FIVE FUNDAMENTALS FOR SUCCESSFUL RESTORATION OF DISTURBED LANDS

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ABSTRACT

Successful restoration of disturbed sites requires a comprehensive and holistic approach. Those overseeing Erosion and Sediment Control (E&SC) and resulting stormwater quality efforts must integrate several considerations supported by proper planning and execution. Measures taken and the degree of success for stabilization realized during active construction can have major and enduring impacts on future water quality.

The first fundamental employs creative methods to develop suitable growing media from less than desirable substrates. “Soil deficient” sites associated with land disturbances offer considerable challenges, particularly when topsoil sources are scarce. Creating strategies to improve growing conditions can only be accomplished by first understanding the make-up of substrates through comprehensive testing for agronomic potential, followed by incorporation of amendments to remedy excesses and deficiencies of key soil constituents. Prior to conducting and interpreting soil tests, it is important to understand relevant soil testing methods for reclamation and/or vegetation establishment projects. Further, it is important to properly collect and label soil samples prior to sending them to a reputable and experienced laboratory.

The second fundamental requires an assessment of suitable plant species for achieving sustainable growth and effective erosion control – while meeting the collective post-reclamation expectations of owners, their consultants, the installer and relevant regulatory agencies. Soil properties, climate, moisture regimes, slope aspect, maintenance, future land use and a host of other considerations contribute to proper species selection.

Once soil and agronomic considerations have been addressed, the third fundamental is to analyze site conditions to assess necessary erosion and sediment control measures. Site conditions, such as slope lengths, gradients and aspects and channel flow hydraulics must be examined and proper controls selected. Quantifiable performance attributes such as erosion control effectiveness, functional longevity and ability to facilitate growth establishment as well as cost effectiveness must be factored into determination of suitable products and/or techniques.

The fourth fundamental entails proper installation practices critical to the success of the rehabilitation program. Detailed guidelines must be developed and combined with onsite supervision to assure proper installation. Finally, once reclamation measures have been installed,
all active sites should be routinely inspected and maintained after each significant precipitation or other potentially damaging event – the fifth fundamental.

This publication will provide overviews highlighting the essential components of each of the five fundamentals. Then, case studies where these fundamentals have been successfully integrated on erosion and sediment control projects will be presented. In addition, a novel software program developed to integrate execution and implementation of these fundamentals will be introduced.

INTRODUCTION

Successful restoration of disturbed sites entails an inclusive approach to assess, address, manage and integrate treatments or techniques to overcome the considerable challenges presented in post-construction environments that may include poor substrates, large unprotected areas with high erosion potential, difficult access, adverse climatic or seasonal weather conditions and much more. Reclamation or rehabilitation managers 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.

THE FIVE FUNDAMENTALS

The Five Fundamentals are neither novel nor revolutionary advancements or methodologies for successful land rehabilitation, but rather the assimilation of time proven design considerations combined with proper execution and implementation in the field. 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 from leaving disturbed sites and entering water bodies. PS³ enables users to effectively integrate and stage multiple considerations into a functional working relationship that entails proper planning and execution of the Five Fundamentals.

Fundamental #1 – Understand Your Soils or Substrates

The first fundamental is employing creative methodologies to develop suitable growing media from less than desirable soils or substrates. This can only be accomplished by first understanding the make-up of the soil or substrate through comprehensive soil testing for agronomic potential and limitations. Soil testing, interpretation of the test results, and incorporation of prescriptive remedies to improve soils should be a fundamental part of any reclamation or revegetation project. It is difficult to predict potential project success without a proper understanding of soils or substrates considered for use as growing media to establish vegetation.

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 laboratory. Detailed instructions are available
through the PS³ software program with three instructive videos that can be accessed at www.profileevs.com/video/soil-foundation-success-part-1-3.

In addition, there is a laboratory dedicated to properly testing soils, including international specimens, for erosion control projects at no cost to the client. More information can be gained at www.profileps3.com. Whether you are utilizing the PS³ 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 - Hydrometer Method
- Soil pH/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
- Particle Size Analysis - Hydrometer Measurement
- 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 the following page provides optimal ranges for various soil parameters and values where deficiencies or excesses may compromise or limit vegetative establishment – using the test methods identified above¹.

