

OFFICIAL PUBLICATION OF THE AMERICAN SOCIETY OF MINING AND RECLAMATION

reclamation *matters*

2019
Conference
and Program



**Proactive management of imperiled species
to avoid federal listing: Monarch butterfly
habitat enhancement on mined lands**





WESTERN STATES

RECLAMATION, INC.

Western States Reclamation, Inc. (WSRI) just celebrated its 35th year in business. Liz and Dave Chenoweth founded WSRI in January 1983. They were both previously employed by a large energy company in the coal mining division. Dave had worked as an environmental scientist overseeing completion of environmental baseline studies and reclamation programs. Liz worked in business development. WSRI focused predominantly on revegetation and erosion control projects the first two years in business.

Today the company is involved in large-scale landscape construction projects, stream channel restoration, and land restoration for a number of government and corporate entities. The company is still very active in oil & gas and mining restoration/reclamation projects, where it founded its roots in 1983. The company's major service areas include earthwork, light civil work, landscape/irrigation construction, storm water management installations, and all forms of seeding and mulching.

WSRI has completed projects in 17 states to date. The corporate headquarters is in Frederick, CO with satellite offices in Grand Junction and Kayenta, AZ. WSRI employs approximately 200 employees between its three office locations.



Western States Reclamation, Inc. has been involved in the restoration and stewardship of land since 1983 in Colorado and the majority of the western United States. Since 1983, both owners and employees of Western States have taken great pride in the work they have completed and the client relationships they have built and maintained. One of the major driving factors behind WSRI's success is the diverse scientific, construction and design backgrounds of the company's staff. It is the combination of decades of experience along with client relationships that positions Western States as a leading reclamation contractor and consulting company in the United States.

RELY ON US FOR RESPONSIBLE LAND MANAGEMENT

Western States Reclamation, Inc. • 303-833-1986 • www.wsreclamation.com

pac-ind

pacific inter-mountain distribution

Providing High Performance Products to Heavy Industry TM

Soil Stabilization • Dust & Erosion Control • Tailing Ponds • Haul Roads • Reclamation



*Next-Gen Industrial Polymers
Activated Carbon
Foam Liquid Concentrates*



“We build strong bonds” TM

1001 South Main Street, Suite 550 • Kalispell, MT 59901 • 406.407.0070 • www.pac-ind.com

SUCH AN IMPRESSIVE LINEUP...



- Replaces Blown Straw | Uniform Coverage
- Wood Mulch Replacement | Saves Money & Time
- Faster Loading & Application Times
- Get More Per Tank Load | Load More – Spray More



Hydrostraw.com
info@Hydrostraw.com



Summitseed.com
info@Summitseed.com

For more information, call 800-545-1755 or visit us online at hydrostraw.com



Some see roots...we see **PERFORMANCE.**

Effective conservation restorations focus on rebuilding vibrant soil, rich in mycorrhizal fungi. This healthy soil supports a correct and diverse balance of native plant and wildlife populations critical for **long-term project success.**

Mycorrhizae are symbiotic extensions of root systems specialized in increasing absorption of water and nutrients, up to 50X greater. Reintroduction of a variety of strains of **mycorrhizae dramatically improves plant performance and survival.**

Forrest Keeling's patented RPM-production includes our special growing media with 21 species of mycorrhizae. **Our rich media naturally grows stronger, healthier plants up to two times faster than traditionally produced plants.** Equally important, the soil media carried by each RPM-produced plant helps improve its planting site's soil for water and nutrient absorption and overall vigor and survivability going forward. Research shows our RPM-produced plants enjoy **over 95% survivability** in conservation projects.

Forrest Keeling Nursery has devoted seven decades to better learn ways our natural environment works and how to best support and protect it. With you, we're **restoring earth's ecosystems...**



ONE TREE
at a time



Traditional seedling (L) vs RPM-produced 3-gallon. These 12-month old oaks show the RPM difference is dramatic.

reclamation matters

is published by
DEL Communications Inc.
www.delcommunications.com

PRESIDENT / PUBLISHER
David Langstaff

MANAGING EDITOR
Lyndon McLean
lyndon@delcommunications.com

SALES MANAGER
Dayna Oulion
dayna@delcommunications.com

SALES REPRESENTATIVES
Corey Frazer
Colin James
Ross James
Kari Philippot

PRODUCTION SERVICES
S.G. Bennett Marketing Services

ART DIRECTOR
Kathy Cable

LAYOUT
Dave Bamburak

ADVERTISING ART
Dana Jensen

© 2019 DEL Communications Inc.

All rights reserved. Contents may not be reproduced by any means, in whole or in part, without the prior written permission of the publisher.

While every effort has been made to ensure the accuracy of the information contained herein and the reliability of the source, the publisher in no way guarantees nor warrants the information and is not responsible for errors, omissions or statements made by advertisers. Opinions and recommendations made by contributors or advertisers are not necessarily those of the publisher, its directors, officers or employees.

Publications Mail Agreement #40934510
Return undeliverable Canadian addresses to:
DEL Communications Inc.
Suite 300, 6 Roslyn Road
Winnipeg, Manitoba R3L 0G5
Email: david@delcommunications.com



PRINTED IN CANADA | 03/2019

In this issue

President's message	10
Editor's message: Like putting lipstick on a corpse	11
Early Career Message: Speaking from experience	12
2019 ASMR Conference Program	13
Welcome Back to Montana, the Land of Reclamation Pioneers!	30
Examining the use of SWAT modeling for assessment of hydrologic benefits resulting from abandoned mine land reclamation	34
How infiltration hydrology varies among Appalachian coal-mine valley fills	37
Evaluation of an innovative calcite precipitation-based passive treatment technology at Bunker Hill, Coeur d'Alene, Idaho	40
Proactive management of imperiled species to avoid federal listing: Monarch Butterfly habitat enhancement on mined lands	44
Re-establishing pollinator habitat on mined lands using the forestry reclamation approach	48

Index to advertisers

Arkansas Valley Seed	36
Biomost, Inc.	51
Ernst Conservation Seeds	28
Forrest Keeling Nursery	5
Full Circle Mushroom Compost Inc.	7
Granite Seed And Erosion Control.....	33
Herrera Environmental Consultants	7
Hydro Straw, LLC	4
Inter-Mountain Labs, Inc.....	22
Pacific Inter-Mountain Distribution, LLC.....	3
Respec	42
Rocky Mountain Bio Products	43
Stantec.....	OBC
Stevenson Intermountain Seed, Inc.....	7
Trihydro	54
Truax Co Inc.	11
Western States Reclamation, Inc.....	IFC, 8 & 9



The Gold Standard of Compost

288 Stevens Road
Rising Sun, MD 21911

www.FullCircleMushroomCompost.com

610-331-1849

**Commercial Applications
That Include Mushroom Compost:**

- ✓ Vineyards/Hops
- ✓ Mine Reclamation Projects
- ✓ Wetland Material
- ✓ Storm Water Management Basins
- ✓ Stream Retrofit Material
- ✓ Highway Site Remediation
- ✓ Parking Lot Islands
- ✓ Green Roofs
- ✓ Filtration Socks
- ✓ Community Beautification
- ✓ Compost Blankets
- ✓ Erosion Control
- ✓ Filters Heavy Material
- ✓ Brownfields
- ✓ Turf Management
- ✓ Horticulture Supplement
- ✓ Landfill Capping
- ✓ Tree Farms
- ✓ Utility ROW Improvements
- ✓ Coal Mine Drainage
- ✓ Vegetable Farms
- ✓ Drilling Pad Restoration



**Remediation and
Reclamation Support
from Site Assessment to
Construction Oversight**



Kyle Johnson, PE providing construction oversight
at Black Pine Mine near Philipsburg, Montana.

406-721-4204
www.herrerainc.com



42ND YEAR IN BUSINESS

Need top quality site and purpose adapted seed specifically selected to meet the requirements of your seeding project this fall?

Stevenson Intermountain Seed Inc. has you covered with over 450 species and varieties of grass, forb, wildflower, legume, and shrub seed in stock and ready for delivery. With this broad base of species, varieties and local origins, we can genetically select those that will be the best match for your project.

All accompanied by great prices, professional, knowledgeable assistance, and 42 years of reputable experience.

Contact us by phone at 435-283-6639, email at sales@siseed.com or mail at Stevenson Intermountain Seed Inc., P.O. Box 2, Ephraim, UT 84627.

Please check out our website at WWW.SISEED.COM



WESTERN STATES

RECLAMATION, INC.



EARTHWORK

Western States Reclamation, Inc. (WSRI) is a full-service earthwork and reclamation contractor. WSRI performs site excavation and grading operations, with the capability to move mass amounts of subsoil and topsoil using scrapers, dozers, loaders and motor graders to accomplish various objectives.

WSRI's earthwork projects include work in the energy industry; comprising oil and gas access roads, pad development and reclamation, as well as solar and wind site revegetation. The primary tasks for this work include: initial earthwork by means of moving several thousand yards of subsoil to contour the site back to its original

landscape, placing fertile topsoil to achieve successful vegetative restoration, followed by native seeding or topsoil preparation for landowners to continue farming practices.

WSRI also provides pond clean-outs, dewatering, river and stream bank restoration; including soil lifts and in-stream structures. In the years following the 2013 flooding, WSRI was contracted for multiple projects on local waterways. WSRI focused on bank restoration and habitat construction on sites including the Big Thompson, Boulder Creek, Cache la Poudre, South Platte, Left Hand Creek and more.



From Planning to Completion, WSRI is America's Trusted Reclamation Partner since 1983



BERTHOUD RESERVOIR

The Town of Berthoud was unable to utilize the existing reservoir as a water supply, due to years of siltation. WSRI was contracted to clear and grub the work site, construct a bifurcation embankment to capture sediment above the existing dam structure and revegetate disturbed areas. Due to excess groundwater, this project potentially required a soft subgrade using track hoes and haul trucks, but WSRI resolved this issue by dewatering and excavating critical areas using scrapers. Approximately 75,000 cubic yards of soil material was stripped and stockpiled from the existing reservoir body; in addition, nearly 37,500 cubic yards of soil material was placed and compacted for the bifurcation

dam. Three concrete water-intake structures and associated piping were constructed to convey water from the ineffectual water cell into the potable water cell.

While working within a residential area, WSRI managed dust and noise control to ensure minimal impact to the neighborhood. Upon project completion, the Town of Berthoud contracted WSRI to build an additional boat dock and utilize excess PVC piping for a recreational catfish habitat. Both the Town of Berthoud and the residents near the reservoir provided positive feedback about WSRI's quality of work and the manner of time in which it was completed.



RELY ON US FOR RESPONSIBLE LAND MANAGEMENT

WESTERN STATES RECLAMATION, INC. • 303-833-1986 • WWW.WSRECLAMATION.COM



Message from the President

By Gwen Geidel, University of South Carolina

The American Society for Mining and Reclamation (ASMR or Society) was founded in 1973 and, during its 46 years, is and has been a leading international clearing house on the practice of land reclamation science and engineering of disturbed lands and waters related to mining. As some may recall, ASMR began as a small West Virginia advisory council concerned with reclamation of lands that had been disturbed by coal extraction. Since then, ASMR has evolved into a professional society of international prominence, including members from 20 countries, nearly half of which will be represented at our 2019 meeting in Big Sky, Montana. Initially, ASMR focused on lands disturbed by mining, but our professional interests now include all aspects of land reclamation, restoration, rehabilitation, reforestation, and the protection and enhancement of soil and water resources regardless of the source of the disturbance. As ASMR moves toward its 50th anniversary, the ASMR National Executive Committee (ASMR-NEC) is reviewing our history, evaluating our current status, and planning for the future through the development of a strategic plan. In this message, I will share some of the highlights from this strategic planning process and, during our annual ASMR Business Meeting on June 4, 2019 in Big Sky, I will seek your input and support.

ASMR's mission continues to represent and serve a diverse national and international community of scientists, practitioners, private industry, technicians, educators, planners, and government regulators involved in the reclamation of anthropogenically disturbed lands. ASMR promotes the advancement of basic and applied reclamation science through research and technology transfer via the society's many events and publications: 1)

annual technical meetings through presentations, 2) published proceeding and abstracts, 3) Journal of the American Society of Mining and Reclamation (JASMR), 4) Reclamation Matters magazine, 5) newsletters, and 6) web site.

Through an analysis of the society's strengths, weaknesses, opportunities, and threats, we understand that there's work to be done to continue to serve an ever-enlarging community of experts from all sectors of reclamation and to enhance our ability to promote effective stewardship of the lands for which we are responsible. While the plan enumerates at least 14 strengths and a number of weaknesses (see full Strategic Plan at: <https://www.asmr.us/About-ASMR/By-Laws-and-Policies>), our strengths generally lie in our diverse membership, extensive database of research and case studies, and financial stability. Our weaknesses involve our small membership size, extent of efforts not captured in our society name, and our current electronic footprint.

As the NEC reviewed the society's external opportunities and threats, we visualize opportunities to promote, enhance, and expand our current diversity of membership to include ecological engineering, geomorphic reclamation design, ecological restoration, aquatic restoration, passive wastewater treatment, agricultural soil restoration, in-situ remediation of contaminated soils, waters and wastes, and the many ways advanced technology can be applied to land and water reclamation-related problems and solutions. However, the NEC is also fully aware that ASMR is now one of several excellent non-profit organizations that provide technology transfer and member support, some of which overlap with ASMR's interests and expertise. However, this year's 36th annual ASMR meeting

and the over 130 abstracts accepted are a testament to the value that the society brings and has brought to this community during the past 46 years. The society must also recognize the changes that have occurred during these years, one of which is that our member's reclamation expertise is no longer tied only to mining, as evidenced by the Technical Program developed for the Big Sky meeting.

Through the strategic planning process, specific goals are identified to leverage the society's strengths, firm up its weaknesses, prioritize and engage in opportunities, and minimize or eliminate threats. One of the outcomes of this strategic planning process strongly suggests that we transition from the society's identity from a mining-related reclamation organization to one with a discipline focus (i.e., applied land and water reclamation science). The NEC approved the strategic plan in December 2018 and recommends that during this transition, re-branding would create the opportunity for many other industries, regulatory agencies, and individuals to see the increased value of membership, conference participation, journal contributions, etc., thus ensuring the sustainability and relevance of the society long into the future.

The strategic plan was requested by and prepared for the ASMR-NEC and I would like to thank the members of the ASMR Strategic Planning Subcommittee whose dedicated efforts and lengthy discussions with the NEC led to the development of this comprehensive plan. These members include Kevin Harvey, Chair and ASMR's President Elect; Amy Blyth (NEC Member Elect); Dustin Wasley (NEC Member); and Gwen Geidel (President).

I welcome your thoughts, comments, or suggestions and look forward to our discussion in June 2019. Feel free to email me at Geidel@sc.edu. ■



Like Putting Lipstick on a Corpse

By Jeff Skousen, West Virginia University

Reclamation is like putting lipstick on a corpse. This statement was expressed by a former congressman of West Virginia. During his years in Congress, he was a crusader for better working and safety conditions for miners, and in his later years, he became an anti-coal activist. This remark has been used by anti-coal and anti-mining groups to support their contention that surface mining in Appalachia is destructive and forever irreparable. They assert the land is dead and reclamation only temporarily and cosmetically conceals the lifeless landscape.

As a member of ASMR and someone who works in the mining and reclamation community, you probably take offense to this statement. Laws and regulations have been passed so that mined land is returned to its approximate original contour, the landscape is rebuilt, native soils are saved then replaced on the reclaimed surface, and the site is revegetated with plants that will support the pre-selected post-mining land uses. Granted, some mined areas are reclaimed to urban or industrial uses, which in their own way are prosperous landscapes. But for those lands that go back into living and breathing ecosystems, the mined area is reclaimed to a condition that will support those organisms of the pre-existing ecosystem. Reclaimed areas initially look different than the pre-mining mature ecosystem, but the requirement and goal of reclamation is to recreate an area that supports or be capable of supporting the organisms and uses that existed before mining. In other words, the land should be analogous or very similar to the pre-mining condition.

Some people may know of unreclaimed sites that are like a corpse and appear dead, where little or no vegetation grows on the site. These areas generally had no

reclamation and no soil-like materials placed at the surface. Such sites may be unstable, contain acid-producing materials that hinder vegetation establishment, have compacted substrates for poor root development, sustain no microbial growth and no nutrient cycling, or possess other water- or soil-related pollution problems. These sites may have one major deleterious factor or a combination of factors that render them "corpse-like."

Reclamation efforts today are devoted to rebuilding thriving landscapes, re-establishing functioning hydrologic systems, returning living soils, and restoring resilient plant communities that are alive, healthy and sustainable. Reclamation involves purposeful planning, thoughtful application of appropriate materials and proven techniques, and, of course, patience. With time, the reclaimed areas blend into the undisturbed landforms and land uses. For those of us in reclamation sciences,

anything less than establishing a dynamic sustainable ecosystem with its inherent ecological services is not reclamation. If Patrick Henry were alive today and was a member of ASMR, he would say, "Give me reclamation or give me death!" ■

"Reclamation today rebuilds landscapes, re-establishes hydrologic systems, returns living soils, and restores resilient plant communities..."



The **preferred tool** for reclamation seeding

(763) 537-6639 • www.truaxcomp.com



Truax OTG (On-The-Go)
No-till Drill Seeders



Speaking from Experience

By Hannah Angel, Early Career Representative

Early career people need hands-on field training that comes with a summer job, an internship, or volunteer work. These experiences help them know how to dress for the weather, tolerate the mud, dust, heat and cold, and get their hands dirty. But more than just learning the physical aspects of work, they need mentorship, guidance, and inspiration. Hence, the need for mentors and mid- to late-career professionals who are willing to provide advice, support, and guidance.

By far, the most influential part of my college career as a forestry undergraduate at the University of Kentucky (UK) was volunteering for the Appalachian Regional Reforestation Initiative (ARRI; <https://arri.osmre.gov/>) and Green Forests Work (GFW; <http://www.greenforestswork.org/>). Based in the Appalachian coal fields, ARRI's and GFW's missions are similar: To restore healthy and productive native forests on mined lands and expedite the establishment of forest habitat through natural succession. Planting trees taught me valuable hands-on field experience, perseverance through difficult weather, and opportunities for leading/teaching large groups of volunteers on how to plant and protect seedlings. My volunteer work for ARRI/GFW led me to an opportunity for undergraduate research with American chestnuts on reclaimed surface mines in eastern Kentucky in 2011. This in turn led to my involvement as a student member in ASMR.

While at UK, opportunities arose for summer internships. I worked for the U.S. Forest Service in South Carolina (2012), the Molpus Woodlands Group in Alabama (2013), and the Luminant Mining Company in Texas (2014). While my undergraduate research gave me a mental push to pursue a M.S. program at Stephen F. Austin State University (SFASU in east Texas) in 2014, the “hands-on” field experience I gained during those summers – collecting stream water/insect samples, cruising loblolly pine timber, conducting revegetation surveys on reclaimed mines – helped prepare me for it. After my M.S. degree, I was still not set on my “direction,” although I knew I was passionate about working with disturbed soils. So, I decided to keep climbing the academic ladder, and I am now currently a second-year PhD student at Virginia Tech (VT) working on mine reclamation projects.

