen

I read an inspiring article written by Steve Young, the retired San Francisco 49ers quarterback who played for 14 seasons in the National Football League. He was named the Most Valuable Player in 1992 and 1994 and was the MVP of Super Bowl XXIX.

He was only six feet tall, which was too short to see over the tall linemen who reached up with their arms to block his passes. Young said, "Many times I would drop back to pass, look for Jerry Rice, and see nothing but bodies in front of me. So I would start to run around to get visibility. And then inevitably I would be tackled and sacked for a loss. The coach yelled, 'Jerry was open and you were protected. Why didn't you throw the ball?'"

Young's response: "Couldn't see him."

Coach's comment: "You'd better start seeing him."

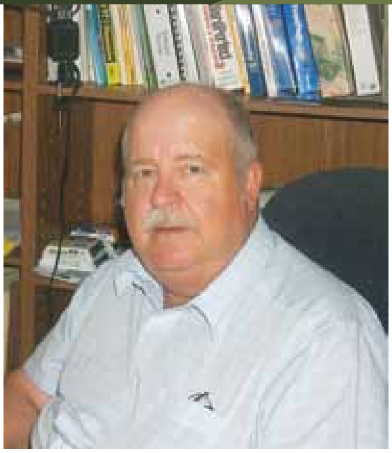
Young continued, "I realized that quarterbacks must trust their receivers. As we came up to the line, I looked over at Jerry Rice who was split out on the line. At the snap, I glimpsed him take off as I dropped back to pass. I knew where he was going and I threw the ball where Jerry was supposed to be. The visibility was just as poor, I couldn't see him, but I threw the football anyway. Jerry was usually there. The longer we were together, the better it worked." Young considers Jerry Rice the best wide receiver who has ever played in the NFL.

Young stated, "I watched a football game the other day and I could see downfield much better than the quarterback behind the line with the raised arms of the defensive lineman. I yelled, 'Throw it there! What are you looking at? Move faster! Throw it now! Watch out behind you! What are you waiting for?' My view from the stands was very different than the view the quarterback had on the field."

He continued, "Quarterbacks unfortunately don't have that perspective. We are expected to call the signals, handle the offense, throw the ball accurately and not make mistakes. In reality, we rely on the line to protect us and expect the receivers and runners to be where they should be."

I suspect we can draw many conclusions from Young's statements. Most of us are like quarterbacks in some respects and we depend on others on the team. We rely on people to do what they are trained to do, we anticipate that they will be where they are supposed to be, and we expect them to do their part. It would be great if we could see clearly over the distractions and foresee upcoming problems, but we often do not have a clear perspective. So we make our best guess with the knowledge we have and throw the ball anyway without knowing exactly where it will land, who may catch it or if it will be intercepted. If we don't throw the ball, we'll be sacked for a loss.

How can we be successful as a quarterback or as a scientist or a reclamationist, or for that matter in any of our undertakings? I think we must rely on the actions and knowledge of others for protection and help, we must trust our co-workers and associates as members of the team, and we must have confidence in ourselves to throw the ball even when we cannot see clearly. ■



ASMR's Online Journal

By Richard Barnhisel

At the end of October 2012, ASMR launched its online Journal. The first issue was small, with only nine articles. I am optimistic that the Spring issue 2013 will have more than twice this number. I have received 19 papers that are under review associated with the national meetings, with expectations of receiving that many more by the middle of March. Submissions will be accepted at any time for one of the seven technical divisions of ASMR. The associate editors are the same as the technical division chairs.

The Journal has four sub-sections for submissions as appropriate articles are received. These include research, case studies, demonstrations and other papers. We strongly encourage color photos and graphics. Within these sections papers may also include review articles or book reviews. Letters to the editor will be considered as well. You do not have to be a member of ASMR; however, in these cases, page charges will apply.

The number of visits to the Journal section of the ASMR web page has been encouraging, with 145 in October, 119 in November, 177 in December and 95 in January. The direct link to the online Journal is http://www.asmr.us/Publications/Journal/Journal.htm. Additional information as to procedures for preparing articles are found in the Journal section of our web page. The general link to ASMR web page is www.asmr.us. ■

Bringing Ideas Together

By Abbey Wick

Topics at a reclamation workshop held in Dickinson, ND along with the recent shift in my career path has got me thinking about the importance of sharing ideas across disciplines, across mines, state and country borders, and across types of disturbance. Let me explain:

In mine-land reclamation, we work well with inter-disciplinary issues. We have to consider all parts of the ecosystem (climate, pests, weeds, plant communities, soil health, topography, wildlife etc.) in order to achieve effective reclamation. We also share information between operations, regions, states and countries through collaborations, meetings, etc. Similar inter-disciplinary approaches and sharing of information are also taken within agricultural industries. But I am going to ask a couple of questions for you to consider as we discuss the sharing of information across industries and types of disturbance (i.e. mining-agriculture-range):

- Are we diligent about updating mined land reclamation management strategies to include recent advances in agricultural or range management?
- Do we effectively share what we learn in mined land reclamation with other groups?
- How effective are we at "bringing in" or adopting new or different knowledge from other industries to our annual ASMR meetings?

These are questions that we should ask ourselves to ensure that we are maximizing our efforts and helping others maximize their efforts. To make it a little more obvious as to why I am asking these questions now as opposed to a year ago, I recently accepted a position at North Dakota State University with a 90% extension and 10% research appointment. So, I travel across the state gathering and sharing information on soil health – tons of information transfer! The two major industries in ND are agriculture and mining (oil/coal/gas), with agriculture covering a greater expanse of land than mining. Unfortunately, our ag industry is facing major salinization issues leading to reductions in crop yields. Because of these dynamics, I've started working a little more with agriculture and little less with mined land reclamation. This has forced me to consider and learn about a different industry other than mining.

I've noticed that as I work more with agriculture, I still pick up my mined land reclamation books to look for solutions to these agricultural issues. How many times in reclamation have we had to create a buffer between saline or sodic spoil material to re-establish plant communities using topsoil material? Isn't the buffer-zone concept the same for a saline soil in agriculture as it is for a saline soil in mine reclamation? Aren't the methods of leaching the salts through the soil profile to obtain a good rooting zone the same? When we deal with compaction on a mine site, aren't the concepts similar to dealing with compaction on agricultural lands? When we control weed populations at a reclaimed mine site, don't we use diverse plant communities to reduce weed pressures similar to the concept of using diverse crop rotations in agriculture? It seems to me that despite the early connection between agricultural practices and mined land reclamation that both industries might now be making advances separately in parallel rather than working together.

So, I ask myself, are we fully utilizing all that we know in each system to make both reclamation and farming better? On a smaller scale, are we sharing what we currently know in coal mine reclamation with oil and gas industries (and vice versa)? These might seem like obvious questions or connections to those who have been doing reclamation for a long time (and may be evident through the creation of reclamation centers at universities to support this transfer of information), but maybe this idea has not crossed the minds of Early Career members. Either way, we need to be diligent about making these connections to not only improve reclamation efforts, but to also help other industries that might be dealing with similar issues. Maybe we can facilitate this transfer of information by getting specialists in other disciplines to attend our meetings using specific sessions on dealing with compaction in all areas such as mined land reclamation, agriculture, and grazing lands (for example). This approach just might make everyone's job easier and improve all of our efforts!

We are planning the Early Career Social event at the upcoming meetings in Laramie which will be held at the new Visual Arts Building on the University of Wyoming campus. Chris Johnston, Lisa Cox and Kristin Herman are in charge. Make sure you don't miss it! ■

2013 Joint Conference

2ND Wyoming Reclamation and Restoration Symposium and

30TH Annual Meeting of the American Society of Mining & Reclamation

June 1-7, 2013 • Hilton Garden Inn • Laramie, Wyoming (USA)

Reclamation Across Industries

Program & Registration Information

Good Ol' Laramie, Wyoming is known as the Gem City of the Plains and is located in the southeast corner of the state, on the edge of the Rocky Mountains at a staggering elevation of 7,220 ft.! Wyoming is a natural resource state and leads the nation in production of coal, bentonite, uranium, and trona as well as being the country's second largest producer of natural gas. With all of this natural resource production, we also have a large land reclamation industry in the state, hence this year's "Reclamation Across Industries" theme. The Joint Conference of the 2nd Wyoming Reclamation and Restoration Symposium and the 30th Annual Meeting of the American Society of Mining and Reclamation is scheduled for the week of June 1-7, 2013 in Laramie, Wyoming.

A **Welcome Social** the evening of Sunday, June 2 will include appetizers and a no-host bar. This provides an opportunity to visit with the Exhibitors as well as other participants, in the Grand Ballroom Lobby at the Hilton. An evening **Sponsor's Social** in the Hilton Conference Center is planned on Monday, June 3. The **Early Career Professionals' Social** will be held on Tuesday evening, June 4 at the UW Visual Arts Building. The **ASMR Awards Luncheon** will be held Thursday, June 6th, with **catered lunches Monday and Wednesday in the Grand Ballroom Lobby.** An evening of **dinner and entertainment** is scheduled for Wednesday, June 5, at the Wyoming Territorial Prison State Historic Site. All **breakfasts** and **refreshment breaks** (coffee in the mornings and soft drinks in the afternoons) will be held in the Grand Ballroom Lobby at the UW Conference Center/Hilton Garden Inn during the technical sessions (See Exhibitor and Arena Maps on the ASMR webpage under Upcoming Meetings http://www.asmr.us/Meetings/UpcomingMeetings.htm). Each of these provides an opportunity for fellowship and technical exchange with colleagues.

ASMR Program Committee

Dr. Pete Stahl, Chair

Dr. Richard Barnhisel, Editor and Registration

George Vance, Co-Chair Technical Program

Gerald Schuman, Co-Chair Technical Program

Brenda Schladweiler and Gary Austin, Fundraising

Jay Norton, Calvin Strom, Pete Stahl and Anna Waitkus, Technical Tours

Kristin Herman and Gerald Schuman, Social Events

Financial Sponsors (to date)

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School of Energy Resources at the University of Wyoming

Silver

KC Harvey

Bronze

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Transportation to Laramie, Wyoming

AIRPORTS:

Denver International Airport (DIA) – Denver, CO - via I-25/I-80 or I-25/US 287

- there are several car rental companies located at DIA
- From DIA, Laramie is about 130 miles (2.5 hour drive). It is an easy drive (unless winter driving conditions are encountered) by taking I-25 north to Cheyenne and then west on I-80 to Laramie. Highway US 287 from Fort Collins, CO to Laramie is a more scenic drive.
- An alternative to flying from DIA to Laramie is a shuttle service operated by Greenride out of Fort Collins, CO (greenrideco.com or 888-472-6656) which has service out of DIA every two hours ($75 one way).

Laramie Regional Airport – Laramie, WY – located 2 miles west of town

- United Express (SkyWest) flies from Laramie to DIA, Denver (book through United.com)
- Shuttle will take you from Laramie airport to Hilton Garden Inn if requested
- http://www.laramieairport.com/

CONFERENCE LOCATION:

Hilton Garden Inn and UW Conference Center

- 2229 Grand Avenue, Laramie, WY
- Enter through double doors on southwest side of the Conference Center
- Map/directions: http://www.uwconferencecenter.com/aboutDirections.html

HOTELS WITH BLOCK RATE:

Hilton Garden Inn – 2229 Grand Avenue, Laramie, WY (307) 745-5500

- Group Name: American Society of Mining & Reclamation
- Group Code: ASMR
- Rate $115-$135
- To reserve room directly: http://hiltongardeninn.hilton.com/en/gi/groups/personalized/L/LARLAGI-ASMR-20130601/index.jhtml?WT.mc_id=POG

Holiday Inn – 204 S. 30th, Laramie, WY (307) 721-9000

- Contact: Gary Treahy
- Group name: ASMR
- Rate $119

OTHER HOTELS CLOSE TO CONFERENCE LOCATION (NO BLOCK RATE):

- Hampton Inn – 3715 East Grand Avenue, Laramie, WY (307) 742-0125
- Comfort Inn – 3420 Grand Avenue, Laramie, WY (307) 721-8856
- AmericInn – 4712 East Grand Avenue, Laramie, WY (307) 745-0777

Pre-Conference Workshops

WORKSHOP 1: Basics of ArcGIS and GPS for Field Mapping (two day workshop)
Date: Saturday, June 1, 9:00am to 5:00 pm AND
Sunday, June 2, 9:00 am to 4:00 pm
Location: tbd
Lead Instructor: Janine Ferarese, Marcelo Calle, and Alan Buss
Number of Students: Minimum 6- Maximum 16
Cost: Dependent upon number of participants between $166 for 6 persons and $65 if only 16 (prorated refund will be made to participants in Laramie).
Description: The workshop is designed to teach participants the fundamentals of using ArcGIS Desktop software and GPS data collection tools to create a map using data collected in the field. Students will learn what coordinate systems, datums, and projections are and why understanding them is vital to working with spatial data. The participants will gain hands on experience using GPS (Trimble and Garmin) in the field, collecting spatial data (points, line, polygons) and transferring collected data from a GPS unit to a computer. Use of simple tools and utilities in ArcGIS, and creation of professional quality maps will be taught. GPS units (Garmin, Trimble GeoXM and Trimble Juno ST) will be provided.

WORKSHOP 2: Reclamation of drastically disturbed salt- and sodium-affected soils
Date: Sunday, June 2, 9:00 am to 4:00 pm
Location: LREC Greenhouse, 30th & Harney Streets
Lead Instructor: Jay Norton, Raymond Ansotegui, Calvin Strom
Number of Students: 10-20
Cost: $25
Description: Reclaiming severely disturbed soils with elevated levels of salt, sodium, or both is difficult. Soil salvage operations often mix surface soils with materials from deeper in the soil profile that may contain higher salt and/or sodium levels, pushing salt/sodium contents at the surface out of the range even of tolerant desert plants. Once concentrations in surface soils are elevated, returning them to levels suitable for establishment and growth, even of salt-tolerant plants, can be challenging. The goals of this workshop are to examine ways to: 1) avoid elevating near-surface salt and/or sodium contents by careful identification of suitable soils for salvage, considering the tolerances of the pre-disturbance plant community, and 2) mitigate elevated near-surface salt and/or sodium levels using combinations of management and soil amendments. The workshop will include hands-on field and lab components as well as interpretation of soil test results for creating salvage and mitigation plans.

Tours

Tuesday, June 4, 2013

WAMSUTTER GAS FIELD, 8AM-5:30PM
Currently the largest on-shore natural gas field in North America and located in the Red Desert of south central Wyoming, the Wamsutter field is a semi-arid sagebrush steppe environment receiving 20 cm of annual precipitation. Several major energy companies are producing natural gas in the Wamsutter field and are responsible for reclaiming thousands of well pads and thousands of miles of access roads. We will have several reclamation experts with broad experience working in the Wamsutter Field as guides on this trip. This tour will be made in cooperation with the High Altitude Revegetation Committee's Summer Field Tour. Lunch provided

Friday, June 7 – Saturday, June 8, 2013

POWDER RIVER BASIN ENERGY TOUR – LARAMIE TO GILLETTE
This general Wyoming Energy Resources and Reclamation Tour is a 2-day trip that will involve driving from Laramie to Gillette, WY. Along the way, we will stop to visit a number of energy production sites. Stops will include the Rolling Hills Wind Energy Farm, an In-situ Uranium Mine, the North Antelope surface coal mine, and a coal fired electrical power generation facility.

Exhibitor's Welcome Social

The Joint Conference Exhibitor's Welcome Social will be held from 5-8pm on Sunday, June 2 at the Hilton Garden Inn and UW Conference Center for all attendees. Light appetizers and refreshments will be available. Renew old acquaintances and meet new people that share mutual professional interests!

