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Fall 2022

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A look at the 39th ASRS Annual Meeting in Duluth


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ASRS IN THIS ISSUE

reclamation matters

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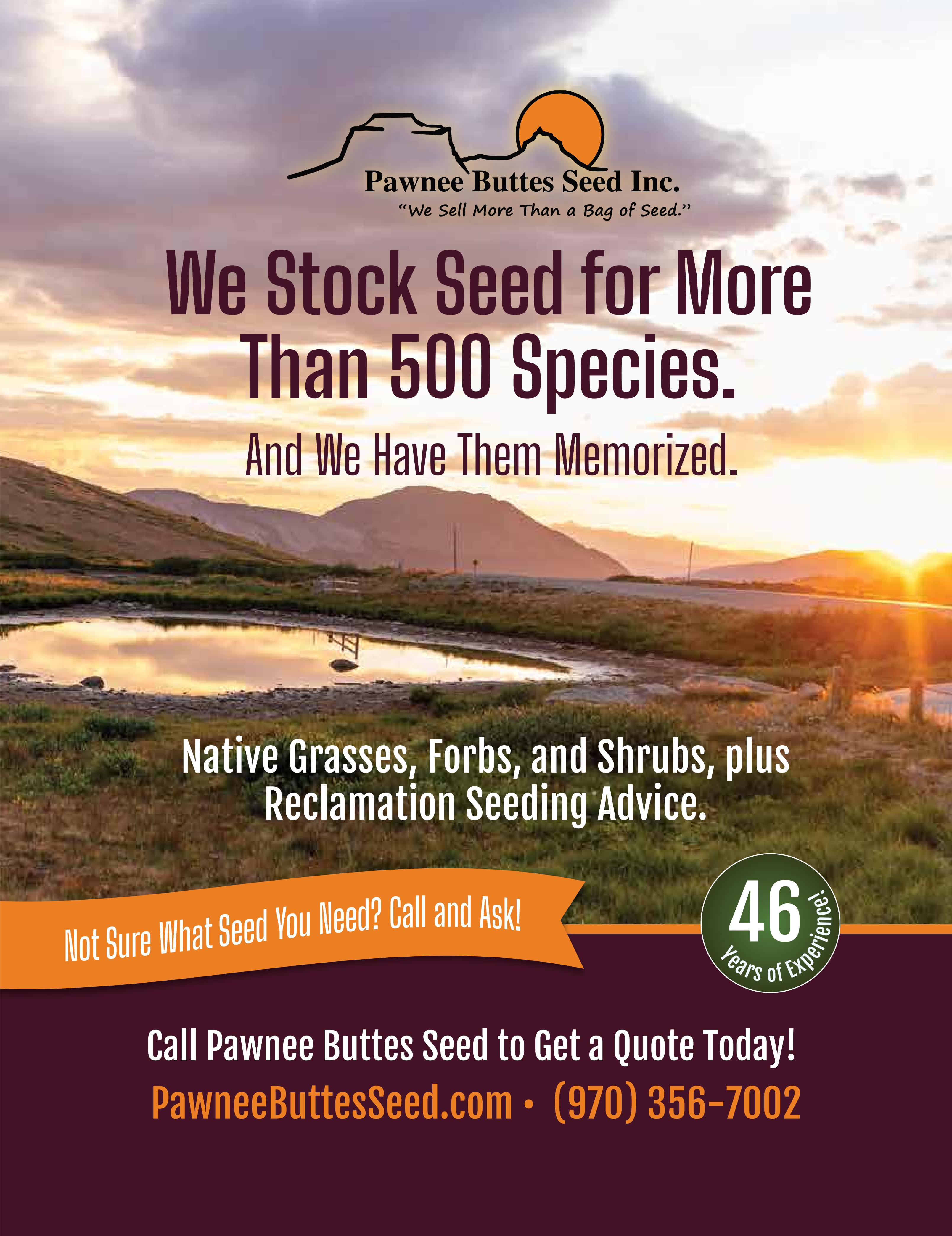

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MICHELE COLEMAN

I first want to congratulate Mehgan Blair of Barr Engineering and her team for the very successful 39th ASRS conference. Due to unforeseen circumstances (thanks COVID!), this meeting had been postponed twice and there were still many uncertainties about restrictions and outbreaks, even into the final months before showtime. So a huge round of virtual applause (are we sick of virtual yet?) is due this very patient and diligent team. It was wonderful to finally be able to see so many people passionate about reclamation in person again. I heard many positive comments about the event but the most prevalent was how welcoming the organization is to young professionals and students – and that is not by accident. It is a mindset that was set in motion by others over the past several decades and is held by anyone who has attended one or more conferences. We are a community, and we strive to welcome everyone.

As the new president of ASRS, I want to thank everyone for the support and confidence you have shown by electing me. I am humbled. Here is why.

I was not a globe-travelling researcher or director of reclamation for a huge mining company. Those categories are for the people I admired. I worked for a small coal mining company in a small province in eastern Canada, a place most people never even heard about – New Brunswick. But many people in my career mentored me, encouraged me, assisted me and researched with me to enable me to have a very interesting career and make a big difference in the reclamation outcomes in my local mining community. The biggest compliment I received was the accolades from locals and my Regulators about how the outcomes of reclamation have changed for the better during my career. This I attributed to what I have learned from reclamation conferences, exchanges with other reclamationists, research projects with the local University of New Brunswick and the Canadian Forest Service and very patient regulators who were willing to accept new reclamation methods, as long as we were willing to go back to the old method if something did not work out. I want to give a shout out to ASRS/ASMR/ASSMR, the Canadian Land Reclamation Association, and Mining and the Environment out of Sudbury as the organizations that provided me with an incredible amount of information and networking. Careers and successes are generally due to the contributions and support of many.

But it was the individuals who mentored me that have helped shape me and gave me the confidence to make a difference.

And that is why I am writing this President's letter today and why I want to pursue that mantra this year. For me, it started out with Dick Barnhisel, who was Executive Secretary of ASSMR/ ASMR at the time, emailing me before or after a conference just to follow up, a personal invite to attend and then chair a technical division meeting, review a paper, or just ask how I was doing and then encourage me to run for a NEC (National Executive Committee) position that made me feel special and included. It was having a dance with Peter Beckett in Breckenridge in 2005. Margaret Dunn telling me that one of her employees saw me running after the sessions ended in Pittsburgh and that he wanted to join me but was too shy to ask. My invitation to Bryan Page started a wonderful friendship and the early morning, everyone welcome, Haulin' ASRS/ASMR running group. The patient Jeff Skousen soliciting articles for *Reclamation Matters*. Brenda Schladweiler inviting me to co-chair Wild Women of Reclamation with her and making me really step outside my comfort zone, as I then had to, being able to invite women whom I may have only met once to either be a speaker at the conference or write an article for the WWR newsletter. Those invites also encouraged many women to step up to tell their reclamation story. I learned that just asking people made them feel included, which included further collaboration and participation and exchange of ideas and it increased my knowledge in many other of areas of reclamation. I now appreciate the value of creating butterfly habitat and the knowledge gained from bird counts for determining habitat biodiversity. I leave every conference with this belief that everyone in reclamation seems to be very passionate about reclamation and outcomes. I never got the impression that reclamation was just a job for someone; we all seem to have this intense believe that we want to do better at restoring degraded areas. I did not have to feel that because someone was an icon in their field, or "just" an undergraduate student, that they were unapproachable. I learned that we all had something to contribute if we just stepped up and made ourselves heard. And by overcoming that barrier, I have made so many more friends, have had incredible memories, collaborated with so many more brilliant researchers and been able to contribute that knowledge to my areas of reclamation.

It has been 28 years since I attended my first joint ASSMR/CLRA meeting in Pittsburgh, PA in 1994. I want to thank everyone who has become my friend, my mentor, and/or my collaborator. I want to encourage everyone to reach out to someone that you have met during the conference just to say how much you enjoyed meeting them, or to discuss some potential collaboration or an idea or to ask some to either join a either a Technical Division, WWoR, Haulin' ASRS or help out on any of the committees that assist in supporting the NEC or to write an article for either *Reclamation Matters* or Reclamation Sciences. If you want to pitch in, don't be shy, but ask, email, call anyone on the NEC or whose card you collected during the conference. Remember that ASRS is not a closed group—our conference was so great because everyone contributed. Please continue to make others feel welcome or to just invite yourself to any activity. Mentor or be mentored. Be that change. Reach out to be all you can be and know that we want more members to be engaged. Your actions will make the difference.

Last lecture

JEFF SKOUSEN, WEST VIRGINIA UNIVERSITY

Recently I read a short book entitled *The Last Lecture* by Randy Pausch, a computer science professor at Carnegie Mellon University in Pittsburgh, PA. Dr. Pausch, a productive researcher and an accomplished teacher at the university, had been asked to give a speech as if it were his final talk. A month before delivering his speech, his doctors confirmed that his pancreatic cancer, which had been discovered a year earlier, was terminal. He gave his "last lecture" on September 18, 2007, and he died July 25, 2008 at the age of 47.

In his lecture, Dr. Pausch described some of the things that he wanted his children to know, realizing his daughter and two sons (ages 2, 4, and 6) would not understand his words until years later after he was gone. For example, he wished they would follow their dreams and learn to overcome obstacles. He emphasized seizing every moment because time is all you have…and it may be less than you expect. His talk was not about *dying*, but about *living*.

While I am not terminally ill or retiring, anyone who has heard Randy Pausch's lecture can't help but contemplate what he or she might impart in their "last lecture." It is said that when an older person dies, a library has been lost. This is certainly true when we consider the years of collected knowledge, understanding, skill, and experience that is now gone with the passing of the person. Pausch's speech and his subsequent book provide one way to lessen the potential loss of wisdom that was gained through a lifetime of experience. Here are some "last lecture" thoughts from me.

First, try. Many won't try because they fear failure. It is okay to make mistakes; however, we must admit to and learn from our mistakes, then press ahead. Getting up after each failed attempt makes us stronger and wiser. Try, and don't be afraid.

Second, prepare. Preparation is a key to success. No one likes those who procrastinate or do sloppy, disorganized work. Preparing and working hard ensure achievement.

Third, have hope. Your surroundings or circumstances may seem hard and even unbearable, especially in today's troubled world. Hope is the attitude that helps us see beyond the tough times and propels us to look to the future with courage.

Fourth, be grateful. Gratitude is a powerful attribute which engenders humility, kindness, cheerfulness, graciousness, and compassion. Counting blessings is far better than recounting troubles.

Fifth, forgive. It is debilitating to hold grudges. Peaceful is the person who can overlook the faults of others and can see and overcome the faults in oneself.

I encourage you to consider the wisdom and advice you would share in a "last lecture" to family members, friends, or colleagues. Your knowledge and experiences have value and imparting them to others pushes forward the lessons you gained to encourage and benefit others. But don't wait until your ending days to share these most important ideas and thoughts. Share them now!

[Editor's note: After 18 years and 36 issues, Jeff Skousen will step down as editor of *Reclamation Matters*, the magazine of the American Society of Reclamation Sciences. *Reclamation Matters* will continue with a new editor beginning with the Spring issue of 2023.)]

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What does an ASRS Early Career Professional representative do?

ALLEN WELLBORN, ASRS EARLY CAREER PROFESSIONAL REPRESENTATIVE, SPRING CREEK MINE, NAVAJO TRANSITIONAL ENERGY COMPANY

A quick read of the ASRS bylaws describes the position as a person who serves as a representative of Early Career Professionals (ECP) to the ASRS NEC Board and is elected by the ASRS Membership to a two-year term. There are multiple aspects to this position that make it more exciting than just sitting in two-hour zoom calls and helping to plan annual meetings. The person in this position actually has a voice in how the NEC governs and administers ASRS policies, provides updates of ECP activities in *Reclamation Matters*, and can represent ASRS at other events. Because the NEC Board is comprised of various levels of membership, the ECP representative ensures equal representation of all members to help guide the society. If we look at ASRS policies, we see a list of other potential responsibilities of ECPs including interacting on social media, working with student groups, and contributions to *Reclamation Matters*.

