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reclamation matters

Fall 2012

A SUSTAINABLE MINING & RECLAMATION APPROACH
FOR THE APPALACHIAN COAL REGION

CO-TREATMENT OF ACID MINE DRAINAGE WITH MUNICIPAL WASTEWATER:
A PROMISING NEW APPROACH

AMERICAN SOCIETY of MINING and RECLAMATION


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It Isn't What Happens…

It's How We DEAL With It!

Bruce Buchanan, ASMR President

How often do we hear "as soon as one door closes, another one opens"? I am of the opinion that the opening and closing of doors is largely controlled by our attitude. Happy people – the ones with a great, positive outlook – have opportunities coming at them from all directions. We even describe them as being lucky. The unhappy people – the ones who see the glass as empty, even when it's near full – never seem to have opportunities. You know them; they are always unlucky.

Well, there is a reason for all of that! Studies have been done to determine why some people are lucky and others are not. Turns out, lucky people have lots of friends. They know well over 100 people they call friends and quite often know over 1,000 people and many of those they consider to be friends. The unlucky people know fewer than 100 people and only have a handful of friends.

The lucky ones always seem to have a door opening for them and the unlucky ones seem to always be facing a closed door. The positive people I know seem to make the most of whatever happens. When the fish are not biting, then it's a good day to practice your cast. By the way, I was not answering my phone earlier this week…my arm was in a cast.

Our friendliness, our attitude, our positiveness all impact how we are perceived as a friend. The more friends, the more interaction we have with people and thus the greater number of opportunities that come our way. Yep! We sure are lucky. Few friends, little interaction, limited opportunities. Yep! Not very lucky.

A dear fly fishing friend of mine was an all American high school football running back some 50 years ago. After one year of football at the University of Montana, he signed with a pro football team. On the way to practice one day, he was hit by another car. It crushed his foot and ankle and he never played football again. As one door closed, he opened the door to a fabulous career in engineering. He patented an invention before he was 30 and has been basically retired ever since. He gave up running to be an engineer. Now he is a great fly fishing friend and is he ever lucky. Want a friend…be a friend.

This year my goal is to again recruit one new member and be in Laramie for one of ASMR's greatest meetings. ■

When MISTAKES Are Made

Jeff Skousen, West Virginia University

I teach two classes at West Virginia University. One is an introductory Environmental Science class with about 100 students, which is taught as a general education curriculum course. The other is a senior-level course in my specialty, "Reclamation of Disturbed Soils," which normally has between 50 and 60 students. As part of this course, I take the students on two field trips to surface mines which emphasize different aspects of the course. After each field trip, I require the students to write a four to six-page report with the hope that writing a report will help the students synthesize the information they learned and experienced on the field trip. I have been doing this for more than 25 years.

Recently, I had five of the 55 students in my reclamation class turn in reports that were clearly copied from last year's reports, an obvious case of plagiarism. I deliberated over and over what I should do, and I discussed the situation with colleagues and my department chairman. My university has a strict academic dishonesty policy which states that the student found cheating or plagiarizing can have one of these penalties: 1) be expelled from the university, 2) fail the course, 3) receive a lower grade in the class, or 4) receive a zero on the assignment. All consequences are at the discretion of the course instructor.

I decided to invite each of the students into my office singly where I could confront them directly with my suspicions. As I talked with each one, I watched closely their eyes and body movements to observe their reaction to my allegation and the potential penalties. Two of the students were truly shaken and recognized that their mistake could result in severe consequences to their academic as well as their professional career. I was pleased that they took it so hard and they got emotional as we discussed the penalties. Each said he was sorry and apologized several times during our discussion. I encouraged them to talk with their parents about what happened. I told them to think about it overnight and talk to me tomorrow.

The other three reacted differently. They weren't particularly surprised by my accusation, they weren't sorry or apologetic, and I got the impression that they had been through this situation before. They weren't ashamed of their cheating; they were simply embarrassed they were caught. I went through the potential penalties with them, being as stern as I could, telling them how disappointed I was in them and how this could affect their careers. I told them to think about it overnight, to contact their parents, and talk to me the next day.

As expected, the two penitent students had very tough evenings, with no sleep, contemplating their fate. The other three seemed more remorseful the next day. I decided on a punishment which was applied to all five students.

The reason I'm sharing this is because of the distinct difference in reaction from these five students. Two were very upset by the whole ordeal and I think they actually learned from the experience and they may never cheat again. On the other hand, I think the other three will simply forget it and continue doing what they have always done…taking shortcuts and sliding along on somebody else's work whenever it suits them.

When this mistake was made, I encouraged those students to take responsibility and accept the consequences for their mistake, to apologize to appropriate people, to do their best to make up for it, and then to never do it again. We all need to be careful about cheating or plagiarizing. All of us are being pushed to do more in our jobs and to cover more areas as downsizing occurs in our companies. Some of us are spread so thin that it is hard to accomplish all the tasks we are given. We must be careful of the temptation to simply take another's work and pass it as our own without giving due credit. I am hopeful that the students who cheated will not do it again. This is a good reminder for all of us. ■

Chris Fields-Johnson

The vast wilderness of Pine Barrens in Southeast New Jersey grows every subtle composition of pitch pine, huckleberry and scrub oak with meandering swamps of cedar, maple, tupelo and blueberry producing pure streams of amber water. Though the region exists in the geometric center of the Richmond-Boston megalopolis and in between the industrial corridor of the Delaware River and the hyper-developed Jersey Shore, to this day one can wander through it for days in a sea of trees without seeing a soul and drink the water directly from springs and small creeks.

At the end of an old fire break and jeep trail leading down from Forked River Mountain was a magnificent old swamp of Atlantic white cedar where stems a foot thick and more stood within arm's reach of each other and rose over a hundred feet to a wispy canopy. On any given day in the 1990s or 2000s could be found in that swamp a man with a chainsaw, rope and pickup progressively clear-cutting it from one end to the other at a steady rate of one acre per year to make cedar timbers and poles for local timber-framers at his nearby mill. The swamp in his wake erupts with re-growth of blueberry, tupelo, maple and sometimes cedar amongst the slash and corduroy roads and is a unique chrono-sequence for ecological study. This process of timbering and succession, repeated since the bog iron mining days of the 17th century, has resulted in 90% losses of Atlantic white cedar stands throughout the Pine Barrens as they are suppressed by broadleaves or choked out by the altered hydrology of road building and debris in streams.

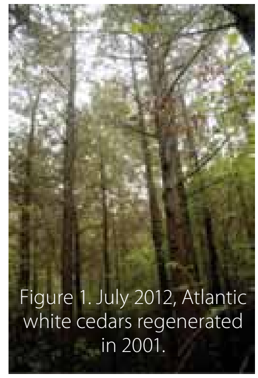


Figure 1. July 2012, Atlantic white cedars regenerated in 2001.

The Pine Barrens are scattered with these failed cedar stands and it is rare to see a cedar stand regenerate on its own today. Along the first corduroy road across that swamp now grows one stand that has beaten the odds with a little assistance. In 2001, as part of a restoration group, I adopted that small section of swamp. Unclogging the stream, trimming back broadleaves and shifting slash so it did not blanket the ground to suppress the cedars' seedbank, we got the cedar seedlings to sprout and get a head start on the other species. Over the years I returned at intervals to thin the cedars themselves to help the strongest along in their growth. By 2005, the cedars had closed canopy and were 10 feet tall. Last weekend when I visited, they were 25 feet tall and some six inches in diameter. I had gone to do a little work, but they looked so good there was nothing left to do but watch them grow. Success there is total.

I will be able to re-visit my area in that cedar swamp for the rest of my life and know that I made the difference there though there are so many failed stands all around that were abused and then neglected. As young reclamationists, we have the opportunity to make good choices and to work hard now and watch our successes grow for many decades. We will be able to pass on these places of inspiration and a lifetime of observation and experimentation to the next generation. It is necessary for us to adopt specific places as our personal projects and see them through to success with a determination meted out over months, years and, if we come to accept it, decades. It is equally necessary for senior reclamationists to give the freedom and means to accomplish this early on in our careers to facilitate the lengthy periods of observation necessary when studying the development and succession of a reclaimed ecosystem. Is it not those few remarkably successful examples of stellar reclamation that so inspire us and keep us coming back to learn more? We need to produce more of those. ■

Dr. Richard (Dick) Barnhisel

Future Meetings – First of all, I hope all of you will consider coming to Laramie, WY, June 1-6, 2013. We are in the planning stages of the program and the call for papers or abstracts will be mailed soon, if they have not already been sent by the time this issue of Reclamation Matters arrives. The program will likely include workshops and pre- and post-conference field trips or tours. Messages related to the meetings will be posted under Upcoming Meetings on the ASMR web page.

The meetings for 2014 will be in Oklahoma City, but the date has not been established. The local host for this meeting is Dr. Robert Nairn. For 2015, a proposal is in process for a joint meeting with ARIES and ARRI in Lexington, KY.

ASMR web page – If you haven't visited the web page recently you need to do so. The address is www.asmr.us. You should regularly visit this site for updates on the meetings, available positions for employment which are posted almost every week, as well as other NEWS and activities of other Societies.

There is a new feature on the web page, this being the actual talks of many of the speakers at the Tupelo Meetings which may be found on the web page under Past Meetings and PowerPoint Presentations. You can listen to their actual presentations which were recorded using new software we purchased for this purpose. There were a few that the audio portion was not acceptable so just the PowerPoint images are given.

Also note that all past Proceedings papers are now on the web page with the exception of the first one in 1984 as these papers are yet to be scanned. There were some volumes that were rescanned in a more user-friendly format. Also ASMR is in the process of starting an Online Journal, which may be activated by the time this issue of Reclamation Matters is available.

Tupelo Mississippi Meetings – I consider the meetings this past June as a huge success. There were over 180 in attendance with 88 oral or poster papers presented. Both pre-conference and post conference field trips were held. Drs. David Lang and Barry Stewart are to be commended for their efforts to make these meetings successful. The meetings were also successful financially. The profit generated will likely be used to support future activities of the Society such as supplementing various endowment funds for Student Travel and Memorial Scholarships and for Early Career activities. A decision as to the allocation of this profit is yet to be made by the NEC. ■

Retired But Not Out – Yet

Viewpoint by Dr. Stephan A. Schroeder

As I sit here writing this article, I am recalling the great annual ASMR meeting that concluded in Tupelo, MS. Well-deserved congratulations should go out to Dr. David Lang and his committee for all the work involved in organizing and holding a meeting (as I well know since I hosted the Bismarck meeting in 2011). Accolades should also go out to David's wife Maureen for hosting the spouses' activities for three days. My wife Nancy had a great time and said the rest of the spouses did also. I can hardly wait to see what will happen at the 2013 Laramie, WY meeting being organized by Dr. Peter Stahl.

