Case Studies for Successful Coal Ash and Mine Closure Using Innovative Cover Systems

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ABSTRACT

Design and construction of cost-effective cover systems are critical to successful coal ash and mine closure projects. Traditional cover system designs typically have involved comprehensive specifications for placement of highly specialized barrier and drainage systems with 12-18 inches (305-457 mm) of cover soils, that are then capped with 4-8 inches (102-204 mm) of a “vegetative soil layer” that is “capable of supporting the growth of vegetation”. A sustainable stand of vegetation will provide enduring control of erosion, capture precipitation to reduce and improve stormwater runoff quality, improve visual aesthetics and foster carbon sequestration while releasing oxygen into the atmosphere. Fertile and productive soils are essential to the development of sustainable vegetative covers.

Soil Health is defined as the continued capacity of soil to function as a vibrant living ecosystem that sustains plants, animals, microorganisms and ultimately, humans through nutrient cycling, filtering and buffering functions. One vexing issue facing successful restoration of coal ash and mining sites is the lack of available soils to cover coal ash and mining waste and create viable environments for establishing sustainable vegetation.

Obtaining acceptable soils can be problematic as most closure sites rarely have salvageable topsoil after decades of operation. The costs of procurement, transportation and placement of suitable offsite soils can be exorbitant on large closure projects. Fortunately, emerging technologies, such as biotic soil technology and prescriptive agronomic amendments can make marginal soils suitable for vegetative establishment with significant cost savings to utilities, mining companies and other stakeholders.

This paper presents an overview of soil testing requirements, guidance for the use of biotic soil technology and other agronomic formulations, and descriptions of complementary erosion control techniques with case histories documenting successful and cost-effective coal ash and mine cover systems. Moreover, these case studies will describe and detail longer term performance monitoring techniques to demonstrate sustained improvements in Soil Health.
INTRODUCTION

Establishment of adequate vegetative cover on Coal Combustion Residuals (CCR) closure sites is required in accordance with regulations under subtitle D of the Resource Conservation and Recovery Act (RCRA). Obtaining suitable vegetative establishment is a key objective in attaining a Notice of Termination (NOT) from the US Environmental Protection Agency (EPA) or local state regulatory agency to close out a project under the auspices of The Clean Water Act.

The Surface Mining Control and Reclamation Act (SMCRA) of 1977 is the primary federal law that regulates the environmental effects of coal mining in the United States. Beyond achieving regulatory compliance, a sustainable stand of vegetation will provide enduring erosion control, capture precipitation to reduce runoff and improve stormwater quality, and improve visual aesthetics. Beyond increasing land value sustainable vegetation releases oxygen into the atmosphere while fostering carbon sequestration in the developing soil profile as nutrient cycling progresses.

Successful rehabilitation of massive soil and vegetation disturbances from mining and fossil plants and subsequent coal ash or mine waste disposal requires a comprehensive and holistic approach. Those overseeing rehabilitation efforts must integrate and stage several considerations into a working relationship that entails proper planning and execution. With a goal of maximizing long-term performance while controlling closure costs, innovative approaches are required to overcome the absence of favorable growing conditions.

One vexing issue facing successful restoration of coal ash sites is the lack of available soils to cover coal ash deposits and create viable environments for establishing and sustaining vegetation. It is recommended that onsite topsoil or suitable overburden be removed and stockpiled for future use to support vegetation establishment. Research has shown that the ability of topsoil to foster and promote sustainable vegetation is linked directly to composition of the topsoil, especially the presence of naturally occurring soil microorganisms. This biological community in soil consists of countless species of bacteria, fungi, and other microbes that promote plant nutrient cycling and improve the soil structure.

Obtaining candidate cover soils at fossil plants and mines can be problematic, as these “soil poor” sites rarely have salvageable topsoil over decades of operation. Even if topsoil is harvested and stored, after a few weeks, only the very top of the stockpile (that portion of which is exposed to sunlight, air and water) actually remains biologically active. Lower levels of the stockpile become inert and would be better termed “top dirt”. Furthermore, topsoil functionality is often lost during the stripping and handling process while its composition is forever changed, never to be as viable as when present in the natural environment.