Early Career Professionals at the ECP social event in Duluth.

Enough about the "official stuff," but I will continue to inform you of other duties in later publications. I am sure you are just dying to know about me and why I would volunteer for this position. Growing up in a small-town farm and ranch community in western Oregon, I wasn't directly dumped into a lifestyle that led to a future in reclamation and restoration. I grew up in the mountains, hunting/fishing and camping when I wasn't raising livestock or building mechanical contraptions. I had an affinity for wildlife, and when it came time for college, I decided to attend the University of Wyoming for a BS in Wildlife Biology. After a few summer internships with the US Fish and Wildlife Service and a few elective classes in the Rangeland Ecology field, I was swayed by none other than Dr. Pete Stahl to enter the amazing realm of plant and soil science. I quickly developed a keen interest in ecological sciences and decided to try some senior level classes in Restoration Ecology, and the rest is history. I joined the then ASMR in 2012 as a student member and graduated with a BS in Rangeland Ecology and Management with a minor and certificate in Reclamation and Restoration Ecology.

During that last summer, I was lucky to obtain an internship at the Spring Creek Mine in southeast Montana. This internship really cemented my passion for reclamation sciences and allowed me to use both my degrees and all my knowledge from wildlife, plant ecology, farming, and soil conservation. After attending the 2013 Annual Meeting in Laramie, I knew I was hooked on ASRS (can that be a term? Can I trademark that?). Soon after this meeting, I became a regular member of ASRS. I spent the next few years on the recruiting and college relations board for my company, giving me the opportunity to travel to both the University of Wyoming and Montana State University to give guest lectures and actively recruit new interns and new environmental engineers in our field.

Fast forward to 2021, which included a few more annual meetings and some surface mine employment changes, and I am now a Senior Environmental Engineer at the Spring Creek Mine, where I first started in 2012. There was a call for interest in the ECP representative position from ASRS in 2021. I remembered how much I gained from the society as a student and how staying active in ASRS during my first few years of full-time employment kept me engaged and helped me professionally. I decided I should run for the position to help pass along my knowledge and experiences to other ECPs and students, helping to keep younger generations of reclamationists interested in our field of reclamation sciences.

I thank everyone who voted for me, and I have some big plans for the next two years involving student and ECP engagement. If you are listed as an ECP member through ASRS or attended the 2022 Duluth ECP event, you should have received an email from me summarizing the week and providing some insight into future events. Be on the lookout for a survey headed your way to gather information for what ECP and student members would like to see going into the future. I hope to see you at Boise in 2023!

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Wild Women of Reclamation, 2022 ASRS meeting, Duluth, MN (left to right). Top row: Jenifer Engstrom, Rachel Lange, Kahindree Ositimehin, Keana Trudel, Ally Kramer, Beverly Alvarez Torres, Annalie Peterson, Katie Larson, Sara Post, Jennifer Franklin, Abbey Wick, Rachel Wagner. 2nd row: McKenzie Dorman, Melissa Bantz, Chantel Mertiz, Ashlyn Campagne, Gwen Geidel, Jenise Bauman, Marsha Patelke, Joy Jenkins, Justine McCann. Bottom row: Annica Brown, Michele Coleman, Apsana Kafle, Mehgan Blair, Natalie Kruse-Daniels and Lena, Summer King, Susan Darmody.

2022 Wild Women of Reclamation

GWEN GEIDEL, UNIVERSITY OF SOUTH CAROLINA

The 8th meeting of the Wild Women of Reclamation (WWoR) was held in conjunction with the 39th Annual American Society for Reclamation Sciences (ASRS) meeting in Duluth, MN, on June 14, 2022. The name change from ASMR to ASRS primarily occurred to provide more transparency to the many sectors that benefit from reclamation science and to encourage all of those engaged in the broad field of reclamation to participate. This has also been the goal of WWoR and we anticipated that the name change to ASRS would also increase our networking umbrella to include more sectors doing the important work of reclamation. At our WWoR gathering, women in all stages of their careers gathered to have breakfast, enjoy presentations by Dr. Abbey Wick and Marsha Patelke, create networking and mentoring opportunities, discuss experiences, and most importantly, share some laughs (which were needed after our two-year hiatus due to the COVID-19 pandemic). We thank everyone who participated, brought a friend, or encouraged attendance.

The goal of the gathering is comradery and to discuss common experiences, unique as women, in the pursuit of improving reclamation. This affiliation is another tool we can use to empower women to have confidence in our abilities to advance our careers in reclamation science, mentor the future generation of professionals, and to improve the lives of everyone through our interactions.

This year's speakers were selected from two different career pathways and demonstrated some of the depth and breadth of our backgrounds. Dr. Abbey Wick, with the North Dakota State University Extension, is a Soil Health Specialist and Associate Professor, and Marsha Patelke, is a recently retired Geologist from the Natural Resource Research Institute (NRRI) at the University of Minnesota-Duluth. We appreciate Abbey and Marsha's willingness to share their experiences and journeys on how they came into the field of reclamation and how the relationships with ASRS have helped shape their careers. If you missed breakfast, I hope these summaries will provide a glimpse of their stories.

Dr. Abbey Wick

Abbey provided a fun photo array of not only her career pathway, but she gave us important insight into some of life's challenging questions. Through the lens of her son Wiley's astute questions, but also "kids say the darndest things," Abbey provided a view of her educational experiences as well as her career in soil health and her work with the agricultural sector and farmers. From teaching about sustainable farming methods on over 75,000 acres of soil and influencing management on over 300,000 acres of farmland to the more subtle aspects of her career, she impressed us with her devotion to her field, her family, and her own life lessons. From her advocacy for continuous learning, appreciating who and what we are, finding the parts of your career that help you re-focus and relax, her life vision provided positive advice for all.

Marsha Patelke

Marsha is a recently retired (2020) geologist who provided insight into the sometimes volatile market for geologists and how to cope, adjust, and move forward when changes to what we perceive as our career allow us to grow and move in alternate directions. For those who remember the oil and iron mining declines of the 1980s, they know the resurgence for many geologists appeared in the environmental field, and Marsha was no exception. Marsha, with a strong background in both library science and geology, entered the environmental consulting field in Duluth and later joined the NRRI at UMD, where she worked on a number of fascinating projects. Among many efforts, her favorite project was documenting and identifying the historical use of the Duluth Superior Harbor. Describing movement within our careers as either ladders or streams, she found her path was more of a meandering stream, due to her movement between the consulting industry and university research yet continuing interesting and important projects that allowed her career to continue to flow forward.

Wild Women of Reclamation was initiated by Dr. Brenda Schladweiler in 2013 as a tool to provide mentorship and professional support for women in reclamation. WWoR is open to any woman in the field of reclamation, whether practitioner, academic, consultant, government employee or service provider in the natural resources industry or other. There are no forms and no formalities to join. We thank our past co-chairs Michele Coleman (who is the current ASRS President!) and Cindy Adams. If you are interested in becoming a co-chair, please contact Michele Coleman or Gwen Geidel (Geidel@sc.edu), and we would love to have you involved! If you have suggestions for improving networking or communications, please don't hesitate to contact me! And we would love to restart our bi-annual newsletter but need to hear topic suggestions from you.

Looking forward to our next gathering in Boise, ID in June 2023!

CASE STUDY

TRM Project Profile: Sunset Farms Landfill - Manor, TX

Previous attempts to revegetate this using a fully synthetic TRM (Turf Reinforcement Mat) on areas of the Sunset Farms Landfill in Manor, TX (just outside of Austin) had not reached satisfactory density vegetation for Republic Services. A solution of using PS42 manufactured by ECBVerdyol, a permanent TRM that has a biodegradable matrix added to the permanent fibers, was suggested by Justin Hitchcock of JTEX Contracting and Larry Hans and Joel Denofrio of Innovative Soil Solutions for the current 105 acre portion of the project. All vegetated shear stress values are determined by testing only on the permanent fibers in the product - so long term design strength is not of concern with a product such as this with a biodegradable component. The addition of the biodegradable straw fibers to a synthetic TRM is vital in such hot dry climates. They significantly moderate the evapotranspiration rates, prevent the mat from heating up to a point where it could impede seed germination and expression, and holds moisture in the seed bed better than their fully synthetic counterparts.

Vegetation results far exceeded those achieved on the other portion of the site that had utilized a fully synthetic TRM. The difference was especially noticeable in the areas installed and seeded during the hottest part of the Central Texas summer. The reduction in heat and the increase in the moisture retention was of significant benefit to re-vegetating the site.

1

2

3

1: Sunset Farms landfill before germination. Coconut blankets can be seen on the downslope side of berms. Installation Summer and Fall of 2016.
2: PS42 Installed on upslope of berms showing the straw included in the matrix.
3: Sunset Farms Landfill - successfully vegetated in the summer of 2017.

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ASRS 2022 Professional Awards

Barnhisel Reclamation Researcher Award: Brad Pinno

Dr. Brad Pinno is an Associate Professor in the Department of Renewable Resources at the University of Alberta in Edmonton. His research focuses on the management of boreal forest ecosystems, in particular the relationships between trees, site characteristics, and operational management practices. Dr. Pinno's background is in forestry and soil science, which has been a perfect fit for forest land reclamation research. He obtained his BS and MS in Forestry from the U of Alberta, and his Ph.D. from the U of Saskatchewan.

For the past decade, Dr. Pinno has worked extensively in the mineable oil sands region of Northern Alberta studying the impacts of different reclamation soils and techniques on ecosystem development. His research has been supported by industry, government, and multi-stakeholder organizations with the goal of improving forest land reclamation. He has authored many publications (32 in the past five years) and co-authored publications with his students and post-doctoral candidates. Past reclamation MS graduates from his research group have gone on to careers with industry, consulting, and government agencies.

One of the things Dr. Pinno really enjoys about reclamation research is how we can balance operational land management questions – essentially, what we can do with a specific piece of land – with important scientific questions related to understanding the ecological relationships.

Congratulations to Dr. Pinno on an outstanding career in reclamation research and his continuing success in his industry endeavors.

Reclamationist Award: Richard Sivils

Rich Sivils P.E. is the Reclamation Engineer at the Usibelli Coal Mine and has worked there since 2013. He graduated in 2008 from the University of Arizona with a BS in Mining Engineering. His first position after graduation was with Kiewit Mining as a reclamation engineer at the Decker Coal Mine in Montana, a surface mine producing 4 million tons per year. He then spent four years working for Freeport McMoRan Copper and Gold as a mining engineer in Arizona before being hired in his current role with Usibelli in Healy, Alaska. At Usibelli, he directs reclamation efforts in the form of dozer regrade, works with federal and state representatives to keep the mine operations in compliance with over 70 active permits, and directs special projects around the mine site related to reclamation. During his tenure at UCM, he has adapted reclamation techniques and best management practices to reduce UCM's bond liability by more than 20 percent in the last eight years – an outstanding achievement for a complex ecosystem in the middle of the vast interior region of Alaska! He has a wonderful wife and three kids and enjoys hunting and flying in Alaska.

Congratulations Rich Sivils on your recognition for outstanding contributions to the reclamation of the disturbed ecosystem in your picturesque region.

Early Career Award: Abhishek RoyChowdhury

Dr. Abhishek RoyChowdhury is an Assistant Professor of Environmental Science and Natural Resources at Navajo Technical University. He earned his BS and MS from University of Calcutta, India. He pursued his Ph.D. from Montclair State University, and his Ph.D. research was geared toward developing a "green" remediation technology for remediation of Acid Mine Drainage (AMD)-impacted soil and water. He has received over $2 million in grants from federal and non-federal sources including NSF, NASA, USDA, USDOI-OSMRE, USDOI-BIA, First Americans Land-Grant Consortium (FALCON), and Alfred P. Sloan Foundation.

