St. Anthony Mine

United Nuclear Corporation

2023 REVEGETATION PLAN

NOVEMBER, 2023

Prepared By:

CEDAR CREEK
ASSOCIATES, INC.

PO Box 272150
Fort Collins, CO 80526
Telephone: (303) 818-1978

Table of Contents

List of Maps, Charts, Tables, and Figures

List of Abbreviations

Best Management Practices	BMP's
Cedar Creek Associates, Inc.	Cedar Creek
Mining Act Reclamation Program	MARP
New Mexico Mining and Minerals Division	NMMMD
Post-Mining Land Use	PMLU
United Nuclear Corporation	UNC
Western Regional Climate Center	WRCC

United Nuclear Corporation (UNC)

St. Anthony Mine
2023 Updated Revegetation Plan

1.0 INTRODUCTION

Cedar Creek Associates, Inc. (Cedar Creek) was contracted in 2018 to update the Revegetation Plan (2018 Plan) in support of the "Closeout Plan" for United Nuclear Corporation (UNC) for the St. Anthony Mine. This updated Revegetation Plan is informed by previous vegetation sampling conducted in 2005, a growth media characterization effort and general site survey conducted in 2018 (Appendix A), the current design, and local and regional experience successfully reclaiming mine sites with similar conditions and challenges. This plan applies to lands within the project area that are subject to revegetation, including the waste piles, soil borrow areas, and the partial backfill of Pit 2, as well as the partial backfill of Pit 1, where site conditions are expected to be sufficiently unique to warrant a different revegetation approach. Revegetation protocols and performance criteria presented in this plan are responsive to the rules, regulations, and guidelines of the New Mexico Mining and Minerals Division (NMMMD). Specifically, the 1996 Closeout Plan Guidelines provide a framework for the monitoring methodology and success criteria (NMMMD, 1996). This plan is also informed by three new guidelines released by NMMMD in 2021 and 2022, 1) Self-Sustaining Ecosystem Guidelines, 2) Guidance for Soil and Cover Material Handling and Suitability for Part 5 Existing Mines, and 3) Revegetation Guidelines for New and Existing Regular Mine Reclamation. This revegetation plan identifies and defines reclamation protocols (Section 2.0), monitoring methodology (Section 3.0), success criteria (Section 4.0), and contingency planning / corrective actions (Section 5.0) to be utilized for revegetation of the St. Anthony Mine.

In consideration of the Self-Sustaining Ecosystem Guidelines, revegetation planning considers: 1) local vegetation communities, 2) post-mining (or post-disturbance) land use (PMLU), 3) specific considerations pursuant to desired post-disturbance management of private lands, and 4) scientifically sound methods and current techniques related to revegetation, soil amendments, seedbed preparation, seeding, mulching, and general reclamation science. In addition, quality assurance and quality control procedures in the form of monitoring surveys will be undertaken to confirm that revegetation efforts are implemented correctly, and the results of the process meet predetermined success criteria. The goal of this planning is to reclaim disturbed areas within the reclamation area to a condition that allows for the re-establishment of a self-sustaining ecosystem on the permit area following closure, appropriate for the life zone of the surrounding areas unless conflicting with the approved post-mining land use. The process of monitoring and evaluation will also allow for an adaptive management approach to reclamation, further assuring a positive project outcome at the St. Anthony Mine Site.

1.1 Regulatory Guidance

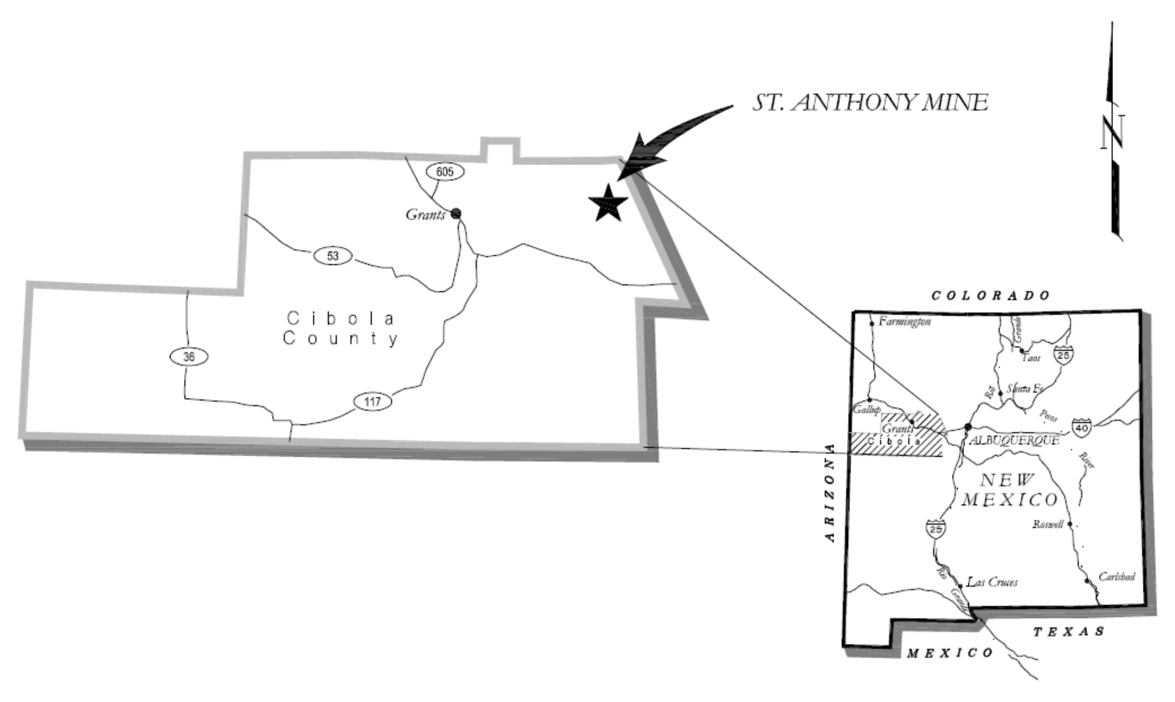
A framework for all reclamation including soil/growth media considerations, seeding considerations, and proposed amendments has been established for the entirety of the project. Industry best management practices (BMP's) will be employed wherever possible to increase the likelihood of positive project outcomes.

The St. Anthony Mine existed prior to the state Mining Act Reclamation Program (MARP), which regulates hard rock mining reclamation activities including uranium properties. Regardless, the revegetation protocols and performance criteria for the St. Anthony Mine Site will be guided by, and aim to meet the standards, rules, and regulations of the NMMMD (New Mexico Administrative Code [NMAC] 19.10.5). New Mexico Closeout Plan Guidelines (NMMMD, 1996). The rules and regulations provide a framework for the revegetation protocols and performance criteria to be applied to the St. Anthony Mine. Three new guidelines released by NMMMD in 2021 and 2022, 1) Self-Sustaining Ecosystem Guidelines, 2) Guidance for Soil and Cover Material Handling and Suitability for Part 5 Existing Mines, and 3) Revegetation Guidelines for New and Existing Regular Mine Reclamation have informed this plan.

1.2 Project Location

The St. Anthony Mine is located approximately 40 miles West of Albuquerque and 10 miles east-northeast of the town of Paguate, in Cibola County, New Mexico (Map 1). The project is located in the USGS 7.5-minute Moquino, New Mexico quadrangle, within the Arroyo de Valle, and is immediately north and east of Gavilan mesa. Reclamation of the facilities (pits, waste dumps. borrows, and other ancillary facilities) associated with the former mine site will result in a disturbance area of about 430 acres.

Map 1 - St. Anthony Mine - Project Location



1.3 General Site Description

The majority of the former mine site lies within an upland valley of floodplains, alluvial fans, and fan remnants dominated by grasses with occasional shrubs. The mine facilities (former pits, ancillary disturbances, several waste piles, and material storage piles) are located in this wide valley, predominantly consisting of fine textured Quaternary alluvium, ranging from approximately 5 to 50 feet in depth. The center of the valley contains an intermittent/ephemeral arroyo with finer, salty soils, supporting tamarisk and other weedy species, along with salt tolerant grasses. Sandstone benches and escarpments, with often shallow and lithic soils, are exposed on the margins of the main alluvial valley, increasing in prominence moving outward to the periphery of the project area. Transitions between observed ecotypes are often abrupt, as the vegetation systems are responsive to the soil systems and local geomorphology. Three vegetation ecotypes that correlate well with the soil-landscape relationship have been identified to dominate both the project site, and the life zone surrounding the project: 1) Grassland ecotype 2) Juniper Scrub ecotype, and 3) Bottomland ecotype.

Grasslands are herbaceous communities dominated by grasses and occasional forbs that can sometimes be seasonally dominant. Trees and larger shrubs are largely absent from this type except for the occasional invader of local sites. Grasslands in this part of New Mexico may be dominated by annual grasses, perennial bunchgrasses, or perennial sod-forming grasses and typically of the warm-season group. In the project area the grasslands are of this latter warm-season perennial sod-forming group. Soils tend to be deep (greater than 6 feet) but are occasionally shallow. Typical geomorphic features are floodplains, alluvial fans, and fan remnants.

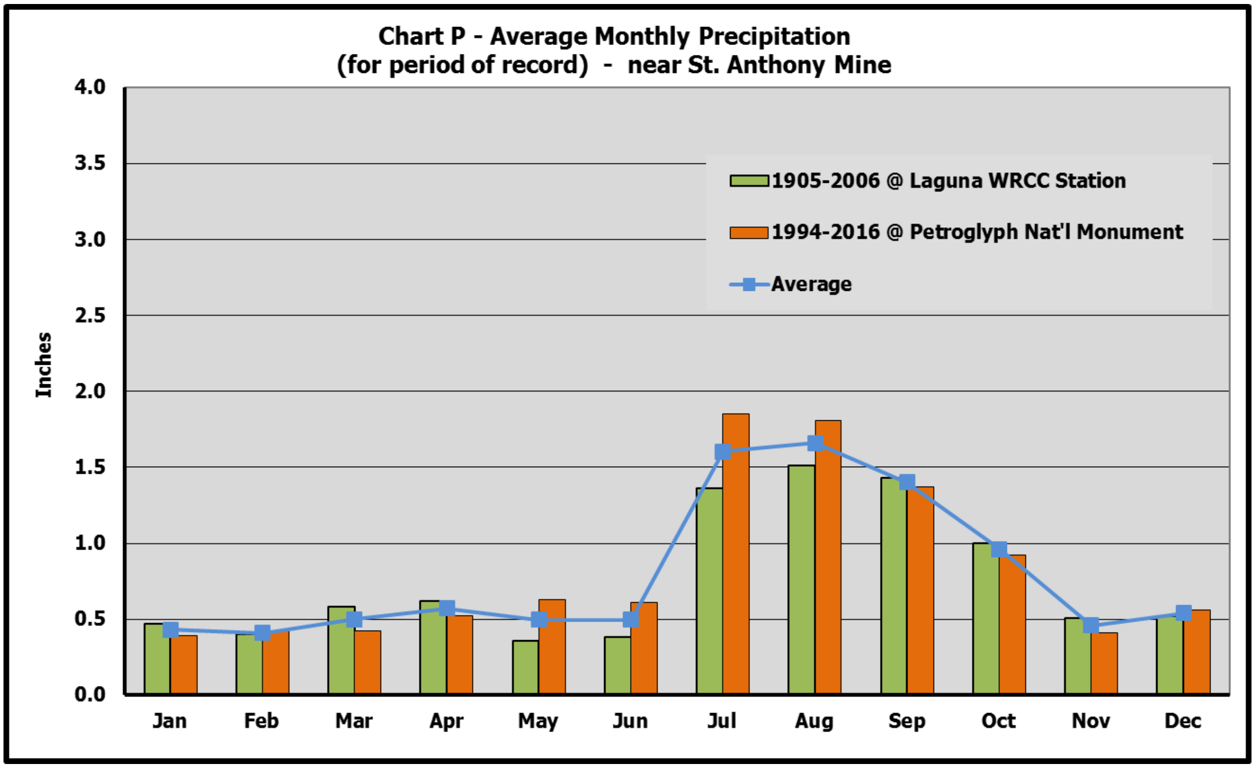
The Juniper scrub ranges between a "savanna" of scattered trees within the benched high-plains grassland, to dense woody dominated areas with very poor herbaceous understories. The Juniper Scrub ecotype is usually associated with rock outcroppings and thin, skeletal soils, often with a sandy texture. Occasional piñon trees are found throughout the ecotype.