The costs of procurement, transportation and placement of suitable offsite soils can be exorbitant on large projects. Fortunately, emerging technologies, such as engineered
soil media and prescriptive agronomic amendments, can make marginal soils suitable for vegetative establishment with significant cost savings to utilities and other stakeholders.

SOIL HEALTH

Soil Health is defined as the continued capacity of soil to function as a vibrant living ecosystem that sustains plants, animals, microorganisms and ultimately, humans through nutrient cycling, filtering and buffering functions. (Schindelbeck, 2017). Once soils are on the path to becoming healthy, sustainable vegetation can occur leading to successful reclamation and rehabilitation – even on some of the most difficult sites. Key components of healthy soils are mineral matter, organic matter, biota, water and air in the approximated proportions shown in Figure 1.

![Figure 1 - Key Components of Healthy Soil](image)

Healthy soils have the capacity to support long-term vegetative cover on closure sites indefinitely, with minimal supplemental inputs and maintenance. This concept is known as sustainability. To achieve sustainability, soil specifications should include detailed requirements for properties such as texture, pH, nutrient content, organic matter, soil respiration, soluble salts, with additional provisions for pre-construction soil testing to ensure specification compliance and quality assurance. One time-proven methodology to ensure soil health and integrate successful control of erosion is to follow the Five Fundamentals of Sustainable Erosion Control (Theisen, 2015).

THE FIVE FUNDAMENTALS

The first fundamental is to assess the soil substrate to determine its make-up through comprehensive soil testing for agronomic potential and limitations. Only by confirming the chemical, biological, and physical properties of the growth media is it possible to understand the proper prescriptive approach to erosion control and vegetative establishment. The second fundamental requires an assessment of suitable plant species for achieving sustainable growth and effective erosion control – while meeting
the collective restoration needs or requirements of regulatory agencies, consultants and utility owners.

After soil, agronomic and species selection considerations have been addressed, it is necessary to analyze site conditions to assess and select erosion and sediment control measures – the third fundamental. Soil types, climate, seasonality, slope lengths, gradients and aspects, ditch and channel flow hydraulics, pond and stream banks, wetlands and more must be examined and proper controls selected.

The fourth fundamental entails proper installation practices critical to the success of the rehabilitation program. Complete guidelines and details must be developed and combined with onsite supervision to assure correct installation. Finally, once the restoration measures have been implemented all active sites should be routinely inspected and maintained at predetermined intervals and after each significant precipitation or other potentially damaging climatic event. Follow-up inspection and maintenance is the fifth and final fundamental.

The Five Fundamentals are not revolutionary advancements in the field of mining and coal ash rehabilitation, but rather represent the accumulation of experience-proven considerations for success at any project site. A web-based design and selection tool, Profile Soil Solutions Software (PS3), has been developed to facilitate the integration of erosion and sediment control engineering with agronomic considerations. PS3 software is a comprehensive resource for designing and selecting techniques to develop holistic, sustainable solutions for cost-effective erosion control, vegetative establishment and subsequent reductions in sediment and other pollutants that have the potential to migrate from coal ash and mining sites and enter water bodies. PS3 enables users to effectively integrate and stage multiple considerations into a functional working model that supports proper planning and execution of the Five Fundamentals. (Profile, 2015).

Successful restoration of mining and coal ash sites entails an inclusive approach to assess, address, manage and integrate treatments or techniques to overcome the considerable challenges presented in post-deposition environments such as poor substrates, large unprotected areas with high erosion potential, difficult access, adverse weather conditions and much more. Designers must then balance these challenges with other operational concerns such as budgetary constraints, cost of materials, availability of labor, the sequencing of earthmoving activities and required timing of completion for closure related activities.

TO SEED OR SOD?

Establishment of sustainable vegetated covers composed of a diverse palette of locally adapted species should always the first consideration over sod monocultures and even synthetic barriers. Species diversity is always the best measure to assure active growth and productivity over longer time periods of with improved resistance to drought, temperature extremes and disease or insect pressure. In fact, development of acceptable species diversity is a bond release requirement in the mining sector as it
facilitates transition of restored lands to naturally occurring climax plant communities. Although establishment of native species may initially be slower than fast growing, turf type grasses, denser and more enduring covers will be developed over time.

