Cost Effective Plans for Successful Mine Closure – Recent Case Studies

2016 ASMR Annual Conference

Spokane, Washington

Author - Marc S. Theisen – M. Sc., CPESC, CPSWQ, CESSWI

and

Presenter - Damon Sump – BC CESCL Northwest RSM

Presentation Overview

- Overview of “The Five Fundamentals”
  1. **Understand Your Substrate**
  2. **Pick the Right Plant Species**
  3. **Select the Right Erosion Control Practices**
  4. **Insure Proper Installation**
  5. **Conduct Inspection and Maintenance Activities**
- Successful Case Histories
- Questions and Answers

Fundamental #1 – Understand Your Substrate

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**

Profile Soil Solutions Software

PS3

PROFILE SOIL SOLUTIONS
SOFTWARE

www.profileps3.com

"In the Ground, On the Ground, and By Your Side"

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.

http://www.profileevs.com/data/soil-testing-properties-tech-bulletin

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
OM (Organic Matter)	OM mass/sample mass	<3%	3%-5%	> 10%
pH	0-14	< 6.3	6.3 - 7.3	> 7.3
HCO_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
N (Nitrogen)	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
K (Potassium)	ppm	< 150	150 - 250	> 250
Mg (Magnesium)	ppm	< 60	60 - 300	> 300
Ca (Calcium)	ppm	< 400	≥ 400	N/A
S (Sulfur)	ppm	< 5	5 - 20	> 20
Zn (Zinc)	ppm	< 1.0	1.3 - 3.0	> 5.0
Mn (Manganese)	ppm	< 2.5	4.1 - 12.0	> 50
Cu (Copper)	ppm	< 1.0	1.0 - 2.0	> 2.0
Fe (Iron)	ppm	< 4.5	7.1 - 20.0	> 70
B (Boron)	ppm	< 0.5	1.0 - 1.5	> 2.0
K (Potassium)	CEC %		3 - 7%	
Mg (Magnesium)	CEC %		15 - 20%	
Ca (Calcium)	CEC %		65 - 75%	
Na (Sodium)	CEC %		0 - 4%	> 15%
H (Hydrogen)	CEC %		0 - 5%	
Cation Exchange Capacity (CEC)		< 5	10 - 30	> 50
Cl (Chloride)	ppm	< 10	10 - 20	> 800

*All values listed in the above table are generalizations from a variety of sources and based on "ideal" soils. Optimal ranges may vary depending on intended site goals, vegetative species, geographic location, and climate. Values outside of optimal ranges do not necessarily imply plant toxicity. Please consult Profile Technical Services for additional details on specific out of range values.

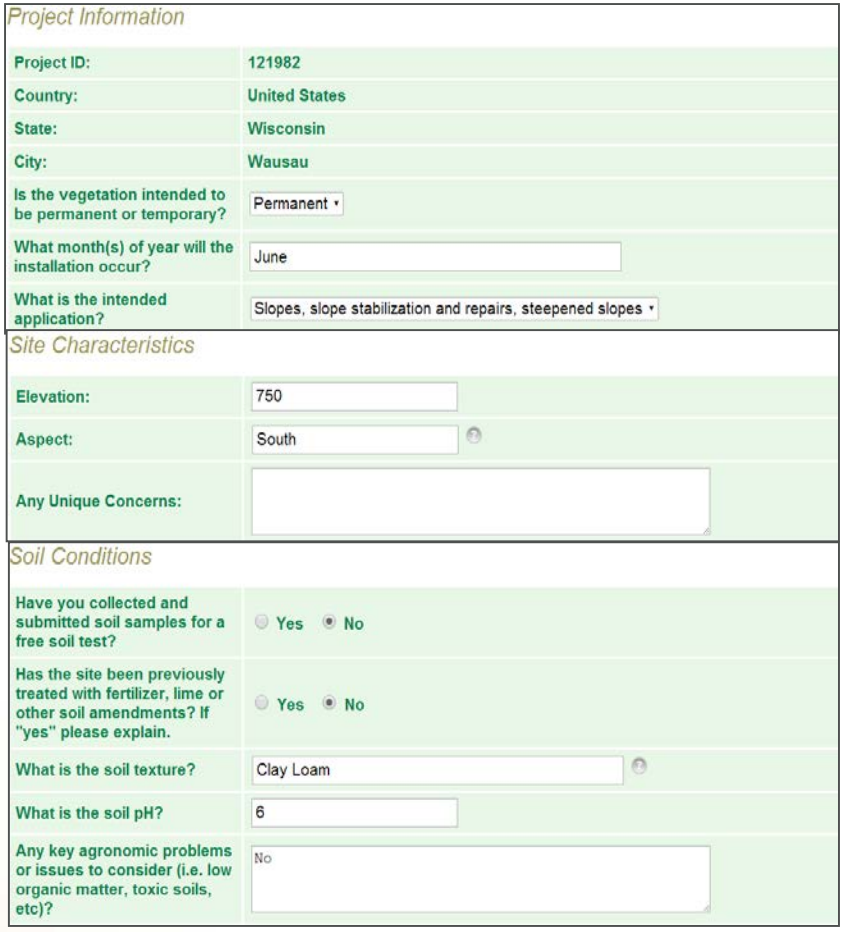
Fundamental #2 – Species Selection

- Where is the project?
- Soil characteristics?
- Permanent or temporary vegetation?
- When will the installation occur – seasonality?
- Desired plant materials
  - Native, introduced, drought tolerant, palatable, warm or cool season, legumes, wildflowers, shrubs, trees, etc.
  - Sod – to get a quick Notice of Termination (NOT)
  - Bird or animal deterrent seeds are now available

Fundamental #2 – Species Selection

- What is the intended application?
  - Slope, channel, riverine, shoreline, levee, cover system, etc.
- Site characteristics – such as elevation, topography, aspect, climatic conditions
- Maintenance activities – irrigation, mowing, supplemental amendments or grazing?

