COST EFFECTIVE PLANS FOR SUCCESSFUL MINE CLOSURE – RECENT CASE STUDIES

Marc S. Theisen

Profile Products LLC, Signal Mountain, TN USA 37377

Jin Xu

Maccaferri China, Changsha, Hunan, China 410001

Abstract

Successful rehabilitation, reclamation or closure of massive soil and vegetation disturbances from mining requires a comprehensive and holistic approach. Those overseeing rehabilitation efforts should assimilate and stage several considerations into a working relationship that integrates five fundamentals for successful mine closure. Employing the discipline to work through the discovery sequence of the first three fundamentals – to analyse soils and substrates, pick the right plant materials for the site and select the most cost effective erosion and sediment control techniques, will undoubtedly lead a 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 knowledgible of the site conditions. Then, 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 and regulatory entity(s). Failure to systematically execute on any of these fundamentals can undermine the best laid plans of any mine closure project.

Mined land sites offer unique and unpredictable challenges for successful closure efforts. Published handbooks or manuals can provide general approaches to mined land reclamation, but rarely can they address the specific needs or conditions of unique mining sites. Successful restoration most typically comes from carefully controlled onsite trials and iterative installations to assess efficacy of various treatment combinations. Such treatments must then be refined and customized to develop cost effective closure plans. Exhaustive research on suitable soil amendments, plant materials and erosion control techniques should be planned and budgeted for – as integral steps in the mine closure progression.

Four selected case studies from North America, Asia and Oceania – demonstrating diverse climates with contrasting environmental and site conditions will be offered to illustrate the discovery (required information gathering) and implementation (execution) of the five fundamentals for successful mine closure.

Key Words: Mine closure, erosion control, revegetation, reclamation, rehabilitation

Introduction

Successful mined closure entails an inclusive approach to assess, address, manage and integrate treatments or techniques to overcome the considerable challenges presented in post-mining environments such as 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 labour, sequencing of earthmoving activities and required timing of completion for mine closure related activities.

Those overseeing rehabilitation efforts must assimilate and stage several considerations into a working relationship that integrates five fundamentals for successful mine closure, supported by proper planning and execution. “Soil poor” sites associated with mining activities offer considerable challenges particularly when topsoil and cover soil sources are scarce or of limited agronomic benefit. Such sites will require innovative thinking and implementation to overcome the absence of favourable growing conditions.

Employing the discipline to work through the discovery sequence of the first three fundamentals – to analyse soils and substrates, pick the right plant materials for the site and select the most cost effective erosion and sediment control techniques, can head a mine closure plan in the right direction.

Following the discovery sequence is development of clear and comprehensive construction plans and specifications to effectively communicate the project requirements to contractors and installers. Once construction commences, capable onsite oversight of acceptable installations must be conducted by qualified inspectors. Then, the active rehabilitation sites must be regularly monitored 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 and regulatory entity(s). Failure to systematically execute on any of these fundamentals can undermine the best laid plans of any mine closure project.

These five fundamentals are by no means novel and have been previously introduced to the mining industry (Theisen 2015). This publication offers a brief overall of five fundamental principles to facilitate successful mined land closure, followed by illustrative case studies where they have been successfully employed in a variety of geographic, climatic and physiographic conditions.

An Overview of the Five Fundamentals

Fundamental #1 – Understand Your Soils or Substrates

The first fundamental is employing creative methodologies to develop suitable growing media – typically 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 incorporating prescriptive remedies to improve soils should be an essential part of any mine closure plan. Without a proper understanding of soils or substrates considered for use as growing media to establish vegetation, it is difficult to predict or achieve potential project success.

Prior to conducting and interpreting soil tests, it is important to understand testing procedures and analytical methodology that are relevant for mine closure and/or vegetation establishment projects. There are various ways to extract measurable soil characteristics and analyse samples, but rarely do different soil testing methods produce identical results. It is important to properly collect and label soil samples prior to sending them to a reputable laboratory. Two referenced publications offer collection and sampling instructions as well as relevant testing protocol for erosion control projects requiring vegetative establishment (Soil Testing and Interpretation, 2015 and Theisen, 2015).