Plenary Session

See Schedule

Waiting for finalization

Evening Social

An evening social for attendees and spouses is scheduled for Wednesday, June 5, 2013 at the Wyoming Territorial Prison State Historic Site and dinner theater. A happy hour will be held at the Hilton Garden Inn from 4:30-5:30 pm. Buses will provide transportation to the Territorial Park, which is located in west Laramie, starting at 5:30 pm. Cost is $30 and includes two drinks (@Hilton Garden Inn), a buffet dinner (eat where the prisoners ate), music by Davis and Mavrick (a nostalgic musical journey through the 50's, 60's and 70's), and a guided Ghost Tour of the prison. This promises to be a great evening of fun and history. This event is limited to a maximum of 160 people, so make sure you register early for this special evening.

Built in 1872, the Wyoming Territorial Prison was restored and renovated in the 1990s by the efforts of the citizens of Laramie. There were 12 women [prisoners] housed here and more than 1,000 men, the most famous of which was Robert LeRoy Parker "Butch Cassidy". The restored Prison building, Warden's house, and Prison Industries building interpret this colorful and dramatic portion of the site's history. Following the removal of prisoners to a new facility in Rawlins (1903), the University of Wyoming acquired the prison property and adapted the buildings and grounds for use as an agricultural experiment station [facility] for the College of Ag. The College of Agriculture utilized the site until 1989, when restoration work began and the site was recognized as a valuable historic property. The 2012 opening of "Science on the Range" exhibit explores the breeding projects and research efforts of students and staff on the "Stock Farm".

http://www.wyomingterritorialprison.com

Early Career Professionals' Social

The Early Career Professionals will host a social on Tuesday, June 4, 2013, 6:00 pm, at the Visual Arts building on the University of Wyoming campus. Located one block north of the Hilton Garden Inn and Conference Center, transportation will not be provided. Appetizers and refreshments will be provided. This is a great opportunity to network with other professionals just beginning their reclamation career and with the "old folks" that have a great deal of experience and knowledge in the field of land reclamation.

Sponsor's Social & Poster Session

Monday, June 3, 2013 5:00 pm – 7:00 pm

Poster Session - Grand Ballroom Lobby and Salon ABC
A Comparison Between Proposed Well Pad Reclamation Vegetal Cover Standards and Their Associated Multiple Land Use Vegetation Communities and Well Pads by M. Heil, B.A. Buchanan and H. McDaniel
Foliar Cover and Canopy Cover Relationships on the Goathill Subsidence in Questa NM by T. Richardson, M. Heil, B.A. Buchanan and D. Heafey
Growth of Switchgrass on Reclaimed Surface Mine by C. Brown and J. Skousen (student)
Canopy Cover Estimation Using Aerial Photography For a Mixed Conifer Zone, Northern, New Mexico by D. Inskeep, M. Heil, B.A. Buchanan and D. Heafey
Impact of Inoculation with Plant Material on Plant Development; Greenhouse Tests by C. Nelson, W. Rider and A. Unc
Seed Source and Sagebrush Habitat Reclamation Success on the Mowry Formation by M. Dillon and M. Cornia
The Use of Amendments in Reclamation of Salt-Affected Soils: Gypsum, Elemental Sulfur, Langbeinite, and Municipal Solid Waste Compost by S.J. Day, J.B. Norton, C.F. Strom, T.J. Kelleners and P.D. Stahl (student)
Carbon isotopes as a basis for evaluating alkalinity generation over time with a sulfate-reducing bioreactor in south-central Indiana by S.W. Emenhiser, P.E. Sauer, T.D. Branam and G.A. Olyphant (student)
Least Limiting Water Range of a Waste of Laundering Bauxite After Eleven Year Revegetated by G.C. Rocha, L.A. de O.P. Guimarães, L.E. Dias, I.R. de Assis, S.M. de Faria, L.C. lemos Neto and J. Carvalho
Closure Criteria for Waste Rock Land forms in Western Australian Goldfields by A. McR. Holm and B. Sinclair
Rehabilitation Ironstones Outcrops Area Degraded by the Iron Mining Activity on Minas Gerais State-Brazil by L.A. Lobo de Rexenda, L.E. Dias, I.R. de Assis and R. Braga
Revegetation of Overburden Dump Slopes in Areas Altered by Iron Mining, Carajás-Pa, Brazil by I.R. Assis, L.E. Dias, G.C Rocha, L.C. Lemos Neto and C.H.S. Rezende
Restoration of Surface Disturbances on the Short grass Steppe of Northeastern Colorado by S.A. Barr, J. Jonas, and M.W. Paschke (student)
Examining the Effectiveness of Mechanical Thinning for Increasing Mule Deer Forage in and Oil and Gas Development Region by G.J. Stephens, M.W Paschke and D.B. Johnston (student)
Genetic Diversity of Brook Trout Populations in Several Sub-watersheds of the West Branch Susquehanna River Watershed by S.M. Rummel and F.J. Brenner
Restoring Remnant Hardwood Forest Impacted by Surface Mining for Coal through Removal of the Invasive Tree-of-Heaven (Ailanthus altissima) by C.M. Peugh, J.M. Bauman and S.M. Byrd
Third Year Survival and Height Growth of American Chestnut on Post-Bond Release Surface Mines in Eastern Kentucky by H.Z. Angel, C.D. Barton and P.N. Angel (student)
Effect of Spoil Type on the Chemical and Hydrologic Profiles of Experimental Mine Reforestation Plots in Eastern Kentucky by K. Sena, C. Barton, C. Agouridis and R. Warner (student)
Reclamation of Abandoned Mine Land through Poultry Litter Biochar Amendment U. Buyantogtokh and M. Guo (student)

Please recycle this publication after you have read and shared it.

Silent Auction

Please bring items to contribute to the ASMR Silent Auction. Items will be displayed prominently in the Grand Ballroom Lobby at the Hilton. This event is used to raise money for the ASMR Student Travel Fund to help students attend future meetings! Bidding will begin on Monday and continue until Thursday at 10:30am. Winners will be announced at the end of the Awards luncheon.

ASMR Awards Luncheon

Thursday, June 6, 2013, noon - 2:00 pm

Cost included in the registration fee, additional tickets may be purchased for spouse and/or significant other.

Spouse/Significant Other Events

One of the most exciting things to do in the Laramie area is to take a drive up to the Snowy Range to see the beautiful forests, subalpine and alpine environments in the Medicine Bow National Forest. It takes less than an hour to get to the Snowy Range Pass at an elevation of 10,000 ft. and the scenery is spectacular. Kristin Herman will be leading a tour to the Snowy Range on Wednesday, June 5.

Snowy Range - hiking, Albany, Centennial, Woods Landing, Old Corral
http://www.stateparks.com/medicine_bow.html

OTHER ATTRACTIONS

- Downtown Laramie
  http://www.laramiemainstreet.org/
- Laramie Plains Museum and Historic Ivinson Mansion
  An interesting historic site to in Laramie is the Old Ivinson Mansion. Completed in 1893, the mansion was home to the prominent Ivinson family and was the most elegantly appointed home in Laramie. Tours are available on Tuesday – Saturday afternoons from 1-4 pm at a reasonable cost.
  http://www.laramiemuseum.org/
- Vedauwoo - Turtle Rock Trail, Ames Monument, Lincoln Monument
- Loveland Outlet Mall, Centerra – shopping
  http://www.outletsatloveland.com/
  http://www.thepromenadeshopsatcenterra.com/
- Visit Wyoming
  http://www.wyomingtourism.org/
  http://www.visitlaramie.org
- Wyoming Territorial Prison
  http://www.wyomingterritorialprison.com/
  975 Snowy Range Road

AT UW

Art Museum
http://www.uwyo.edu/artmuseum/index.html
Berry Biodiversity Conservation Center
http://www.uwyo.edu/berrycenter/
Fine Arts/Theatre/Vedauwoo Rock performers
http://www.uwyo.edu/finearts/
Geology Museum
http://www.uwyo.edu/geomuseum/
Insect Museum
http://wyoalumni.uwyo.edu/s/1254/index.aspx?sid=1254&gid=1&pgid=390
Planetarium
http://www.uwyo.edu/physics/_files/docs/planetarium.html
Williams Conservatory
http://www.uwyo.edu/botany/williams-conservatory/index.html

Exhibitor Information

The 2nd Wyoming Reclamation and Restoration Symposium in conjunction with the 30th Annual Meeting of the American Society of Mining and Reclamation will provide an exceptional opportunity for your company or organization to interface with mining reclamation professionals and those who influence decisions about the purchase of products and services for the land reclamation industry. Register now to be a sponsor and/or to bring your company exhibit to Laramie in June 2013!

An **Exhibitor's Welcome Social** the evening of Sunday, June 2 will include appetizers and a no-host bar. An evening **Sponsor's Social** in the Hilton Conference Center is planned on Monday, June 3. **The Early Career Professionals' Social** will be held on Tuesday evening, June 4. An evening of dinner and **entertainment** is scheduled for Wednesday, June 5, at the Wyoming Territorial Prison State Historic Site. The **ASMR Awards Luncheon** will be held Thursday, June 6th, with **catered lunches Monday and Wednesday in the Grand Ballroom Lobby**. All **breakfasts and refreshment breaks** (coffee in the mornings and soft drinks in the afternoons) will be held in the Grand Ballroom Lobby at the UW Conference Center/Hilton during the technical sessions (See Exhibitor and Arena Maps on the **ASMR** webpage under **Upcoming Meetings, http://www.asmr.us/Meetings/UpcomingMeetings.htm**). Each of these provides an opportunity for fellowship with colleagues with similar reclamation interests.

Exhibitors will be listed on the ASMR website by name/logo which includes either a link to the company's website or short listing of contact information. The website listing will stay on the main ASMR website until the 2014 annual meeting. Your company can also be a sponsor of any or all of these activities (please see separate information for sponsors for more details).

Traditional booths for display feature a 2' x 6' table with chairs and a backdrop. Arrangements should be made separately should you require additional features such as electrical service; please contact us and we will try to accommodate as best we can. The Grand Ballroom Lobby at the UW Conference Center has been arranged to facilitate traffic throughout the entire exhibit area by strategic placement of refreshment areas and concurrent technical session rooms. **Set-up can begin Saturday, June 1 at 10:00am, but must be completed by Sunday, June 2 at 5:00 pm. Breakdown can begin after 2pm on Thursday, June 6 and must be completed by Thursday night.** The UW Conference Center will be open daily during the conference with locked security at night. A floor plan outlining the location of booths within the center is listed on the following pages. Please select three locations by preference. Reservations will be made upon receipt of funds on a first-come, first-serve basis. Please note that the booth floor plan is subject to change dependent upon number of exhibitors. An updated floor plan will be posted on the ASMR web page as exhibit spaces are sold. That may be found at **www.asmr.us** under Upcoming Meetings, Laramie: Exhibitor Map

The final registration materials for attendees will include a packet identifying all exhibitors, their addresses, and the services and/or products provided. Please include a short narrative of your business for this packet. We anticipate 1 to 2 additional mailings for this Conference, as well as website exposure, and these will include confirmed exhibitors and sponsors. To maximize your company's exposure, early registration is essential!

Please fill out the Sponsor/Exhibitor Registration Form and **return with payment prior to April 1, 2013:**

American Society of Mining and Reclamation (ASMR)
c/o Dr. Richard Barnhisel
3134 Montavesta Road
Lexington, KY 40502
E-mail: asmr5@insightbb.com • (859) 351-9032

Sponsorship Details

Platinum Level Sponsors- $10,000

- One free exhibitor booth.
- Four free registrations.
- Meal tickets for all meals including social event.
- Special recognition and award at Awards Luncheon.
- Special recognition at the Business Meeting.
- Display of your logo and name on a separate frame in a continuing loop PowerPoint of sponsors between sessions, during breaks, etc.
- Your logo will be on the conference bag to be provided to all conference participants at registration.
- Your logo will be given on give-aways and the outside of the program front cover.
- A link to your company website will be attached to the ASMR website for one month before the 2013Laramie meeting and will continue to run until one month before the 2014 meeting.
- Recognition ribbons on conference participant name tags.

Gold Level Sponsors- $5,000

- One free exhibitor booth.
- Two free registrations.
- Meal tickets for all meals including social event.
- Special recognition and award at Awards Luncheon.
- Special recognition at the Business Meeting.
- Display of your logo and name on a separate frame in a continuing loop PowerPoint of sponsors between sessions, during breaks, etc.
- Your logo will be on the conference bag to be provided to all conference participants at registration.
- Your logo will be given on give-aways and the outside of the program front cover.
- A link to your company website will be attached to the ASMR website for one month before the 2013 Laramie meeting and will continue to run until one month before the 2014 meeting.
- Recognition ribbons on conference participant name tags.

Silver Level Sponsors- $3,000

- Exhibitor booth at a reduced rate (if exhibiting) (Booth cost is $750, normally $1,000.)
- One free registration
- Meal tickets for all meals excluding social event.
- Special recognition and award at the Awards luncheon.
- Special recognition at the Business Meeting.
- Display of your logo and name on a frame with two other companies in a continuing loop PowerPoint of sponsors between sessions, during breaks, etc.
- A link to your company website will be attached to the ASMR website for one month before the 2013 Laramie meeting until the end of 2013.

Bronze Level Sponsors- $1,000

- Exhibitor booth at a reduced rate (if exhibiting) (Booth cost is $750, normally $1,000.)
- Special recognition at the Business Meeting.
- Display of your logo and name on a frame with three other companies in a continuing loop PowerPoint of sponsors between sessions, during breaks, etc.
- A link to your company website will be attached to the ASMR website for one month before the 2013 Laramie meeting and for two additional months after the meeting.