While sod can provide the rapid cover required to achieve an NOT, field experience show that it can be a poor decision over time. Beyond the increased grading and soil preparation costs, then the added time and expense related to obtaining, trucking and installing sod, there also may be unbudgeted maintenance costs. Unless sod is installed during an optimal growing season blessed with abundant precipitation, it will be vulnerable to stress from lack of moisture and will likely require supplemental irrigation. Moreover, even when well-watered, sod tends to develop a perched root system that may not work downward into the soil profile. Lack of a fully developed root system can reduce sod’s erosion control effectiveness and make it more susceptible to drought once supplemental irrigation is no longer available.

Turf-type sods do not provide desirable species diversity and are either cool or warm season species monocultures. Thus, they cannot be year-round performers and must be placed in climates and soils where they can persist. For example, placing warm season Bermuda grass sod in more temperate to northern climates can be very problematic because it will only be green and vibrant during the summer season, while dormant and brown over the rest of the year. This in turn allows for more invasive weed growth and higher maintenance costs for eradication of undesirable species. Another concern is the potential of Bermuda grass monocultures killed off should major cold temperature events occur. Likewise, cool season sods in geographies with long, hot summers will typically result in the gradual decline of vegetative cover. Therefore, erosion control experts generally will recommend seed over sod to create a more diverse and failsafe cover.

Finally, the majority of sod has plastic netting to improve harvesting, handling and placement. These nettings can become dislodged and become environmental hazards for mowers, wildlife entanglement and ultimately deposition in receiving water bodies, leading to concerns over the potential introduction of microplastics in aquatic environments. (USDA NRCS, 2016)

SYNTHETIC COVERS

Synthetic covers are another option for capping waste containment sites. These materials can be simplistically described as artificial turf laminated to a polyethylene geomembrane. Despite very high upfront costs, these products offer some compelling considerations to eliminate placement of 2 feet (0.6 m) of cover soil over waste materials with significant reductions in installation time. An increase in airspace with a cover that should not be susceptible to erosion are also desirable attributes. One manufacturer even claims an 80% reduction in carbon footprint compared to traditional soil/vegetative covers.
There are, however, questions regarding the carbon footprint and environmental legacy of synthetic cover systems over time. Will they endure against real-world environmental stressors such as ultraviolet radiation, violent storms, and temperature extremes? Certainly these covers will capture heat and raise surface and water temperatures versus the cooling effects of vegetated covers to help moderate climate change. Moreover, what is the fate of synthetic grass fibers as they detach and/or degrade over time? Are they destined to become microplastic contaminants in nearby surface waters?

Further, as these covers cannot capture or retain water, another concern is accelerated runoff during precipitation events. Larger detention ponds or treatments areas must be constructed to capture and treat stormwater runoff prior to discharge into receiving water bodies. This then reduces airspace as the capacity of the waste containment facility is laterally compromised. By contrast, vegetated covers act as reservoirs and buffers to reduce quantity and improve quality of stormwater exiting containment facilities.

Aesthetic considerations also play a role in the selection of natural or synthetic cover systems. A constant, uniform green or tan color, while appealing for a sports field, will never match the natural environment for color mosaic and diversity over the changing seasons. This type of stark landscape may impact the potential for creative and environmentally beneficial uses such as parks, recreational areas or wildlife refuges.

TRADITIONAL COAL ASH CAPPING DESIGNS

Traditional cover system designs typically involve comprehensive specifications for placement of highly specialized geosynthetic barrier and drainage systems capped with layers of protective soil, which are then covered with topsoil and revegetated. Cover soil depths typically range from 18-24 inches (457-610 mm) and then are capped with 4-8 inches (102-204 mm) of a topsoil or “vegetative soil layer,” often with vaguely specified requirements such as “capable of (or suitable for) supporting the growth of vegetation.” Figure 2 presents a schematic of a basic coal ash cover design employing a multi-layered engineered capping system.