Species Selection Questionnaire



Project Information

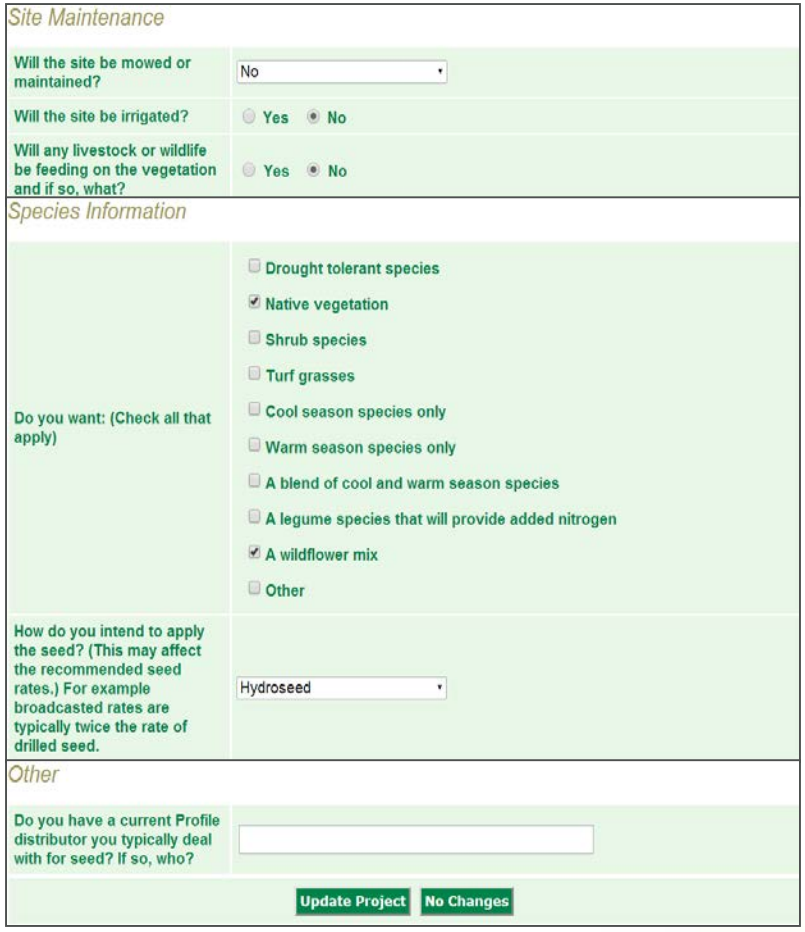
Project ID:	121982
Country:	United States
State:	Wisconsin
City:	Wausau
Is the vegetation intended to be permanent or temporary?	Permanent
What month(s) of year will the installation occur?	June
What is the intended application?	Slopes, slope stabilization and repairs, steepened slopes

Site Characteristics

Elevation:	750
Aspect:	South
Any Unique Concerns:	

Soil Conditions

Have you collected and submitted soil samples for a free soil test?	Yes / No
Has the site been previously treated with fertilizer, lime or other soil amendments? If "yes" please explain.	Yes / No
What is the soil texture?	Clay Loam
What is the soil pH?	6
Any key agronomic problems or issues to consider (i.e. low organic matter, toxic soils, etc)?	No



Site Maintenance

Will the site be mowed or maintained?	No
Will the site be irrigated?	Yes / No
Will any livestock or wildlife be feeding on the vegetation and if so, what?	Yes / No

Species Information

Do you want: (Check all that apply)	☐ Drought tolerant species ☑ Native vegetation ☐ Shrub species ☐ Turf grasses ☐ Cool season species only ☐ Warm season species only ☐ A blend of cool and warm season species ☐ A legume species that will provide added nitrogen ☑ A wildflower mix ☐ Other
How do you intend to apply the seed? (This may affect the recommended seed rates.) For example broadcasted rates are typically twice the rate of drilled seed.	Hydroseed

Other

Do you have a current Profile distributor you typically deal with for seed? If so, who?	