Break and Meal Sponsors

- Your company's name will appear on a board next to food and beverage area, as well as in the program.
- Announcements will be made by moderators prior to breaks and meals that mention the sponsor of the upcoming break.
- Meal sponsorship: Breakfast $500 Lunch $750
- AM Break $300 PM Break $350

Other Sponsorships Available

Early Career

Recent Professionals in the Field Social Event $250-1,000

Program Advertising (camera-ready artwork)

Business Card Size (4"x2") $250

1/2 Page Advertisement (4"x4") $500

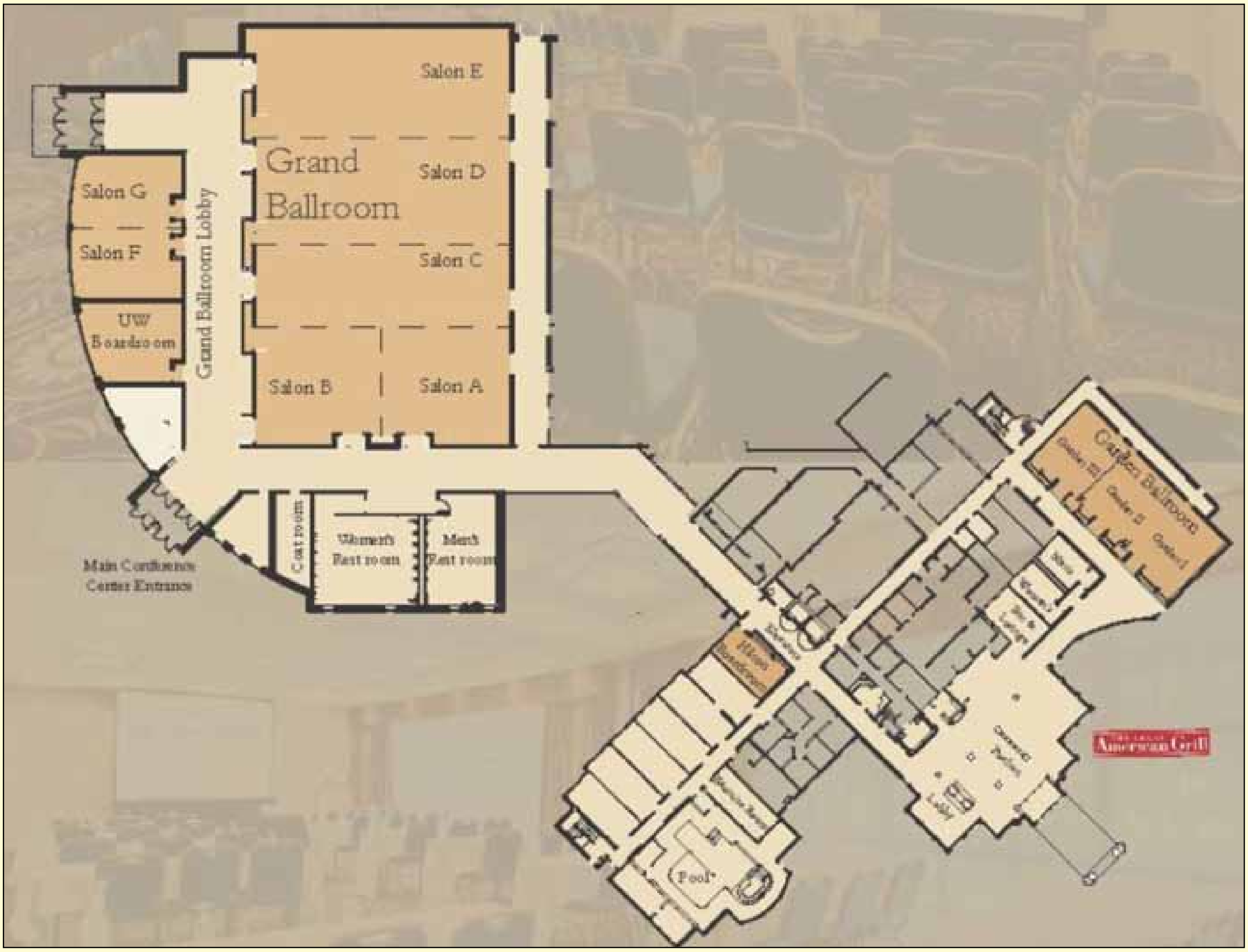
Full Page Advertisement (4"x8") $1,000

Exhibitor/Sponsorship/Advertising questions, contact:

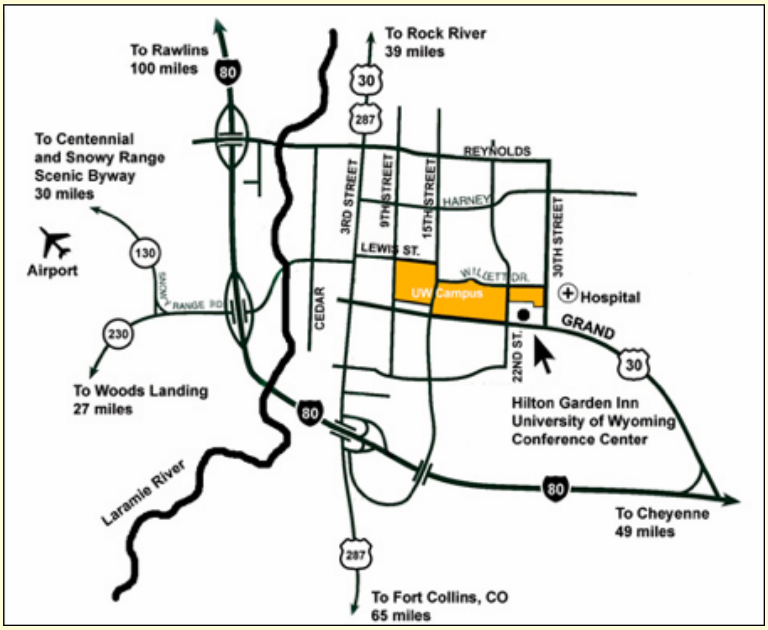
Kristin Herman	**Dick Barnhisel**
WRRC	**3134 Montavista Rd.**
(307)766-3576	**Lexington, KY 40502**
	(859) 351-9032

Spaces are Limited-Reserve Now!

Hilton Garden Inn and UW Conference Center



Map to the Hilton



EXHIBITOR/SPONSOR REGISTRATION FORM

Company Name: ____

Registrant(s)/Contact Name(s): ____

Address: ____

City/Province: ____

State: __________ Zip: _______________ Country: ________________

Phone: ____________________ FAX: _________________________

E-Mail: ____

Web page address____

Booth Preferences (#1 – 28 on Attached Map, visit ASMR web page to see available locations www.asmr.us This is under Annual Meetings, Laramie, exhibit hall, First Come, First Served)

1st 1st Choice	2n 2nd Choice	3r 3rd Choice

Exhibitor Selections and Costs

Non-sponsor Booth $1000 ________ (Includes 2 non-refundable complete registrations)

Sponsor Booth $ 750 ________ (Gold Sponsors receive one free booth, Silver and Bronze sponsors may reserve one booth at a discounted price of $750)

Meal Sponsorship: Breakfast: $500.00 __ Lunch: $750.00 __ Evening: $1,000 ___

Refreshment Sponsorship: AM Break: $300.00 __ PM Break: $350.00 __

SUBTOTAL: ___________

(Please add 6% for processing fee if using a credit card) – or 4% if using PayPal at www.asmr.us click on PayPal and enter appropriate amount under the Meetings Button and the processing fee under Misc. button. If you are not a PayPal user you may need to first register with this organization and I believe this will "pop" up first before you can proceed.

Visa or MasterCard #________ ________ ________ ________ Expiration Date _______

TOTAL: ____________

Checks should be made payable to ASMR by April 1, 2013

*NOTE: For additional information and/or to discuss Company Logo, please contact Richard Barnhisel at asmr5@insightbb.com or call (859) 351-9032

Mail to ASMR, 3134 Montavesta Rd, Lexington, KY 40502

Preliminary Agenda (draft, subject to change)

Monday, June 3, 2013				
6:30 am – 10:00 am	Breakfast – salon FG			
7:30 am – 8:30 am	Registration - lobby			
8:30 am – 9:00 am	Welcome by Dr. Pete Stahl and Dr. Frank Galey, Dean, College of Agriculture and Natural Resources Salon ABC			
9:00 am – 9:30 am	Land Reclamation in the Rocky Mountain West* Mark Paschke, Shell Endowed Chair of Restoration Ecology Forest and Rangeland Stewardship Department and Research Associate Dean Warner College of Natural Resources, Colorado State University			
9:30 am – 10:00 am	Economic Importance of Land Reclamation in Wyoming and the West* tbd			
10:00 am – 10:30 am	break - lobby			
10:30 am – 11:00 am	Governor Matt Mead* *speakers tentative			
11:00 am – 11:45 am	Ghost Towns of the Rocky Mountains Preethi Burkholder			
11:45 am – 1:00 pm	Lunch – Salon ABC			
	Wildlife Garden Ballroom	Forestry Salon D	Soils Salon E	Water Salon FG
1:00 pm – 1:30 pm	Sustaining Raptor Populations at the North Antelope Rochelle Mine in Northeast Wyoming by G. McKee, P. Griswold and M. O'Rourke	Rebuilding Soils for Forest Restoration on Appalachian Mined Land by C.E. Zipper, J.A. Burger, C.D. Barton and J.G. Skousen	Reclamation Planning for Energy Development projects: Wamsutter, WY; A Case Study by C. Driessen, B. Teson, D. Marshall and R. Ansotegui	Passive Aeration Using a Trompe by B.R. Leavitt, B.J. Page, C.A. Neely, R.M. Mahony, T.P. Danehy, C.F. Denholm, S.L. Busler and M.H. Dunn
1:30 pm – 2:00 pm	Female Wild Turkey Ecology on a Midwest Reclaimed Surface Mine by K.S. Delahunt, J.R. Nawrot and C.K. Nielsen	Growth of Hardwood Trees on Brown and Gray Mine Spoils in West Virginia by L. Wilson-Kokes, J. Skousen, P. Emerson, C. DeLong and C. Thomas (student)	Quantitative Monitoring in oil and Gas Reclamation: What Can It Do For You? By T.J. Minnick	Passively-Enhanced Lime Mixing and Dissolution by T.P. Danehy, B.R. Leavitt, B.J. Page, R.M. Mahony, C.A. Neely, C.F. Denholm, S.L. Busler and M.H. Dunn
2:00 pm – 2:30 pm	North Cumberland Wildlife Management Area Proposed Coal Mining Simulations and Animation by J. Spencer	Native Tree Survival and Growth on an Experimentally Reclaimed Appalachian Coal Mine by S.C. Koropchak, C.E. Zipper, J.A. Burger and D.M. Evans (student)	Approaching oil and gas pad reclamation using data modeling: A framework for the future by M.F. Curran, B.J. Wolff and P.D. Stahl (student)	Filed Trial of a Pulsed Limestone Diversion Well by P.L. Sibrell, C. Denholm and M. Dunn
2:30 pm – 3:00 pm	Can Elk Mitigate Disturbance Risk Associated With Natural Gas Development? By C.B. Buchanan and J.L. Beck (student)	The Presence of the Tree-of-Heaven Ailanthus Altissima) Interfers with Beneficial Symbionts and Negetively Impacts Oak Regeneration on Reclaimed Coal Mine Lands by J.M. Bauman, S. Hiremath, C. Byrne and S.M. Byrd	Defining Oil and Gas Pad Reclamation Success on Wyoming BLM Lands by M.F. Curran, B.J. Wolff and P.D. Stahl (student)	Off-the-Grid Aeration to Address Nuisance Consituent Production from Specific Passive Treatment System Process Units by R.W. Nairn, K.A. Strevett and J.A. LaBar
3:00 pm – 3:30 pm	break - Salon ABC and lobby			

3:30 pm – 4:00 pm	Predicting the Influence of Restoration on Greater Sage-Grouse Lek Connectivity by B.A. Fitzpatrick and M.A. Murphy (student)	Factors Influencing the Establishment of Volunteer Vegetation on Quarry Overburden by J.A. Franklin and D.S. Buckley	Challenging the Idea of Reference Sites as Indicators for Oil and Gas Pad Reclamation Success by M.F. Curran, B.J. Wolff and P.D. Stahl (student)	The Construction and Initial Results of a Demonstration Passive Treatment System for Removing Sulfate at a Site on Vancouver Island, British Columbia by E.P. Blumenstein, R.J. Schipper and J.J. Gusek
4:00 pm – 4:30 pm	Greater Sage-Grouse Response to Bentonite Mining in the Bighorn Basin, Wyoming by A. C. Pratt and J.L. Beck (student)	Russian Thistle Population Dynamics at a Former Coal Mine in Northern New Mexico by A. Maier and J. White	Monitoring and Thresholds For Irrigated Lands in Coal Bed Methane Areas by J. Thomas	Seasonality of Iron Removal Within the Initial Oxidation cell of a Passive Treatment System by L. R. Oxenford and R. W. Nairn (student)
4:30 pm – 5:00 pm	Technical Division Meeting for Forest/Wildlife	Conserving an S1/G5/T2 Mustard at a Southcentral Montana Coal Mine Through Nursery Propagation and Transplanting by G.L. Johnson and R. A. Prodgers	Using Isotopes to Study Coalbed Natural Gas Co-Produced Water and Soil Interactions by K. J. Lilly and G. F Vance (student)	Passive Treatment Systems for the Removal of Selenium: Barrel Substrate Studies, Design, and Full-Scale Implementation by R.C. Thomas, M. A. Girts, J.J. Tudini, J. S. Bays, K.B. Jenkins, L. C. Roop and T. Cook
5:00 pm – 7:00 pm	Sponsor's Social/Posters – Grand Ballroom Lobby and Salon ABC			

Tuesday, June 4, 2013

6:30 am – 10:00 am	Breakfast – Salons ABC
8:00 am – 5:00 pm	Wamsutter field trip
6:00 pm – 10:00 pm	Early Career Professionals Social, UW Visual Arts building

Wednesday, June 5, 2013

6:30 am – 10:00 am	Breakfast – Salons ABC			
	Case Studies in Geomorphic Reclamation Garden Ballroom	Forestry/Wildlife Ballroom D	Ecology Ballroom E	Stream Restoration & Wetlands Ballroom FG
8:00 am – 8:30 am	Geomorphic reclamation of abandoned coal mines on Vermejo Park Ranch near Raton, New Mexico I. Design and construction oversight by R. Spotts, M. Brennan, R. Wade, K.J. Malers, K.E. Carlson and Z. Isaacson	Long-Term Effects of Organic Amendments and Potential Carbon Sequestration in Southwest Virginia Mine Soils by W.L. Nash, W.L. Daniels and J. A. Burger	Fitness More Than Diversity Guides Vegetational Recovery by R.A. Prodgers	Long-Term Trends of Specific Conductance in Waters Emerging From Headwater Valley Fills in Virginia, USA by D.M. Evans, C.E. Zipper, P.F. Donovan, and W.L. Daniels (student)
8:30 am – 9:00 am	Geomorphic reclamation of abandoned coal mines on Vermejo Park Ranch near Raton, New Mexico II. Reclamation and Revegetation by K.E. Carlson, R.F. Bay, R. Spotts, Z. Isaacson	The Fate of Nitrogen in Biosolids Amended Mineral Sands Mine Soils by J. Dickerson, W. L. Daniels, G. Evanylo and K. Haering (student)	Vegetation Inventory and Survey Methods; A Reclamation Tool by M.L. Pokorny, D.R. Neuman, K. Edwards and P.D. Smith	Chemical Constituents in Water and Sediment from Grand Lake O' the Cherokees, Oklahoma, Downstream from the Tri-State Lead-Zinc Mining District by S.C. Zawrotny, J. Arango-Calderon, L. Diede, A. McLeod, G. Rutelonis, M. Salisbury, M.P. Beltran-Zuniga, G.A. Busch, K.R. Douglas, E.F. Garifalos, L. Liu, N. Nabavizadeh, M. Rice, D.W. Stevens, J.A. LaBar, D.E. Townsend III, R.C. Knox and R.W. Nairn (student)

