Biotic Soil Technology for Cost Effective Mine Closure Cover Systems

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Profile Products LLC

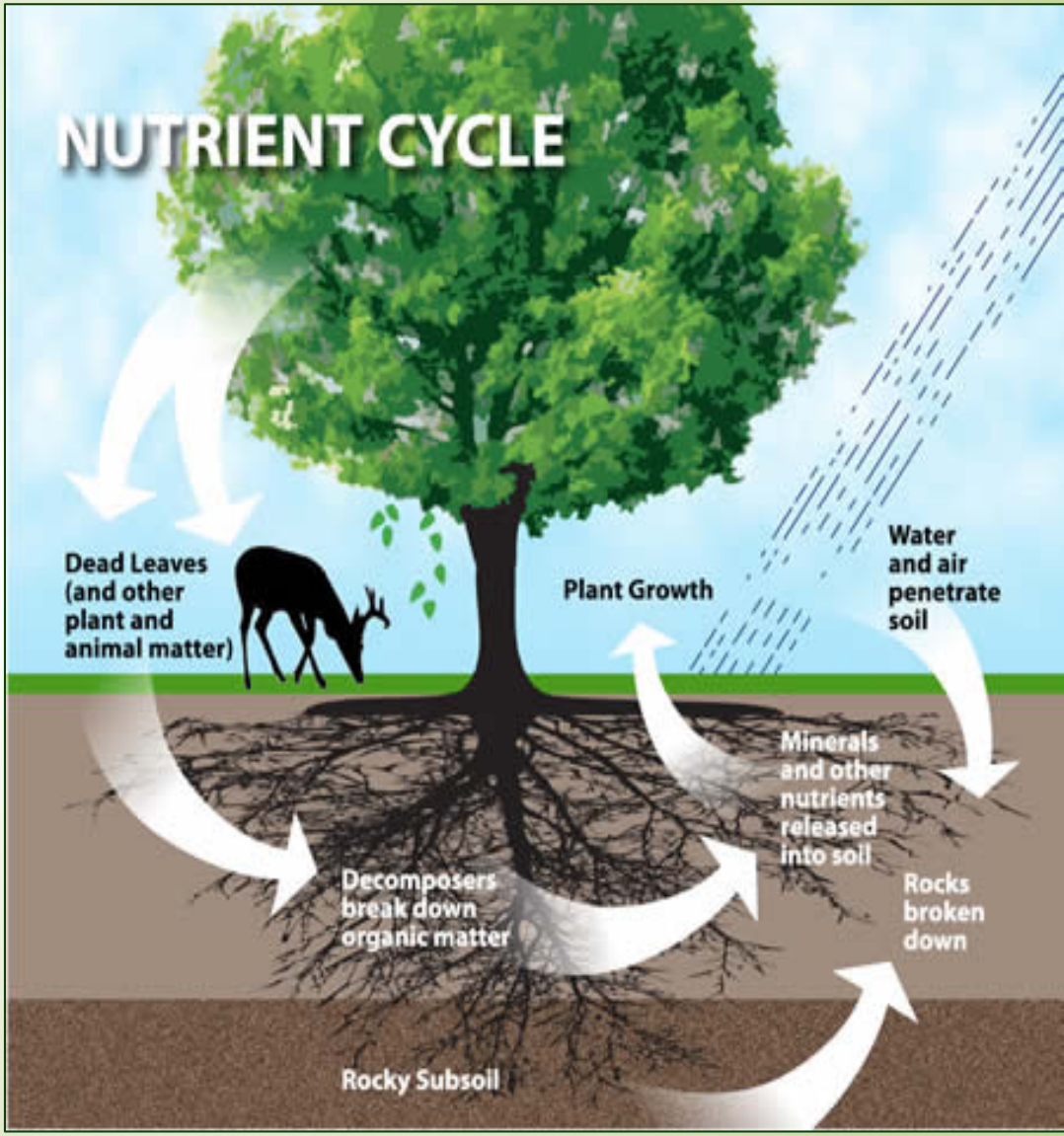
Presentation Overview

- What is **Biotic Soil Technology (BST)**?
- What goes into BST materials, how do they work, and when/where to use them?
- Engineered Soil Cover Systems (ESCS)
- Testing, Inspection and Monitoring Protocol
- Case Studies
- Discussion


What is the Most Cost-Effective form of Erosion Control?
Sustainable Vegetation!
04.29.2015 22:13

What Is Sustainable Vegetation?

- **Vegetation** that when once established **can persist through nutrient cycling** in the natural environment
- A **healthy soil is required** as the infrastructure to support and nurture vegetation
- The **vegetation must be adapted** to the site conditions.



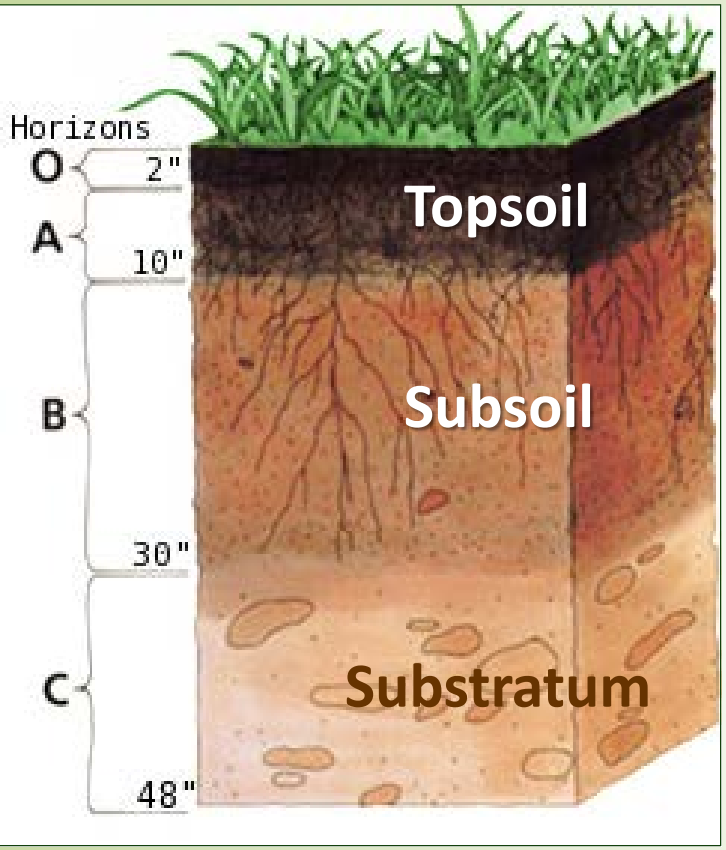
Key Elements of Healthy Soil

- **Minerals**
  - Carbon, macro-nutrients (N-P-K), micronutrients
- **Organic Matter**
  - Needed for microorganisms to convert or break down minerals to humus
- **Biological Activity**
  - Bacteria, fungi, protozoa, molds, nematodes, worms, etc.
- **Water**
  - Carrier of nutrients, all living things require water
- **Air**
  - Roots and many organisms require oxygen to survive