Since I have now retired after 30+ years of research and regulatory work in North Dakota, I really have no professional need to stay a society member or attend meetings since I am not currently working in the reclamation field. However, I am still interested in the reclamation of drastically disturbed lands since it seems that more and more hectares of North Dakota land is being disturbed not only by coal mines but now oil well activity and wind power generation sites. Thus I want to keep as current as possible on the newest methodologies to reclaim these areas when the current activity ceases. But I feel there is another reason I should stay involved in the society. That reason was brought to the attention of everyone by President Buchanan at the ASMR Awards Dinner in Tupelo. The discussion focused on how all of us "older" members, retired or not, should be mentors to our "younger" members whether they be graduate students or those just starting out in their careers.

Leadership in our society comes in many forms including not only chairing or serving on committees or on the NEC within the organization, but also through the interaction of the members with other members especially at the annual meetings. Reasons I used to convince my bosses of the importance of attending annual meetings were the contacts made and information gathered conversing with other professionals, in addition to materials given in the research papers and posters presented. The personal exchanges during breaks could sometimes be more informative than the papers or posters since more time was involved and greater details could be discussed without time constraints. Now since I've retired and no longer get any travel expenses reimbursed, I still think that these interactions with others at the annual meeting justify my time and money to attend. Regardless of whether you call these discussions part of mentoring or just keeping current and adding my two cents worth to research projects, it is important to interact in these ways. The real benefit is realized as those discussions turn into knowledge and action. Hopefully the information I impart is worthwhile and can be used to further the goals of reclamation and, thus, could be considered mentoring.

Each and every one of us in the society probably knows a unique facet of reclamation that does not always fit well into a poster presentation, research paper or peer-reviewed research publication. It is important that this information is "passed on" to the next generation from experience gained by others. Discussions such as these may save a graduate researcher time and money doing research or trying methodologies that have been tried in the past and didn't work then and will not work now. Or maybe a "tweaking" of the methodologies may result in new ideas and progress. Many times these ideas have never been shared in a publication and thus can only be passed on through the interaction with others. This is where the importance of being a mentor can work well for our society. As President Buchanan stated in his message, "What can you do for the society?" Being a mentor is one of the easiest and maybe the most important ways of helping our society and reclamation research moving forward in the future. Let's each resolve to being a mentor to someone throughout the year and at the next annual meeting.

See you next year in Laramie.

Dr. Schroeder is a former Reclamation Research Scientist with North Dakota State University's Land reclamation Research Center in Mandan, North Dakota and retired as an Environmental Scientist for the Reclamation Division of the North Dakota Public Service Commission in Bismarck, North Dakota. He has been a member of ASMR for over 20 years. ■

Keith E. Lindbeck

Our recipient of the 2012 Reclamationist of the Year Award has been involved in natural resource management and reclamation programs since 1969. He has worked in the field with state government, international consulting companies and since 1997 he has managed his own consulting company involved in environmental assessment, land rehabilitation and training of environmental personnel in land rehabilitation and revegetation technology. He is a lifetime member of ASMR and consistently participates in the annual meeting. He has also been very supportive and dedicated to ensuring his company's younger employees participate in scientific conference like ASMR to help broaden their experience and knowledge in the field. He has arranged for several of his employees and subcontractors to travel with him to the ASMR conferences over the last two decades. He has worked with agencies such as BLM to assess how they manage environmental issues and land rehabilitation on public lands. He has also organized sabbatical exchanges with scientists and managers from other countries to work with the mining industry and government entities associated with land rehabilitation. He has received Stage 3 accreditation (highest accreditation bestowed) as a Certified Professional Soil Scientist from the Soil Science Society of Australia, Inc. He has published numerous papers on his work, several in the proceedings of the ASMR conferences and also in scientific journals. One of his letters of support clearly states the impact our recipient has had on mined land rehabilitation in Australia. He stated, "He has produced practical guidelines that were easily understood by the industry and which led to improved environmental management at mine sites. He is a leading environmental consultant in Western Australia and has had a major role in mentoring the industry operators and his own staff." Our recipient received his educational training from Wagga Agricultural College, University of New England (Physical Geography and Botany), Macquarie University and the University of Western Australia. It is with great honor that I present Keith Lindbeck, Principal and Owner of Keith Lindbeck and Associates of Western Australia as our 2012 Reclamationist of the Year Award. Congratulations Keith. He was nominated by Belinda Clark. ■

Gwendelyn Geidel

Our recipient of the Richard L. and Lela M. Barnhisel Reclamation Researcher of the Year Award for 2012 has been involved in research relating to mine land reclamation since 1980. Her research dealt with surface and ground water contamination by acid mine drainage. She and her husband (Frank Caruccio) were a team in working in this area of research. Their research involved using anoxic alkaline channels to route acid mine drainage for treatment which proceeded the passive approach of wetland treatment. She has presented numerous papers at the annual ASMR conferences on the team's research. She has been active in the Society by serving on the Memorial Scholarship Awards Committee and has reviewed numerous papers for the Water Management Technical Division for papers submitted for presentation and publication in the ASMR annual conference proceedings. She has also been active in the International Association of Geochemistry and Cosmochemistry and the Interest Group on Water-Rock Interactions, International Association of Land Reclamationists, and the South Carolina Bar Association. She has been recognized by Who's Who of American Women and Elected to the National Honor Society. One of her support letters states very well her role in environmental activities: "She has always been a pragmatic environmentalist who is not content to complain about environmental problems; she looks for and finds practical, cost-effective solutions to real-world problems." Her educational training includes a B.S., M.S. and Ph.D. in geology from the University of South Carolina and Juris Doctor, School of Law, University of South Carolina. It gives me great pleasure to announce the 2012 Richard L. and Lela M. Barnhisel Reclamation Researcher of the Year Award is Gwendelyn Geidel, Research Assistant Professor of Geology and Assistant Director of the School of Environment, University of South Carolina.

Congratulations Gwen! She was nominated by Richard Barnhisel. ■

W. Lee Daniels

Our recipient of the 2012 William T. Plass Award has been involved in reclamation research and its application for over 30 years. He has served ASMR as chair of the Soil and Overburden Technical Division, Chair of the national meeting committee, and as its president. He has served on numerous regional and state technical committees including the Governor's Select Advisory Committee for Regulatory Program Development-1984-1994; Interagency committee for development of guidelines for the utilization of waste products on mined lands-1994-present; Chemistry and bioavailability of waste constituents in soils—1998-2008; and Virginia Board fro Certified Professional Soil Scientists and Wetland Delineators—Member/Chair—2002-2008. His career demonstrates a long-standing consistent commitment to research, teaching and service concerning reclamation of disturbed lands, including lands impacted by mining, waste disposal, road building, and other drastic disturbances. He has led a cooperative exchange program with scientists from the People's Republic of China, enabling him to study reclamation problems associated with semi-arid lands under different political and socioeconomic conditions. He has visited China numerous times and has developed a long-term cooperative agreement to exchange research technologies and ideas, faculty visitors, and graduate students. He has also maintained long-term relationships with a disturbed land reclamation group in Brazil and has assisted scientists in Brazil as they develop reclamation procedures and protocols for their emerging mining industry. He was keynote speaker at the First South American International conference on Rehabilitation of Degraded Lands and also hosted numerous Brazilian scientists and reclamationists at the Richmond ASMR/10th International Affiliation of Land Reclamationists conference. He served as the member and principal reclamation scientist of the USEPA/USAID mined land restoration project in Upper Silesia, Poland. The project was extremely successful and resulted in a variety of awards/honors from local environmental protection agencies and recognition by EPA in its 1997 annual report to Congress. In 2000 he was awarded the prestigious National Biosolids Utilization Research Award by EPA on the basis of this work. He has authored or co-authored several hundred publications, abstracts, book chapter and presentations. In addition to his outstanding research and international program, he teaches 3 courses concerning land reclamation and advises numerous graduate students and post-doctoral candidates. One of the supporters of this nomination stated, "Given this is a lifetime achievement award, I should begin by saying that this individual has been a reclamation specialist since completing his B.S. degree." His international influence has also been very important in aiding in the development of sound reclamation practices abroad. Our recipient of the William Plass Award received his B.S. (Forestry), M.S. (Agronomy-Soil Genesis), and his Ph.D. (Soil Mineralogy and Geomorphology) from Virginia Tech. It is with great pleasure and satisfaction that I announce that Dr. Lee Daniels, Thomas B. Hutcheson Jr. Professor of Soil Science, Virginia Tech, as the 2012 recipient of the William T. Plass Award of the American Society of Mining and Reclamation. Congratulations, Lee. Lee was nominated by Carl Zipper ■

Scholarship Awards

B.S. Scholarship – Hannah Angel

M.S. Scholarship – Nina Craig

Not pictured: Ph.D. Scholarship recipient Julie LaBar

Travel Grant Awards

Hannah Angel

Kelsea Palmer

Ashley Neptune

Haley Smith

Sarah Yepez

Not pictured:
Travel Grant recipients

Stephen Emenhiser
Luke Martin
Robert Waddle

Oral Presentation Winners

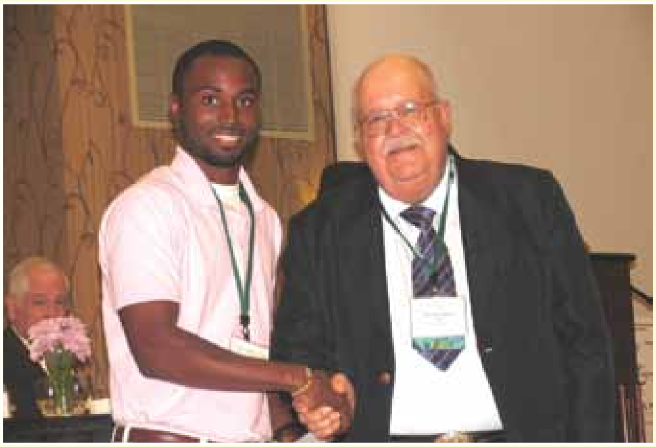
1st Place – Haley Smith

2nd Place – Leah Oxenford

3rd Place – Nina Craig

Poster Presentation Winners

1st Place – Hannah Angel



2nd Place – Timothy Bradford

3rd Place – Kelley McMillen with Melanie Letalik

4th Place – Ashley Neptune and Kelsea Palmer

Pennington - Russell Chambless

Stream Restoration Inc.