One vexing issue facing successful restoration of disturbed sites is lack of available topsoil to create viable environments for establishing sustainable vegetation. In markets such as residential and commercial construction, energy development, mining, landfilling, and other construction related activities, it is recommended that the contractor remove or strip onsite topsoil or suitable overburden and stockpile them for future use. Unfortunately, this is not always a standard practice and even if topsoil stockpiles are constructed, after a few weeks only the very top of the pile (that receives sunlight, air and water) actually remains biologically active. Lower levels of the stockpile would be better termed “top dirt”. Further, a lot of topsoil simply is lost during the stripping and handling process while its composition is forever changed, never to be as viable as when in its former condition in a natural environment.
When onsite topsoil is not readily available the standard approach has been to locate nearby soil borrow areas and truck in suitable cover material prior to revegetation or restoration. This technique is often cost prohibitive and rarely will this material be truly viable “topsoil”. One way to enforce quality of “replacement soil” is to include very specific specifications for its composition, required depths and quality assurance from load to load. Rarely are comprehensive soil specifications included into project designs, thus many construction sites will have need of prescribed amounts of supplemental organic matter and soil amendments to create a sustainable growing medium. Such applications may be perceived to be expensive, but cost savings can be substantial versus expensive imported topsoil, subsoil and even compost. Recently biotic soil media/amendments have been developed to effectively complement or replace topsoil – thus reducing quantity requirements and costs while improving project success.

<table>
<thead>
<tr>
<th>Soil Characteristic Tested</th>
<th>Unit</th>
<th>Low Value (Deficiency*)</th>
<th>Optimal Range (Sufficiency*)</th>
<th>High Value (Toxicity*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Texture (Hydrometer Method)</td>
<td>%</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>OM (Organic Matter)</td>
<td>OM mass / sample mass</td>
<td>&lt; 3%</td>
<td>3%-5%</td>
<td>&gt; 10%</td>
</tr>
<tr>
<td>pH</td>
<td>0-14</td>
<td>&lt; 6.3</td>
<td>6.3 - 7.3</td>
<td>&gt; 7.3</td>
</tr>
<tr>
<td>HCO3, (Bicarbonate)</td>
<td>ppm</td>
<td>N/A</td>
<td>&lt; 50</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Electrical Conductivity (EC)</td>
<td>mmhos/cm = dS/m</td>
<td>N/A</td>
<td>&lt; 0.75</td>
<td>&gt; 7.0</td>
</tr>
<tr>
<td>Total Dissolved Solids (TDS)</td>
<td>ppm</td>
<td>N/A</td>
<td>&lt; 480</td>
<td>&gt; 4480</td>
</tr>
<tr>
<td>Sodium Adsorption Ratio (SAR)</td>
<td>N/A</td>
<td>&lt; 2.0</td>
<td>&gt; 7.0</td>
<td></td>
</tr>
<tr>
<td>N (Nitrogen)</td>
<td>ppm</td>
<td>&lt; 10</td>
<td>10 – 30</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>Bray 1 P (Phosphorus) pH&lt;7.2</td>
<td>ppm</td>
<td>&lt; 20</td>
<td>20 – 40</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Olsen P (Phosphorus) pH&gt;7.2</td>
<td>ppm</td>
<td>&lt; 10</td>
<td>10 – 25</td>
<td>&gt; 25</td>
</tr>
<tr>
<td>K (Potassium)</td>
<td>ppm</td>
<td>&lt; 150</td>
<td>150 - 250</td>
<td>&gt; 250</td>
</tr>
<tr>
<td>Mg (Magnesium)</td>
<td>ppm</td>
<td>&lt; 60</td>
<td>60 - 300</td>
<td>&gt; 300</td>
</tr>
<tr>
<td>Ca (Calcium)</td>
<td>ppm</td>
<td>&lt; 400</td>
<td>≥ 400</td>
<td>N/A</td>
</tr>
<tr>
<td>S (Sulfur)</td>
<td>ppm</td>
<td>&lt; 5</td>
<td>5 – 20</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>Zn (Zinc)</td>
<td>ppm</td>
<td>&lt; 1.0</td>
<td>1.3 - 3.0</td>
<td>&gt; 5.0</td>
</tr>
<tr>
<td>Mn (Manganese)</td>
<td>ppm</td>
<td>&lt; 2.5</td>
<td>4.1 - 12.0</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Cu (Copper)</td>
<td>ppm</td>
<td>&lt; 1.0</td>
<td>1.0 - 2.0</td>
<td>&gt; 2.0</td>
</tr>
<tr>
<td>Fe (Iron)</td>
<td>ppm</td>
<td>&lt; 4.5</td>
<td>7.1 - 20.0</td>
<td>&gt; 70</td>
</tr>
<tr>
<td>B (Boron)</td>
<td>ppm</td>
<td>&lt; 0.5</td>
<td>1.0 - 1.5</td>
<td>&gt; 2.0</td>
</tr>
<tr>
<td>K (Potassium) CEC %</td>
<td>CEC %</td>
<td>3.0 - 7.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg (Magnesium) CEC %</td>
<td>CEC %</td>
<td>15 – 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca (Calcium) CEC %</td>
<td>CEC %</td>
<td>65 - 75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na (Sodium) CEC %</td>
<td>CEC %</td>
<td>0 - 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H (Hydrogen) CEC %</td>
<td>CEC %</td>
<td>0 - 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cation Exchange Capacity (CEC)</td>
<td>meq/100g</td>
<td>&lt; 5</td>
<td>10 - 30</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>Cl (Chloride)</td>
<td>ppm</td>
<td>&lt; 10</td>
<td>10 - 20</td>
<td>&gt; 800</td>
</tr>
</tbody>
</table>
Fundamental #2 – Proper Species Selection