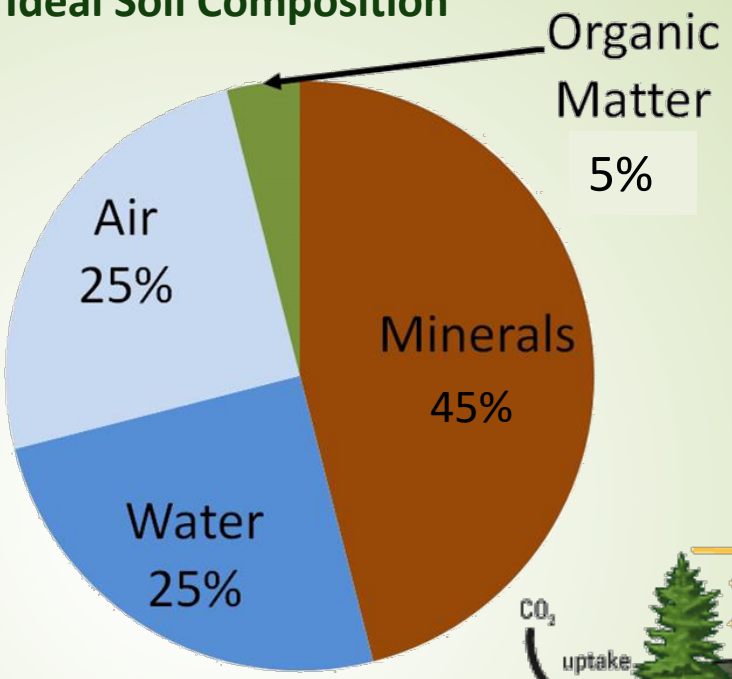
“Strive for 5%” Organic Matter

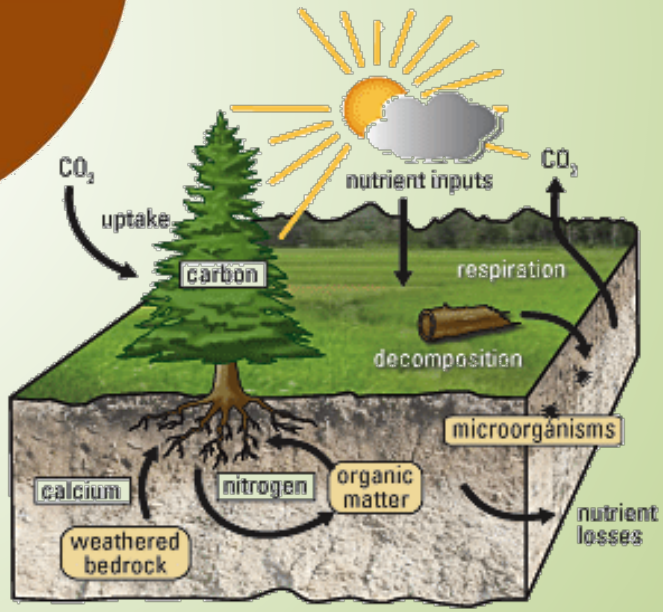
- **Improves establishment and survival of vegetation**
- **Improves soil structure** to better accommodate drainage and increases water retention
- **Improves erosion resistance**
  - Creation of pore spaces
  - Enhancement of soil aggregation (through microbial activity)
- **Reduces need for chemical based inputs**
  - Fertilizers, pesticides, herbicides and more
- **Improves rain/stormwater absorption and infiltration**
- For every **1% increase in organic matter, water-holding capacity increases by 16,500 to 27,000 gallons per acre** – depending on soil type (USDA NRCS 2013)

Ideal Soil Profile & Nutrient Cycling



Ideal Soil Composition

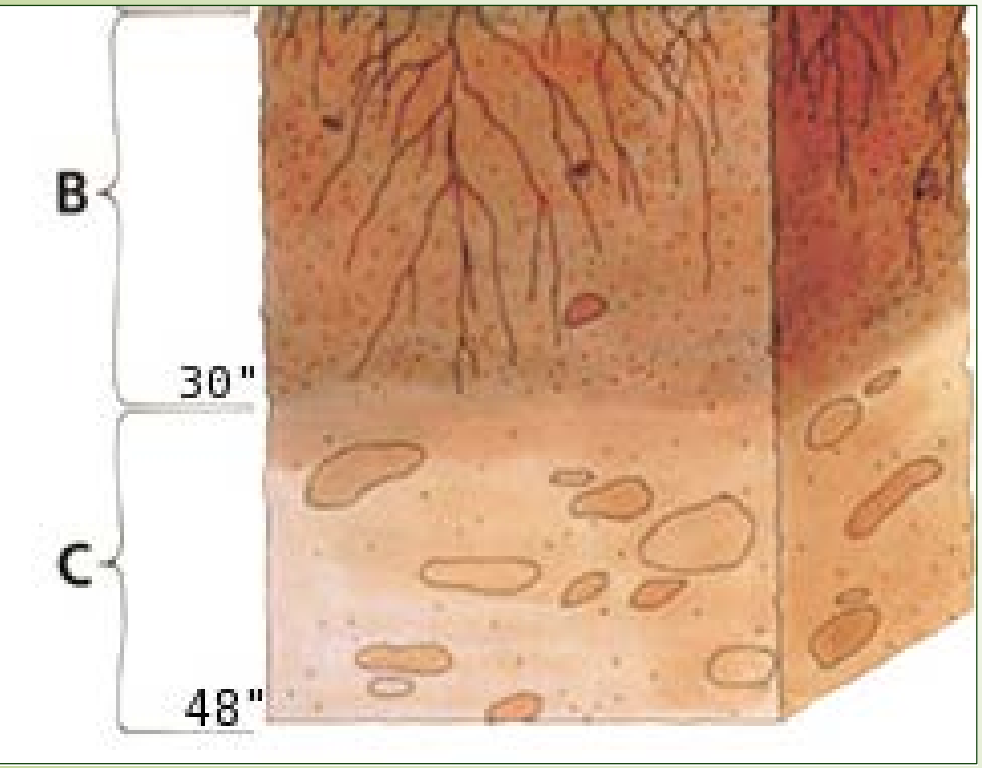




Carbon Sequestration!

Typical Denuded Site Soil Profile

Organic Matter < 1%



Most projects start with “B” or “C” horizons, maybe even worse:

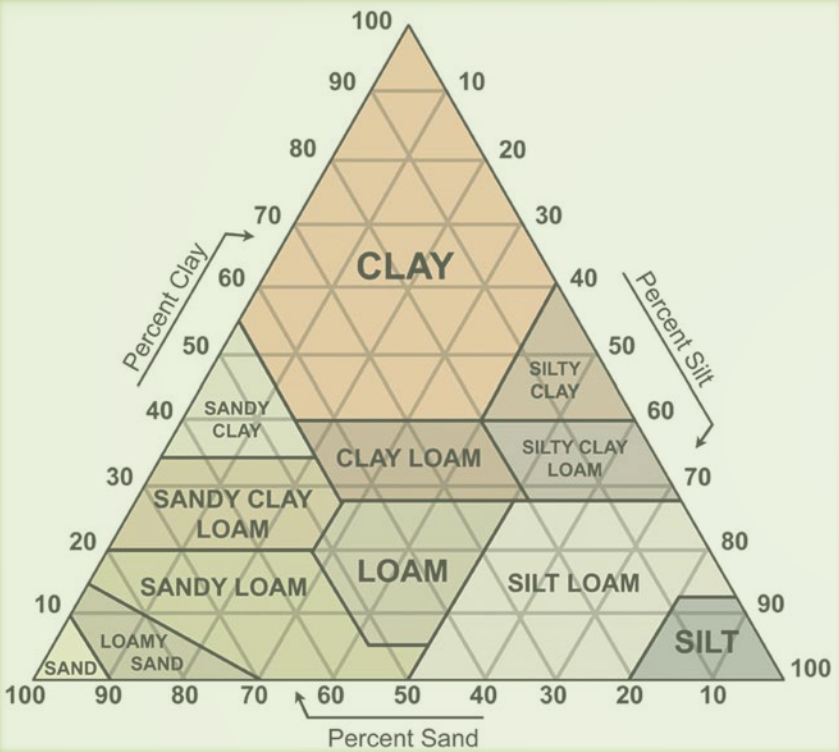
- Subsoils
- Saline Soils
- Mine Wastes
- Industrial Wastes
- Coal Combustible Residuals (CCR)

Start with a Soil Test!