The Bottomland ecotype is primarily characterized as having higher available water within the soil profile (more loamy, less sandy). Also, the higher available water is due to the ecotype being physically located in the arroyo bottoms that tend to collect surface runoff and fine-textured erodible materials. The increased soil moisture and loamy texture leads to increased vegetative cover from herbaceous taxa. Visible salt crusts were noted within the drainage bottom and along the cut banks (Cedar Creek, 2018 attached as Appendix A). The arroyo is deeply incised, and the upland grasslands immediately adjacent to the arroyo are not subject to flooding from typical precipitation events. On occasion, the bottomland community can exhibit areas of shrub domination by four-wing saltbush in areas exhibiting moderately elevated salt accumulations but can also exhibit areas of dominance by winterfat or Bigelow's sagebrush.

Other areas may be nearly absent of shrubs whereby grasses (and rarely forbs) are dominant. Tamarisk and other noxious weeds were also noted in the drainage bottoms.

1.4 Climate Data

The closest available weather stations to the project site, with prolonged and reliable climate data, are located in Laguna (~10 Miles to the southwest) and at Petroglyph National Monument (~33 miles to the east). The Laguna Western Regional Climate Center (WRCC) station period of record dates from April 1905 to March 2006, where average precipitation measures approximately 9.66 inches per year. The Petroglyph National Monument WRCC station period of record dates from April 1994 to May 2016, where average precipitation measures approximately 9.61 inches per year. The general agreement between these two data sets suggests the Petroglyph national monument site could be applicable to evaluating rainfall at the site in any given year during the reclamation process. Chart P below displays the average monthly data from each weather station, and averaged between stations, over the respective periods of record.



2.0 REVEGETATION PROTOCOLS

2.1 Growth Medium Considerations and Reapplication Depths

Once waste rock piles and other mine facilities have been graded to final contour, they will be top-dressed with an adequate amount of growth media. The growth media will be applied to develop an acceptable profile conducive to revegetation establishment and sustainability. A growth media characterization study was completed in 2018 (Appendix A), pertaining to the suitability of several soil Borrow Areas, Topsoil Piles, and Waste Piles for use as growth media and/or subsoil rooting media in the reclamation of the St. Anthony Mine Site. The study details the soil chemical and physical properties that exist across the project area and provides recommendations that have been incorporated into several sections of this work plan. Soils in the project area generally have elevated levels of salts and high proportions of sand, which will exacerbate drought stress and erosion potential, but are suitable for use in reclamation through the use of BMP's and a risk-based approach to reclamation. A variety of BMP's (seeding, mulching, slope design, etc.) and conservative reclamation design elements will be implemented to ensure the likelihood of reclamation success.

The laboratory testing parameters, methodologies, and suitability criteria utilized in the growth media characterization study to inform this reclamation plan are presented below in Table 1. These suitability criteria are generally in agreement with the Soil and Topsoil Suitability Ratings of the NMMMD Closeout Plan Guidelines and the more detailed Guidance for Soil and Cover Material Handling and Suitability for Part 5 Existing Mines.

Table 1 St. Anthony Mine - Revegetation Plan

Soil Laboratory Results - Suitability Criteria

Paramater	Method	Acceptable Average Values	Units
pH (paste)	ASTM D4972 - 13	6 - 8.3	N/A
Electrical Conductivity	4F1a1a1*	< 6	mmhos/cm
Organic Matter	Walkley-Black	< 10	% of Total Soil
NO_3-N	4D6*	$> 0.1^+$	ppm
Phosphorus (P)	4D6*	$> 1^+$	ppm
Potassium (K)	4D6*	$> 20^+$	ppm
Zinc (Zn)	4D6*	$> 0.25^+$	ppm
Iron (Fe)	4D6*	$> 1.0^+$	ppm
Manganese (Mn)	4D6*	$> 0.1^+$	ppm
Copper (Cu)	4D6*	$> 0.1^+$	ppm
Calcium (Ca)	EPA Method 3050B	Addressed as SAR	ppm
Magnesium (Mg)	EPA Method 3050B	Addressed as SAR	ppm
Sodium (Na)	EPA Method 3050B	Addressed as SAR	ppm
Sodium Adsorption Ratio (SAR)	EPA Method 3050B	< 15	N/A
Texture by hydrometer	ASTM D422-63(2007)e2	No Textural Extremes	% Size Fraction

* Soil Survey 2014 as Reference + Values Can Be Increased Through Organic Matter Additions

* EC > 6 excludes use as surficial growth media unless mixed. EC between 3-6 requires special consideration in the reclamation plan.

Based on the results of laboratory analysis, soils and growth media Borrow Areas have been ranked by preference for use as a surficial reclamation planting and growth media, and appropriate minimum cover depths have been suggested for each borrow source (Table 2). Both the quality of the borrow sources that will be utilized as cover materials, and the quality of the typical underlying waste materials, were considered when recommending cover depth requirements. The erodibility and generally elevated salinity in both surficial growth media, and especially in the underlying rooting media, were significant factors when suggesting minimum 24-inch cover depths.

Reclamation of Pit 1 entails partially backfilling the pit with waste rock from in-pit waste rock piles followed by loose material (Dakota sandstone and Mancos Shale) to be removed from the pit highwall. The resulting Pit 1 floor will be contoured to collect meteoric water within a low-lying depression near the center of the pit. Similar to the reclamation of other facilities, growth media, to a minimum of 24 inches depth, will be placed on top of the partially backfilled pit bottom.

Results from all laboratory analysis of borehole samples from each borrow source and waste pile are available in Appendix A.

Table 2 St. Anthony Mine - Reclamation Plan - 2018

Growth Media Borrow Source Summary

Potential Growth Media Borrow Source	Rank by Preference	Placement Suitability	Recommended Minimum Thickness	Material Types Observed
North Topsoil Pile	1	Cover / Planting Media	24 inches	Topsoil
West Borrow	2	Cover / Planting Media	24 inches	Topsoil
				Alluvium
Lobo Tract	3	Cover / Planting Media	24 inches	Topsoil
				Alluvium
Borrow South	4	Cover / Planting Media	24 inches	Topsoil
				Alluvium
Topsoil / Overburden Pile	5	Cover / Planting Media (on < 10% slopes)	24-36 inches	Topsoil
				Alluvium
				Shale
		Subsoil / Rooting Media		Coal
				Gypsum Precipitates
South Topsoil Pile	6	Subsoil / Rooting Media	N / A	Topsoil
				Alluvium
				White Saline Sandstone
				Black Carbonaceous Sandstones
				Shale
				Coal

Handling of growth media shall be performed prudently to avoid excessive disruption to soil structure. A specification for growth media placement will be developed as part of the CCOP. Handling or disturbance of growth media materials immediately following precipitation events shall be avoided, when possible, to limit issues associated with compaction. During construction, final placement, seed bed preparation or amendment application, care should be taken to avoid unnecessary or repeated trafficking of growth media to limit compaction. If compaction is expected, deep ripping or chisel plowing should be implemented, and always on the contour.

2.2 Soil / Growth Media Amendments and Fertility

Nutrient levels within the proposed growth media borrow areas and topsoil piles are within the acceptable ranges (Appendix A), signifying fertility specific amendments are not required. However, when materials are disturbed (plowed, harvested, tilled), organic matter and associated fertility can be released (volatilized) by a subsequent increase in microbial activity. In addition, organic amendments, particularly fibrous composts, can increase the water holding capacity and general condition of the seedbed, particularly during the critical period of germination and plant establishment. Therefore, a general application rate of 2 tons/acre (dry weight) incorporated into 3 inches depth of composted cow manure, green manure, or composted biosolids should be applied, and will benefit establishing vegetation on all reclaimed facilities throughout the mine site, including the Pit 1 backfill.

If composted cow manure or biosolids are utilized, the moisture content, salinity, organic content, and radioactivity will need to be tested by a certified laboratory. All testing should be conducted on representative samples from the same batch intended for use on reclamation, as the composting industry is unregulated and material quality can vary. Moisture and organic matter are used to accurately calculate target application rates. Given the potential for elevated salts in the soils, only low salt amendments should be used. Composted biosolids will be tested to ensure Radium 226 is less than 5 pCi/g.

Composted manures and/or composted biosolids are more desirable than inorganic fertilizers and industrial byproducts such as Biosol because they are significantly lower in inorganic and total nitrogen. Nitrogen preferentially stimulates the growth of undesirable weedy annual species, which reduces available water and nutrients for desirable perennial vegetation. In addition to the low nitrogen levels, the physical structure of the compost increases localized water holding capacity and creates islands of fertility to aid germination. Plant germination and establishment in the first few years is critical, as native seed sources then begin to supplement the initial seeding and stabilize the soil medium. Organic amendment application shall occur immediately prior to seeding, and be incorporated as soon as possible, preferably by disk harrow. Composted manure and/or biosolids left on the soil surface, exposed to warm temperatures and potential precipitation will readily decompose, thus making it less beneficial and therefore amendments shall be incorporated into the growth media as soon as practicable of placement.

2.3 Erosion Control and Seedbed Preparation

Long-term erosion controls are being included as part of the engineering design. Short-term (i.e. during vegetation establishment) erosion control measures will be implemented as part of the Contractor's construction stormwater pollution prevention plan (CSWPP) in accordance with the CCOP engineering plan set. The following are recommendations from an ecological perspective to allow for reclamation establishment. Slopes at, or gentler than, 25 percent (4:1) to increase the likelihood of a successful seeding effort and reduce the potential for erosion. The proposed growth media available onsite is primarily comprised of sandy soils; these soils are generally acceptable for vegetation growth but pose an elevated erosion risk (Cedar Creek, 2018). Therefore, where steeper slopes must be constructed, additional erosion control treatments (such as erosion matting, wattles, or rock/wood chip mulch) may manage erosion risk. On all sloping sites, apply reclamation techniques perpendicular to the direction of water flow as machinery access and safety considerations allow. Slope lengths are recommended to be broken by terraces such that no slope ever exceeds 400 feet uninterrupted and would be best if terraced at 100 or 200-foot length intervals.