![Figure 2 – Schematic of Coal Ash Cover Design (Duke Energy, 2015)](image)
As noted earlier, obtaining candidate soils at fossil plants can be problematic as these “soil poor” sites rarely have salvageable topsoil after decades of operation. The costs of procurement, transportation and placement of suitable offsite soils can be exorbitant on large coal ash closure projects. The processes used to excavate, transport, and then spread the soil generates significant air, water and noise pollution concerns. Moreover, the time required to complete these processes can significantly delay the project, especially during periods of inclement weather resulting in saturated or frozen soils.

It is widely accepted that soils capable of supporting sustainable vegetation should contain at least 5% organic matter – hence the slogan “Strive for 5% Organic Matter”. Realistically, in practice, most “construction” soils offer less than 1% organic matter which is typically insufficient to support sustainable vegetation. It is also important to understand the stormwater management benefit of organic matter in soils. Depending upon soil type, for every 1% increase in organic matter, the soil can capture and hold between 16,500 and 27,000 gallons of water per acre (154,461 and 252,755 L/ha) (USDA NRCS, 2013).

How can this shortfall in organic matter be best overcome? The traditional options are by importing copious quantities of topsoil, compost, peat, and manure or sources of fibers such as wood chips, saw dust and more. It is suggested instead that a paradigm shift be considered, where a process is initiated to develop organic matter onsite rather than importing it.

Emerging technologies, such as engineered soil media, biotic soil technologies and prescriptive agronomic formulations, can make marginal soils suitable for vegetative establishment with significant cost savings to utilities and other stakeholders. When combined with prescriptive seed mixes and highly effective erosion control materials, more cost effective and environmentally friendly revegetation of mining and coal ash cover systems can be accomplished. Ideally, materials utilized in the development of growing media and establishment of vegetation would be derived from recycled natural sources, completely biodegradable, free of plastic and safe for the environment.

ENGINEERED SOIL MEDIA

In the absence of adequate sources of “topsoil,” new techniques have been developed to treat and revive depleted soils in order to render them more capable of accelerating and sustaining vegetative growth. Essentially, on-site soils can be modified and/or blended to improve their physical and biological properties. Beyond that, agronomic amendments such as those used to increase organic matter and fertility can be added to effectively “engineer” marginal soils into productive and sustainable growth media.

Engineered Soil Media™ (ESM) is a term to describe the emerging field of manufactured growth media containing naturally derived biodegradable fibers, biostimulants, biological inoculants, soil building components and other materials designed to accelerate sustainable vegetative establishment and promote regeneration of denuded soils. ESM have been developed as cost-effective alternatives and/or complements to soil, compost and other materials that are commonly prescribed when
topsoil is unavailable or too costly to import, lacking nutrients and organic matter, or in situations where there is little to no biological activity in the soil.

ESM contain a variety of components that can be grouped into three sub-categories as those described below:

Base Fiber Components
- 100% recycled, phytosanitized, “peat-like” bark and wood fibers that are free of weed seeds and potential pathogens to provide organic matter, erosion resistance and high moisture retention to facilitate plant growth.

Building Components
- Biochar (biological charcoal) which are stable, porous particles that demonstrate a high Cation Exchange Capacity (CEC) which measures a material or soil’s ability to hold water and nutrients. Biochar also acts as habitat, analogous to a coral reef for beneficial bacteria and fungi to colonize.
- Porous ceramic particles from calcined illite clay which improve infiltration while also increasing moisture and nutrient retention. These particles also provide a very high cation exchange capacity and habitat for microorganisms.
- Beneficial Bacteria, which colonize “fresh” substrates and are essential for soil processes, nitrogen fixation, aggregation of soil particles, and maintenance of soil nutrients.
- Endomycorrhizae, a symbiotic association of fungi with plant root hairs to facilitate nutrient and water uptake which improves drought, disease and salinity resistance.
- Humic acid, the principal component of humic substances, which are the major organic constituents of soil (humus) and peat produced by biodegradation of dead organic matter.
- Seaweed extracts, a natural source of cytokinins – which are plant growth substances (phyto-hormones) that promote cell division or cytokinesis in plant roots and shoots.

Performance Enhancing Additives
- Naturally derived, Cross-linked polysaccharide biopolymers or flocculants, which increase water-holding capacity, viscosity, bond strength, erosion resistance and flow of the hydraulic slurry through installation equipment.