Equally important to addressing soils is developing an understanding of plant species that will sustain growth and provide adequate erosion and sediment control (E&SC) performance. The second fundamental requires an assessment of suitable plant species that will provide long-term effective erosion control – while meeting the collective post-reclamation needs of regulatory agencies, site owners and operators. Soil properties, climate, moisture regimes, slope aspect, maintenance, future land use and a host of other considerations contribute to proper species selection.

Perhaps the best resource for obtaining information and availability of suitable plant species are regional growers, collectors and suppliers of locally adapted seeds and plant materials. Experienced botanic professionals are well versed in seasonal pricing, quantities and availability of native or introduced seed sources as well as containerized or bare root shrubs and tree species.

In the US there is a wealth of botanical information available from universities, specialized consultants and contractors, as well as federal, state and local agencies such as Office of Surface Mining Reclamation and Enforcement (OSMRE), US Natural Resource Conservation Service (NRCS), US Bureau of Land Management (BLM), US Forest Service (USFS), US Army Corps of Engineers (USACE), state mining agencies and departments of transportation (DOTs) and local soil conservation chapters.

Beyond these resources a module has been placed within PS3 to offer species selection assistance to its users. Essentially, the module is designed as a self-assessment asking the user a series of questions such as:

- Where is the project located?
- What are the soil characteristics?
- Do you want to achieve permanent or temporary vegetation?
- When will the installation occur – seasonality?
- What are the desired plant materials?
  - Native, introduced, drought tolerant, palatable, warm or cool season, legumes, wildflowers, shrubs, trees, etc.
- What is the intended application?
  - Slope, channel, riverine, shoreline, levee, cover system, etc.
- What are the site characteristics – such as elevation, topography, aspect, climatic conditions?
- Will there be maintenance activities – irrigation, mowing, supplemental amendments or grazing?
- Do you want to discourage birds and other wildlife from inhabiting the area?

Once the project information is uploaded, the user can ask to be contacted by an agronomic professional for additional input and potential advice, and then directed to other knowledgeable references and/or suppliers of the desired species or plant materials. Certainly the best resources
are individuals intimately aware of the site specific conditions with prior experience with the
selected plant materials in that vicinity.