His research projects include reclamation of abandoned mine sites, helping Native American communities to access clean water, and creating economic opportunities for them. One of his ongoing research projects, funded by the OSMRE Applied Science Program, involves demonstration of a field-scale sustainable reclamation technology for revegetation and stabilization of gob piles of mine spoils in the Carthage coalfield in New Mexico. His other ongoing research project involves evaluation of stream health in the San Juan River system impacted by 2015 Gold King Mine Spill. He has published 18 peer-reviewed journal articles, one book chapter, and 38 conference proceedings. He is serving as an Associate Editor of International Journal of Environmental Science and Technology (IJEST), and as an Academic Editor of PLOS Water. He is the elected Secretary/Treasurer of the Geology and Health Division of The Geological Society of America. He has received multiple awards and honors including the ASMR 2015 Memorial Scholarship Award (Ph.D. level).

Congratulations to Abhishek RoyChowdhury on an outstanding early career in disturbed ecosystem reclamation, and keep up the good work.

2022 Student Scholarships Awards

Bachelor of Science

Matthew Berzonsky is a senior environmental engineering student at Saint Francis University, where he actively participates in research with the Center for Watershed Research and Service. He also enjoys fly fishing and backpacking in his free time.

Master of Science

Loren Gormley is a master's student at West Virginia University studying Environmental, Soil, and Water Sciences. She is working on a thesis that studies the effects of acidic soils in the Monongahela National Forest four years after an aerial lime application in 2018. She is very passionate about the outdoors and loves learning about different reclamation practices that can help restore nature back to its original beauty and function. After graduate school, she would like to do water quality work to help reclaim impaired streams and water bodies throughout our nation. When she's not working, she enjoys running, walking her two dogs, or sewing new projects.

Doctor of Philosophy

Charles "C.J." Spellman is a fifth-year Ph.D. student in the Civil & Environmental Engineering program at the University of Rhode Island and is expecting to graduate this August. C.J. is a member of the Water for the World research lab at URI. His research focuses on innovative iron-based water and wastewater treatment technologies, with specific aims of bringing these technologies closer to full scale implementation.

C.J. earned a bachelor's degree in Environmental Engineering from Saint Francis University and a master's in Civil & Environmental Engineering from URI. A primary focus of his graduate studies has been the active co-treatment of mine drainage in municipal wastewater treatment plants. This research has resulted in several peer-reviewed publications, an article in the Water Environment Federation trade journal, and a presentation award at a prior ASRS conference. C.J. has also used this research to expose undergraduate students to mine reclamation topics, a field of study generally overlooked and not discussed in most New England college engineering curriculums. Congratulations to C.J. on this well-deserved honor.

39th ASRS Annual Meeting
Duluth, Minnesota, June 12–16, 2022
Sponsors

Above: Don Newton,
2022 WY AML Sponsor.

Right: Ryan Neeley,
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39th ASRS Annual Meeting
Duluth, Minnesota, June 12–16, 2022
Exhibitors

Michelle Scanlon and Monica Jacobwith, Barr Engineering.

Dan Tix, MNL Restoration.

Greg Kedzierski, Ernst Seeds.

Joel James, Melissa Bautz and Ike Issacson, Brierley Associates.

Josh Buck, Granite Seed.

Michael Curran, Abnova Ecological Solutions.

Michael Ricci, RESPEC.

Society of Mining, Metullurgy & Exploration, Minnesota Section.

(Root) Tips for Reclamation: The many roles of fungi in landscape recovery

CHELSEA M. HARRIS AND JENISE M. BAUMAN, WESTERN WASHINGTON UNIVERSITY, COLLEGE OF THE ENVIRONMENT

Figure 1. The iconic Fly Agaric mushroom (Amanita muscaria) transcends many geographic and cultural boundaries with its colorful cap and psychoactive properties. Ecologically, this species is an important ectomycorrhizal symbiont to many evergreen and deciduous tree species worldwide (Photo credit: Jenise M. Bauman).

Strategies in ecological restoration utilize the principles of succession, the change of plant communities over time. However, as seen in disturbed sites, many major organismal players are missing from the landscape and their absence will have consequences that cause restoration failures. These include many keystone species of flora and fauna; however, some not-so-evident organisms represent a diverse assemblage of microbes that play pivotal roles in ecological succession. Microbiota such as photosynthetic bacteria and protozoans participate in energy transfers and biochemical cycling that will respond to and influence the overarching successional processes. Fungi are another key group of micro- and macro-organisms who make-up integral processes required for diverse and resilient landscapes (Figure 1). Fungal species also change with the flora and fauna, while making valuable ecosystem contributions as pathogens, decomposers, and mutualists. Their presence adds a spectrum of antagonistic and facilitative attributes to the already dynamic successional pathway.

Fungi have the power to situate, decimate, and deconstruct forests

As pathogens, fungi create an adaptive pressure on young seedlings and the death blow to forest giants. Land managers restoring timber lands will contest that soil fungal and fungal-like oomycete pathogens impose major influences on what tree species can be re-introduced to a site. Decades of managing monocultures invite pathogen attack that are difficult to treat on a forest-scale (Figure 2). This negative

Figure 2. Laminated root rot caused by fungal pathogen Phellinus weirii causes large-scale mortality on conifers causing growth loss, buttress decay, uprooting, and tree morality (Photo credit: Robert L. James, USDA Forest Service, Bugwood.org).

Figure 3. Types of common tree damage from buttress and root pathogens cause weakened trunks and roots that are prone to windthrow in forests. Though potentially dangerous, these constant, small disturbances in forests create horizontal complexity and tree gaps that encourage growth of other species and size classes to forests (Photo credits: Jenise M. Bauman).

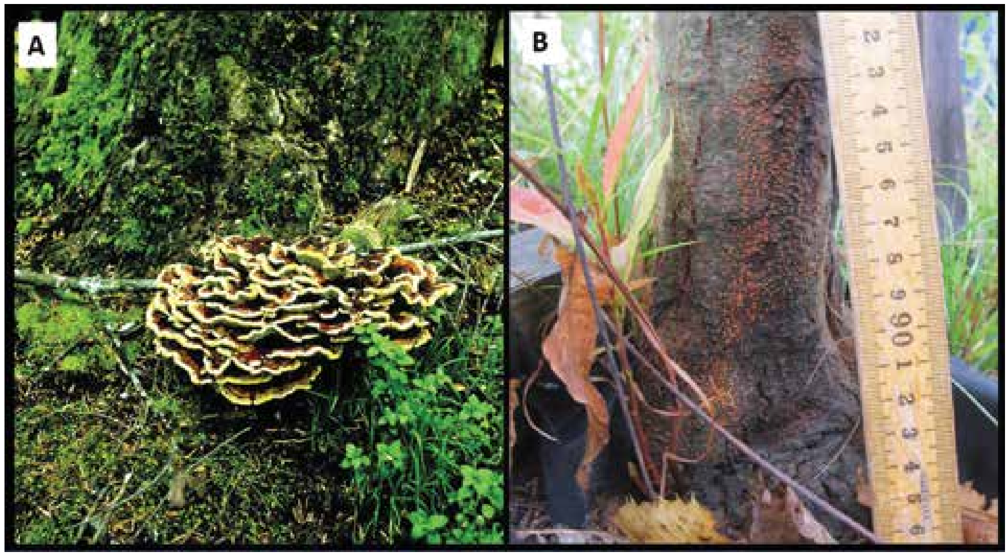

Figure 4. A) Velvet-top fungi (Phaeolus schweinitzii) on Sitka spruce (Picea sitchensis) is an example of a pathogen of old-growth, ancient trees. Unfortunately, by the time the velvety conk is observed, the internal damage is done and the tree is now suspectable to toppling to the forest floor (Photo credit: Tom Laurent, USDA Forest Service, Bugwood.org). B) Chestnut blight fungus (Cryphonectria parasitica) is an introduced pathogen that decimated American chestnut (Castanea dentata) throughout the eastern forests of North America. Current mine reclamation projects utilizing chestnut and chestnut hybrids have noted orange stroma associated with canker formation within the first five years of planting (Photo credits: Jenise M. Bauman).

feedback loop will wreak havoc in restoration planning; however, fungal pathogens will actually play an important role in structuring plant communities (Bever 2003) while facilitating the migration of trees into new ranges. Mortality by pathogens will create gaps in young canopies that may allow for the recruitment of other woody species that aid in the species diversification of forest stands. Some fungal species can be thought of as ecosystem engineers by weakening old trees and rendering them prone to windthrow (Figure 3 and 4A). These small and constant disturbances create complexity and diversity in forest stands where different successional stages add dynamism to old-growth forests. The large woody debris that falls to the forest floor, while taking out many trees along the way, also add horizontal complexity to adjacent riparian zones, streams, and rivers.

The iconic American chestnut *(Castanea dentata)* of the eastern USA forests have an interesting history with infamous introduced fungal pathogen *Cryphonectria parasitica*, causal agent of chestnut blight. The virulence of this fungus combined with the lack of resistance from the American chestnut was responsible for reshaping the tree composition of the North American eastern forests. Current Appalachian mine-land restoration projects are seen as advantageous because these disturbed sites are theoretically pathogen-free, thereby creating opportunity for large-scale reintroduction utilizing hybrids bred for resistance to chestnut blight. However, chestnut projects report early chestnut blight infection within five years of planting (Figure 4B), which may actually aid in the natural selection of chestnut hybrid genotypes able to reproduce blight-resistant progeny early in the reclamation process (Bauman et al. 2014). Also interesting is the fungal-like *Phytophthora* pathogens that are now denying chestnut's re-introduction into the southern forests. Do these soil microbes represent a micro-pressure that is heralding chestnut's migration northward in response to a changing climate?

Inevitably, trees will fall, leaving behind carbon-rich cells comprised primarily of cellulose and lignin, essential for plant structural growth and protection

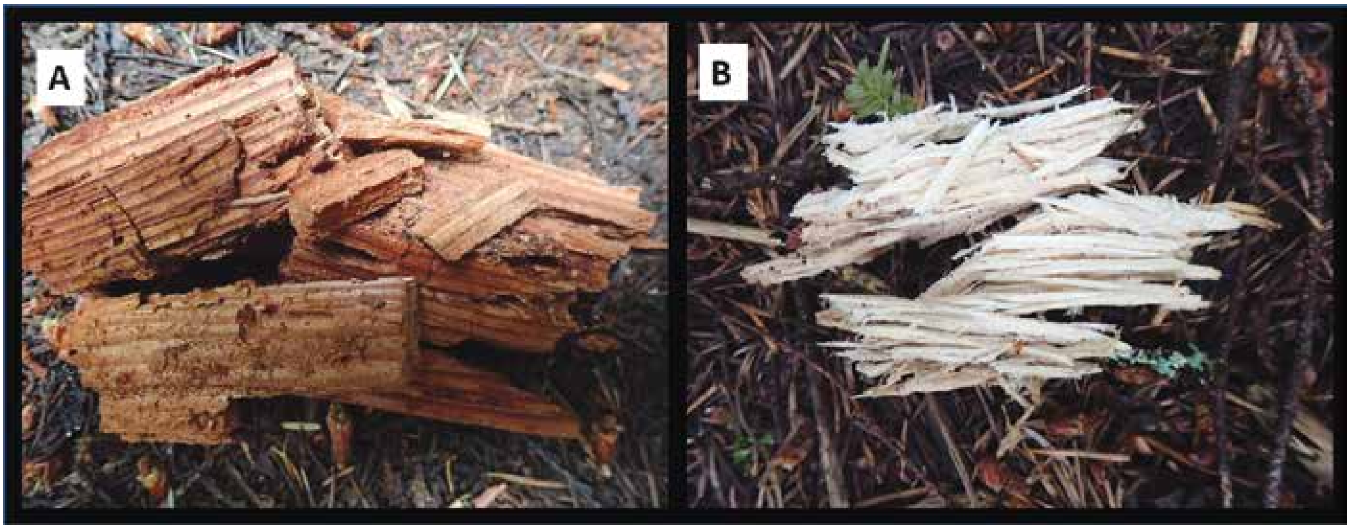

Figure 5. The rich, organic layer of the forest floor harbor fungal organisms responsible for saprophytic decay. A) Brown-rot fungi decay cellulose within wood cell walls, but they lack the lignin-degrading enzymes, thereby leaving behind dark brown, cubical wood. B) White rot fungi, in contrast, have the enzymes required for lignin degradation leaving wood with a white and stringy appearance (Photo credits: Jenise M. Bauman).

from pests and disease. However, lignin compounds in particular have incredibly strong bonds that are difficult to breakdown biologically (Lockhart 2013). Fortunately, as good stewards of the forests, fungi have the ability to tidy up after themselves as decomposers, which places them in imperative roles within the carbon and nutrient cycles. Fungi will be found as the primary microbe associated with decomposing litter and wood, deconstructing the intricate cellular structures thereby releasing nutrients important for primary productivity and habitat development.