Test	Objective
Water, salt and buffer pH levels	Soil reaction and neutralization requirements
Extractable Elements:	
Macronutrients – Primary and Secondary (NO_3, P, K, Ca, Mg, SO_4)	Nutrient element availability
Micronutrients (B, Cl, Cu, Fe, Mo, Mn, Se, I, Zn)	Nutrient element availability
Other Elements (Al, Na)	Toxicity
Trace Elements and Heavy Metals (As, Cd, Co, Cr, Cu, Mn, Pb, Ni)	Toxicity
Organic Matter Content	Physical and chemical characteristics
Soluble Salts	Total salts in soil solution

Agronomic Handbook Management of Crops, Soils, and Their Fertility **by J. Benton Jones, Table 11.1**

Soil Texture



- Quantitative classification based on **sand, silt, and clay** percent composition
- Determined using a **soil textural calculator** & **triangle**
- **Soil Texture can be an indicator** for Cation Exchange Capacity, Buffer pH, Moisture Retention, and Erodibility

Profile Technical Document

Soil Testing and Interpretation

Introduction

Soil testing, interpretation of the test results, and incorporating prescriptive remedies to improve soils should be a fundamental part of any reclamation or revegetation project. Without a proper understanding of soils or substrates considered for use as growing media to establish vegetation, it is difficult to predict potential project success.

Prior to conducting and interpreting soil tests, it is important to understand test methods that are relevant for reclamation and/or vegetation establishment projects. There are various ways to extract measurable soil characteristics and analyze samples, but rarely do varying soil testing methods produce identical results. Further, it is important to properly collect and label soil samples prior to sending them to a reputable lab. Profile Products provides detailed instructions in its PS^3 software program with three instructive videos that can be accessed at www.profileevs.com/video/soil-foundation-success-part-1-3. In addition, Profile has a laboratory dedicated to properly testing soils for erosion control projects at no cost to the client. Please go to www.profileps3.com and create your own account for more details.

Whether you are utilizing the Profile Products soil testing laboratory or another facility, please refer to the methodologies listed below to insure you are employing relevant testing protocol for erosion control projects that require vegetative establishment.

Testing Methodology

- Texture/Particle Size Analysis - Hydrometer Method
- Soil pH and Soluble Salts - 1:1 Soil/Water Slurry and Saturated Paste Extraction
- Buffer pH - Sikora Method
- Cations (Ca, K, Mg, Na) - Ammonium Acetate Extraction
- Phosphorus - Bray 1 Extraction or Olson Extraction
- Trace Elements (Zn, Mn, Cu, Fe) - DTPA Extraction
- Sulfur - Phosphate Extraction
- Boron - DTPA/Sorbitol
- Nitrate Nitrogen - Cadmium Reduction
- Salinity Evaluation - Saturated Paste Extraction
- All Soluble Nutrients - Saturated Paste Extraction

Consistency in testing methods allows for simplified and more rapid evaluations of the results. **Table 1 on Page 4 of this document provides optimal ranges for various soil parameters and values where deficiencies or excesses may compromise or limit vegetative establishment - using the test methods identified above.** If your soils were tested with different methods or you need assistance in reviewing soil test results from our lab, please contact Profile Products Technical Services Department at (847) 215-3464 or tech@profileproducts.com.

General Soil Test Interpretation

Soil Characteristic Tested	Unit	Low Value (Deficiency)	Optimal Range (Sufficiency)	High Value (Toxicity)
Texture	Physical Description	n/a	n/a	n/a
Organic Matter (OM)	OM mass/sample mass	< 3%	3% – 5%	> 10%
pH	0 – 14	< 6.3	6.3 – 7.3	> 7.3
$HC0_3$ (Bicarbonate)	ppm	n/a	< 50	≥ 50
Electrical Conductivity (EC)	mmhos/cm = ds/m	n/a	< 0.75	> 7.0
Total Dissolved Solids (TDS)	ppm	n/a	< 480	> 4480
Sodium Adsorption Ratio (SAR)	—	n/a	< 2.0	> 7.0
Nitrogen (N)	ppm	< 10	10 – 30	> 30
Bray 1 P (Phosphorus) pH < 7.2	ppm	< 20	20 – 40	> 40
Olsen P (Phosphorus) pH > 7.2	ppm	< 10	10 – 25	> 25
Potassium (K)	ppm	< 150	150 – 250	> 250
Magnesium (Mg)	ppm	< 60	60 – 300	> 300
Calcium (Ca)	ppm	< 400	≥ 400	n/a
Sulfur (S)	ppm	< 5	5 – 20	> 20
Zinc (Zn)	ppm	< 1.0	1.3 – 3.0	> 5.0
Manganese (Mn)	ppm	< 2.5	4.1 – 12.0	> 50
Copper (Cu)	ppm	< 1.0	1.0 – 2.0	> 2.0
Iron (Fe)	ppm	< 4.5	7.1 – 20.0	> 70
Boron (B)	ppm	< 0.5	1.0 – 1.5	> 2.0
Chloride (Cl)	ppm	< 10	10 – 20	> 800
Cation Exchange Capacity (CEC)	—	< 5	10 – 30	> 50

How Do We Increase Organic Matter Content in Our Soil?

- Topsoil
- Compost
- Peat
- Manure or biosolids
- Wood chips, sawdust, straw, etc.

Ideally – We Would Place 4-8 in. (10-20 cm) of Biologically Active, Organic Rich Topsoil Over Every Project

However,

- There is **not enough quality topsoil available**.
- Even if available, topsoil may be too wet or frozen to dig or transport.
- Topsoil cannot be effectively placed on steep slopes and can actually increase erosion potential.
- Stockpiled topsoil results in mostly **"top dirt"** since only the surface material remains biologically active after only a few weeks of storage.
- **Costs of obtaining, hauling and placing topsoil can be significant.**
- Borrow Areas must then also be reclaimed!

Stockpiling of Onsite Topsoil

Do you think there will be much biological activity within the pile within a few weeks?

Is your topsoil simply "The Dirt that lies on Top?"

Photo from Wikipedia


Claire Pendrous Copyright


Skip Brown

How About Just One Truck?