**Fundamental #3 – Select the Most Cost-Effective Erosion Control Techniques**

Once the substrate’s agronomic potential and species selection considerations have been
addressed, it is appropriate to begin analyzing site conditions or characteristics to assess and
select necessary erosion and sediment control measures. Site conditions, such as soils, climate,
seasonality, slope lengths, gradients and aspects, ditch and channel flow hydraulics, pond and
stream banks, wetlands and more must examined and proper controls selected.

PS² uses widely accepted methodologies such as the Revised Universal Soil Loss Equation
(RUSLE/RUSLE 2) for predicting annual soil loss on slopes combined with erosion control
effectiveness, an international rainfall database, growth establishment rates, functional
longevities and factors of safety to facilitate product selection for slopes using the following
equation. (Renard, K.G, et. al., 1997)²

**Revised Universal Soil Loss Equation:**

\[ A = R \times K \times LS \times C \times P \]

Where:

- \( A \) = computed soil loss/unit area/year
- \( R \) = rainfall factor
- \( K \) = soil erodibility factor
- \( L \) = slope length factor
- \( S \) = steepness factor
- \( C \) = vegetation or cover factor
- \( P \) = erosion control practice factor

C-Factor is calculated as the soil loss ratio of a treated surface versus the soil loss of an untreated
control surface. For example, if the treated surface produces 5 lb of soil loss while the untreated
surface produces 100 lb of soil loss, then the C-Factor would be 5 lb/100 lb = 0.05. The lower
the C-Factor value, the more effective the erosion control technique is at preventing erosion.

Conversely, percent erosion control effectiveness (PE) may be calculated from the following
equation using the above example C-Factor of 0.05 as follows:

\[ PE = (1 - \text{C-Factor}) \times 100\% \]

\[ PE = (1 - 0.05) \times 100\% = 95\% \]

Although comparative low C-Factors or high PE values can at first blush appear to be
impressive, the potential soil loss values can be very surprising and perhaps alarmingly high
without constructed sediment capture and retention devices or practices. For example, as shown
in Table 2, an erosion control technique demonstrating a seemingly impressive 95% effectiveness could potentially lose 16,700 lb/ac/year of soil.

Table 2: Annual Soil Loss Calculations for C-Factor and % Effectiveness Values

<table>
<thead>
<tr>
<th>C-Factor</th>
<th>% Effectiveness</th>
<th>Potential Soil Loss (lb/ac/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>99</td>
<td>3,340</td>
</tr>
<tr>
<td>0.05</td>
<td>95</td>
<td>16,700</td>
</tr>
<tr>
<td>0.1</td>
<td>90</td>
<td>33,400</td>
</tr>
<tr>
<td>0.2</td>
<td>80</td>
<td>66,800</td>
</tr>
<tr>
<td>0.3</td>
<td>70</td>
<td>100,200</td>
</tr>
<tr>
<td>0.5</td>
<td>50</td>
<td>167,000</td>
</tr>
<tr>
<td>0.75</td>
<td>25</td>
<td>250,500</td>
</tr>
</tbody>
</table>

However, the C-Factor and erosion control effectiveness values are in an unvegetated condition and their ability to foster or accelerate vegetation establishment must go into design and selection criteria. If a designer is confident an erosion control technique can rapidly establish vegetation and still provide suitable erosion control effectiveness, then he or she may opt to go with a lower cost, less robust technique.

One determination of the ability of a material to improve vegetation establishment is using ASTM D7322 - Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Ability to Encourage Seed Germination and Plant Growth Under Bench-Scale Conditions. This test has been modified to accommodate hydraulically-applied erosion control and other types of products used for revegetation.

Another key product characteristic is functional longevity – which can be determined using ASTM D5338 - Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials Under Controlled Composting Conditions, Incorporating Thermophilic Temperatures. This test determines predicted longevities of various biodegradable erosion control techniques and is often correlated with field observations to offer material functional longevity ranges. Functional longevity will be affected by a material’s composition as well as site specific conditions such as temperature, moisture, sunlight, soil composition, biological activity and other environmental factors. Thus, localized observations should prevail.