Fundamental #2 – Proper Species Selection

Equally important to addressing soils is the selection of plant species that exhibit sustainable growth and resulting erosion and sediment control (E&SC) performance. The second fundamental requires an assessment of suitable plant species for achieving both requirements – while meeting the collective post-reclamation needs of regulatory agencies and mine owners. Soil properties, climate, moisture regimes, slope aspect, maintenance, desire for native plant stock or ecotypic progeny, 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 containerised or bare root shrubs and tree species. Certainly universities, researchers, consultants and agencies can also provide wisdom and guidance.

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

Once soil, agronomic and species selection considerations have been addressed, it is appropriate to begin analysing 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 be examined and proper controls selected.

A relevant and widely accepted methodology for assessing erosion protection on slopes is the Revised Universal Soil Loss Equation (RUSLE/RUSLE 2) for predicting annual soil loss (Renard et. al., 1997). RUSLE combined with erosion control effectiveness, an international rainfall database, growth establishment ratings, documented functional longevities and factors of safety all help to facilitate product selection for slope protection.

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) can be used for both unvegetated and vegetated channel designs and selection of techniques. Primary design formulas are Manning's Equation to determine maximum permissible velocity while maximum permissible tractive force is determined using the Shear Stress or Tractive Force Equation (Theisen, 2015).

Erosion control effectiveness, growth establishment (ability to facilitate vegetative growth) and functional longevity (persistence of the technique) are the three pillars of product performance and fundamental to selection criteria for erosion control techniques. Assessing these three key performance attributes in addition to relevant physical or index properties can assist designers in their risk versus reward selection scenarios – balancing costs and ease of implementation versus requisite factors of safety.

Fundamental #4 – Oversee and Insure Proper Installation

Suitable 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.

Installation guidelines are readily available from manufacturers, consultants and trade associations for erosion and sediment control techniques, including Hydraulically-applied Erosion Control Products, Rolled Erosion Control Products, and Sediment Retention Fibre Rolls (ECTC, 2014).

All installations should be overseen by qualified and experienced professionals who are intimately immersed in the mine closure requirements. Experience, preferably site specific experience, is always a desired prerequisite!

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

Once erosion and sediment control measures have been installed, it is important to visually inspect and maintain them on a regular basis. Inspections should be conducted by qualified professionals whose expectations are consistent with the installer as well as 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 the final inspection and maintenance fundamental is perhaps the most underappreciated and overlooked practice with the “one and done” mentality that often is associated with construction bidding and contracting. Savvy mine reclamation managers should consider incorporating performance and/or maintenance requirements into their construction contracts or internal requirements. Mines with onsite resources should always make inspection and maintenance a standard operating procedure.

Subsequent to the initial “grow in” period, inspections should be conducted to assess agronomic aspects of rehabilitation efforts. Beyond monitoring vegetation vigour, cover and species composition; soils or substrates should be tested to determine if supplemental applications of seed, fertiliser, biological inoculants, other soil amendments or additional erosion covers 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. Maintenance related activities should be accounted and budgeted in comprehensive mine closure plans.

Selected mine closure case studies

The following case studies have been selected as examples where the five fundamentals were effectively employed and successfully executed on a variety of sites with contrasting geographic, environmental, climatic and physiographic conditions.

Case History #1 – Canadian Nickel Mine

This project is in the famous Sudbury nickel mining district in the Ontario Province of Canada, one of the world's largest fully-integrated mining, milling, smelting and refining operations. Over the years the operator had produced a mountain of slag, a by-product of the smelting process, which was threatening to overrun parts of the city. As a result, the company studied new ways to accelerate its ongoing reclamation of the slag piles and quickly convert them into green landscape.

An analysis of the slag showed it to be highly acidic and very low in organic matter and nutrients. Thus, it was deemed to be unlikely to sustain vegetation and 61,164 m^3 of a low permeability clay soil cover was specified for placement over the slag material to a 46 cm depth. In October 2006 through February 2007, the slag piles were reshaped to create a series of 3H:1V slopes – each 30 m long and divided from the next by horizontal benches 6 m wide. The clay cover was cat tracked (dozer walked) to create a roughened surface with mini-check dams to reduce sheet flow erosion potential, increase infiltration and provide pockets for water retention and enhanced growth. After placement of the clay soil cover in October 2007; lime, synthetic fertiliser, two biostimulants and a prescribed seed mix were hydraulically applied directly on the clay with a flexible growth medium tracer.