9:00 am – 9:30 am	Comparison of vegetation characteristics between geomorphic and traditional reclamation areas at a surface coal mine in northwestern New Mexico by J. Voss and T.C. Ramsey	From BS to BMP- Using Biosolids for Taconite Tailings Reclamation by P. Eger, C. Lincoln, T. McMillen, K. Hamel, K. Dykhuis, C. Maxwell and J. Takala	Comparison of Vegetation Cover vs. Precipitation on a Reclaimed Coal Mine in Northeastern Wyoming by D. Gardner	Comparison of Natural Recovery of Surface Waters From Coal and Phosphate Mining by R.S. Grippo and J.R. Pratt
9:30 am – 10:00 am	Achieving contemporaneous geomorphic reclamation at El Segundo Mine, New Mexico by E. Hydrusko	Compost Rates for Remediating Reclaimed Saline Soils by C. Strom	Long-term Comparison of Vegetation Reference Area on Reclaimed Coal Mines in Northeastern Wyoming by B. Schladweiler	Using Texas Rapid Assessment Method for Premine and Post-mine Wetland Evaluations by E.D. Bearden and J.D. Wooten
10:00 am – 10:30 am	Break – Salons ABC			
10:30 am – 11:00 am	Stream Restoration Initiative at the Jewett Lignite Mine by J.McKinney, J. Young and D. Ezell	Biochar for Reclamation in the Rocky Mountains: context, Science and Policy – can we find a nexus that works? By A. Harley, B. McMullen, and M. Williams	How far have we come? A Reclection of Rehabilitation Research i n Australia Over the Past Two Decades by D.R. Mulligan	Determination of Dominant Trace Metal Sequestration Processes in Two Vertical Flow Bioreactors Using Modified Tessier Extractions by J.A. LaBar and R.W. Nairn (student)
11:00 am – 11:30 am	Interactive Discussion	A Comparison of Different Volumes of Biochar on Acidic Soils to Increase Plant Growth and Reduce Soil Acidity by C.D. Peltz	Developments in Mine Closure and Integration with Operations in Australia by H. Lacy	Decommissioning of an Anaerobic Passive Biochemical Reactor at the Standard Mine Superfund Site, Crested Butte, CO by N.T. Gallagher, E. Blumenstein, T. Rutkowski and J. DeAngelis
11:30 am - noon	Interactive Discussion	A Combination of Alumina Refining Residue (Bauxsol Acid B Extra™) and Biochar to Reduce Metal Concentrations in Acid Mine Drainage by C.D. Peltz, C. Zillich and K.L. Brown	The 10th Year of the International Mine Closure Conferences: its Positive Influences on Effective Mine Closure, Completion and Reclamation in Australia by H.W.B. Lacy	Ten Years After: The Operation of the Luttrell Biochemical Reactor by D.J. Reisman, A.K. Frandsen, D.T. Shanight and T. McAdams
12:00 – 1:00 pm	Lunch – Salons ABC			
	Advances in the Science of Geomorphic Reclamation Garden Ballroom	Geotech/Soil Ballroom D	Revegetation Technologies Ballroom E	Soil Biogeochemical Processes Ballroom FG
1:00 – 1:30 pm	Geomorphic principles applied to reclamation at BHP Billiton's Navaho Mine by C. Brandt, T. Ramsey, L. Raymond	Infiltration in Reconstructed Channels by K. Bramlett, J.C. Stormont and M. Stone (student)	Benefits of Transplanting Salvaged Sagebrush Plants to Accelerate Reclamation by M. Clancy, K. Fothergill, K. Tindall, L. Meyers, J. Diehl, M. Callen and S. Paulsen	Geochemical Properties of Weathered Soils and Underlying Overburden of the Pottsville Group in Central Appalachia by D.K. Johnson and W.L. Daniels (student)
1:30 – 2:00 pm	Evaluation of geomorphic reclamation performance and models in the Southwestern U.S. by M. Stone, J. Stormont, E. Epp, C. Byrne, S. Rahman, R. Powell, W. Rider and S. Perkins	Channel Armoring Techniques Using Cellular Confinement Systems by J.A. McConnell, and B. Wedin	Investigating Sagebrush Reclamation Success for Bentonite Mined Areas in the Big Horn Basin, WY by Z J. Liesenfeld, P.D. Stahl and L.C. King (student)	Predicting Total Dissolved Solids Release from Overburden in Appalachian Coal Fields by J. Odenheimver, J. Skousen and L.M. McDonald (student)
2:00 – 2:30 pm	Comparative analysis of multiple softwares used in aiding geomorphic reclamation by K. Brown	Weathered Spoil as a Low Permeable Barrier by M. da Rosa, C.T. Agouridis and R.C. Warner (student)	Mature Subalpine Tree Transplanting at the Climax Mine, Climax, CO by R.F. Bay, K.E. Carlson and A. Hilshorst	Leaching Potentials of Coal Spoil: Effects of Rock Type and Degree of Weathering by Z. Orndorff and W.L. Daniels

2:30 – 3:00 pm	High resolution LiDAR as a base for designing geomorphic reclamation schemes for surface mines in the Central Appalachians by C. Yuill	A Comparison of Soil Condition, Vegetation Communities, and Soil Redox Characteristics of Surface Mined Wetlands and Natural Wetlands in Southern Illinois by B. Borries, K.W.J. Williard, J. Schoonover and S. Indorante (student)	Field Simulation of Different Approaches to Revegetate an Acid Sulfide Spoil in Brazil by L.E. Dias, I.R. de Assis, J.M. Esper and O.A. Ferreira	Technical Division Meeting for Soils and Overburden
3:00 pm – 3:30 pm	Break – Salons ABC			
	Advances in the Science of Geomorphic Reclamation Garden Ballroom	Geotech/Soil Ballroom D	Geotech Tailing Ballroom E	Soil Biogeochemical Processes Ballroom F-G
3:30 – 4:00 pm	A Comparison of Stream Chemistry in Three Restored Illinois Coal Basin Streams: Initial Conditions vs. 10 and 20 Years Post-Restoration by B. Borries, K. Williard, J. Schoonover, and J. Nawrot (student)	Soil Test and Bermudagrass Forage Yield Responses to Two Years of Animal Waste and FGD Gypsum Amendments by J.J. Read, A. Adeli, J.P. Brooks and D.J. Lang	Federal Agency Benefit Analysis of a Remediation Monitoring tool for Abandoned Mine Lands by L.M. Barber Franklin and D.R. Neuman	Changes in Spoil Electrical Conductivity (EC) and Sodium Adsorption Ration (SAR) Following Irrigation at a Mine Site in Northwestern New Mexico by S. Perkins, K. Applegate, B. Musslewhite and B. Buchanan
4:00 – 4:30 pm	Interactive Discussion	Reclamation of Mined Land with Switchgrass, Miscanthus, and Arundo for Biofuel Production by J. Skousen and B. Gutta	Transitioning From Clean Water Act Nationwide Permitting to Individual Permitting by M.P. Owens and C.K. Applegate	Coal Combustion By-Products Disposal Practices at a Surface Coal Mine in New Mexico: Leachate & Groundwater Quality Study by C. Parker, K. Hart, B. Thomson, J. Stormont and M. Stone
4:30 – 5:00 + pm	Technical Division Meeting for Land Use Planning Geotechnical Engineering/ Tailings	Ectomycorrhizal Species Beneficial for Plant Establishment on Abandoned Mine Lands by S. Hiremath, K. Lehtoma and J.M. Bauman		Technical Division Meeting for Water Management
4:30 pm – 5:30 pm	Happy hour, Hilton bar/lobby			
6:30 pm – 10:00 pm	Social, Wyoming Territorial Park			

Thursday, June 6, 2013

6:30 am – 10:00 am	Breakfast – Salons ABC		
	Reclamation Success Evaluation Ballroom D	Revegetation on Oil & Gas Ballroom E	Water Ballroom FG
8:00 am – 8:30 am	Is the Definition of Scale the Key to our Understanding and Delivery of the Components of Structure, Diversity and Function in the Restoration of Ecosystems? By R.N. Humphries	Soil Amendment Application during Drought on Oil and Gas Sites in Wyoming by B. Schladweiler	A Study on the Possibility of Passively Treating a Heap Leach Pad Drain Down Soluntion by A.M. Moderski, J.J. Gusek, C. Bucknam, C. Hager and T.R. Wildeman
8:30 am – 9:00 am	Development of a Spodumene (Lithium) Mine on Agricultural Land in the Southwest of Western Australia by K. Lindbeck and B. Clark	Design, Development, and Field Experience with Wood-Strand Erosion Control Mulch for Mine and Pipeline Projects by J.H. Dooley, D.N. Lanning and M.C. Perry	Bench-Scale Treatability Testing for In Situ Bioremediation of Mining-Influenced Water by N.T. Smith, N.A. Anton, D.J. Reisman, M.R. Nelson, A.K. Frandsen, R.L. Olsen and W.A. Rosche
9:00 am – 9:30 am	Reclamation of Two Coal Mines in Mongolia: The Eren Mine and the Planned Tavan Tolgoi Mine by S.E. Williams, V. Pfannensteil and A. Jalsrai	Silvertip Pipeline Spill Revegetation by L. J. Ballek and L. Alvey	Antimony Removal From Mine Water Using Adsorbent Media by D.T. Klempel
9:30 am – 10:00 am	The Contribution of Active Surface Mines in the Conservation of Lower Plant Communities in the South Wales Coalfield, United Kingdom by R.N. Humphries	Soil property recovery on a natural gas pipeline reclamation chronosequence by C.K. Gasch, S.V. Huzurbazar and P.D. Stahl (student)	A Short History of Pyrite and Acid Rock Drainage: An Engineer's Perspective of ARD by J.J. Gusek
10:00 am – 10:30 am	Break – Salons ABC		

	Reclamation Success Evaluation Ballroom D	Revegetation on Oil & Gas Ballroom E	Remediation Problems for Reclamation Ballroom FG
10:30 am – 11:00 am	Using The RQ-11 Raven A and the T-Hawk for Oversight Inspections of Surface Coal Mines in West Virginia by N.L. Carter, L.J. Monette and D.T. Beaman	Natural Gas Field Reclamation Integrating Reclamation Science, Weed Management, and Monitoring by D. Marshall, R. Ansotegui, B. Teson and C. Driessen	Co-Treatment of Acid Mine Drainage with Municipal Wastewater using the Activated Sludge Process: Performance Evaluation by T.A. Hughes and N.F. Gray
11:00 am – 11:30 am	Field Direct, A Field Inspection Application Designed to Improve Data Integrity and Accessibility for Management Oversight by K. Ward	Comparison of Basal and Aerial Cover for Total Vegetation Cover and Total Ground Cover on Oil and Gas Sites in Wyoming by C. Adams	Onsite Wasterwater Natural Treatment and Effluent Reuse System At The Omnilife Soccer Stadium in Guadalajara, Mexico by A. Garrido, M. Ogden, P. Munoz and E. English
11:30 am – 12 noon	Technical Division Meeting for LUP	Technical Division Meeting for Ecology	
12:00 – 2:00 pm	ASMR Awards Luncheon Salon ABC		
	Innovations in Reclamation Evaluation Ballroom D	Geotech Tailing Ballroom E	Special Reclamation Challenges Ballroom FG
2:00 pm – 2:30 pm	Geotechnical-Geophysical Void mapping and Foamed-Sand Backfilling of the Rapson Coal Mine, Colorado Springs, Colorado – Case Study by K. Hanna, J. Pfeiffer, S. Hodges, D. Dunham, R. Palladino and A. Amundson	Azurite Mine – A Cercla Removal Action Case Study by D.G. Wasley	Surface Reclamation of the Captain Jack Mill Superfund Site by N. Anton, T. Bragdon, M. Boardman, J. Jenkins and C. Van Drie
2:30 pm – 3:00 pm	Ecological Restoration Plan for Abandoned Underground Coal Mine Site in Eastern China by Z. Hu, W. Xiao, Y. Zhao and F. Wang	Creative Approaches To Old Reclamation Challenges by D. Close	Site Characterization and Evaluation of Reclamation Alternatives at the Black Pine Mine by K.T. Houck, D.J. Clary and M.R. Donner
3:00 pm – 3:30 pm	Statistical analysis of the effects of restoration on stream morphology in the Kerber Creek watershed, CO by T. I. Klein, L. Archuleta, J. Willis and N. Tedela	Geochemical Modeling of Uranyl Sorption At A Colorado Test Site by K.M. Brown	Remediation of the Milltown Sediments in Montana by D. Neuman, F. Hons, T. Moore, H. Shahandeh, R. Loeppert and C. Bangira
3:30 pm – 4:00 pm	Application of Innovative Reclamation Technique for a Steeply Dipping Open Pit Mine of India: A Case Study by P. Kumar and A. Horel	Application of Landform Grading To Reclaim a Former Wyoming Uranium Mine by J.K. Murphy and M.R. Donner	Case Study: Utilizing Paste Technology for Reclamation of the Ute Ulay Upper Tailings Impoundments, Lake City, Colorado by T. Tafi

2013 Joint Conference

2ND WYOMING RECLAMATION AND RESTORATION SYMPOSIUM AND

30TH ANNUAL MEETING OF THE AMERICAN SOCIETY OF MINING & RECLAMATION

June 1-7, 2013 ▪ Hilton Garden Inn ▪ Laramie, Wyoming (USA)

RECLAMATION ACROSS INDUSTRIES

REGISTRATION FORM

In order to facilitate transportation, lodging, meal functions, and meeting room needs for the Conference, and to avoid late fees, the Program Committee strongly encourages pre-registering for the Conference. Costs for registration, the various workshops and tours, plus other events are listed below.

Name ______________________________

Company/Affiliation ______________________________

Address ______________________________

Address ______________________________

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GENERAL AND TECHNICAL SESSIONS

		Number	Total
Sunday-Thursday, June 1-6, 2013 **Pre-registration** *(until May 1, 2013)* *Includes ASMR Awards banquet ticket*	$275 /person		$
Late registration *(after May 1, 2013)* *Includes ASMR Awards banquet ticket*	$325 /person		$
Accompanying person/Spouse registration	$100 /person		$
One Day Registration *(check day)* *[ ] M [ ]Tu. [ ]W [ ]Th.*	$125 /person		$
Student Registration *(submit copy of student ID with the registration form)*	$125 /person		$
Late registration *(after May 1, 2013)*	$175 /person		$

WORKSHOPS

		Number	Total
Basics of ArcGIS and GPS for Field Mapping Sat. June 1, 9am – 5pm and Sun. June 2, 9:00am – 4:00pm With Janine Ferarese, Marcelo Calle and Alan Buss	Enter $166 but look at page 3		$
Reclamation of drastically disturbed salt- and sodium- affected soils Sun. June 2, 9am-4pm with Jay Norton, Raymond Ansotegui and Calvin Strom LREC Greenhouse (30th & Harney Streets)	$25/person		$

SUBTOTAL: REGISTRATION AMOUNT (US DOLLARS) $__________

TOURS *(FIRST COME, FIRST SERVED)*

		Number	Total
Wamsutter Gas Field *(maximum 250)*	$ 40/person		$
Powder River Basin – *Rolling Hills Wind Farm, Smith Ranch, ISR Uranium Mine, North Antelope Coal Mine* *(maximum 50)*	$ 150 /person		$

OTHER FUNCTIONS

		Number	Total
Early Career Professional's Social (Visual Arts Center) *(2 drinks, appetizers)*	$25 /person		$
ASMR Awards Banquet *(those not registered will need a ticket)*	$30 /person		$
Evening Social, Wyoming Territorial Prison Dinner Theater *(dinner, entertainment) Limited to 160 people maximum*	$35 /person		$

SUBTOTAL: TOURS & FUNCTIONS AMOUNT (US DOLLARS) $__________

TOTAL REGISTRATION AMOUNT (US DOLLARS) $__________

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Selecting Tree Species for Reforestation of Appalachian Mined Land

V. Davis, J.A. Burger, R. Rathfon, C.E. Zipper, C.R. Miller

Photo 1: This young northern red oak seedling will have an excellent chance to survive, grow, and contribute to the development of a post-mining forest because it was planted on a mine site where FRA reclamation practices were used.

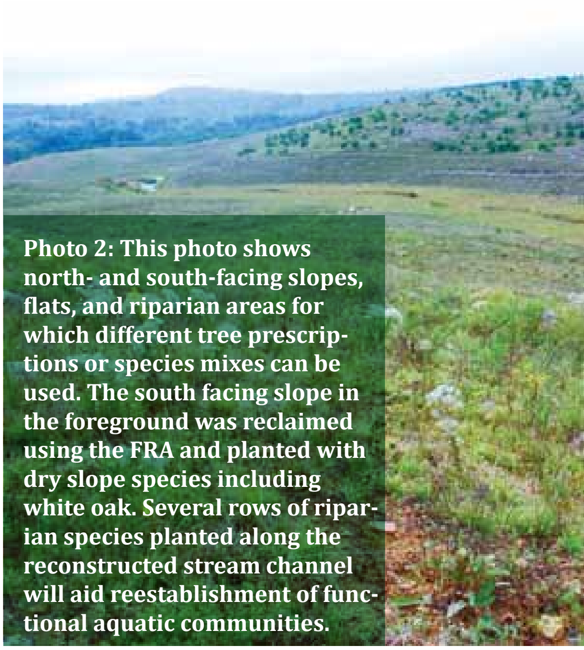

Photo 2: This photo shows north- and south-facing slopes, flats, and riparian areas for which different tree prescriptions or species mixes can be used. The south facing slope in the foreground was reclaimed using the FRA and planted with dry slope species including white oak. Several rows of riparian species planted along the reconstructed stream channel will aid reestablishment of functional aquatic communities.