Erosion control effectiveness, growth establishment and functional longevity are the three pillars of product performance and fundamental to PS3 selection criteria for erosion control techniques. Assessing these three key properties can assist designers in their risk versus reward selection scenarios – balancing performance versus costs and ease of implementation versus factors of safety.

As demonstrated in Table 3, the erosion control practice factor or P-Factor from the Universal Soil Loss Equation can have a large impact on erosion control effectiveness. Using a default value of 1.0 for a loose disked slope, relative P-Factors can be determined for various grading techniques. It is important to note that roughened slopes demonstrate reduced erosion control potential versus slopes that have been smoothed to accommodate and ensure intimate soil contact for techniques such as rolled erosion control products. For example, a compacted and smooth
surface has a 20% greater erosion potential than loose disked soil. Rough graded or tracked sites demonstrate up to 42% less erosion potential versus compacted and smoothed soil. More flexible techniques such as hydraulically-applied erosion control products or blown hay/straw can be applied on rough or cat tracked slopes – providing less costly and in some cases superior erosion control effectiveness.

<table>
<thead>
<tr>
<th>P-Factor Practice</th>
<th>P-Factor Value</th>
<th>Potential Soil Loss Relative to P-Factor = 1.0 (lb/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact and Smooth Surface</td>
<td>1.2</td>
<td>120,000</td>
</tr>
<tr>
<td>Loose – Disked Plough Layer</td>
<td>1.0</td>
<td>100,000</td>
</tr>
<tr>
<td>Rough Surface with Tracks in all Directions</td>
<td>0.9</td>
<td>90,000</td>
</tr>
<tr>
<td>Tracked Up and Down Slope</td>
<td>0.7</td>
<td>70,000</td>
</tr>
</tbody>
</table>

Methodologies from the US Federal Highway Administration’s Hydraulic Engineering Circular Number 15 (HEC 15) – Design of Roadside Channels with Flexible Linings (Kilgore and Cotton, 2005) are used for both unvegetated and vegetated channel design and product selection. Primary design formulas are Manning’s Equation and the Shear Stress or Tractive Force Equation as follows:

**Manning’s Equation for Permissible Velocity**

\[
V = \frac{C}{n} R^{\frac{1}{2}} S_t^{\frac{1}{2}}
\]

Where:

- \( V \) = average velocity (ft/s, m/s)
- \( C = 1.49 \) for U.S. Customary Units; \( = 1 \) for SI Units
- \( n \) = Manning’s roughness coefficient (dimensionless)
- \( R \) = hydraulic radius (ft, m)
  - = cross sectional area divided by wetted perimeter (A/P)
- \( S_t \) = friction slope of channel (can be approximated as average bed slope for uniform flow conditions) (ft/ft, m/m)

**Permissible Shear Stress or Tractive Force Equation**

\[
\tau = \gamma d S_o
\]

Where:

- \( \tau \) = shear stress or tractive force (lb/ft^2)
- \( \gamma = \) unit weight of water (62.4 lb/ft^3)
- \( d \) = maximum flow depth (ft)
- \( S_o \) = average bed slope (ft/ft)
Performance data for these erosion control products has been obtained from the most prestigious US universities and private testing laboratories and provides the impetus for proper product selection. Once the appropriate product(s) and techniques have been selected, a detailed project summary report along with a suite of supporting information is available including: product brochures, installation guides, CAD drawings, SDSs, example specifications, certification letters, case studies and other relevant material.

Next on PS\(^3\) is a calculator tool that can be used to determine how much mulch, fertilizer, seed, and agronomic amendments should be mixed into each hydroseeder load and how much will be required for a specific site. It allows U.S. Customary or Metric conversions between common units found for all product recommendations. Additionally, unit pricing may be entered for all selected products, providing cost estimates based on slope and channel analysis, soil testing, and plant species selection. This enables users to develop comprehensive project cost estimates as well as mixing and loading rates for tank loads of hydraulically-applied products – based upon the size of the equipment and anticipated loading rates.