Once the project area is regraded to approximate final configuration and overlaid with the native borrow material, deeply rip areas of steeper slopes (4:1 or greater) s with a single or double-toothed chisel plow pulled by a D8, or equivalent dozer, as appropriate. Deep ripping ideally would occur along the contour to a minimum depth of 12 inches to break the "slippage" zone between spoil materials and growth media and to create contour ridges to help preclude erosion. Ripping shall occur at nominal intervals of 4 feet (but no more than 6 feet) between the ripper teeth.

Once the engineered erosion controls have been implemented, a field level assessment of erosion risk shall be implemented following construction to determine the appropriate temporary erosion controls, if needed. The risk assessment shall consider slope gradient, slope length, and contributing area. Areas with high consequences of erosion shall receive permanent rock mulches and mixed into the growth media, or a combination of rock and wood shreds. Mulch can help conserve soil moisture for seed germination and aid initial plant establishment as well as provide additional soil erosion protection from both wind and water until a plant cover is established. Areas with lower consequences of erosion shall receive certified weed-free wood shred mulch, wood chip mulch, or crimped straw mulch.

2.4 Seeding Considerations

Seed mixes are designed to facilitate growth of appropriate and sustainable species for the targeted reclamation community. Species proposed for this mix are suitable for use, as demonstrated by their establishment on nearby revegetation at the L-Bar Mine Site, and other reclamation projects in similar soils and climates throughout the Grants Uranium Belt and rangelands surrounding Mount Taylor.

Based on the planned reclamation for the site, two targeted revegetation communities will be established on the mine site. The upland revegetation community is planned for most of the reclaimed mining facilities, including the majority of the Pit 1 surface. This target community is dependent on precipitation to establish and persist on reclaimed mining facilities. The mesic community is planned for the low-lying areas of the mine site, such as the meteoric water collection point in Pit 1, low lying depressions throughout the site used to discourage wildlife from using the eventual expressed water in Pit 1, and portions of reclaimed arroyo bottoms, if necessary. (The upland community is analogous to the Upland Vegetation Community found in the life zone of the project. The mesic community is analogous to the Bottomland Vegetation Community found in the life zone of the project where vegetation is dependent on surface water or groundwater.

Schedule permitting, seeding will be implemented at optimal times for site conditions (late fall/early spring). However, if a unit must be seeded during inopportune months, a field level assessment will determine whether temporary erosion control measures (such as crimped hay, wood shreds, wattles, etc.) are needed to stabilize the surface prior to anticipated vegetation establishment. Seeding will be accomplished using either (or both) broadcasting and drilling techniques, following final contouring and compost application/incorporation. If seed is broadcast, a light disc harrowing perpendicular to the flow of energy (wind and/or water) applied immediately follow seeding should increase seed to soil contact and provide some protection from wind or water erosion and granivory. If seed is drilled, drilling shall occur on the contour, to create subtle ridges perpendicular to the flow of energy.

The two proposed seed mixes are comprised of native species suitable for the local climate and edaphic conditions. Select species and application rates for each target revegetation community are presented on Tables 3 (Upland Target Community) and 4 (Mesic Target Community). Seed mixes have been designed to establish mixed shrub and grassland community, to provide for the PMLU of grazing and incidental wildlife habitat. In the mesic community certain species have been selected that develop well in and around periodically saturated communities. Trees are not specifically targeted in the seed mix but are expected to gradually volunteer on reclamation areas once the site stabilizes and natural successional processes commence. Volunteer vegetation (non-seeded species) is encouraged to establish on the revegetation parcel as long as species are not noxious weeds and do not impact the ability to achieve a sustainable perennial vegetative community.

Based on the planned reclamation, the initial conditions within the Pit 1 reclamation will allow for seeding of the upland and mesic targeted communities. In the majority of Pit 1, the upland seed mix will be the most suitable. The low area in the center of Pit 1, where meteoric water collects, will be seeded with the mesic mix. When the groundwater rises and emerges at the surface, saturated conditions will support the water obligate species. Essentially, the planned revegetation will use site conditions to determine seed mix suitability.

Seed mixes will be obtained from reputable commercial sources and information regarding the percent purity, percent weed seed, and percent germination will be reported on the seed tag (a regulatory document describing the contents of the seed you are purchasing). Besides being very useful information to the consumer, state and federal laws require seed companies to provide a description of the seed being sold. The information on the tag is based on tests that have been performed on the seed by a seed testing laboratory. The quality and viability of the seed is tested using standards and rules approved by the Association of Official Seed Analysts (AOSA). Seed test results are of interest to both growers and users of the seed. Seed quality is tested by determining the percentage of pure seeds relative to the percentage of contaminants such as weed or other crop seeds and inert matter (e.g., stems, chaff, small stones). Seed viability can be evaluated by standard germination tests that determine the percentage of viable seeds in a sample that have potential to germinate and produce seedlings under favorable field conditions. The percentage of pure live seed (PLS), calculated as the percent purity multiplied by the percent germination, is commonly used as a standardized indicator of seed quality.

Table 3 St. Anthony Mine - Reclamation Plan

Upland Seed Mix

No.	Obs. On Site	Common Name	Scientific Nomenclature	Recommendations PLS/lb.**	Recomd. PLS lbs/ac	PLS / ft^2	% of Seeds in Mix	This entire mix can be drill seeded Comment (Based on Site-specific Findings or Professional Judgment)
1	XX	Western wheatgrass	*Agropyron smithii*	110,000	1.50	3.8	4.4%	NRCS indicated climax species
2	XX	Alkali Sacaton	*Sporobolus airoides*	1,758,000	0.75	30.3	35.3%	NRCS indicated climax species
3	XX	Blue Grama	*Bouteloua gracilis*	825,000	0.50	9.5	11.0%	Stong component of native community
4	XX	Galleta	*Hiliaria jamesii*	159,000	0.50	1.8	2.1%	Stong component of native community
5		Thickspike Wheatgrass	*Agropyron dasystachyum*	154,000	1.00	3.5	4.1%	Good performer - Offers diversity
6	XX	Indian Ricegrass	*Oryzopsis hymenoides*	141,000	1.00	3.2	3.8%	Should do well in areas of sandy texture
7	XX	Sideoats Grama	*Bouteloua curtipendula*	191,000	1.00	4.4	5.1%	Good performer - Offers diversity
8	XX	Bottlebrush Squirreltail	*Sitanion hystrix*	192,000	0.25	1.1	1.3%	Fair performer - Offers diversity
			Subtotal		**6.50**	**57.6**	**67.1%**	
9	XX	Desert Globemallow	*Sphaeralcea ambigua*	500,000	0.75	8.6	10.0%	Sufficient performer for diversity
10		Palmer Penstemon	*Penstemon palmeri*	610,000	0.50	7.0	8.2%	Good performer - Offers diversity
11	XX	Rocky Mountain Penstemor	*Penstemon strictus*	592,000	0.25	3.4	4.0%	Fair performer - Offers diversity
12		Lewis Flax	*Linum lewisii*	293,000	1.00	6.7	7.8%	Good performer - Offers diversity
			Subtotal		**2.50**	**25.7**	**30.0%**	
13	XX	Fourwing Saltbush	*Atriplex canescens*	52,000	1.00	1.2	1.4%	NRCS indicated climax species - good forage value
14	XX	Winterfat	*Ceratoides lanata*	56,700	1.00	1.3	1.5%	Excellent performer - good forage value
			Subtotal		**2.00**	**2.5**	**2.9%**	
			Total		**11.00**	**85.8**		**This entire mix can be drill seeded**

Alternative species which may be used as substitutes for tertiary species or added to the overall mix for additional diversity.

Grasses	XX	Sand Dropseed	*Sporobolus cryptandrus*	5,298,000	0.00	0.0		
		Arizona fescue	*Festuca arizonica*	550,000	0.00	0.0		Use in moist areas only, likes 14" of precip.
	XX	New Mexico Needlegrass	*Stipa neomexicana*	70,000	0.00	0.0		
	XX	Purple three-awn	*Aristida purpurea*	250,000	0.00	0.0		
Forbs		Small Burnet	*Sanguisorba minor*	55,000	0.00	0.0		
Shrubs		Wyoming Big Sagebrush	*Artemisia tridentata wyo.*	2,500,000	0.00	0.0		
		Rubber Rabbitbrush	*Chrysothamnus naseousus*	400,000	0.00	0.0		
		Black Sagebrush	*Artemisia nova*	907,200	0.00	0.0		

■	Primary Species - Should not be substituted.
▒	Secondary Species - Substitute only when seed is not available. Substitutions should be: grass for grass, forb for forb, shrub for shrub.
	Tertiary Species - May be substituted, but recommendation is to plant as indicated.

* The 11 lb/ac mix is designed for drill seeding. When broadcast and harrow methods are used, the rate should be increased 1.5 times.

** PLS = Pure Live Seed.

Table 4 St. Anthony Mine - Reclamation Plan

Mesic Seed Mix				Recommendations				This entire mix can be drill seeded
No.	**Obs. On Site**	**Common Name**	**Scientific Nomenclature**	**PLS/lb.****	**Recomd. PLS lbs/ac**	**PLS / ft^2**	**% of Seeds in Mix**	**Comment (Based on Site-specific Findings or Professional Judgment)**
1	**XX**	Western wheatgrass	*Agropyron smithii*	110,000	2.00	5.1	5.3%	NRCS indicated climax species
2	**XX**	Purple Three Awn	*Aristida purpurea*	250,000	0.50	2.9	3.0%	
3	**XX**	Alkali Sacaton	*Sporobolus airoides*	1,758,000	0.50	20.2	21.4%	NRCS indicated climax species
4	**XX**	Blue Grama	*Bouteloua gracilis*	825,000	1.00	18.9	20.0%	Stong component of native community
5	**XX**	Galleta	*Hiliaria jamesii*	159,000	3.00	11.0	11.6%	Stong component of native community
6		Thickspike Wheatgrass	*Agropyron dasystachyum*	154,000	1.00	3.5	3.7%	Good performer - Offers diversity
7	**XX**	Indian Ricegrass	*Oryzopsis hymenoides*	141,000	2.00	6.5	6.9%	Should do well in areas of sandy texture
8	**XX**	Sideoats Grama	*Bouteloua curtipendula*	191,000	2.00	8.8	9.3%	Good performer - Offers diversity
			Subtotal		**12.00**	**76.8**	**81.2%**	
9	**XX**	Rocky Mountain Penstemor	*Penstemon strictus*	592,000	0.25	3.4	3.6%	Fair performer - Offers diversity
10		Lewis Flax	*Linum lewisii*	293,000	1.00	6.7	7.1%	Good performer - Offers diversity
			Subtotal		**1.25**	**10.1**	**10.7%**	
11	**XX**	Fourwing Saltbush	*Atriplex canescens*	52,000	2.00	2.4	2.5%	NRCS indicated climax species - good forage value
12	**XX**	Winterfat	*Ceratoides lanata*	56,700	2.00	2.6	2.8%	Excellent performer - good forage value
13	**XX**	Rubber Rabbitbrush	*Ericameria nauseosa*	400,000	0.75	2.6	2.8%	Excellent performer
			Subtotal		**4.75**	**7.6**	**8.1%**	
			Total		**18.00**	**94.5**		**This entire mix can be drill seeded**
Alternative species which may be used as substitutes for tertiary species or added to the overall mix for additional diversity.								
		Arizona fescue	*Festuca arizonica*	550,000	0.00	0.0		Use in moist areas only, likes 14" of precip.
	XX	New Mexico Needlegrass	*Stipa neomexicana*	70,000	0.00	0.0		
▓		Primary Species - Should not be substituted.						
░		Secondary Species - Substitute only when seed is not available. Substitutions should be: grass for grass, forb for forb, shrub for shrub.						
		Tertiary Species - May be substituted, but recommendation is to plant as indicated.						