The following seed mix was applied at a rate of 252 kg/ha:

> Grasses – *Lolium perenne*, *Poa compressa*, *Phleum pratense*, *Agrostis gigantea*, *Festuca ovina*, *Festuca rubra*, *Festuca elatior*, *Festuca rubra* subsp. *commutata*
>
> Nitrogen-fixing legumes – *Trifolium hybridum*, *Trifolium pratense*, *Trifolium repens*, *Lolium corniculatus*

Due to an anticipated late fall seeding and the long 3H:1V slopes, a flexible growth medium was specified to be applied at the high rate of 5,100 kg/ha in a second application above the seed and soil amendments. The flexible growth medium was applied from two directions and then, fibre filtration tubes were installed at 11 m intervals to serve as slope interruption devices to slow sheet flow from storm events and snow melt. Installations were closely monitored by the owner and there were minimal maintenance activities necessary after the initial installations.

Despite the fall seeding, germination occurred quickly and vegetation was growing in the areas first treated prior to the onset of winter and a snow cover approaching 1 m in depth that persisted throughout the winter season. The following spring vegetation emergence continued and the site achieved exceptional cover with the combination of prescribed soil amendments, seed mix and flexible growth medium.

Figure 1 - Initial installation – Oct 2007

Figure 2 - Successful vegetation – June 2008

Case History #2 – Chinese Limestone Mine

Located in the Huzhu county of Qinghai province near the entrance of Beishan National Forest Park, exceptional rehabilitation of the Huzhu JinYuan was mandated by the Chinese government with a planned budget in excess of 50 M CNY. Excavated rock slopes devoid of organic matter and nutrients in excess of 100 m vertical heights at 65° - 70° slope gradients with exposed loose stone and gravel proved to be very challenging. Moreover, the site is at 3,280 meters in elevation, subject to rapid weather changes with sudden rain and snow, periods of drought and a short growing season running from April through September.

Key problems to be resolved were:

- How to cover and maintain a stable layer of soil on steep rocky slopes?
- How to prevent loose rock from falling down the slopes?
- How to prevent soil and seed to be washed away by rainfall and snowmelt?
- How to insulate and warm the soil while holding moisture?
- How to accelerate growth establishment in a short growing season?

The mine elected to utilize a “high-performance reinforced hydroseeding method” which entailed synergistic components including a hydraulically-applied engineered soil layer, combined turf reinforcement mat and rockfall netting, and a hydraulically-applied erosion control matrix as illustrated in Figure 3.

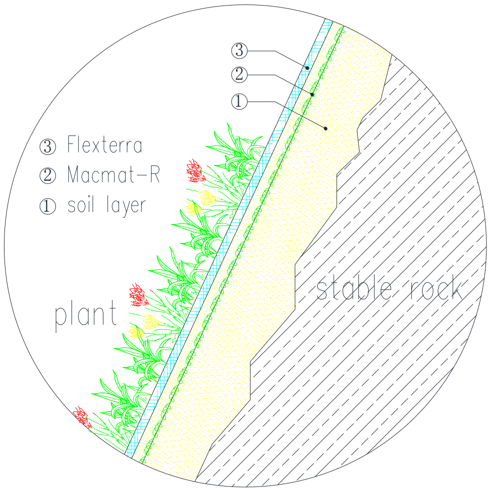

Figure 3 - Schematic of high-performance reinforced hydroseeding method

Soil layer

A combination of screened soil, fertiliser and a soil binding agent were mixed in water using a hydroseeder and the slurry was sprayed on to the rock surface. The binding agent helped to make the soil more stable with a more porous structure while sticking it more firmly to the rock surface.