Like many other graduate students, I wear more than one “hat” as a student, researcher, and teacher. I remember when my M.S. advisor told me that I'd be teaching forest dendrology in the fall of 2014 – I bubbled over with joy! Currently, I am the

lead teaching assistant for the basic soils lab at VT, and it is something I look forward to each week. Much of my field and laboratory work has really helped me to know the subject so that I can convey that information to my students. This is one reason I strive to stay actively involved in the Soil Judging Team at VT. After I graduate, it is my goal to continue strengthening my “practical” skillset – the value of this type of transformative learning has been important for my personal and professional growth throughout my college career. I believe what makes many of my past and current professors at UK, SFASU, and VT effective university educators is that they are actually “speaking from experience.”

As we near the spring of 2019, if you or someone you know (particularly a group of people) are interested in an “alternative spring break,” Green Forests Work will work to accommodate you into their Spring Tree Planting Schedule. Please visit <http://www.greenforestswork.org/> and/or contact Michael French at michael.french@gfw.org directly to learn more about how you can get involved!

Early Career Events

In the fall of 2009, Reclamation Matters began incorporating articles dedicated to early career professionals in ASMR. This first Early Career Message was written by Abbey Wick, the first-ever EC Chair. She and others promoted early career involvement through organizing EC social events, field tours, and increasing overall awareness of professional development and other opportunities within ASMR. Since then, many others have contributed a variety of fun articles narrating career journeys, offering career advice, guidance, useful information, and highlighting ASMR student chapters.

Today, ASMR carries on these traditions (e.g., EC Social Event), while continuing to develop new ideas for connecting professionals at all career stages across a diverse range of fields throughout the year (beyond annual meetings). ASMR is an avenue for discovering ways of volunteering, learning about new ideas and technologies, forming valuable relationships and collaborations, and finding new directions and inspirations. We look forward to a relaxing yet fun and interactive evening of social networking at the Early Career Event in Big Sky, Montana. Feel free to contact Hannah Angel (angelhz@vt.edu) if you would like to offer any suggestions, new ideas, and feedback toward early career involvement, development, and networking within the organization. ■

Welcome Back to Montana, the Land of Reclamation Pioneers!



We are pleased to announce the 36th Annual Meeting of the American Society of Mining and Reclamation (ASMR), June 3 to 7, 2019, at the Big Sky Resort in Montana.



This conference will focus on the research, technical, and regulatory issues associated with the land and water implications of anthropogenic land disturbances. It will provide a forum for the dissemination of information through presentation of research findings, field tours, and open discussion of public policy relating to the applied science of reclamation, rehabilitation, remediation, and restoration of areas disturbed by mining, oil and gas, conventional and alternative energy production, contaminated industrial sites, agriculture, road construction, large-scale commercial development, and other disturbances to land and water resources.

Presentations will include traditional oral presentations, posters, and, new this year, video presentations will be featured. Students are especially encouraged to attend. Kevin Harvey, the

Photos courtesy Big Sky Resort

ASMR President-Elect, is the Conference Chairman, and KC Harvey Environmental, LLC will be the host of the conference. The Preliminary Program, included in this publication, shows the preliminary schedule, session topics, presenters, and special events.

Our special events have been carefully designed to maximize professional networking and provide the opportunity to absorb the incredible Rocky Mountain environment and culture:

Professional Field Tour 1: June 2. McLaren Tailings Reclamation Project. Join us for a tour of the McLaren Tailings site, located near Cooke City, Montana, in a valley drained by Soda Butte Creek, which runs through the site and into Yellowstone National Park. We will explore the reclamation work the DEQ began in June 2010. Excavation of the tailings required extensive construction dewatering and water treatment to excavate the tailings safely. This event includes transportation and lunch.

Welcome Reception: June 3. A time in the evening to meet the registrants of ASMR 2019; food and drinks provided.

Haulin' ASMR: Mornings. The running group for ASMR membership and meeting attendees. A chance to run at an elevation of 7,000+ feet.

Wild Women of Reclamation: June 4, 7:00AM. A chance to have breakfast with the distaff side of ASMR. All are invited.

Networking Event: June 4. Join us for food, beverages, live music, and networking at the social event, which will take place at the Big Sky Pavilion (weather dependent) at the base of some of the biggest skiing in North America.

Cultural Event 1: June 5. Shopping and lunch in historic downtown Bozeman. This event, aimed at spouses and guests, will include chartered transportation from Big Sky Resort to historic downtown Bozeman. Explore the charming Western mountain town full of shops, cafes, restaurants, art, and music. Lunch is on your own.

Poster Session: June 5. Poster presentations will be on display, with authors present after the technical sessions finish that day.

ASMR Film Festival: June 5. The First Annual ASMR Reclamation Film Festival of the best-in-show videos will be in the evening after the poster session.

Cultural Event 2: June 6. Grizzly and Wolf Discovery Center. While you are visiting us here in the Rocky Mountains, come meet some of our fiercest wildlife up close and personal! The Grizzly and Wolf Discovery Center in West Yellowstone is a wildlife park and educational facility that houses seven grizzly bears, five wolves, and several birds of prey. This event includes chartered transportation from Big Sky Resort to the Discovery Center and admission.

Photos courtesy Big Sky Resort

Early Career Professional Event: June 6. This event will bring together early career professionals (<10 years into their careers) and experienced professionals who will provide valuable mentorship. Attendees will board the brand-new ski access tram to travel up the slopes to Everett's 8800, a mountain top bar and grill named for its elevation above sea level. The event will include food, beverages, and fun ways for early career professionals and mentors to interact.

Silent Auction: Until noon on June 6. Provides an opportunity to donate and bid on items, with profits going to support the ASMR student scholarships.

Professional Field Tour 2: June 7. Yellowstone National Park. Discover the magic of America's first national park in a bus tour that will hit all the classic tourist locations while also highlighting the effect of forest fires on the park and restoration efforts. You will see thermal features, wildlife, scenic views, and more in this guided tour of the park. This event includes transportation and lunch.



All of this information- and more- can be found in detail on the conference's website at <https://www.asmr.us/Meetings/2019-Annual-Meeting> and also on both ASMR's and KC Harvey's LinkedIn and Facebook pages.

Attendees should fly into the Bozeman airport (BZN) and arrange transportation from there to Big Sky Resort, which is about 52 miles south of the airport. Transportation recommendations are included on the conference website. Temperature can change quickly at this ski mountain resort at elevation 7,510 feet (2,289 meters), so make sure to be prepared for any kind of weather. It could be warm and sunny or a complete blizzard. Pack warm layers so you can add or subtract clothing with ease to stay comfortable. Average temperatures in Big Sky for the first week in June ranges from 32 to 65 °F, (0 to 18 °C), and there is a 20%-30% chance of snow or rain on most days. Bring weatherproof clothing—rain jacket, rain boots, warm and light jackets, etc., and remember to check the weather a few days before you travel!

Photos courtesy Big Sky Resort



ASMR

JUNE 3-7, 2019



2019 Conference Program

Big Sky Resort



Meeting Financial Sponsors/Exhibitors
Gold

Peabody

**KC HARVEY
ENVIRONMENTAL, LLC**



Silver



Meeting Financial Sponsors/Exhibitors (con't)

Bronze (also Exhibiting)



BKS Environmental
Associates, Inc.

BKS Environmental Associates, Inc.

Pacific Inter-Mountain Distribution



Energy Labs

Conference Mobile App Manager

Trihydro Corporation



Break Sponsors

Still available

Breakfast Sponsors

Still available

Lunch Sponsor

Granite Seed

Early Career Professional Event

Still available

Field Tour Sponsor

High Altitude Revegetation Committee



Exhibitors

ACZ Labs

Pioneer Technical

Bio Lynceus



Granite Seed

Rocky Mountain Bio Products

Trihydro Corporation

RESPEC

GeoEngineers



A Division of COWMAN Construction Supply, Inc.



If you would like to sponsor or exhibit, please visit our website <https://www.asmr.us/Meetings/2019-Annual-Meeting/Sponsor-Exhibits> for more information.

ASMR 2019 Program Committee

Kennet Bertelsen	Morrison-Maierle
Mehgan Blair	2020 Conference Chair/Barr Engineering
Amy Blyth	Trihydro Corporation
Dr. Robert Darmody	ASMR Executive Secretary
Dr. Gwendelyn Geidel	ASMR President/University of South Carolina
Kevin Harvey	KC Harvey/Conference Chairperson/AMSR President - Elect
Julie LaBar	Centenary University
Rachel Schmidt	KC Harvey/Conference Co-Chairperson
Dr. Pete Stahl	University of Wyoming
Dustin Wasley	GeoEngineers

See you in
beautiful Duluth, Minnesota
in June 2020!

Thank you for your support and
attendance this year.

Sunday, June 2, 2019

8:00 a.m. – 5:00 p.m. **Professional Field Tour #1: McLaren Tailings Reclamation Project.** Join us for a tour of the McLaren Tailings site, located near Cooke City, Montana, in a valley drained by Soda Butte Creek, which runs through the site and Yellowstone National Park. We will explore the reclamation work the Montana Department of Environmental Quality began in June 2010. Excavation of the tailings required extensive construction dewatering and water treatment to excavate the tailings safely. This event includes transportation to and from Bozeman and lunch.

Monday, June 3, 2019

8:00 a.m. – 5:00 p.m.

Registration – Firestone Lounge

10:00 a.m. – 5:00 p.m.

Exhibitor Setup – Gallatin

10:00 a.m. – 4:00 p.m.

NEC Meeting – Shoshone Boardroom

6:30 p.m. – 9:00 p.m.

Welcome Reception – Jefferson/Madison

All day

ASMR Office – Lake

Tuesday, June 4, 2019

6:30 a.m. – 7:30 a.m.

Haulin' ASMR – Meet in lobby of Huntley Lodge

Don't miss the chance to run at an elevation of 7,000 feet with beautiful views of Big Sky Resort and the Gallatin National Forest as Haulin' ASMR kicks off every morning of the annual meeting. Big Sky is known for its vast abundance of native wildflowers that usually hit full bloom in late spring! All runners and walkers are welcome and encouraged to join the group as they get ready for the day. This is a great opportunity to network with other conference attendees while enjoying the fresh mountain air and beautiful scenery Big Sky has to offer. Don't forget to bring your running or walking shoes, pack a few extra layers and check the weather! For questions, contact Michelle Coleman, mcoleman@nbpower.com.

6:30 a.m. – 8:30 a.m.

Breakfast – Huntley Dining Room

7:00 a.m. – 8:30 a.m.

Wild Women of Reclamation – Cheyenne

Participants meet before the morning talks at a kickoff breakfast early in the conference. Every woman is welcome. Presentations in the past have dealt with choosing your own path, mentoring, starting your own business and juggling a research career with family and community obligations. For questions, contact Michelle Coleman, MColeman@nbpower.com.

7:30 a.m. – 5:00 p.m.

Registration – Firestone Lounge

8:00 a.m. – 6:00 p.m.

Silent Auction – Cheyenne

9:00 a.m. – 9:30 a.m.

Plenary Session – Jefferson/Madison

Mr. Kevin Harvey – ASMR President-Elect and Conference Chair – Welcome to Big Sky

Dr. Gwendelyn Geidel – ASMR President – President's Welcome

Dr. Robert Darmody – ASMR Executive Secretary – Welcome & Announcements

9:30 a.m. – 10:00 a.m.

Keynote Speaker – Jefferson/Madison

**Gwendelyn Geidel PhD, JD, Research Professor; School of the Earth, Ocean and Environment,
University of South Carolina: Grid Security, Coal and Sustainable Reclamation**

10:00 a.m. – 10:30 a.m.

Break – Lower Atrium

10:30 a.m. – 12:00 noon

Keynote Speakers – Jefferson/Madison

Dr. William Inskeep, Thermal Biology Institute, Montana State University:

Earth's Natural Laboratories: What Can Reclamation Science Learn From Geothermal Systems in Yellowstone?

**Autumn Coleman, Abandoned Mine Land Program Manager, Montana Department of Environmental Quality:
Ecological Recovery of Yellowstone's Soda Butte Creek**

12:00 noon – 2:15 p.m.

AWARDS LUNCHEON – Huntley Dining Room

TUESDAY, JUNE 4, TECHNICAL SESSIONS

	WATER QUALITY CHALLENGES SESSION 1A ROOM Moderator - Dan Guy	STREAM RESTORATION SESSION 1B ROOM Moderator - Sara Klopff	ALTERNATIVE APPROACHES FOR REMEDIATING LEGACY MINE SITES SESSION 1C ROOM Moderator - Amy Blyth
2:30 p.m. - 3:00 p.m.	Streamflow Variability and Treatment System Effectiveness in a Changing Climate by N.A. Kruse Daniels, Z. Matthews	Recovery of Mining-damaged Stream Ecosystems: How Recovered is Recovered Enough? by Christopher Mebane, Rob Eakins, Brian Fraser, William Adams	Trout Unlimited - A Non Profit Approach to Mine Reclamation by Rob Roberts
3:00 p.m. - 3:30 p.m.	An Evaluation of Biological and Chemical Improvements at Various Spatial Scales in the West Branch Susquehanna River Watershed, Pennsylvania by S. Rummel, A. Wolfe, R. Kester, K. Lavelle, A. Lutz	Stream Restoration Techniques to Mitigate the Yellowstone Hydroelectric Decommissioning Project in Duchesne County, Utah by Crystal Young, L. Forbes	Golden Sunlight's Outside Ore Program by Steve Lloyd
3:30 P.M. - 4:00 P.M. - BREAK - GALLATIN - EXHIBIT HALL			
	UAV MONITORING AND MODELING TECHNOLOGIES SESSION 2A ROOM Moderator - Natalie Kruse Daniels	MINE WASTE COVERS AND SOURCE CONTROL TECHNIQUES SESSION 2B ROOM Moderator - Nicholas Shepherd	INTERNATIONAL RECLAMATION CASE STUDIES SESSION 2C ROOM Moderator - Zepei Tang
4:00 p.m. - 4:30 p.m.	Prediction of Optical and Non-Optical Water Quality Parameters in Oligotrophic and Eutrophic Systems Using a Small Unmanned Aerial System by Juan Arango* & R. Nairn	Performance of Conventional and Ecological Engineering Covers for Uranium Mill Tailings by W. Waugh, et al.	Reclamation of Sulfur Borehole Mine Sites and Environment Consequences of S Extraction (Poland) by M. Pietrzykowski and J. Likus-Cie-lik

4:30 p.m. - 5:00 p.m.	Evaluating the Role of Optical Depth on Spectral Reflectance Data from sUAS-Mounted Multispectral Sensors and... by B. Holzbauer-Schweitzer*, R. Nairn	Application of Coupled Surface and Subsurface Hydrological Modeling in Hydrology-Based Reclamation Technique of Mine Lands by Z. Fred Zhang, T. Tesfa, C. Liao	Spatial Distribution of Reconstructed Soil Volume Density in Loess Open-pit Mining Area Based on IDW Interpolation (China) by Shu-fei Wang, Y. Cao, Z. Bai
5:00 p.m. - 5:30p.m.	Applying UAV Imagery to Minimize Impacts to Surface Water from Oil and Gas Development by M. Strager, P. Kinder, S. Grushecky, J. Strager	Biological Microencapsulation Coating of Waste Ores and Tailings by Loran Brooks*, E. Lauchnor, C. Gammons, R. Nagisetty, D. Proudfoot	Evaluation of Restoration Achievement for the Release of Upland Grasslands from Statutory Aftercare Provisions at a Surface Mine in South Wales, UK. by Neil Humphries, R. Thompson
5:30 p.m. - 6:00 p.m.	Coal Mining Subsidence and Its Effects on Agricultural Land-A UAV Based Investigation in Eastern China by W. Xiao, Z. Hu, J. Chen	Geotechnical and Soils TD Business Meeting	International Tailings TD Business Meeting

6:30 P.M. - 8:00 P.M. SOCIAL EVENT: BIG SKY PAVILION OR HUNTLEY DINING ROOM (DEPENDING ON WEATHER)

Join us for food, beverages, live music, and networking at the social event, which will take place at the Big Sky Pavilion (weather dependent) at the base of some of the biggest skiing in North America.

WATER • SOIL • AIR

YOUR ENVIRONMENTAL MONITORING PARTNER



www.intermountainlabs.com

(307) 672-8945

Wednesday, June 5, 2019

- 6:30 a.m. – 7:30 a.m.Haulin' ASMR - meet in the Lobby
- 7:00 a.m. – 8:00 a.m.Breakfast – Huntley Dining Room
- 7:45 a.m. – 8:30 a.m.JASMR Editorial Meeting, TD Chair Meetings (TBA)
- 8:00 a.m. – 6:00 p.m.Silent Auction – Cheyenne Room
- 7:30 a.m. – 5:00 p.m.Registration – Firestone Lounge
- 11:00 a.m. – 4:00 p.m.Cultural Event #1

Shopping and Lunch in Historic Downtown Bozeman – This event, aimed at spouses/guests, will include chartered transportation from Big Sky Resort to historic downtown Bozeman. Explore the charming Western mountain town full of shops, cafes, restaurants, art, and music. Lunch is on your own.

WEDNESDAY, JUNE 5, TECHNICAL SESSIONS				
	ECOLOGICAL ENGINEERING APPROACHES TO TREATING WATER SESSION 3A ROOM Moderator - Travis Tasker	RECLAMATION OF OIL AND GAS RELATED DISTURBANCES SESSION 3B ROOM Moderator - Micheal Curran	INTERNATIONAL RECLAMATION CASE STUDIES SESSION 3C ROOM Moderator - Jennifer Franklin	GIS TECHNOLOGIES APPLIED TO RECLAMATION SESSION 3D ROOM Moderator - Kari Lagan
8:30 a.m. - 9:00 a.m.	Removal of Gaseous and Aqueous Biogenic Sulfide from Vertical Flow Bioreactor Effluent via Solar-Powered Blowers by R. Nairn, T. Wall	Restoration of Native Grasslands to Provide Monarch Habitat on the Enbridge Valley Crossing Pipeline in the South Texas Sand Sheet by T. Falk, K. Pawelek, F. Smith, D. Hoetzel	Land Reclamation Planning for Underground Coal Mining Areas and Case Studies in China by Zhenqi Hu	Geocoding ASMR Proceedings to Preserve and Easily Access Reclamation Research by A. Rovder*, S Wolfe, K. Lagan, L. Currie, W. Strosnider, P. Smyntek
9:00 a.m. - 9:30 a.m.	A Permeable Reactive Barrier (PRB) for the Immobilization of SE in Seep Water and Shallow GW at a Phosphate Mine an Southern ID: Results of Bench Scale Testing by William J Walker, et al.	Soil Reclamation after a Bakken Crude Pipeline Release: A Summary of Research Results by T. DeSutter, P. O'Brien, S. Croat, C. Gasch, F. Casey, A. Wick	Mine Landforms in Australia; Evolution and Benchmarking by Harley Lacy	Development of a GIS Tool for Estimating Post-Mining Water Levels in Underground Coal Mines of Ohio by R. Steinberg*, et al.