Sustane Natural Fertilizers - Greg Naffz

Truax - Charles Christianson

USDA-ARS - John Brooks & John Read

Web Soil Survey - Steve Depew

Western States Reclamation - Joe Schneider

Environmental Products - John Vermillion

Environmental Solutions - Jim Oliver

Finn - Andy Hodek

FTN - Jarvis Harper

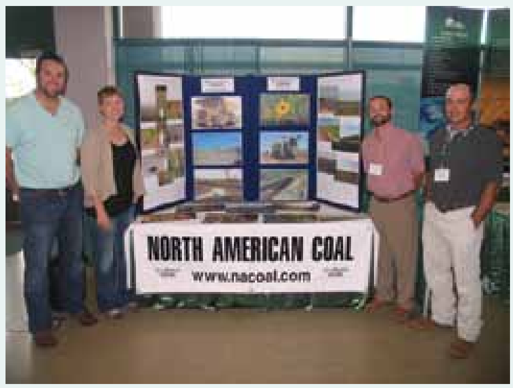
Golder Assoc. - Jim Gusek

Green Forests Work - Nathan Hall

Hydro Straw - Ed Lee & Ron Edwards

JRW Bioremediation - Mike Sieczkowski

Mississippi State - David Lang



NA Coal - Josh Johns, Bryan Mattison,
Judd Sanborn & Jessica Unruh

New South

OSM - Kim Vories

Applied Polymer Systems - Joyce Iwinski

ASMR - Lela Barnhisel

Bruker Elemental

A Sustainable Mining & Reclamation Approach for the Appalachian Coal Region

Jim Burger, Virginia Tech

Sustainable Reclamation

What does sustainable reclamation mean? How do we reclaim sustainably? Sustainable Reclamation was the overall program theme for the June, 2012, American Society for Mining and Reclamation annual conference, held in Tupelo, MS. I doubt that we thoroughly answered those questions during the course of the conference, but I applaud the effort because I believe the answers are necessary for a viable and healthy coal industry. I have been reflecting on the even broader notion of sustainable *mining* and reclamation, its definition, the goals of those who espouse the use of the idea, and how reclamation specialists might help the industry meet the provisions of sustainable mining and reclamation as they have been expressed and accepted by progressive companies within the industry.

There is little argument that humanity must live sustainably, but how to define and implement the concept is challenging. A formal definition was published by the World Commission on Environment and Development (*Our Common Future*, Brundtland Commission, 1987): Sustainability is based on the premise that resources be used by current human generations without compromising their availability to future generations. The concept has been largely accepted by national and international political groups, research organizations, the business sector, and non-governmental organizations. Increasingly rigorous environmental legislation controlling mining activities and heightened environmental awareness on the part of the general public has made essential the inclusion of mining activities within the sustainable development paradigm (Humphreys, 2001; IIED and WBCSD, 2002). As a result, the major organizations representing the mining industry in developed countries have subscribed to sustainability principles and practices. They include, among others, the Minerals Council of Australia, the European Association of Mining Industries, the Mining Association of Canada, Chile's state-owned CODELCO, and the National Mining Association of the United States. Many individual international mining companies have adopted sets of company-specific sustainability guidelines; Newmont (http://www.beyondthemine.com/2011/), Peabody Energy (http://www.peabodyenergy.com/content/152/Environmental-Responsibility), and BHP Billiton (http://www.bhpbilliton.com/home/aboutus/sustainability/Pages/default.aspx) are examples that provide models that could be emulated.

Most of these mining organizations obtained guidance from the Mining, Minerals and Sustainable Development (MMSD) program initiated globally to develop ways for the mining industry to become sustainable. In the final report called *Breaking New Ground* (IIED and WBCSD, 2002), the MMSD group couched sustainable mining and reclamation within the "triple bottom line" used by other industries (Fig. 1). In a nut shell, a mine may be considered sustainable *economically* if the viability of the project is assured and if the community will be better off as a result; it is sustainable *ecologically* if pre-mining capability and ecosystem services are restored; and it is sustainable *socially* if people's well-being is maintained or improved (Fig. 1). Full elaboration of these principles can be found in the WBCSD report (IIED and WBCSD, 2002).

Achieving *ecological* sustainability is the piece of the "triple bottom line" with which we reclamation specialists can be especially helpful. Restoring pre-mining capability and the products and services the land provided has been challenging since the U. S. Surface Mining Control and Reclamation Act (SMCRA) was implemented 33 years ago. However, after much experimentation and trial and error, and by using an agronomic approach entailing soil building, tillage, fertilization, and seeding, most pre-mined croplands and grasslands have been successfully replaced in the Midwestern and Western Coalfields.

In the Appalachian Region, sustainable mining and reclamation has been more difficult to achieve. Most mined land was originally covered with native forest which has been replaced with post-mining grass and wildlife shrubs. Most of these reclaimed lands are not being managed for their promised post-mining land uses and are now covered with scrub and invasive species. Furthermore, mountaintop mining (MTM) has become increasingly common since the early 1990s. Even when constructed to approximate original contour, excess spoil, steep terrain, and the large scale of the operations create additional reclamation challenges. Because of the cumulative impacts of MTM on terrestrial, aquatic, and human conditions, citizen groups have been using litigation to challenge the practice, particularly the process of placing excess spoil in valley fills which reportedly violates the SMCRA buffer zone rule and provisions of the Clean Water Act (CWA). Impacts identified in an environmental impact statement conducted by the U.S. Environmental Protection Agency (EPA, 2005) included loss of terrain features, loss of headwater streams, modified hydrologic flow paths, degraded stream water quality, loss of forest and interior forest, reduced nutrient and carbon cycling, reduced soil and forest productivity, and loss of required habitat and native biodiversity. In a recent article in the journal *Science*, 12 renowned scientists (Palmer et al., 2010) charged that MTM "… impacts are pervasive and irreversible and that mitigation cannot compensate for losses." They concluded that "Damage to ecosystems is

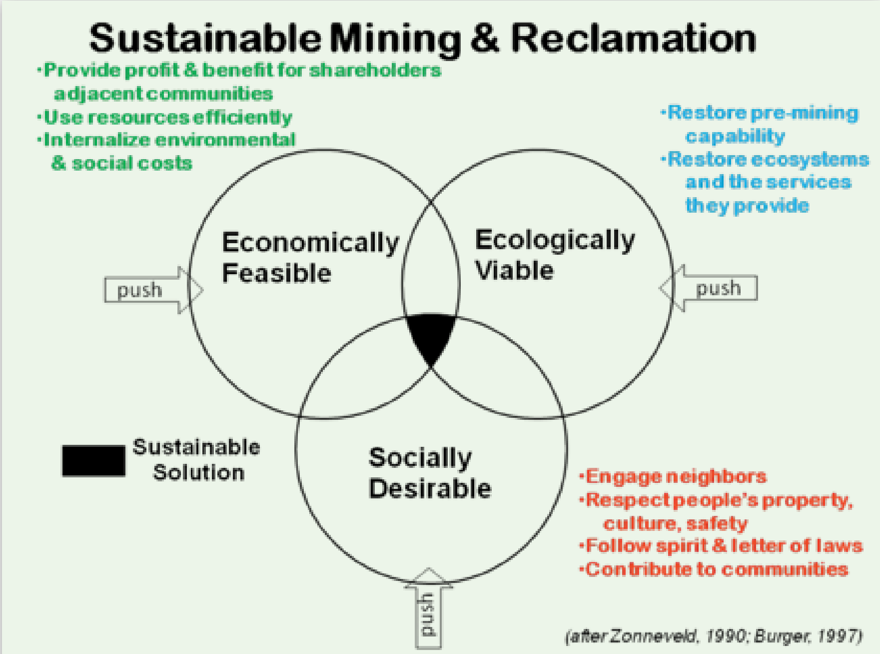


Figure 1. The "triple bottom line" for achieving sustainable mining and reclamation and maintaining a social license to operate.

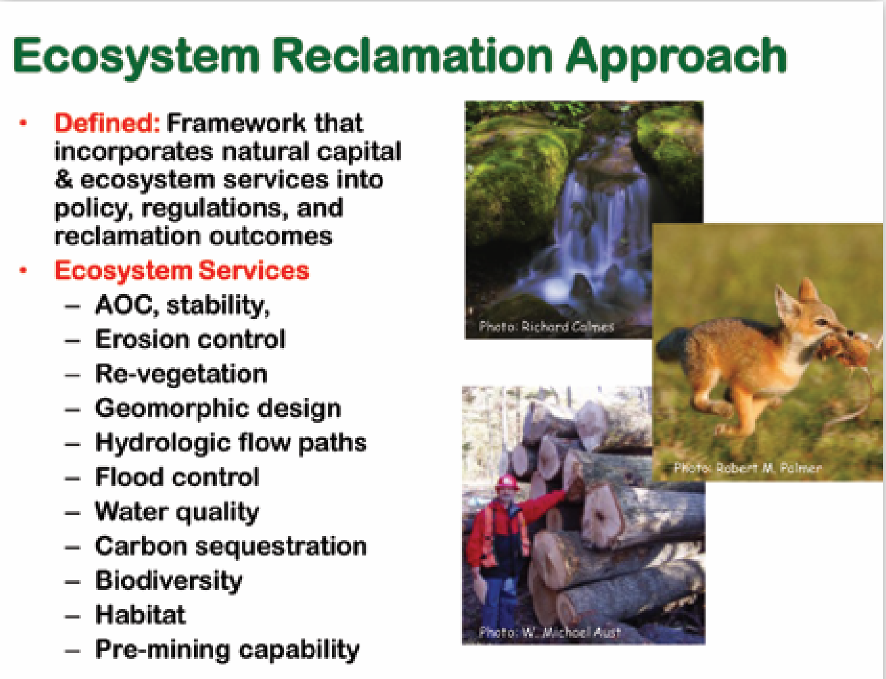


Figure 2. Ecosystem reclamation approach defined; examples of ecosystem services restored with good reclamation practices.

pervasive and irreversible…lack of effective mitigation requires new approaches to mining and reclamation."

Ecosystem Reclamation Approach

To help remedy these problems, I recommend an ecosystem reclamation approach (ERA) that incorporates conservation of natural capital and ecosystem services into policy, regulations, and reclamation outcomes. Ecosystem services are defined as services provided by the natural environment that benefit people (DEFRA, 2007). Natural capital includes terrain, hydrology, water quality, soil productivity, and biodiversity that allow the ecosystem to produce services (Figure 2). This approach has been championed by the Millennial Ecosystem Assessment, the Global Restoration Network, and the Society for Ecological Restoration. The United Kingdom's Department for Environment, Food and Rural Affairs (equivalent to the U.S. Department of Agriculture) adopted the concept as a framework for achieving natural resource and agricultural sustainability. An ecosystem approach emphasizes function, structure, and processes (Armsworth et al., 2007). This approach is consistent with the reclamation model proposed by A. D. Bradshaw (1984) showing reclamation and restoration of ecosystems as a process of returning ecosystem function (y axis: biomass/carbon accumulation, hydrologic function, flood control, etc.) and structure (x axis: species diversity, habitat, water quality) from a degraded condition towards its original condition (Fig. 3). According to Bradshaw, achieving restoration requires establishing reclaimed mined land conditions that allow balanced restoration of both function and structure, represented by a trajectory within nominal boundaries (large dashed arrow in model). Several alternatives to restoration include *neglect* (pre-SMCRA), *replacement* (forest conversions to unused grassland/scrub), and *rehabilitation* (the forestry reclamation approach; Burger et al., 2005; Zipper et al., 2011) (Fig. 3). Although rehabilitation using a forestry reclamation approach provides the best trajectory of these alternatives, it, too, when used alone, falls short of a level of ecosystem recovery that would likely meet the expectations of the public as expressed in the final programmatic EIS (US EPA, 2005).