* The 18.00 lb/ac mix is designed for drill seeding. When broadcast and harrow methods are used, the rate should be increased 1.5 times.

** PLS = Pure Live Seed.

2.5 Pit 1 Design Elements and Reclamation Considerations

Once the Pit 1 backfill has been graded to final contour, a soil cover system consisting of growth media conducive to revegetation establishment and sustainability will be constructed. The revegetation procedures presented in Section 2.1 to 2.4 are still applicable to the soil cover system at the bottom of Pit 1. However, it is predicted that groundwater will express between 0 to 6 acres over the seasons in the approximate center of Pit 1. This hydrologic condition is anticipated to begin several years after initial revegetation and has been considered in the revegetation design. Under this condition, different communities will be present in the bottom of Pit 1:

- Zone 1 – Upland Community: This community will be comprised of upland species which rely on precipitation for sustainability. This community will occur in the higher elevation areas of Pit 1.
- Zone 2 – Groundwater/Collected Meteoric Water Modified Community: This community will be comprised of both upland and phreatophytic species. This community is expected to be established by episodic collected meteoric water and/or expressed shallow groundwater around the lowest area of Pit 1. This community will occur between the water obligate and upland communities in Pit 1.
- Zone 3 – Water Obligate Community: Once the expressed water establishes within Pit 1 at a frequency or duration to support a water obligate community, this area may be inter-planted with water obligate willows and other herbaceous species, as discussed below, along the fringe of the water to add diversity. These plants rely on saturated soil conditions.

The area where each seed mix will be placed is shown on the design plans. Based on field conditions, some adjustment may be warranted during reclamation.

The proposed seed mixes for Pit 1 are comprised of native species suitable for the local climate and edaphic conditions. Select species and application rates for the upland community are presented on Table 3 and for the groundwater modified community on Table 4 (Mesic). Seed mixes have been designed to establish shrubs and grasses throughout the reclamation, to support the PMLU of grazing and incidental wildlife habitat. The mesic seed mix has a variety of species that will accommodate both the zone 1 upland community and the anticipated zone 2 groundwater-modified community.

During the monitoring period, an adaptive management approach will be used to evaluate if inter-planting or inter-seeding to improve diversity of the zone 3 water obligate community is warranted. If warranted, hand planting of cuttings, tubelings, or plugs will be planted to improve species diversity and attempt to occupy the niches that less desirable species infill. Appropriate plant materials for inter-planting include coyote willow (*Salix* exigua), threesquare bulrush (*Scirpus pungens*), hardstem bulrush (*Scirpus acutus*), common spikerush (*Eleocharis palustris*), , Torrey rush (*Juncus torreyi*), and Baltic rush (*Juncus balticus*). Volunteer vegetation (non-seeded species) is encouraged to establish on the revegetation areas as long as species are not noxious weeds and do not impact the ability to achieve a sustainable perennial vegetative community. Although, due to the expected conditions and its prevalence, it may be impracticable to prevent the establishment of salt cedar (*Tamarix ramosissima*).

2.6 Noxious Weed Considerations

Prior to and during construction activities, listed noxious weed species found within the project area will be treated (chemically, mechanically, or biologically) to limit the spread of noxious weeds. Russian thistle is not a listed noxious weed in New Mexico (Witte, 2016) and is commonly found in the arid west where it decreases as perennial plant communities establish and disturbance diminishes. Russian thistle and other invasive annual species common to the area do not need to be treated.

3.0 VEGETATION SAMPLING METHODS

Methods set forth in this section conform to the new Revegetation Guidelines for New and Existing Regular Mine Reclamation. Vegetation sampling protocols involve an emphasis on ground cover to facilitate repeatable statistical comparisons among treatment areas (or unique revegetation units). Concentration on a single variable of plant ecology facilitates improved comprehension and comparability over time and among treatment scenarios. Ground cover data, especially when determined using a very precise method such as the point-intercept procedure, provides some of the most important information regarding community variability that ecologists can evaluate. Such data facilitate the determination of true species composition, relative health (condition), and successional status of the sampled area. Furthermore, the same data can be utilized to develop the "sister" variables of frequency and species composition if desired. In addition, strong inferences can be developed with other reasonably correlated variables such as production when species composition is factored into the analysis. Also, ground cover is a preferred variable for revegetation monitoring because cover data can be readily obtained in a statistically adequate and cost-effective manner (using the proper procedures), has broad application for evaluation (including erosion control modeling), precisely reflects species' dominance of a given area, and when collected using bias-free techniques such as the point-intercept procedure, is one of the most repeatable variables among independent observers.

Deficiencies in vegetation, both general and localized, and other pertinent information relative to the reclamation are also recorded while traversing monitoring units during vegetation evaluations. During these traverses, the observer is vigilant for: 1) areas of poor establishment/growth, 2) pervasively weak or stressed plants, 3) indicators of soil fertility problems, 4) noxious weeds or invasive plant infestation, 5) evidence of unintended livestock grazing, 6) excessive erosion, and 7) any other similar revegetation / reclamation related issues.

3.1 Sample Site Selection / Location

The primary field efforts call for sampling revegetation and corresponding reference area(s). The systematic procedure for the determination of sample locations occurs in the following stepwise manner.

1. A fixed point of reference is selected for the entire area to facilitate location of the systematic grid in the field.
2. A systematic grid of appropriate dimensions (i.e., 200 ft X 200 ft) is selected by Cedar Creek to provide a minimum number of coordinate intersections; reclaimed areas are conducted to a minimum of 20 (for areas greater than 1 acre) or 5 (for areas less than 1 acre) initial transects whereas reference area sampling is conducted to a minimum of 15 initial transects.

3. A scaled representation of the grid is overlain on field maps extending parallel to major compass points to facilitate field location.
4. Unbiased placement of this grid is controlled by selection of two random numbers between 0 and 200 (used as coordinates).
5. Utilizing a handheld GPS, all of the initial sample points are located in the field.

3.2 Determination of Ground Cover

Ground cover at each sampling site is determined utilizing the point-intercept method (Bonham 1989) as illustrated on Figure 1. This method has been utilized for range studies for over eighty years; however, Cedar Creek utilizes state-of-the-art instrumentation that it has pioneered to facilitate much more rapid and accurate collection of data. Implementation of the technique for the sampling effort occurs as follows: First, a transect of 10 meters length is extended from the starting point of each sample site toward the direction of the next site to be sampled. Then, at each one-meter interval along the transect, a laser point bar is situated vertically above the ground surface, and a set of 10 readings recorded as to hits on vegetation (by species), litter, rock (greater than 2mm), or bare soil. Hits are determined at each meter interval by activating a battery of 10 specialized lasers situated along the bar at 10-centimeter intervals and recording the variable intercepted by each of the narrow (0.02 inch) focused beams (see Figure 1). In this manner, a total of 100 intercepts per transect are recorded resulting in 1 percent cover per intercept. The point-intercept procedure has been widely accepted in the scientific community as the protocol of choice for vegetation monitoring and is used extensively within the mining industry in connection with bond release determinations.

3.3 Determination of Woody Plant Density

At each sample site, a 2-meter wide by 50-meter-long belt transect is established parallel to the ground cover transect and in the direction of the next sampling point (in a cardinal compass direction – Figure 1). Occasionally 4 x 25 meter transects are employed where distance between points necessitates shorter belts. Then within each belt, all woody plants (shrubs, trees, and succulents) are enumerated by species and age class. Determination of whether or not a plant could be counted depends on the location of its main stem or root collar where it exited the ground surface with regard to belt limits. Sample adequacy is determined for informational purposes only.