Applied with conventional hydraulic seeding equipment

Biotic Soil Technology (BST)

- **Generic term** to describe **manufactured growth media** or **“engineered soils”** containing recycled biodegradable fibers, biostimulants, biological inoculants and other amendments
- Designed to promote **regeneration of denuded soils** and accelerate **sustainable vegetative establishment**
- Why **import “topsoil”** when **you can build a soil** in place?

Mixing and Application

- **Pre-packaged bales** mixed with water, seed, fertilizer, amendments and other components
- **Applied below** hydraulically-applied or rolled erosion control products, blown straw or **even sod**
- **Complements performance** of hydraulically-applied erosion control products such as Flexible Growth Medium

One-Step Approach

More convenient/uniform application using standard equipment

Biotic Soil Media, Biostimulant, Seed, and Fertilizer Application
< 1.5 tank loads/acre with a 3,000 gallon hydromulcher

Safety!

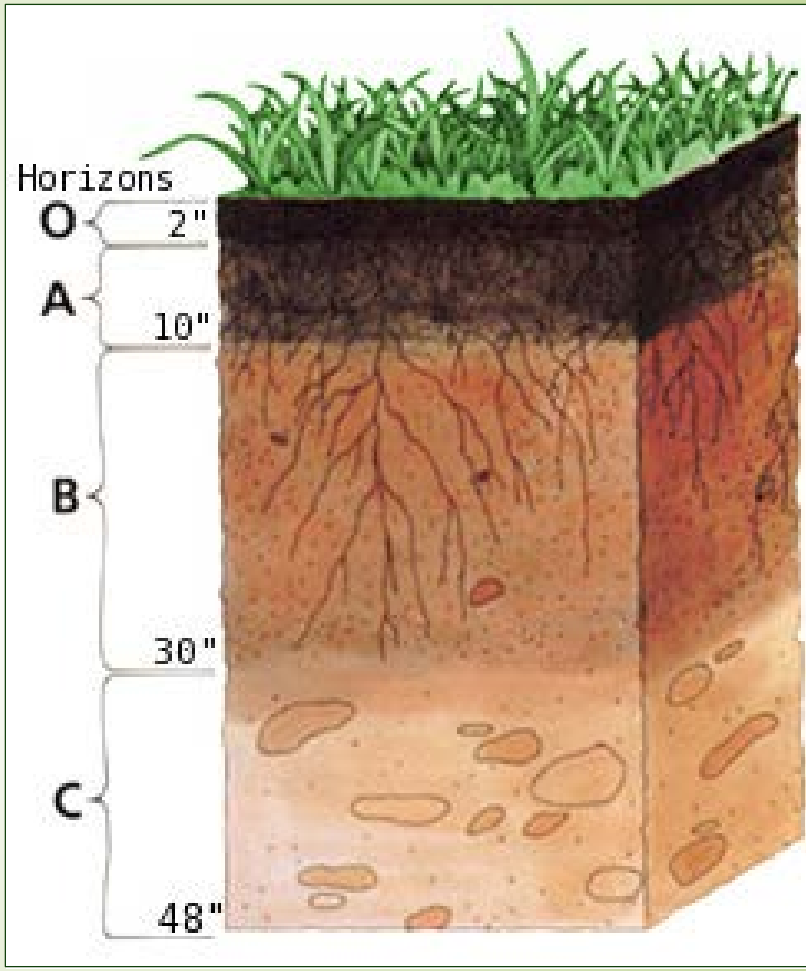
Caltrans
Hwy 133 & 241 Toll Roads

Some Common BST Components

- **Bark and Wood, Straw, Flax, Fibers** – **phyto-sanitized** to provide organic matter, erosion resistance and high moisture retention **without weed seeds and pathogens**
- **Soil Building Components:**
  - **Porous Ceramics and Biochar** – stable, porous particles that demonstrate a high CEC, ability to hold water/nutrients & act as habitat ("coral reef") for beneficial bacteria and fungi
  - **Beneficial Bacteria –** colonize "fresh" substrates and essential for soil processes, Nitrogen fixation, aggregation of soil particles, and maintenance of soil nutrients
  - **Endomycorrhizae** – symbiotic association of a **fungus** and plant roots to facilitate nutrient and water uptake that improves drought, disease and salinity resistance
  - **Humic Acid –** principal component of humic substances, which are the major organic constituents of soil (humus), peat and coal produced by biodegradation of dead organic matter
  - **Seaweed Extract (cytokinins) –** plant growth substances (phyto-hormones) that promote cell division or cytokinesis in plant roots and shoots
- **Cross-linked Polysaccharide Biopolymers/Flocculants** – increase water-holding capacity, viscosity, bond strength and **"shoot-ability"** of the media matrix

How Do BST Work to Build Soils?

- BST improves soil **chemistry** – which later improves soil **structure/texture** with **increased organic matter and biological activity** combined with plant establishment and subsequent nutrient cycling.
- Helps O & A horizons to regenerate faster by creating a **“revegetation platform”.**
- While the soil chemistry is improving, the media provides **a more ideal growing environment.**
- Provides rapid growth establishment and sustains long-term vegetation.



Five Weeks After BST Installation
Developing an "Engineered O Horizon"

North Carolina DOT

Typical BST Application Rates

% Organic Matter	lb/ac	kg/ha
< 0.75	5,000	5,600
≥0.75 to <1.5	4,500	5,040
≥1.5 to <2.0	4,000	4,480
≥2.0 to <5.0	3,500	3,920