**Fundamental #4 – Oversee and Insure Proper Installation**

Proper installation practices are critical to the success of any rehabilitation program. Comprehensive and detailed construction specifications with clearly delineated plans and drawings as well as complete mixing/application guidelines and details must be developed and combined with onsite supervision to assure proper installation.

PS\(^3\) provides detailed installation guidelines and CAD drawings for several erosion and sediment control techniques, including Hydraulically-applied Erosion Control Products (HECPs), Rolled Erosion Control Products (RECPs), and Sediment Retention Fiber Rolls (SRFRs). In addition, PS\(^3\) houses an installation calculator to facilitate HECP mixing ratios and/or application rates shown in Figure 1. A standard generic detail for installation of degradable RECPs is provided in Figure 2.
Figure 1: Loading Chart for Hydraulically-Applied Products (Profile Products LLC)

Figure 2: Erosion Control Blanket Installation Guidelines – (Colorado Department of Transportation, 2011)
All installations should be overseen by qualified and experienced professionals who are intimately immersed in and familiar with the construction requirements for the project. Experience…preferably site specific experience is always a desired pre-requisite!

**Fundamental #5 – Coordinate and Conduct Timely Inspection and Maintenance Activities**

Once the erosion and sediment control measures have been installed it is important to visually inspect and maintain them on a regular basis. All active construction sites must be inspected and maintained after each significant precipitation or other potentially damaging event. Inspections should be conducted by qualified professionals whose expectations are consistent with the installer, owner and regulatory entity(s).

Initial inspections should insure that all installations are in accordance with plans and specifications with all material quantities and activities fully documented. Subsequent inspections should be executed at pre-determined time intervals and maintenance activities conducted after each significant precipitation or other potentially damaging weather event.

Obvious examples requiring maintenance would be damaged silt fences or sediment control devices, rills appearing on treated slopes, displacement or movement of rock check dams or slope interruption devices, and excessive sediment being deposited at toes of slopes or near/into receiving water bodies. Timely inspections and maintenance can prevent small problems from turning into major complications.

Regrettably this final fundamental is perhaps the most underappreciated and is frequently acted upon with the “one and done” mentality that often is associated with construction bidding and contracting. Savvy stormwater managers should consider incorporating performance requirements and/or maintenance requirements into their construction contracts. Sites with onsite resources should always make inspection and maintenance a standard operating procedure.

Inspections subsequent to the initial “grow in” period should be conducted to assess agronomic aspects of rehabilitation efforts. Beyond monitoring vegetation vigor, cover and species composition, soils or substrates should be tested to determine if supplemental applications of seed, fertilizer, biological inoculants or other soil amendments are warranted. Soil tests may also identify developing problems with soil pH, excessive salts or upward migration of heavy metals or contaminants from underlying substrates.

**CASE STUDIES**

Following are example projects where the Five Fundamentals have been successfully applied on disturbed sites. The two examples discuss final cover systems for coal ash and steps taken to obtain a Notice of Termination on a badly denuded construction site.

**Case Study #1 – Final Cover on Southeastern US Coal Ash Disposal Site**

Soil tests indicated the coal ash was low in both organic matter and fertility and slightly acidic with a pH range of 6.0-6.3. The slopes were reshaped to create a series of 3H:1V gradients – ranging from 65-100 feet long and divided from the next by horizontal benches 10 feet wide. The owner elected to place 4 in of topsoil over the ash prior to seeding. The soil cover was rough graded to reduce sheet flow, increase infiltration and provide pockets for water retention and enhanced growth.
Lime, synthetic fertilizer, two biostimulants (one fast-acting and the second designed for sustained release) and a prescribed seed mix were hydraulically-applied directly on the soil with a small amount of flexible growth medium as a tracer. A biodegradable fugitive green dye in the flexible growth medium assisted in visually metering coverage and application rates.