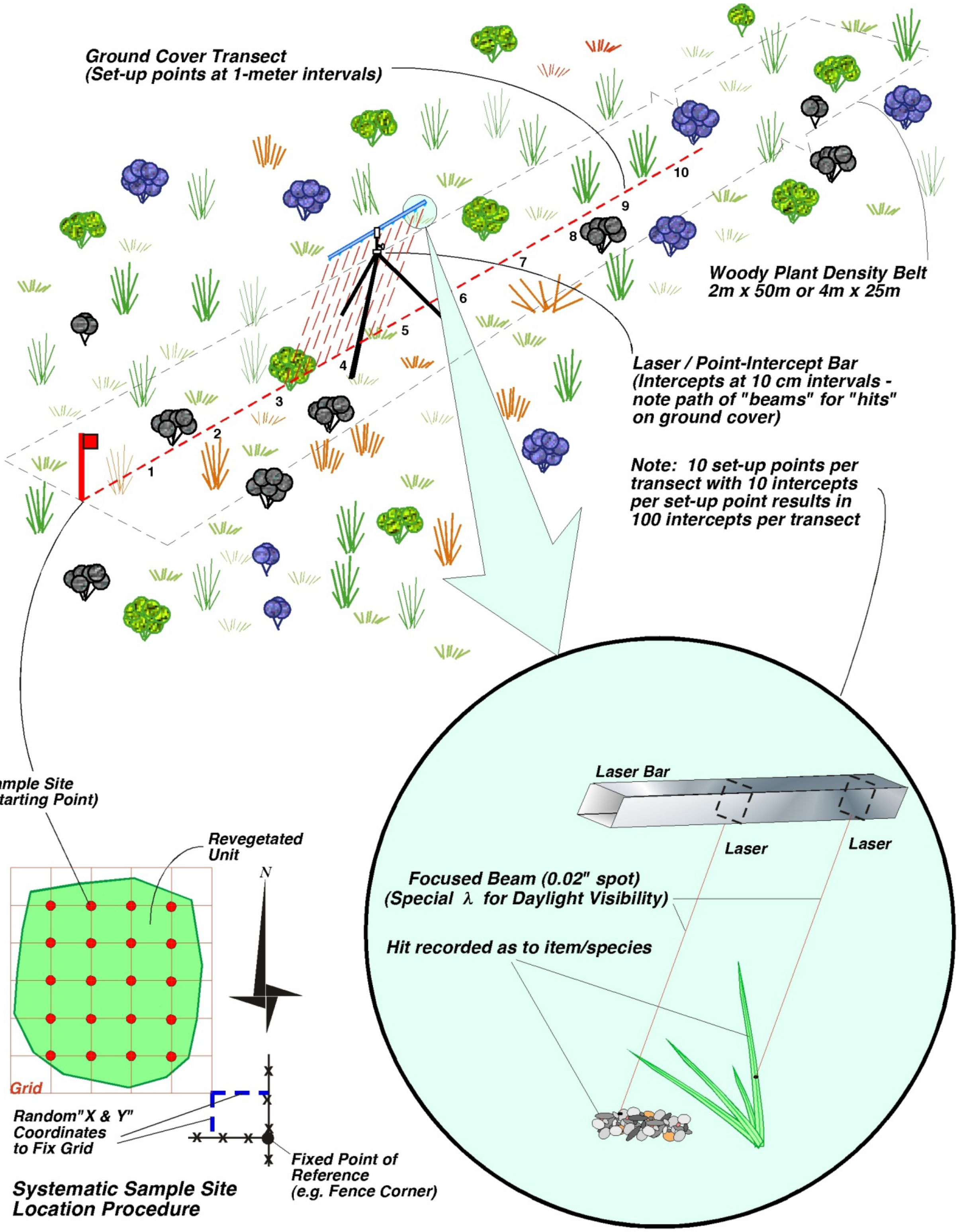


Figure 1

Sampling Procedure at a Systematic Sample Site Location

3.4 Photo Monitoring

Permanent photo-points (marked in the field with wood lathe and GPS coordinates) are established within revegetation areas to visually catalog vegetation progress. At each point, four photos are exposed, one each in a cardinal compass direction (N-E-S-W) using a photo board to indicate photo-point and direction visible in each frame. Photos are exposed in portrait orientation (as opposed to landscape) with the horizon at the very top of each photo. In this manner, all vegetation from very close to very far is observable. A map of the photo points will be provided in the revegetation monitoring reports.

3.5 Year 1 – Emergent Density Monitoring

Following the first growing season after seeding, each reclaimed unit will be subjected to a relatively brief one-time evaluation to document plant establishment as well as record other pertinent reclamation considerations. This evaluation consists of a revegetation specialist traversing the reclamation areas and evaluating vegetation establishment and related physical and biotic conditions. Approximately 1 hour of review time per 20 acres is expended for qualitative efforts. During these traverses, the observer is vigilant for: 1) areas of poor seedling emergence, 2) pervasively weak or stressed seedlings, 3) indicators of soil fertility problems, 4) noxious weeds or invasive plant infestation, 5) evidence of unintended livestock grazing, 6) excessive erosion, 7) pockets of the aforementioned, and 8) any other similar revegetation / reclamation related issues.

In addition to the physical and biotic attributes evaluation, the surveying observer will collect semi-quantitative samples to document the emergent density of seeded species. In this regard, between 5-15 samples are collected from each of the reclaimed units. Each sample consists of a cluster of five 1.0 ft^2 quadrats distributed in an unbiased manner. Following a random toss of each quadrat, the number of emergent plants rooted within the frame's perimeter is recorded accordingly into one of five classes: perennial grass, perennial forb, shrub/tree (by species), annual grass, or annual forb. This procedure typically takes only 2-3 minutes per sample point (five quadrats) yet yields valuable information on the success of the seeding effort. Typically, efforts that result in an average of fewer than one perennial emergent per ft^2 should be considered to be poor and a possible candidate for remediation. Efforts with 1 – 2 perennial emergents per ft^2 are considered to be fair, 2 - 3 perennial emergents per ft^2 are considered moderately good, 3 – 4 perennial emergents per ft^2 are considered to be good and 4 – 5 perennial emergents per ft^2 are considered to be very good. Finally, greater than five perennial emergents per ft^2 are considered to be excellent. Barring overly adverse events (grazing, drought, etc.), the number of observed emergents following the first growing season provides both an indication of the quality of eventual revegetation as well as the expected time necessary for the new community to reach maturity.

This semi-quantitative procedure is also implemented by Cedar Creek to provide perspective to an otherwise difficult visual circumstance. Because new seedlings are putting the vast majority of their energy into underground root systems during the first growing season, the above-ground plant parts are typically very small, obscure, and/or difficult to observe by the untrained eye. Because of this phenomenon, typical observation from a height of 5 - 6 feet (standing human) typically reveals only a small fraction of emergent plants. Oblique angle observation from a distance of more than 15 feet reveals almost zero discernible emergents.

4.0 REVEGETATION MONITORING SCHEDULE AND SUCCESS EVALUATIONS

The monitoring program and success criteria will follow the framework from the NMMMD. In this regard, a qualified revegetation specialist will review the revegetated areas on a pre-scheduled basis (during the peak of the growing season in September or shortly thereafter) to capture developing problems early in the process.

4.1 Revegetation Monitoring Schedule – NMMMD Framework

Under the NMMMD framework, the revegetation liability period (period of time that the owner is responsible for revegetation performance) is 12 years with monitoring every three years. The site visits for the revegetation will be as follows:

Year 1 – Emergent Density Evaluation

Year 3 – Qualitative and quantitative evaluations (managerial information only).

Year 6 – Qualitative and quantitative evaluations (managerial information only).

Year 9 – Qualitative and quantitative evaluations (managerial information only).

Year 11 – Qualitative and quantitative evaluations (final success evaluation).

Year 12 – Qualitative and quantitative evaluations (final success evaluation).

As indicated, the final efforts, during year 11 and 12, would be an evaluation for success determination. Years 11 and 12 information will be collected in such a manner as to provide defensible verification that success has been achieved. If it is determined that vegetation needs additional time to mature, monitoring will continue once every 3 years, thereafter, until success evaluations are positive. Other than first year efforts, annual monitoring would be a combination of both qualitative and quantitative efforts to facilitate tracking and progress toward revegetation success standards. Erosion assessments will primarily occur as part of the engineering site inspections.

4.2 Pit 1 Expressed Water Action Plan

During the revegetation evaluation in Years 1, 3, 6, and 9, the conditions pertaining to the Pit 1 expressed water will be assessed by a revegetation specialist. Specifically, the specialist will survey for saturation conditions which could support water obligate species. If favorable conditions are observed, then an action plan to implement inter-planting and inter-seeding will be submitted to the NMMMD. A revegetation specialist may, within his or her discretion, perform additional site inspections.

4.3 Revegetation Success Criteria

Success criteria will also generally follow the NMMMD framework. The determination of revegetation success will consider the following four factors:

- Comparison will be to a representative reference area encompassing the adjacent vegetation community and/or desirable ecological conditions (for the variables of ground cover and diversity);
- Plant species from the approved (and planted) seed mixes are present on reclamation;
- Lifeforms found within the reference area are present on reclamation; and
- PMLU (e.g., livestock grazing with incidental wildlife habitat) has been established and the vegetation is capable of being grazed at proper grazing intensity.

A reference area approach will be utilized for revegetation success comparisons. Because disturbance occurred prior to baseline data collection, original delineations of unique vegetation communities are not available. Site surveys indicate the overwhelming majority of current disturbance and planned reclamation will occur within upland areas, with alluvial soils, within the broader alluvial valley. The areas surrounding planned reclamation are dominated by mixed native grasses with occasional shrubs and represent the desired PMLU. Reclamation materials (both surficial growth media and subsoil rooting media) will be loose and fine, deep, and generally lacking coarse fragments; these reclamation conditions will mimic the upland alluvial areas adjacent to reclamation units and be most conducive to the establishment of mixed grass and shrub rangeland. Two reference areas in close proximity to the reclamation units, and representative of the edaphic conditions and PMLU of the reclamation system, will be proposed to NMMMD prior to revegetation sampling. It is anticipated that the majority of the site (representing upland vegetation communities) will be compared against a reference area in the undisturbed grassland ecosystem in the vicinity of the project. Low, lying mesic areas and the groundwater modified and water obligate communities in Pit 1 will be compared against a reference area in the undisturbed bottomland community in the vicinity of the project.

When utilizing reference areas (that are late seral by definition) for determinations of revegetation success, certain allowances must be made when comparing them to early seral revegetated communities; otherwise, comparisons would be scientifically invalid. As such, precedent has been set in this regard in both the coal and hard-rock industry's reclamation regulatory mandates. These allowances are a reduction in the amount of ground cover and diversity from late-seral values.

Revegetation success in revegetated units targeting livestock grazing land uses with incidental wildlife habitats will concentrate on two performance standards: (1) vegetative ground cover, and 2) woody plant density. Therefore, revegetation efforts will be considered successful when the following criteria have been met following at least 12 years of growth and development.

1. Vegetative Ground Cover Criterion:

   The perennial vegetative ground cover (exclusive of listed noxious species) below breast height (1.25 meters) in the target revegetated unit equals or exceeds 70 percent of the extended reference area's perennial vegetative ground cover, with 90 percent statistical confidence.

   The success criterion was developed based on the NMMMD’s precedents. The NMMMD has accepted 70% ground cover comparison on legacy mine sites which existed prior to the establishment of the MARP.

2. Woody Plant Density Standard:

   Woody plant density, as indicated by number of stems per acre in each revegetated unit equals or exceeds 60% of the stems per acre found in the reference area.

   OR

   The density of live shrubs, sub-shrubs, trees, and woody cacti rooted within the boundaries of the revegetated unit equals or exceeds a success criterion of 200 plants per acre.

The success criterion was developed based on the NMMMD’s precedents. The NMMMD has accepted 60% woody plant density comparison on legacy mine sites which existed prior to the establishment of the MARP. Additional information used to develop this success criterion is data from Hoenes and Bender (2012) for measured native shrub density on grassland communities of New Mexico with results of approximately 200 shrubs per acre on average.

4.4 Sample Adequacy Determination

Ground cover sampling within reclaimed areas is conducted to a minimum of 20 initial transects whereas reference area sampling is conducted to a minimum of 15 initial transects. From these preliminary efforts, sample means and standard deviations for total non-overlapping vegetation ground cover are calculated. The procedure is such that sampling continues until an adequate sample, n_{min}, has been collected in accordance with the Cochran formula (below) for determining sample adequacy, whereby the population is estimated to within 10% of the true mean (μ) with 90% confidence. These limits facilitate a very strong estimate of the target population.

When the inequality ($n_{min} \leq n$) is true, sampling is adequate and nmin is determined as follows:

$$\boxed{n_{min} = (t^2 s^2) / (d\bar{x})^2}$$

where: n = the number of actual samples collected

t = the value from the one-tailed t distribution for 90% confidence with n-1 degrees of freedom

s^2 = the variance of the estimate as calculated from the initial samples

$\bar{x}$ = the mean of the estimate as calculated from the initial samples

If sampling is designed for a formal success evaluation and the initial samples do not provide a suitable estimate of the mean (i.e., had the inequality been false), additional samples will be collected until the inequality ($n_{min} \leq n$) became true or until a maximum of 40 samples are collected. If sample adequacy is not achieved after 40 samples are collected, a reverse null approach will be used to demonstrate success. The demonstration of success will utilize the central limit theorem which assumes approximate normality when a sufficiently large number of samples are collected (greater than 30). A one-sided, one-sample, reverse-null t-test is considered appropriate. Since sampling adequacy is not required (nor recommended) for woody plant density, one density belt will be co-located with each ground cover transect, but adequacy shall not be tested for this variable. Resulting data can then be considered reasonable for the evaluation purposes intended.