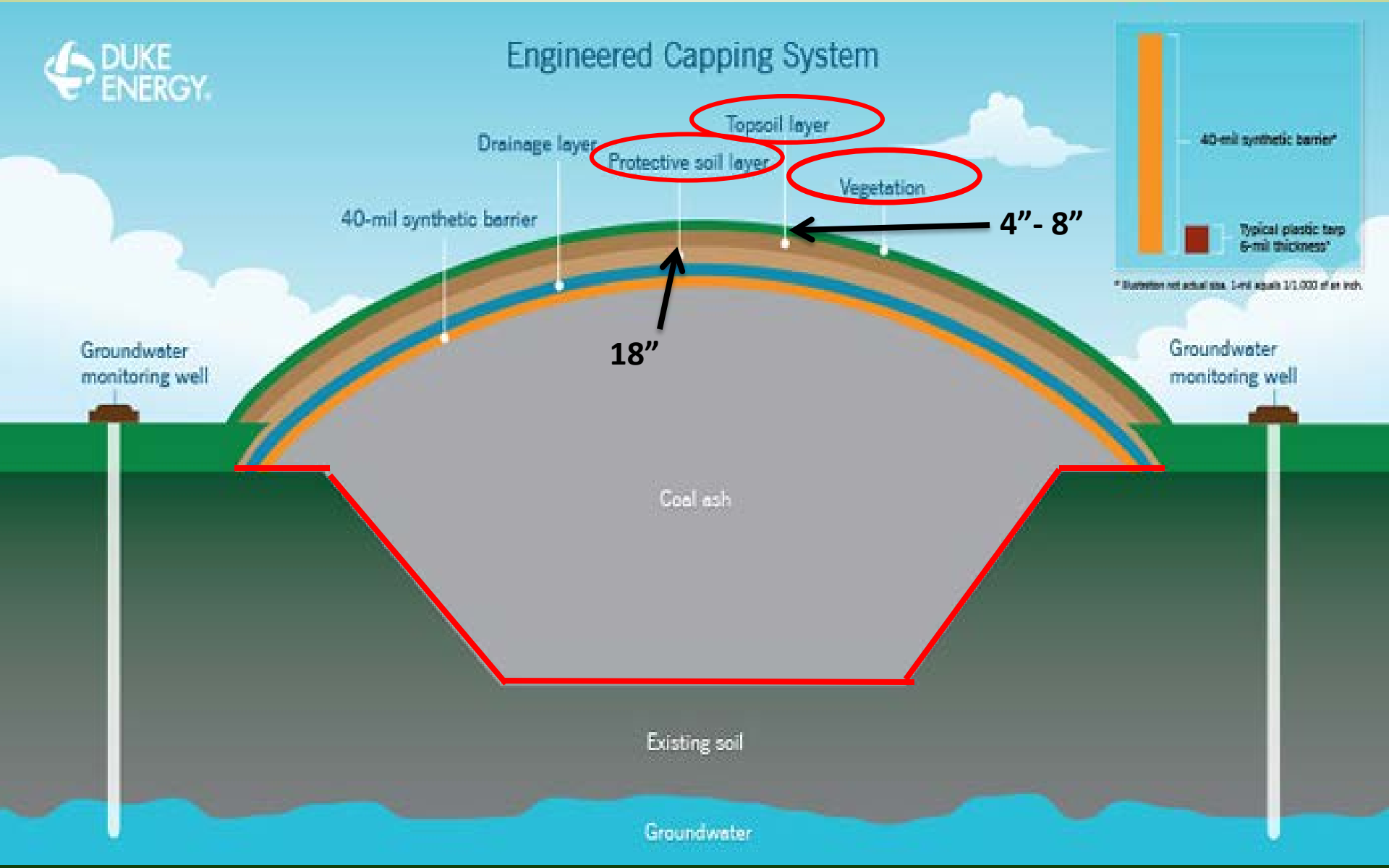
- Always conduct a soil test to determine agronomic needs.
- Soils with organic matter >5% typically do not require BST.
- Depending on the test results, it is typically advisable to apply fertilizer, pH neutralizers and/or additional biostimulants with BST.

Biotic Soil Technology (BST)

Descriptors or **Categories** include:

- Biotic Soil Amendment (BSA)
- Biotic Soil Media (BSM)
- Engineered Soil Media (ESM)
- Hydraulic Growth Medium (HGM)
- Hydraulic Biotic Soil Amendment (HBSA)
- Organic Fiber Matrix (OFM)