A better approach for Appalachian mines, an *ecosystem reclamation approach* (Fig. 4), might begin with a geomorphic landscape design that would accomplish approximate original contour while creating a landscape that mimics stable, natural mountain slopes while being cost-effective, attractive, and resistant to surface erosion and mass wasting (Ayres et al., 2006; Schor and Gray, 2007). Backfill materials would be selected and placed to minimize hydrologic contact with materials with high soluble salt levels to minimize total dissolved solids in stream water (Orndorff et al., 2010). Streams would be reconstructed based on pre-mining patterns and capacities using a technique known as natural steam channel design, which seeks to reconstruct the pools, riffles, and other habitat features of undisturbed streams, with the goal of restoring the ecological functions that were lost due to the original stream disturbance (Keystone Stream Team, 2007; Fritz et al., 2010). Soils would be constructed to accommodate native flora and fauna by salvaging topsoil, litter layers, seed pools and coarse woody debris, and mixed with suitable overburden materials to achieve a minimum depth of four feet (Skousen et al., 2011). Reforestation practices (Burger et al., 2005) would be incorporated to ensure native forest biodiversity, productivity, and connectivity that would potentially support native wildlife including interior forest species (McComb et al., 1989; Wood et al., 2006; Wickham et al., 2007) (Fig. 4).

Adopting an Ecosystem Reclamation Approach

Compared to traditional reclamation approaches used in the Appalachian region, the ERA may appear complex and difficult to implement. However, the practices associated with the steps above are well established in science and practice, but not widely applied together in the Appalachian coalfields. An excellent model of an ERA is one developed and used by Alcoa World Alumina Australia on their mines in Western Australia (Gardner and Bell, 2007). An iterative process of adaptive management might be the "how to" for adopting the ERA. It is learning by doing in an organized way that combines ongoing operations with monitoring, research, assessment and training. Adaptive management focuses on learning and adapting, through partnerships of coal operators, regulators, scientists, and other stakeholders who learn together how to reclaim mined land in a sustainable way (Williams et al., 2009).

Native ecosystem restoration, in lieu of other PMLUs that add little or no value to the mined landscape, would appear to be in the best interest of all current stakeholders. Given current expectations, a sustainable mining and reclamation philosophy and a holistic, ecosystem approach for reclamation are needed to deal with aquatic, terrestrial, and human justice issues associated with surface mining in the eastern U. S. coalfields. An ERA could help maintain a "social license to operate" for coal operations (Joyce and Thompson, 2000; Kurlander, 2001).

Take Home Message

The demand for energy throughout the world grows each year, and coal will be needed to meet a large portion of that demand despite newly found gas resources. Coal mining techniques in the Appalachian coalfields have evolved to mine larger land areas and multiple seams at greater depths. New reclamation approaches, practices, and regulations must evolve to minimize cumulative impacts on aquatic, terrestrial, and human capital. As all stakeholders of the mining and reclamation process appreciate the value of ecosystem services provided by native ecosystems, there will be greater emphasis on ensuring their restoration

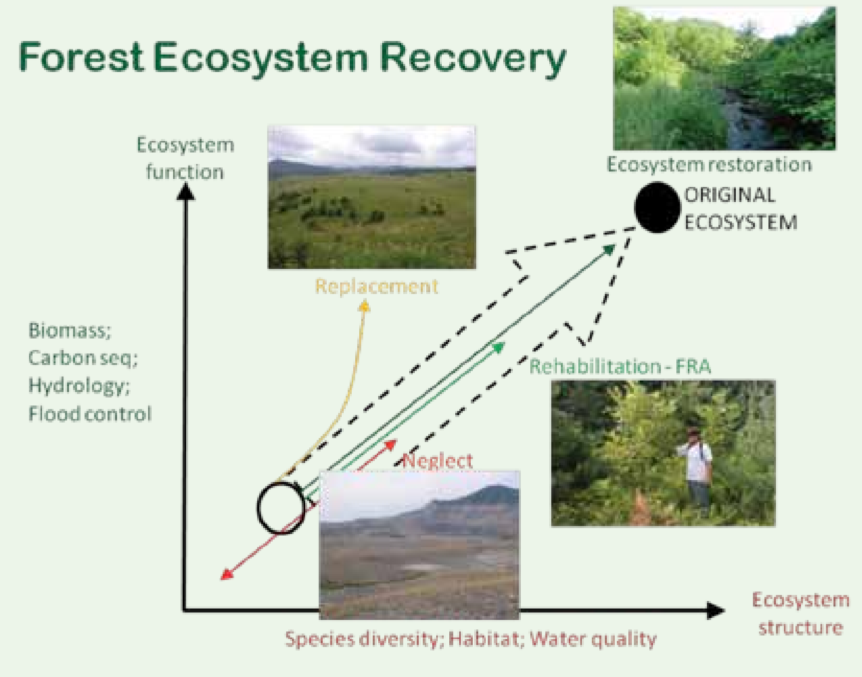


Figure 3. Reclamation alternatives after surface mining in the eastern United States coalfield regions (model adapted from Bradshaw, 1984).

Figure 4. Reclamation steps implementing ecosystem reclamation to restore pre-mining land capability.

and proper functioning on reclaimed mined land. Greater public demand for stream protection, water quality, biodiversity, carbon sequestration, native wildlife habitat, and human protection requires a more comprehensive ecosystem reclamation approach. In my view, the components of such an approach have an established basis in science and could be applied through a process of adaptive management to help the Appalachian coal industry maintain its social license to operate.

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Tailings Pond Reclamation:
Impermeable Covers versus Open Surface Reconfiguration

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Picture 1: East Tailings Pond at the Graves Mountain Kyanite Mine in 1994.

Picture 2: Kyanite crystals (blue) with quartzite and fine grained pyrite.. Kyanite is used in refractory bricks and on space shuttle heat shields.

Picture 3: An herbaceous and woody vegetation has developed on the tailings.

Pyrite, water, air and limestone – four simple ingredients when mixed together require complex solutions. In Lincoln County, Georgia, researchers from the University of South Carolina (USC), working with the current land owner, ABB, Inc., have developed and implemented a long term reclamation plan that has reclaimed a former pyrite-containing kyanite mine that operated from the early 1960's to 1980's (Picture 1). The reclamation successes are measured in improved surface water and pore water quality, enhanced soil quality, and vegetative succession and wildlife diversity. Reclamation of the mine's tailings ponds is one aspect of the overall plan and this paper compares the hydrology of two reclamation strategies; one tailings pond with a traditional impermeable membrane cover and the second with an open, surface reconfiguration (OSR) methodology.

Kyanite (a clay mineral used in refractory bricks and space shuttle heat shields) was extracted from a kyanite-quartzite-pyrite metamorphic ore deposit at the Graves Mountain mine. (Picture 2). Ore processing produced fine grained waste tailings The waste tailings minerals include quartz, pyrite, micas, lazulite, rutile, and various iron oxides and hydroxides (Cook, 1985; Hartley, 1976). The tailings were transported from the processing plant by slurry pipeline to various tailings ponds. The "ponds" were constructed by removing or scraping the surface soil and constructing dams to create holding ponds with depths ranging from 20 to 80 ft and sizes ranging from less than 1 acre to 77 acres. The weathering of the minerals, especially pyrite (FeS2), within the tailings ponds coupled with the flotation process fluids, have produced acidic discharges with elevated metal and sulfate ions. These discharges were captured and actively treated. However, with the completion of the mining operation and changes in ownership, in-situ technologies, passive treatment and ecological engineering practices were developed to replace active treatment systems.

The general chemical reactions defining the oxidation of pyrite and the production of acidity, sulfate and metals are well

Picture 4: Organic layer of about 1-2 cm is establishing in the tailings.

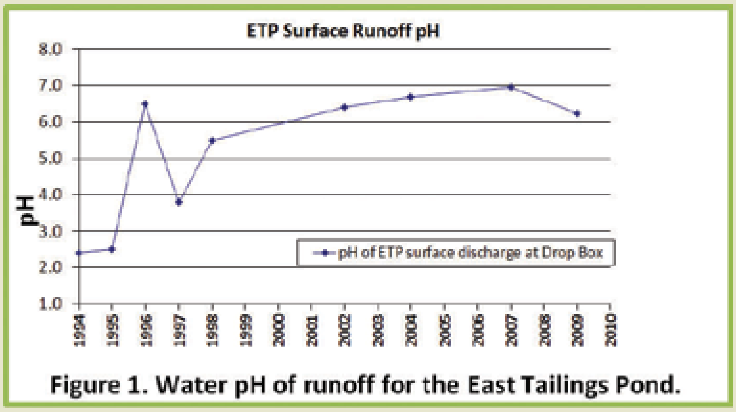

Figure 1. Water pH of runoff for the East Tailings Pond.

known and the resulting impacts on water quality have been documented in many scenarios including coal mining (Skousen, et al., 1998; Geidel and Caruccio, 2000), mineral mining (Lappako, 2002) and various anthropogenic activities (Daniels, 2003). As a result of the on-going reactions and changes in water availability, the tailings ponds represent geochemical and hydrologic systems that evolve with time.

The ore-body host rock rises about 300 ft above the surrounding landscape and ground and surface water discharge radially from the site. While a number of tailings ponds exist around the base of the mountain, the two primary ponds studied are the East Tailings Pond and the Pyrite Pond.

The East Tailings Pond (ETP) is approximately 77 acres and tailings depths vary from about 45 to 75 feet. The reclamation included the addition of limestone ,organic material, fertilizer and seed and the surface was reconfigured with ridge and furrows (OSR) which encourages rainfall to accumulate in the furrows. The less dense rain water establishes pockets of fresh water that float within the acidic matrix. With time, the ridges have become purged of acidity and fresh water zones have established. The revegetation has been successful (Geidel et al., 1999) and by 2012, the ETP is covered with grass and shrub vegetation and approximately 1/3 is forested with a variety of pines, yellow poplar, sweet gum, willow and oak (Picture 3). In addition, the surface is developing an A horizon in the upper 1-2 cm with increased levels of organic carbon (Picture 4). Hydrologically, quicksand conditions no longer exist and the water table is not at the surface. During rainfall events with sufficient intensity and duration, precipitation runoff occurs. The pH of the runoff, pre-reclamation was 2.2-2.8 and post reclamation, continues to be maintained between pH 6 and 7 (Figure 1).

To evaluate the potential changes in the hydrology, two shallow (4-ft deep) piezometers were installed in 2003. Within several years, the water level dropped below 4 feet. In 2010, two sets of wells with three wells per set were installed using direct push methods (Geoprobe®) mounted on a small remote controlled vehicle to minimize disturbance of the ridge and furrow configurations. Each well set included one well screened to the base of the tailings (100% depth), one at about 60% depth and the third at approximately 33% depth. ETP-2 was the deepest set (75 ft, 45 ft and 25 ft depths) and ETP-1 was more shallow (45 ft, 30 ft and 20 ft). In 2010, a number of borings were also completed to determine the total depth of the tailings and water level elevations (Figure 2; Geidel, 2012).

The Pyrite Pond (PP) is approximately 2 acres and derived its name, apparently, from the storage of pyrite. Pyrite tailings were sold as a coloring agent for brown glass. When no market existed for the pyrite, the pyrite tailings were placed in the tailings pond along with the other wastes. The upper and steep slope of the PP area has tailings depths up to 6 ft on the northeast slope, but within the pond the tailings depths are up to 80 feet.