5.0 CORRECTIVE ACTIONS / CONTINGENCY

After the initial seeding occurs and monitoring has begun, circumstances may require additional management actions to facilitate revegetation parcels toward the desired outcomes. The management actions presented below are normal land management activities. However, prior to implementing any inter-planting or inter-seeding, a plan will be submitted to NMMMD for approval. This plan will outline the areas needing action, proposed actions, and a timeline for implementation. The list of actions presented below may not represent an exhaustive list of potential options, as additional management alternatives may be needed to address site-specific issues that arise. Modifying success criteria may be required if unforeseen circumstances occur.

5.1 Inter-Seeding / Inter-Planting

In situations where revegetation is not meeting expectations or lacking diversity, inter-seeding / inter-planting can be used to increase diversity within revegetation parcels as required without restarting the liability period. This approach will be used if it is determined that adding water obligate species in the area of the Pit 1 water expression is warranted.

5.2 Weed Control

If noxious weeds are creating an obstacle to revegetation success, they will be treated to allow desirable revegetation to establish. Best management practices will be employed on vehicles and work equipment to preclude the spread of noxious weeds.

5.3 Range Fencing

Range fencing, cattle guards, and gates should be installed around areas deemed necessary to exclude grazing livestock from revegetated areas. Grazing permittees will be notified that grazing of the revegetated area will not be permitted until approved by a qualified revegetation specialist (biologist or ecologist).

5.4 Mulching

If revegetation parcels are eroding at an unforeseen rate while vegetation is still establishing, mulch can be used to provide rainsplash and wind protection, reduce evaporation, and stabilize the seedbed. Preferably, a wood fiber or wood shred mulch would be used, as it is more robust than hay or straw and more likely to provide wind protection.

If used, wood fiber mulch or wood shred mulch will consist of specially prepared wood fibers and will not be produced from recycled material such as sawdust, paper, cardboard, or residue from pulp and paper plants. If necessary, such as on a steep slope or an area deemed a high wind erosion risk area, a tackifier can be used with the wood-fiber mulch to improve adhesion. If erosion areas are localized, small, or well-sheltered, simple straw mulch should suffice in providing rainsplash protection. Interseeding will most likely be necessary if erosion is sufficient enough to require post-revegetation corrective mulching.

5.5 Supplemental Irrigation

Supplemental irrigation is not considered a suitable treatment mitigation alternative for reclamation in the arid west, even in instances of extreme drought. Underperforming areas will be addressed using common techniques, such as reseeding and applying mulch or other amendments to improve vegetative growing conditions. Previous revegetation efforts in the region demonstrate that successful revegetation can be established without supplemental irrigation.

6.0 LITERATURE CITED

Bonham, Charles D. Measurements for Terrestrial Vegetation. John Wiley & Sons. 338 pp. 1989.

Cedar Creek Associates, Inc. St. Anthony Mine Growth Media Materials Characterization. 2018.

Hoenes, B. D. and L. C. Bender. Factors influencing foraging habitats of mule deer (Odocoileus hemionus) in the San Andres Mountains, New Mexico. The Southwestern Naturalist, Vol. 57, No. 4 pp. 370-379. 2012.

New Mexico Mining and Minerals Division. Closeout Plan Guidelines for Existing Mines. April 30, 1996.

New Mexico Mining and Minerals Division. Rules and Regulations for Existing Mining Operations, Non-Coal Mining, Natural Resources and Wildlife. 19.10.5 NMAC. May 15, 2001.

Soil Survey 2014. Kellogg Soil Survey Laboratory Methods Manual. Soil Survey Investigations Report No. 42, Version 5.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

Witte, Jeff. New Mexico Noxious Weed List Update. New Mexico Department of Agriculture. October 19, 2016.

CEDAR CREEK ASSOCIATES, INC.
5586 Overhill Dr. Fort Collins, Colorado 80526 (970) 223-0775

Cedar Creek Technical Report

To: Stantec
From: CEDAR CREEK ASSOCIATES, Inc.
Date: October 4, 2018
Subject: St. Anthony Mine Materials Characterization

1.0 Introduction

Cedar Creek Associates, Inc. (Cedar Creek) was contracted by Stantec to complete a materials characterization study pertaining to the suitability of several Borrow Areas, Topsoil Piles, and Waste Piles for use as growth media in the reclamation of the St. Anthony Mine Site in Cibola County, New Mexico. This technical report serves to summarize observations made during field surveys and sample collection which took place from March 26th through April 17th and subsequent laboratory analysis.

Previous mining activities have resulted in unvegetated piles at the St. Anthony mine site. Limited topsoil salvage and stockpiling occurred during historic mining activities. However, in order to achieve successful reclamation of the St. Anthony Mine Site, in accordance with New Mexico Mining and Minerals Division (NMMMD) – Closeout Plan Guidelines, sufficient volumes of topsoil and/or alternate growth media are required. The Waste Piles, Topsoil Piles, and Borrow Areas were observed and sampled to determine whether materials comprising each facility exhibit suitable chemical and physical characteristics for use as a reclamation planting media (seedbed/surface material) or rooting media (subsurface material).

To optimize the required thickness of suitable growth media, numerous local soil-vegetation systems were also observed. These observations help inform the required thickness of cover materials to support the establishment of a self-sustaining vegetation community.

2.0 General Methodology

2.1 Field Sampling Preparation

Prior to the field surveys, available site-specific soils and geologic data were gathered. Publicly available data from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil surveys were reviewed to identify major soils that dominate the project area. Soil characteristics of each identified NRCS soil type along with corresponding mapping, both within and adjacent to the project area, were on hand during the field evaluation. In addition, agronomic analytical laboratory results from previous soil sampling efforts detailed in the 2007 Materials Characterization Report (MWH, 2007) were also reviewed and on hand during field evaluation. Various aerial imagery, geologic maps, and topographic maps were acquired to aid the field surveys.

2.2 Bore-Hole Sampling and Cataloging

A drilling program to characterize materials encountered throughout the various mine facilities and potential Borrow Areas was conducted by Stantec. Drilling locations and drilling methodologies were pre-determined by Stantec. Selected drilling sites were randomly distributed throughout each of the mine facilities and represented each facility adequately. Cedar Creek was onsite during drilling to observe materials excavated from the boreholes and to describe and characterize the properties and features of the materials encountered. Samples were collected throughout the drilling process for laboratory analysis of agronomic properties of the various material types encountered.

2.2.1 Sample Collection Methodology

A hollow stem rotary auger (with and without a core sampler) and a modified California sampler were the primary methods used to extract, observe, and sample soils. Numerous sample locations were selected for material core extraction, where more detailed observations of soil properties could be recorded. On all borehole locations, regardless of whether cores were extracted, cuttings brought up through the auger bit were continually inspected, observations recorded, and occasionally collected for laboratory analysis.

Observations pertaining to the properties and features of soil and geologic materials were recorded. Field characterizations generally followed NRCS soil description protocols and terminology in version 3 of the Field Book for Describing and Sampling Soils. NRCS pedon descriptions focused on features such as color, texture, structure, pedon concentrations, consistence, roots and pores, chemical response, coarse fragments, and any other features that were encountered and deemed potentially pertinent for informing revegetation success.

Soil and geologic materials were sampled by a combination of systematic and targeted sampling approaches. Professional judgement was required in deciding which materials would be sampled and tested for agronomic analysis to adequately characterize the site. Efforts were made to sample all material types, with several duplicates of material types. Samples selected for laboratory analysis came from either:

1. Fixed interval composite samples from intact soil cores.

2. Horizon sampling from intact soil cores.

3. Bulk composite samples from both rotary cuttings and cores.

4. Targeted samples of materials with unique or extreme properties or features.

On the Waste Piles and Topsoil Piles, soil and alluvial materials were often mixed with geologic materials as a result of the excavation, transport, and placement during previous mining activities. When materials were mixed, soil sampling defaulted to fixed interval composite sampling.

When intact core samples were extracted with materials in distinct layers (i.e., not mixed), horizon sampling techniques could be utilized to test the properties of the individual soil and geologic material types. This was the most common sampling approach in undisturbed, native Borrow Areas, but occasionally occurred on both Waste Piles and Topsoil Piles.

When intact cores were not extracted or were heavily disturbed and partially intact, bulk composite samples were instead utilized. This method was the least preferred, and was only utilized where necessary.

When unique or extreme variants of a material type were encountered (i.e., unweathered shale, coal, pure white saline sandstone), targeted sampling methods were utilized, to identify the bounds in which soil properties and features could vary within the various distinct geologic materials onsite.

2.3 Laboratory Analyses

Laboratory analyses consisted of numerous tests pertaining to the agronomic properties of the soils and geologic materials. The parameters tested, along with the methods and suitability criteria, are found below in Table 1. Methods and suitability criteria either meet or exceed the Soil and Topsoil Suitability Ratings within Attachment 1 of the NMMMD Closeout Plan Guidelines.

Table 1 St. Anthony Mine - Materials Characterization - 2018

Soil Laboratory Results - Suitability Criteria

Paramater	Method	Acceptable Average Values	Units
pH (paste)	ASTM D4972 - 13	6 - 8.3	N/A
Electrical Conductivity	4F1a1a1*	< 3 < 6	mmhos/cm
Organic Matter	Walkley-Black	< 10	% of Total Soil
NO_3-N	4D6*	$> 0.1^{+}$	ppm
Phosphorus (P)	4D6*	$> 1^{+}$	ppm
Potassium (K)	4D6*	$> 20^{+}$	ppm
Zinc (Zn)	4D6*	$> 0.25^{+}$	ppm
Iron (Fe)	4D6*	$> 1.0^{+}$	ppm
Manganese (Mn)	4D6*	$> 0.1^{+}$	ppm
Copper (Cu)	4D6*	$> 0.1^{+}$	ppm
Calcium (Ca)	EPA Method 3050B	Addressed as SAR	ppm
Magnesium (Mg)	EPA Method 3050B	Addressed as SAR	ppm
Sodium (Na)	EPA Method 3050B	Addressed as SAR	ppm
Texture by hydrometer	ASTM D422-63(2007)e2	No Textural Extremes	% Size Fraction
Sodium Adsorption Ratio	EPA Method 3050B	< 15	N/A

* Soil Survey 2014 as Reference + Values Can Be Increased Through OM Additions

* EC > 6 excludes use as surficial growth media unless mixed. EC between 3-6 requires special consideration in the reclamation plan.