Brown and white rot fungi are two broad pathogenic and saprophytic fungal groups that are found in abundance in the organic layer of soils. Important for the carbon cycle, they are able to store carbon in soils three times higher than either the atmosphere or plants (Averill et al. 2014). Brown-rot fungi (BRF), use both a non-enzymatic and an enzymatic approach to decay wood cell walls, but they lack the main lignin-degrading enzymes found in the white-rot fungi (Akgul and Akgul 2018). Therefore, BRF will break down cellulose and leave behind a modified lignin that results in a dark brown wood that is often cubical in formation (Figure 5A). In contrast, white rot fungi (WRF) are extremely unique; they have enzymes with the capability to degrade the ridged, strongly bonded lignin in woody plants (Miyauchi et al. 2020). This leaves wood with a white and stringy appearance as it degrades (Figure 5B). In addition, WRF use those lignin biproducts for their own nutrition thereby positioning these organisms as key players in the sequestration of lignin-derived carbon in soils (del Carro et al. 2021).

In addition, BRF and WRF play key roles in breaking down toxic components into less harmful forms (Akgul and Akgul 2018). Forming the basis of mycoremediation, these fungal organisms either degrade, sequester, or immobilize hazardous organic and inorganic substances which results in considerable reduction in soil pollutant levels (Singh and Singh 2014). Their expansive mycelium form thick, root-like rhizomorphs which can grow long-distances through inhospitable soil conditions while excreting polymer-degrading enzymes that digest then absorb toxins throughout the fungal body (Wali et al. 2020). Certain BRF species can ingest, immobilize, and precipitate copper, thereby rendering copper ions inert in the soil environment (Humar et al. 2004). WRF can be utilized in the mycoremediation of industrial pollutants such as dyestuffs, bleach plant effluents, olive oil wastewater, rubber byproducts, and biodegradation of hormone disrupting compounds (Asgher et al. 2008). Heavy metals have also been found to be removed by WRF via absorption through the cell walls and membranes (Chen et al. 2022). In fact, WRF's sophisticated extracellular enzymes can be used to enhance the reclamation of degraded soils, which ultimately aids in ecosystem recovery (Wali et al. 2020).

A little help from fungal friends

Despite the importance of pathogens and saprophytes, it is the fungal mutualisms that have major influence on the success of newly planted seedlings into disturbed soils. Located within the rhizosphere, the specialized region between the plant root and soil, the carbohydrate and amino acid root exudates stimulate fungi that, in-turn, will enhance plant nutrient uptake, water acquisition, and disease resistance (Allen et al. 2003). Though the structures and types are quite complex, this article will focus on two broad groups of these fungal mutualisms: arbuscular mycorrhiza and ectomycorrhiza (Figure 6).

Arbuscular mycorrhiza (AM) is the most common form within the

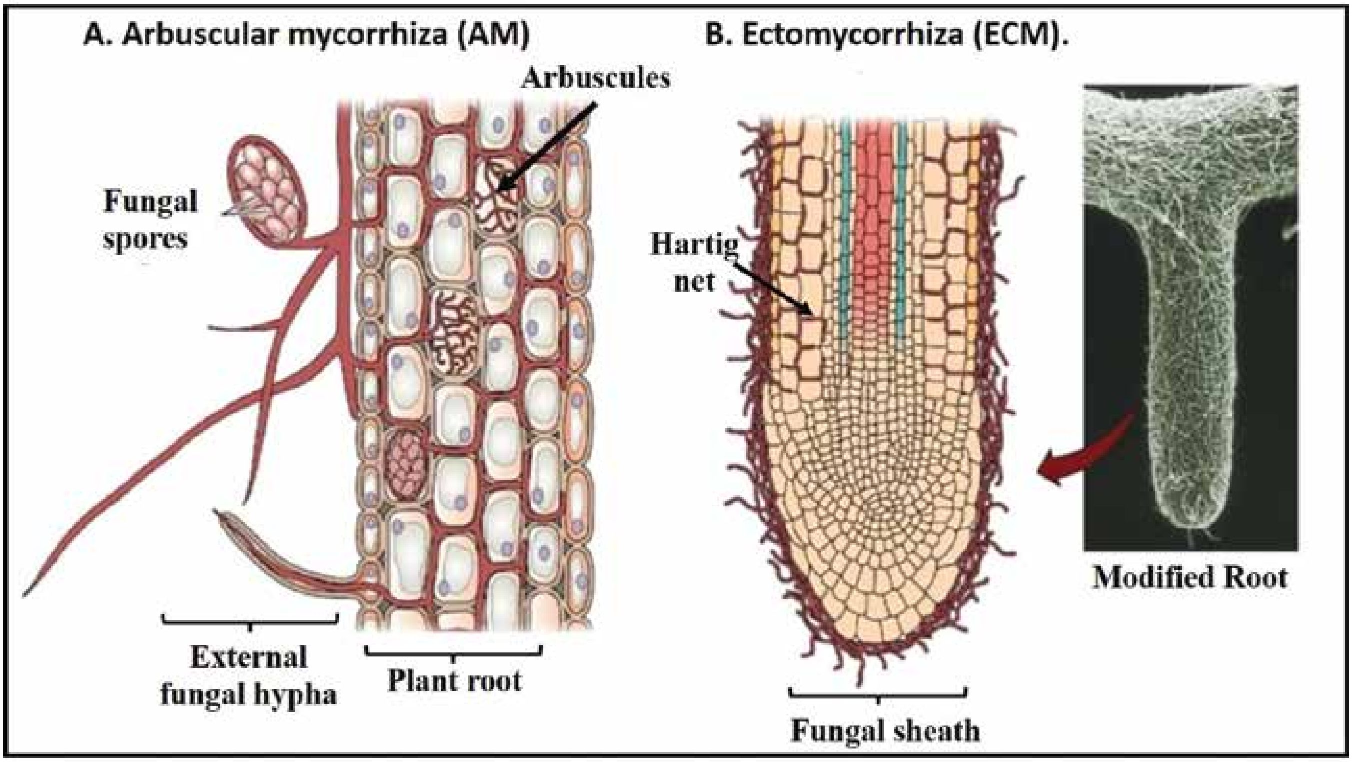

Figure 6. Mycorrhizal fungi are important plant mutualisms aiding in nutrient uptake, water acquisition, and disease resistance. A) Arbuscular mycorrhiza are characterized by their sub-soil spores, appressorium for root penetration, and intercellular arbuscules. B) Ectomycorrhizal fungi are distinguished by the fungal sheath and modified lateral roots with an inner cellular interface called the Hartig net. Spores are generally produced within mushroom fruiting bodies found aboveground (Image credit: William Anderson (2000) with modification).

phylum Glomeromycota and have been established on this planet for about 600 million years (Smith and Read 2008). Approximately 80 percent of plant species form relationships with AM fungi in nearly all environments (Bonfante and Genre 2008). They are characterized primarily by their sub-soil spores, appressorium for root penetration, and arbuscules within the cortex of the cells that interface fungi with the plant (Figure 6A; Requena et al. 2007). Though most notable on herbaceous plants, some common forest trees also form arbuscular mycorrhiza. The intimate, cellular relationship induces the plant's defense response aiding in protection from disease. Genera such as *Thuja* (cedar), *Sequoia* (redwoods), *Juniperus* (junipers), *Acer* (maple), *Fraxinus* (ash), and *Cornus* (dogwoods) are characterized as arbuscular mycorrhizal hosts (Dumroese 2012). The symbiosis is important for the health of both symbionts and for the forest as a whole and are particularly crucial for reclamation projects that are typically comprised of young, mineral soils that are prone to drought (Chen et al. 2018). AM are able to alleviate drought stress by allowing young trees to produce deep root systems that can spread to ground water, foundational for forest development. Important for nutrient acquisition, AM fungi have the enzymes that can extract phosphorus from mineral soils making limiting resources available to the host plant.

Along the successional pathway there is a shift from mineral soils to organic soils and a parallel shift in mycorrhizal types from dominance by AM to ectomycorrhizal fungi (ECM). The increased organic matter, soil moisture and the accumulation of litter from early successional species may contribute to eventual succession of ECM fungi important to many forest tree species, thereby promoting long-term recovery (Piotrowski et al. 2008).

ECM associations are distinguished from other mycorrhizal interactions by the fungal sheath and modified lateral root with an inner cellular interface called the Hartig net that regulates the nutrient/carbon transfer (Figure 6B; Reddy et al. 2005). The spores are found in the aboveground mushroom fruiting body that is attached to the roots of forest trees via underground hypha. Benefits include greater access to water, nutrients (particularly nitrogen bound in organic matter), alleviation of metal toxicity, and physical protection from root pathogens via fungal sheath. Additionally, seedlings may be incorporated into an existing network of hyphae that facilitate the establishment of newly arriving seedlings by carbon and nutrient transfer from existing, non-related, vegetation (Simard et al. 1997). Like AM fungi, ECM receive carbon in the form of photosynthates from their host forming a mutualistic relationship between plant and fungi (Smith and Read 2008).

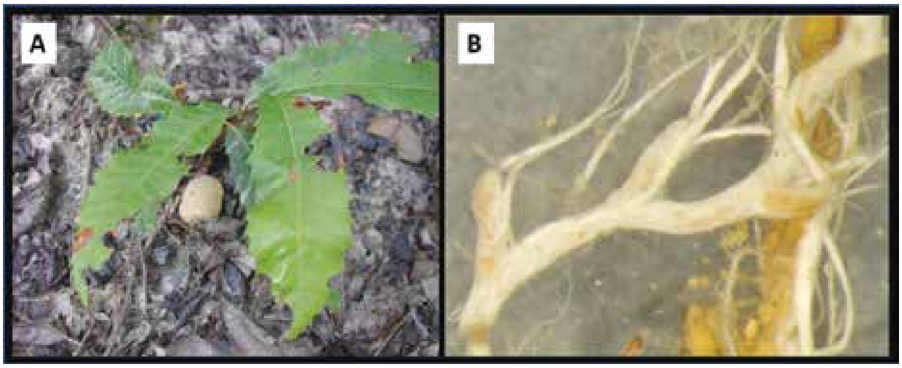

Figure 7. Ectomycorrhizal fungus Scleroderma citrinum has been found to be an important early successional species in disturbed sites. A). S. citrinum puffball on one-year-old hybrid chestnut may come with a carbon cost, however it is effective in aiding in establishment in highly acidic soils. B) Belowground, this fungus produces white fungal sheaths with thick rhizomorphs rearing radiating hypha that maximize water and nutrient acquisition (Photo credits: Jenise M. Bauman).

Important in the reclamation of soils with known heavy metal accumulation, ECM aid in protecting host plants by providing a physical barrier of hyphae around root tips, sequestering metals into fungal cell walls, and binding metals to soil particles (Feng et al. 2017). Puffballs *(Scleroderma spp.)* have been found to have great benefits for their tree partners by aiding in establishment and decreasing heavy metal uptake on abandoned mine sites (pH <3.0, Figure 7; Bauman et al. 2012). ECM can also induce the host plants antioxidant system by releasing enzymes capable of increasing the expression of certain metal tolerant genes that increase metal binding proteins that improve plant productivity (Liu et al. 2022). The release of these enzymes also allows plants to better decrease oxidative stress, which protects essential components of living plant cells, including photosynthetic chloroplasts (Chaki et al. 2020). Studies have also found that ECM fungi may be able to successfully tolerate and degrade various hydrocarbons and various salts resulting from the use of alkaline hydroxides in oil extraction processes (Treu and Falandysz 2017).