The PP pond surface was reclaimed in 1992 using an impermeable plastic membrane. A thin (1-ft) veneer of soil was placed over the membrane and seeded with grasses (E.R. Dotson, 1999, per. com.). After three years, the predominant, albeit sparse, vegetative cover was weeping lovegrass (Eragrostis curvula). During the reclamation of the flat surface of the tailings pond in 1992, the upper slope was not reclaimed and the tailings remained exposed. In 1998, the slope tailings were treated by applying two thin veneer coatings of "lime slurry," a slurried calcium oxide. The first veneer was applied 0.5-1 cm thick, the gullies filled with clay and tailings mix, a second veneer applied and a final cover of soil distributed. An additional 1 foot of soil was also distributed over the surface of the PP pond membrane. Both the slopes and Pyrite Pond surface were fertilized and seeded with grasses and legumes. Currently, the pond is completely vegetated and approximately 25% is forested.

In 1999, fifteen wells were drilled within the PP drainage basin. Of the 15, three were within the tailings pond (PP-12, PP-

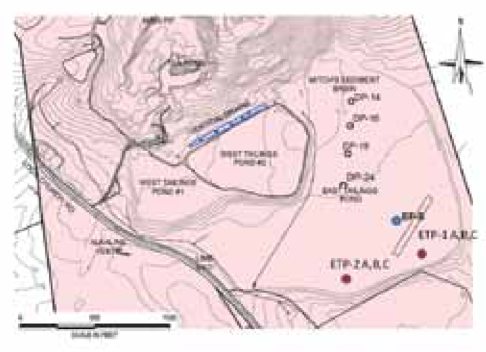

Figure 2. Location of borings and wells in the East Tailings Pond.

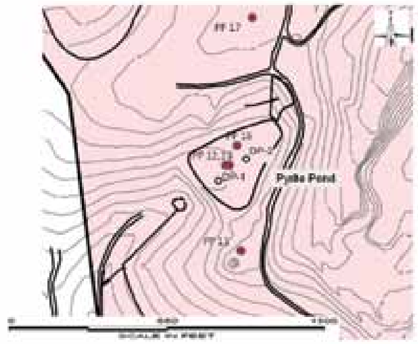

Figure 3. Locations of wells and borings in the Pyrite Pond (PP).

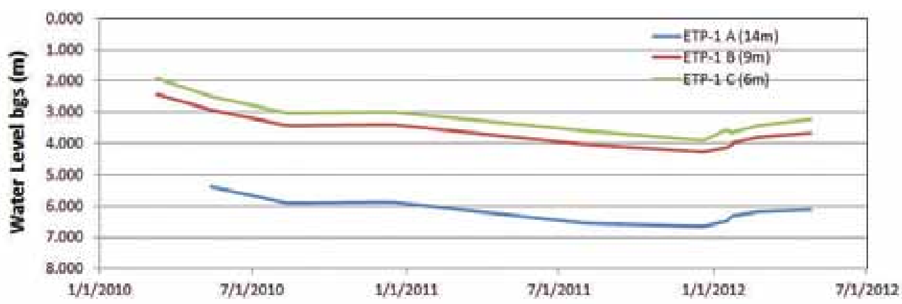

Figure 4. Decline in water levels below ground surface (bgs) at ETP-1 well set.

13 and PP-16), one up-gradient (PP-17) and another in undisturbed rock immediately south of the pond (PP-11). Of the wells within the tailings pond, PP-12 was completed within the tailings (to 35' bgs) while PP-13 and -16, were screened at the tailings/clay interface (to 77 ft and 85 ft, respectively). In 2010, two additional borings (DP-1 and 2) provided tailings information (Figure 3).

Periodic water level measurement data and water quality samples have been collected from the ETP and PP wells since their installation. Within the ETP, the water level measurements from the two well sets compare data from two depths of tailings, and also compare the water level variations with time and precipitation. While each of the wells has a very similar declining trend, the differences suggest that the tailing deposition process and the fine nature of the tailings allow for stratification and that a number of perched layers may exist within the tailings. This is consistent with the initial piezometer data in the vicinity of ETP-1, which indicated a steady decline in water levels from 2003 to 2005 to greater than 4 ft below the surface (Figure 4). Assuming a long term steady water level decline in the near surface horizons, the decline from 3 ft below ground surface in 2003 to greater than 4 ft in 2005 to nearly 11 ft in 2012 suggests a long term trend of decreasing water levels in a shallower portion of the ETP, most likely the result of increased evapotranspiration. Rainfall plays a role as noted below, but not as related to long term declines.

In the area of the second well set, ETP-2, standing surface water was common during rain events and, coupled with the OSR reclamation, it was assumed that the surface water was an expression of the water table. However, well data indicate that the surface ponding merely reflects low percolation rates of the surface tailings since the water levels in all wells were in excess of 3 ft below the surface. While rainfall was determined to influence the well water levels, the delay between the precipitation event and changes in water level, which may be on the order of months, suggests that a base flow component may be an important element determining water level elevations within the tailings. Traditional tailings pond hydrology suggests that water in the pond is the result of the original slurry and rainfall. The findings at this site suggest a third component is the up-gradient groundwater.

Water level measurements from the wells in the Pyrite Pond area have been intermittently collected since 1999. Measurements from Wells PP-11 and PP-17 (Figure 3) represent water levels in sections of the site which were not mined and the wells were drilled to the depth at which water was first encountered (81 ft and 200 ft, respectively) and the bottom 5 ft were screened. Wells PP-11 and PP-17 provide background against which changes in water levels within the tailings pond can be evaluated (Figure 5). Within the PP, the similarity in water level elevations between PP-12 and PP-16 is striking (Figure 5). Although there is an average percent difference between PP-12 and 16 of 23%, a strong relationship exists between the water levels in the two wells ($R2 = 0.9538$).

These data suggest that the liner does not completely isolate the tailings from precipitation events given the increase in the water level in 2003 (Figure 5). The response is not as flashy as that associated with PP-11 in the surrounding bedrock, but is similar to the level of response shown by PP-17 suggesting that the tailings pond is influenced by a ground water component. This would be consistent with the location of the tailings in a natural discharge area and the inability of a surface liner to be able to address and intercept the base flow component (Figure 6). While the liner appears to minimize the impact of surface infiltration, the upslope area with up to 6 ft of tailings on the surface provides a direct avenue for surface infiltration, although this has most likely been somewhat moderated by the clay layer and vegetation now established on the slope.

Figure 5: Water levels in Pyrite Pond and in surrounding wells, and precipitation from 1999 to 2012.

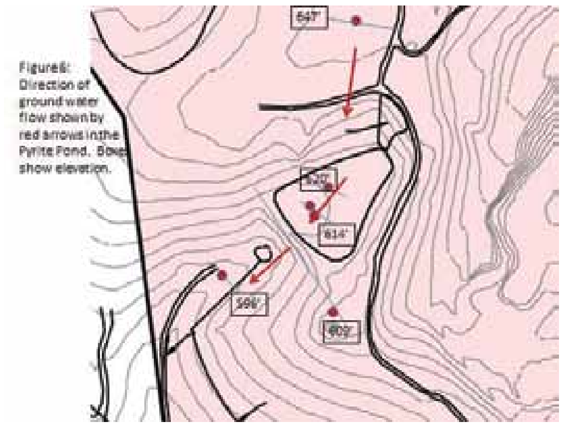

Figure 6: Direction of ground water flow shown by red arrows in the Pyrite Pond. Boxes show elevation.

This limited surface infiltration most likely accounts for the variation in water depth of only 16 ft, while PP-11 had a variation in excess of 34 ft and was drilled to nearly the same depth as PP-16.

Summary & Conclusions.

This study suggests three major influences on the hydrologic parameters between two kyanite ore process tailings ponds which were reclaimed with different reclamation strategies; one reclaimed with an impermeable plastic liner membrane and the other with an open, surface reconfiguration (OSR) methodology. The first tailings pond, the East Tailings Pond (ETP), was constructed and filled in the 1970's and early 1980's and reclaimed in 1995-96 by surface reconfiguration and the addition of soil amendments (straw, fertilizer and fine grained limestone). The second, the Pyrite Pond (PP), was constructed and filled during the 1960's and early 1970's. In early 1992, the Pyrite Pond was capped with an impermeable membrane, covered with a thin (1-ft) soil veneer and vegetated. In 1998, the upslope was reclaimed with an application of lime slurry, covered with soil and the entire tailings pond area revegetated. Piezometers and wells were installed into both tailings ponds and also in close proximity to the Pyrite Pond. Results indicate that while both tailings ponds exhibit delayed response to precipitation events suggesting infiltration and compaction/layering effects on hydrology, the delay in the ETP deep wells and PP wells could not be adequately described by a surface infiltration model. Further consideration of the surrounding well data, coupled with the tailings cross sections and water levels, suggest that the hydrologic characteristics of both tailings ponds are significantly influenced by base flow infiltration and ground water seepage into the up-gradient areas of the tailings ponds.

Acknowledgements:

Deep appreciation is extended to ABB, Inc. for their dedication and support for the various projects at this site. I would also thank the site engineers, E. Ray Dotson and John Adcock, who often had creative ideas for implementing scientific principles. The successes at this site are also a testament to the creativity of Dr. Frank Caruccio.

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Co-Treatment of Acid Mine Drainage with Municipal Wastewater:

A Promising New Approach

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Theory

Co-treatment of acid mine drainage (AMD) and municipal wastewater (MWW) is a new synergistic treatment approach that blends aspects of passive AMD treatment and conventional active MWW treatment. Passive treatment of AMD by bacterial sulfate reduction (BSR) generates alkalinity via bicarbonate production and removes metals from solution via sulfide precipitation. Successful BSR systems require electron donors, the capacity to strip oxygen, and to reduce metal through bacterially-mediated reactions. Numerous carbon sources, including horse and cow manure, chicken litter, ethanol, methanol, and municipal sewage sludge and compost, have been successfully applied to treat AMD by BSR; MWW contains a wide variety of organic compounds ranging from simple sugars to cellulose, indicating suitability as a rich substrate for microbial communities. Metals may also be removed from solution by sorption to the aforementioned organic substrates (Hughes et al. *in review*).

In conventional active MWW treatment using the activated sludge process, organic compounds and nutrients are primarily removed via bacterial oxidation and assimilation. Further treatment of effluents is often required to meet discharge limits, e.g. UV or chemical disinfection to re-

Figure 1: Potosí, Bolivia is an example of one of the many population centers that abut AMD sources in which co-treatment may be a more fiscally and environmentally sustainable solution.

Figure 2: A stream in Potosí, Bolivia in which untreated AMD and MWW mix uncontrolled, severely degrading water quality.

move pathogens and the addition of coagulants (e.g. alum ($Al_2(SO_4)_3 \cdot 18\ H_2O$) or ferric chloride ($FeCl_3 \cdot 6\ H_2O$)) to remove phosphate and to improve sludge flocculation and suspended solids removal. Adapting the activated sludge process to co-treat AMD and MWW takes advantage of the natural alkalinity of MWW (typically 200-250 mg/L as $CaCO_3$) and the adsorptive properties of MWW particulates and activated sludge biomass to remove acidity and metals by precipitation and adsorption.