Additionally, textural extremes (very poorly graded or well sorted materials) should be avoided for use in reclamation. Due to the extremely arid climate and challenging soil chemistry, the range of suitable textural classifications is more restrictive than typical for rangeland systems in the arid west. Below is a textural classification triangle highlighting unsuitable textural designations.

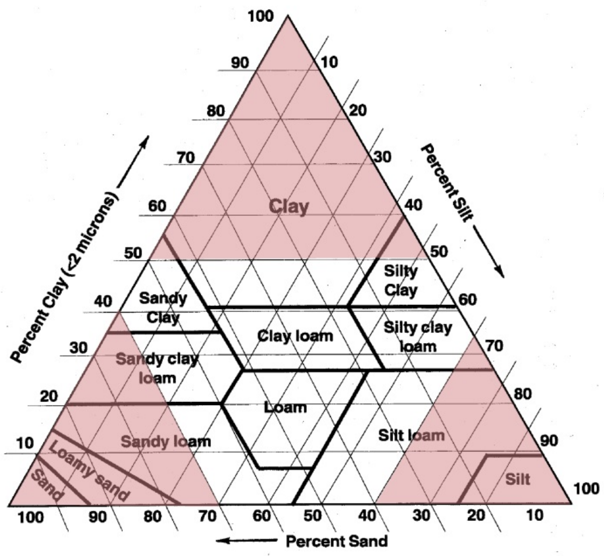


Figure 1: – Soil texture triangle, with unsuitable textural classes highlighted in red.

2.4 Additional Field Observations

Undisturbed soil-vegetation systems with comparable parent and geologic materials to the projected reclamation systems were targeted for observation, primarily to approximate cover thicknesses needed to support undisturbed plant communities. The depth of topsoil overlying geologic materials, particularly in thinner, lower-quality (productivity) soil systems, were specifically observed and noted. Observations were made contrasting areas that are currently supporting vegetation with unvegetated areas across the site. Emphasis was placed on geomorphic features most comparable to the eventual revegetation communities. Also, successful vegetation species were observed and recorded to assist in the compilation of a site-specific seed mix for inclusion in the reclamation plan.

3.0 Results

Any exceedances of the acceptable ranges for each parameter in Table 1 are denoted in red for easy identification within the tables in Section 3.0. Similarly, moderate or marginally elevated laboratory results below the suitability thresholds defined in Table 1 are denoted in orange. The degree of suitability for any parameter exists on a continuum, and moderate or marginal exceedances of most parameters may still require additional consideration in reclamation planning and design.

3.1 Boreholes

The predetermined sampling approach for the growth media characterization efforts was organized primarily by facility, under the assumption that materials in each pile would be consistent throughout. In reality, several piles contained varying combinations of unique geologic materials, randomly structured (layered and deposited) and often mixed. While conducting the field efforts, and after reviewing laboratory data specifically targeting representative samples of each material type, it became apparent that assessing the reclamation potential of any pile would be wholly dependent upon the material types eventually exposed at the surface of each pile.

The success of any direct revegetation efforts or reclamation of placed cover materials will be directly linked to the properties of the underlying geologic material types. Because the piles include somewhat random mixtures of numerous, individual types of geologic materials, it is inappropriate to discuss reclamation potential by facility, and more suitable to discuss reclamation potential by material type.

The features and properties of soil and geologic materials encountered across the property can be easily differentiated and summarized by color. Section 3.0 presents data as it was sampled, by facility. The discussion section (Section 4.0) will transition to discuss the reclamation potential of pertinent facilities by color coded material types, as it more useful for reclamation planning, design, and implementation.

3.1.1 South Borrow

Ten samples from three boreholes were analyzed from the South Borrow. Overall, field observations indicated that native soils in the South Borrow are relatively uniform, productive soils. The South Borrow is comprised of a small alluvial fan, with a slope alluvium and colluvium influence, exhibiting moderately deep soils with some deeper and shallower areas. Salinity, measured as electrical conductivity (EC), was slightly elevated in four samples, moderately elevated in three samples, and strongly elevated in one sample (above suitability threshold). The pH in one sample was slightly acidic. Two samples exhibited moderate elevations of sodium, measured as the Sodium Adsorption Ratio (SAR). Eight samples exhibited moderately high proportions of sand, while two samples were very high in sand (above suitability threshold). Otherwise, all agronomic parameters of individual samples were within the suitability criteria.

Table 2 St. Anthony Mine - Soil and Geologic Materials Characterization

South Borrow

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	--------Paste------- pH	EC mmhos/cm	Lime Estimate	% Organic Matter	----------ppm---------- NO_3-N	P	K	Zn	Fe	Mn	Cu
R2608	BS-1	1	5	8.1	0.4	very high	1.3	0.35	1.89	128.20	1.43	3.14	1.08	4.97
R2609	BS-1	5	10	8.0	5.7	very high	0.8	1.10	3.24	98.96	0.22	7.88	1.80	1.29
R2610	BS-1	0	10	7.7	2.7	very high	0.9	3.90	1.68	107.20	0.83	3.52	2.06	2.89
R2611	BS-1	10	20	7.7	2.9	high	0.8	4.10	1.26	81.03	0.16	3.37	0.78	0.66
R2612	BS-1	20	21	6.5	3.5	low	0.7	0.51	1.51	64.30	0.53	22.98	1.38	1.86
R2613	BS-3	0	5	7.5	2.8	high	0.9	1.40	2.00	134.20	0.10	3.08	1.10	0.64
R2614	BS-3	5	10	7.6	3.2	high	0.7	1.70	2.01	81.88	0.09	3.19	1.40	0.73
R2615	BS-3	10	15	7.7	2.7	high	0.6	1.20	1.69	62.19	0.10	5.25	1.42	0.56
R2616	BS-6	0	10	7.9	1.0	high	0.8	0.32	1.68	114.70	0.07	3.31	1.43	0.50
R2618	BS-6	10	20	7.9	6.1	high	0.5	1.50	1.57	45.85	0.07	1.97	0.58	0.37

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	----------meq/L---------- Ca	Mg	Na	K	SAR	----------%---------- Sand	Silt	Clay	Texture
R2608	BS-1	1	5	3.0	0.7	1.3	0.2	1.62	60	22	18	Sandy Loam
R2609	BS-1	5	10	33.4	0.5	34.4	29.7	4.02	60	16	24	Sandy Clay Loam
R2610	BS-1	0	10	32.5	1.6	4.3	1.1	0.80	58	24	18	Sandy Loam
R2611	BS-1	10	20	29.5	1.0	5.5	2.6	0.98	60	18	22	Sandy Clay Loam
R2612	BS-1	20	21	25.8	1.5	8.7	4.2	1.41	74	8	18	Sandy Loam
R2613	BS-3	0	5	28.8	2.0	4.4	1.0	0.85	56	22	22	Sandy Clay Loam
R2614	BS-3	5	10	32.2	1.2	4.3	1.5	0.78	64	18	18	Sandy Loam
R2615	BS-3	10	15	30.1	0.7	5.4	1.6	0.96	68	16	16	Sandy Loam
R2616	BS-6	0	10	6.0	0.9	2.3	1.0	1.27	72	10	18	Sandy Loam
R2618	BS-6	10	20	40.1	0.5	32.1	18.5	3.75	62	20	18	Sandy Loam

*= Below Reporting Limits

[+] Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

[+] Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.2 West Borrow

Four bulk composite samples from four boreholes were analyzed from the West Borrow. Overall, it was noted that native soils in the West Borrow are relatively uniform, productive soils. The West Borrow is a large alluvial fan and fan plane, with very deep soils. Salinity was slightly elevated in two samples, and strongly elevated (above the suitability threshold) in one sample. Otherwise, all other agronomic parameters were within the suitability criteria. When averaged, assuming mixing will occur through excavation, transport, and placement/grading, all parameters are within the suitability criteria.

Table 3 St. Anthony Mine - Soil and Geologic Materials Characterization
West Borrow

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste		Lime Estimate	% Organic Matter	ppm						
				pH	EC mmhos/cm			NO_3-N	P	K	Zn	Fe	Mn	Cu
R2829	BW-1	0	35	8.0	7.3	very high	0.7	1.50	1.40	138.90	0.15	5.90	1.70	1.60
R2830	BW-2	0	20	8.3	2.0	very high	0.6	0.79	1.50	130.30	0.12	2.80	0.86	1.50
R2831	BW-3	0	15	8.4	1.1	very high	0.6	0.29	1.80	106.00	0.14	2.80	1.20	1.50
R2832	BW-4	0	20	7.9	3.5	medium	0.6	8.60	1.10	153.50	0.11	2.40	0.91	1.20
Average				8.1	3.5	very high	0.6	2.80	1.45	132.18	0.13	3.48	1.17	1.45

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L				SAR	%			Texture
				Ca	Mg	Na	K		Sand	Silt	Clay	
R2829	BW-1	0	35	3.1	0.2	2.8	4.7	0.80	49	20	31	Sandy Clay Loam
R2830	BW-2	0	20	4.6	1.2	6.1	7.6	1.50	42	28	30	Clay Loam
R2831	BW-3	0	15	2.4	0.9	3.8	3.3	1.40	40	27	33	Clay Loam
R2832	BW-4	0	20	27.4	2.4	7	3.4	1.00	49	22	29	Sandy Clay Loam
Average				9.4	1.2	4.9	4.8	1.18	45	24	31	Clay Loam

*= Below Reporting Limits

[+] Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

[+] Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.3 Lobo Tract Borrow

Seventeen samples from seven boreholes were analyzed from the Lobo Tract Borrow. Overall, observations note that native soils in the Lobo Tract Borrow are somewhat variable (salinity), productive soils. The Lobo Tract Borrow is located in a wide valley bottom flood plain. Flowing surface water was observed in the region, with evaporative salt deposits consistently lining the waterway, and along the flood bank of the alluvial features. Salinity was slightly elevated in eleven samples, and moderately elevated in two samples. One sample exhibited a moderate level of sodium, while three samples were slightly elevated. Five samples exhibited moderately high proportions of sand, while two samples were very high in sand (above the suitability threshold). Four samples were high in clay, while three samples were moderately high in clay. Otherwise, all other agronomic parameters were within the suitability criteria. When averaged, assuming mixing will occur through excavation, transport, and placement/grading), all parameters are within the suitability criteria.