Turf Reinforcement Mat (TRM) and Rockfall Netting Composite

A permanent TRM and rockfall netting composite was used to hold the soil slurry while also acting as the main structure to reinforce the soil and subsequent developing root mass. Moreover, the TRM/rockfall netting composite was also used to control soil erosion and provide loose rock protection. Due to long periods of limited precipitation, an irrigation system was also incorporated into the project design. For more rapid, consistent and safe deployment, the irrigation water lines and spray head components were pre-assembled within the TRM/rockfall netting at the manufacturing facility. Beyond the single-step installation advantages the irrigation system offered the ability to carefully meter water on an inaccessible, high and steep slope above an engineered soil composite lying on a nearly impervious rock substrate. The gravity fed system running downward from the top of the slopes also led to significant energy savings versus conventional irrigation systems.

High Performance Hydraulically-applied Erosion Control Products

Lastly, a 100% biodegradable, flexible growth medium consisting of wood fibres, biodegradable interlocking fibres, naturally derived biopolymers and wetting agents was hydraulically-infilled into the TRM/Rockfall composite. This material has been rated at 99% effectiveness for erosion control and demonstrates a water holding capacity exceeding 1,700% with a growth improvement factor of 800% over bare soil. The very high erosion control performance, combined with ability to foster vegetative establishment and a proven functional longevity of up to 18 months led to the selection of this component to complete the high-performance reinforced hydroseeding method.

Installation sequencing was as follows:

- Clean the rock surface

- Fix top anchors and steel wire rope
- Hang TRM/Rockfall netting composite in close contact with rock surface of slope
- Spray mixed soil slurry through the open and porous composite
- Spray high performance hydraulically-applied flexible growth medium into the TRM/Rockfall netting composite above the soil slurry
- Install irrigation system