Several theoretical advantages to co-treatment arise because components which are highly concentrated in one effluent stream tend to be low in the other. For example, metal concentrations in MWW are relatively low (typically <500 μg/L) compared to AMD; therefore, adsorption sites on wastewater particulates (and activated sludges) are theoretically available for metal uptake from AMD. Dilution and neutralization of AMD by mixing with alkaline MWW cause the pH to increase, leading to further removal of dissolved metals. Also, the high concentrations of suspended solids in MWW may enhance Fe removal by oxyhydroxide precipitation by serving as nucleation sites for Fe (Johnson and Younger 2006). In turn, co-treatment can potentially improve the efficiency of MWW treatment. For example, Fe and Al oxyhydroxides may provide attachment sites for bacteria which have important roles in nutrient removal from MWW (i.e., nitrifying and denitrifying bacteria, Demin et al. 2002). The Fe and Al in AMD can also be used as effective substitutes for commercial coagulants (Rao et al. 1992).

Brief History

Although Roetman (1932) first suggested mixing AMD with MWW for pathogen removal, only a few systems have been intentionally constructed to simultaneously co-treat these effluents. Recently, McCullough and Lund (2011) documented water quality improvement and bacterial sulfate reduction as high-strength AMD was accidentally introduced to secondary MWW. They followed that by investigating the bioremediation of AMD using sewage and green waste (e.g., lawn clippings) as amendments to facilitate sulfate reduction in microcosms containing pit lake water with pH 2.4 and 200, 690, and 16 mg/L Al, Fe, and Zn, respectively. They found higher bioremediation rates with sewage than green waste. Johnson and Younger (2006) built a field-scale, single-stage constructed wetland treatment system that successfully improved the water quality of weak secondary MWW effluent (5-day biochemical oxygen demand (BOD_5) of ~14 mg/L) and relatively weak (net-alkaline with ~3 mg/L Fe) AMD. Strosnider and Nairn (2010) demonstrated that multiple metals and metalloids of concern could be removed from solution with single-stage incubation of high-strength AMD from Cerro Rico de Potosí, Bolivia and raw MWW with and without the presence of limestone.

Recently, a flow-through laboratory mesocosm system simultaneously and passively treated high-strength AMD and raw MWW. This system consisted of a clarification pond, a bioreactor containing limestone overlain by an inert biofilm media, and an aerobic wetland. The system continuously and effectively processed high-strength synthetic AMD and grit-screened municipal wastewater from the City of Norman, OK, without requiring ongoing nonrenewable energy inputs. Strosnider et al. (2011a, 2011b) documented removal of Al, As, Cd, Fe, Mn, Pb and Zn with concentrations consistently decreasing by 99, 88, 98, 99, 14, 88 and 73%, respectively, and net acidic influent conversion to net alkaline circumneutral effluent (Figures 3 and 4). The system received MWW with mean 265 mg/L BOD_5 and produced effluent with BOD_5 below detection limits (Strosnider et al. 2011c). Orthophosphate (PO_4^{3-}) was decreased to below detection limits and ammonium (NH4+) was decreased 46% (Strosnider et al. 2011c). A near 100% reduction in total coliforms, fecal coliforms, *E. coli*, and fecal streptococci was also noted (Winfrey et al. 2010). A batch-reactor mockup of the system was tested using the raw MWW and AMD of Potosi, Bolivia, and met with promising nutrient and metals processing results (Strosnider et al. *in review*). These

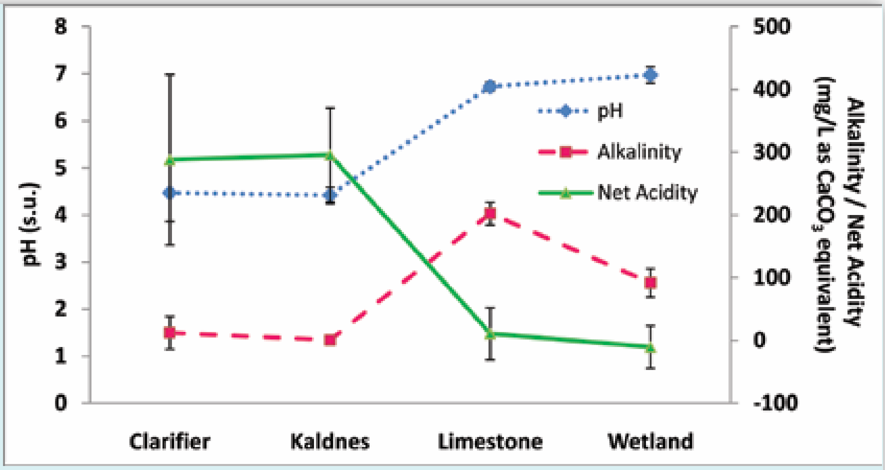

Figure 3: Low pH, net-acidic waters were converted to net-alkaline, circumneutral pH waters as they passed through four unit processes (Clarifier to Wetland) in the passive co-treatment system developed by Strosnider et al. (2011a).

studies demonstrated that AMD generally considered too high-strength for passive treatment could be successfully and passively co-treated with MWW.

Of late, studies have indicated that the conventional activated sludge process could be applied successfully to the active co-treatment of AMD and MWW. Three critical aspects of co-treatment using this approach have been investigated: (i) the treatability of AMD by activated sludge, (ii) the metal removal and neutralization capacity of MWW and activated sludge biomass, and (iii) the impacts of AMD loading on MWW treatment performance. In treatability studies, Hughes and Gray (2012) demonstrated that spiked addition of relatively high ratios of high-strength synthetic AMD did not cause significant decreases in sludge oxygen uptake rate in activated sludge from municipal wastewater treatment plants, and microbial adaptation was observed after continuous AMD loading. In batch tests with synthetic high-strength AMD, removals of 90-100% for Al, Cu, and Fe, 65-100% for Zn, and 60-75% for Mn were achieved using grit-screened MWW (Hughes and Gray *in review-b*), and the AMD pH was increased from pH 2.8 to 6.2 at 50% vol AMD/vol MWW. Using activated sludge, average removal efficiencies for Al, Cu, Mn, and Zn were 10-65%, 20-60%, 10-25%, and 0-20%, respectively, with sludge solids concentration being an important controlling factor (Hughes and Gray *in review-b*). In process evaluations using laboratory-scale activated sludge reactors treating AMD at a range of strengths (Hughes and Gray *in review-a*), continuous AMD loading caused no significant decreases in organics removal. Removals for dissolved Al, Cu, Fe, and Pb were 52-84%, 47-61%, 74-86%, and 100%, respectively, and Mn and Zn removals were strongly linked to acidity; removal from net-acidic AMD was <10% for both metals, whereas removal from circumneutral AMD averaged 93-95% for Mn and 58-90% for Zn. Where AMD contained Fe and Al, final effluent total phosphorus concentrations typically ranged from 1-2 mg/L (Figure 5). Phosphate removal was most likely occurring by precipitation with Fe and Al and/or sorption onto Fe oxyhydroxide precipitates. These results demonstrated an important co-treatment synergy, indicating that AMD can serve as a substitute for proprietary chemicals and coagulants for improving phosphate removal.

Research Avenues

For co-treatment of AMD and MWW to become a design option, multiple lines of research are needed. Regarding passive co-treatment, the processing or recycling of the solids produced, reliable rates of sulfate reduction and oxygen stripping, suitable effluent loading rates, and mixing ratios should be investigated and then field-scale pilots initiated. Regarding active co-treatment using the activated sludge process, the impact of AMD on sludge biomass structure and settleability when using real MWW as substrate should be evaluated. Non-synthetic MWW should be mixed with AMD in simulations of the primary sedimentation process to rigorously examine the removal of dissolved metals and suspended solids, as well as alkalinity consumption, during primary treatment. Finally, the impact of metals on anaerobic sludge digestion should be investigated.

The recent findings outlined above demonstrate the feasibility of co-treatment using passive and active technologies. Co-treatment is an opportunity to increase the efficiency of both MWW and AMD treatment, while presenting a sustainable passive treatment option for high-strength AMD. Offering potential savings in materials, proprietary chemicals, and energy inputs, co-treatment is a viable approach to AMD and MWW remediation in developed areas as well as in remote, resource-poor, or developing regions.

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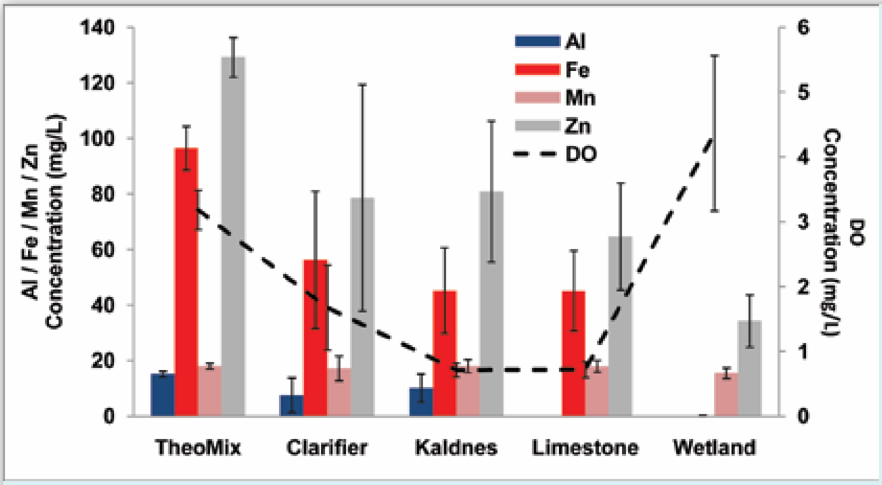

Figure 4: Key metals were removed and oxygen was stripped then reintroduced in the passive co-treatment system developed by Strosnider et al. (2011a). AMD was much higher strength than that typically treated via passive means (pH 2.6 and acidity of 1870 mg/L as CaCO3 equivalent containing a mean 46, 2.0, 290, 55, 1.2 and 390 mg/L of Al, Cd, Fe, Mn, Pb and Zn, respectively).

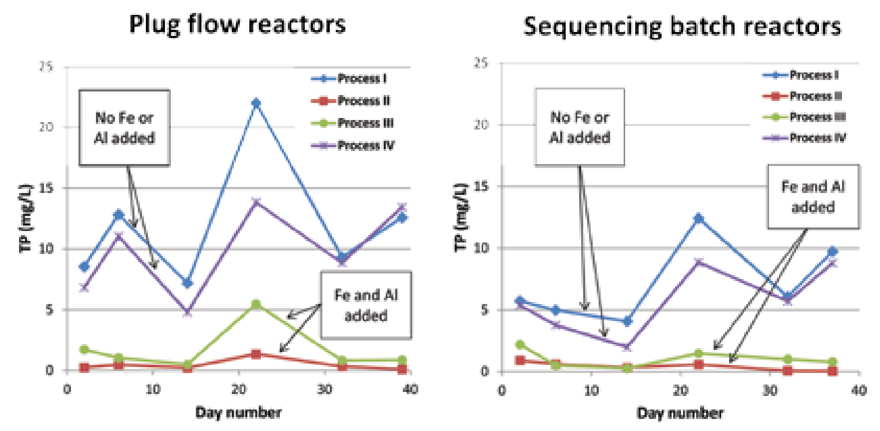

Figure 5: Final effluent concentrations of total phosphorus (TP) in laboratory-scale plug flow and sequencing batch reactors co-treating synthetic MWW and AMD for a 40 day period (Hughes and Gray *in review-a*). Process I (control) received no AMD, while Processes II, III, and IV received continuous loading of AMD at a range of strengths. Day number is the number of days after continuous AMD loading began.