9:30 a.m. - 10:00 a.m.	The Influence of Bacteria on Passive Remediation Systems by Michelle Valkanas*, N. Trun	Subsurface Mine Void and Karst Imaging Using 3D Seismic Methods; Adapting Oil and Gas Seismic Advancements to Develop 3D Integrated Site Characterization Models by Jamey Turner	Biodiversity Development and Soil C Sequestration Efficiency of Certain ... Woody Species Planted on Coal Mine Habitats... , India: A Case Study by A. Singh, R. Kaur	Evaluating Herbicide Treatment Effectiveness Using GPS Treatment Data & ArcGIS tools: 2016-2018 by W. Erickson, A. Matthews
10:00 A.M. - 10:30 A.M. BREAK - GALLATIN - EXHIBIT HALL				
	ECOLOGICAL ENGINEERING APPROACHES TO TREATING WATER SESSION 4A ROOM Moderator - Nancy Trun	RESTORATION OF NATIVE GRASS COMMUNITIES SESSION 4B ROOM Moderator - Brenda Schladweiler	THE FUTURE OF COAL SESSION 4C ROOM Moderator - Louis McDonald	LOOKING AT RECLAMATION OVER THE LONG TERM SESSION 4D ROOM Moderator - Robert Hedin
10:30 a.m. - 11:00 a.m.	Temperature Effects on Selenium (SE) Cycling in Simulated Constructed Wetland Microcosms by Michael P. Natrass *, J. I. Morrison, and B. Baldwin	Native Warm-Season Grasses That Germinate on Command by Brian Baldwin, J. Morrison, J. B. Rushing	New Generation Coal Fired Power Plants: Innovation at the Dry Fork Station, Gillette Wyoming by B. Schladweiler, D. Hugo	Acid Mine Drainage Takes Its Time to Burn Out – a case for Interceding with Spot Treatments? by Michele Coleman, K. Butler, D. Loomer
11:00 a.m. - 11:30 a.m.	Modeling the Effects of Mass Transfer Limitations in Limestone-Based Passive Treatment Systems by Joel Bandstra, W. Strosnider	Establishing Native Grassland Plants on Mineral Sands Mines by Sara Klopff, L. Daniels, Z. Orndorff	Analysis of Coal Production, Severance Tax Revenues, and Water Infrastructure Relationships in West Virginia by Hannah Patton*, E. Sarver, L-A. Krometis	Financial Assurance for Long-Term Reclamation by D. Sutton, D. Herrera
11:30 a.m. - 12:00 p.m.	Retrofit Options for an Aging Passive Treatment System by J. Gaughan*, et al.	Assessment of Native Warm Season Grasses for Post-mining Reclamation by Jesse Morrison, M. Parker, N.R. McGrew, B. Baldwin	SMCRA Fee Collection Reauthorization: Ensuring the Future of Abandoned Coal Mine Reclamation by A. Wolfe, A. McAllister	Effects of Grazing Management and Climate Change on Extent of Semiarid Riparian Meadows by B. Fulcher*, J.B. Norton, M. Kasten
12:00 P.M. - 1:30 P.M. LUNCH- SPEAKER: DR. TIMOTHY MCDERMOTT - HUNTLEY DINING ROOM				

	ACID MINE DRAINAGE, HYDROLOGY AND TREATMENT SESSION 5A ROOM Moderator - Gwendelyn Geidel	RECLAMATION: SOIL SCIENCE SESSION 5B ROOM Moderator - Brad Pinno	ALTERNATIVE APPROACHES FOR REMIEDIATING LEGACY MINE SITES SESSION 5C ROOM Moderator - John Stefanko	MINE FIRES AND EMERGENCY RESPONSES SESSION 5D ROOM Moderator - Ryan Mahony
1:30 p.m. - 2:00 p.m.	Developing a Long-Term Hydrologic Monitoring Plan for Surface Coal Mines by K.D. Krogstad	Impacts of Soil Stockpiling on Seed Viability and Vegetation Communities by Jennifer Buss*, B. Pinno	Reclamation of Abandoned Mine Lands in Conjunction with Economic and Community Development and Reuse Goals - Implementation of the 2016 AML Pilot Program in PA by Dean Baker	Phillips Mine Fire - A Containment & Extinguishment Design Plan by C.A. Neely, T. Danehy, R. Mahony, B. Page, M. Dunn, D. Guy, D. Baker, R. Rummel
2:00 p.m. - 2:30 p.m.	50 Years of AMD Pollution and Remediation at the Anna S Mine, Tioga County, PA by Robert Hedin	Effect of Topsoil Stockpiling and Organic Amendments on Soil Properties and Tree Growth during Gold Mine Reclamation in Ghana by Paul K. Nsiah*, W.Schaaf	Non-Traditional Reclamation of Abandoned Mine Lands to Support Economic Revitalization and Community Development - Implementation of the 2017 AML Pilot Program in PA by Eric Cavazza	Unconventional Seismic Studies at a Coal Mine Fire Before and After Reclamation Efforts by L. Steel, D. O'Connell, J. Nuttall, T. Tafi, J. Turner
2:30 p.m. - 3:00 p.m.	Effects of Precipitation Patterns on Sediment, Nutrient, and Biofilm Dynamics in an Acid Mine Drainage Stream by J. Brancho*, N. Kruse Daniels, M.L. Vis	Soil Water Chemistry of Reforested Mine Site in West Virginia by A. Hass, J. Skousen, R. Cantrell	Implementation of the 2018 AML Pilot Program in Pennsylvania - AML Reclamation as an Economic Catalyst by B.J. Bradley	Emergency Response to Historic Pit Mine Washout Leads to Improved Resiliency, Functionality and Aesthetics by P. Kero, J. Olson, L. Johnson
3:00 p.m. - 3:30 p.m. BREAK - GALLATIN - EXHIBIT HALL				
	ACID MINE DRAINAGE, HYDROLOGY AND TREATMENT SESSION 6A ROOM Moderator - Kennet Bertelsen	RECLAMATION OF FOREST COMMUNITIES SESSION 6B ROOM Moderator - Amir Hass	RECLAMATION CASE STUDIES SESSION 6C ROOM Moderator - Meghan Blair	SKILL SET NEEDS FOR NATURAL RESOURCE MANAGERS SESSION 6D ROOM Moderator - Abbey Wick

3:30 p.m. - 4:00 p.m.	Preliminarily Assessing Ferrate (Fe(VI)) as an Acid Mine Drainage Treatment Option by J.E. Goodwill, J. LaBar, D. Slovikosky, W. Strosnider	Early Tree Growth in Brown and Gray Mine Soils Compared to Growth in Native Forest Soils by J. Skousen, K. Dallair	Life Cycle of a Successful Reclamation Program by R. Spang	Helping Students of Natural Resource Management Develop a Land Ethic by Pete Stahl
4:00 p.m. - 4:30 p.m.	The Use of Advanced Membrane Filtration as an AMD Remediation Method by M.J. McCluskey	Development of Mine Soils in a Chronosequence of FRA-Reclaimed Sites in Eastern Kentucky by K. Sena, K. Yeager, J. Lhotka, C. Barton	Atlantic City Iron Mine, Wyoming Case Study Post-Reclamation 17-Year Status by Brenda Schladweiler and James Gusek	University of Wyoming Extension Reclamation Workshops by Jay Norton
4:30 p.m. - 5:00 p.m.	Abatement of AMD at Abandoned Coal Mines in North Central Missouri: An Overview by Paul Behum, D. Wedemeyer, M. Mueller	Tree Growth and Regeneration on Reclaimed Oil Sands Mine Sites in Northern Alberta by Brad Pinno	Reclamation Case Study: Road Decommissioning in Indiana and Pennsylvania Gulches, White River National Forest by Tony Matthews, J. Feedback	Succession Planning for 2025 - Do You Really Know the Next Generation of Reclamation Researchers? by S. Bellgard, S. Williams
5:00 p.m. - 5:30 p.m.	Source Control or How to Eliminate Acidophiles and Influence Water Quality by Paul Eger, J. Gusek, L. Josselyn, T. Clark	A Recently Translocated Woodland Plant-Soil Ecosystem: Some Early Outcomes and Lessons Learnt (UK) by Neil Humphries	Reclamation of the McLaren Tailings: The Rest of the Story by M. Bennett, T. Henderson, A. Coleman	Skill Set Needs for Effective Natural Resource Managers by Steve Williams, S. Bellgard
5:30 p.m. - 6:00 p.m.	Water Management TD Business Meeting	Using the Forestry Reclamation Approach in the Western Gulf Region: Impacts on Pinus taeda Seedling Growth and Survival by Cassie Phillips*, J. Stovall, H. Williams, K. Farrish	French Gulch Restoration Case Study (MT) by Matt Barnes	Land Use TD Business Meeting

6:00 P.M. - 7:00 P.M. POSTER SESSION AND NETWORKING EVENT - LOWER ATRIUM

Poster presentations will be on display, with authors present after the technical sessions finish.

7:00 p.m. - 8:00 p.m. Film Festival - Amphitheater

ASMR Film Festival: Join us for the First Annual ASMR Film Festival in Big Sky Resort's Amphitheater. We will bring reclamation related topics to you in a whole new way with short (~5-15 minute) films highlighting exciting and intriguing reclamation projects. Awards will be presented to the best in show, and libations and classic movie theater snacks will be provided.

Thursday, June 6, 2019

6:30 a.m. – 7:30 a.m.Haulin' ASMR - Meet in lobby

7:00 a.m. – 8:00 a.m.Breakfast – Huntley Dining Room

7:30 a.m. – 5:00 p.m.Registration - Firestone Lounge

8:00 a.m. – 11:00 a.m.Silent Auction (winners announced at lunch)

11:00 a.m. – 4:00 p.m.Cultural Event #2

Grizzly and Wolf Discovery Center – While you are visiting us here in the Rocky Mountains come meet some of our fiercest wildlife up close and personal! The Grizzly and Wolf Discovery Center in West Yellowstone is a wildlife park and educational facility that houses 7 grizzly bears, 5 wolves, and several birds of prey. This event includes chartered transportation from Big Sky Resort to the Discovery Center and admission.

THURSDAY, JUNE 6, TECHNICAL SESSIONS

	MINE WASTE CHARACTERIZATION AND REMEDIATION SESSION 7A ROOM Moderator - Craig Kreman	RECLAMATION OF FOREST COMMUNITIES SESSION 7B ROOM Moderator - Hannah Angel	WILDLIFE HABITAT RESTORATION SESSION 7C ROOM Moderator - Summer King	GEOMORPHIC RECLAMATION STRATEGIES SESSION 7D ROOM Moderator - Mark Donner
8:30 a.m. - 9:00 a.m.	Fred Burr Creek Historic Tailings Characterization by Ed Spotts, C. Lucy	Field-testing Transgenic American Chestnuts on Reclaimed Coal Mines by Sara Klopff and J. Holiday	Insect Response to Reclaimed Natural Gas Well Pads in Semi-Arid Wyoming by Michael Curran	Modeling Water Balance of Geomorphic Evapotranspiration Covers for Reclamation of Mine Land by Z. Fred Zhang, Y.Fang, N. Bugosh, T. Tesfa
9:00 a.m. - 9:30 a.m.	Development of a Reliable Field Testing Protocol for Acid-Forming Materials by Lee Daniels, B.T Thomas, E. Shatnawi, E. Farouz.	Tree Response to Soil Treatments on Quarry Overburden by Jennifer Franklin, D. Buckley	Remediation of Tar Creek: Shifts in Bird Community Composition over Time by Christine Rega-Brodsky, S. King, K. Mallatt	Finite Element Water Balance Modeling in a Coal Refuse Pile Cap and Cover Reclamation by I.L. Santos*, L. Cyphers, J. Quaranta, L. Hopkinson
9:30 a.m. - 10:00 a.m.	Techniques to Refine Initial Amendment Selection for Dispersed Mine Tailings Reclamation by A. Harley, J. Willis	Soil Characterization and Identification of Native Hyper- Accumulating Plant Species for Phytoremediation (Nigeria) by A.A. Adesipo*, O.O. Awotoye, A.T. Salami, and D.J. Oyedele	Bird Use in a Restored Riparian Corridor, Southwest Montana by R. Proddgers, N. Kohler	Lessons about Geomorphic Reclamation from Sediment Yield Quantification and Erosion Modeling Studies by Nicholas Bugosh
10:00 a.m. - 10:30 a.m. BREAK - GALLATIN - EXHIBIT HALL				

	PASSIVE TREATMENT OF MINE WATER SESSION 8A ROOM Moderator - Cliff Denholm	RECLAMATION STRATEGIES AND TECHNIQUES SESSION 8B ROOM Moderator - Jennifer Franklin	DEEP MINE CLOSURE AND RECLAMATION SESSION 8C ROOM Moderator - Seth Cude	GEOMORPHIC RECLAMATION STRATEGIES SESSION 8D ROOM Moderator - Mark Donner
10:30 a.m. - 11:00 a.m.	Case Study: Baird Wetland Mitigation 3rd Year Update by S.L. Busler, et al.	Cost-effective Strategies for the Restoration of Drastically Disturbed Sites by D.F. Polster	Abatement of Abandoned Coal Mine Hazards Beneath a Rural Road by C. Stock, J. Nuttall, M. Bautz	An Analysis of Cost Factors in Geomorphic Mine Reclamation by Harold Hutson
11:00 a.m. - 11:30 a.m.	Performance Evaluation of the North Fork Montour Run Passive Treatment System by T. Danehy, R. Beam, R. Mahony, C. Neely, C. Denholm, D. Guy	Successful Revegetation Techniques for Legacy and Active Mine Sites by Brent Hardy	Challenges to Mine Back- filling in Poor Rock For- mation with High Artesian Mine Water Pressure by M. Gamal, D. Hibbard, M. Bautz	A Cost Effectiveness Analysis of Geomorphic Reclamation by Roger Coupal, K. Hufford, K. Fleisher
11:30 a.m. - 12:00 p.m.	Land Application Disposal System Design for Bio- chemical Reactor Treated Effluent by N.R. Anton, D.T. Shanight, C.S. Storrar, M.J. Fischer, E.M. Janoviak, and B. Lala	Industrial Hemp as a Potential Crop for Reclaiming Disturbed and Contaminated Soils by Louis McDonald	Geochemistry of Improved Groundwater Quality Resulting from Adit Plug- ging, Glengarry Mine, New World District, Cooke City MT USA by Lisa Kirk, L. Bozeman, A. Kirk, M. Marks	Assessing Physiographic Controls on Snow Accumulation and Vegetation Cover in Traditional and Geomorphic Mineland Reclamation Using Airborne Lidar and High- Resolution Satellite Data by E.A. Gage, K. Fleisher, K. Hufford
12:00 P.M. - 1:30 P.M. - LUNCH AND STUDENT AWARDS - HUNTLEY DINING ROOM				

Restoring the *native* balance



ernstseed.com
sales@ernstseed.com
800-873-3321

ERNST SEEDS

POLLINATOR APPROVED

Facebook, LinkedIn, Twitter, Instagram, YouTube icons

DEL Communications Inc.
 SUITE 300, 6 ROSLYN ROAD, WINNIPEG, MANITOBA, CANADA
www.delcommunications.com

**DEL Communications & You,
the key to publishing success.**

*We offer outstanding
personal service and quality in the areas of...*

- Creative Design • Advertising Sales
- Trade Publications • Video Production & Editing
- Qualified Sales & Editorial Team

	REGULATORY ISSUES RELATED TO RECLAMATION SESSION 9A ROOM Moderator - Neil Humphries	SAGE GROUSE HABITAT RESTORATION SESSION 9B ROOM Moderator - Pete Stahl	NOVEL RECLAMATION STRATEGIES AND TECHNIQUES SESSION 9C ROOM Moderator - Michele Coleman	MINE RECLAMATION HYDROLOGY SESSION 9D ROOM Moderator - Dustin Wasley
1:30 p.m. - 2:00 p.m.	Navigating Regulation to Promote Reclamation by J. Staldine, D Yde	Restoration of Wyoming Big Sagebrush to Intact Rangelands within a Greater Sage-grouse Core Population Area, Converse County, Wyoming by Jana White	Innovative Methods for Cost Effective Rehabilitation of Challenging Mining and Energy Sites by M. Theisen, A. Jung	Restoring the Hydrology - Key to Successful Reclamation at the Riley Pass Uranium Mine by Mary Beth Marks, M. Hatten, M. Donner
2:00 p.m. - 2:30 p.m.	A River Runs Through It: Designing and Permitting the Stibnite Gold Project by Dale Kerner	Seeding the Future: Wyoming AML Native Plants Project by Gina Clingerman and D. Newton	Evaluation of Effectiveness and Cost-Benefits of Woolen Reclamation Products by R. Ament, M. Pokorny, S. Jennings, E. Cuehlo	Mine Water Reclamation in Appalachia Facilitated by Student Support and Technical Assistance from Academia by Travis Tasker, J. Eckenrode, W. Strosnider
2:30 p.m. - 3:00 p.m.	Potential Effects of the Proposed New Definition of Waters of the U.S. in Relation to Mining by R. T. Franzman	Reestablishment of Wyoming Big Sagebrush in Eastern Wyoming for Sage Grouse Habitat Restoration by Pete Stahl	Usibelli Coal Mine (AK): Concurrent Reclamation is Yielding Success! by R. C. Sivils	Day Loma Pit - Water Filled Pit Backfill Method by Harold Hutson
3:00 p.m. - 3:30 p.m.	How Do We Know That the Land Has Been Reclaimed - Regulatory Approach for a Surface Coal Mine (WY, USA) by A. K. Waitkus	Seed Enhancement Technologies for Native Plant Restoration on Reclaimed Mine Land by M. Eshleman , C. Riginos	Cast Blasting as a Cost Saving Reclamation Tool: A Case Study by S. M. Cude	Laboratory Testing to Optimize Retention Time in Auto-Flushing Limestone Beds by J. LaBar*, C Neely, C. Denholm, T. Danehy, W. Strosnider
3:30 p.m. - 4:00 p.m.	Ecology TD Business Meeting	Forestry and Wildlife TD Business Meeting		

* indicates Student presentation

NEC WRAP UP MEETING 4:00 PM Shoshone Board Room

5:30 P.M. - 10:00 P.M. EARLY CAREER PROFESSIONAL EVENT: EVERETTS 8800.

This event will bring together early career professionals (<10 years into their careers) and experienced professionals who will provide valuable mentorship. Attendees will board the brand-new ski access tram to travel up the mountain to Everett's 8800, named for its elevation above sea level. The event will include food, beverages, and fun ways for early career professionals and mentors to interact.

Friday, June 7, 2019

Breakfast on Your Own

8:00 a.m. – 5:00 p.m. **Professional Tour #2:** Yellowstone National Park. Discover the magic of America's first national park in a bus tour that will visit all the classic tourist locations while also highlighting the effect of forest fires on the park and restoration efforts. You will see thermal features, wildlife, scenic views, and more in this guided tour of the park. This event includes transportation to and from Big Sky Resort and lunch.