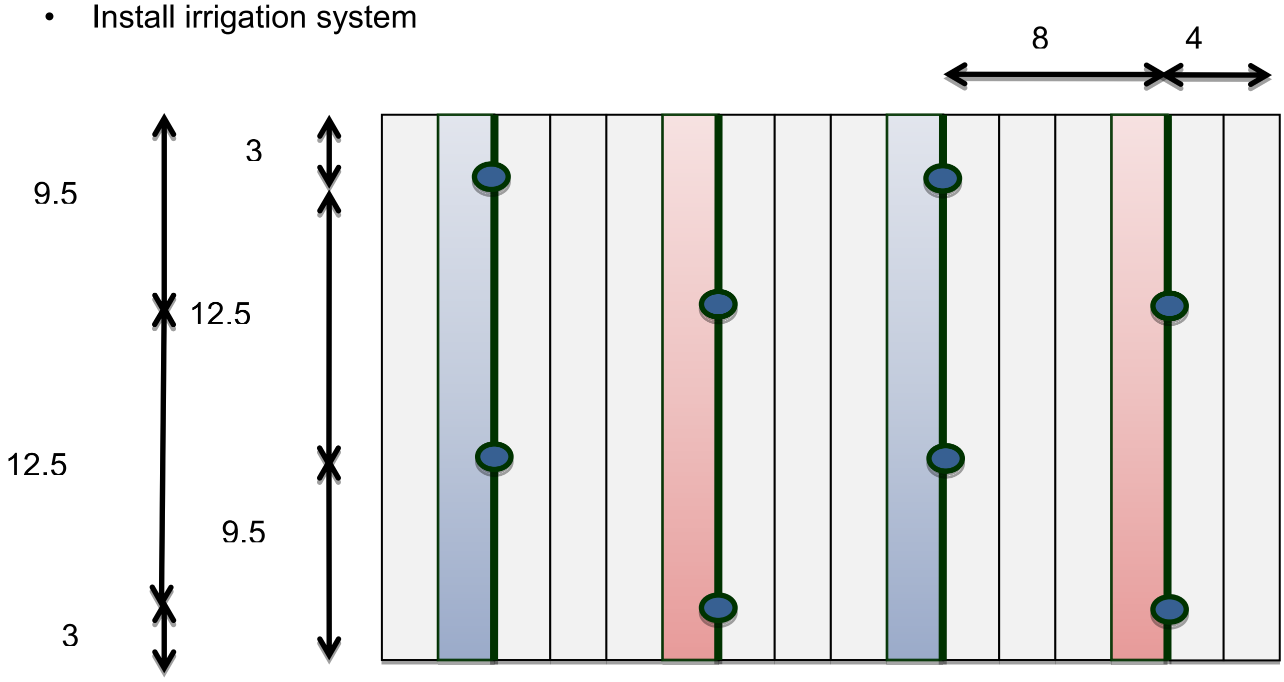

Figure 4 - Schematic of the irrigation system sprinkler head frequency in meters

Planting experiments were conducted with guidance from Qinghai Provincial University to determine locally available plant species adapted to the harsh site conditions. Selected species included *Elymus nutans, Festuca arundinacea, Calendula officinalis* and *Hypoxis sp.* at a rate of 35 kg/ha. Installation of the reinforced hydroseeding method occurred in July and August of 2014. The irrigation system was used when necessary and a reasonable cover of vegetation was established going into the winter season.

Figure 5 - Growth after 10 days

Figure 6 - Growth after 60 days

The winter season commenced and site then was covered with snow for a period of four months. When more moderate temperatures returned in the spring very minimal erosion or sloughing of the system was noted and vegetation establishment persisted through the

2015 growing season. The following photos document the vegetative establishment during the summer of 2015. The Chinese government was very pleased with the system employed and commended the project results. The mine is now employing this technique on other sites and have plans to “fertigate” existing slopes by introducing liquid fertilisers into the gravity feed irrigation system. Efforts in 2015 have continued and the seeding rate has been increased to 50 kg/ha with increased growth and ground cover noted.

Figure 7 - Prior to installation in 2014

Figure 8 - Growth in summer of 2015

Case History #3 – Indonesia Gold and Copper Mine

Situated in very mountainous terrain in the tropical Papua region of eastern Indonesia is a large open pit and tunnelling gold and copper operation reaching elevations of 4,500 m in both sub-alpine and alpine zones. The climate may be characterized as cool and extremely wet with annual precipitation approaching 7,000 mm.

Hydroseeding techniques have been used to revegetate the site’s overburden stockpiles since the late 1990s. These techniques have been employed on areas that are not easily accessible, on steep slopes in areas that require quicker vegetation cover, and to introduce additional plant cover in previously revegetated areas. Hydroseeding has promoted the establishment of mosses and grasses such as *Deschampsia klossii* – both of which are locally abundant and indigenous to the area’s sub-alpine zone.

Attempts to hydroseed with hand collected *D. klossii* seeds have shown mixed results likely due to low seed germination and viability coupled harsh site conditions. The mine maintains a nursery where *D. klossii* seeds are propagated and seedling transplants have demonstrated good survivability on substrates within favourable pH ranges and with some organic matter and nutrients. Where site conditions allow, results have been encouraging.

More recently the mine experimented with various techniques to stabilise and reclaim overburden piles consisting of waste rock from underground tunnelling operations. The rock dump material is acidic with little organic matter, nutrients or microbial activity. Placement on long 2H:1V slopes precludes usage of *D. klossii* transplants due to the substrate challenges and more importantly – worker safety.

The mine evaluated germination and growth of *Deschampsia caespitosa* in addition to erosion control and growth establishment technologies; including a hydraulically-applied flexible growth medium (FGM), biostimulants, and a fast release micronized lime material.

In April 2013, using a multifactorial design, nine test plots (375 square meters each) were devised to assess erosion control effectiveness of the flexible growth medium, seeding rates of *D. caespitosa*, organic fertilizer rates, and biostimulant rates as shown in Table 1.

Table 1 – Mass of components per 375 m^2 test plot

Plot No.	FGM (kg)	Moss (kg)	*D. caespitosa* (kg)	Fertiliser (kg)	Biostimulant (kg)
1	136.2	50	0.3	0	0
2	136.2	50	0.3	16.8	0
3	136.2	50	0.3	33.6	0
4	136.2	50	0.6	0	0
5	136.2	50	0.6	16.8	0
6	136.2	50	0.6	33.6	0
7	136.2	50	0.6	0	4
8	136.2	50	0.6	16.8	4
9	136.2	50	0.6	33.6	4

Due to the limited amount of test materials, only one replicate of each treatment could be installed. However, the large plot sizes offered significant area to see differentiation in performance from plot to plot and throughout the plot from top to bottom. The plot shapes varied with the lower plot numbers being more rectangular across the slope face, while the higher numbered plots were more rectangular going up and down the slope face. Thus, the higher numbered plots offered longer slopes that could be considered to be more challenging and received the highest amounts of seed, fertiliser and biostimulants.