Hydrologic Engineering

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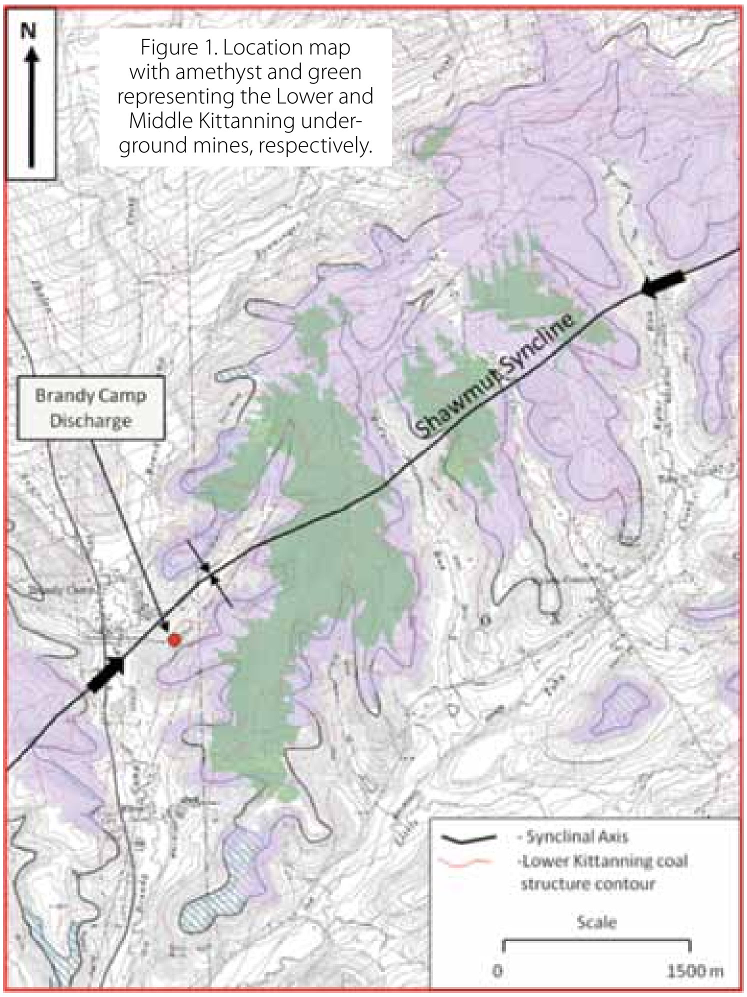

Figure 1. Location map with amethyst and green representing the Lower and Middle Kittanning underground mines, respectively.

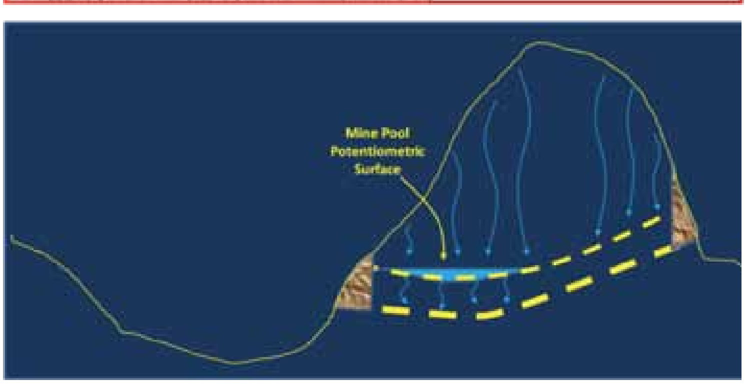

Figure 2. Shawmut Mine pool yielding diffuse recharge water to the underlying Elbon Mine under normal conditions.

Introduction

There are times when the complexity and unexpected nature of underground mines create conditions that foster unconventional solutions. A mine complex dominated by two stacked abandoned underground mines located in north central Pennsylvania poses such a situation (Figure 1). The majority of the mine water emanates from the Lower Kittanning Elbon Mine at a structural and topographic low point (the Brandy Camp discharge). However, the overlying Middle Kittanning Shawmut Mine is the major controlling component of the hydrologic regime. The mines are separated by a relatively thin interburden (average of 38 feet) comprised predominantly of claystone and shale. Through relatively simple, yet effective, use of hydrologic engineering, the Brandy Camp discharge rate from this mine complex has been lowered, and the potential for large scale periodic flushing events, which have occurred in the past, has been minimized.

Historical Setting and Conditions

The Brandy Camp discharge has existed since mining on the Lower and Middle Kittanning coals was completed in the late 1930s and early 1960s, respectively. Extensive surface mining of outcrop areas of these two seams occurred from the 1980s into the early 2000s. Surface mining of the crop coal of the Lower and Middle Kittanning seams progressed until the underground mine entries were encountered. The subsequent reclamation buried the exposed coal creating essentially anthropogenic subcrops. Substantial surface mining also occurred on several overlying seams during that time interval.

The Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation constructed a treatment plant for the Brandy Camp mine discharge in their ongoing efforts to restore Commonwealth waterways. However, once the plant was completed in 1999, it was determined to be undersized. The Brandy Camp discharge rate had markedly increased from baseline levels. The plant, which was originally constructed for 400 gallons per minute (gpm), was consistently discharging at 600 gpm, and frequently exceeded 1,000 gpm. An investigation determined that the substantial surface mining which had occurred in the watershed significantly increased the infiltration rate into the mine (Hawkins and Smoyer, 2011). Greatly increased permeability and porosity of the mine spoil allowed for more of the precipitation to infiltrate into and through the backfill blanketing the watershed, and subsequent-

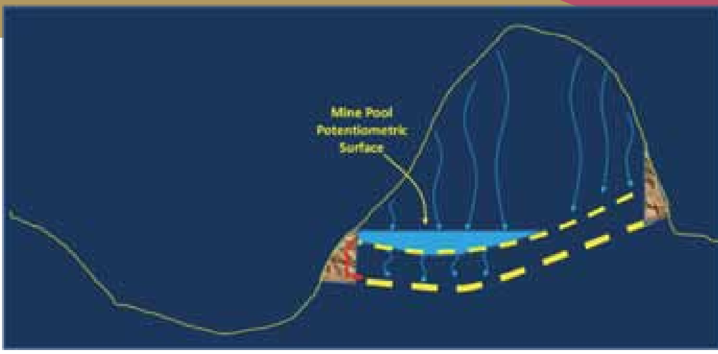

Figure 3. Greatly elevated Shawmut Mine pool yielding water Elbon mine via spillover through spoil at the buried highwall during high recharge episodes.

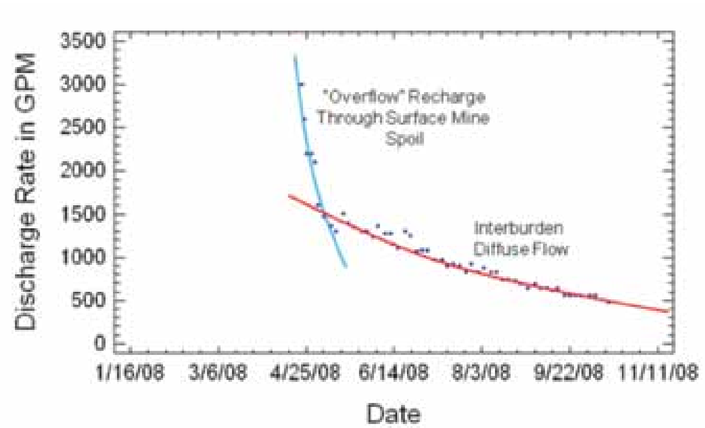

Figure 4. Regression hydrograph of the Brandy Camp discharge from the spring 2008 flushing event.

ly increased recharge to the underlying deep mines.

The underground mines straddle the axis of the northeast-southwest trending Shawmut Syncline. The Shawmut Syncline is slightly doubling plunging, so strata form somewhat of a canoe-like structure (Figure 1). The majority of the water from the two underground mines discharges from a single point draining from a structural low point in the Elbon Mine at the Brandy Camp discharge. The Brandy Camp discharge drains from a piping system installed into a buried portal. Thus, there is no pooled water in the Lower Kittanning Elbon Mine; the water drains through the mine freely and relatively unrestricted.

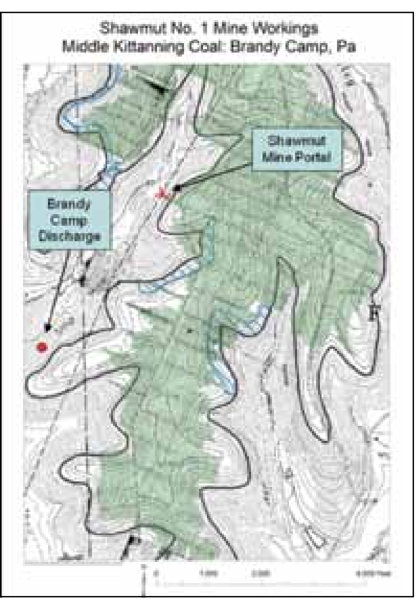

Figure 5. Buried portal location in the Shawmut Mine.

Figure 6. Portal Excavation on September 15, 2009.

On the other hand, the geologic structure in concert with the low permeability interburden causes the overlying Shawmut Mine to form a "perched" mine pool; the size of which varies seasonally. The pool elevation has been recorded to fluctuate at least 16 feet. The Shawmut Mine pool provides a relatively steady diffuse recharge to the underlying Elbon Mine by vertical leakage through fractures in the thin interburden (Figure 2). It has been observed that when the mine pool in the Shawmut Mine rises to near 1659 feet above mean sea level (a.m.s.l.) and higher there is a substantial increase in the recharge rate to the underlying Elbon Mine. The mine discharge rate at Brandy Camp increases commensurately. With the mine pool at or above 1659 feet a.m.s.l., the Shawmut Mine drains recharging water out of the buried entries exposed at the subcrop, rather than just leaking through to the underlying mine. The mine-pool "spills over" and excess water flows rapidly down through the highly-permeable spoil until it reaches the pit floor of the Lower Kittanning (Figure 3). At that point, the mine water flows down dip along the pit floor, enters the Lower Kittanning Elbon Mine, and subsequently surfaces at the Brandy Camp discharge.