Update Project | No Changes

Fundamental #3 – Erosion Control Practices

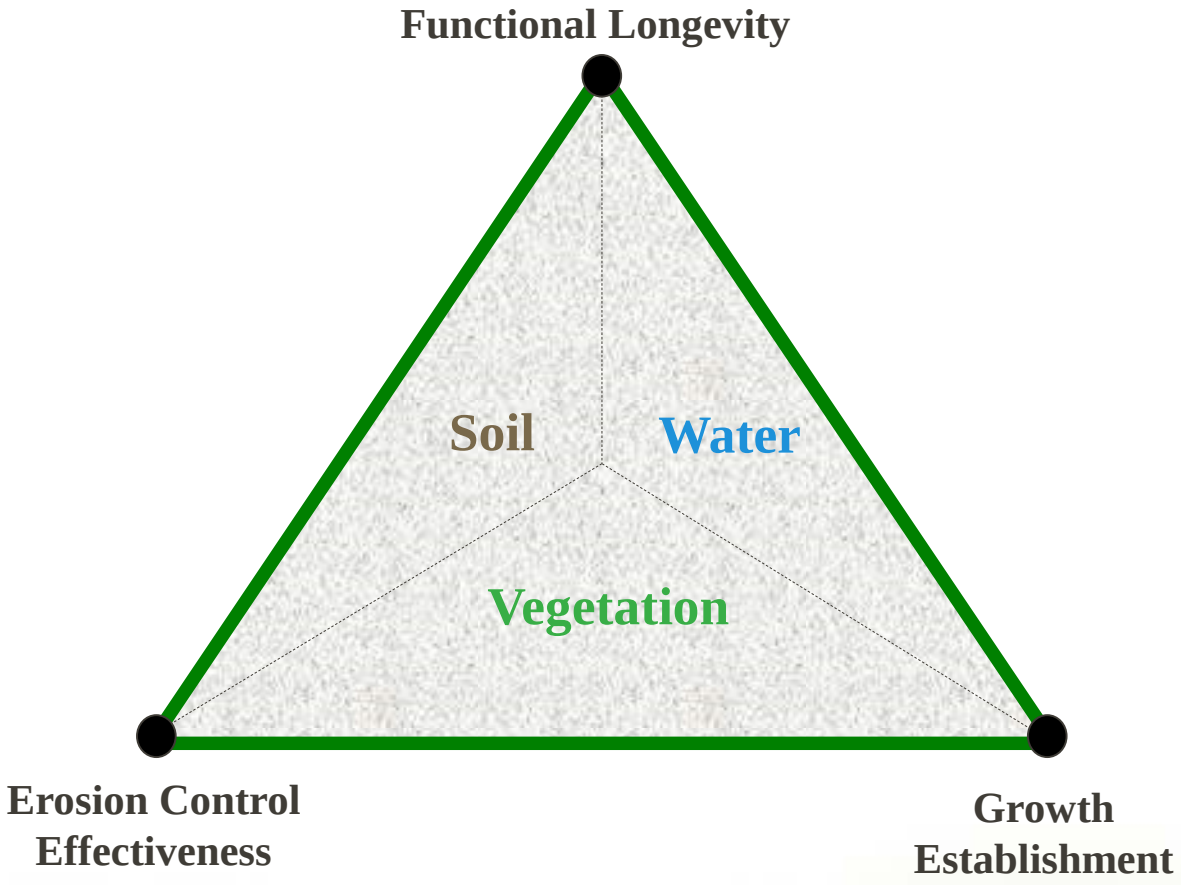
Establishing vegetation requires balancing

NATURAL VARIABLES

and

PRODUCT BENEFITS

to create the best environment for growth and establishment



“The Green Engineering Triangle”

Texas Transportation Institute Indoor Facility

- 4 ft x 40 ft m test beds
- Adjustable slopes
  - 2H:1V & 3H:1V
- Sand & clay soils
- Test both RECPs & HECPs

Large-Scale Flume Testing of Vegetated Turf Reinforcement Systems – Colorado State University

Flume test box in place

Velocity – 30 ft/sec
Shear Stress – 17 lb/ft^2

Fundamental #4 – Proper Installation

- Comprehensive and detailed construction specifications with plans/drawings
- Complete installation guidelines
- Tools or calculators to facilitate mixing ratios and/or application rates
- Experience…preferably site specific experience!

Fundamental #5 – Inspection and Maintenance

- Inspection by qualified professionals whose expectations are consistent with installer as well as owner and regulatory entity(s)
- Initial inspections to insure installations are in accordance with plans/specs with material quantities and activities fully documented
- Subsequent inspections conducted at pre-determined time intervals and maintenance activities conducted after each significant precipitation or other potentially damaging weather event


Chrome Mine
Rustenburg/Krondaal Area, South Africa
January 2012


Chrome mill tailings
are acidic and contain no
organics or nutrients
Surface temperatures reach 63º C (145ºF)

The Integrated Approach

- Prescriptive biological soil treatment hydraulically-applied at 8,000 kg/ha (7,142 lb/ac)
  - Organic matter – composted manure
  - Humic and fulvic acid
  - Microbial cultures
  - Slow release soft rock phosphate
- Lime applied at 2,240 kg/ha (2,000 lb/ac)
- Slope roughening to slow surface runoff, increase infiltration, and create pockets for germination and growth

The Integrated Approach

Prescriptive seed mix – “The Big Five”

- *Eragrostis tef* – “Tef “ annual lovegrass
- *Eragrostis curvula* – Weeping Lovegrass/Oulandsgras
- *Digitaria eriantha* – Smutsfinger/Common Finger Grass
- *Chloris gayana* – Rhodes Grass
- *Cynodon dactylon* – Bermuda or Kweek Gras

Erosion Control Material

- Flexible Growth Medium
  - To resist heavy downpours
  - Facilitate growth establishment
  - Long dry season – functional longevity > 1 year
- Hydraulically-applied at 3,600 kg/ha (3,214 lb/ac) on 2H:1V slopes, 8 -10 meters high
- Two-step application
  - Step one – amendments, seed mix and tracer
  - Step two – flexible growth medium from two directions


January 2012
3 weeks growth


June 2012
6 months later


February 2013
14 months later

Nickel Mill Slag

Remediation Project

Sudbury, Ontario, Canada

The Integrated Approach – Soil Test

- Slag – highly acidic, low in organic matter and nutrients
- 18 in (46 cm) clay cover
- 80,000 yd^3 (61,164 m^3)
- Lime, synthetic fertilizer and biostimulants applied directly on clay cover

Placement of Cover Material

The Integrated Approach – Seed Mix

- Grasses – Perennial Ryegrass, Canada Bluegrass, Timothy, Red Top, Hard Fescue, Creeping Red Fescue, Meadow Fescue, Chewings Fescue
- Legumes – Alsike Clover, Red Clover, White Clover, Birdsfoot Trefoil
- Hydraulically-applied at 225 lb/ac (252 kg/ha)

Erosion Control Material

- Flexible Growth Medium
- Hydraulically-applied at 4,500 lb/ac (5,100 kg/ha) on 3H:1V slopes, 100 feet (30 meters) long
- Late fall dormant seeding
- Cat tracked (dozer walked) slopes
- Fiber filtration tubes for slope interruption
- Two-step application
  - Step one – amendments, seed mix and tracer
  - Step two – flexible growth medium from two directions