ESM are typically mixed with water and hydraulically-applied as a uniform slurry using standard hydraulic seeding and mulching equipment; offering the distinct cost advantage of also placing seed, fertilizer and other amendments in one convenient application. Although ESM offer a moderate level of erosion protection, they normally are covered with higher performing hydraulically-applied, rolled or other erosion control materials, even blown straw or hay and sod to further protect the soil and provide additional moisture retention for growth establishment.
A two-step combination of an ESM and a Flexible Growth Medium™ (FGM) erosion control matrix applied at standard areal rates can absorb and retain over 11,000 gallons per acre (103,000 L/hectare) of water. It is a distinct cost saving advantage to use the same hydraulic seeding equipment to apply an erosion layer over the ESM. (Theisen, 2017)

Upon application, ESM will not match topsoil when considering physical properties such as depth, volume, texture, sieve analysis and possibly organic matter. Alternatively, ESM foster topsoil development on deficient substrates within the rhizosphere – the region of soil where plant roots are concentrated and the soil’s chemistry and microbiology are influenced by their growth, respiration, and nutrient exchange. The initial input of organic material from the ESM and overlying erosion control materials promotes faster seed germination and provides long term nutrient cycling that enhances sustainable vegetation establishment as additional organic matter is developed. Monitoring of sites treated with ESM have documented significant increases in organic matter and microbial communities within just one growing season.

Unlike field harvested topsoil, sub-soil and compost; these materials are manufactured under controlled factory conditions with specific formulations that ensure product quality, consistency, and performance.

ENGINEERED SOIL COVER SYSTEM (ESCS)

Since the primary functions of ESM are to accelerate growth of sustainable vegetation and increase organic matter in depleted soils, these materials can be considered as a functionally equivalent alternative to topsoil on coal ash or mining cover systems. Figure 3 offers a traditional vegetated cover design versus an engineered soil cover system.

![Figure 3 – Side by Side Comparison of Traditional versus ESCS Alternative](image)

Independent of the required cover soil thickness, an ESCS can potentially eliminate 4-8 inches (102-204 mm) of topsoil. A good rule of thumb is to estimate that topsoil will cost 4 to 5 times the installed cost of cover soil. For example, an 18" (457 mm) cover soil and 6" (152 mm) top soil design could be replaced with a 24" (610 mm) cover soil topped with an ESM, resulting in substantial cost savings over large sites. Roots of the
vegetation will carry the BSM plant and soil development components downward into the subsoil and begin converting it to a more productive growth medium. If physical and environmental stressor considerations can be accommodated with a reduction in cover soil thickness, then additional cost savings may be offered by the ESCS.

CASE HISTORY #1 – Tennessee Valley Authority Kingston Fossil Plant

The Tennessee Valley Authority (TVA) Kingston Fossil Plant coal ash pond breach led to significant changes in the regulations for CCR management, handling and storage. In the days, weeks, months and then years after the disaster, TVA and its supporting consultants and contractors conducted a herculean effort to first mitigate the disaster and then successfully reverse its environmental impacts.

Vegetation establishment over seemingly hostile substrates and topsoil unavailability was a major impediment toward successful site restoration. Soil test results revealed a sandy loam cover soil that was somewhat acidic (pH – 5.9) with only 1% organic matter and low nutrient levels. In lieu of topsoil, a compost manufactured from buffalo droppings was specified to increase organic matter content of the cover soil while supplying some nutritive value. Biostimulants and a soil neutralizer were specified per as shown in Table 1.

Table 1 – Soil Amendments and Application Rates

<table>
<thead>
<tr>
<th>Soil Amendment</th>
<th>Description</th>
<th>Rate (lb/ac)</th>
<th>Rate (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td>19-19-19 (N-P-K)</td>
<td>250</td>
<td>280</td>
</tr>
<tr>
<td>Micronized Lime</td>
<td>Calcium carbonate</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Biostimulant A</td>
<td>Fast acting</td>
<td>5</td>
<td>47</td>
</tr>
<tr>
<td>Biostimulant B</td>
<td>Sustained release</td>
<td>160</td>
<td>179</td>
</tr>
<tr>
<td>Engineered Soil Media</td>
<td>Buffalo chip compost</td>
<td>4,000</td>
<td>4,480</td>
</tr>
</tbody>
</table>

The prescribed seed mix included both cool and warm season perennial grasses, legume and an annual cover crop at the following rates during the active growing season as shown in Table 2.