POSTER SESSION - LOWER ATRIUM

WEDNESDAY, JUNE 5 6:00 PM - 7:00 PM

1	Abatement of AMD at the Germantown AML site in West Central Missouri by Paul Behum
2	Prediction of Sludge Generation in Mine Drainage Treatment Plan with Lime Dosing by Young-Wook Cheong
3	Scale Composition and an Automatic Cleaning Device for pH Electrode used in Mine Drainage Treatment by Gil-Jae Yim, et. al
4	The Role of Solar-Powered Float-Mix Aerators on Iron Oxidation Rates in Passive Treatment Oxidation Ponds by Dayton Dorman*
5	One Steppe: Efforts from Multiple Stakeholders in Wyoming to Streamline Disturbance, Reclamation, and Conservation Efforts by M. Curran*, N. Graf, T. Wychoff, P. Stahl
6	Flow Visualization Utilizing Airborne Thermography by John Gaughan*
7	Sulfate Removal by Selected Organic Substrates in Continuous Flow-Through Columns by J.D. Ingendorf*
8	Post-Reclamation Long-Term Monitoring and Care at the Shullsburg Mine in the Upper Mississippi Valley Lead-Zinc District by Sage Tanck*, John Zurawski*, Yari Johnson*
9	Optimization of Drainable Limestone Beds for Treatment of Acid Mine Drainage by Kari Lagan*
10	Super Absorbent Polymer effects on Soil Physical Properties as Functions of Application Rate and Soil Texture by Megan Ostrand*
11	Geocoding American Society of Mining and Reclamation Proceedings to Preserve and Easily Access Reclamation Research by Ashley Rovder*
12	Locating and Characterizing Mine Drainage Sources in a Topographically Challenging Location at the Tar Creek Superfund Site, Oklahoma by Nick Shepherd*
13	Modeling the Effects of Improved Stormwater Management at a Large Open-Pit Mine by Staci Shoemaker*
14	Treating Acid Mine Drainage with Ferrate (Fe VI): A Preliminary Assessment by Debbie Slovikosky*
15	Bench Scale Assessment of Acid Mine Drainage Addition to Secondary Municipal Wastewater Treatment Processes for Co-treatment by Charles Spellman*
16	The Role of Mixing on Nutrient and Metal Interactions at the Sediment-Water Interface by Zepei Tang*
17	Reclamation Planning in the Intermountain West by Brad Teson
18	Vegetation Community Dynamics on Soil Islands in Oil Sands Reclamation by Kaitlyn Trepanier*
19	Succession After Reclamation: Identifying and Assessing Ecological Indicators of Forest Recovery on Reclaimed Oil and Natural Gas Well Pads by Randi Lupardus, A. McIntosh, A. Janz, D. Farr
20	The Ecological and Economic Efficacy of Hillslope Erosion Control Features in Forest Lands after Severe Wildfire by Patrick McGunagle*
	* denotes Student

FILM FESTIVAL - LOWER ATRIUM

WEDNESDAY, JUNE 5 7:00 PM - 8:00 PM

Join us for the First Annual ASMR Film Festival in Big Sky Resort's Amphitheater. We will bring reclamation related topics to you in a whole new way with short (~5-15 minute) films highlighting exciting and intriguing reclamation projects. Awards will be presented to the best in show, and libations and classic movie theater snacks will be provided.

1	Reclamation of the Graves Mountain Mine Site by Gwendelyn Geidel
2	A Reclamation in the Heartland: Cleaning up the Tar Creek Superfund Site by Brandon Holzbauer-Schweitzer*
3	Superfund Remediation at Tar Creek by Summer King
4	Industrial and Metallic Minerals Mine Reclamation in Missouri by Mariah Morrison
5	Rewinding A River by Paul Parson
6	Google Earth Tour of Reclamation in the Wamsutter Natural Gas Field by Brad Teson
7	Salinity Management Strategies, Parts 1 and 3 by Abbey Wick

* denotes Student

For more information and to register, visit our conference website, <https://www.asmr.us/Meetings/2019-Annual-Meeting> or follow ASMR on LinkedIn and Facebook.

We hope to see you in Big Sky!

granite SEED and erosion control

The largest selection and highest quality native seed in the western United States, custom blended to your project's unique specifications.

Reclamation presents real challenges.
Granite Seed is ready to help.

Utah 801.768.4422
Colorado 720.496.0600
Arizona 480.355.1695
graniteseed.com

Examining the use of SWAT Modeling for Assessment of Hydrologic Benefits Resulting from Abandoned Mine Land Reclamation

By Charles D. Spellman Jr.; Jon C. Vander Werff;
and Soni Pradhanang, University of Rhode Island, Kingston, RI

Introduction

Acid Mine Drainage (AMD) is one of the most prevalent water pollution issues in Pennsylvania (U.S. Geological Survey 2010). In addition to impaired waterways, abandoned mine lands have left the surrounding landscape scarred. The Pennsylvania Department of Environmental Protection (DEP) established the Bureau of Abandoned Mine Reclamation in 1983 after the federal government passed the Surface Mining Control and Reclamation Act of 1977 which recognized the environmental and aesthetic need for mine land reclamation. Reclaiming land after mining activities has been shown to be a crucial part of preventing, or resolving, acid mine drainage and a variety of other environmental problems. Proper land reclamation is a large undertaking but is essential to proper environmental management (Sheoran et al. 2010). It has even been proven that ecological based reclamation can enable mined land to be used for agriculture, which could bring future economic benefit (Miao and Marrs 2000).

In addition to the ecologic and environmental benefits of mine land reclamation, it can be hypothesized that there are also benefits to an impaired watershed hydrology by improving land cover. AMD pollution impact has frequently been simulated with the USGS program PHREEQC as it provides accurate assessment of the hydro- and geochemical interactions that occur in waterways (Sarmineto et

al. 2008; Madzivire et al. 2011). However, PHREEQC does not analyze the AMD impact on the greater watershed like the Soil and Water Assessment Tool (SWAT). SWAT, an ArcMap tool developed by USDA Agricultural Research Service and Texas A&M University, expands original “field-scale” models to a large river basin analysis system (Arnold and Fohrer 2005). The more in-depth model includes components such as, weather, hydrology, erosion/sedimentation, plant growth, nutrients, pesticides, agriculture management, stream routing, pond/reservoir routing, bacteria transport routines, urban routines, Green and Ampt infiltration equations, solar radiation, relative humidity, wind speed and potential evapotranspiration. SWAT is a physically-based, semi-distributed conceptual model that runs on a continuous time step (Arnold et al. 1998). These parameters input into the models such as topographic, soil, land use and climate together create a very detailed representation of the watershed, in which predictions can be made to show management decisions for different watershed attributes. There are very few studies that have directly linked AMD impacts on waterways through model applications. Galvan et al. (2009) was one of the first to examine AMD-impacted waterways with the assistance of SWAT, which was able to provide necessary historical flow data to calculate metal loads. SWAT was later used to analyze the impact of AMD on an impaired watershed (Galvan et al. 2016), but there is little additional research using SWAT to show potential benefits of land

reclamation efforts on small watershed hydrology. This communication aimed to examine SWAT's ability as a tool to model pieces of abandoned mine land before and after reclamation.

Methods

Area of Interest

The Brubaker Run watershed, located in Cambria County in western Pennsylvania and a home to a large parcel of abandoned mine land impaired by AMD (Figure 1), was used as a case study site. We applied SWAT model to evaluate pre- and post-AMD water quality changes.

Brubaker Run is the largest source of AMD entered into the southern half



Figure 1. Landscape view of the acid mine drainage site in Brubaker Run Watershed, PA (near 40° 37' 17.4036" N, 78° 30' 6.3324" W)

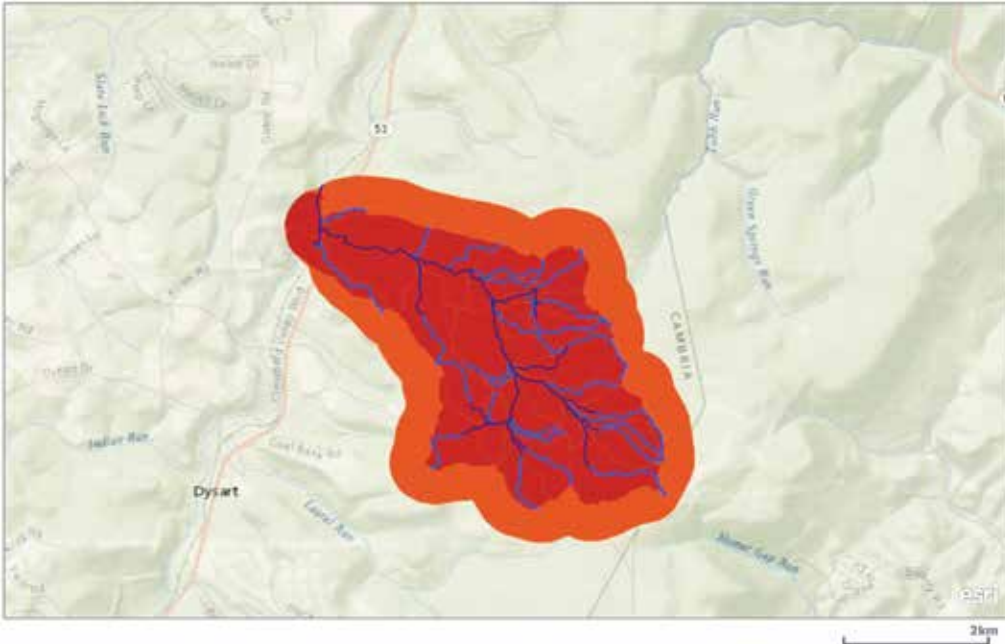


Figure 2. Watershed delineation showing major waterways (dark blue), smaller tributaries (light blue), main watershed area (dark red) and modeling buffer (orange). Produced with ESRI ArcMap.

of Clearfield Creek, a tributary to the West Branch of the Susquehanna River (Clearfield Creek Watershed Association, 2015). The effects of the acid entering the ecosystem can be noticed for about twelve miles below the confluence of Brubaker Run and Clearfield Creek. The effects of the acid input from Brubaker Run render that stretch of river mostly dead, which makes it the highest priority for environmental remediation (Clearfield Creek Watershed Association, 2015).

Model Set Up

Hydrologic modeling analysis was completed using the Soil and Water Assessment Tool (SWAT) plugin for ESRI ArcMap (ESRI, 1234 REF needed for ArcGIS) The SWAT modeling tool is intended to “predict the effect of management decisions on water, sediment, nutrient and pesticide yields with reasonable accuracy on large, ungauged river basins” (Neistch et al. 2012). After initial model set up, the target watershed’s digital elevation model (DEM) was added from USGS StreamStats to ArcMap via the SWAT watershed delineator (Figure 2).

In order for SWAT to analyze each of the hydrologic response units (HRU) defined within the watershed, NRCS soil data and PASDA land cover spatial data was

added to the model. A soil map for the watershed was obtained by extracting soil data from the USDA NRCS Web Soil Survey by importing the watershed DEM as the area of interest. National Land Cover Database’s 2011 Multi-Resolution Land Characteristic land use data was obtained from the Pennsylvania Spatial Data Access website. Weather data, in the form of precipitation, relative humidity, solar radiation, wind speed and temperature, was obtained by requesting data from the closest weather stations to the site according to the SWAT global weather database. The simulation was run for a 20-year period (1994-2014).

Model Calibration

To ensure relative accuracy of the model, a three-year time period of the model output was calibrated using SWAT calibration/uncertainty program (SWAT-CUP) (Arnold et al. 2012). Since the stream in question is ungauged, the USGS suggested method for ungauged stream flow was followed using flow data from the closest USGS gage that contained the watershed in question (#01541500 Clearfield Creek/Dimeling, PA). Several model parameters were varied in a 100-run simulation to determine the best Nash-Sutcliffe efficiency between the model and the measured data.

Runoff Curve Number Adjustment

Soil class for the information for runoff curve number calculations was determined from the Web Soil Survey and used to determine which class made up the largest percentage of the watershed. The predominant soil class is NRCS classes C (> 60 percent) and A (> 30 percent), with B and D making up less than 10 percent of watersheds soil class. Due to predominance, curve numbers from class C were assumed in all calculations. The runoff curve number for the watershed in its current state is approximately 77. To simulate watershed land reclamation, model curve number was manually adjusted by assuming all poor-quality land use (such as the barren arid soil, and hay) were to be changed to a higher quality land use such as fair to good wooded area. The percentages from the removed land use types were summed and added to a single improved land use type. The runoff curve number adjustment, calculated manually according to NRCS tables, is compiled in Table 1.

Land Use	Original Area %	New Area %	Soil Class	New CN
Residential -Low Density	3.43	3.43	C	79
Residential -Medium Density	0.08	0	C	83
Residential -High Density	0.03	0	C	90
Industrial	0.02	0	C	91
Southwestern US (Arid) Range	8.84	0	C	86
Forest-Deciduous	62.18	80.87	C	74
Forest-Evergreen	4.9	4.9	C	74
Forest-Mixed	9.19	9.19	C	74
Range-Grasses	0.76	0	C	75
Hay	8.96	0	C	81
Agricultural Land-Row Crops	1.57	1.57	C	85
Wetlands-Non-Forested	0.04	0.04	C	100
			CN:	74

Results

Model results were viewed with the output analysis software SWAT-Check, which also allowed for identification of potential limitations of the model due to input errors. The results from the simulations showed slight, but noticeable, improvements in watershed hydrology with simulated land reclamation. Over the two 20-year simulations, SWAT determined that the average daily discharge (in CFS) between the reclaimed and impaired runs essentially remained constant at 0.224 and 0.225, respectively. Although the average flow remains constant, reclaimed land would have a far lower metals loading downstream. The twenty-year peak flow value decreased slightly from 6.8 CFS to 6.4 CFS, which may not be significantly different. However, the total number of high discharge events (CFS > 1.0, 4 times the average) did decrease 12 percent. The fewer high discharge events are worth noting and could offer significant improvement in greater watershed quality as it would lead to decreased

amounts of noticeable, high impact events on Clearfield Creek.

The reclaimed land simulation also has a smaller standard deviation and the median flow value was closer to the average value, which is significant to note. The larger clustering of data points around the average suggests there is less variation in flow. These noted improvements occurred from only a four percent decrease in runoff curve number (77 to 74). One important factor to consider for future research is the accuracy of the curve number estimations. It has been shown to be difficult to accurately estimate runoff curve numbers of reclaimed mine sites even using common engineering techniques (McCormick and Eshleman 2011). Yet, McCormick and Eshleman also confirmed the hypothesis that it is possible to restore some of watershed functionality through proper land reclamation techniques.

Conclusions

The results from this simulation suggest that with proper reclamation techniques, Brubaker Run's hydrology would improve slightly, but would have extreme benefits for the local watershed environment. Although the watershed examined with SWAT did not show significant simulated improvements, future work could prove its benefit. The SWAT model has the potential to be extensively used within the mine land reclamation field to help predict watershed hydrology improvements. Future SWAT work could also be coupled with the GIS plugin ArcMine for higher value results for potential mine land reclamation projects (Kim et al. 2012). With higher quality calibrations and more rigorous runoff curve number determination, SWAT could accurately be used to show why parcels of abandoned mine land should be reclaimed.

References

Arnold, J., and Fohrer, N. (2005). SWAT2000: Current capabilities and research opportunities in applied watershed modeling. *Hydrological Processes* 19: 563–572.

Arnold, J., et al. (2012). SWAT: Model use, calibration, and validation. *Transactions of the ASABE*. 55(4):1491–1508.

Arnold, J., et al. (1998). Large area hydrologic modeling and assessment Part I: Model development. *Journal of the American Water Resources Association* 34: 73–89.

Clearfield Creek Watershed Association. (2015). Brubaker Run. Available online at <http://www.clearfieldcreekwatershed.org/brubaker-run.html>

Galván, L., et al. (2009). Application of the SWAT Model to an AMD-affected River (Meca River, SW Spain). Estimation of transported pollutant load. *Journal of Hydrology* 377: 445–454.

Galván, L., et al. (2016). Hydrological modeling of a watershed affected by acid mine drainage (Odiel River, SW Spain). Assessment of the pollutant contributing areas. *Journal of Hydrology* 540: 196–206.

Kim, S., et al. (2012) ArcMine: A GIS extension to support mine reclamation planning. *Comput. Geosci.* 46: 84–95.

Neitsch, S., et al. (2012) SWAT 2012 Input/Output Documentation. Texas Water Resource Institute TR-439. Available online at <https://swat.tamu.edu/media/69296/swat-io-documentation-2012.pdf>

Madzivire, G., et al. (2011) Fate of sulphate removed during the treatment of circumneutral mine water and acid mine drainage with coal fly ash: Modelling and experimental approach. *Minerals Engineering* 24: 1467–1477.

McCormick, B., and Eshleman, K. (2011) Assessing hydrologic change in surface-mined watersheds using the curve number method. *J. Hydrol. Eng.* 16(7): 575–584.

Miao, Z., and Marrs, R. (2000) Ecological restoration and land reclamation in open-cast mines in Shanxi Province, China. *Journal of Environmental Management* 59: 205–215.

Sarmiento, A., et al. (2008) Hydrochemical characteristics and seasonal influence on the pollution by acid mine drainage in the Odiel River Basin (SW Spain). *Applied Geochemistry* 24: 697–714.

Sheoran, V., Sheoran, A., and Poonia, P. (2010) Soil reclamation of abandoned mine land by revegetation: A review. *International Journal of Soil, Sediment and Water* 3, Article 13.

United States Geological Survey (USGS). (2010) Coal Mine Drainage Projects in Pennsylvania. Available online at <https://pa.water.usgs.gov/projects/energy/amd/> ■



Arkansas Valley Seed

*Supplying QUALITY Seed
With INTEGRITY Since 1945*

***Rabbit Ears Brand**
Native Grasses, Wildflowers & Shrubs

***Wide Selection of Site-Specific
Ecotype Species**

***Temporary Cover Crops &
Erosion Control Blankets**

***Custom Mixing to Your
Specification Our Specialty**

**4300 Monaco St.
Denver, CO 80216**

Toll Free: 1-877-907-3337

Proud Member of the
American Society of Mining and Reclamation

How Infiltration Hydrology Varies Among Appalachian Coal-Mine Valley Fills

By Erich Hester, Kathryn Little, Joseph Buckwalter, Carl Zipper, and Thomas Burbey, Virginia Tech

Surface coal mines release waters with elevated concentrations of constituents throughout central Appalachia. These constituents include major ions, as indicated by elevated total dissolved solids (TDS) concentrations and electrical conductivity and are often associated with altered aquatic ecology (Pond et al. 2014, Timpano et al. 2018). Research demonstrates that valley fills are major sources of TDS in mining regions. These effects create challenges for mine permitting, and are of concern to mining companies, government agencies, and the public. TDS concentrations vary among streams draining valley fills due to differences in factors such as valley-fill age, construction technique, and reclamation method, but the causal links between such factors and discharge water quality remain unclear (Evans et al. 2015). This limits the mining industry's ability to address TDS water-quality concerns through modification of valley-fill construction practices.

The link between fill construction or reclamation techniques and mine-water TDS is the hydrology of mine-spoil fills and other mined landscapes. Water flowpaths through mine spoils determine where, when, and how much TDS is acquired by the waters moving through valley fills and delivered to streams. Little is known about how waters move through valley fills and other surface-mined landscapes. In this study, we used a geophysical technique called electrical resistivity imaging (ERI) to map subsurface structure of, and hydrologic flowpaths through, a series of valley fills in southwestern Virginia's

coalfield (Greer et al. 2017, Hester et al. 2019). ERI sends electrical current into the ground in certain locations and measures it at other locations to form a multi-dimensional map of electrical resistivity in the subsurface. Because resistivity can be correlated with rock type or water content, ERI is frequently used to understand subsurface geology or moisture patterns. On mined lands, this technique enables assessment of fill infiltration and interior flowpaths, and therefore a more complete understanding of valley-fill hydrology than is possible using conventional techniques. We also used conventional techniques (e.g., borehole drilling) to confirm our ERI interpretations.