Major Meltdown and Flushing

Melting of a significant snow pack by over 5.3 inches of rain in the spring of 2008 caused a major flushing event at the Brandy Camp discharge. The discharge rate rose from about 1,000 gpm to well over 3,000 gpm, which is more than seven times the original design capacity of the plant. During this flush, peak discharge rate was likely closer to 5,000 gpm, but could not be accurately determined due to much of the flow bypassing the plant through an unmetered ditch. As is common with these large scale underground mine flushing events, as the flow rate increased, the water quality also became substantially worse (Ziemkiewicz and Brant, 1997). Prior to the flushing event, the pH of the Brandy Camp discharge averaged 4.8 standard units (S.U.) with a net acidity of 167 mg/L, and iron concentration averaged 63 mg/L. The pH of the discharge during the flush dropped to 4.5 S.U. with net acidity increasing to 400 mg/L (2.4 times the long term average) and iron concentration increasing to 126 mg/L, (two times the average concentration). The discharge of several thousand gallons per minute of the untreated poor quality mine water severely impacted the receiving stream, Brandy Camp Creek.

The openness of the mine entries and the high permeability of the mine spoil facilitate rapid high-volume recharge to the Elbon Mine from the subcrop spillover, when the mine pool rises above 1659 feet a.m.s.l. As the mine pool level recedes, there is a point where water is no longer spilling over the buried highwall. At that pool level, recharge from the Shawmut Mine to the Elbon Mine is once again dominated by the diffuse flow through the interburden. The mine discharge regression curve shows a sharp line break where the slope is markedly reduced at the point when the diffuse recharge becomes predominant (Figure 4). The pool level at which

Figure 7. Shawmut portal discharge May 2011.

the break in the line occurs was determined to be near 1659 feet a.m.s.l.

Under normal diffuse recharge conditions, the mine water flow paths through the Lower Kittanning Elbon Mine do not vary much and are comprised of thin film waters flowing along the mine floor. So, the exposed iron salts are dissolved at a quasi steady state rate and the water quality remains relatively consistent throughout the year. The high volume recharge in the spring of 2008 created transient conditions. The drastic change in recharge mode when the pool exceeded 1659 feet a.m.s.l. caused large volumes of water to flow through Elbon Mine entries that normally receive little water and at much higher rates than otherwise occurs. The mine works were likely rinsed more completely by the large inflows with increased metal and acid loads in the discharge. Once the water levels receded below the 1659 feet a.m.s.l., the flushing event ended and the normal recharge mode resumed. The water quality of the Brandy Camp discharge returned to pre-flush chemical concentrations within a few months.

Controlling Future Flushing Events

After the 2008 flushing event, the question became; is there some way that the water level in the mine pool could be controlled to prevent future flushing occurrences? Fortunately, the configuration of the Shawmut Mine lent itself to that possibility. There was a buried portal located on the northwestern side of the mine that could serve as a drainage relief point for the mine pool (Figure 5). The elevation of the bottom of the coal at the portal is approximately 1657 feet a.m.s.l., which is about two feet below the spillover elevation. Mine water had been seeping from this portal at a rate of less than one gpm. The portal was excavated to create an avenue for the water to laterally discharge from the mine before it rises to the spillover level at the subcrop-exposed entries. A temporary dam was placed across the face of the portal to retain the mine water which was impounded behind the earthen seal. A piping system was installed to drain the initial outflow, which had considerable suspended iron (Figure 6). The mine water quickly clarified after the initial outrush.

The drain pipe was inserted back into the portal entry in order to constantly drain the upper mine-pool and prevent the pool from rising to the "spillover" elevation. This prevents future flushing events. The drain pipe system was installed permanently, buried, and the portal face was reclaimed. The flow from the Shawmut portal is about two gpm during the driest parts of mid-summer to early fall. However, during the early to mid-spring, the discharge rate has been recorded to reach at least 3,000 gpm (Figure 7).

The drainage relief provided by opening the upper mine portal has been substantial. The Shawmut Mine pool level has only once, very briefly (less than 36 hours), exceeded the 1659-foot spillover level in the nearly three years since the portal was opened (Figure 8). That exceedance episode was less than 0.3 feet. An 8-inch inside diameter pipe was installed as the drainpipe. In hindsight, we would have installed a 10- or 12-inch diameter drain pipe had the full nature of the mine pool and its upper level recharge rate been better understood.

Figure 8. Shawmut Mine pool hydrograph

Opening the portal effectively decants a considerable amount of water that would otherwise recharge the underlying Elbon Mine. Besides preventing future flushing events, the opening of the portal promotes a two-fold improvement toward water treatment of the Brandy Camp mine complex watershed, and specifically the discharge. The water of the Shawmut Mine is much better quality than that which ultimately emanates at the Brandy Camp discharge. The Shawmut mine water is essentially effluent quality without treatment. Water discharging at the Shawmut portal is net alkaline with a pH between 5.9 and 6.0. The iron concentration averages less than 0.3 mg/L. Any water that is diverted out the Shawmut portal and does not recharge the Elbon Mine, even during low-flow conditions, reduces the amount of water requiring treatment. Secondarily, the Shawmut water is discharged into the receiving stream further upgradient in the reach from the treatment plant which helps to improve the in-stream water quality by diluting any degradation from small unchecked seeps and polluted base flow.

Future considerations are to determine the economic feasibility of installing a horizontal or slightly upward inclined borehole into the lowest part of the mine pool to drain off most of the Shawmut water before it infiltrates down to the Elbon Mine. Thus, degradation of the relatively good water of the Shawmut Mine could be prevented from being degraded by removing the water before its entrance to the Elbon Mine and possibly used at the plant to aid with the treatment.

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Pennington Seed Exceeds Alpha Natural Resources' Expectations with Enhanced Reclamation Practices

In 2009, Alpha Natural Resources, Inc. in Julian, West Virginia approached Madison, Georgia-based Pennington Seed to assist them in their revegetation efforts on reclaimed surface mines. One primary goal of the partnership was to improve permanent vegetation establishment during initial seeding applications to meet permit requirements and to avoid the compounded costs associated with failed revegetation projects. The cost of seeding materials was minimal compared to the total reclamation cost, which included earthmoving and hydroseeding equipment, mobilization, fuel, maintenance and labor.

Utilizing a collaborative approach between Alpha's environmental managers and Pennington's agronomic team, a more efficient reclamation model emerged. Mine site operators began to coordinate soil tests and analyses with Pennington prior to seeding to allow for site-specific reclamation plans that addressed soil fertility, pH, erodibility factors, seed selection and erosion control-measures. This increased the establishment success rate of permanent vegetation that complemented post-reclamation land uses. The following steps were essential in implementing this new model:

Grey Eagle site before seeding

Grey Eagle site with established vegetation one year after seeding

Soil Testing Establishes Solid Foundation for Growth

Soil testing prior to seeding is critical on mine sites to help insure the establishment of permanent vegetation. Depending on the geological profile from which material is mined, the surface soils can vary greatly in composition. Soil organic matter (OM), nutrient availability and pH can range widely, even within a close proximity on the surface. Acidic conditions can also arise in post-mining operations due to the presence of certain elements and Acid Mine Drainage (AMD).

The majority of the sites tested had extremely low levels of organic matter (0.2 - 1.4 percent), since the seed bed was largely comprised of crushed bedrock and shale. Desiring a minimum of 4 percent organic matter to sustain long-term vegetation success, mycorrhiza soil fungi, beneficial bacteria and multiple bio-stimulants—the building blocks to healthy soil—were applied to the prepared slopes at the time of seeding to address organic matter deficiencies.

Most soil analyses indicated acidic pH levels with differing inherent nutrient values. Large amounts of lime were required to raise the pH to an ideal range between 6.0 - 6.5, where soil nutrients become plant available. Customized fertility plans also increased reclamation efficiency by eliminating excess fertilizer and the potential for water quality impairment compared to standardized applications.

Selecting the Right Seed and Seeding Method

Much of the seed that Alpha's legacy sites in West Virginia and Kentucky had previously used was not properly labeled and yielded inconsistent results. Third-party seed laboratory tests determined that temporary, annual grasses, such as wheat and rye, dominated the mixes; while permanent perennial legumes, such as birdsfoot trefoil or yellow blossom clover, were lacking under permit requirements. Vegetation establishment efforts were greatly enhanced by selecting properly labeled seed mixes with guaranteed analysis that complemented permit species requirements.

Due to the steep terrain of the basin and large tracks of land needed to be reclaimed, hydraulic seeding or hydroseeding was the preferred seeding method. Hydroseeding offered a distinct advantage over other seeding methods in that the ingredients in the tank mix recipe could be easily adjusted based on soil test results and site requirements. This allowed for the implementation of site-specific revegetation plans that could accurately and efficiently address all major obstacles to vegetation establishment at the time of seeding.

Expanding the Model

Overburden materials (by-products of coal processing) are often used to reclaim high walls and valley-fill impoundments. These sites are a particular challenge to vegetate. The common practice for reclaiming these areas is to apply a minimum soil layer of 18 - 24 inches as a "cap" on top of the overburden material prior to seeding. Alpha was impressed with Pennington's previous success record for establishing vegetation directly on fly ash, and as a result, opted to direct seed the overburden areas. By eliminating the need for a soil layer on top of the overburden material, the potential saving in time and money were enormous.

When analyzed, the overburden material and fly ash were quite similar. They both exhibited low pH and percent organic matter, along with a dark surface color that readily absorbed thermal radiation, making the surface at least 20 degrees F hotter than surrounding soils in the summer. To sustain vegetation, the acidic pH levels were raised with pulverized limestone and fast-acting dry lime. Nutrient deficiencies were resolved with the re-introduction of highly concentrated bio-stimulates, beneficial soil microbes and fertilizer.

When this approach was implemented at Alpha's Grey Eagle processing site in Mingo County (W. Va.), the project team selected a cool-season SLOPEMASTER seed mixture specifically designed for stressed environments and a Mohawk cold-tolerant bermudagrass. The seed mixture was treated with GermMax germination aid to increase seedling vigor during germination and establishment, as well as MYCO Advantage mycorrhiza inoculants to increase nutrient and water absorption and help mitigate drought and salt stress. Starting in March 2011, the seed was hydraulically applied along with soil amendments and 3,000 pound per acre of a high-performance, fiber-reinforced matrix that effectively stabilized the site from erosion, while also acting as a sunscreen over the dark material to reduce temperatures and evaporation rates.

By the one-year mark, the site had been converted from a 40-acre impoundment of exposed refuse and minimal vegetation to a lush and heavily vegetated site. The dense, permanent vegetation establishment across the site greatly exceeded Alpha's expectations, with the site operator commenting that "the impoundment area looked as lush as a state park."

Lessons Learned

The collaborative effort addressed the traditional challenges of vegetation establishment on rehabilitated surface mines, as well as value-enhanced seeding applications on coal refuse and overburden areas. The site-specific reclamation model provided improved BMPs for soil stabilization and erosion control, while dramatically improving permanent vegetation establishment. Starting with a soil test, corrective actions were taken to mitigate soil conditions at the time of seeding to create the right foundation for long-term, sustainable growth.

By utilizing a comprehensive approach that encompassed soil science, agronomy and improved soil stabilization techniques, Alpha substantially increased vegetation establishment success rates from initial seeding applications. Alpha continues to utilize Pennington in the evaluation of their reclamation best management practices.

To schedule a Free Soil Analysis and a Sustainable Vegetation plan from a Pennington Seed Agronomist, contact 1-800-588-0512 or e-mail proturfsolutions@penningtonseed.com. ■