Unfortunately, anthropogenic disturbances such as mining, pesticide use, and industrial farming have destroyed soil hyphal networks and degraded the symbioses between plants and fungi. Mycorrhizae fungi are able to lay dormant in soil via spores, hyphae, and within dead plant tissue and when ready to germinate they search for plant roots to colonize (Smith et al. 2022). However, neither AM or ECM fungi are adapted to endure mining and other industrial disturbances that destroy hyphal networks, introduce unfavorable chemical or physical factors, and remove host plants (Jasper 2007). Soils left behind large anthropogenic disturbance events tend to reach temperatures and dryness extremes not conducive for fungal survival. Soils that are stockpiled tend to become waterlogged or droughty, either of which will likely decrease the survival of fungal species required for the re-establishment of restoration trees.

Root tips for reclamation

The recovery of fungi and their ability to reconnect with host plants following large-scale mining may take several years if it occurs at all (Allen et al. 2002). Some sites where topsoil is unavailable, practitioners will utilize weathered and unweathered rock substrate as a soil replacement strategy (Wilson-Kokes et al. 2013). However, this replacement substrate is generally devoid of biological legacies required for suitable fungal symbionts and organic matter required for functional mycorrhizas. The severe decline of these symbionts contributes to the mortality of tree species, which can impact reforestation efforts for decades (Marx 1991). Success of these plantings will be maximized by their fungal counterparts, which under normal circumstances would be part of that soil profile.

Therefore, the question comes up: to inoculate or not to inoculate newly reclaimed sites? Studies have shown that adding AM inoculum to disturbed grasslands improves plant species richness and diversity (Torrez et al. 2016). Other studies have demonstrated that AM inoculum can improve plant biomass in habitats where nutrients are low (Aavik et al. 2021). With regard to ECM fungi, artificial inoculation of seedlings is a common practice in highly disturbed soils where host plants are absent. *Pisolithus tinctorius*, affectionately referred to as "dog poop fungus" (Figure 8) has been used extensively in mine reclamation projects due to its broad host range and ability to survive in inhospitable soil conditions. Inoculated seedlings have been reported to have increased root and shoot growth, increased water uptake during drought conditions, and higher foliar nutrient concentrations (Walker et al. 2004). However, not all plant and fungal combinations result in functional mycorrhizas; symbioses that are observed in the laboratory or greenhouse may differ significantly from those sampled in the field (Smith and Read 2008). Regardless, studies have shown that introduced inoculum, even if it does not persist long-term, will increase survival during the first growing season (Bauman et al. 2011).

Another strategy are methods that conserve native mycorrhizal species that are comprised of local genotypes adapted to the surrounding ecology. One technique uses cover-crops to conserve and enhance the recovery of local fungal populations. Planting a mix of perennials and deep-rooting tree species in shallow soil stockpiles will serve two functions: 1) provide a niche to AM and ECM fungal species and 2) deter excessive soil moisture via plant transpiration (Allen et al. 2002). If available, forest soils from adjacent sites will add valuable, local inoculum while adding other microbes that will synergistically enhance mycorrhizal efficiency. Also, re-incorporating salvaged soil with stumps, roots, and branches will aid in organic richness increasing mycorrhizal infectivity. Another strategy is to model mycorrhizal succession. Planting a diverse mix of early successional, AM host tree species may be the better tree selection for soils that are either underdeveloped, highly mineral, or those transforming from AM dominant grasslands.

On the other end, managing habitats to enhance reinvasion will include understanding wind-blown spore activity using windbreaks or natural patch plantings that act as both an inoculum source and as host plants to fungi (Allen et al. 2002), while also attracting wildlife activity that will re-introduce fungal propagules to the site. Large woody debris becomes another important strategy that adds complexity to restoration sites, microsites for fungal refuge, perch sites for wildlife, and food sources for saprophytic fungal activity. In compacted reclamation sites, decreased soil porosity diminishes the diffusion of signaling molecules between plant root exudates and fungal auxins that deter the primary synthesis of mycorrhizal roots (Podila 2002). Therefore, reclamation techniques that alleviate soil compaction not only bolster plant growth, but also improve the communication and subsequent symbiosis between plant and fungi that will result in a significant improvement in tree growth and survival (Bauman et al. 2013).

Soils left behind after anthropogenic disturbances tend to be severely compacted, deficient in organic matter, and challenged by a vast array of exotic plant species. Fungal communities responsible for nutrient cycling, soil structure, habitat diversification, and biological interactions are severely altered. Developing management strategies that enhance fungal activity is integral to the recovery of soil properties necessary for a resilient landscape. Proper tree selection utilizing disease resistant varieties can add organic matter to the soil, attract seed-carrying wildlife, and provide inoculum for incoming species leading to forest recovery by natural succession. Therefore, maximizing plant growth, while stimulating disease, saprophytic, and symbiotic interactions may aid in the recruitment of other tree and fungal species that may be the catalyst required to accelerate the natural successional pathway into habitat recovery.

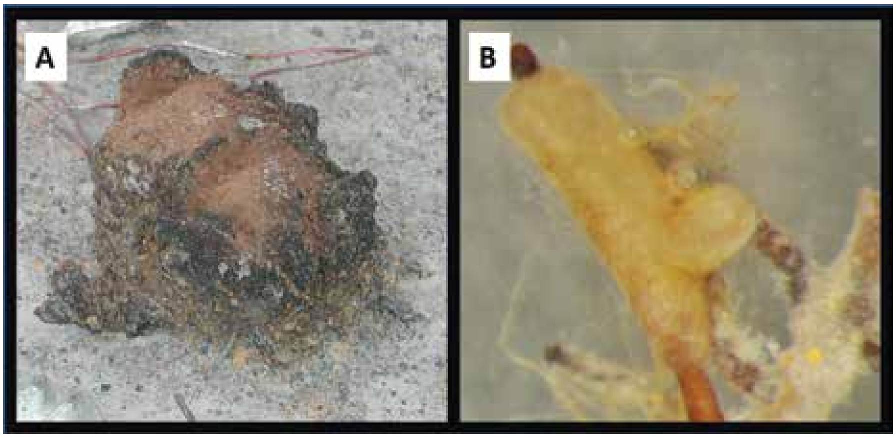

Figure 8. Look closely on highly disturbed soils associated with old mine sites for fruiting bodies that are remnant inoculum from Pisolithus tinctorius. A) Dog poop fungus fruiting bodies (P. tinctorius) may have a face only a mother can love but is an important symbiont on harsh sites. B) Despite its aboveground appearance, this fungus boasts of a characteristic golden sheath with delicate, radiating hyphae below (Photo credits: Jenise M. Bauman).

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Sage-grouse mating rituals on a Wyoming Lek. (Photo credit: Stan Harter, WY Game and Fish.)

Sage–Grouse R & R

JOSH OAKLEAF, CERP, WYOMING ABANDONED MINE LANDS PROJECT MANAGER & VEGETATION COORDINATOR

The sagebrush steppe ecosystem is the largest interconnected habitat type in North America. It covers 165 million acres in 11 western states and one Canadian province and is home to hundreds of obligate wildlife species that rely upon the ecosystem's health and vigor, including the greater sage-grouse *(Centrocercus urophasianus)*. Sage-grouse habitat fragmentation and population declines across the sagebrush steppe have been so severe in the last half a century that the species has been designated as a candidate for listing under the Endangered Species Act. An endangered species listing could have the potential to severely impact Wyoming's two most iconic industries, agriculture, and energy development.

Current population estimates of 425,000 breeding individuals show a staggering decline from the historical population estimate of 16 million. A wide variety of factors ranging from disease, energy development, habitat fragmentation, invasive species encroachment, mining, wildfires, and urbanization has caused sage-grouse population declines that may best be described as death by a thousand cuts. Could the solution be a million stitches?

A dedicated group of interdisciplinary professionals have been working closely with the Wyoming Department of Environmental Quality, Abandoned Mine Land Division (AML) building off past AML success, to expand reclamation objectives to include sage-grouse habitat restoration. In 2019, Governor Mark Gordon strengthened Wyoming's Sage-Grouse Core Area Management Strategy by adding habitat restoration and enhancement as a conservation priority (Exec. Order No. 2019-3). AML identified this Executive Order as an opportunity to maximize reclamation outcomes by setting goals to establish functional sage-grouse breeding, brood rearing, and nesting habitats on large-scale geomorphic reclamation projects. AML's goal of designing and building sage-grouse breeding habitat, known as leks, on large-scale geomorphic projects is a lofty goal that requires an innovative reclamation approach. This approach is aimed at achieving the objectives identified within the Governor's Executive Order, with the additional goal of expanding the greater sage-grouse range.

Achieving these restoration goals in the arid West can often seem insurmountable. To address these varied challenges, AML has created an interdisciplinary group of professionals from the Wyoming Game and Fish (WYGF) Department, Wyoming Bureau of Land Management (BLM), The Nature Conservancy (TNC), multiple environmental consultancies, and Dr. Matt Holloran to define, develop, and record lek creation and range expansion efforts as part the AML Native Plants Project (AML NPP).

Dr. Holloran is a research ecologist with over 20 years of experience specializing in the study of sagebrush-dependent wildlife species with an emphasis on sage-grouse, and he was instrumental in leading AML's sage-grouse habitat restoration efforts. This effort has been designed as a multi-phased, multi-year project to develop, implement, and record a standardized, repeatable approach that AML can share with industry, land managers, and restoration ecologists throughout the sagebrush steppe. If successful, the developed approach, may be broadly applicable to other wildlife species of concern in other regions of the country. With these goals defined, AML set forth on the following four-phase approach.

Phase 1

Development of a lek sampling protocol to measure the abiotic and biotic attributes associated with the most successful sage-grouse leks within a spatially and ecologically relevant proximity

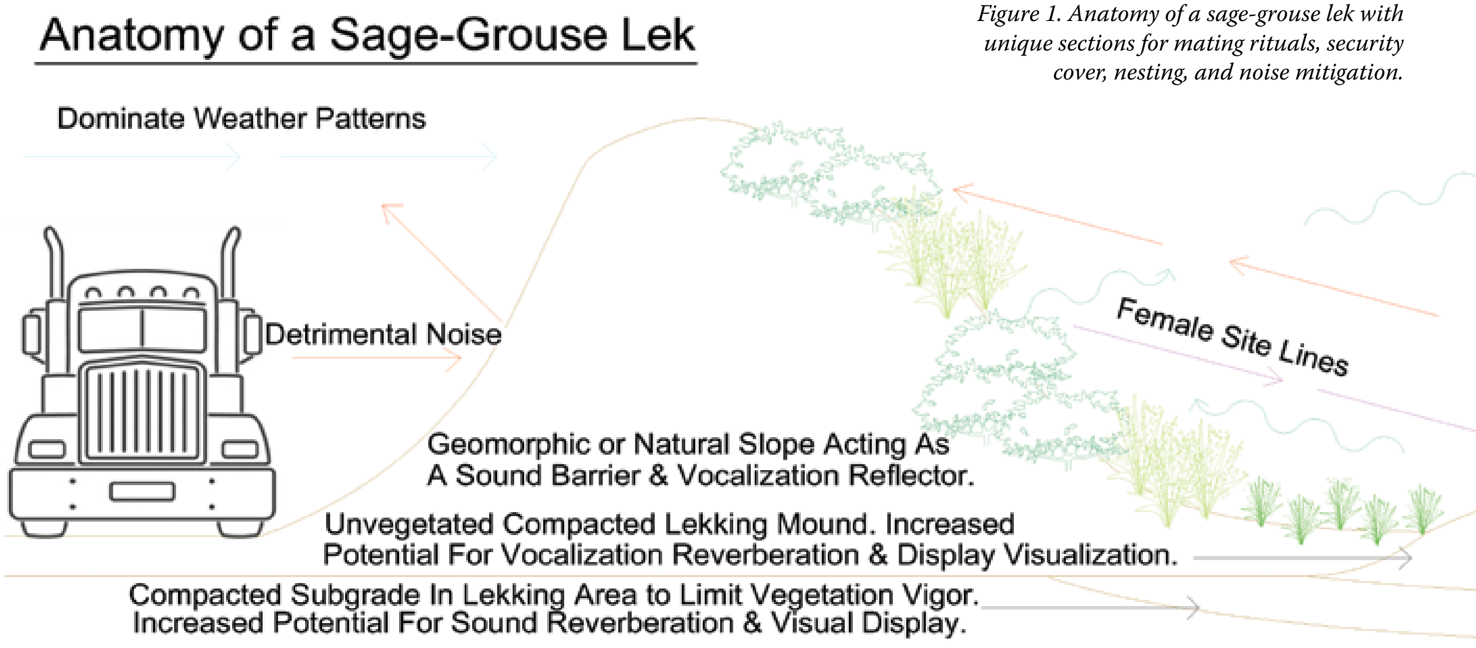


Figure 1. Anatomy of a sage-grouse lek with unique sections for mating rituals, security cover, nesting, and noise mitigation.