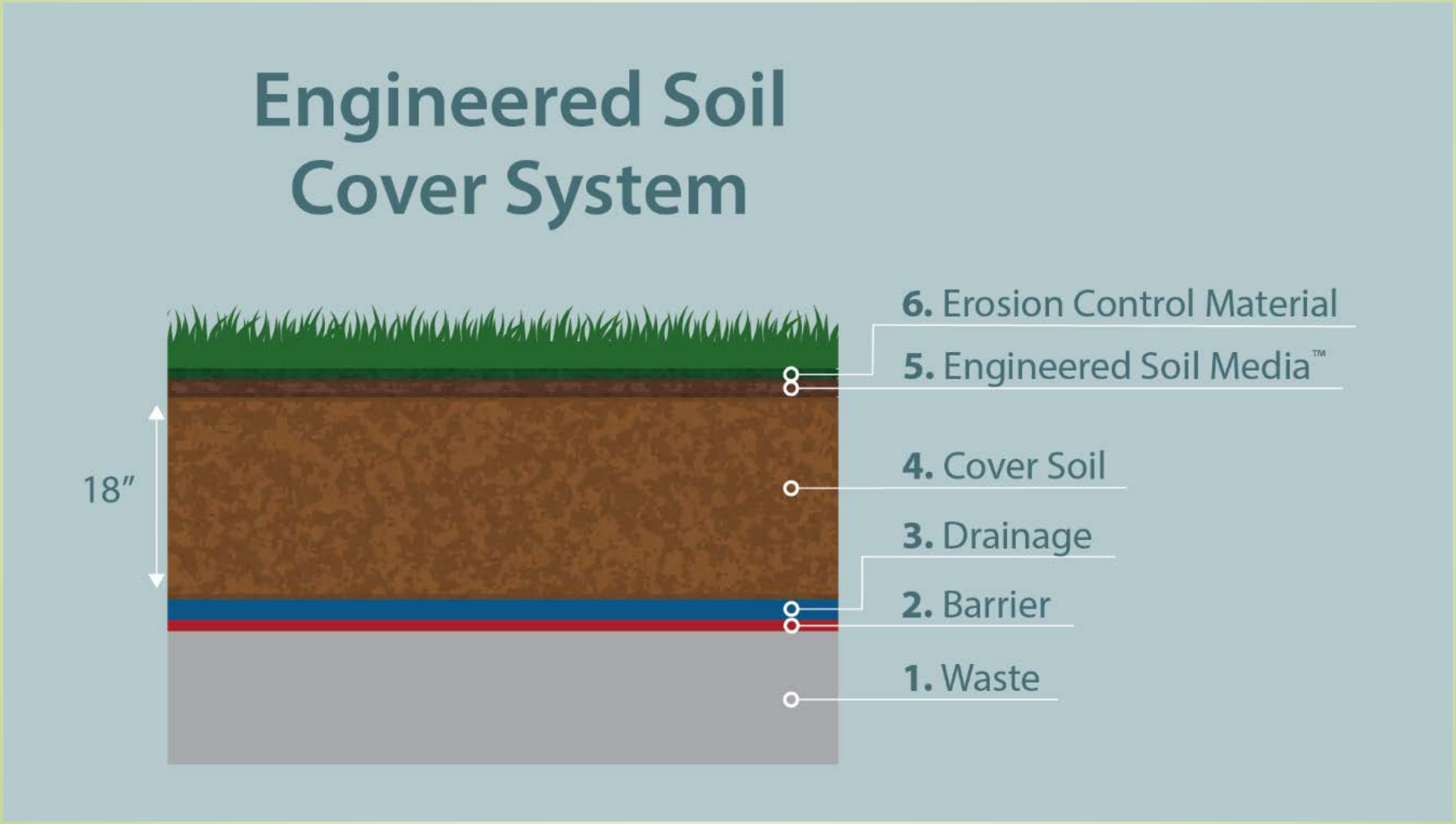
Coal Ash Closure Capping System



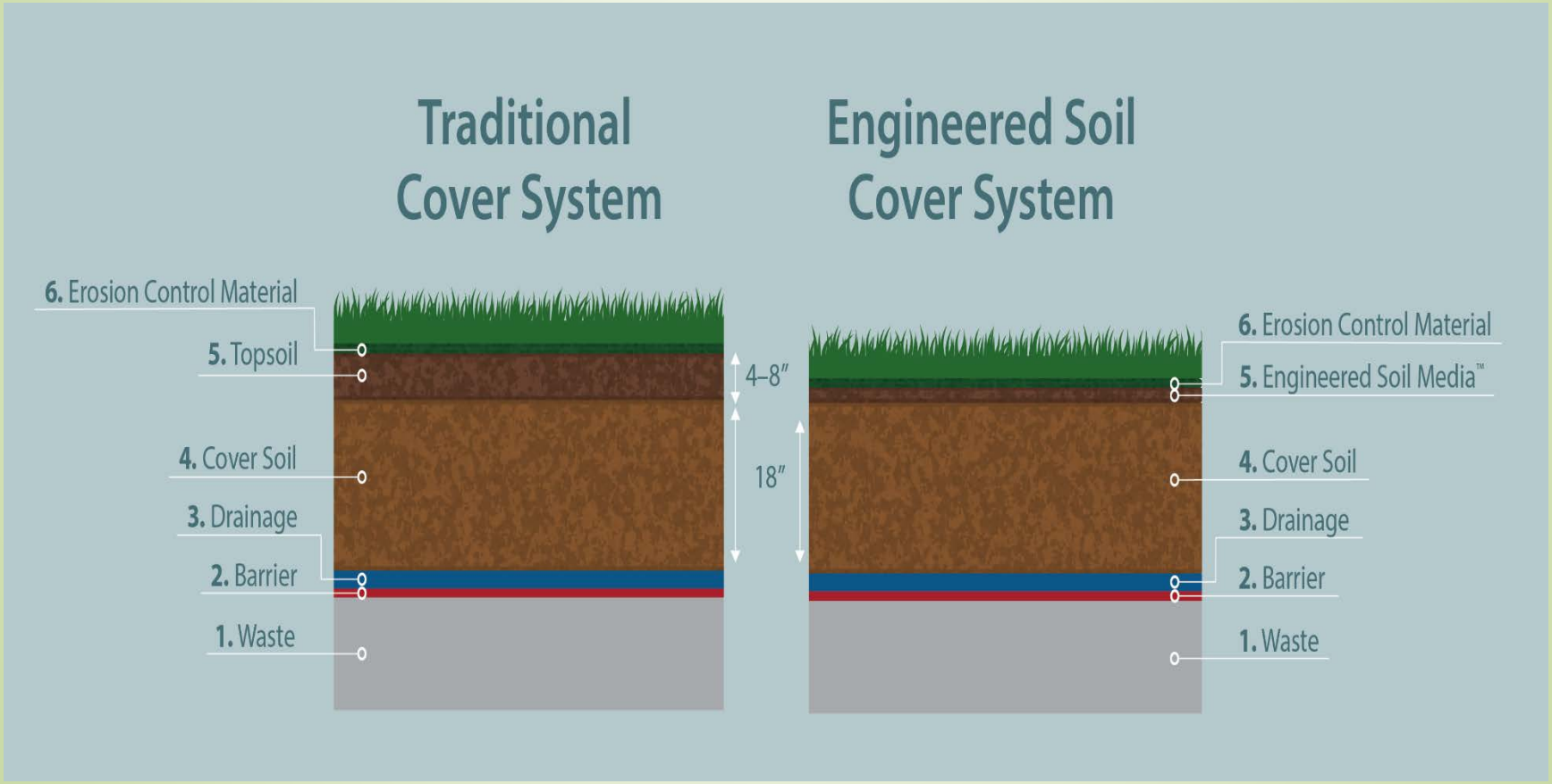
“Traditional Cover System”

18” Cover Soil and ~6” Topsoil

Engineered Soil Cover System (ESCS)



A Side by Side Comparison



Cost Comparison Calculator

Coal Ash Cover Example

Input Units:	U.S.	Editable Data
Acres	300	
Square Feet	13,068,000	

Volume Based Topsoil and/or Compost

MATERIAL COST

Material	Depth in Inches	Cubic Yards Needed	Cost Per Cubic Yard	Total Cost
Topsoil	6	242,000	$10.00	$2,420,000.00
Compost/Other	0	0	$0.00	$0.00
Total Material	**6**	**242,000**		**$2,420,000.00**

TRANSPORTATION & INSTALLATION COST

	Cubic Yards			Total Truckloads
Truck Size	22			11,000
Material Hauling	**Number Of Truckloads**	**Miles to Job Site**	**Cost Per Mile[1]**	**Total Cost**
Topsoil	11,000	0	$0.00	$0.00
Compost	0.0	0	$0.00	$0.00
Installation	**Cubic Yards Material**	**Cost Per Cubic Yard**		
Topsoil	242,000	$8.00		$1,936,000.00
Compost	0	$0.00		$0.00
Total Transportation & Installation Cost				**$1,936,000.00**
Total Cost				**$4,356,000.00**

Cost Comparison Calculator

ProGanics™ BIOTIC SOIL MEDIA

Material	Application Rate (lb/ac)	# Bags Needed	Cost Per Bag	Total Cost
Biotic Soil Media	3,500	46,297	$45.00	$2,083,370.08
Transportation		**Number Of Pallets[2]**	**Cost Per Pallet[3]**	
Biotic Soil Media		1,157.4	$0.00	$0.00
Installation[4]	**Acres**	**Cost per Acre**		
Biotic Soil Media	300	$2,000.00		$600,000.00
Total BSM Cost				**$2,683,370.08**
		BSM Cost Savings:	**38.4%**	**$1,672,629.92**

BSM Application on Cover System over Dirt FIll

Flexible Growth Medium Erosion Control “Cap”

Three Weeks Later!

Cripple Creek and Victor Gold Mine

- Famous gold mining district in Rocky Mountains of Colorado
- Elevation is 2,927 m (9,600 feet) in elevation
- Site receives snow in winter with summer rains, < 750 mm/year (30 in/year)
- Biotic Soil Technology was first applied in summer of 2014
- Topped with Flexible Growth Medium - FGM