Table 2 – TVA Kingston Seed Mix

<table>
<thead>
<tr>
<th>Seed Type</th>
<th>Rate (lb/ac)</th>
<th>Rate (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall Fescue</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>Bermuda Grass</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Perennial Ryegrass</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>Weeping Love Grass</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>White Sweet Clover</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Red Clover</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>German Millet</td>
<td>15</td>
<td>17</td>
</tr>
</tbody>
</table>

Other areas out of the coal ash exclusion zone were designated to create linear parks and recreation areas and treated with a “Deer and Turkey Habitat” seed mix composed
of 16 native and indigenous grasses, forbs and legumes. There was also a Detention Basin Mix that incorporated native wetland and aquatic species.

The engineered soil, soil neutralizer, fertilizer, biostimulants and seed were applied in the first pass and then, topped with a flexible growth medium at a rate of 3,500 pounds per acre (3,490 kg/ha). Installation of the cover system proceeded through 2013-14 with restoration starting on the final cover in the fall of 2013. Figures 4 - 7 document the construction of the final cover and dramatic results from the same vantage point. Subsequent site visits have confirmed the sustained vegetation, cover and efficacy of the design employed by TVA.

Figure 4 – Final Grading of Ash (2013)  
Figure 5 – Installation of Cover System

Figure 6 – Installation of Final Cover  
Figure 7 – Luxuriant Growth in 2015

Figures 8 and 9 illustrate the massive ash pond failure in 2008 and document the dramatic results showing following completion of the restoration efforts in 2015.
CASE HISTORY #2 – Southeastern US Clay Mine

After several years of activity, in 2003 a specialty clay mining company attempted to reclaim a 39 acre (15.8 ha) site. Successful reclamation would allow the company to gain its closure bond release and obtain permits to open up adjacent properties for future mining. Following four reclamation attempts over 13 years employing traditional seeding and straw mulching techniques, a 5 acre (2 ha) section near a valuable water body sat partially barren and badly eroded as shown in Figures 10 and 11.

When the site experienced heavy rain events typical of the region, the seeds and straw mulch were washed away and erosion commenced. Over time, rill and gully formation progressed to create a highly denuded landscape with small amounts of vegetation struggling to persist. In November of 2015, the mining company was approaching a deadline for mine closure and to obtain their reclamation bond release from the regional regulatory authority. A fourth failed attempt at revegetation was not an option. An expert team assessed the project site encompassing The Five Fundamentals for Successful Reclamation. The first step in the process was to conduct tests to determine soil fertility and other relevant properties to assess soil health and steer the project...
toward sustainable vegetative establishment. The soil tests revealed poorly draining, highly erosive soils with low fertility and low organic matter as described in Table 3.

Table 3 – Soil Test Analysis (Profile, 2016)

Based upon the soil test results and site assessment a comprehensive design was developed to address the deficient soils and high erosion potential. Topsoil was the first option to address the low organic matter content and low nutrient levels. However, the nearest sources were located nearly an hour (over 50 miles) from the site, ruling out topsoil due to the exorbitant transportation. Soil amendments and engineered soil media represented significant cost savings and were prescribed as presented in Table 4.

Table 4: Prescriptive Soil Amendments

<table>
<thead>
<tr>
<th>Soil Amendment</th>
<th>Rate (English)</th>
<th>Rate (SI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineered Soil Media</td>
<td>5,000 lb/ac</td>
<td>5,600 kg/ha</td>
</tr>
<tr>
<td>Fast-Acting Biostimulant</td>
<td>5 gal/ac</td>
<td>47 L/ha</td>
</tr>
<tr>
<td>Slow-Release Biostimulant</td>
<td>160 lb/ac</td>
<td>179 kg/ha</td>
</tr>
<tr>
<td>Fast-Acting Lime</td>
<td>160 lb/ac</td>
<td>179 kg/ha</td>
</tr>
</tbody>
</table>

Next, a prescriptive seed mix was developed to include fast growing and locally adapted species and rates shown in Table 5.