to AML geomorphic reclamation projects. This protocol was developed by AML's NPP, Holloran, and Trihydro, in 2020 to gather information for informing reclamation objectives using the ArcGIS Collector Application. ArcGIS Collector enables teams consisting of a biologist, a botanist, and a soil scientist to ensure consistent data collection across dozens of surveyed leks. A broad, although not exhaustive, description of the data collected includes population dynamics, lek use, lek terrain, surrounding terrain, vegetation on the lek, surrounding vegetation, lek soil profile analysis, predominant wind direction, distance to security cover, and distance to closest potential raptor perches.

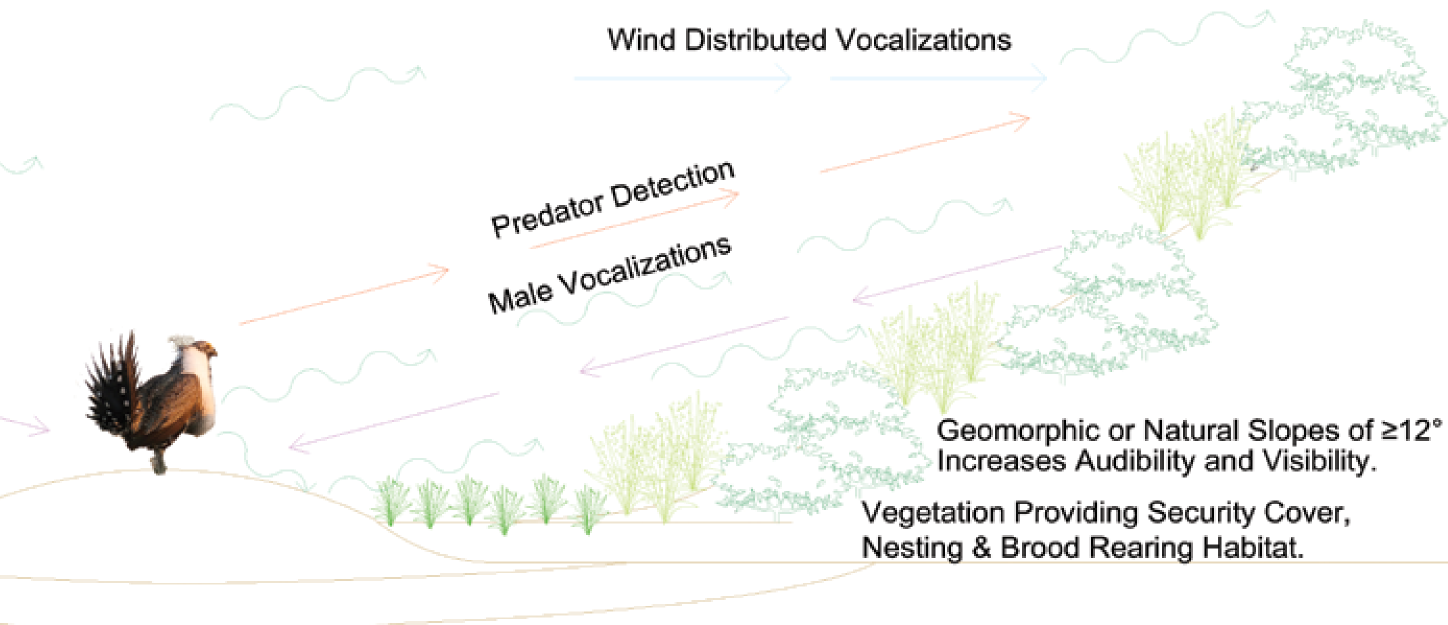
The collection of this abiotic data is based on several studies regarding courtship and reproductive behaviors. Acoustic communication is extremely important in the reproductive behaviors of sage-grouse (Blickley et al. 2012). Female sage-grouse use male vocalizations to find males on the lek (Gibson 1989) and, during courtship, females assess male vocalizations and other aspects of male display when choosing a mate (Wiley 1973, Gibson and Bradbury 1985, Gibson 1996, Patricelli and Krakauer 2010). Based on field observations, the team theorized that the most successful leks have abiotic properties best described as a natural amphitheater or sports stadium where ambient and detrimental noise are mitigated, and where male vocalizations can carry the farthest distance across the landscape (Figure 1). Additionally, it has been observed that the dominant males will occupy the most prominent locations within a lek such as raised mounds, where the performers are lighted with natural lighting (Figure 2), sound propagates from the stage (lek), and female grouse (the fans) watch from sagebrush bleachers.

Phase 2

Design and construction of functional sage-grouse breeding, brood rearing, and nesting habitat on large-scale geomorphic reclamation projects. The AML Shirley Basin 400 Pile Project was chosen as the pilot project for the first AML constructed sage-grouse lek. Shirley Basin is in southeastern Wyoming along the Little Medicine Bow River and is surrounded by Wyoming's designated Sage-Grouse Core Area. The Wyoming Core Area Strategy was established in 2008 by the Governor's Sage-Grouse Executive Order (SGEO). The primary goal of SGEO was to protect the habitat for at least 67 percent of male sage-grouse leks. The SGEO limits the timing and the amount of surface disturbance from energy and other development within 31 Core Areas that encompass 24 percent of Wyoming (Beck, 2018).

Large open-pit uranium mining occurred in Shirley Basin for two decades starting in 1960 and was a significant historic contributor to sage-grouse habitat fragmentation in Wyoming. In 2021, AML with help from Herrera Environmental

Figure 2. Male sage-grouse during mating display. (Photo credit: Stan Harter, WY Game and Fish.)



Consultants began work on the 400 Pile Project with four primary goals: 1) reduce hazards, 2) reduce environmental degradation, 3) increase livestock and wildlife forage, and 4) establish functional sage-grouse breeding habitat. Figure 3 delineates the designed lek area and strutting mounds. Four distinct seed mixes were developed containing 25 species aimed at establishing a native, ecologically diverse, vegetation community similar to those recorded on the five most successful leks near the 400 Pile. The most challenging vegetation goal associated with this project will be establishing tall (≥ 18 cm), dense stands of sagebrush (≥20% canopy cover) near the lek. Tall, dense stands of sagebrush protect sage-grouse from predation while lekking and nesting and provide critical shelter in Wyoming's highly variable climatic conditions. Several AML projects are seeing measurable success at establishing Wyoming Big Sagebrush from seed (Figure 4), proving AML is building the necessary experience and information needed to address this challenge.

Phase 3

Development of a site monitoring prioritization matrix, efficient monitoring protocols, and a site action and management matrix by a team composed of AML, Abnova Ecological Solutions, and Tetra Tech. In 2022, this team developed a prioritization ranking system using weighted scores of the following criteria: 1) erosional features, 2) undesirable species, 3) desirable species

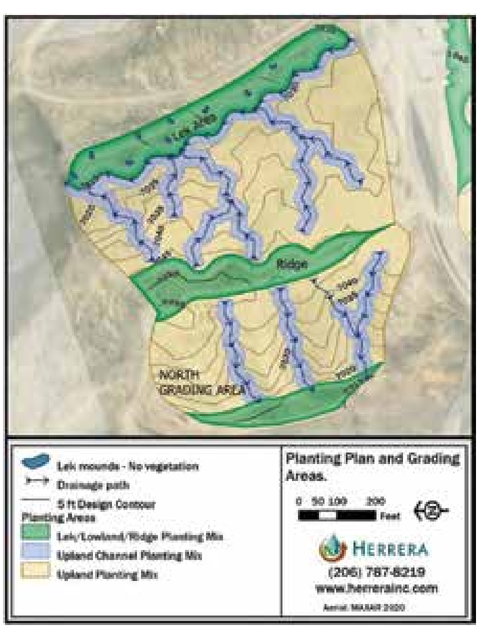


Figure 3. Lek and vegetation plan for part of the 400 Pile Restoration Project.

Figure 4. Second-year sagebrush and vegetation establishment on AML project where sage-grouse brood rearing and nesting habitat is a goal. (Photo credit: Oakleaf)

establishment, 4) proximity to sage-grouse core area, 5) proximity to leks, 6) date last monitored, 7) land ownership, and 8) the size of surface disturbance. This matrix enabled the team to effectively rank 60 recent AML projects where 12 sites were ranked as a 1st (highest) priority and the rest were evenly distributed from 2nd through 4th (lowest) priorities.

The monitoring protocols are designed to evolve alongside maturing reclamation and restoration projects, measuring the rate at which project goals are achieved from Phase 2. The development of efficient monitoring protocols has streamlined monitoring data collection resulting in decreased data collection efforts, data analytics, and report generation by approximately 70 percent while improving the consistency of the data collected. The site action and management matrix will provide recommendations based upon the criteria defined within the prioritization matrix and monitoring data to allow AML project managers to prioritize field efforts such as invasive species control, erosional feature repairs, or diversity island plantings to maximize the long-term effectiveness of restoration. The subsequent creation of an ArcGIS dashboard with uploaded monitoring efforts and collected data will facilitate effective real-time management decisions by land managers within days of site monitoring.

Phase 4

Focus on sage-grouse range expansion and "enticing" sage-grouse to occupy and utilize the created leks. This phase will occur in very close coordination with Federal and State wildlife biologists and is estimated to commence in or around 2027, although it will only occur at sites where AML habitat restoration goals established in Phases 1 through 3 have been met and where there is documented sage-grouse use of the project or nearby areas. While the means and methods of enticing sage-grouse to use the man-made leks are yet to be defined, a key aspect focuses on using male sage-grouse vocalization recordings and decoys. It is hypothesized that juvenile male sage-grouse could be enticed to occupy and establish new sage-grouse populations on man-made leks created on AML projects.

The State of Wyoming has been a leader in sage-grouse management since 2008. Its approach has been embraced by agriculture, extractive industries, and conservation organizations alike. It has provided a model that many western states and the federal government use to guide management approaches across the vast sagebrush steppe. The AML sage-grouse habitat project has strived to create a standardized, repeatable, and rigorous approach to creating best management practices for establishing functional sage-grouse breeding, brood rearing, and nesting habitats that we hope will continue and expand the tradition of the State of Wyoming's leadership in sage-grouse restoration and management. The team believes this four-phased approach has broad applications for sage-grouse restoration and reclamation efforts throughout the sagebrush steppe ecosystem across the western United States and we look forward to future collaborations.