Sudbury, Ontario
October 2006


October 2006
Slag
Clay Cover


June 2007

Huzhu JinYuan Cement Ltd

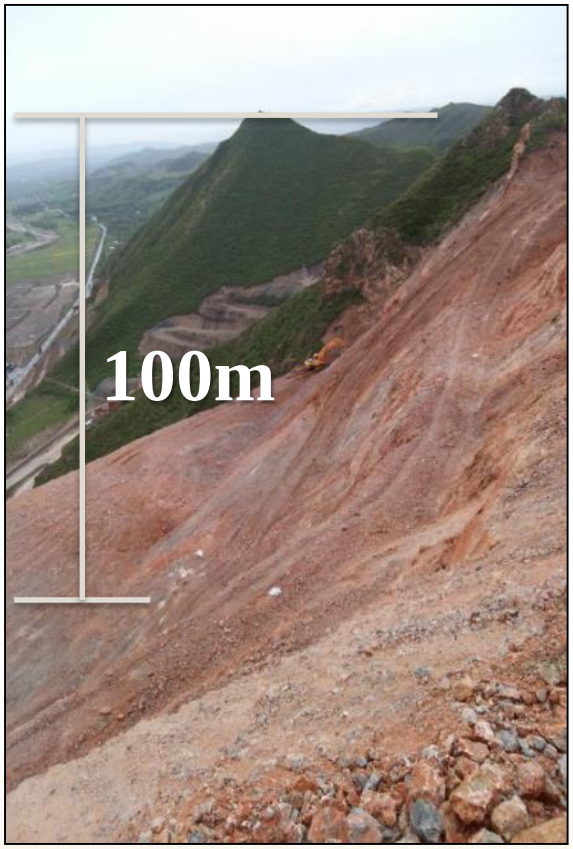
Xi Ning Project

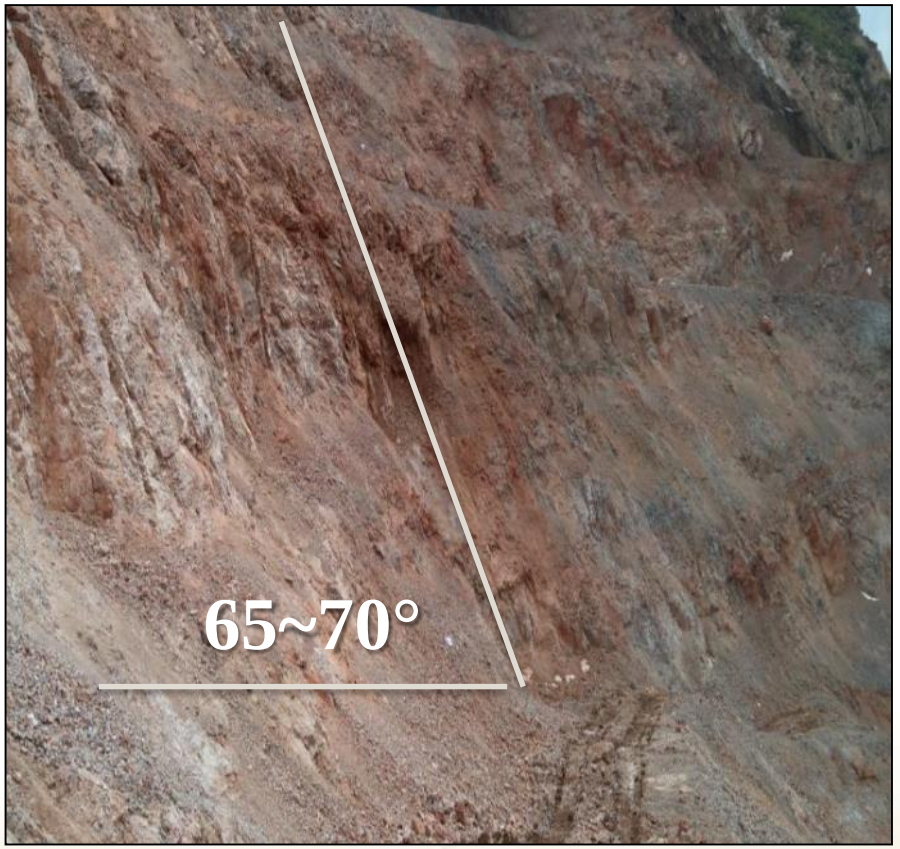
Xi Ning Project – Background and Issues

- Mine adjacent to Beishan National Forest Park
- Chinese government required owner to restore vegetation on slopes or factory would be shut down.

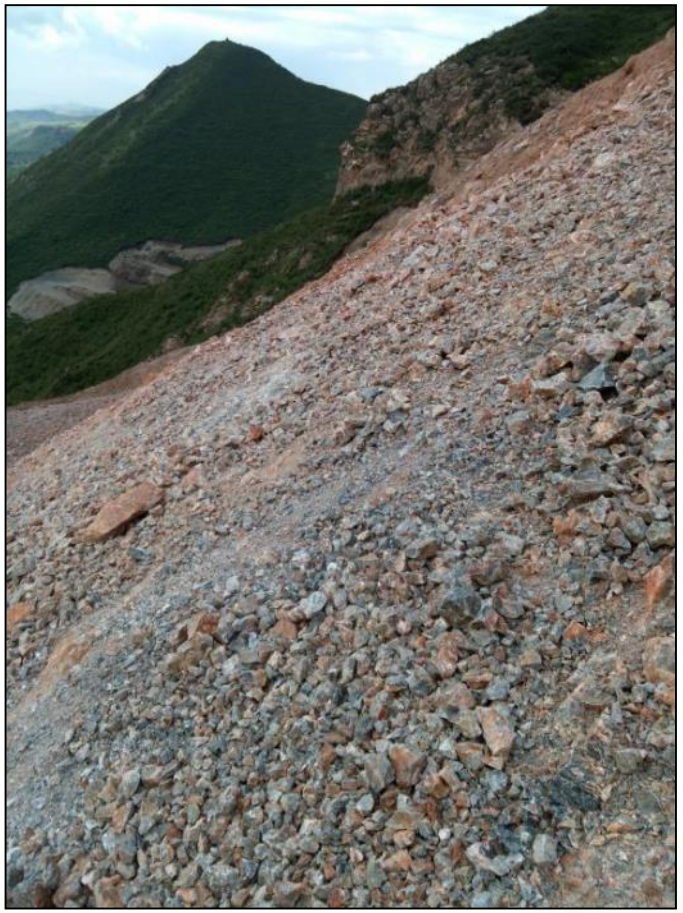
A Very Challenging Project!