Table 5: Prescriptive Seed Mix

<table>
<thead>
<tr>
<th>Seed Type</th>
<th>Variety</th>
<th>Rate (lb/ac)</th>
<th>Rate (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahia Grass</td>
<td>Pensacola</td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>Bermuda Grass</td>
<td>Common Unhulled</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Browntop Millet</td>
<td>Generic</td>
<td>18</td>
<td>8</td>
</tr>
</tbody>
</table>

Due to the high erosion potential a high performance Flexible Growth Medium was specified. This biodegradable material is composed of 100% recycled, Thermally Refined™ virgin wood fibers, naturally derived crimped, interlocking cellulosic fibers,
cross-linked biopolymers and water absorbents, and micro-pore granules. It provides greater than 99% erosion control effectiveness and increases growth establishment 8 times faster than bare soil with a functional longevity of up to 18 months. In addition, it is effective upon application and requires no curing or drying time to demonstrate highly effective erosion control.

As shown in Figure 12, the site was regraded using the “cat tracking” method to increase soil roughness, reduce erosion potential and create pockets for water capture and germination. The selected materials and products were installed in April of 2016 with growth commencing within three weeks.

In early June 2016, Tropical Storm Colin hit the project site and dumped 5 inches (127 mm) of rain in a 36-hour period. The site was inspected by the design engineer and he said, “The site did remarkably well with no erosion, rills, gullies or ditches forming (not even small rills). The ProGanics, Flexterra and soil amendments stayed in place after the event and the project area benefited from the overall design. The water clarity in the lake was clear and the site withstood a significant storm event.”

By September 1, 2016, the project was approved for reclamation release by the regional regulatory authority – opening up more permitted areas for mining. An interesting note about this project and timing was that one day after the project was released by the regional regulatory authority, Hurricane Hermine hit the area and dropped 10 inches (254 mm) of rain in a 24-hour period. However, the vegetative cover established at the site withstood the deluge and no erosion losses were reported. Figure 13 shows the site fully vegetated in October of 2016.

Monitoring of the site for organic matter, soil respiration (an indicator or biological activity), and total biological counts was performed from project initiation in March 2016 through September 2017 to provide validation and reclamation bond release. As shown in Figures 14 and 15, the key soil health parameters of organic matter and biological activity have increased significantly over the 18-month testing period:
The data collected offers compelling data demonstrating improvements in Soil Health and its long-term impacts on sustainable and successful site remediation.

- pH increased from 4.8 to 5.3
- Soil respiration increased by 271%.
- Bacterial counts increased by 240%.
- Fungal counts increased by 345%
- Organic matter increased from 0.4% to 2.0% versus a background level of 1.5%

Utilizing the Five Fundamentals in conjunction with and innovative ESM and biostimulant materials, improved soil health and sustainable vegetation was established which will allow full reclamation for this mine site. Post-closure monitoring confirms the mine site is demonstrating a return of soil health, sustainable vegetation and is on the path to restoration of the native plant community.
CONCLUSION

There are compelling reasons to properly design and construct vegetated cover systems over mining, coal ash and other waste containment sites. Arguments have been presented for incorporating comprehensive designs calling for agronomic soil tests and prescriptive soil amendments; diverse, site adapted seed mixes; proper erosion control materials; then correct installation, inspection and maintenance activities. These Five Fundamentals have been a time proven model for successful disturbed land reclamation working in many of the planet’s biomes, climates, and environments; addressing multiple types of soils and substrates.

Engineered soil cover systems (ESCS) can significantly reduce or eliminate the need for costly topsoil on coal ash cover systems with very promising results as documented in the two case histories presented. Engineered soil media work to accelerate vegetative establishment while effectively rejuvenating depleted soils in place as nutrient cycling progresses. ESCS can offer dramatic cost decreases over traditional excavation, hauling, spreading and placement of imported topsoil on coal closure sites.

Finally, compelling data demonstrating improvements in Soil Health and its long-term impacts on sustainable and successful site remediation was presented.

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REFERENCES