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SOILS OF ALASKA: Cold-Region, Permafrost-Affected, and Arctic Soils

ROBERT G. DARMODY, EXECUTIVE DIRECTOR OF ASRS

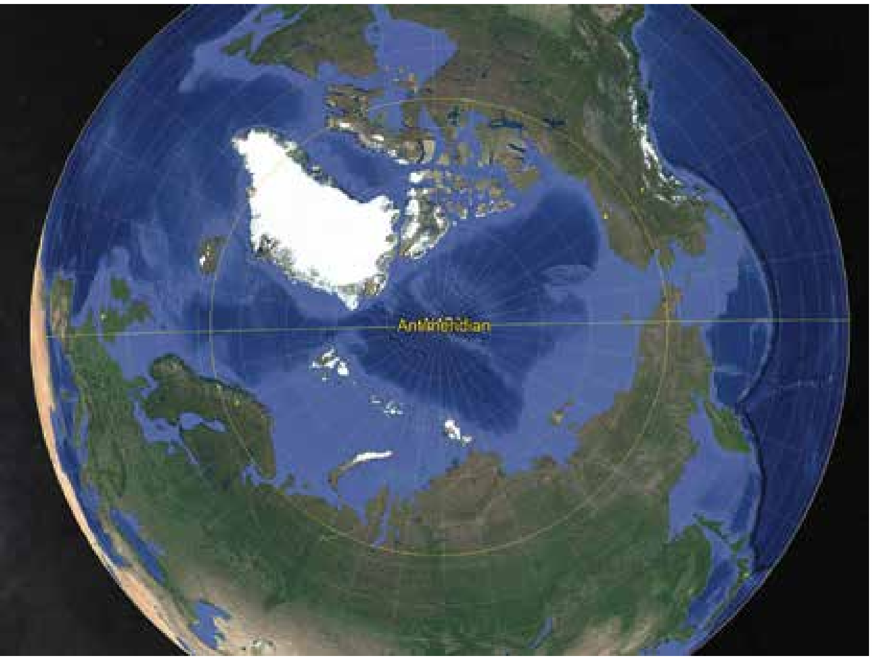

Figure 1. In this image from Google Earth, the arctic circle is the yellow latitude line at 66°32'N.

Figure 2. Locations of Permafrost in the Northern Hemisphere.

Last summer, I took a trip to Alaska along with some students enrolled at the University of Alaska Fairbanks. The trip was organized primarily by Dr. John Galbraith, Professor of Soils at Virginia Tech. He had assistants on the trip including Dr. Yamina Pressler, Assistant Professor of Soil Science and Restoration Ecology at Cal Poly, San Luis Obispo; Dr. Alexander (Sasha) Kholodov, Research Assistant Professor, Permafrost Laboratory, Geophysical Institute, at the University of Alaska Fairbanks (UAKF); and Mark Clark, retired NRCS State Soil Scientist. There were 15 graduate and undergraduate students on the trip, and I could have easily been the grandfather of some of the younger ones! I have worked in the arctic-alpine of Europe but have not visited similar soils and landscapes in North America. I was happy to be invited but had to pay tuition as did my fellow students.

The Arctic (Fig. 1) is the area north of the Arctic Circle (66°32'N), which is also sometimes defined as the boundary between the Boreal (Taiga) forest and Tundra biomes. This is a climate zone where the cold Arctic air meets warmer air masses from further south.

At those high latitudes, permafrost (permanently frozen) soils are found (Fig. 2). An objective of the trip was to investigate permafrost and discuss the implications of it melting due to climate change.

The trip started with flying into Anchorage and driving to Palmer and then north to Fairbanks, and eventually to Prudhoe Bay on the Arctic Ocean (Fig. 3).

We camped at the Matanuska Research and Extension Center in Palmer, the easiest campsite on the trip (Fig. 4).

We also visited the Alaska Plant Materials Center, located on a massive stream terrace without underlying permafrost (Fig. 5).

Not too far away from Palmer is the Matanuska Glacier, (61.802 Lat - 147.813 Long). Access is privately owned, and after paying an entry fee, we took a guided hike on the glacier (Figs. 6, 7).

Figure 3. Locations in Alaska involved in the tour: Anchorage, Palmer, Denali National Park, Fairbanks, and finally Deadhorse (Prudhoe Bay).

Figure 4. Campsite on the lawn of the Matanuska Research and Extension Center in Palmer, we camped here three nights. Standing is Dr. Galbraith.

Figure 5. Agricultural field research at the Alaska Plant Materials Center, Palmer.

Figure 6. View of the Matanuska Glacier from the access parking lot. For scale. look for tiny figures on the left which is the guided tour that proceeded us.

Figure 7. The class on the glacier.

Figure 8. Hiking upslope in Hatcher Pass.

Figure 9. We made detailed soil descriptions at nearly every soil stop on the trip.

Figure 10. Side by side soil surface profiles from adjacent pedons. On the left is an Andosol and on the right is a Spodosol. Different vegetation species account for the soil differences despite otherwise identical factors of soil formation including the parent material of volcanic ash.

The next day we drove to Hatcher Pass (61.781 Lat - 149.213 Long) to see soils on steep slopes under varying vegetation (Figs. 8. 9, 10) .

When we left Palmer, we headed towards Fairbanks and the University. We stayed one night in our tents at Denali NP, but it was cloudy, and we could not see Denali. While at Fairbanks, we stayed three nights at Sven's Basecamp Hostel, a collection of four-person tents with bunks and wooden floors and pay showers. While at Sven's, we visited the CRREL Permafrost Research Tunnel near Fox. This is not a thing many people get to do, and we were pleased that we were allowed access and very impressed with the experience and the permafrost features (Figs. 11, 12, 13).

We also visited the Fort Knox Gold Mine near Fairbanks. We saw the post-mining reclaimed soils (Figs. 14, 15) and I held a 25-pound gold bar (Fig. 16). The mine works 24/7 all year, lots of cold and lots of dark days. They produced about $454 million worth of gold in 2021, but their production costs must be considerable.

Also, near Fairbanks is the Alyeska Pipeline viewing point (Fig. 17). I had a friend who worked at the pipeline as a soil boring logger when it was under construction. He made only about 25 percent of what the heavy equipment operators made, and they called him the "Pebble Pimp."

Not too far away, we viewed a permafrost soil (classified as a Turbel) near the town of Clear. The landform was an extensive floodplain, and we got our first good look at the permafrost (Figs. 18-20).

We then went north on the mostly dirt Dalton Highway for 500 miles to Prudhoe Bay (Fig. 21), an early stop was to observe the effects of the 2020 Isom Creek fire near Coldfoot (Figs. 22, 23).

Figure 11. Entrance to the CRREL Permafrost Research Tunnel.

Figure 12. Inside the CRREL Permafrost Research Tunnel.

Figure 13. Me posing by a relict ice wedge, deep below the surface and within the permafrost tunnel.

Figure 14. Post-mining landscape at the Fort Knox Gold Mine.

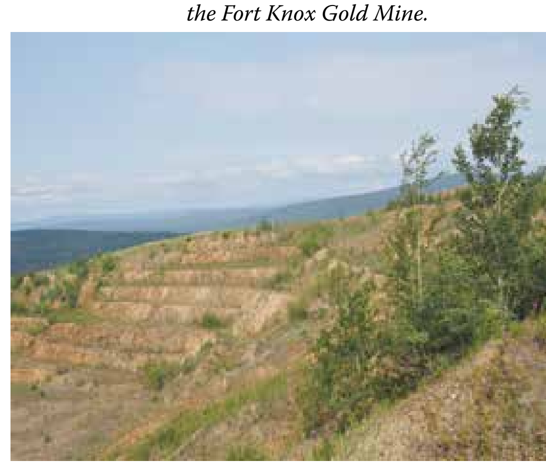

Figure 15. Post-mining soil at the Fort Knox Gold Mine. It was quite rocky and dry, very low in organic matter.


Figure 16. Me holding a 25-pound gold bar at the Fort Knox Gold Mine (that is about $680,000 these days). Note the Mastodon tusk that the miners found while gold-digging.


Figure 17. The Alyeska Pipeline viewing point. The Alaska Oil Pipeline is elevated for the most part and has cooling fins to prevent the permafrost from being impacted. The pipeline is the reason for essentially any infrastructure north of Fairbanks.


Figure 18. Landscape near Clear, AK, an alluvial feature, near level and poorly drained.


Figure 19. We dug down through the seasonal active layer to the permafrost table. Note the incorporated organic matter in the ice.


Figure 20. It did not take long for the permafrost to begin to melt in the summer heat.

At highway milepost 166, we entered the Brooks Range and took a group photo at the Arctic Circle sign (Lat 66.556 - 150.810 Long) (Fig. 24).

Our place to stay for two nights while exploring the area was at Marion Creek campground. Grizzly Bears frequent the local area, and we took measures to protect ourselves (Fig. 25).

Day trips from Marion Creek included a visit to Sukakpak Mountain (Fig. 26). In the foreground is a poorly drained terrace that has a series of palsas (Lat 67.597 - 149.772 Long), or permafrost-cored mounds. They are covered with soils that would class out as highly cryoturbated soils, or Turbels (Fig. 27).

As we went further north, permafrost becomes the norm. Sasha was a pro with the Cipre corer, a device to bore into permafrost. We typically would dig down to the permafrost table on the tundra (Fig. 28), while Sasha would power up the Cipre (Fig. 29), retrieving a beautiful permafrost core sample (Fig 30).

Atigun Pass, at 4,739 feet, cuts through the Brooks Range (Fig. 31). It is a wonderful place to enjoy the view in the summer (Fig. 32) but deadly in bad weather. It is where the Dalton Highway crosses the Continental Divide, and tundra vegetation dominates to the north.

We camped at Galbraith Lake campground (Lat 68.456 - 149.482 Long) while still heading north, and on the way back at the end of the tour. On the way north, we had a visit with a tundra/permafrost restoration project by independent consultant Lorene Lynn to repair damage from the installation of two fiberoptic cables running along the Dalton (Fig. 33).

We spent one night at the hotel at Deadhorse and paid an extra $70 to take a van to the shore of the Beaufort Sea at Prudhoe Bay. I would not recommend it; you cannot stop the van or roll

Figure 21. The Dalton Highway. Much of it is unpaved and traveled by overly large trucks. The dust makes travel challenging. All of our vehicles had cracked windshields.

Figure 22. The apply-named Fireweed is an early colonizer of burned over areas. Given its remote location and dry summer weather, wildfires are common in the taiga.

Figure 23. Soil profile at the Isom Creek fire, dark surface horizon is mostly charcoal and wood ash, a poorly developed soil, probably an Inceptisol.

Figure 24. Class photo at the Arctic Circle sign along the Dalton Highway.

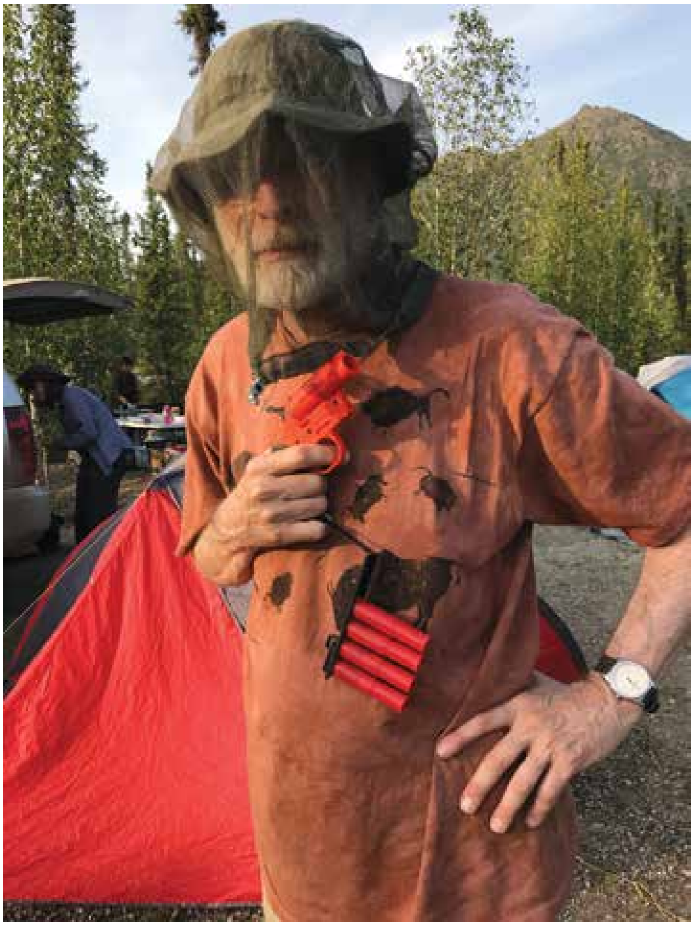

Figure 25. I was issued with a flair gun for Grizzly protection. First shell, shoot into the air, second shell, shoot into the ground at the charging Grizzly's path, third shell, shoot the Grizzly in the face, then run away (left). One of the attractions for bears to come into camp was the food smells. Mark Clark, who had been attacked by a Grizzly bear in the past, was nonchalant near the food in camp (right).