- Slope vertical height: up to 100m (328 ft)
- Slope gradients: 65~70°, negative slopes in areas





Loose Gravel and Rockfall Potential



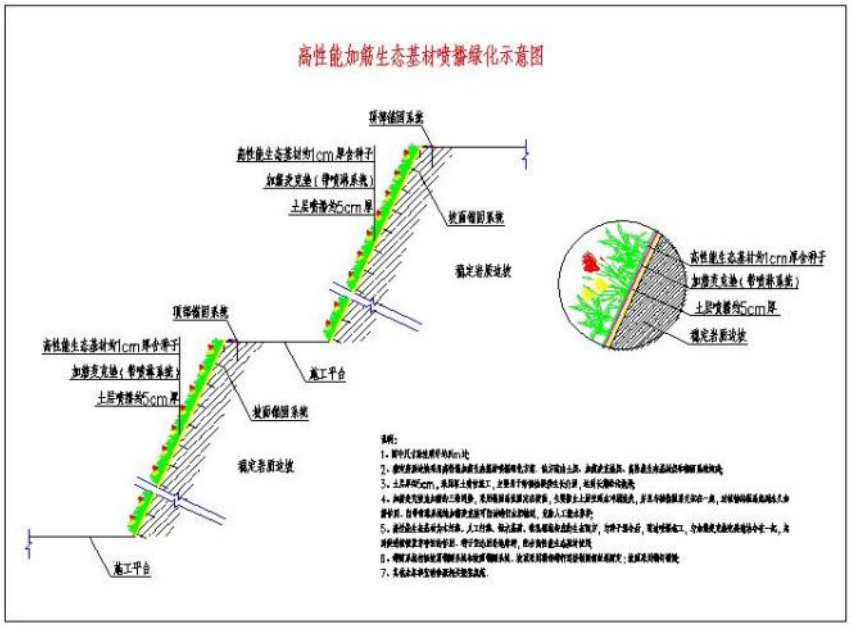
Challenging Growing & Climatic Conditions

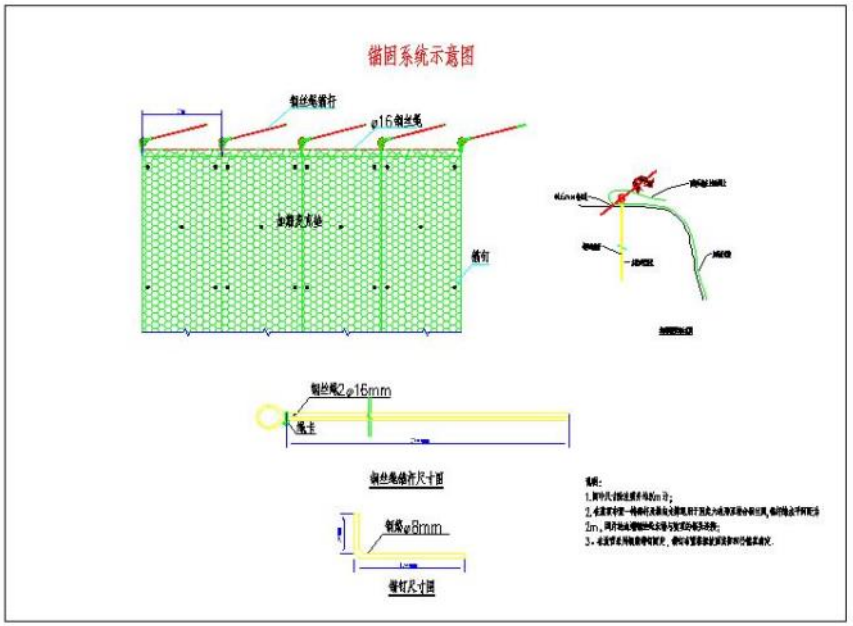
- High altitude – 10,758 feet (3,280 meters)
- Sudden changes in temperature, rain and snow
- Limited growing season – April to September

Key Issues to be Solved

- Eliminate rockfall potential – Safety!
- Create stable soil layer above loose rock
- Develop sustainable growing medium
- Select seed mix of locally adapted species
- Accelerate growth establishment in compressed growing season(s)
- Maintain soil moisture
- Control of surface erosion during “grow in” period of 2-3 years