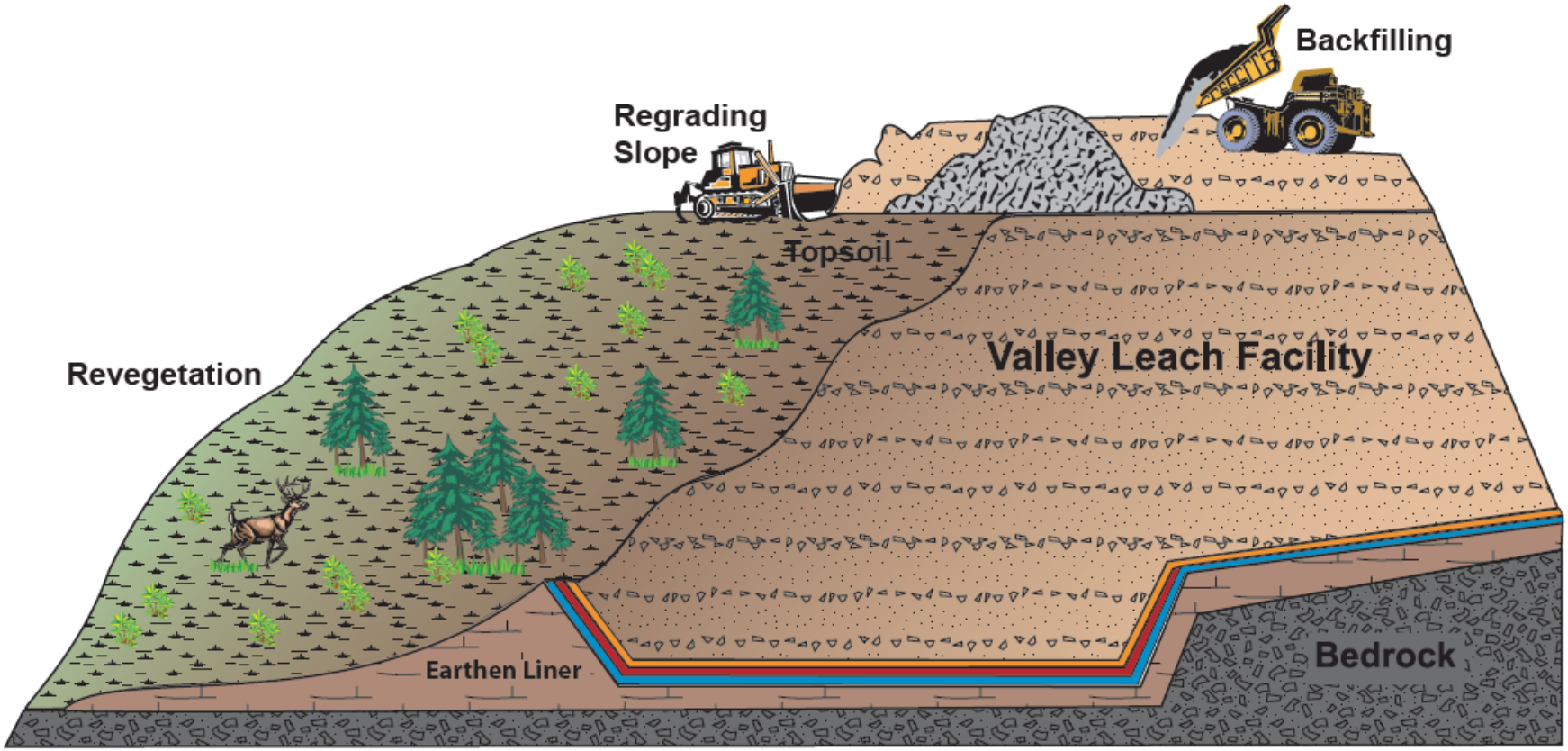
Cripple Creek & Victor Gold Mining Company

VLF Closure and Reclamation

PO Box 191 • Victor, CO 80860 • Phone (719) 689-4044 • www.ccvgoldmining.com

1. **VLF Chemical Closure:** Following gold recovery, CC&V will rinse the spent ore with water over a period of several years to meet State water quality standards.

2. **VLF Final Reclamation:** Following chemical closure activities, the VLF liner will be punctured and the slopes will be regraded to an erosionally-stable shape, topsoil will be placed, and the area will be revegetated to meet post-mining land use goals.



ANGLOGOLD ASHANTI
ANGLOGOLD ASHANTI (COLORADO) CORP


Remote Placement
of Biotic Soil Tech


Flexible Growth Medium
Applied Over BST


Hydroseeder w/Remote Hoses

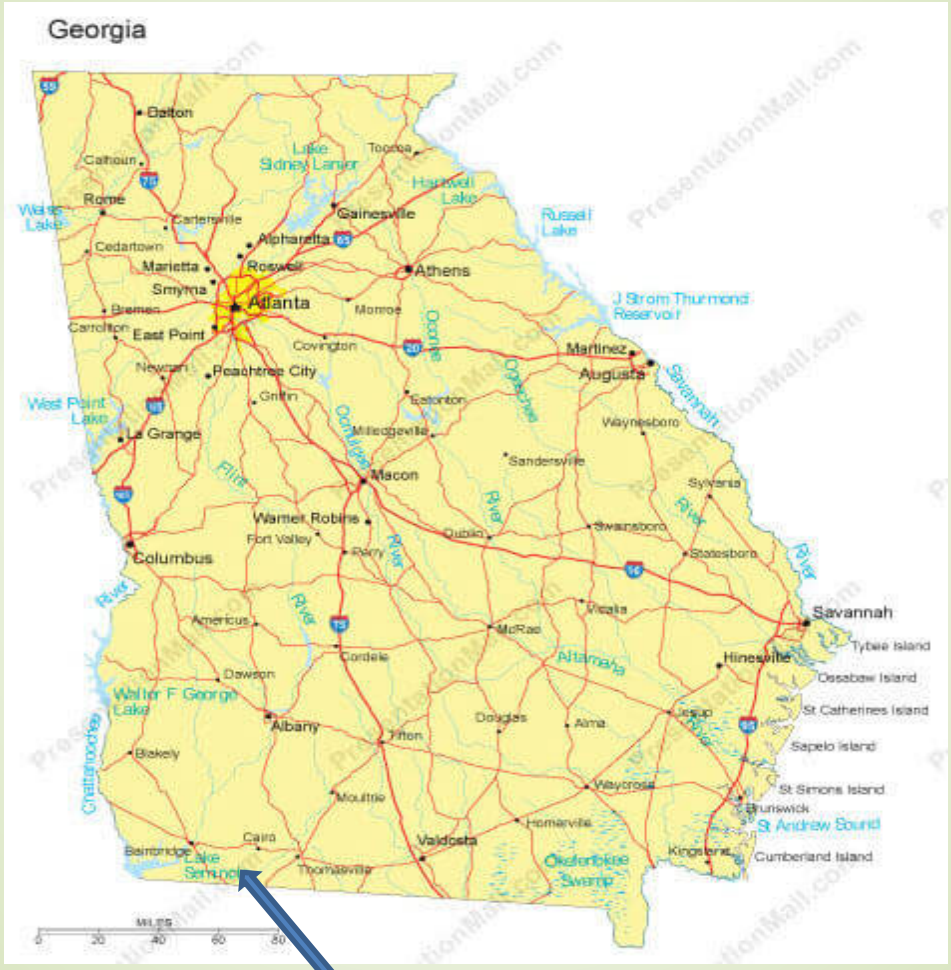
October 2014 -
Good growth for 1st Growing Season in High and Dry Climate

Degraded Mine Site
Southeastern US – March 2016

Erosion Over 10 Year Period

3 Failed Reclamation Attempts

Mine Location



Results of Initial Soil Tests

December 2015
Sandy Clay Loam • Organic Matter – 0.4% • pH – 5.0 • Very low in nutrients

Typical BSM Application Rates

% Organic Matter	lb/ac	kg/ha
< 0.75	5,000	5,600
≥0.75 to <1.5	4,500	5,040
≥1.5 to <2.0	4,000	4,480
≥2.0 to <5.0	3,500	3,920

- Always conduct a soil test to determine agronomic needs.
- Soils with organic matter >5% typically do not require BST.
- Depending on the test results, it is typically advisable to apply fertilizer, pH neutralizers and/or additional biostimulants with BSM.