Figure 26. Sukakpak Mountain - a prominent feature along the Dalton Highway.

Figure 27. More exciting to a soil scientist than the mountain scenery is at the base, the palsas. A curious landform along the Dalton at this location, a palsa is a periglacial feature essentially a frost boil generated by groundwater feeding into a freezing zone that grows until the insulating soil erodes off, thus exposing the ice and leading to the feature's demise.

Figure 28. Tundra excavated to permafrost table.

Figure 29. Sasha powering into the permafrost with the Cipre corer.

Figure 30. Dr. Yamina Pressler holding the permafrost core retrieved from about a meter below the surface with the Cipre corer (left) and a close-up showing clean ice and incorporated organic matter (right).

Figure 31. Atigun Pass with an oversized truck barreling down the north slope.

Figure 32. We took a break to enjoy the view from Atigun Pass looking to the north.

Figure 33. Students listening to Lorene Lynn explain her tundra restoration project.

Figure 34. Oil drilling infrastructure feeding crude oil into the Alaska Pipeline (left). A caribou wandering around a parking lot at Deadhorse (right).

Figure 35. Dr Galbraith showing off his northernmost Geloll.

Figure 36. Students standing on a floating sphagnum bog. About 80 cm of histic epipedon is floating on about another 80 cm of water. Mark Clark said that he has seen similar situations where the water depth exceeds 30 m.

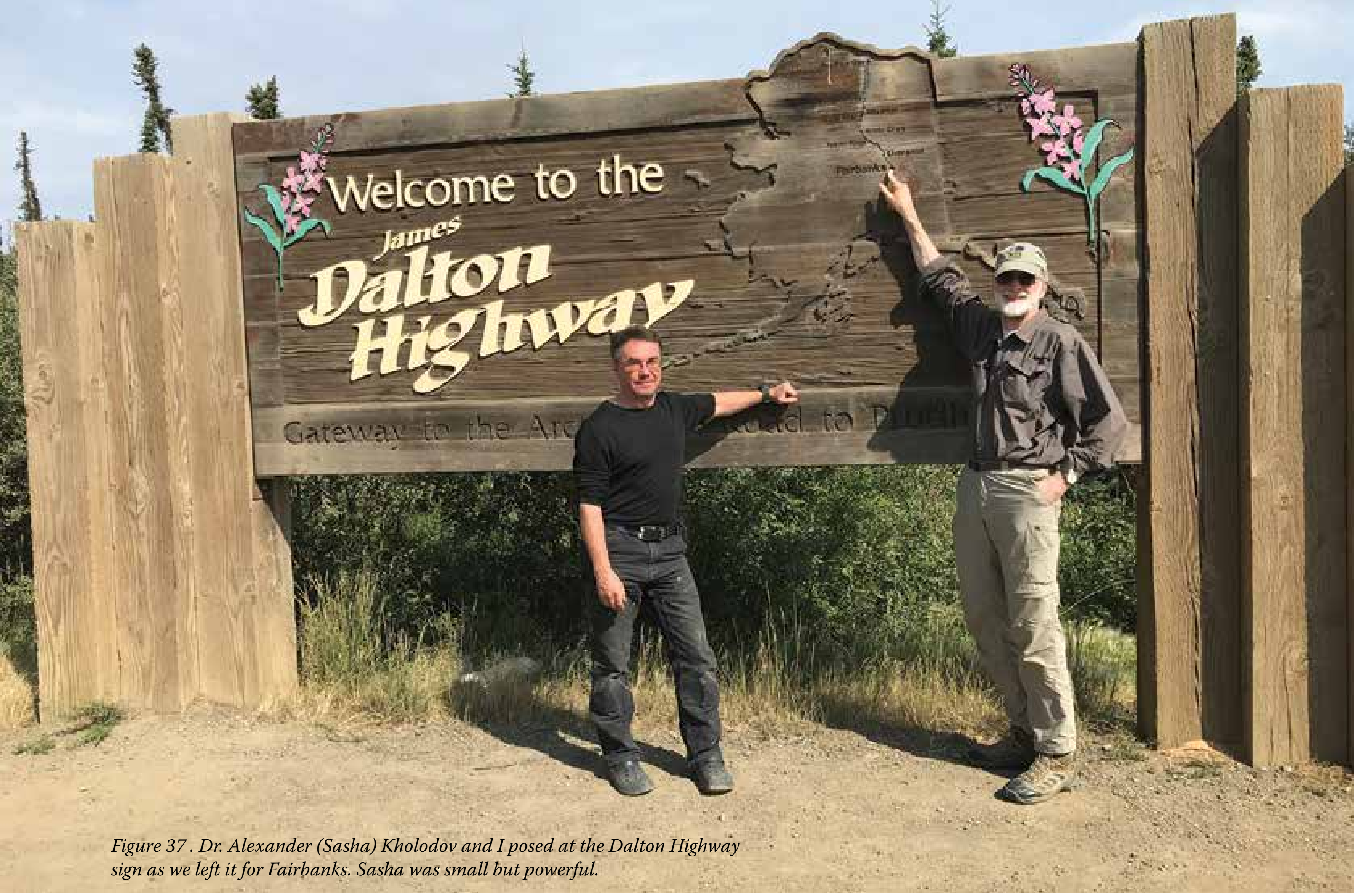

Figure 37 . Dr. Alexander (Sasha) Kholodov and I posed at the Dalton Highway sign as we left it for Fairbanks. Sasha was small but powerful.

down windows, and the shore is trashy with rusty oil drums and steel cables. However, we saw more wildlife among the oil-drilling buildings than anywhere on the trip (Fig. 34).

Near the Galbraith Lake campground is Fossil Creek (Lat 68.468 - 149.541 Long). That was where Dr. Galbraith showed us a soil classified as a Geloll (Fig. 35). This was interesting, but a big disappointment to me because I thought that I held the record for the furthest north soil described Geloll near Abisko Sweden at 68.398° N. Close, but no cigar.

Our last soils stop was a floating sphagnum bog, an organic soil classified as a Histosol (Fig. 36).

After the final soils stop, we high-tailed it back to Fairbanks on the Dalton because some students were on the plane home that evening (Fig. 37).

The focus of this Alaska trip was primarily soil- and landscape-based, with emphasis on permafrost. While we were there it was quite warm, and it was surprising to dig down only a few feet and find ice-filled frozen soil. And watching it quickly melt in the hot sun helped the students recognize the potential global warming impacts. The take-home message they undoubtedly left with is that climate change is real and something needs to be done about it before all the permafrost melts.

This was a once-in-a-lifetime experience for the students and me. However, Dr Galbraith has led this trip several times and, so far, has come home with all the students he left with. Logistics, equipment, and living conditions are all quite challenging, and rallying student support for the trip is quite an accomplishment for him. He is passing the responsibility on to Dr. Yamina Pressler, and I wish her luck.

Message from the author

It is with sadness that I announce my resignation from my position as Executive Director of the American Society of Reclamation Sciences for health reasons, effective July 1, 2022. I joined the then ASSMR in 2006, and it has been my privilege to serve as the Soils Technical Division Chair for many years, then President, and more recently as the Executive Director since 2013. During my time as a member, officer, and director, I have gained many friends through the society, learned numerous reclamation principles and practices from many of you, valued my association with you, and benefited from serving you in these leadership positions. I look forward to the continued growth and development of the society with our new name and new leadership. The future of the society is bright.

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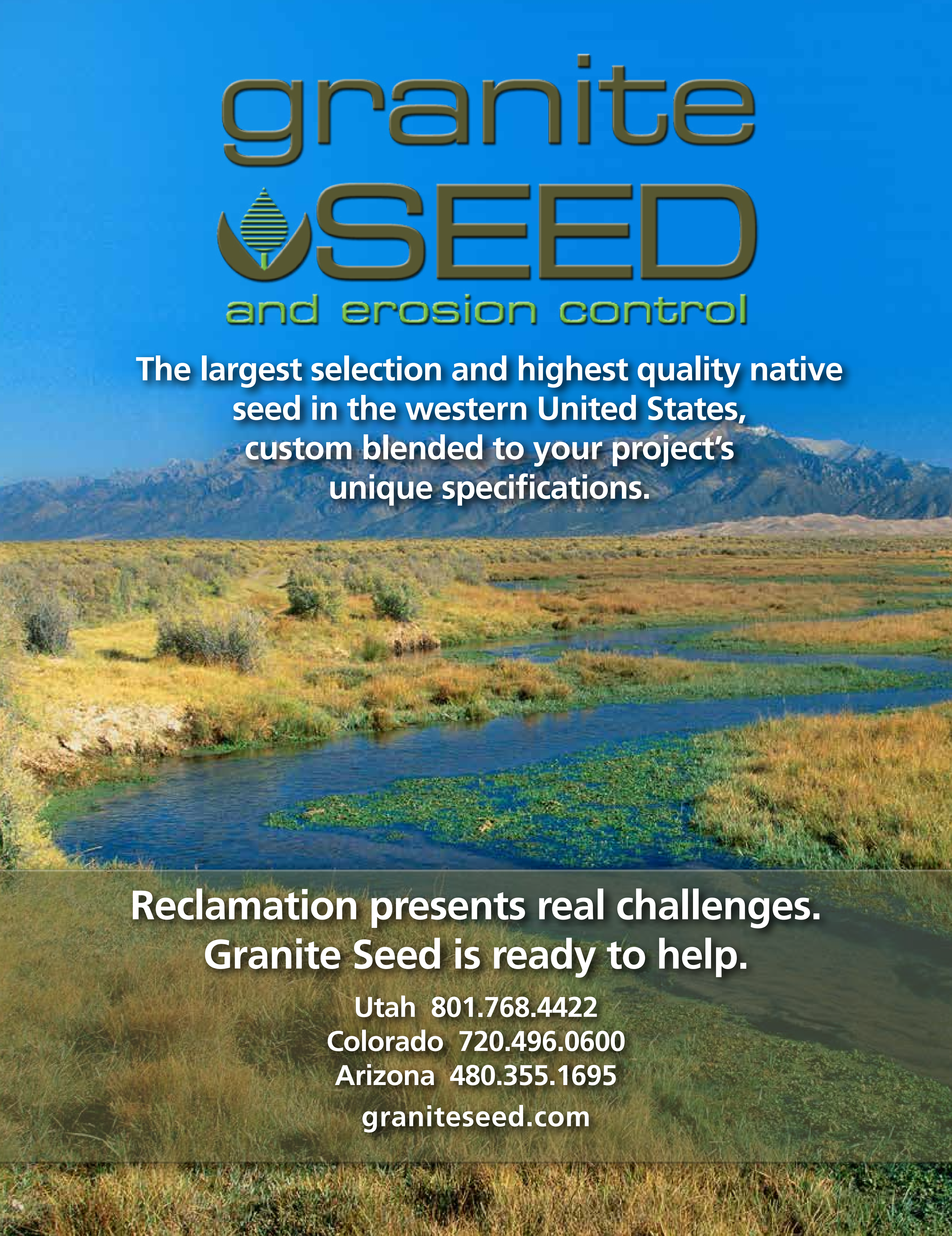
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