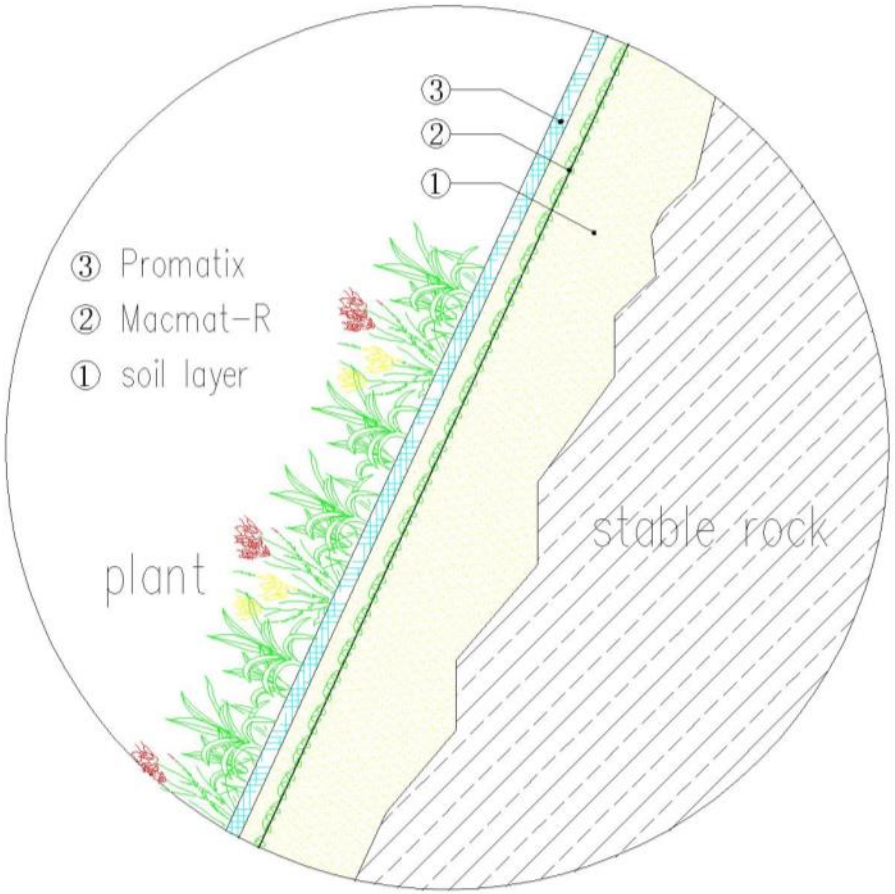
Solution and Design

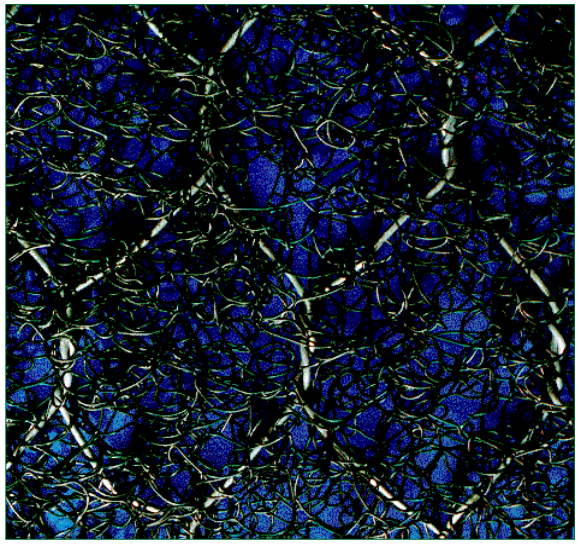


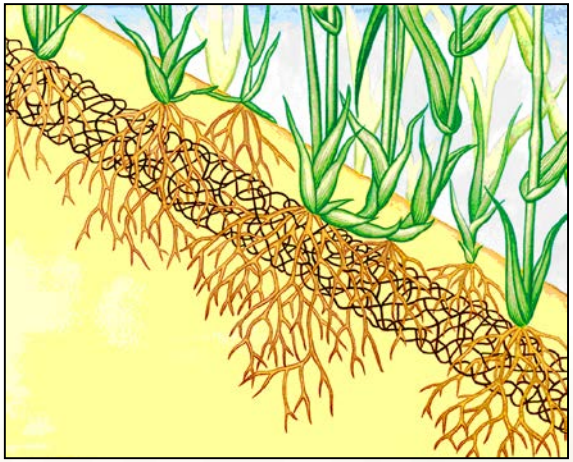


Turf Reinforcement Mat (TRM) and Rockfall Netting Composite

“High-Performance Reinforced Hydroseeding Method”







Plant Species Selection

- Planting experiments conducted with Qinghai Provincial University to determine locally available plant species adapted to the harsh site conditions.
- Selected species seeded at a rate of 31 lb/ac (35 kg/ha):
  - *Elymus nutans* – rye or wheatgrass
  - *Festuca arundinacea* – tall fescue
  - *Calendula officinalis* – calendula
  - *Hypoxis sp.* – star grass
- Fertilizer and amendments added