Methods

We used ERI to map the subsurface structure and to determine residence times of hydrologic flowpaths in four fills (Office Fill, End Fill, Bearwallow,

and Barton Hollow). The first three valley fills were constructed using conventional end-dump methods. Barton Hollow was an experimental valley fill constructed by placing low-TDS mine spoils in a vertical series of 50-foot lifts and compacted surfaces with the intent of reducing TDS effluent (Figure 1). We used ERI surveys both under dry-weather conditions to reveal subsurface structure and during artificial rainfall to reveal infiltration hydrology. We verified our ERI interpretations with a series of strategically-executed hydrogeologic investigations including borings and excavation.

The ERI investigation involved setting up ERI equipment (Figure 2, left) at each of the four valley fills, conducting an ambient ERI survey under dry-weather conditions to assess valley fill structure, and then conducting an artificial-rainfall ERI survey to assess infiltration flowpaths. The dry survey extended

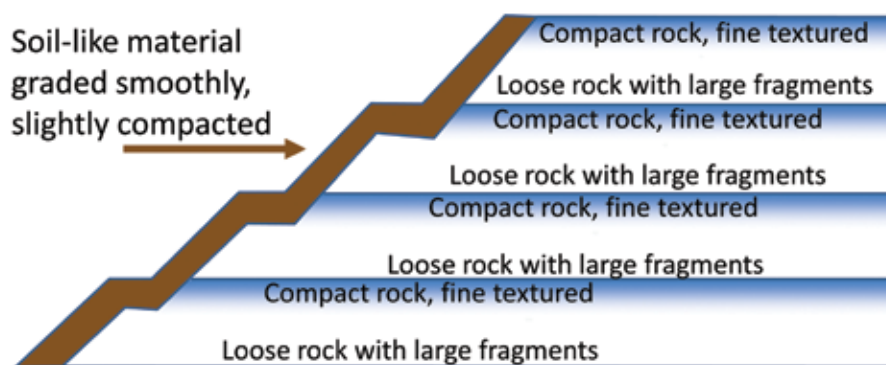


Figure 1. Simplified cross-sectional diagram of Barton Hollow's internal structure which represents the experimental construction method which selected low-TDS rocks for placement in the valley fill. Four vertical sections or "lifts" are shown, each approximately 50 feet thick.



Figure 2. ERI and artificial rainfall (sprinklers) at Barton Hollow fill (left), and drilling at Office Fill (right). (Photo credits to Kathryn Little (left), and Joseph Buckwalter (right)).

across most or all the centerline of the valley fill, while the artificial rainfall survey occurred only over the lower portion of the slope. Artificial rainfall was applied using a water pump and sprinklers during four to five hours at each valley fill. The field data were then analyzed to produce tomograms, which are maps of electrical resistivity in the subsurface, both as absolute values (to assess structure) or differences between dry and wet conditions (to assess flowpaths). Finally, ERI interpretations were verified by excavating shallow (~ one metre deep)

pits to assess surface layer structure and infiltration flowpaths at Office Fill and End Fill, and by using a drill rig (Figure 2, right) to conduct a boring to 18-metre depth with a down-hole camera to assess larger-scale valley fill structure and moisture variation at Office Fill.

Results

The ERI results for ambient conditions (i.e. without artificial rainfall, Figure 3) show variations in subsurface structure across most or all of each valley fill,

beneath the valley-fill centerlines. Areas of lower electrical resistivity (blue) indicate subsurface zones with finer-grained soil-like material that retain water and therefore conduct electricity well, whereas areas of higher resistivity (orange and red) indicate areas of larger rocks, likely with void spaces (i.e. no fines) in between that do not retain water or conduct electricity well. Ambient ERI results revealed significant variation in subsurface structure among the four valley fills.

The experimentally constructed Barton Hollow valley fill had a relatively small range of resistivity compared to the three conventionally constructed loose-dump valley fills, suggesting more consistent internal structure. The loose-dump valley fills showed considerably greater subsurface variation, consistent with their loose-dump construction.

The ERI results for artificial rainfall conditions (Figure 4) show variations in subsurface infiltration pathways within the lower portion (25 to 45 feet) of each valley fill. The spatial extents of the tomograms in Figure 4 therefore are subsets of the spatial extent of the tomograms in Figure 3, as indicated by the horizontal scales which are consistent between the two figures for each valley fill. Areas of increasing electrical conductivity (blue/green) indicate regions of the subsurface that have gotten wetter as a result of the artificial rainfall. We refer to these areas as water accumulation zones. Comparing the tomograms for the four valley fills in Figure 4 indicates considerable variability in the pattern of accumulation zones among the fills. In particular, we observed fewer deep-water accumulation zones at Barton Hollow than at the other three fills, suggesting that the internal structure of the experimental fill limits water movement from the surface to the fill interior, relative to what occurs in the loose-dump fills. There was also considerable variation among the loose-dump fills, indicating that high variability in subsurface fill structure had significant effects on water flowpaths. Zones that are red/orange are known as “artifacts” of the inversion process and represent conditions that contrast with other near-by zones; they do not represent drying conditions. Based on the identified accumulation zones, we estimated an

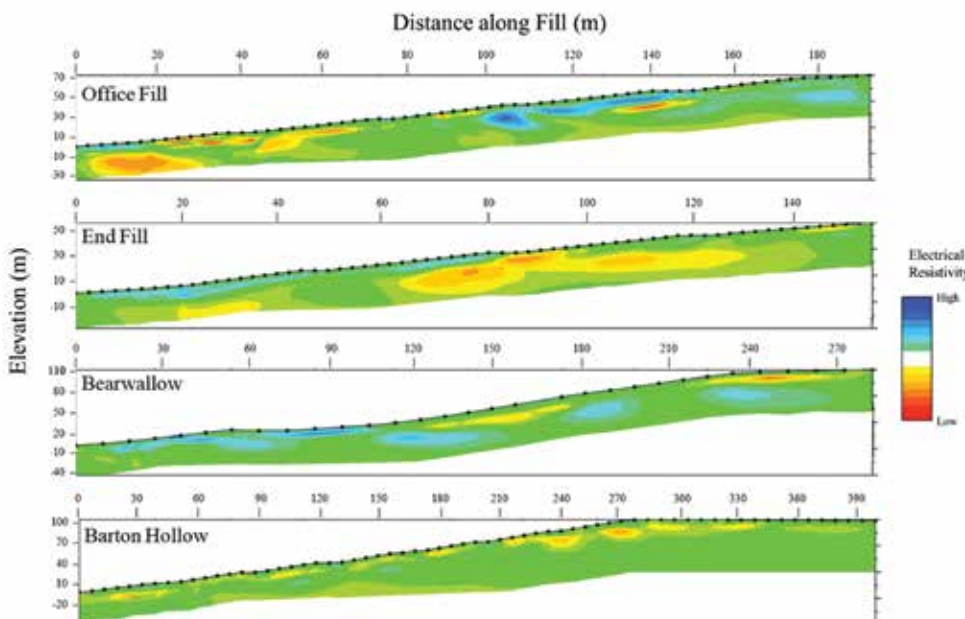


Figure 3. ERI tomograms showing spatial variation in electrical resistivity (in ohm-m) along a vertical slice of each valley fill along the fill centerline during dry-weather conditions (no artificial rainfall). Blue colors represent zones of lower resistivity, fine-grained materials that retain water and, hence, conduct electricity; while orange and red colors are low-resistivity zones that do not retain water, such as large boulders or voids.

average preferential flow pathway that was at least 6.6 meters long and required approximately 1.4 hours for water to traverse. Hence, calculated water-movement velocities along the flow paths averaged 5.1 m/h or 0.14 cm/s. These velocities were likely underestimates due to our measurement methods; the true velocities were likely higher. Nonetheless, the calculated velocity values indicated faster subsurface water movement than typically occurs on natural lands; this finding is not surprising, given that subsurface voids and rocky materials, which can transmit water rapidly, are known to occur within valley fills and other reclaimed-mine land structures.

Observations from soil pits and infiltration studies successfully confirmed ERI interpretations. At both Office Fill and End Fill, soil pits revealed possible preferential flowpaths through the shallow surface layer in the form of voids between rocks and associated water-flow pathways that were consistent with patterns observed in ERI tomograms. Observations from down-hole video in the bore-hole drilled into Office Fill and inspection of drill cores also successfully verified ERI interpretations, including that smaller rocks with more fines were found near the surface of the valley fill and larger rocks with larger voids were found at depth, and more water was stored in the finer materials at the surface of the valley fill.

Conclusions

This project confirmed the value of ERI as a noninvasive tool for hydrogeologic analysis of valley fills, as it is able to image internal structure under dry conditions and subsurface flowpaths under artificial-rainfall conditions. Our investigations revealed considerable variability of subsurface structure and infiltration hydrology among conventional loose-dump fills. Deep preferential infiltration flowpaths with water-transit velocities much higher than those that occur in undisturbed lands were a common feature of the loose-dump fills. By contrast, the experimental design with compacted lifts of the Barton Hollow fill kept infiltration shallower within the fill, which together with use of

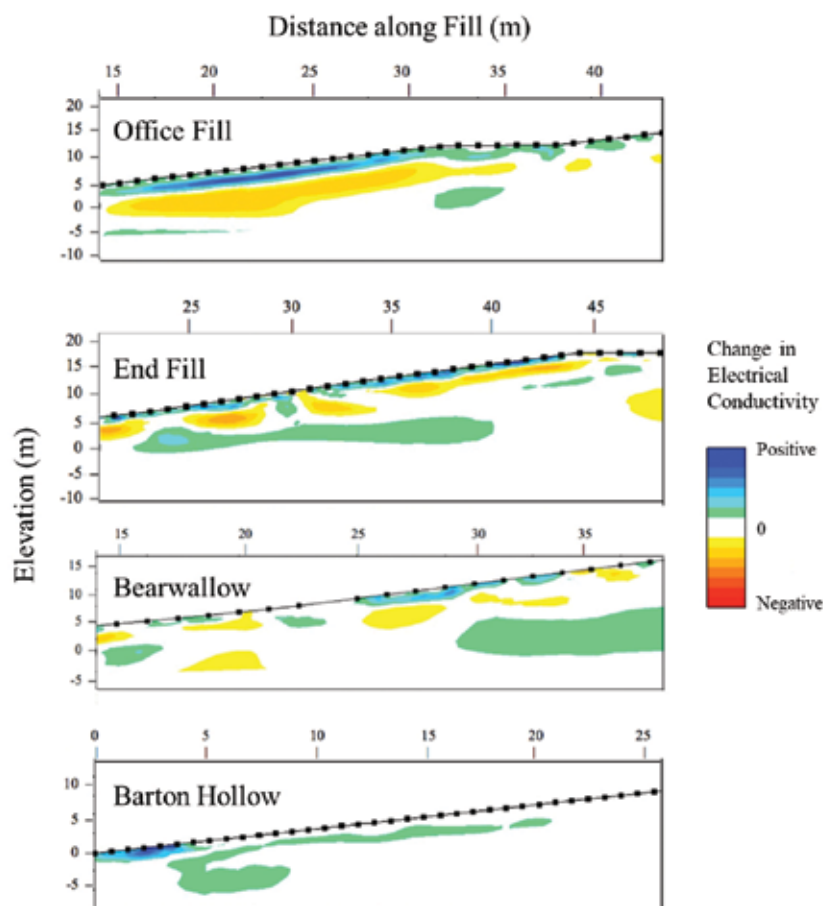


Figure 4. ERI tomograms showing spatial variation in change in electrical conductivity (in percent) along a vertical slice of each valley fill along the fill centerline. These tomograms span only the lower 25- to 45-foot portion of each fill, and compare conditions three hours after the start of artificial rainfall to ambient conditions before artificial rainfall. Blue/green areas represents zones where water is accumulating.

rocks with less potential to release TDS, shows promise for reducing effluent TDS in future fills. For a more complete description of the research and findings, please see Hester et al. (2019); for a copy of that article, please email ehester@vt.edu.

Acknowledgements

The authors thank US Office of Surface Mining for funding under Cooperative Agreement S16AC20076; and Contura Energy and Cambrian Coal for their assistance.

References

- Evans, D., C. Zipper, E. Hester, and S. Schoenholtz. 2015. Hydrologic effects of surface coal mining in Appalachia (USA). *Journal of American Water Resources Association* 51:1436-1452.
- Greer, B. M., T. J. Burbey, C. E. Zipper, and E. T. Hester. 2017. Electrical resistivity imaging of hydrologic flow through surface coal mine valley fills with comparison to other landforms. *Hydrological Processes* 31:2244-2260.
- Hester, E. T., K. L. Little, J. D. Buckwalter, C. E. Zipper, and T. J. Burbey. 2019. Variability of subsurface structure and infiltration hydrology among surface coal mine valley fills. *Science of the Total Environment* 651:2648-2661.
- Pond, G. J., M. E. Passmore, N. D. Pointon, J. K. Felbinger, C. A. Walker, K. J. G. Krock, J. B. Fulton, and W. L. Nash. 2014. Long-Term Impacts on Macroinvertebrates Downstream of Reclaimed Mountaintop Mining Valley Fills in Central Appalachia. *Environmental Management* 54:919-933.
- Timpano, A. J., S. H. Schoenholtz, D. J. Soucek, and C. E. Zipper. 2018. Benthic macroinvertebrate community response to salinization in headwater streams in Appalachia USA over multiple years. *Ecological Indicators* 91:645-656. ■

Evaluation of an Innovative Calcite Precipitation-Based Passive Treatment Technology at Bunker Hill, Coeur d'Alene, Idaho

By Kent Whiting, Nick Anton, and Roger L. Olsen, CDM Smith

Legend has it that the Coeur d'Alene “rush” in northeastern Idaho began after a mule, owned by prospector Noah Kellogg, kicked over a chunk of galena ore. Like most prospectors of the late 1800s, Kellogg was prospecting for gold, but he realized the importance of his mule’s discovery and helped to develop one of the greatest silver-lead-zinc districts in the world. As of 1996, the district had produced 1.1 billion ounces of silver, 8.1 million tons of lead, and 3.3 million tons of zinc (Springer 1997). The district has produced more silver than any district in the World, except for possibly Potosí, Bolivia. The Coeur d'Alene is also one of the largest mining districts in the World, covering 3,900 km² (Figure 1).

Typically, each mine had its own mill where the ore was crushed and concentrated. In the early years, the concentrated ore was shipped via steamboat to the Northern Pacific railhead at Coeur d'Alene for transport to smelters in Montana or Washington (NRC 2005). Later, in 1917, a smelter was built near the Bunker Hill Mine to process the concentrates from the district. The tailings produced at each mill site were typically discharged into the nearest gulley, creek, or stream producing “dead zones” where fish could not live. The tailings would wash

down stream, eventually reaching agricultural areas, poisoning livestock. The mine adits discharged metals laden and sometimes low pH water into the streams, making many water sources unfit to drink and potentially lethal to aquatic organisms. An ecological study conducted in 1932 found that the Coeur d'Alene River was nearly devoid of fish and plankton. Native fish placed in cages and submerged within the river died within three days (NRC 2005).

In 1983, the district was added to the National Priorities Superfund List (NPL) as the Bunker Hill Mining and Metallurgical Complex. Bunker Hill is one of the largest and most complex NPL Sites in the country. Operable units (OUs) 1 and 2, include a 21 square mile area, known as “the box” which includes the Bunker Hill mine, mill, and smelter. OU3 includes areas outside of the “Box” from near the Idaho-Montana border to the State of Washington where mining-related contamination is present.

In December 2009, U.S. EPA announced a \$1.7 Billion settlement with ASARCO, the largest Superfund settlement in EPA history. Settlement funds were placed in a Successor Coeur d'Alene Custodial and Work Trust (Coeur d'Alene Trust). A large portion of the budget is devoted to tailings management (building tailings repositories, drainage designs, etc.). However, without clean water, remediated streams would be re-contaminated, fisheries could not be re-established, and human health could potentially be affected (for non-regulated water sources). Therefore, water treatment is an important component of the remedial strategy. The water management plan for the site is to collect and transport (some via pipeline) the mining influenced water (MIW) to a centralized treatment plant. EPA’s Adaptive Management Plan allows for flexibility in onsite treatment approaches to reduce infrastructure costs such as pipelines. The use of “point source” treatment at the discharge locations for each mine could potentially result in significant cost savings. However, the mines of the district are often in remote mountainous regions that are difficult to access, especially during the winter, and access roads are often narrow, winding, and unimproved. Passive water treatment technologies are well suited to the Site conditions.

The Coeur d'Alene Trust selected the Rex Mine on Nine Mile Creek as one of the test sites to evaluate potential point source treatment technologies (Figure 2). The Rex Mine was originally named the Sixteen-to-One and began production in early 1900 (USGS 1908). Early on, the mine produced mainly lead and silver,

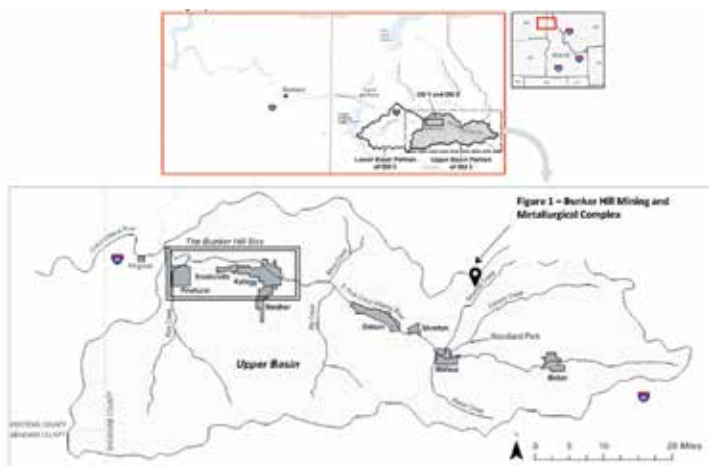


Figure 1 – Bunker Hill Mining and Metallurgical Complex



Figure 2. Rex Mill and mine site in 1911. Photo courtesy of University of Idaho Library Special Collections and Archives.

but later produced predominantly zinc due to an increase in zinc demand and prices during World War I (USGS 1923). The ore body contains sphalerite (ZnS) and galena (PbS), which are the main economic minerals, as well as pyrite (FeS₂), pyrrhotite (FeS_{1-x}), and chalcopyrite (CuFeS₂).

Discharge from the Rex Mine adit has a pH between 5 and 6, and the main metals of concern are cadmium, lead, and zinc (Table 1). Laboratory batch and column tests were conducted to find a water treatment technology that was passive, could handle variable flow rates, and was effective for the MIW type present. The Rex Mine adit discharges to Ninemile Creek, which eventually flows into the Coeur d'Alene River. The goal of establishing a fishery within Ninemile Creek required an estimated 80 percent decrease in metals loading within the watershed, which provided a benchmark for the treatment technology evaluation.