April 25, 2016

Per soil test recommendations installed:

- **5,600 kg/ha (5,000 lb/ac) of BST**
- **3,920 kg/ha (3,500 lb/ac) of HP-FGM**
- **Fast-Acting Lime**
- **Slow-Release and Fast-Acting Biostimulant Additives**

Slopes were cat tracked to:

- **Increase soil roughness**
- **Reduce erosion potential**
- **Create pockets for germination**

April 25, 2016

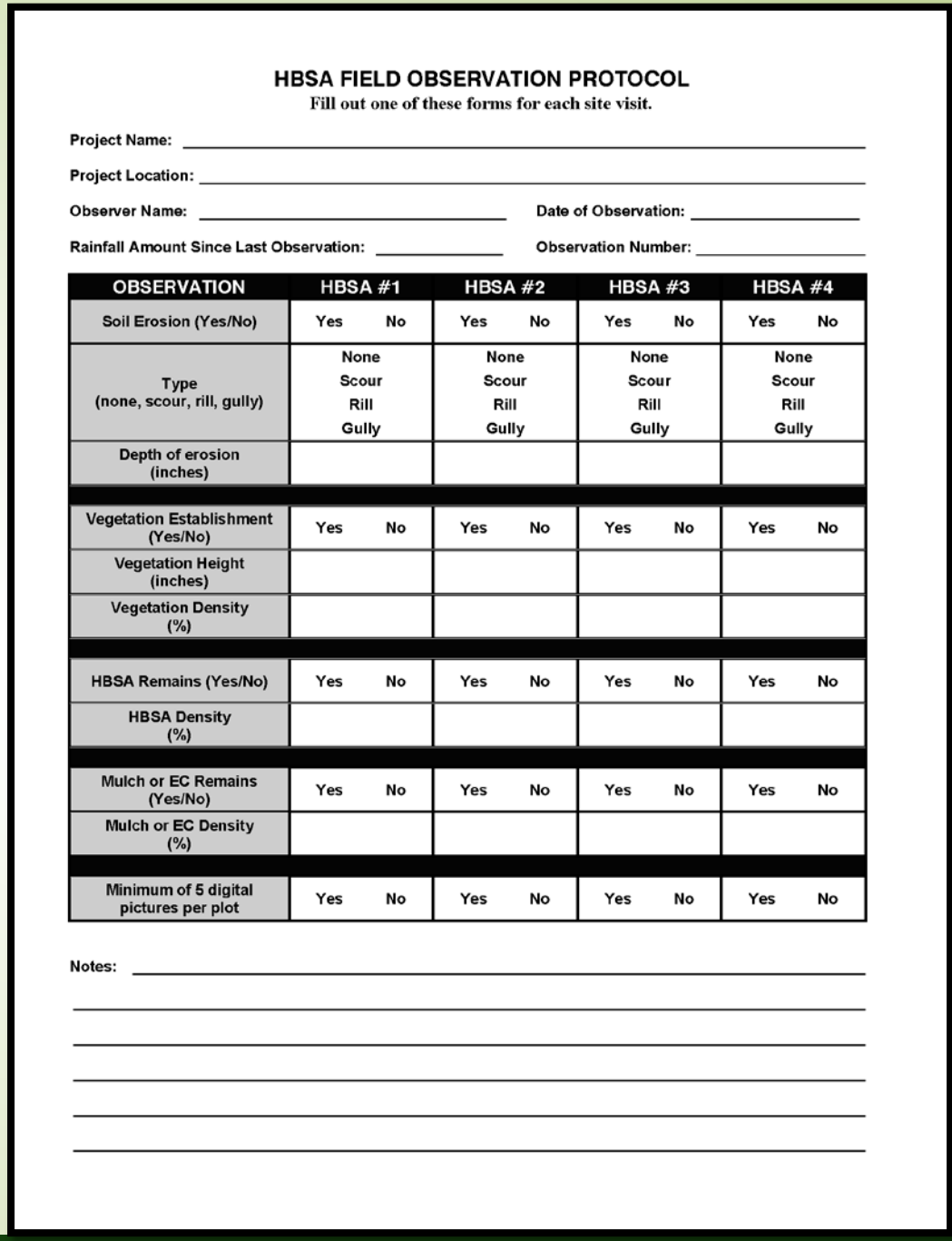
Drone shot of applications over 2 hectare (5 ac) site

- **Site after Tropical Storm Colin dumped 150 mm (6 in) of rain on June 5-6**
- **No soil loss into lake**

Day After Tropical Storm Colin

Field Data – Follow-up Visits

- Soil erosion
- Vegetation establishment
  - Basal Cover
  - Biomass
  - Species diversity
- Functional longevity
- Precipitation and weather data



HBSA FIELD OBSERVATION PROTOCOL

Fill out one of these forms for each site visit.

Project Name: _____

Project Location: _____

Observer Name: _____ Date of Observation: _____

Rainfall Amount Since Last Observation: _____ Observation Number: _____

OBSERVATION	HBSA #1	HBSA #2	HBSA #3	HBSA #4
Soil Erosion (Yes/No)	Yes No	Yes No	Yes No	Yes No
Type (none, scour, rill, gully)	None Scour Rill Gully	None Scour Rill Gully	None Scour Rill Gully	None Scour Rill Gully
Depth of erosion (inches)				
Vegetation Establishment (Yes/No)	Yes No	Yes No	Yes No	Yes No
Vegetation Height (inches)				
Vegetation Density (%)				
HBSA Remains (Yes/No)	Yes No	Yes No	Yes No	Yes No
HBSA Density (%)				
Mulch or EC Remains (Yes/No)	Yes No	Yes No	Yes No	Yes No
Mulch or EC Density (%)				
Minimum of 5 digital pictures per plot	Yes No	Yes No	Yes No	Yes No

Notes: _____

Mine Reclamation Complete

October 2016

Project Summary

- Initiated/Completed Final Design Jan/Feb 2016
- Completed Grading & re-Contouring & Application by end of April 2016
- Site inspection mid-August 2016 by Regulatory Agency
- Achieved Bond Release on September 1, 2016
- < 4 Months from Time of Installation until Release

Field Soil Properties

- Ongoing testing of representative site soils conducted by an accredited laboratory
- Determine agronomic potential
- Monitor key parameters such as:
  - pH, texture, percent OM, availability of macro- and micro-nutrients, CEC, and TDS
- Subsequent tests over the first few growing seasons
- Document changes in soil make up and chemistry

Mine Site Soil Test Results

December 2015	December 2017
Sandy Clay Loam • Organic Matter – 0.4% • pH – 4.8	Sandy Clay Loam • Organic Matter – 2.0% • pH – 5.3

Background Organic Matter is 1.5%

Soil Respiration

Condition	Average C-CO_2 (ppm)/100g/day	% Increase in Soil Respiration
Untreated Soil	17.4	n/a
BST Treated Soil	47.1	271%

- Significant increase in soil respiration with BST treated soil compared to untreated area after 18 months
- Indicator BST treated soil is improving soil health

Bacteria/Fungal Counts

Condition	Bacteria (cells/g soil)	% Increase in Bacteria	Fungi (cells/g soil)	% Increase in Fungi
Untreated Soil	6.7E+09	n/a	1.1E+07	n/a
BST Treated Soil	2.3E+10	345%	1.6E+07	142%

- Significant increase in both bacteria and fungal counts in BST treated soil compared to untreated area after 18 months
- Indicator BST treated soil is improving soil health

“The Five Fundamentals”

Create Optimal Soil Conditions

Pick the Right Plant Species

Select the Correct Erosion Control Materials

Ensure Proper Installation

Inspection and Maintenance

Biotic Soil Technology

“Spray it, Don’t Spread it!”