The application rate of the FGM was held constant at a rate of 3,638 kg/ha – which was slightly less than the recommended application rate of 3,900 kg/ha for the 2H:1V slopes used for the test plots. This was due to a limited supply of the material on this remote site. The rate of hand collected native moss sprigs were also held constant at 1,333 kg/ha per plot. On 10 and 11 April 2013, all materials were hydraulically-applied in one step using a 4,169 L capacity hydromulcher in predominantly wet, cool conditions.

Figure 9 – Hand collected moss sprigs

Figure 10 – Application of slurry to top of slope

Results after two years of monitoring were predictable given the sterile overburden characteristics combined with the challenging site conditions. Germination of the *D. caespitosa* was spotty and the seedlings demonstrated gradual die off from lack of organic matter, soil structure, microbial activity and available nutrients to sustain growth of the grasses. However, the moss sprigs performed reasonably well and have begun to colonize the exposed rock surfaces. There is a distinct correlation to amounts of organic matter and biostimulants applied to the test plots. Those plots with higher amounts of organic matter and biostimulants showed greater establishment and coverage of the moss as shown in Figures 11 and 12.

This is very encouraging as the mosses will colonize the rock and initiate the soil building process creating a more favourable habitat over time for *Deschampsia klossii* and other indigenous species to develop a sustainable ecosystem via the process of natural succession. Older reclaimed sites where soils are more developed demonstrate dense and uniform stands of *Deschampsia klossii.*

Figure 11 – Plots 1-7 – varying amendment rates

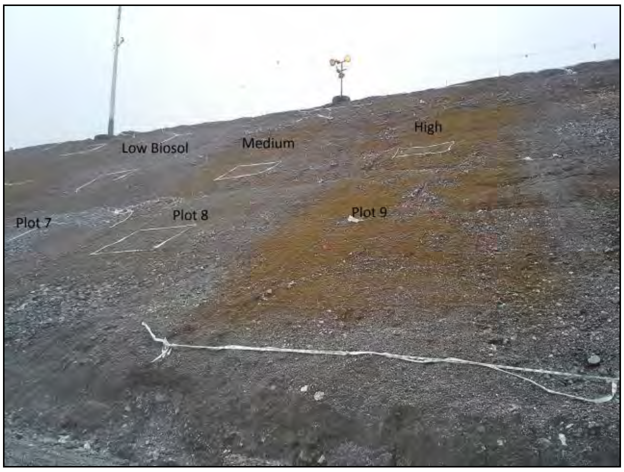

Figure 12 – Plots 8-9 with more amendments

The mine is planning more test plot installations in 2016 to expand research on relationships between types of and application rates of various erosion control and soil building treatments. This is all a part of their enduring commitment to create sustainable biodiversity in a very unique ecosystem.

Case History #4 – New Caledonia Nickel Mine

This large nickel mine is located on the Island of New Caledonia some 1,200 km off the east coast of Australia. The site ranges from 900 m in elevation where the ore is mined and then conveyed down to a port facility at sea level. The natural topography is mountainous while the climate may be characterized as tropical with a hot and humid season from November to March with temperatures between 27 °C and 30 °C, and a cooler, dry season from June to August with temperatures between 20 °C and 23 °C. Annual precipitation on the site ranges from 1,000-1,200 mm. Between December and April, tropical depressions and cyclones can cause wind speeds in excess of 100 km/hr. with gusts of 250 km/hr. and very abundant rainfall.

Initial soil testing revealed the reclamation sites had an abundance of metals and soil pH levels ranging from 5.5 to 8.2. Moreover, there was a lack of organic matter and nutrients present to encourage plant growth. Furthermore, Calcium deficiencies, excessive Magnesium levels and low Cation Exchange Capacities were observed. The surfaces requiring reclamation had been stripped during the mining process, so they lacked healthy topsoil. Slopes were steeper than 60° in places and contained valleys left by the mine excavation process. In areas with little rock the slopes were highly compacted with slick surfaces while other slopes were very rocky.