The Forestry Reclamation Approach (FRA) is a method for reclaiming coal surface mines to forested post-mining land uses (FR Advisory No. 2, Burger and others 2005). The FRA's fourth step is to plant native trees for commercial timber value, wildlife habitat, soil stability, watershed protection, and other environmental benefits. This advisory provides guidance for selecting native tree species to plant on mine sites that are reclaimed using the FRA in the Appalachian region.

Favorable soil properties and non-competitive ground cover are essential features on mine sites intended for reforestation. Use of the FRA will provide these features for planted trees while also providing conditions suitable for natural seeding of plants from nearby forests.

Selecting Tree Species

More than 100 native tree species and numerous native shrub species grow within Appalachian forests. This diversity reflects the many site conditions found across the region. Forest site conditions are affected by many factors including sunlight, moisture, soil properties, proximity to native seed sources, and competition among species. The native trees most likely to produce healthy, productive forests on mine sites are those well suited to the site's growing conditions (see Photo 1). Landowner objectives, permitting and bond release requirements, and the mine's location relative to species' native ranges should also be considered when selecting trees.

Site Types for Tree Species Selection

Proper species selection for any portion of a mine site is determined by its location on the landscape, because landscape position influences availability of soil moisture and sunlight.

Landscape position is a combination of site aspect and topography, so direction of slope, slope steepness, and location on the slope are the primary factors to consider when selecting tree species for planting (Figure 1).

Aspect is the direction that a slope faces. Slopes facing south receive more solar radiation than north-facing slopes. While east- and west-facing slopes receive similar amounts of sunlight, the west-facing slopes receive sunlight during the hottest part of the day – mid and late afternoon. As a result, slopes with south and west aspects have drier soils than those that face north and east. Northeast- and east-facing slopes are generally most favorable for tree growth because of higher levels of soil moisture, while southwestern slopes are generally least favorable because of their dryness (Figure 2).

Topography describes the surface shape, relief or terrain, and elevation of a site's position on the land surface. Topography will influence soil moisture availability. Steep slopes are drier than more gentle slopes because they shed more rainfall as runoff, allowing less water to infiltrate the soil. Large, uncompacted, flat areas on mine sites can provide moist soil conditions and good growth potential; while landscape channels, depressions, and stream banks will have wetter soil conditions.

Here, we describe four general landscape positions, or site types, that can be applied to mined landscapes when selecting tree species for planting (Figure 1).

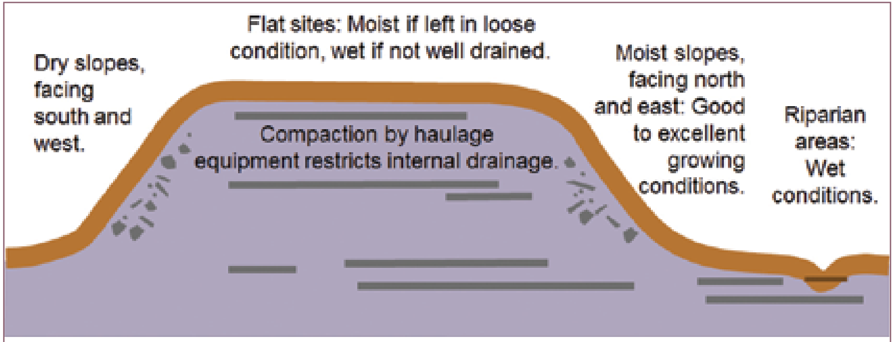

Figure 1. Four site types that commonly occur on coal surface mines and influence tree species suitability.

Dry Slopes: Slopes facing south and west; areas with dry growing conditions (Photo 2).

Moist Slopes: Slopes facing north and east; areas with moist growing conditions and soils that are well drained.

Flat Sites: Flat and rolling areas with moist growing conditions if soils are left in a loose condition and with enough landscape relief to allow water to drain easily, or wet if not well drained.

Wet Sites: Areas within and adjacent to channels and surface depressions, including reconstructed streams and wetlands: areas with wet soils caused by landscape position or poor internal drainage.

Tree Prescriptions

A tree prescription is a list of species to be planted, with planting rates, for any portion of a mine or the entire area. We recommend that tree prescriptions be developed for the major site types that occur within each area to be planted. Most large mines will have several site types, each of which can be targeted for planting with its own tree prescription.

We provide examples of tree prescriptions that can be applied on Appalachian mined lands (Table 1) for each of the four primary site types (Figure 1). The example prescriptions are for mines where the reclamation goal is native forestland that will produce commercial timber and environmental services.

Mine operators can change these prescriptions as needed. Table 2 includes information for other tree species, and range maps for most native trees can be found on the internet (for example: USFS, 1990, "Silvics of North America"; or USDA, 2012, "Plants Database).

Some mines contain only one primary site type. For example, a contour mine on a southern slope would be a "dry

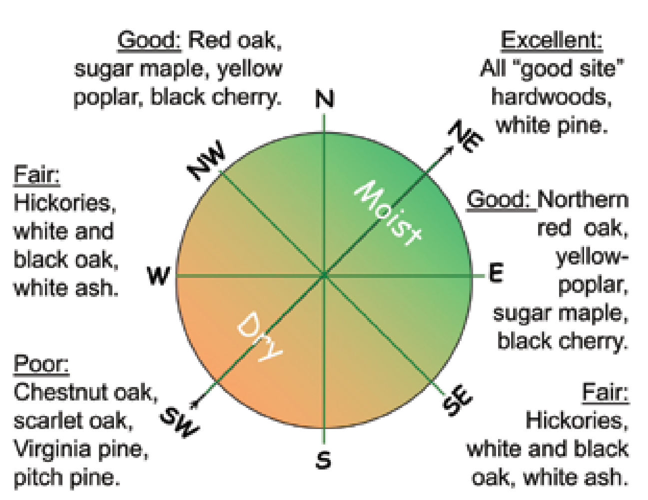

Figure 2. The direction in which a slope faces (its aspect) will influence both soil moisture and sunlight availability and should be considered in tree species selection. Aspect is rated as having excellent, good, fair, or poor tree-growth potential. "Good site" hardwoods are those prescribed for sites with good growth potential in the diagram.

Photo 3 (above top): Planting several rows of wet-site species along water channels can accelerate restoration of streamside vegetation, as has occurred on this mine. Riparian woody vegetation aids functioning aquatic communities in reconstructed streams by shading the channel and producing organic matter that enters the stream.

Photo 4 (above bottom): This south-facing slope on a Tennessee mine site, photographed during its seventh growing season, was reclaimed with the FRA and planted with oaks, green ash, yellow-poplar and eastern white pine. Volunteer species including sweet birch, red maple, black gum, and black cherry also became established.

slope" over most of its area, so prescribing "dry slope" species for the entire site would be an effective strategy. However, other mines include extensive areas of several site types. For example, a mountaintop mine reclaimed to approximate original contour could be planted with dry-slope species on its south- and west-facing slopes, moist-slope species on north- and east- facing slopes, and wet-site species along drainage channels and ponds.

For all tree prescriptions, species should be planted as a diverse mix across the landscape, not as single-species rows or blocks. Planting a diverse mix can be achieved by planters carrying half of the prescribed species and mixing them as they plant. The person planting the adjacent row could plant different species, so that all prescribed species are mixed into two adjacent rows.

Tree Prescription Advice and Guidance

Select Species Suited to Site Conditions.

Species should be prescribed by a person who is knowledgeable of local tree species, mine site conditions, and landowner and reclamation goals. If this expertise is not available, the Table 1 example may be used. Parties using Table 1 should check that each prescribed species' native range includes the planting area. If not, this publication can be used to select substitutes that are native to the area and suited to site conditions (Table 2).

Plant Enough Seedlings To Get The Job Done.

On mines with bond-release requirements of 450 surviving stems or less, we recommend planting 700 trees per acre – equivalent to an 8 feet x 8 feet spacing. Assuming that survival rates on mine sites often average about 70%, the result would be 490 surviving trees per acre (70% of 700 planted). If a larger number of surviving stems is required, the number of planted trees should be increased accordingly. It is important to work closely with the state regulatory authority to identify and establish the tree stocking standards that will be applied at bond release, and to plant enough trees to provide a margin of safety to ensure compliance with bond release standards.

Plant and Mix Multiple Species

Appalachia's native forests are diverse. It is common to find 40 or more tree and shrub species per acre in these forests. On mine sites, soil and site conditions are often quite variable. The presence of multiple species can help a plant community persist if a pest or pathogen severely affects one or several of its species. For these reasons, we recommend planting multiple species.

Wet-site species are often planted as several rows along stream banks, ponds, or wetland borders (Photos 2 and 3). Flowing waters will attract wildlife, thus creating opportunities for unplanted species' recruitment. Most flat site types will be on large area or mountaintop mines far from forest seed sources, so that prescription includes more species than for other site types.

Plant Crop Trees, Wildlife Trees, and N-fixing Trees.

For most mine areas, we recommend that three types of species be prescribed for planting.

1. Crop trees that will form a forest canopy;
2. Tree species selected for wildlife benefits; and
3. Tree species that will fix atmospheric nitrogen (N), improving soil quality.

Crop trees are species such as black cherry, yellow poplar, sugar maple, and the oaks that can produce economic value for the landowner and form the forest canopy.

Some crop-tree species have heavy seeds that are slow to disperse. For example, oaks and hickories are major forest components throughout much of Appalachia, but their heavy seeds will not travel far without the help of animals. Hence, our prescriptions emphasize heavy seeded crop-tree species that are important components of the region's natural forests, especially the oaks.

Wildlife Trees and Shrubs: Although many crop tree species provide wildlife benefits, tree and shrub species of lesser commercial value but important to wildlife value also occur in natural forests Thus, in addition to crop trees, other tree and shrub species should be prescribed for improving wildlife habitat in the FRA planting.

Species such as flowering dogwood and eastern redbud establish and grow rapidly, producing early canopy structure used by birds for cover and nesting, and fruits and seeds that serve as wildlife food. Attracting wildlife aids natural succession and forest development. Mammals and birds consume fruits and seeds in unmined habitats and then move through the reclaimed mine where seeds passing through them are deposited. If site conditions are favorable, such seeds may germinate to produce live seedlings.

Some tree species occurring in natural forests at relatively low densities, such as common persimmon and black walnut, produce large fruits and seeds. These species' large seeds make them especially valuable as wildlife food sources but also limit their spread into the reclaimed mine landscape by wind and animals. Planting heavy-seeded species as seedlings is usually necessary to establish them on reclaimed mines.

Certain species produce physical structures that will aid habitat development as they mature. For example, native pines planted at low densities will provide winter cover for wildlife species such as white-tailed deer. As another example, shagbark hickory and white oak have exfoliating bark that can provide shelter for bat species, including the endangered Indiana Bat. Most crop tree species also provide wildlife benefits. For example, oaks produce acorns, an important winter food source for game species such as white-tailed deer. As we use the term here, wildlife trees are those planted in addition to crop trees for providing additional wildlife benefits.

Nitrogen (N) Fixing Trees remove N from the air, transforming it to organic forms that enrich the soil. Unless constructed from salvaged forest soils that contain surface organic material (see FR Advisory No. 8, Skousen and others 2011), mine soils will generally be low in N, an essential plant nutrient. If not taken up by plants, the N applied as fertilizer will remain in the soil to support forest development only for the first few years. Thus, we recommend planting at least one tree species that is able to "fix" N from the atmosphere.

Encourage Natural Succession

The term natural succession describes the natural progression of plants becoming established and replacing other plants over time on disturbed areas. The FRA is designed to create a tree growth environment that will support natural succession to develop a diverse forest plant community (Photo 4) (see FR Advisory No. 5, Groninger and others 2007,).

Early-succession trees are often referred to as pioneer plants because they colonize open areas, need full sunlight to germinate (they are not shade tolerant), grow very fast and are short-lived. Mid-succession trees replace the pioneer species overtime, have intermediate shade tolerance, and are also fast growing but longer-lived than the pioneer species.

Late-succession species make up most of the trees in the mature forest, they can grow and establish well in full shade (they are shade tolerant). Late-succession species such as sugar maple, American beech, and shagbark hickory establish and grow more slowly than early- and mid-succession species but are long-lived and will eventually replace them in the developing forests, especially on moist sites. On dry sites, the oaks will persist.

We recommend prescribing a compatible mix of early-, mid- and late-succession tree species that will shorten the period of time from bare ground to a diverse, valuable, mature forest. This can be accomplished by planting a mix of crop trees and wildlife trees.

Species-Specific Considerations

Table 1. Example tree species prescriptions (stems per acre). Use species native to the planting area, and those that are suited to the landscape position of the mine site. If more than 450 surviving stems are required by state regulations, increased planting numbers are advised.

Dry Slopes (south, west)		**Flat Sites** (and rolling)		**Moist Slopes** (north, east)		**Wet Sites:** (riparian)	
Crop trees		*Crop trees*		*Crop trees*		*Crop trees*	
white oak	200	white oak	100	white oak	100	pin oak / river birch †	200
scarlet or post oak	100	northern red oak	100	northern red oak	200	American sycamore	200
black oak	100	sugar maple	100	sugar maple	100	sweetgum	200
chestnut oak	100	yellow- poplar	100	yellow poplar	100		
Virginia pine	100	black cherry	100	black cherry	100		
		black walnut	100				
Nitrogen fixing tree		*Nitrogen fixing tree*		*Nitrogen fixing tree*		*Nitrogen fixing tree*	
black locust	25	bristly locust	20	bristly locust	25	alder	25
Wildlife trees		*Wildlife trees*		*Wildlife trees*		*Wildlife trees*	
common persimmon	25	flowering dogwood	20	eastern white pine	25	black willow	25
eastern redbud	25	bitternut hickory	20	shagbark hickory	25	silky dogwood	25
mockernut hickory	25	eastern white pine	20	green hawthorn or gray dogwood	25	elderberry	25
		American hazelnut	20				

† Select either species, considering native range.

Hickories and black walnut are heavy-seeded late-succession species. Unfortunately, efforts to plant them on surface mines have often met with low success. Because of their importance as crop trees and wildlife habitat, hickories and black walnut should be included in tree prescriptions in low numbers as an effort to ensure that some do become established and eventually serve as seed sources. Hickories are important to wildlife, providing both mast and habitat on dry and moist slopes and flat areas. Black walnut can be prescribed for moist sites that have been reconstructed using salvaged soils (see FR Advisory No. 8, Skousen and others 2011).

White and green ash have been used in mine reclamation plantings with good success. We have not included ash species in Table 1 because an invasive insect pest, the emerald ash borer, is highly destructive to ash trees. Although the ash borer is not a current threat within most of the Appalachian coalfield, its range is spreading rapidly. Hence, many nurseries have ceased their production of ash seedlings.

Historically, American chestnut was a dominant forest species throughout Appalachia. However, most American chestnut have succumbed to invasive pests, a pathogenic fungus commonly known as the chestnut blight and the water mold *Phytophthora* root rot. Efforts are underway to develop blight and root-rot resistant hybrids of American chestnut that grow well on mine sites. However, the ability of currently available hybrids to withstand these pathogens over full life cycles has not been demonstrated.

American elm is another native tree species that is being affected by a fungal pest. Like American chestnuts, blight-resistant American elm hybrids are being developed.

Site-Specific Considerations

Although site type (Figure 1) is the major consideration for selecting tree species, other site conditions can also influence species selection.

Tree Growth Medium

The replaced mine soil must be able to provide growing trees with moisture, nutrients, and a drained and aerated soil condition if those trees are to survive and grow well. Soils selected and replaced using FRA practices will support most native species, but some soil conditions will limit species selection (see FR Advisory No. 8, Skousen and others 2011).