The Rex adit water is a particularly difficult water type to treat for a biochemical reactor (BCR) type passive treatment technology because of its low sulfate. BCRs work by reducing sulfate present in the water to sulfide which produces low solubility precipitates with the metals present in the water. The low sulfate concentrations limit the main removal mechanisms within a typical BCR (without adding sulfate to the water). Because the Rex adit water has low iron and aluminum concentrations, armoring of the limestone in the calcite precipitation process is less of a risk compared to MIW from some other adits.

The use of calcite precipitation to remove zinc and cadmium from mine water was discovered by accident during a study conducted for another site in the CDM Smith laboratory. Zinc-bearing mine water (pH ≈ 5) was passed through a column containing crushed limestone as a pre-treatment for another passive treatment system. The effluent from the column was sampled, analyzed and found to contain 9,000 µg/L dissolved zinc. The remainder of the sample was allowed to sit in an open container overnight. As an afterthought, the "aged" sample was analyzed. Dissolved zinc concentrations had decreased to



Figure 3. Rex Mine adit in 2003.

50 µg/L. Where did the zinc go? The working theory was that the initial solution was supersaturated with carbon dioxide gas (as are many groundwaters and adit discharges). The lower pH allowed some of the calcite to dissolve within the column. However, when the effluent solution was allowed to equilibrate with the atmosphere, the excess carbon dioxide degassed from the solution, resulting in a pH increase. The pH increase caused calcite to become supersaturated and precipitate, and concurrently removed most of the zinc. When the sample was filtered, the solid calcite particles, containing most of the zinc as impurities, were retained on the filter.

Cadmium and zinc have long been known to adsorb to the mineral calcite. Cadmium and zinc can also become incorporated into the solid matrix of calcite, which increases not only the capacity for removing these metals, but also the stability of the solid formed (Zachara et al. 1989; Stipp et al. 1992).

A treatment scheme consisting of the following steps was developed:

- Step 1 - Adjust the pH of the MIW (using carbon dioxide) to dissolve the limestone (calcite), if necessary. Many MIWs already have a sufficiently low pH.

Parameter	Value
pH (su)	5.62
Cadmium (mg/L)	0.029
Lead (mg/L)	0.38
Zinc (mg/L)	5.1
Iron (mg/L)	0.022
Sulfate (mg/L)	36
Total Dissolved Solids (mg/L)	97
Measured April 2014	

Table 1 – Rex Mine Water Quality

- Step 2 - Contact the zinc-bearing MIW with calcite via a limestone bed, resulting in dissolution of some of the calcite.
- Step 3 - After the MIW water exits the limestone bed, strip the water of carbon dioxide using an air sparging system or cascades and channels. The pH increases resulting in precipitation of zinc- and cadmium-bearing calcite.

Essentially, the technology consists of dissolving calcite and re-precipitating the calcite in the presence of the zinc and cadmium. The carbon dioxide is used to manipulate the pH and dissolve or precipitate calcite. A passive treatment system based on the three steps above would consist of a simple and potentially inexpensive design consisting of a carbon dioxide system (may not be needed if the pH is already <6) followed by a crushed limestone bed (to provide the calcite) and a series of riffles or an aeration basin (for carbon dioxide stripping).

The first step in evaluating the suitability of the technology to the Rex Mine was to determine if the addition of carbon dioxide would be necessary. A water sample was collected from the adit at the point where it exits the workings (Figure 3) and analyzed for a full suite of dissolved inorganic parameters (see select list in Table 1). The results were then modeled using the USGS equilibrium model PHREEQC (Parkhurst and Appelo 2013). The model results

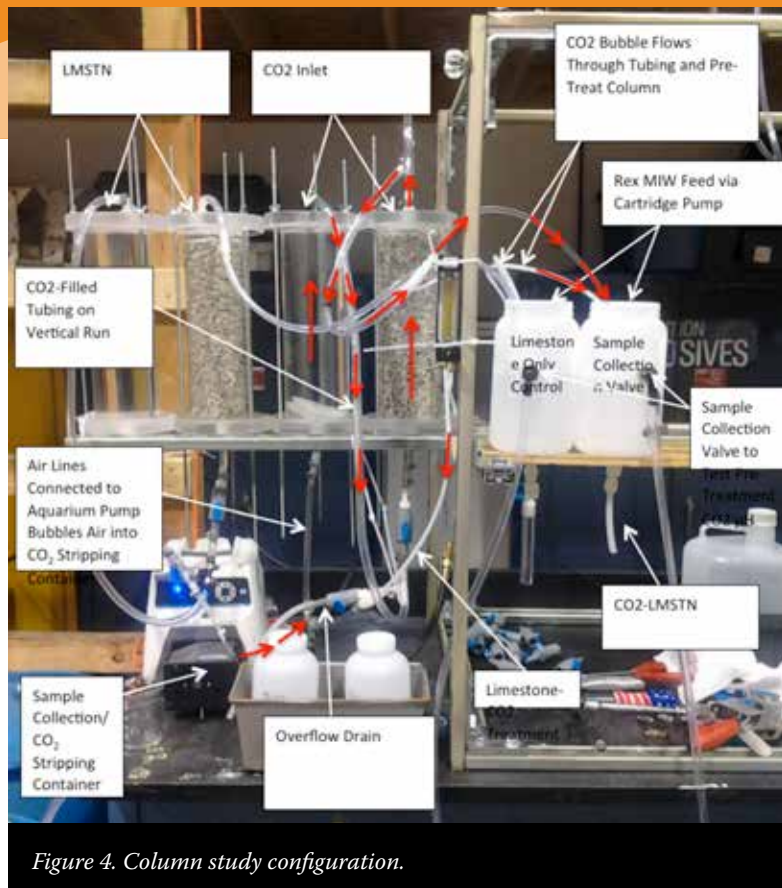


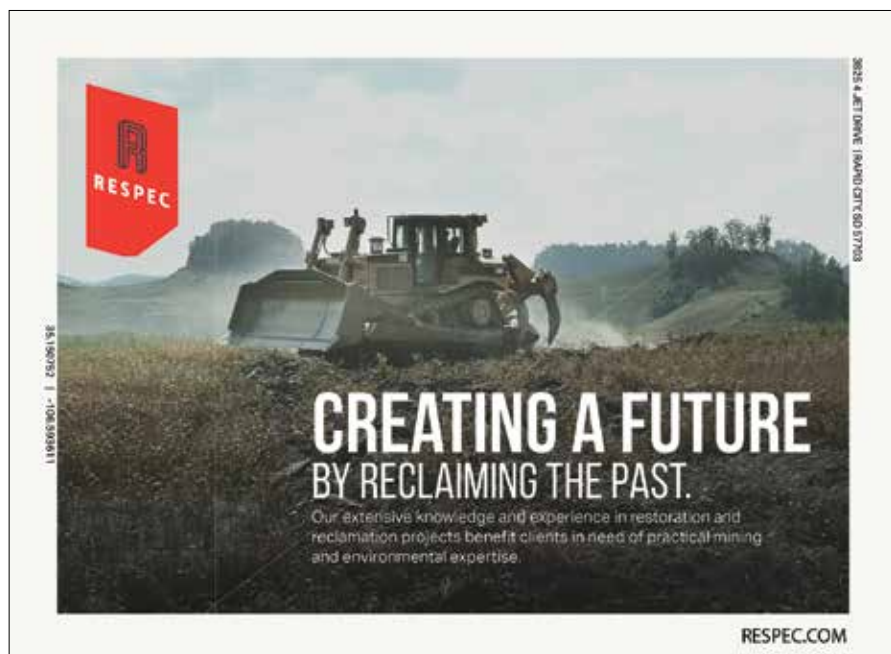
Figure 4. Column study configuration.

showed that the water was significantly undersaturated with respect to calcite. In other words, the mine adit water, when brought into contact with limestone would result in calcite dissolution. The model also showed that the water was supersaturated with carbon dioxide, meaning that if the water is allowed to equilibrate with the atmosphere, carbon dioxide degassing will occur and

the water pH will increase. The results showed that no carbon dioxide addition is required, but that the water must be placed in contact with the limestone immediately upon exiting the adit, before any carbon dioxide degassing can occur.

Bulk adit water was collected in May 2014 using HDPE 35-gallon drums. When received at the laboratory, the water had a pH of near 7 due to carbon dioxide off gassing. In the batch study, the adit water was restored to field pH by bubbling carbon dioxide through the water. The water was then immediately placed in bottles with crushed limestone, tightly sealed, and agitated in a rotary tumbler for 48 hours. Following tumbling, the water was decanted from the limestone and sparged with compressed air to strip the dissolved carbon dioxide. The pH, and dissolved cadmium, lead, and zinc of the water were then analyzed. Removals of 99 percent were achieved for all three metals.

The laboratory batch study was followed by a laboratory column study to more closely match field conditions. Carbon dioxide was bubbled through an empty column until a pH of about 5.5 was achieved, followed by an upflow crushed limestone column, and then a carbon dioxide stripping container (Figure 4). As a control, a limestone column receiving adit water without initial pH adjustment with carbon



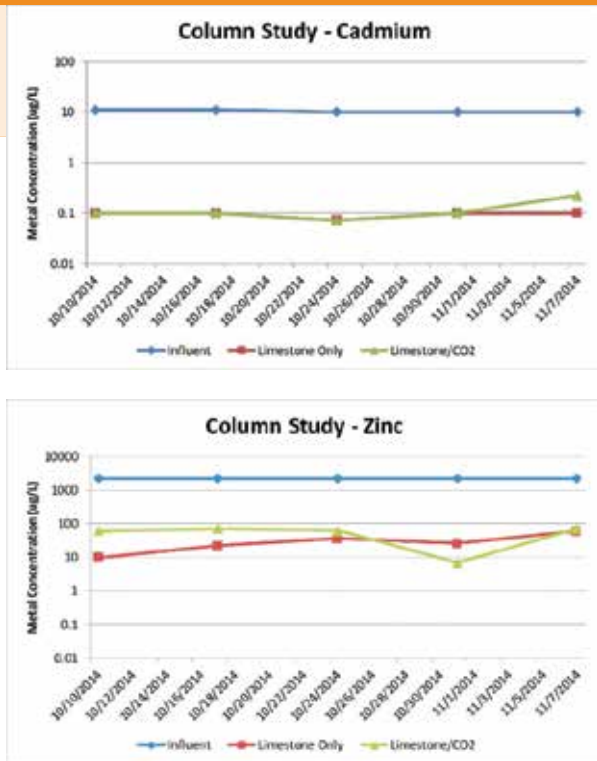


Figure 5. Column study results for cadmium and zinc.

dioxide was conducted in parallel. Samples were collected from the influent, after the limestone columns, and after the carbon dioxide stripping containers. The results are shown in Figure 5 for cadmium and zinc after carbon dioxide stripping.

Approximately 99 percent and 90 percent removals were achieved for cadmium and zinc, respectively for both of the columns. Comparison of the results from before and after the carbon dioxide stripping step indicated that for the control (without carbon dioxide addition), the metals were removed within the limestone column. In contrast, metal removal for the limestone plus carbon dioxide column occurred during the sparging step. In addition, mass balance calculations on calcium and alkalinity showed that calcite dissolution only occurred for the column in which carbon dioxide was added. The conclusion was that without carbon dioxide addition, the metals adsorbed to the limestone within the column. With the addition of carbon dioxide, the system performed as designed.

The results of the column tests were very encouraging, and showed that a few simple and inexpensive components, correctly arranged, could provide a viable, effective, and passive, point-source treatment system even for a challenging water type. Under the current adaptive management plan for the site, this technology is being considered for potential future onsite water treatment, although currently, other mines in the district with greater metals concentrations and flows are higher priority for water treatment. To eliminate the need for carbon dioxide addition, flow through a limestone bed inside the adit portal could be implemented where the pH is sufficiently low to dissolve calcite. Based on recent inspections, after few minor repairs within the adit, limestone could be safely installed. Outside of the adit, topographic conditions provide a long and steep slope to apply a rock channel for the carbon dioxide stripping step.

References

National Research Council (NRC). (2005) Superfund and Mining Megsites: Lessons from the Coeur d'Alene River Basin. Washington, DC: The National Academies Press. doi: 10.17226/11359.

Parkhurst, D., and Appelo, C. (2013) Description of input and examples for PHREEQC Version 3-A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. Chapter 43 of Section A, Groundwater Book 6, Modeling Techniques. US Geological Survey Techniques and Methods 6-A43.

Springer, D. (1997) More than a century of mining in the greater Coeur d'Alene mining region. Wallace District Mining Museum Production Summary.

Stipp, S., Hochella, M., Parks, G., and Leckie, J. (1992) Cd²⁺ uptake by calcite, solid-state diffusion, and the formation of solid-solution: Interface processes observed with near-surface sensitive techniques (XPS, LEED, and AES). *Geochimica et Cosmochimica Acta* 56: 1941-1954.

United States Geological Survey (USGS). (1908) The Geology and Ore Deposits of the Coeur d'Alene District, Idaho. USGS Professional Paper 62.

_____. (1923) Geology and Ore Deposits of Shoshone County, Idaho. Bulletin 732.

Zachara, J., Kittrick, J., Dake, L., and Harsh, J. (1989) Solubility and surface spectroscopy of zinc precipitates on calcite. *Geochimica et Cosmochimica Acta* 53: 9-19. ■

Poor Soil?

Activate Your Soil with Biosol's High Quality Nutrients!

WE FIX DIRT!

BIOSOL

Natural Plant Based Organic Fertilizer

- Increases humus growth 5x's faster than natural succession
- Unique slow release plant based fertilizer that supports soil and plant growth for years

Reclaiming the worst soils around the world for over 30 years!

Rocky Mountain Bio Products

Phone 303-696-8964

www.wefixdirt.com

Proactive Management of Imperiled Species to Avoid Federal Listing: Monarch Butterfly Habitat Enhancement on Mined Lands

By Kristi Dodson, Illinois Department of Natural Resources

The unique life history strategy and feeding behaviors of the monarch butterfly (*Danaus plexippus*) make the species well known to biologists, conservationists, and the public. These strategies and behaviors also play a crucial role in the decline and vulnerability of the species. The larvae stage (caterpillar) of monarch butterfly are specialist herbivores, they only feed on milkweed plants within the genus *Asclepias*. Milkweed produces a milky sap containing toxic compounds that are stored in the tissues of the monarch which can induce various negative

physiological effects on predators (e.g. birds). The monarch butterfly adults are brightly colored, a defense mechanism known as aposematic coloration that serves as a warning to potential predators. The bright colors and distinguishable wing patterns of the butterfly are associated with an unpalatable reaction, and potential predators learn to avoid the species as a meal. Although the larvae stage is a specialist and requires milkweed for survival, the adults are generalists and feed on a wide variety of nectar-producing forbs.

The eastern population of the species overwinters and takes shelter in one specific high-altitude forest in central Mexico. Round trip migration (Figure 1) from the overwinter site in Mexico, into the United States and as far north as just over the border into Canada, and back again requires four and sometimes five generations of monarchs. Adult butterflies leave Mexico moving north, become reproductive, and lay first generation eggs on milkweed plants. The eggs will hatch into the larvae stage that feed on milkweed, then over several life cycle stages will morph into adults. First generation adult monarchs continue north feeding on the nectar-producing plants, breeding, and laying second generation eggs on milkweed. Generations will successively move north with the last generation of late summer entering reproductive diapause (basically suspended reproduction or reproduction on hold). This last fourth or fifth generation will make the long trip, up to 3,000 miles, all the way back to central Mexico to overwinter. The complete life cycle and survival of the monarch butterfly depends on the availability of both native milkweed and native pollinator plants throughout their migration pathways.

Population levels of the monarch butterfly naturally fluctuate; however, it is estimated that the eastern population of the monarch butterfly has declined by 80 percent within the past 20 years. Major causes of decline can be attributed to the reduction of habitat quantity and quality due to loss of native prairie acres and the use of pesticides and herbicides which decrease the number of available milkweed plants along migration routes.

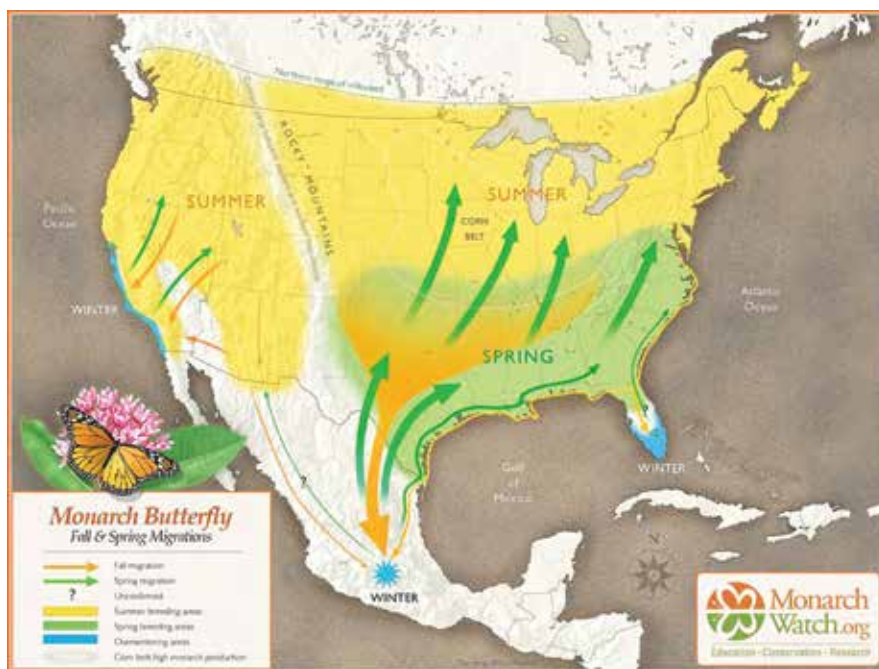


Figure 1. Monarch migration map. Map source: Monarch Watch, <https://monarchwatch.org/blog/2010/05/13/two-way-monarch-migration-map/>

The monarch population has declined at a level and rate sufficient to cause concern for the longevity of the species leading several non-profit organizations to petition the U.S. Fish and Wildlife Service (USFWS) to list the species for protection under the Endangered Species Act. Utilizing a pre-listing approach to conservation of the species, a Mid-America Monarch Conservation Strategy has been developed that involves multiple stakeholders. This strategy represents a nationwide movement toward approaching conservation of declining species proactively versus reactively (prevention versus cure). Efforts are focused on voluntary habitat restoration/enhancement and promotion of land management best practices to avoid federal listing and subsequent regulatory requirements. The strategy document and other information about the monarch butterfly and conservation initiative can be found on the Mid-West Association of Fish and Wildlife Agencies web page (http://www.mafwa.org/?page_id=2347). Formal public review and comment period concluded in May of 2018. A partner conference was held in November of 2018 and an initial listing decision by the USFWS is tentatively expected in June of 2019.

The Illinois Department of Natural Resources, Office of Mines and Minerals, Land Reclamation Division participated in the regional strategy by surveying the Office of Surface Mining Reclamation and Enforcement (OSMRE), other states with coal regulatory and abandoned mined lands (AML) programs and drafting a chapter section focused on non-rights-of-way energy infrastructure. The mined lands chapter section focused on potential scale of efforts, current initiatives, and strategies for improvement. The USFWS has identified several core conservation units for the monarch butterfly (Figure 2). The eastern north and south core units represent the major migration routes of the eastern population of the monarch butterfly. The vast amount of acreage in these regions bonded for mining and reclamation make state regulatory and abandoned mine lands programs important factors in proactive monarch conservation.