The combination of challenging site conditions, particularly – acidic substrates lacking organic matter and nutrients, long dry seasons mixed with wet seasons with intense rainfall and steep slopes – led to the selection of a wide-ranging portfolio of materials in the reclamation recipe. Earlier revegetation attempts with open weave jute mattings were unsuccessful due to the rough soil conditions in some areas and highly compacted slopes in others. Due to the challenging site conditions the mine selected a hydraulically-applied flexible growth medium (FGM) that provides a very high level of erosion protection while facilitating vegetative establishment. The FGM also provides up to 18 months of functional longevity which was deemed to be very important with slow vegetative establishment anticipated. In addition to the organic matter afforded by the FGM, the mine used compost produced on site from kitchen waste from their cafeteria and other sources of organics.

Outside of bamboo there are no indigenous graminoid species on the island of New Caledonia. Thus, all grass seeds must be imported. The initial seed mix included *Echinochloa esculenta* for an annual cover crop and *Chloris gayana* and *Cynodon dactylon* as perennial grasses to establish an erosion resistant cover. Over time indigenous forb and shrub species will begin to colonize and then dominate the grassed areas via natural succession and return the land to its natural ecosystems.

The mine utilized hydraulic seeding techniques in a two-step application process. Table 2 offers the prescribed components and application rates:

Table 2 New Caledonia material and application rates

First Pass		Second Pass	
Material	**Application Rate (kg/ha)**	**Material**	**Application Rate (kg/ha)**
FGM	1,680	FGM	2,240
Compost	2,775	Compost	1,100
Soil tackifier	20		

Crusting agent	30		
NPK fertilizer	200	NPK fertilizer	100
Urea fertilizer	100	Urea fertilizer	50
Fish emulsion	100 L/ha		
Annual grass	70		
Perennial grasses	25		

Installations were conducted in July/August of 2012 employing the two-step methodology as described above. Despite very heavy rains soon after installation establishment of the grasses was very good with consistent ground coverage as shown in Figures 13 and 14.

Figure 13 - Second application over compost layer

Figure 14 - Establishment of grasses in first year

Soon after these installations the New Caledonian government instituted regulations prohibiting the importation and use of non-indigenous grasses on mining sites. Thus, all seeds used moving forward must be harvested from the island. While the New Caledonian mines and government are learning which species seeds will be viable for massive reclamation efforts, this mine continues to employ the two-step methodology described, now with a third maintenance step occurring several months following the initial treatments. An additional mulch and organic layer is hydraulically-applied with more native seed, soil amendments and fertilizer to stimulate more germination and biomass from the slow growing shrub and forb species. The mine now has a nursery to better evaluate potential of various hand collected seeds from promising species.

Figure 15 - Indigenous shrub seedling growth

Figure 16 - Native plant nursery

Conclusions

The five fundamentals for mine rehabilitation as described and demonstrated in this publication have been a time-proven model for successful mined land reclamation over six continents working in many of the planet's biomes, climates, and environments; addressing multiple types of mining and substrates. Employing the discipline to work through the discovery sequence of the first three fundamentals – to analyse soils and substrates, pick the right plant materials for the site and select the most cost effective erosion and sediment control techniques, are requisites to head mine closure plans in the right direction. These fundamentals must be followed by the development of clear and comprehensive construction plans and specifications to effectively communicate reclamation or rehabilitation requirements to contractors and installers. Once construction commences, onsite oversight of acceptable installations must be conducted by qualified inspectors and experienced professionals who are intimately immersed in the mine closure requirements. Active rehabilitation sites must then 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 installer as well as the owner and regulatory entity(s).

Software programs can be used as a platform for coordinating a rehabilitation approach into a cohesive and interconnected framework for the designer as well as other project stakeholders. Processes within the software programs are enhanced with the continued input of environmental conditions, rainfall return frequencies and project information supplied by users around the world.

Case histories from different continents and contrasting environmental conditions were provided to briefly illustrate the discovery (required information gathering) and implementation of the mine rehabilitation fundamentals – leading to successful mined land rehabilitation. There are many more mining, energy, infrastructure, construction and other projects from other market segments around the world to substantiate the utility and legacy of this approach.

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