Most native tree species grow well in moderately acidic soils with pH in the 5.0 to 6.5 range. Soil pH levels above 7.0 are often found in mine soils constructed with unweathered spoils and will limit tree species selection. The FRA prescribes soil construction using "topsoil, weathered sandstone and/or the best available material." On most mines, materials will be available to enable construction of moderately acidic soils. This isfortunate because only a few of the species available for planting are able to tolerate highly alkaline or acidic soil. Bur oak and shumard oak can tolerate soil pH above 7.5, while a few species, including pin oak, can tolerate soil pH below 4.0.

Soil compaction will also limit species selection. A few native species such as green ash and American sycamore can survive in compacted soils, but most species will not survive. If a mine site is compacted, future forest productivity will be significantly diminished. The FRA recommends leaving soils loose and uncompacted. Where equipment traffic causes soil compaction, such soils should be ripped to produce loose conditions prior to planting.

Climate

Many hardwood species such as northern red oak and white oak occur throughout the Appalachian region and can be planted widely, but some species should be restricted only to certain site conditions. Species like sugar maple, bigtooth aspen, and red spruce are adapted to cool climates and will be more successful in northern areas and at elevations above 3000 feet in central Appalachia. In contrast, species such as southern red oak are adapted to the warmer climates of southern areas and lower elevations. Table 2 includes information on species' climate suitability.

Proximity to Seed Sources

Some tree species, like red maple, yellow-poplar, and American sycamore have wind-blown seed that can travel great distances, and they establish readily on mine sites with favorable soils. If an adequate seed source exists near the mine site, then these species do not need to be planted.

How "Flats" and "Moist Slopes" Differ

Large flat areas on mine sites often have poor internal drainage, meaning they lack subsurface channels to carry infiltrating water and air into the rooting zone. Poor internal drainage is a problem for planted trees because such soils retain excessive moisture and restrict access by plant roots to soil air. Although we generally recommend species for flat and rolling areas similar to those used on moist slopes, large flats with little surface relief will often have sufficient soil moisture to support wet-site species.

Wet-site species, however, will rarely do well on slopes because slopes have better internal drainage. The FRA recommends that soils be kept loose, but this is often accomplished more readily on slopes. More importantly, gravity aides the movement of subsurface water within the planted rees' rooting zone on sloped sites.

Standards for Success

Federal law (SMCRA) requires coal mining operations to restore the land's pre-mining capability. Many mining operations are conducted on lands that were forested prior to mining. Proper use of the FRA should produce a healthy forest that satisfies that SMCRA mandate. Selecting and planting tree species that are well suited to site conditions is essential to successful reforestation with the FRA.

Planted trees of many species will survive and grow well if the land is reclaimed using the FRA. Placing trees on soil and landscape conditions for which they are well suited will increase their survival and growth, improving prospects for prompt and trouble-free bond release. Proper use of the FRA will also allow volunteers of certain species to establish, increasing the restored forest's diversity and land use capability. Tree species should be selected for planting considering their suitability for the soil and landscape conditions on the mine site, and understanding that the resulting forest's composition will be a mix of planted and volunteer species.

Table 2. Suitable Woody Species for Appalachian Mine Site Reclamation. (A spread sheet with additional information is available on the ARRI website along with this Advisory)

Species	Latin	Leaf Type[a]	Site Type	Potential crop tree?[b]	Growth Rate[c]	N Fixer?	pH Range[d]	Climate[e]
boxelder	*Acer negundo*	d	wet		rapid		M-H	
red maple	*Acer rubrum*	d	all	see note	rapid		L-M-H	
sugar maple	*Acer saccharum*	d	moist, flat	yes	slow		L-M-H	C
gray alder	*Alnus incana*	d	wet		rapid	M	M	
speckled alder	*Alnus incana ssp. rugosa*	d	wet		mod.	L	L-M-H	
hazel alder	*Alnus serrulata*	d	wet		rapid	M	M	
mountain alder	*Alnus viridis ssp. crispa*	d	wet		mod.	L	L-M-H	
allegheny serviceberry	*Amelanchier laevis*	d	moist, flat		mod.		L-M-H	
false indigo bush	*Amorpha fruticosa*	d	moist		slow	M	L-M-H	
yellow birch	*Betula alleghaniensis*	d	moist, flat		slow		L-M-H	C
sweet birch	*Betula lenta*	d	moist, flat		mod.		L-M	
river birch	*Betula nigra*	d	wet	yes	rapid		L-M	W
bitternut hickory	*Carya cordiformis*	d	moist, flat	see note	slow		L-M-H	
pignut hickory	*Carya glabra*	d	dry	see note	slow		L-M-H	
shellbark hickory	*Carya laciniosa*	d	moist, flat	see note	slow		M	
shagbark hickory	*Carya ovata*	d	moist, flat	see note	slow		L-M-H	
mockernut hickory	*Carya tomentosa*	d	dry	see note	slow		L-M	
American chestnut	*Castanea dentata*	d	dry, moist	see note	rapid		L	
northern catalpa	*Catalpa speciosa*	d	moist, flat		rapid	L	M	
New Jersey tea	*Ceanothus americanus*	d	dry, moist		slow	L	L-M	
common hackberry	*Celtis occidentalis*	d	moist, flat		rapid		M-H	
common buttonbush	*Cephalanthus occidentalis*	d	moist, wet		mod.		L-M-H	
eastern redbud	*Cercis canadensis*	d	moist, flat		slow		M-H	
silky dogwood	*Cornus amomum*	d	moist, flat		mod.		M	
flowering dogwood	*Cornus florida*	d	moist, flat		mod.		L-M-H	
gray dogwood	*Cornus racemosa*	d	all		mod.		L-M	
American hazelnut	*Corylus americana*	d	moist, flat		mod.		M	
green hawthorn	*Crataegus viridis*	d	moist, flat, wet		mod.		L-M-H	
common persimmon	*Diospyros virginiana*	d	moist, wet		slow		L-M-H	
American beech	*Fagus grandifolia*	d	moist, flat	see note	slow		L-M-H	
white ash	*Fraxinus americana*	d	moist, flat	see note	mod.		L-M-H	
green ash	*Fraxinus pennsylvanica*	d	moist, flat, wet		rapid		L-M-H	
water locust	*Gleditsia aquatica*	d	wet		mod.	L	M-H	
honeylocust	*Gleditsia triacanthos*	d	moist, wet		rapid		L-M-H	
Kentucky coffeetree	*Gymnocladus dioicus*	d	moist, flat		slow	L	M-H	
American witchhazel	*Hamamelis virginiana*	d	moist, flat		slow		L-M	
American holly	*Ilex opaca*	e	moist, flat		slow		L-M-H	
common winterberry	*Ilex verticillata*	d	all		mod.		L-M-H	
black walnut	*Juglans nigra*	d	moist, flat	see note	rapid		L-M-H	
eastern redcedar	*Juniperus virginiana*	e	moist, flat		slow		L-M-H	
sweetgum	*Liquidambar styraciflua*	d	moist, wet	yes	rapid		L-M-H	
yellow-poplar	*Liriodendron tulipifera*	d	moist, flat, wet	yes	rapid		L-M	
sweet crab apple	*Malus coronaria*	d	moist, flat		slow		M	
red mulberry	*Morus rubra*	d	moist, flat		mod.		M	
hophornbeam	*Ostrya virginiana*	d	moist, flat		slow		L-M-H	
sourwood	*Oxydendrum arboreum*	d	dry, flat		slow		L-M	
red spruce	*Picea rubens*	e	moist, flat	yes	mod.		L-M	C
shortleaf pine	*Pinus echinata*	e	moist, flat	yes	rapid		L-M	W
pitch pine	*Pinus rigida*	e	dry		rapid		L	
eastern white pine	*Pinus strobus*	e	moist, flat	yes	rapid		L-M	
loblolly pine	*Pinus taeda*	e	dry	yes	rapid		L-M-H	W
Virginia pine	*Pinus virginiana*	e	dry		rapid		L-M-H	
American sycamore	*Platanus occidentalis*	d	moist, flat, wet	yes	rapid		L-M	
eastern cottonwood	*Populus deltoides*	d	moist, wet	yes	rapid		L-M	
bigtooth aspen	*Populus grandidentata*	d	moist, flat, wet		rapid		L-M	C
American plum	*Prunus americana*	d	moist, flat		mod.		M	
pin cherry	*Prunus pensylvanica*	d	moist, flat		rapid		L-M-H	
black cherry	*Prunus serotina*	d	moist, flat	yes	rapid		L-M-H	C
white oak	*Quercus alba*	d	dry, moist, flat	yes	slow		L-M	
scarlet oak	*Quercus coccinea*	d	dry	yes	rapid		L-M	
southern red oak	*Quercus falcata*	d	dry, flat	yes	mod.		L-M-H	W
bur oak	*Quercus macrocarpa*	d	dry, moist, flat	yes	mod.			
chestnut oak	*Quercus montana*	d	dry	yes	slow		L-M	
chinkapin oak	*Quercus muehlenbergii*	d	dry	yes	mod.		M-H	
pin oak	*Quercus palustris*	d	moist, wet	yes	rapid		L-M	
northern red oak	*Quercus rubra*	d	moist, flat	yes	mod.		L-M-H	
Shumard oak	*Quercus shumardii*	d	dry, flat	yes	mod.		M-H	W
post oak	*Quercus stellata*	d	dry	yes	slow		L-M	
black oak	*Quercus velutina*	d	dry	yes	mod.		L-M	
bristly locust	*Robinia hispida*	d	dry, moist, flat		rapid	M	L-M-H	
black locust	*Robinia pseudoacacia*	d	all		rapid	M	L-M-H	
black willow	*Salix nigra*	d	wet		rapid		L-M-H	
American black elderberry	*Sambucus nigra ssp. canadensis*	d	moist, flat, wet		rapid		L-M-H	
sassafras	*Sassafras albidum*	d	moist, flat		mod.		L-M-H	
American basswood	*Tilia americana*	d	moist, flat	yes	mod.		L-M-H	
American elm	*Ulmus americana*	d	moist, flat	see note	rapid		M-H	
slippery elm	*Ulmus rubra*	d	moist, flat		rapid		M-H	
highbush blueberry	*Vaccinium corymbosum*	d	wet		mod.		L-M-H	
southern arrowwood	*Viburnum dentatum*	d	all		slow		L-M	
blackhaw	*Viburnum prunifolium*	d	dry, moist		slow		L-M-H	

[a] Leaf Type: d = deciduous, e = evergreen.

[b] Notes concerning crop trees: Hickories, American beech, and black walnut have growth forms that are well suited for crop trees, but consistent success in planting these species on coal surface mines has not been demonstrated. Red maple is not recommended for planting because it volunteers readily. American chestnut, white ash, and American elm are well suited as crop trees when healthy but are subject to special considerations due to their susceptibility to pests as described in text.

[c] Growth Rate: mod = moderate.

[d] Soil pH range: Trees are grouped by soil pH suitable for the species. L = low (pH<5); M = medium (pH 5-7); H = high (pH>7).

[e] Climate Suitability. C = does well in cool climates, including northern Appalachia and at higher elevations (>3000 ft) in central and southern Appalachia; W = does well in warm climates, including Appalachia's southern region and parts of central Appalachia. If neither C nor W is specified, the species does well throughout the region.

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Passive Treatment of Coal-Mine Drainage by a Sulfate-reducing Bioreactor in the Illinois Coal Basin

By P. T. Behum, L. Lefticariu, E. Walter and R. Kiser

Figure 1. The Tab-Simco "kill zone" in 2006 prior to treatment system construction.

Introduction

Passive treatment, a technology pioneered to treat coal mine drainage in Appalachia (Hedin et al., 1994), has also been used to mediate environmental impacts of abandoned coal mine drainage in the Midwestern U.S. (Behum et al., 2002, 2010 and 2012). A major shortfall of the passive remediation technologies is the inability of providing long-term (>10 year) treatment of acid mine drainage (AMD) with high metal and in particular high aluminum contents (Al >20 mg/L). Premature passive treatment failure has been attributed to plugging by precipitates, dissolution of available carbonate minerals, and exhaustion of the organic carbon source (Thomas and Romanek, 2002; Neculita et al., 2008a and 2008b). However, one passive technology, sulfate-reducing bioreactors, has showed promise for treating this high aluminum, high acidity drainage (Behum, 2012; Behum et al., 2011). Sulfate-reducing bioreactors are similar in construction to a successive alkalinity producing systems (SAPS). The SAPS technology has been widely used in remediation of coal mine AMD in Appalachia (Kepler and McCleary, 1994). Bioreactors provide an environment in which organic carbon, as represented by CH_2O, is oxidized to bicarbonate (HCO_3^-) and sulfate (SO_4^{2-}) is reduced to hydrogen sulfide, $H_2S_{(aq)}$. Bicarbonate is available to react with H^+, decreasing the acidity in the system; dissolution of limestone included in the bioreactor adds to the bicarbonate alkalinity. H_2S readily dissolves in water and combines with divalent metals (Me), such as Fe, Ni, and Zn, to form sulfide mineral precipitates (MeS). Additional metal removal can occur: (1) during biologically-mediated precipitation of metal oxyhydroxide in the oxidized zone (at a low pH where abiotic precipitation is unlikely); Thomas and Romanek, 2002; Burgos et al., 2008), and (2) by adsorption onto clay minerals and organic matter (Evangelou, 1998).

Site Description

Tab-Simco is an abandoned coal mine located southeast of Carbondale in Jackson County, Illinois. Underground mining of the Murphysboro and Mt. Rorah coal beds of the Pennsylvanian age Spoon Formation occurred between 1890 and 1955; surface coal mining affected the area in the 1960's and 1970's. A series of exploratory drill holes have delineated an acidic mine pool within the abandoned underground mine workings. AMD seeps from this mine pool at a rate of about 35,000 gallons per day, which resulted in a significant aquatic impact on nearby Sycamore Creek. Prior to treatment the largest, a 1.2 LPS (19 GPM) discharge, had a pH = 2.4, dissolved Fe = 422 mg/L, dissolved Al = 147 mg/L, dissolved Mn = 31.4 mg/L, SO_4^{2-} = 2,370 mg/L, and total acidity = 1,816 mg/L CCE (all median values). This discharge flowed across small floodplain and created a 3.65-ha (9-acre) area "kill zone" devoid of vegetation (Fig. 1; Smith, 2002). Natural processes within this "kill zone" resulted in attenuation of metals and SO_4^{2-}. For example, Fe was lowered to 196.3 mg/L, which represents a 53.5% reduction; Al was reduced to 124.4 mg/L, a 15.4% reduction; and, SO_4^{2-} was reduced to 1,834 mg/L, a 22.6% reduction (Behum et al., 2011, 2012). Nevertheless, low pH (2.48) metal laden water effluent still had a negative impact on the receiving stream, Sycamore Creek. Baseline studies showed that downstream of the "kill zone", the discharge was characterized by a pH = 2.92 mg/L, total Fe = 10.0 mg/L, total Al = 18.4 mg/L and total Mn = 33.8 mg/L (median values).