The installation took place in May of 2009 using the following warm season seed mix applied at combined pure live seed rate of 75 lb/ac:

- 50% *Cynodon dactylon* var. Sahara – Bermuda grass – warm season sod forming grass
- 25% *Lespedeza cuneata* – Serecia lespedeza – Nitrogen fixing legume
- 10% *Trifolium repens* var. Durana White Clover – Nitrogen fixing legume
- 10% *Urochloa* sp. – Browntop Millet – warm season annual grain used as a cover crop
- 5% *Eragrostis curvula* – Weeping Lovegrass – warm season bunch grass

Due to anticipated hot and dry summer conditions and the long 3H:1V slopes with significant erosion potential, a flexible growth medium was specified to be applied at the rate of 3,500 lb/ac in a second application above the seed and soil amendments. The flexible growth medium was applied from two directions using a hydroteeder.

Adequate precipitation was received and significant growth was noted in the weeks following the installation such that an abundant stand of vegetation was quickly established as evidenced by the before and after photos shown below. This resulted in a significant cost savings for the utility while quickly achieving its Notice of Termination for the treated areas. A subsequent site visit in July of 2010 showed essentially the same amount of dense vegetative cover confirming a sustainable stand of vegetation was established over a significantly reduced cover soil depth than typically specified and/or mandated by regulatory agencies.
Case Study #2 – Rehabilitation of Abandoned Residential Site Development

A 2.7 acre home development site sat abandoned in rural Tallassee, Alabama after it was forced into foreclosure in 2009. As the heavily eroded site began to wash away and impact stormwater quality, the Alabama Department of Environmental Management (ADEM) pressed its owner for stabilization.

Contractor Hunter Bruce, P.E. and owner of SpreadRite, LLC was tasked to engineer and implement a quick and cost-effective solution to remedy the situation and allow the owner to achieve its Notice of Termination from ADEM. Initial site assessments determined the site to be highly denuded and devoid of topsoil with significant erosion and discharges of turbid water leaving the site. The contractor’s first step was to obtain soil tests to examine the viability of the site substrates and determine remedial actions to create a suitable environment for growth establishment and effective erosion control.

Results of the soil tests confirmed very low levels of organic matter, acidic conditions and a lack of available nutrients to support growth of vegetation. The contractor’s first option to improve the site conditions was to identify a nearby source of available high quality topsoil to accommodate a 4 inch depth over the re-graded substrate. A second option was to consider an engineered topsoil alternative – Biotic Soil Media (BSM) – to add organic matter, biostimulants and other soil building components to the denuded substrate.

A detailed cost analysis determined an estimated installed cost of $27.41/cubic yard for a topsoil source located just ½ mile from the site. Further, the contractor speculated that over 66 truckloads (22 tons) and 4 to 5 days would be required to harvest, transport, spread and grade the topsoil over the 2.7 acre site. When assessing the BSM alternative, an application rate of 4,500 lb/ac was considered in the cost analysis as prescribed for the organic matter levels averaging just 1% versus an ideal range of 3-5% for sustainable growth. The estimated installed cost of the BSM was $13,635 – representing a savings of $26,163 – or nearly 1/3 of the total estimated cost of $39,798 to place the topsoil.

Moreover, BSM can be hydraulically-applied through conventional hydroseeding/mulching equipment along with seed, fertilizer and prescribed soil amendments in one cost efficient
application. Hydraulically-applied, dry-applied or even rolled erosion control products are then placed over the BSM for added protection from erosive forces as would also be required to protect topsoil as dictated by site conditions. Thus, BSM technology can reduce topsoiling and even compost costs while dramatically reducing installation time. For these reasons the contractor elected to pursue the BSM option.

Grading of the site substrate to remove gullies, rills and prepare the seedbed commenced in Mid-March of 2015. The flatter areas were leveled and left in a rough condition while the slopes were cat tracked to reduce potential runoff and create pockets and check dams to hold water and seed for quicker growth. Installation of the BSM, seed, and soil amendment as well as erosion and sediment control measures was completed on March 25 in just one day.