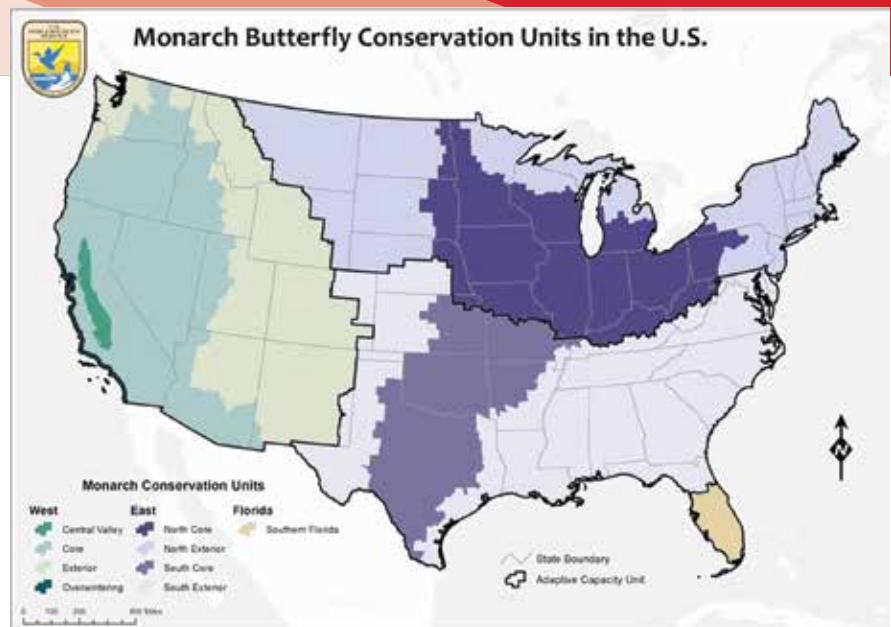


Figure 2. The USFWS monarch butterfly conservation units, March 2017.
Map source: U.S. Fish and Wildlife Service

Current Initiatives

OSMRE has embraced a science-based technology called the Forestry Reclamation Approach (FRA) on both active and abandoned mine site reclamation projects. This method focuses on planting native herbaceous and woody species on non-compacted soils which can greatly increase pollinator foraging opportunities and volunteer native species. In addition, the FRA Pollinator Advisory (<https://arri.osmre.gov/FRA/Advisories/FRA-14-ReestablishingPollinatorHabitat-Feb2017.pdf>) provides guidance on re-establishing pollinator habitat on mined lands with some nuances of mined lands considered. The West Virginia Department of Environmental Protection, Division of Mining and Reclamation is an example of a state regulatory authority that has adopted this approach. OSMRE supports the state regulatory authorities and AML programs by providing information about the FRA and Pollinator Advisory, encouraging the use of native species for revegetation, and providing educational and field observation opportunities to interested parties.

Title IV AML reclamation projects do not typically face the same limitations that permanent program sites encounter. For this reason, most of the current mined lands monarch butterfly habitat restoration occurs on these sites.

Multiple state AML programs within the Railroad Commission of Texas, West Virginia Department of Environmental Protection, and the Ohio Department of Natural Resources currently utilize native species seed mixes on reclamation projects. The seed mix developed in Ohio is specifically geared toward pollinator habitat. Two state AML programs have received grant funding from the National Fish and Wildlife Foundation (NFWF) to move forward with pollinator habitat and monarch butterfly conservation initiatives on their respective abandoned mined lands projects.

1. The Abandoned Mined Lands Reclamation Program of the Iowa Department of Agriculture and Land Stewardship in partnership with Pathfinders RC&D and the Iowa Division of Soil and Water Conservation received portions of a NFWF grant in 2015. The Iowa AML program has committed to several educational field days and has seeded upwards of 150 acres with pollinator friendly plant species. Future plans are to incorporate pollinator habitat seed mixes on reclamation projects as it fits with landowner use of the site. The AML program in Iowa has also been actively involved with the Iowa Monarch Consortium along with Iowa State University.
2. The Abandoned Mined Lands section within the Missouri Department of



Figure 3. Monarch butterfly and red clover. Photo courtesy of Larry Reuss, Prairie State Generating Company.



Figure 4. Monarch butterfly on reclaimed mined land. Photo courtesy of Kevin Brown, Illinois DNR/Land Reclamation Division

Natural Resources has formulated a new initiative focused on increasing the ecological fitness of pollinator species by improving the quality, quantity, and connectivity of habitat on landscapes affected by historic mining activities. The AML program is pursuing a multi-objective approach to revegetating mined lands, which includes the integration of native milkweed and other nectar-producing forbs into warm-season grass mixes. The Missouri program received grant funding from the NFWF Monarch Butterfly Conservation Fund and planned on planting native warm-season grasses and forbs in the spring of 2018 on approximately 100 acres.

State regulatory authorities under the Title V program typically encourage and support the voluntary addition of native milkweed species and other pollinator friendly forbs in revegetation seed mixes for Fish and Wildlife Habitat and Pasture/Hay post-mining land uses (Figures 3 and 4). Where coal companies and consultants are amenable, state regulatory authorities work to educate on the importance of monarch butterfly and pollinator friendly seed mixes. Some state regulatory authorities have seen voluntary adoption of these seed mixes and have approved adoption of best management practices (BMPs) for mowing and maintenance to effectively cultivate pollinator friendly habitat. The Ohio Department of Natural Resources partnered with the USFWS to present educational information at a coal industry meeting to encourage potential habitat enhancement on mined lands. In addition, the encouragement of conservation buffers composed of native grasses and forbs in conjunction with agricultural production post-mining land use acreages is a fairly common practice among state regulatory authorities, particularly those coal mining states in the Midwest such as Illinois and Iowa.

Strategies for Improvement of Current Efforts

Improvement of current efforts regarding mined land reclamation for pollinator species, including the monarch butterfly, should focus on educational outreach and

increasing an understanding with potential partners about the limitations faced on mined lands. These limitations include but are not limited to funding, landowner buy-in, regulations, effectiveness of native forbs for erosion control, and opposition from other sectors. General strategies to address these limitations are outlined below:

1. Although BMPs already exist for establishment of pollinator friendly habitat, coal regulatory programs require practices that are specifically tailored to mined lands that may still be in operation. For example, there will be limited or no capacity to burn on site, which is a major component of most BMPs for pollinator habitat. One approach to this issue is creating partnerships between stakeholders representing both mined land reclamation and conservation groups to draft appropriate mined land BMPs.
2. Access to cost effective pollinator-friendly seed mixes that also function to adequately control erosion is limited. Seed mixes that contain native grasses and forbs are typically exponentially more expensive than standard pasture grass seed mixes. A company or state program that is reclaiming several hundreds of acres would need to have multiple thousands of dollars available in a budget to spend on native seeding materials. Concern has also been expressed that forb-heavy seeding might contribute to sediment control issues leading to water quality violations and the need for expensive repairs on slopes. One approach to this issue is providing incentives to purchase higher-priced seed mixes, such as cost sharing. Additionally, entering into agreements with state agencies or conservation organizations to offset the cost of seed while committing to set aside acreage specifically for monarch habitat could be effective. Research through universities or state agencies to develop native pollinator friendly seed mixes that also control erosion could stimulate increased conservation efforts on mined lands.
3. OSMRE plays an important role with state regulatory authority and AML programs. Programs less familiar with the FRA may benefit from an increased awareness and promotion of the FRA

and Pollinator Advisory document and discussions on how this approach fits with regulations and program objectives. In addition, training and collaboration opportunities between OSMRE and the state programs could be beneficial. Conservation areas within cropland and Industrial and Commercial post-mining land use acreages present an untapped area for increasing pollinator habitat. Discussions between states and OSMRE regarding flexibility with these land uses might move additional conservation efforts forward. Initiatives involving cropland would require buy-in from the agricultural community, assistance with outreach to those landowners might be beneficial. Exploring the use of federal grants through OSM for both Title IV and Title V projects, potentially including operators, as incentives to restore land as monarch butterfly habitat might offset some limitations for both programs.

4. Education outreach and training for coal mine operators, consultants, land owners, and state programs is imperative for conservation efforts to take hold on mined lands. Resources that may benefit these stakeholders include explanations on how federal listing of the monarch butterfly could affect mining operations and permitting, and information explaining the human benefit for proactively conserving species in jeopardy.
5. Coal mining operations sometimes receive negative feedback and opposition from non-profit groups, conservation agencies, and universities regarding potential adverse effects on the environment from mining. A conservation effort with a broad scope such as the monarch butterfly initiative provides an opportunity for those groups to offer technical assistance and partnerships to operators and consultants for the benefit of the environment.

Potential Scale of Mined Land Efforts

Approximately 1,234,624 acres of land are bonded through coal mining regulatory programs across the states of Texas, West Virginia, Ohio, Oklahoma, Pennsylvania,

Kansas, Kentucky, Missouri, Arkansas, Illinois, and Indiana, all in various stages of operations and reclamation. The post-mining land uses of these acres vary between Fish and Wildlife habitat types, Forest, Industrial/Commercial, Cropland, Pasture and others. Several states responded to inquiries regarding the available potential monarch butterfly habitat acreage within their respective programs. Looking specifically at Fish and Wildlife Habitat, Pasture/Hay, and limited Forest post-mining land uses, there are approximately 504,000 acres bonded and in various stages of operations or reclamation regulated by state regulatory programs across Arkansas, Illinois, Indiana, Kentucky, Ohio, Oklahoma, Missouri, Texas, and West Virginia. Readers should understand that this number does not reflect Pennsylvania and does not reflect each states variation in post-mining land use terminology. For example, the acreage that Illinois contributed to this total does not reflect Fish and Wildlife Woody or Wetland nor does it reflect Forest post-mining land uses. Forest land uses were not reported from all responding states. The total number of the potential scale of regulated mined land acres is likely higher than that reported here. According to the states that responded to inquiries regarding abandoned mined land program acreages, there are approximately 18,900 acres across Indiana, Iowa, and Missouri of unreclaimed project sites and Ohio reclaims about 1,500 acres per year.

Mined lands provide a unique potential opportunity to increase pollinator habitat across the Midwest to benefit the monarch butterfly conservation initiative (Figures 5 and 6). Effective educational outreach to operators and consultants, consideration of monarch butterfly and pollinator seed mixes that are effective for erosion control, and fostering partnerships that defray pollinator habitat enhancement reclamation costs are necessary to move the initiative forward. The combined proactive conservation efforts of many stakeholders can potentially help stabilize the eastern monarch butterfly population and prevent federal listing of the species. ■



Figure 5. Monarch butterflies in flight. Photo courtesy of Mike Dudas, Hanson Professional Services, Inc.



Figure 6. Monarch butterflies feeding on golden rod at a reclaimed mine site. Photo courtesy of Kristi Dodson, Illinois DNR/Land Reclamation Division

Re-establishing Pollinator Habitat on Mined Lands Using the Forestry Reclamation Approach

By Tammy Horn, Patrick Angel, Carl Zipper, Michael Ulyshen, Michael French, Jim Burger, Mary Beth Adams

Previously published in
Forest Reclamation Advisory
No. 14, February 2017.

Pollinators are animals that play an essential role in the reproduction of many plants by transferring genetic material, in the form of pollen, from male to female flower parts. Because pollinator communities are under threat both in the US and worldwide, there is great interest in incorporating the needs of pollinators into habitat restoration plans. Forests provide many important resources such as nectar and pollen throughout the warm-weather seasons as well as critical nesting habitats. This Advisory describes mine reforestation strategies that can encourage and support pollinator conservation in the eastern U.S. We also provide background information concerning pollinators and their conservation needs.



Figure 1. A small bumble bee (*Bombus vagans*) on an aster flower growing on a surface mine in Elk County, PA. Photo by Michael French.

Why are Pollinators Important?

At least 80 percent of the world's more than 300,000 flowering plant species rely on pollinators such as bees, butterflies, moths, flies, wasps and beetles to aid in reproduction (National Research Council 2007; Ollerton et al. 2011). Since flowering species are rooted in place, pollinators transfer pollen between plants, thus ensuring that pollen-producing species are able to produce live seed. In return, the insects gain nutrition from pollen and nectars. Every year a honey bee colony consumes between 35 to 75 pounds of pollen and up to 125 pounds of nectar.

It is hard to overstate the importance of pollinating insects to the agricultural systems humans depend on for food and other products. Pollinators account for \$15.2 billion worth of agricultural productivity for crops such as almonds. This estimate, however, does not take into consideration the full value of commodities that indirectly benefit from pollination, such as cattle, which are dependent on clover and alfalfa (Calderone 2012). The importance of pollinators for ensuring food supplies is well known, but they also perform other important ecosystem functions such as setting seed for many wildflowers and other plants that occur in forests. A large number of forest tree species depend on the services of pollinators, including many tree species of concern to the Appalachian Regional Reforestation Initiative (ARRI).

Pollinators Under Threat

Honey bees are considered the “workhorse” of agricultural pollinators,

both in the U.S. (where they were introduced from Europe in the 17th century) and worldwide. Honey bees are challenged today by parasites and pathogens, chemical use in agriculture, and by habitat loss/degradation. A serious biological threat to honey bees is an Asian parasite called varroa mite (NRC 2007). Moreover, large areas of forest ecosystems that formerly served as habitat for honey bees have been lost to various kinds of development, including mining (Sayler 2008, Drummond and Loveland 2010). Declines in many pollinator groups are due to habitat loss, fragmentation, and deterioration (NRC 2007).

Given the many threats facing honey bees, it is fortunate that we are not entirely dependent on this single species for our pollination needs. There are approximately 4,000 species of native bees in North America (Moisset and Buchman 2011), for example, and these insects are also highly effective at pollinating plants in both natural and agricultural systems. Other native North American pollinators include butterflies and moths, flies, wasps and some vertebrate species like hummingbirds and bats. Recent research has documented declines of pollinators, both globally and in North America, and identifies a number of potential causes including environmental stressors such as pesticides, non-native invasive plants that displace native pollen-producing species, viruses and other pathogens and habitat loss (Goulson et al. 2015, Kearns and Inouye 1997, Cane and Tepedino 2001, Potts et al. 2010).

In Appalachia, forest loss due to surface mining and other disturbances results in less pollinator habitat. In recent decades, more than one million acres of forests

Locating apiaries on reforested surface mines.

Owners of land that has been surface mined and reclaimed with the FRA and pollinator-friendly plants have opportunities to use them for honey production. Similarly, for owners of legacy surface mines that have been mitigated and reforested with "honey plants," beekeeping can provide extra income and unique educational experiences (right). Landowners can also promote pollinators by providing experienced beekeepers with access to their nectar- and pollen resources on reforested surface mined land. Groups of honey bee hives (called apiaries) can be located almost anywhere on a mine site or on property adjacent to a mine site, but choosing the best possible location increases the chances for the development of strong colonies and successful honey production.

Here are some points to consider when locating an apiary on a reforested surface mine:

- Locate the apiary as close as possible to good nectar and pollen sources. Honey bees will fly two miles in any direction to find what they need to survive, and in times of stress, can fly up to five miles.
- Honey bees need to be located near a water source because they use water to regulate

the temperature of the hive and to create liquid food for larvae. The water source does not have to be crystal clear. Honey bees will collect minerals from muddy ponds used by cattle.

- Windbreaks may be needed to provide protection from cold winds in the winter.
- Since bad weather tends to come from west to east, place bee hives so that they face to the east or south.
- In hilly terrain, it is better to locate bee hives at the bottom of a slope instead of on top of a slope since bees fly uphill to forage and downhill when loaded with nectar and pollen.
- Avoid locating hives near large sediment ponds since bees could fall into the water and drown when returning back to the hive loaded down with nectar.
- Erect a solar-powered electric fence around the apiary if bears are a potential threat. It is a good idea to erect a fence before moving hives to an area instead of after.
- To minimize vandalism or theft, the apiary should be located in an area that is naturally hidden from view from access roads, water impoundments, etc. Apply a camouflaged paint pattern to the bee hives. Road access to the apiary should be controlled by a strong gate.



- Have a first-aid kit containing an epi-pen or Benadryl for those who may be allergic reaction to bee stings.
- Having a fire extinguisher in the truck is encouraged since smokers are used and beeswax is flammable.

Numerous resources are available to beginner or expert beekeepers to learn more about apiculture such as books, the internet, beekeeping suppliers, local or state clubs. Contact your State Cooperative Extension Service, Natural Resources Conservation Service (NRCS) or State Apiarist for guidance and more information.

have been mined and replaced with non-forest vegetation that often includes significant presence by non-native plants (Zipper et al. 2011; Oliphant et al. 2016). Displacement of native plant communities by non-native exotics is often unfavorable to pollinators (Hanula et al. 2016). Returning active and legacy surface mines to healthy, productive forests by using the Forestry Reclamation Approach (FRA) can help conserve both managed and native pollinators.

FRA and Pollinator Habitat Needs

The FRA is a method for reclaiming coal-mined land to forest (Burger et al. 2005; Forest Reclamation Advisory No. 2) and is based on knowledge gained from both scientific research and experience. The FRA can achieve cost-effective regulatory compliance for coal operators while creating productive forests that generate value for their owners, provide environmental services, and create

habitat that benefits pollinators.

Bees and other pollinators require habitats that supply resources that are essential to their life processes. These resources include:

- water, which is important for proper hive thermoregulation and nutritional preparation;
- floral hosts that supply pollen and nectar matched to a given species and blooming periods that meet the species' needs;
- nest-building materials consisting of plants and soils;
- nesting substrates, such as soils with organic materials, living plants, and dead plants such as decaying woody debris with cavities.

Because pollinators are so diverse in their habitat requirements, the National Research Council (2007) recommends conserving and restoring diverse plant

communities and conserving existing habitats. The FRA can be applied as a means of creating habitat for pollinators and other animals that is similar to pre-mining habitat.

A primary habitat requirement of pollinators is the presence of a variety of flowering plants that provide nectar and pollen resources throughout the growing season. Reclamation using the FRA presents an opportunity to initiate plant community development from bare ground, with the goal of establishing a diversity of flowering tree, shrub, and herbaceous plants that are pollinator-friendly.

Also, research indicates that bees are especially sensitive to certain pesticides that are used commonly in agricultural and residential settings when trees are in bloom. Thus, reclaimed mine sites are excellent candidates for establishing healthy pollinator habitat because of the minimal use of agricultural chemicals

associated with the reclamation process.

Restoration of pollinator habitat can be yet one more measure of success for coal companies seeking to demonstrate environmental stewardship through reclamation practices. Such habitat can also provide landowners with gainful income and aid economic development in nearby communities by supporting opportunities for commercial beekeeping (Box 1).

Below, we recommend methods for applying the FRA with the intent of restoring habitat conditions that are favorable to pollinators.