Installation Sequence

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

Clean Surface to Remove Dangerous Rocks

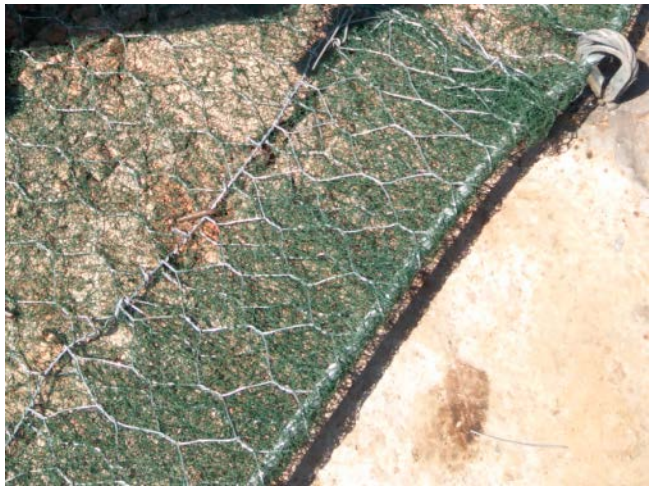
Fix Top Anchors and Steel Wire Rope

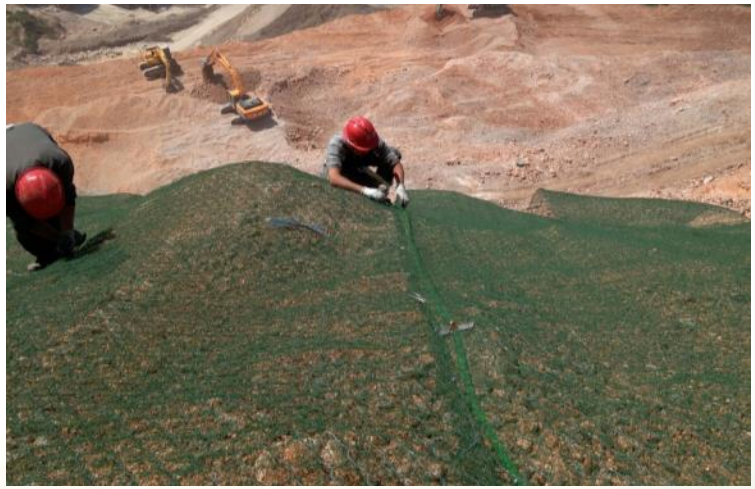
Anchors

Steel Wire Rope

Hang Green Colored TRM/Rockfall Net Composite





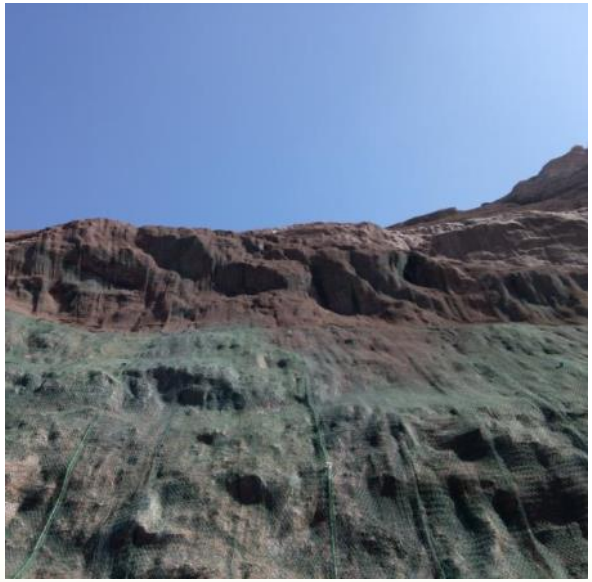


Anchor Composite to Rock Slope Surface

Spray Soil Mixure Slurry

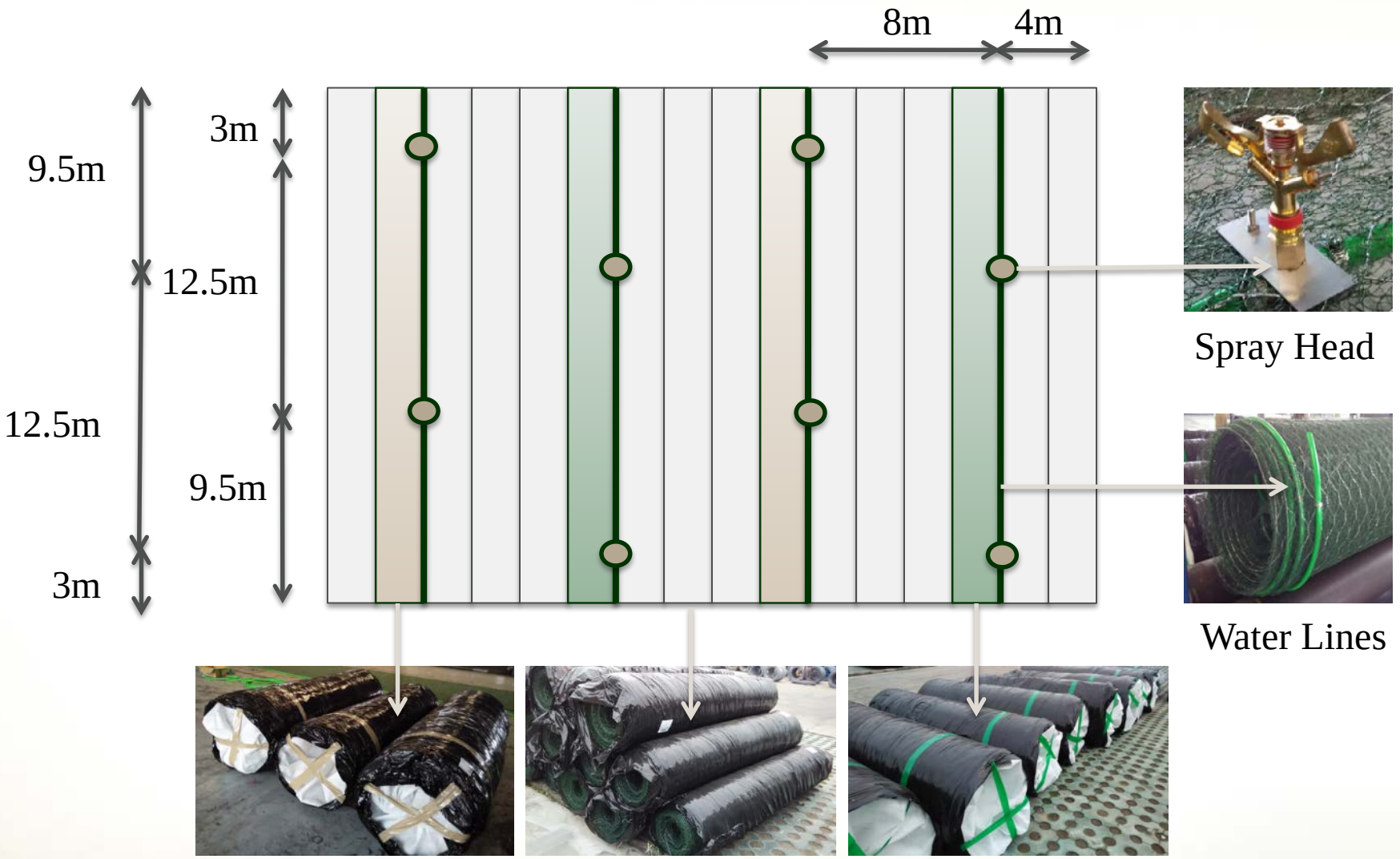
Soil test → Soil improved formula → Binding Agent