Passive Treatment System Construction

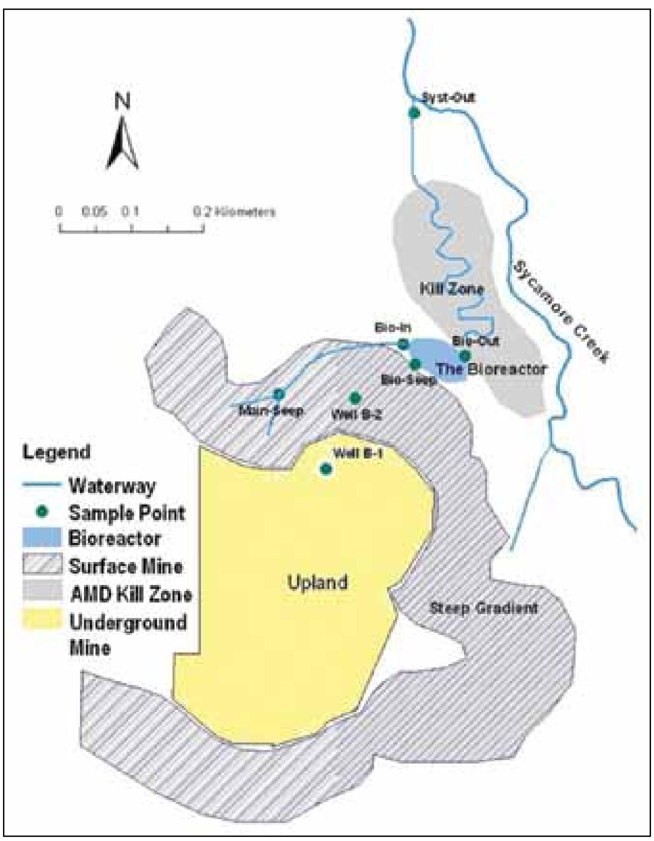

Figure 2. Overview of the Tab-Simco Treatment System, Illinois (Segid et. al., 2010).

The Illinois Department of Natural Resources, Office of Mines and Minerals (IDNR-OMM) constructed a passive-type treatment system in 2007 to abate the pollution caused by the largest of the mine's AMD seeps (Main Seep, Fig. 2; Segid, 2010; Behum et al., 2011, 2012). The principle technology employed was a 0.3-ha (0.75-acre) sulfate-reducing bioreactor, which was one of the first full scale bioreactor employed for the treatment of acidic, coal mine drainage in the US. This bioreactor was constructed in three layers: a shallow (0.3 m deep) acid impoundment, an underlying thick (1.8 m) layer of compost, a geotextile fabric, and finally a 0.3 m-thick limestone layer with embedded drain pipes (Figs. 3-5). The organic substrate was composed of approximately 5,887 m3 (7,700 cubic yards) of "compost," a blend of (by volume): 53% wood chips, 27% straw, 11% seasoned municipal (yard waste) compost and 9% agricultural ground limestone (Figs. 3 and 4). A series of oxidation cells/surface-flow wetlands follow the bioreactor unit constructed to allow for the precipitation of the remaining metals before the treated water discharges into Sycamore Creek (Fig. 5).

Figure 3. Construction of the Tab-Simco bioreactor cell: limestone-bedded underdrain.

Figure 4. Construction of the Tab-Simco Bioreactor Cell: placement of the compost layer.

Currently, the Tab-Simco system treats a 1.35 LPS (21.5 GPM) coal mine discharge with a high Fe and Al content (Table 1; Smith, 2002; Segid, 2010; Behum et al., 2011, 2012). Following the 2007 construction, about 50% of the inlet AMD was captured by a collection ditch (Bioreactor In) with the remainder seeping directly into the cell from a series of small seeps (Bioreactor Seep); more extensive data collected for nearby monitoring well B-2 are used as a proxy for chemistry of Bioreactor Seeps (Figs. 2 and 3, Table 1).

Table 1 – Median Geochemical Data for the Tab-Simco Treatment System, Illinois (2008-2011)*

Site ID	pH	D. Fe	D. Mn	D. Al	D. Ni	D. Zn	Acidity	Alk.	SO_4
Main Seep	2.83	654.2	38.4	173.5	2.25	2.87	2,551	0	3,563
Well B-2	2.85	287.3	34.6	98.2	1.33	1.92	1,306	0	2,373
Bioreactor In	2.93	606.5	39.3	147.1	2.48	2.64	2,213	0	3,913
Bioreactor in/ Well B-2 mix	2.89	446.9	37.0	122.7	1.91	2.28	1,760	0	3,143
Bioreactor Out	6.34	113.0	32.5	0.85	0.07	0.12	275.8	289	2,099
System Out	5.79	6.80	24.6	0.96	0.16	0.25	71.0	27.3	1,691

**All values except pH are in mg/L; acidity and alkalinity (Alk.) are calcium carbonate equivalent values; acidity = calculated acidity; average pH for Bioreactor In/B-2 Mix calculated using [H^+] values.*

Figure 5. Overview looking north of the Tab-Simco passive treatment system in March 2008.

In a bioreactor system design, the cumulative divalent metal removal rate of the inlet AMD must be equal or less than the rate of SO_4^{2-} removal by the bacterial sulfate reduction (BSR) process for a high level of metal removal (except for Mn) as monosulfides. However, most field installations are designed for metal removal instead of sulfate removal. Limited performance data is available from pilot-and full-scale bioreactors treating coal mine drainage to serve as a guide for design of new treatment systems (URS Corp., 2003). Designs are typically set by increasing the volume of the organic substrate to limit the sulfate or metal loading (mass/unit time) that is applied to the treatment cell. Gusek (2002) suggests a design goal a SO_4^{2-} loading of 0.30 moles/m^3/day. Therefore, in a 24 hour period AMD containing no more than a total of 24 grams of SO_4^{2-} would pass through each cubic meter of organic substrate. However, researchers with the URS Corp (2003) recommend a relatively low cumulative heavy metal load value of 0.15 moles/m^3/day. Due to the geotechnical constraints of the site, the Tab-Simco bioreactor component has a higher SO_4^{2-} and metal loading than these design goals with a SO_4^{2-} loading of 0.66 moles/m^3/day and a cumulative metal loading (excluding Mn) of 0.26 moles/m^3/day (Table 2). The Tab-Simco bioreactor is undersized, a design shortcoming that may potentially impact the longevity of the system.

Sampling and Analysis

The research team has conducted quarterly water quality measurements and sample collection since 2005 by IDNR-OMM with assistance from the Office of Surface Mining Reclamation and Enforcement (OSMRE) and Southern Illinois University Carbondale (SIUC). Details of field and laboratory methods were described by Behum et al. (2011). In brief, field parameter measured include pH, temperature, specific conductance, oxidation-reduction potential (ORP), and dissolved oxygen by electrochemical methods. Field laboratory tests include total and dissolved ferrous Fe by colorimetric methods and field alkalinity for samples with a pH more than 4.5 using the Hach micropipette method (Hach Company, 2002).

All analytical tests have been performed at IDNR, OSMRE and SIUC laboratories (Table 1). Metals analyses are by a combination of ion couple plasma (ICP) and Hitachi (Schaumburg, IL) Z-2000 Polarized Zeeman atomic absorption (AA) mass spectrometry and colorimetric methods following Standard Methods; major anions have been determined by ion chromatography (IC), colorimetric, and gravimetric methods. The stable isotope ratios of sulfur of the dissolved SO_4^{2-} were measured at Indiana University using a Finnigan MAT 252 mass spectrometer equipped with an elemental analyzer. Sulfide and chemical oxygen demand (COD) analysis are conducted by colorimetric methods using a Hach DR 2800 spectrophotometer.

Results

Between January2008 and October 2011, important geochemical trends have been measured at the Tab-Simco site. Acidity of the AMD has dropped from a median of 1,760 mg/L CCE in the bioreactor inlet to 275.8 mg/L CCE in the cell's discharge, an 84.3% improvement; SO_4^{2-} has decreased by 33.2% at the bioreactor outlet to 2,099 mg/L (Fig. 8). During this period metal removal by the Tab-Simco bioreactor cell has averaged 74.7% for Fe, 99.3% for Al, 96.3% for Ni and 94.7% for Zn (Table 1). Over this time period the discharge from the follow-up oxidation pond and surface flow wetland has a median pH of 6.34 and is net alkaline (100.2 mg/L CCE; Table 1). The following water quality improvements have been recorded between 2008 and 2011 at the inlet AMD to the system outlet: (1) acidity has dropped from a median 1,760 to 71 mg/L CCE, a 96% improvement (Table 1), (2) SO_4^{2-} has decreased by 43.4% (from a median of 3,143 to 1,691 mg/L), and (3) a cumulative dissolved metal removal of 99.7% (Table 2). Pollutant removal rates based on mass calculations in Table 2 are a more accurate because mass-based calculations account for variations in flow.

Table 2 - Median Loading (2007-2011) and Removal Rates: Tab-Simco Passive Treatment System *

Site ID	D. Fe	D. Al	D. Mn	D. Ni	D. Zn	Cumulative Metals	SO_4
Bioreactor Loading* Rate(moles/m^3/day)	0.160	0.091	0.0140	0.0005	0.0006	0.260	0.658
Bioreactor Removal Rate(moles/m^3/day)	0.122	0.090	0.0018	0.0005	0.0006	0.214	0.202
Removal (%)	72.9	99.3	13.2	98.6	96.2	82.3	30.7
Wetland Cell Load Rate(moles/m^2/day)	0.1477	0.0833	0.0127	0.0005	0.0006	0.2321	0.6139
Wet. Cell Removal Rate(moles/m^2/day)	0.1208	0.0832	0.0018	0.0005	0.0006	0.2051	0.1868
Cum. Removal (%)	99.9	99.4	36.1	89.8	90.8	99.7	43.4

**Bioreactor inlet channel and B2 mix; All values except pH are in mg/L; acidity and alkalinity are calcium carbonate equivalent values; acidity = calculated non-manganese acidity.*

Discussion

During the first 4-years of operation of the Tab-Simco system the high net acidity of the inlet AMD (median = 3,143 mg/L CCE; Table 1) is lowered by HCO_3^- alkalinity generated by the SO_4^{2-} reduction reaction and carbonate dissolution. However, the trend acidity values at the bioreactor outlet have not been constant throughout this period. The median acidity during system start-up period (2008 and 2009) was 244.1 mg/L CCE at the bioreactor outlet. This increased to 545.4 mg/L CCE (median 2010 and 2011). Conversely, the bioreactor outlet alkalinity decreased from 340 mg/L CCE (median 2008 and 2009) to 159.2 mg/L CCE (median 2010 and 2011). The increase of bioreactor discharge acidity is paralleled by an increase of dissolved Fe in the bioreactor discharge (2008 to 2009 median = 75.0 mg/L; 2010-2011 median = 174.1 mg/L). This increase may be due to: (1) a loss of available organic matter adsorption sites (Evangelou, 1998), (2) a decrease in retention time due to the reduction of compost pore space as a result of accumulation of metal precipitates and compaction, and 3) a decrease in the rate of BSR processes.

Between 2008 and 2011 SO_4^{2-} removal rate measured at the Tab-Simco system is 0.20 moles/m^3/day, a value slightly lower than the optimal rates suggested by comparable bench- and pilot-scale studies (Gusek, 2002; URS Corp, 2003; Table 2). This may be due to the fact that the system is somewhat undersized. A 2009 study by the SIUC research team found that the average $\delta^{34}S$ value of the SO_4^{2-} in the untreated Tab-Simco AMD was 7.3 ‰; this value was similar to the $\delta^{34}S$ values of the pyrite in the coal seams, indicating that pyrite was the source of the inlet SO_4^{2-} (Segid, 2010). The $\delta^{34}S$ value of SO_4^{2-} increased in the bioreactor from an average value of 6.9‰ (inlet) to 9.2‰ (outlet), suggesting that BSR processes were ongoing (Segid, 2010). Geochemical analyses have showed a small seasonal variation in SO_4^{2-} removal rates with the seasons, with average values of 33.0% in the cooler months (October-March) and 38.6% in the warmer months (April – September).

Our experience with bioreactor applications has suggested that during the initial period operation (< 4-yr.) most metals except Mn are retained within the bioreactor (Segid, 2010; Behum et al., 2011, 2012). This is consistent with published research that has shown that divalent metals such as ferrous Fe, Ni, Zn and Co are mostly retained as sulfides (e.g., Neculita et al., 2008b). Under the pH conditions of the bioreactor (pH > 4.5) dissolved Al is removed to a low level (0.85 mg/L). Aluminum is likely to be either precipitated as aluminum hydroxides or oxysulfates (Gusek, 2002; Thomas and Romanek, 2002). Between 2007 and 2011, an estimated 14.6 metric tons of Fe and 5.2 metric tons of Al are retained in the bioreactor annually. Considerable dissolved Fe may discharge from bioreactors where loading is high (Table 1). However, due to the high alkalinity and favorable pH of a fully functional bioreactor, the remaining dissolved Fe will rapidly precipitate whenever adequate oxidation structures are constructed following the bioreactor cell. Although the bioreactor cell discharge contained a median of 128.0 mg/L dissolved Fe, in follow up oxidation cells subsequent Fe precipitation occurs as Fe(III) sulfate and oxide-hydroxide minerals (Fig. 3), resulting in a decrease of dissolved Fe concentration in the system discharge to 6.8 mg/L (median values), an overall 98.5% Fe removal rate.

Conclusions and Future Research

Between the end of 2007 and 2011, the Tab-Simco system has effectively treated AMD of a quality that heretofore has been difficult to treat by passive methods due to the high acidity and aluminum content. During this period operation of the Tab-Simco treatment system has significantly reduced pollutant loads to of Sycamore Creek. Operational issues include plugging of the bioreactor discharge with ferruginous precipitates, seepage of untreated AMD into the "fresh" water bypass channel and the development of an 8-inch layer of precipitates on the bioreactor compost layer surface. System operational problems and the existence of an untreated AMD seep upstream have periodically impacted receiving stream water quality. A steep decline in bioreactor performance was observed in 2012 that is being investigated by SIUC under an OSM research cooperative agreement to support the 2013 maintenance efforts by IDNR-OMM. Additional research is needed to characterize the fate of metal precipitates within the Tab-Simco bioreactor. For example, Fe can be removed as Fe sulfate and oxyhydroxide precipitates in the upper oxidized zone, whereas the lower anoxic (sulfidic) zone Fe is removed as sulfide mineral precipitates. Additional SIUC research in 2013 will include solid phase analyses of mineral precipitates and biological diversity assessments to investigate the geochemistry and microbiology to provide insight into both the depletion of organic matter and armoring and clogging of substrate material by precipitated metal oxides, sulfates, and sulfides, conditions which will greatly affect performance and longevity. ■

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Abandoned Mine Drainage Remediation Efforts in the West Branch Susquehanna Watershed in Northcentral Pennsylvania

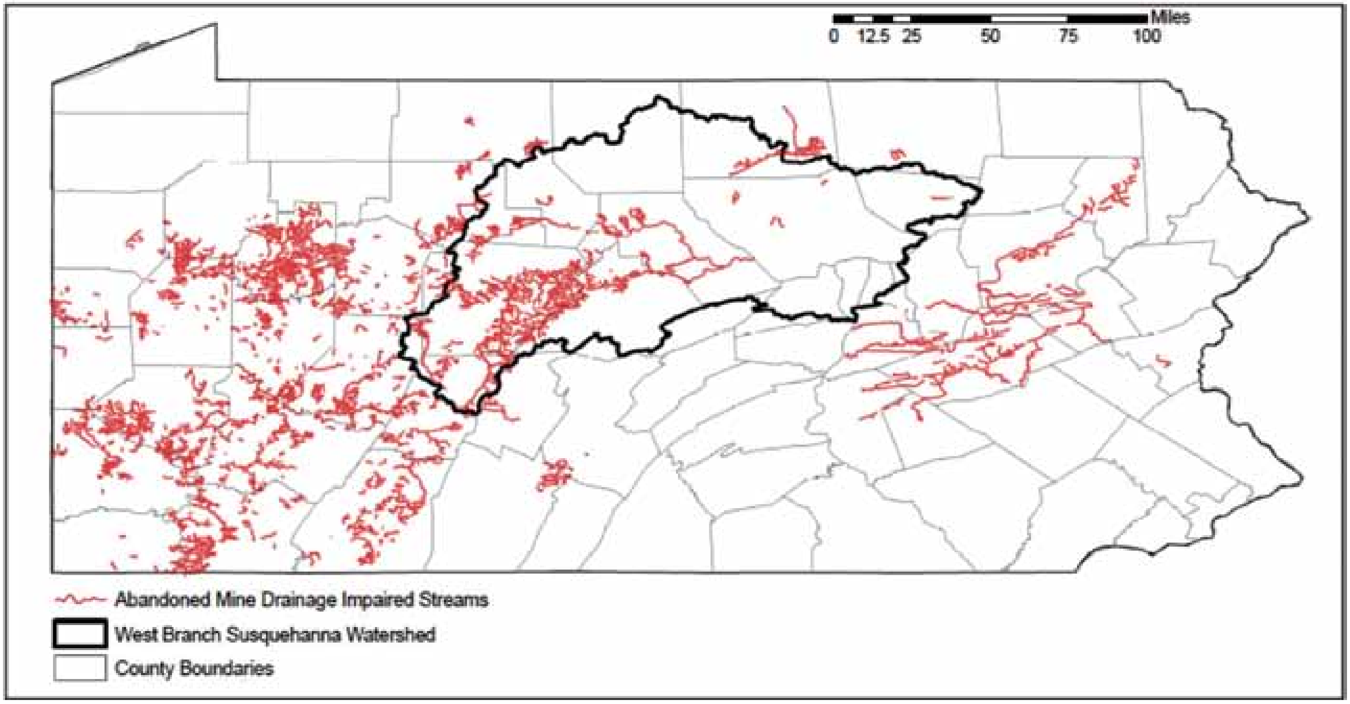

Figure 1: Map of Pennsylvania showing streams impaired by AMD (shown in red). The West Branch Susquehanna watershed is outlined.