Guidelines for Pollinator Habitat Enhancement on Mined lands

1. Apply the FRA in reclamation; apply all five steps.

Re-establishing forest plant communities and other ecosystem components on mined lands is more favorable to pollinators than conventional reclamation strategies. The goal of the FRA is to restore, to the extent that is possible, native forest ecosystems on reclaimed mines. Research demonstrates that many components of pre-mining forested ecosystems can be restored successfully on mine sites when all five steps of the FRA are applied:

1. Create a suitable rooting medium for good tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone and/or the best available material;
2. Loosely grade the topsoil or topsoil substitute established in step one to create a non-compacted growth medium;
3. Use ground covers that are compatible with growing trees;
4. Plant two types of trees—early successional species for wildlife and soil stability; and commercially valuable crop trees; and,
5. Use proper tree planting techniques.

2. When possible, use natural soil that has been salvaged with soil organic matter, roots, and woody debris.

The FRA's first two steps are to construct a growth medium of at least four feet in

depth using the best available materials, and to use minimal compaction grading techniques on the reconstructed land's surface. Including natural soils with organic debris as part of the growth medium will aid re-establishment of forest plant communities and ecosystem services such as watershed protection in addition to being a superior growth medium for forest trees (Skousen et al. 2011; Forest Reclamation Advisory #8). Use of natural soils with organic debris to construct mine soils is in full accord with the FRA. Freshly salvaged soils contain live roots and seeds that can give rise to plant species that are not seeded and can enable successful establishment of native plants that enter the site as wind- or wildlife-carried seed. A diverse community of native plants will save the operator planting costs by increasing the number of native trees and ground cover species present during bond release revegetation analysis. These species will also be more favorable pollinator habitat than the restricted and non-native dominated plant communities that often follow conventional reclamation.

In addition to these benefits, we expect that loosely placed spoil materials containing organic debris may provide habitat for ground-dwelling pollinators. Because most North American bees are ground-nesting (NRC 2007), the presence of organic debris in non-compacted mine soils will provide habitat conditions that are more suitable, and more similar to natural conditions than compacted soils constructed of rock spoils. The presence of organic debris in non-compacted mine soils can help maintain soil porosity. Some pollinator species require resources such as dead wood, living plants of specific types, or soil materials for nest-building purposes. All of these can be obtained more readily on reclaimed mines if the reconstructed ecosystems resemble natural systems. Construction of post-mining ecosystems that provide the same ecosystem services as pre-mining ecosystems is intended through application of the FRA.

3. Seed pollinator-friendly ground cover that will not compete with tree seedlings. Select species to produce a continuous flowering sequence throughout the growing season.

Step 3 of the FRA calls for the use of ground cover vegetation that balances erosion control and competition for the light, water and space required by trees. Both grasses and broadleaved plants may provide pollinator-friendly and tree-friendly habitat. While little scientific research has been conducted to evaluate pollinator-friendly groundcover seeding strategies for reforestation to date, seeding with native herbaceous plants can provide benefit to pollinators (Cusser and Goodell 2013).

Table 1 provides an example of a seed mixture that has been used on mine sites that could serve as a pollinator enhancement to seed mixes already in use. This pollinator-friendly groundcover seed mix could be seeded as presented, or as a mixture with conventional tree-compatible ground cover with the goal of adding native forbs to the seed mix.

Common Name	Lbs. / acre ^a
GRASSES	
<i>Little Bluestem</i>	3 ^b
FORBS	
<i>Lance-leaved Coreopsis</i>	.3
<i>Plains Coreopsis</i>	.2
<i>Illinois Bundleflower</i>	.5
<i>Purple Coneflower</i>	.3
<i>Grey-headed Coneflower</i>	.3
<i>Partridge Pea</i>	.5
<i>Black-eyed Susan</i>	.1
<i>Maximilian Sunflower</i>	.5
<i>Canada Goldenrod</i>	.5
<i>Butterfly Weed</i>	.5
<p>a Seeding rates on Appalachian mine sites when all are used together. When used in combinations with other tree-compatible groundcovers, these rates can be varied.</p> <p>b grasses/legumes are included in the mix primarily to provide soil stabilization. Rates can vary to meet this goal.</p>	

Table 1. Example of a pollinator-friendly groundcover seed mix that has been seeded successfully on mine sites.



Figure 2. Sourwood sapling blooming in mid-summer. Such blooming trees are excellent for mine land reforestation and provide pollinator habitat. Photo by Tammy Horn.

A tree compatible seeding mix which may be used as a starting point for reclamation practitioners as they experiment with additions of flowering plants can be found in *Forest Reclamation Advisory No. 6* (Burger et al. 2009). The goal here is to reduce the seeding rates of grasses and legumes by adding a healthy component of native forbs to the mix. As a starting point, we suggest reducing the seeding rate of the current operational mixture to half the current rate, and adding native forbs (Tables 1 and 2). If good vegetation establishment and suitable groundcover are seen over the first year, the grass/legume seeding rate can be further reduced.

To establish conditions most favorable to pollinators, plants are best used in groupings that provide continuous flowering from early spring through late fall. Table 2 lists flowering plants, and their season of flowering. Since the plants listed are all native to the eastern U.S., we expect that their presence on mine sites during the early stages of reforestation will be compatible with tree seedlings. However, that expectation has not been tested with field trials.

4. Plant pollinator-friendly tree and shrub species that will produce a continuous flowering sequence through most or all of the growing season.

FRA Step 4 concerns the selection of tree species for planting. Guidance for tree species selection has been published

by Davis et al. (2012) and Rathfon et al. (2015) as *Forest Reclamation Advisories Nos. 9 and 13*. When applying FRA Step 4, pollinator-friendly tree and shrub species that are adapted to site conditions can be selected (Monteleone et al. 2017). An excellent mix for pollinators will include one or more tree or shrub species that flower and produce large amounts of nectar and/or pollen in the spring, along with one or more species that do

so in the summer. An ideal mix would also include a fall-flowering species, such as American witchhazel. Seedlings from most of the tree species listed in Table 2 are easily available from commercial nurseries.

5. Consider tree and ground cover species together when designing a pollinator- friendly reclamation strategy.

For two decades, **BioMost, Inc.** has developed advanced passive mine drainage treatment technology to support the varying needs of government and private organizations.



Our experienced team of professionals offer a full-service solution while aiming for the lowest long-term client cost. We evaluate the site, design a specific plan, and provide construction, including managing permits. By offering complete project services, we are able to closely monitor and ensure quality.

Visit our website
or contact us to
learn more.



www.biomost.com
724.776.0161
bmi@biomost.com

The flowering sequence of herbaceous and woody plants can be considered together. For example, very few fall-flowering tree species are available for mine plantings. However, the Canada goldenrod, which grows well in full sun and partial shade, is highly persistent, beneficial to pollinators, and produces fall flowers. Yellow crownbeard is another fall-flowering native species favorable to pollinators that persists in partial shade. However, neither of these species have been tested for compatibility with growing trees on reclaimed surface mines. By considering flowering sequences of both ground cover and tree/shrub species, the goal of season-long flowering can be achieved. Further research can clarify how groundcover and trees interact when used in pollinator plantings.

Commercial Bee and Honey Production on Mine Sites

Reclaimed forests with pollinator-friendly plant species can support commercial bee and honey production as well as robust native pollinator communities. There are many examples of initiatives to establish beekeeping enterprises on mined lands. In 1976, the University of Kentucky, Tennessee Valley Authority and Peabody Coal developed a collaborative honey production project on reclaimed surface mined land in Muhlenberg County in western Kentucky (Angel and Christiansen 1976). More recently, commercial beekeepers collaborated with coal companies to develop pollination yards on their surface mine sites (Figure 3; Horn 2012). In addition to using the FRA, the four coal companies agreed to provide understory trees, such as sourwood, and wildflowers that are particularly honey bee friendly. Working with Virginia Cooperative Extension in Wise County, Virginia, local beekeepers have maintained and operated hives for honey production on mine sites at Powell River Project since 2010. In 2015, West Virginia, a state with large amounts of surface mine land that can be turned into pollinator-friendly forests, launched a program to train veterans on how to keep bees and produce honey. Guidelines for siting apiaries on reclaimed mine lands are presented in Box 1.

Summary

Many pollinator species are under threat worldwide for many reasons, including habitat loss. In Appalachia, native forests serve as pollinator habitat. This Advisory describes methods for re-establishing pollinator habitat on coal surface mines by reforesting mine sites using the FRA. We recommend that the FRA be applied in a manner that will produce soil conditions on mine sites similar to those of unmined forests. We also recommend establishing a diverse community of seeded and naturally invading native plants; and re-establishing native plant species that will provide a continuous bloom cycle throughout the growing season.

Literature cited

- Angel P.N. and C.M. Christensen. 1976. Honey Production on Reclaimed Strip Mine Soil. p. 708-711, in: Hill Lands: Proceedings of an International Symposium. West Virginia University, Morgantown.
- Burger J.A., V. Davis, J. Franklin, J. Skousen, C. Barton, C.E. Zipper. 2009. Tree-compatible ground covers for reforestation and erosion control. ARRI Forest Reclamation Advisory No. 6. 6 p.
- Burger J.A., D. Graves, P. Angel, V. Davis, C.E. Zipper. 2005. The forestry reclamation approach. ARRI Forest Reclamation Advisory No. 2. 4 p.
- Calderone N.W. 2012. Insect Pollinated Crops, Insect Pollinators and US Agriculture: Trend Analysis of Aggregate Data for the Period 1992–2009. PLoS ONE 7(5): e37235. doi:10.1371/journal.pone.0037235
- Cane J.H., V.J. Tepedino. 2001. Causes and extent of declines among native North American invertebrate pollinators: detection, evidence, and consequences. Conservation Ecology 5 (1).
- Cusser S., K. Goodell. 2013. Diversity and distribution of floral resources influence the restoration of plant–pollinator networks on a reclaimed strip mine. Restoration Ecology 21: 713-721.
- Davis V., J.A. Burger, R. Rathfon, C.E. Zipper, C.R. Miller. 2012. Selecting Tree Species for Reforestation of Appalachian Mined Lands. ARRI Forest Reclamation Advisory No. 9. 8 p.



Figure 3. Apiary site on a reforested mine land in Kentucky. Photo by Tammy Horn.

- Drummond, M., and T. Loveland. 2010. Land-use pressure and a transition to forest-cover loss in the eastern United States. Bioscience 60:286–298.
- French M., C. Barton, B. McCarthy, C. Keiffer, J. Skousen, C. Zipper, P. Angel. Re-establishing American Chestnut on Mined Lands in the Appalachian Coalfields. Forest Reclamation Advisory No. 12.
- Goulson D., E. Nicholls, C. Botias, E. Rotheray. Bee declines driven by combined stress from parasites, pesticides, and a lack of flowers. Science 347: 1435.
- Hanula J.L., M.D. Ulyshen, S. Horn, S., 2016. Conserving pollinators in North American forests: A review. Natural Areas Journal 36: 427-439.
- Hopewood, J., S. Black, S. Fleury. 2015. Roadside Best Management Practices that Benefit Pollinators: Handbook for Supporting Pollinators through Roadside Maintenance and Landscape Design. Report FHWA-HEP-16-059. U.S. Department of Transportation, Federal Highway Administration. Washington D.C. 88 p.
- Horn 2012. Beeconomy: What Women and Bees Can Teach Us about Local Trade and the Global Market. Lexington, KY: University Press of Kentucky. 392 p.
- Kearns, C.A., D.W. Inouye. 1997. Pollinators, flowering plants, and conservation biology. Bioscience 47: 297-307.
- Moisset B., S. Buchmann. 2011. Bee Basics: An Introduction to Our Native Bees. U.S. Department of Agriculture, Forest Service. http://www.fs.usda.gov/Internet/FSE_

Common Name	Scientific Name	Flowering season†
Beggarticks	<i>Bidens alba</i>	Spring
Lance-leaved Coreopsis	<i>Coreopsis lanceolata</i>	Spring
Plains Coreopsis	<i>Coreopsis tinctoria</i>	Spring
Illinois Bundleflower	<i>Desmanthus illinoensis</i>	Late spring - summer
Purple Coneflower	<i>Echinacea purpurea</i>	Late spring - summer
Grey-headed Coneflower	<i>Ratibida pinnata</i> <i>Achillea millefolium</i>	Late spring – summer
Yarrow	<i>Asclepias syriaca</i>	Spring - summer
Common Milkweed	<i>Monarda fistulosa</i>	Summer
Wild Bergamot		
Partridge Pea	<i>Chamaecrista fasciculata</i>	Summer – early fall
Black-eyed Susan	<i>Rudbeckia hirta</i>	Summer – early fall
Boneset	<i>Eupatorium perfoliatum</i>	Summer – early fall
Maximilian Sunflower	<i>Helianthus maximiliani</i>	Fall
Canada Goldenrod	<i>Solidago canadensis</i>	Fall
Yellow Crownbeard	<i>Verbesina occidentalis</i>	Fall

† As per NPIN, Native Plant Information Network, www.wildflower.org. Additional information on plant species being considered for seeding can be found at <http://plants.usda.gov/> and in Hopewood and others (2015).

Table 2. Flowering herbaceous plants that are native to the eastern US that can be used as part of a pollinator-friendly groundcover seed mix, such as that described by Table 1. A minimum of 6 different flowering plants should be included in the mix. The utility of these species with tree-compatible seeding mixes recommended for use with the FRA has not yet been tested.

Common Name	Scientific Name	Flowering Season
Eastern Redbud	<i>Cercis canadensis</i>	Early spring
Serviceberry	<i>Amelanchier</i> spp.	Early spring
Washington Hawthorn	<i>Crataegus phaenopyrum</i>	Early spring -- early summer
Red Maple	<i>Acer rubrum</i>	Early spring
Willows	<i>Salix</i> spp.	Spring
Black Chokeberry	<i>Aronia melanocarpa</i>	Spring
Nannyberry	<i>Viburnum lentago</i>	Late spring
Tulip Poplar	<i>Liriodendron tulipifera</i>	Late spring – early summer
Black Locust	<i>Robinia pseudoacacia</i>	Late spring – early summer
Persimmon	<i>Diospyros virginiana</i>	Late spring – early summer
Basswood	<i>Tilia americana</i>	Early-mid summer
Sourwood	<i>Oxydendron arboreum</i>	Mid-summer
Gray Dogwood	<i>Cornus racemosa</i>	Summer
American Chestnut †	<i>Castanea dentata</i>	Summer
American Witchhazel	<i>Hamamelis virginiana</i>	Fall

† includes genetically improved hybrids, as described by French et al. (2015).

Table 3. Tree and shrub species that can be used with the FRA to provide flowers for pollinators.

DOCUMENTS/stelprdb5306468.pdf

Monteleone, A., J. Skousen, L. McDonald, J. Shuler, J. Pomp, M. French, and R. Williams. 2017. Evaluation of small tree and shrub plantings on reclaimed surface mines in West Virginia. *Land Degradation Development* 29: 1683-1693.

Native Plant Information Network. 2016. Native Plant Database. <https://www.wildflower.org/plants/>

National Research Council (NRC). 2007.

Status of Pollinators in North America. National Academy of Sciences, National Academies Press. Washington DC. 326 p.

Oliphant A.J., R.H. Wynne, C.E. Zipper, W.M. Ford, P.F. Donovan, J. Li. 2016. J., Autumn olive (*Elaeagnus umbellata*) presence and proliferation on former surface coal mines in Eastern USA. *Biological Invasions*, pp.1-17.

Ollerton J., R. Winfree, S. Tarrant. 2011. How many flowering plants are pollinated by animals? *Oikos* 120: 321-326.

Potts, S.G., J.C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger, W. E. Kunin. 2010. Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution* 25:6. p. 345-353.

Rathfon, R. J. Groninger, D. Jacobs, J. Burger, P. Angel, C. Zipper. 2015. Tree and shrub species selection for mine reclamation in the midwest region of USA. *Forest Reclamation Advisory No. 13. Appalachian Regional Reforestation Initiative*, US Office of Surface Mining.

Sayler, K.L. 2008. Land cover trends:

LIVE EACH DAY WITH COURAGE

Whatever challenges 2018 brings, we'll be here to maximize your investments, lower your costs, and reduce risk to your organization.

As your engineering and environmental partner, we'll help you tackle what's to come with courage, optimism, and plain hard work.



Trihydro is a national consulting firm that provides engineering and environmental solutions to meet the needs of the mining industry.

EVERYONE NEEDS PRINCIPLES TO GO BY.

Learn more about how we do business at trihydro.com.

1252 Commerce Drive, Laramie, WY 82070 | Plus a network of offices nationwide

WWW.TRIHYDRO.COM | 800-359-0251

Central Appalachians. U.S. Department of the Interior, U.S. Geological Survey. Available at <http://landcover.trends.usgs.gov/east/eco69Report.html>

Skousen J., C.E. Zipper, J. Burger, C. Barton, P. Angel. 2011. Selecting materials for mine soil construction when establishing forests on Appalachian mine sites. ARRI Forest Reclamation Advisory No. 8. 6 p.

U.S. Natural Resource Conservation Service. 2016. Plants Database. <http://plants.usda.gov/>

Zipper, C.E., J.A. Burger, J.M. McGrath, J.A. Rodrigue, G.I. Holtzman. 2011. Forest restoration potentials of coal-mined lands in the eastern United States. *Journal of Environmental Quality* 40: 1567-1577.

Acknowledgements

Faculty and researchers from the following universities and organizations contributed to this Forest Reclamation Advisory: American Bird Conservancy, Berea College, Green Forests Work, Indiana University of Pennsylvania, Ohio State University, Ohio University, Pennsylvania State University, Purdue University, Southern Illinois University, Stephen F. Austin State University, The American Chestnut Foundation, US Forest Service, US Geological Survey, US Office of Surface Mining Reclamation and Enforcement, University of Kentucky, University of Maryland, University of Tennessee, Virginia Tech, West Virginia University, and Wilkes University.

Authors

Tammy Horn (Tammy.horn@ky.gov), State Apiarist for Kentucky, Frankfort, KY.

Patrick Angel (pangel@osmre.gov), Office of Surface Mining, U.S.D.I., London KY.

Carl Zipper (czip@vt.edu), Virginia Tech, Blacksburg VA.

Michael Ulyshen (mulyshen@fs.fed.us), USDA Forest Service, Southern Research Station, Athens, GA.

Michael French (michael.french@acf.org) Green Forests Work, American Chestnut Foundation, Hope, IN.

Jim Burger (jaburger@vt.edu) Virginia Tech, Blacksburg, VA.

Mary Beth Adams (mbadams@fs.fed.us), USDA Forest Service, Morgantown, WV. ■



2020

CLRA SWS SER

Québec RE³ Conference
RECLAIM RESTORE REWILD

June 7-11, 2020
 Québec City Convention Centre
 Canada

WWW.RE3-QUEBEC2020.ORG

We are proud to host a joint conference between the Canadian Land Reclamation Association (CLRA), the Society for Ecological Restoration (SER) and the Society of Wetlands Scientists (SWS) from June 7th to 11th, 2020.

The proposed theme of the conference for 2020 is **"From Reclaiming to Restoring and Rewilding"**. It aims to stimulate discussions about the evolution of management approaches carried out by the societies invited to join the conference.



Before



After



Mine closure: **reclamation** for future generations

Our approach to mine closure is simple – we partner with clients to develop and implement tailored solutions that streamline reclamation and meet project objectives – all while considering stakeholder needs. Stantec is a world leader in the closure of operating, inactive, historic, and abandoned mines.

stantec.com/mine-closure