Soil source → Soil sift → Mixture → Spray mixture



Apply High Performance Flexible Growth Medium

Irrigation System Design



TRM/Rockfall Net Composite with Pre-Assembled Irrigation Lines

Irrigation System Works Well

Results and Influence

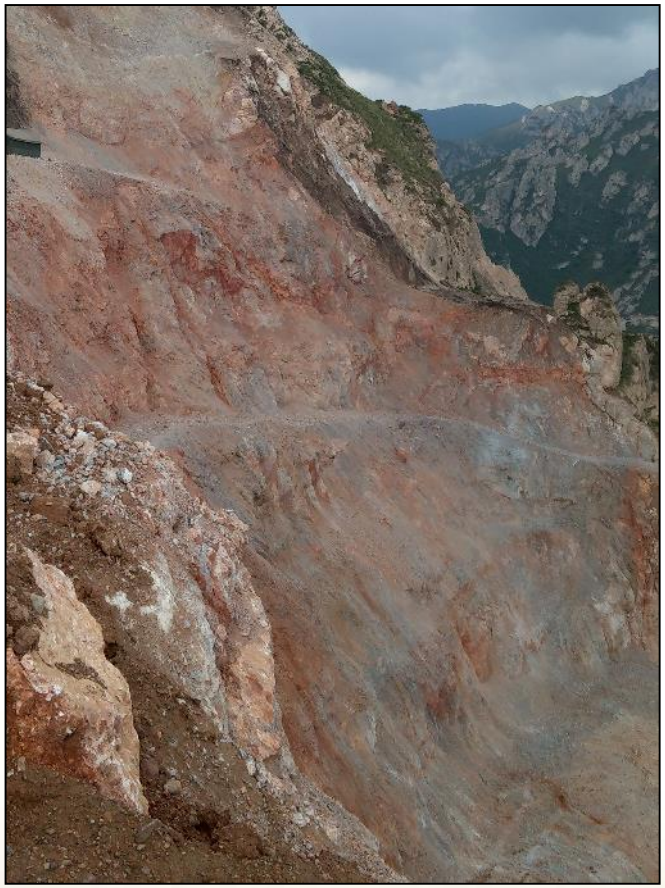

10 days
20 days
40 days
60 days

Plants Doing Well in First Season!

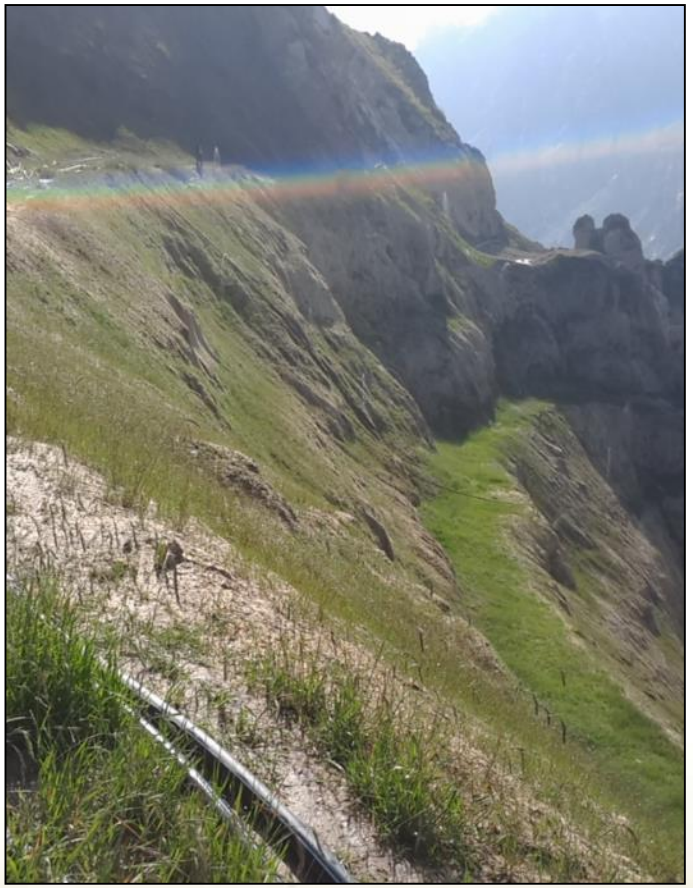
Site Snow Covered for Four Months

Vegetation Re-Emerged in 2015

Before construction – 2014



Summer 2015



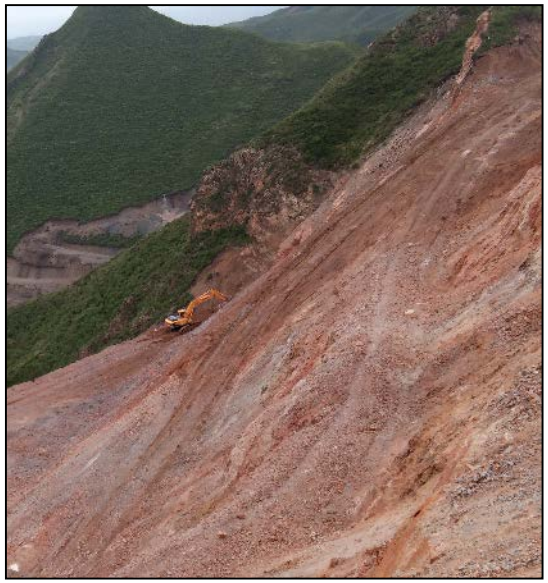
Vegetation Re-Emerged in 2015

Before construction – 2014

Summer 2015

So Far, So Good…

2014



2015

Site was “fertigated through irrigation system in summer of 2015
Chinese government approved mine’s efforts


Questions?
mtheisen@profileproducts.com