A prescriptive seed mix was designed for quick germination and growth, but also to facilitate establishment of a sustainable vegetative cover through the hot summer conditions and over the following winter and beyond. Key species included:

- *Festuca arundinacea* var. K31 – Tall Fescue – cool season turf forming grass
- *Eragrostis curvula* – Weeping Lovegrass – warm season bunch grass
- *Cynodon dactylon* var. Numex Sahara – Bermuda grass – warm season sod forming grass
- *Paspalum notatum* – Pensacola Bahiagrass – warm season sod forming grass
- *Lespedeza cuneata* – Serecia Lespedeza – Nitrogen fixing legume
- *Trifolium repens* var. Durana – White Clover – Nitrogen fixing legume
- *Trifolium incarnatum* var. Dixie – Crimson Clover - Nitrogen fixing legume
- *Lolium multiflorum* – Annual Ryegrass – cool season annual used as a cover crop
- *Urochloa* sp. – Browntop Millet – warm season annual grain used as a cover crop

Soil amendments included a micronized lime to quickly raise soil pH, 19-19-19 fertilizer, a fast acting biostimulant and a sustained release biostimulant. The seed and amendments were applied in the first pass with the BSM.

The flatter areas were then straw mulched at 2 tons/acre and then covered with a hydraulically-applied mulch at 500 lb/ac and tackifier product designed to hold straw and hay mulches in place. The slopes were designed with gradients of up to 3H:1V and an engineered fiber matrix (EFM) was applied at 3,500 lb/ac over the BSM for additional erosion protection.
Wet conditions prevailed soon after the installations and over the month of April with the site receiving nearly 14 inches of precipitation. Despite the heavy rainfall amounts minimal erosion was observed. Some of the flatter areas were topped with an exposed very light colored, material known locally as “Ghost Clay”, which led to some ponding and overland flow down over the 3H:1V slope. Degradable erosion control blankets were installed with additional seed in two areas where concentrated flow had caused some spot erosion. Meanwhile vegetative growth flourished within weeks of the installation. The photos shown in Figures 9 and 10 highlight the rapid and dense growth the site experienced in only five weeks.

Over the succeeding weeks the vegetative cover was fully restored and ADEM granted the site owner a Notice of Termination on May 27. Site visits in the spring of 2016 have revealed the vegetative cover remains sustainable and intact. As designed, the species composition has changed from the rapidly growing cool season annuals and tall fescue to a cover now dominated by the more adapted warm season perennial species, lespedeza and clovers that will persist better through the hot summer conditions in 2016 and the years to come.

CONCLUSION

The Five Fundamentals have been a time proven model for successful disturbed land reclamation on six continents working in most of the planet’s biomes, climates, and environments; addressing multiple types of soils and substrates. Employing the discipline to work through the discovery sequence of the first three fundamentals – to analyze soils and substrates, pick the right plan materials for the site and select the most cost effective E&SC techniques, will undoubtedly head any project in the right direction. These fundamentals must be followed by the development of clear and comprehensive construction plans and specifications to effectively communicate the project requirements to contractors and installers. Once construction commences, onsite oversight of acceptable installations must be conducted by qualified inspectors. Then, the active rehabilitation sites must be regularly inspected and maintained after each significant precipitation or other potentially damaging event. Inspections should be conducted by qualified professionals whose expectations are consistent with the installer as well as the owner, consultant and regulatory entity(s).
The software program introduced in this publication serves as a platform for coordinating the Five Fundamentals into a cohesive and interconnected framework for the designer as well as other project stakeholders. The contributions of this software program will become increasingly enhanced with the continued input of environmental conditions, design rainfall return frequencies and project information supplied by users around the world.

The two case studies with varying environmental conditions were provided to briefly illustrate the discovery (required information gathering) and implementation of the Five Fundamentals – leading to successful restoration of disturbed land. There are many more projects from mining, energy, coal ash, transportation, home building and other market segments around the world to substantiate the utility and legacy of the Five Fundamentals.

REFERENCES


BIOSKETCHES

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He is a founding member of the Erosion Control Technology Council (ECTC) and a member of the ASTM D18 and D35 Committees on Erosion Control, Sediment Control and Geosynthetics. He is an active and longtime member and past Technical Vice President of the International Erosion Control Association (IECA). In 2007 Marc was recognized by Land Development Today magazine as a Stormwater All-Star – one of the most influential people in stormwater management.

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