Shawn Rummel, Frederic Brenner, Rachel Kester and Amy Wolfe

The West Branch Susquehanna watershed is located in northcentral Pennsylvania and drains an area of 6,978 square miles (Figure 1), making it the largest of the six major subbasins in the Susquehanna River basin. The watershed is one of extreme recreational value, as it contains some of Pennsylvania's most pristine waters (Figure 2). This includes over 1,200 miles of Exceptional Value (EV) streams and 5,229 stream miles of High Quality Cold Water Fisheries, as designated by the Pennsylvania Department of Environmental Protection (DEP) (West Branch Susquehanna River Task Force, 2005). Approximately 50% of the watershed is public land (state forests, state game lands, and state parks). The small, coldwater streams within the West Branch Susquehanna watershed also hold some of the best habitat for eastern brook trout (Salvelinus fontinalis) within Pennsylvania. Nearly 90% of streams surveyed throughout the watershed have been documented as containing either excellent or supporting habitat for aquatic life. However, the legacy of historical, unregulated mining continues to impact large portions of the watershed (see Figure 1).

Historically, the majority of the economically mineable coal in the West Branch Susquehanna River watershed occurs in the Brookville, Clarion, Lower, Middle and Upper Kittanning, and the Lower and Upper Freeport coal seams of the Allegheny Formation (Reese and Sisler, 1928). The majority of the total coal reserves in the West Branch watershed occur in Cambria and Clearfield Counties. Not surprisingly, so too is much of the abandoned mine drainage (AMD) pollution (see Figure 1).

Coal mining first began in the West Branch Susquehanna River watershed around 1785. In 1813, near the mouth of Mosquito Creek in Clearfield County, Peter Karthaus began mining coal and transporting it to Philadelphia and Baltimore via the Chesapeake, Delaware, and Union Canals (Sisler, 1926). The village of

Figure 2: View of the West Branch Susquehanna River from Hyner Mountain.

Karthaus sprang to life around this industry. A mere ghost town today, it is a reminder of both the boom and bust cycle that defines coal mining in the West Branch Susquehanna watershed.

Prior to the passage of the federal Surface Mining Control and Reclamation Act (SMCRA) in 1977, many coal operations were closed and abandoned with no parties being held responsible for the pollution emanating from the mines. According to 2010 DEP data, this has led to over 1,200 miles of West Branch streams being listed as impaired by the DEP due to AMD. There are approximately 1,964 AMD discharges in the West Branch Susquehanna watershed (SRBC, 2008).

With the passage of SMCRA, reclamation finally became a regulatory requirement of coal mining in Pennsylvania. Today surface and deep mining operations still occur throughout much of the West Branch Susquehanna watershed; however, due to permitting requirements, no longer produce mine drainage pollution as they have historically. In fact, the coal mining industry has become an important partner in West Branch Susquehanna River restoration efforts. Re-mining and reclamation, combined with state and federal programs and citizen-led restoration efforts are beginning to improve water quality and erase the scars of the past.

The West Branch Susquehanna watershed contains over one thousand miles of Pennsylvania's AMD polluted streams. The costs required to remediate the entire watershed range between $110 and $453 million in capital costs and up to $16 million annually in operation and maintenance costs (SRBC, 2008). However, the negative effects of AMD are not limited to water quality and aquatic biology. In 2006, it was estimated that the West Branch Susquehanna watershed lost approximately $22.3 million in annual sport fishing revenue dollars due to AMD impairments on over a thousand stream miles (Downstream Strategies, 2008). In addition, owners of single family residences in Clearfield County, the most heavily AMD impacted county within the watershed, have lost an estimated $4 million in property values due to AMD pollution (Downstream Strategies, 2008). When these long-term economic benefits of restoring the watershed from AMD are considered, the initial costs of remediation appear to be well worth the investment.

Over $70 million in Pennsylvania Growing Greener grants and other funding sources have been awarded for AMD projects within the watershed. The completion of many AMD treatment systems and reclamation projects have also been made possible by funds from the Office of Surface Mining's Watershed Cooperative Agreement Program, EPA's 319 Nonpoint Source Grant Program, the National Fish and Wildlife Foundation, The Foundation for Pennsylvania Watersheds, and other philanthropic organizations (Trout Unlimited, 2011). These efforts have been led by numerous local, state, and federal government and non-government organizations utilizing a coordinated, strategic, and cost-effective AMD cleanup approach for the entire river basin. Trout Unlimited has been the lead non-profit organization for this initiative. Trout Unlimited also provides organizational support to the West Branch Susquehanna Restora-

Figure 3 (above left): Kettle Creek downstream of Twomile Run. Twomile Run is impaired by AMD and effects of it can be seen in the iron and aluminum precipitate in Kettle Creek.

Figure 4 (above right): AMD discharge on Brubaker Run.

tion Coalition (WBSRC), a group that represents the collective efforts of watershed groups, Trout Unlimited chapters, county conservation districts, businesses, and others that work to address AMD issues in the watershed.

Reclamation efforts have been a combination of passive treatment methods, active treatment facilities, coal refuse pile removal, surface reclamation, and remining efforts (Figures 5, 6, 7 and 8). As of 2011, there were approximately 300 passive treatment systems in Pennsylvania. A total of 46 passive treatment systems have been built in the West Branch Susquehanna watershed since the mid-1990s (Figure 9). In addition, the DEP oversees the operation and maintenance of over 30 active treatment facilities within the watershed.

The monitoring of water quality from AMD treatment systems is a vital component to the operation and maintenance of these systems to ensure the systems are functioning properly. In the West Branch Susquehanna watershed, monitoring efforts are typically the responsibility of the DEP, non-government groups such as Trout Unlimited, and coordinated volunteer efforts by local watershed associations.

In 2009, Trout Unlimited led a collaborative effort in partnership with DEP, the Pennsylvania Fish and Boat Commission (PFBC), Susquehanna River Basin Commission (SRBC), and members of the WBSRC, to quantify the improvements of the watershed resulting from the remediation projects that have been implemented throughout the watershed (Trout Unlimited, 2011). Results from this project demonstrated significant improvements in water quality and biological conditions compared to the previous assessments completed by the United States Geological Survey in 1984 (Hainly and Barker, 1993). Overall, 85% of the tributaries to the West Branch Susquehanna River between Curwensville and Renovo had a higher pH than in 1984 and 79%, 68%, and 92% of the tributaries were lower in acid-


Figure 5: Aerial view of the passive treatment system on Middle Branch. The treatment system treats water that eventually flows into Kettle Creek.

Figure 6: Active treatment on Bear Run.

Figure 7: Former Barnes Watkins coal pile.

ity, iron, and aluminum concentrations, respectively, compared to 25 years ago (Trout Unlimited, 2011). These results demonstrate that although major improvements have been made in water quality, the watershed remains in the preliminary stages of recovery. It will be important to maintain the trajectory of improvements through continued diligence and collaboration amongst the entities involved in this restoration effort. Trout Unlimited plans to revisit this study in several years to continue to gauge improvements on the watershed scale.

In addition to water quality, efforts are currently underway to assess the status of biological recovery on several streams that have been remediated from AMD. These efforts include water quality monitoring, benthic macroinvertebrate collections, and fishery surveys in areas once decimated by AMD. Many of these

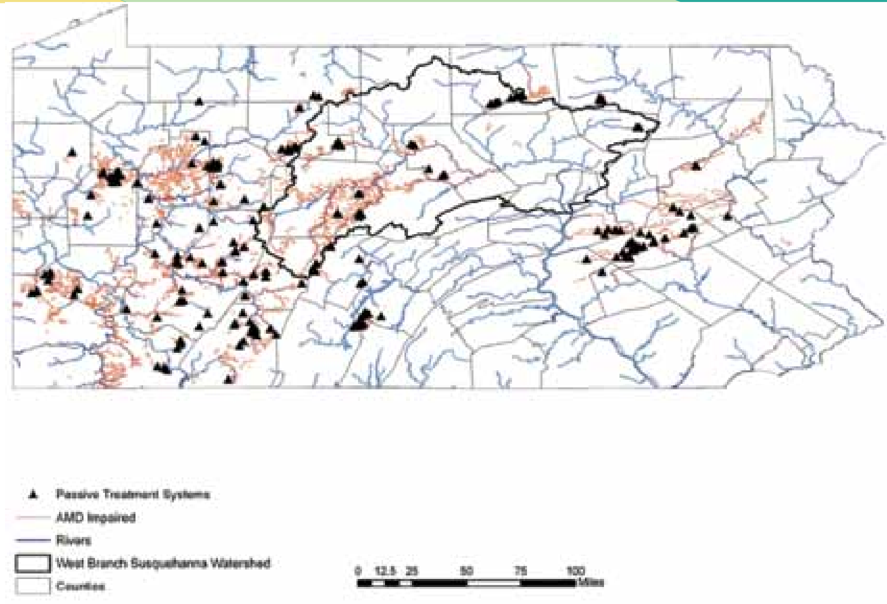

Figure 8 (above): Present-day site of former Barnes Watkins coal pile.

Figure 9 (right): Location of passive treatment systems in Pennsylvania.

streams are showing signs of significant recovery and may soon reach a point where they could be removed from DEP's impaired streams list. For example, Babb Creek, a stream once devoid of life due to AMD has been successfully restored and was removed from the impaired streams list in 2010 (Figure 10).

One of the benefits of restoring areas in the West Branch Susquehanna watershed impacted by AMD is the opportunity to restore eastern brook trout populations (Figure 11). The eastern brook trout is the only native trout species occurring in the eastern United States. The species has adapted to a wide range of habitats, from small headwater streams to large rivers and lakes. Prior to colonial times, brook trout were present in nearly every cold-water stream and river throughout the eastern United States. In addition, the eastern brook trout is often viewed as a biological

Figure 10 (far left): Babb Creek Watershed Association celebrates the removal of Babb Creek from the impaired streams list.

Figure 11 (left): Example of an eastern brook trout captured during electrofishing surveys within the West Branch Susquehanna watershed.

indicator for healthy water due to their sensitivity to pollution. Populations of these fish began to decline in the West Branch Susquehanna watershed as human impacts such as agriculture, logging, and mining became abundant throughout the watershed. As a result of these activities, only an estimated four percent of the watersheds within the West Branch Susquehanna subbasin are home to strong populations of the eastern brook trout (Eastern Brook Trout Joint Venture, 2006).

However, biological survey data are lacking for a majority of Pennsylvania's streams. Of the 45,000 waterways in Pennsylvania (second only to Alaska in the number of stream miles), biological survey data is only available on approximately 3,000 streams, making management of brook trout populations difficult. In 2010, PFBC launched the Unassessed Waters Initiative as part of its five year trout management plan (Weisburg, 2011). In partnership with colleges and conservation groups throughout the state, a massive effort is underway in Pennsylvania to document wild trout populations throughout the state. Since 2010, over 1,100 streams have been surveyed by PFBC and its partner groups (PFBC, personal communication). As of 2011, wild trout were found in roughly 50% of the streams that were surveyed in 2010. Streams in which populations of wild trout are documented may be afforded a certain level of protection from future human impacts by the DEP.

Genetic data on brook trout populations are also being collected throughout the watershed. Over 100 years of AMD pollution impacts in the West Branch Susquehanna watershed has not only eliminated brook trout populations from impacted streams, but has also resulted in fragmented brook trout habitats and isolated trout populations in headwater streams. Small, isolated populations of a species often results in a genetic bottleneck that may or may not affect the long-term survival of these isolated populations. These isolated populations are currently being evaluated as to their size and genetic diversity. Fin clips are being collected from each population surveyed in the West Branch Susquehanna watershed, preserved in alcohol and the DNA is isolated and analyzed for variations in the displacement region (D-Loop) of the mitrochrondrial DNA (mtDNA) to determine the existence of maternal lineages within each population and extent of mtDNA variation among these isolated populations. In addition, we plan on also analyzing nuclear DNA in these fish to determine the pattern of specific haplotypes and nucleotide diversity within these isolated populations. This information will be beneficial for more effective management of brook trout populations within the West Branch Susquehanna River watershed.

In summary, the restoration of the West Branch Susquehanna watershed is certainly on the path towards recovery. Major successes have been documented in a relatively short amount of time. However, on a large scale, the watershed is still in the early stages of recovery. In order to maintain the current trajectory of restoration success, it is important that funding continues to focus on AMD remediation, not only in the West Branch Susquehanna watershed, but throughout regions where water resources have been degraded by historical mining practices. The restoration efforts within the West Branch Susquehanna watershed have been an excellent example of a large scale collaborative effort between local citizen groups, conservation groups, and state and federal agencies. These types of collaborations are vitally important to ensure success in any large scale remediation effort. ■

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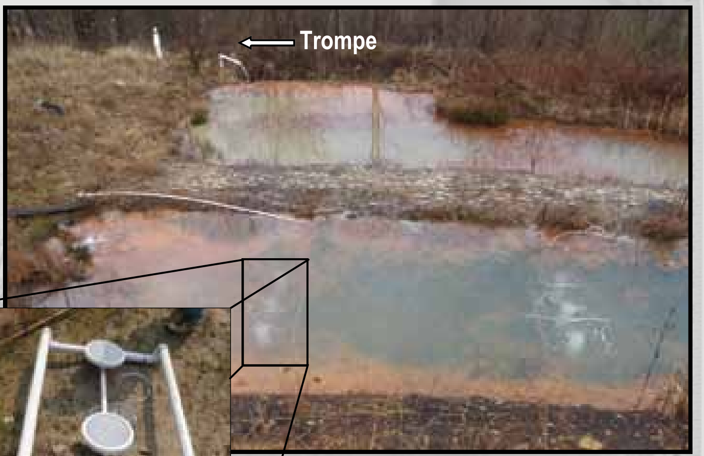


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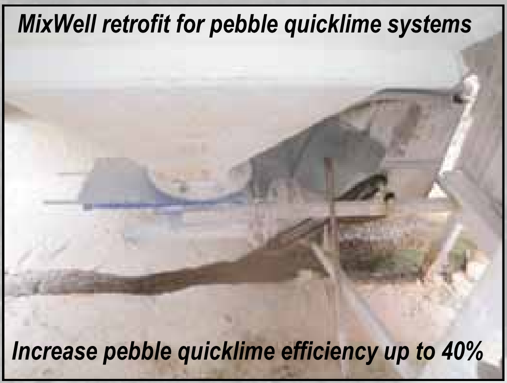
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