Table 4 St. Anthony Mine - Soil and Geologic Materials Characterization
Lobo Tract Borrow

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	--------Paste-------		Lime Estimate	% Organic Matter	------------ppm------------						
				pH	EC mmhos/cm			NO_3-N	P	K	Zn	Fe	Mn	Cu
R2593	L1-1	0	5	8.0	0.6	very high	1.0	4.60	7.12	99.26	1.09	4.03	2.88	1.86
R2597	L1-1	5	6	8.1	1.7	very high	1.3	1.80	1.78	262.30	0.35	12.49	2.53	4.73
R2594	L1-1	7.5	10	7.6	3.1	very high	0.9	4.50	3.56	125.20	0.19	4.28	0.38	2.56
R2595	L1-1	10	15	7.8	1.4	very high	0.8	8.50	2.75	119.20	0.29	4.07	0.53	1.72
R2596	L1-1	15	20	8.0	1.0	very high	0.7	8.00	2.36	80.77	0.20	4.70	0.51	3.40
R2591	L1-4	0	10	7.5	2.5	high	1.5	5.20	3.21	217.50	0.47	9.51	1.66	3.54
R2592	L1-4	13	20	7.7	2.4	high	0.2	2.20	4.36	31.42	0.67	4.81	0.38	3.67
R2598	L1-5	0	5	7.6	4.4	very high	1.0	3.80	1.59	249.40	0.27	8.71	0.59	3.33
R2599	L1-5	7.5	10	7.5	4.5	very high	1.2	18.80	2.56	274.60	0.45	9.69	0.47	3.88
R2600	L1-5	15	20	7.7	3.2	high	0.4	2.60	2.89	56.14	0.18	2.06	0.19	0.56
R2601	L2-1	0	20	7.7	5.0	very high	0.7	0.35	2.27	151.10	2.35	5.34	2.57	8.02
R2604	L2-5	0	10	7.5	3.5	high	1.2	12.00	2.25	330.70	2.27	8.61	3.55	7.73
R2605	L2-5	10	20	7.5	3.3	high	1.7	17.10	2.05	290.10	1.59	12.21	4.87	5.72
R2602	L2-6	7	10	7.6	5.1	very high	1.1	5.50	2.51	214.20	0.43	9.90	0.50	3.29
R2603	L2-6	11	13	7.6	3.9	very high	1.0	3.40	2.51	178.00	0.32	9.42	0.53	3.02
R2606	L2-7	0	10	7.6	2.9	very high	1.2	4.90	2.64	188.80	1.39	4.84	2.27	6.29
R2607	L2-7	10	20	7.7	3.6	very high	1.0	0.30	1.60	105.30	1.64	5.64	2.64	6.22
Average				7.7	3.1	very high	1.0	6.09	2.82	174.94	0.83	7.08	1.59	4.09

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	-----------meq/L-----------				SAR	---------%---------			Texture
				Ca	Mg	Na	K		Sand	Silt	Clay	
R2593	L1-1	0	5	0.3	0.0	0.1	0.0	0.33	64	18	18	Sandy Loam
R2597	L1-1	5	6	8.3	0.9	5.3	4.8	1.42	34	22	44	Clay
R2594	L1-1	7.5	10	22.6	0.9	6.4	5.0	1.20	46	22	32	Sandy Clay Loam
R2595	L1-1	10	15	9.1	0.5	2.9	4.0	0.88	48	20	32	Sandy Clay Loam
R2596	L1-1	15	20	5.5	0.3	2.0	3.4	0.77	60	19	21	Sandy Clay Loam
R2591	L1-4	0	10	127.0	6.1	48.7	56.3	3.58	32	30	38	Clay Loam
R2592	L1-4	13	20	36.4	3.9	15.7	7.9	3.34	84	10	6	Loamy Sand
R2598	L1-5	0	5	27.0	1.9	6.4	12.3	1.09	32	24	44	Clay
R2599	L1-5	7.5	10	27.0	1.5	5.8	13.8	1.00	16	28	56	Clay
R2600	L1-5	15	20	20.0	0.4	5.7	8.4	1.07	74	12	14	Sandy Loam
R2601	L2-1	0	20	30.4	2.0	18.6	16.9	2.64	62	20	18	Sandy Loam
R2604	L2-5	0	10	30.2	2.1	4.6	6.0	0.83	28	28	44	Clay
R2605	L2-5	10	20	25.3	1.6	5.0	8.8	0.92	24	22	54	Clay
R2602	L2-6	7	10	37.8	1.1	16.6	14.7	2.38	26	20	54	Clay
R2603	L2-6	11	13	21.6	0.6	7.2	10.8	1.24	14	22	64	Clay
R2606	L2-7	0	10	19.7	2.5	7.1	3.7	1.39	60	19	21	Sandy Clay Loam
R2607	L2-7	10	20	24.4	1.2	8.0	9.1	1.33	52	26	22	Sandy Clay Loam
Average				27.8	1.6	9.8	10.9	1.50	44	21	34	Clay Loam

*= Below Reporting Limits

[+] Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

[+] Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.4 Waste Piles 1, 2, 3, 4 and 7

Ten samples from nine boreholes were analyzed from Waste Piles 1, 2, 3, 4, and 7. Overall, it was noted that various geologic materials encountered between the piles were consistent, but with extensive variability within each pile. The piles contained a random mixture of saline sandstone, carbonaceous sandstone, shale, and coal. Significant yet variable coarse fragment contents were observed, ranging from gravels to boulders. Salinity was slightly elevated in two samples, moderately elevated in three samples, strongly elevated in two samples (above suitability threshold), and extremely elevated in one sample (specifically targeted for testing due to suspected high salt content). Four samples exhibited moderate levels of sodium, while one sample exhibited a moderately high level of sodium. Four samples exhibited moderately high proportions of sand, while four samples were very high in sand (above suitability threshold). One sample was slightly acidic, one sample was moderately acidic, and two samples were extremely acidic. One Sample was high in clay. Otherwise, all other agronomic parameters were within the suitability criteria.

Table 5 St. Anthony Mine - Soil and Geologic Materials Characterization
Waste Piles 1, 2, 3, 4, and 7

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste pH	Paste EC mmhos/cm	Lime Estimate	% Organic Matter	ppm NO_3-N	ppm P	ppm K	ppm Zn	ppm Fe	ppm Mn	ppm Cu
R2586	P1-2	60	65	4.2	9.8	low	1.2	0.08	2.93	88.38	6.36	187.20	32.90	3.92
R2587	P2-1	25	30	4.2	4.6	low	1.1	<0.1	4.14	136.80	2.29	153.30	15.69	4.99
R2590	P3-2	0	45	8.4	1.9	very high	0.4	3.70	3.46	52.50	0.90	6.01	1.00	1.27
R2588	P3-4	0	25	6.2	2.5	low	0.4	0.39	2.10	34.31	0.86	11.72	1.30	3.80
R2589	P3-4	35	40	5.8	4.1	low	0.7	<0.1	4.13	50.71	0.51	44.53	4.90	2.04
R2585	P4 (white sand)	0	1	8.2	42.1	low	0.8	60.40	1.43	94.48	0.32	5.15	0.20	0.77
R2833	P4-5	0	1	7.9	10.7	high	0.9	0.07	2.30	44.70	3.70	61.00	27.60	1.60
R2834	P4-7	0	1	6.9	1.3	low	0.2	0.30	1.60	66.70	0.23	6.70	4.10	0.42
R2835	P4-9	0	1	7.5	3.6	medium	0.4	<0.1	2.00	19.90	0.20	2.70	1.10	0.54
R2836	P7-1	0	1	7.6	4.8	high	0.4	0.07	1.00	68.50	0.16	5.00	0.97	1.00

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L Ca	meq/L Mg	meq/L Na	meq/L K	SAR	% Sand	% Silt	% Clay	Texture
R2586	P1-2	60	65	219.8	37.8	105.9	51.3	4.70	66	10	24	Sandy Clay Loam
R2587	P2-1	25	30	201.6	13.1	54.7	9.6	3.68	58	12	30	Sandy Clay Loam
R2590	P3-2	0	45	236.8	16.1	46.6	55.7	2.88	78	8	14	Sandy Loam
R2588	P3-4	0	25	249.5	33.6	81.5	65.0	4.17	76	10	14	Sandy Loam
R2589	P3-4	35	40	9.0	10.6	2.4	169.6	0.22	76	8	16	Sandy Loam
R2585	P4 (white sand)	0	1	18.3	7.1	84.5	451.8	3.96	76	10	14	Sandy Loam
R2833	P4-5	0	1	18.8	1.8	17.2	0.9	1.40	42	9	49	Clay
R2834	P4-7	0	1	6.1	2.0	1.8	5.2	0.50	55	29	16	Sandy Loam
R2835	P4-9	0	1	17.4	1.7	7.2	16.4	1.00	53	22	25	Sandy Clay Loam
R2836	P7-1	0	1	21.6	1.2	9.3	16.6	1.10	39	32	29	Clay Loam

Note: Averages Exclude Sample P4 (white sand)

* = Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.5 North and South Topsoil Piles

One sample from one borehole was analyzed from the North Topsoil Pile. Overall, it was noted that the stockpiled native soils in the North Topsoil Pile were consistent, productive soils. The origin of the topsoil is unknown, but observations suggest that the North Topsoil Pile has not been visibly mixed with geologic materials, and is uniform. Sampling was constrained by the proximity of the North Topsoil Pile to the pit wall, and complicated by signs of cracking and instability adjacent to the North Topsoil Pile. Due to the small size of the North Topsoil Pile, a lone sample was deemed representative of the entire pile. The lone sample exhibited a high proportion of sand (above threshold values). Otherwise, all other agronomic parameters were within the suitability criteria.

Five samples from three boreholes were analyzed from the South Topsoil Pile. Overall, it was noted that soils in the South Topsoil Pile were extensively mixed with crushed, unweathered geologic materials. The origin of the material is unknown. Salinity was slightly elevated in two samples, moderately elevated in two samples, and strongly elevated in one sample (above suitability threshold). Three samples exhibited moderately high proportions of sand, while two samples were high in sand (above suitability threshold). One sample each was slightly acidic, moderately acidic, and strongly acidic. Otherwise, all other agronomic parameters were within the suitability criteria.

Table 6 St. Anthony Mine - Soil and Geologic Materials Characterization
North and South Topsoil Piles

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	--------Paste-------		Lime Estimate	% Organic Matter	----------ppm----------						
				pH	EC mmhos/cm			NO_3-N	P	K	Zn	Fe	Mn	Cu
R2619	TN-2	0	25	8.0	1.0	high	0.8	17.90	1.58	98.18	0.07	2.13	0.64	0.59
R2620	TS-2	20	30	5.2	6.3	low	0.6	1.50	4.24	57.54	1.80	69.82	5.85	1.98
R2621	TS-3	0	10	6.9	3.5	low	1.0	0.40	1.59	147.20	1.09	5.80	2.15	3.26
R2622	TS-3	25	30	5.9	5.7	low	0.7	1.70	2.08	90.85	4.81	37.79	7.39	13.22
R2623	TS-4	0	10	7.1	3.8	high	0.6	0.28	1.61	87.64	1.53	5.08	1.88	4.79
R2624	TS-4	10	20	7.2	4.6	high	1.0	3.80	2.10	72.99	1.80	14.67	2.13	6.30

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	----------meq/L----------				SAR	--------%--------			Texture
				Ca	Mg	Na	K		Sand	Silt	Clay	
R2619	TN-2	0	25	4.9	0.8	3.1	1.6	1.62	72	12	16	Sandy Loam
R2620	TS-2	20	30	23.8	2.1	12.9	4.0	1.63	74	12	14	Sandy Loam
R2621	TS-3	0	10	27.6	2.6	6.5	6.0	1.14	62	16	22	Sandy Clay Loam
R2622	TS-3	25	30	22.3	2.0	11.9	7.1	1.61	68	6	26	Sandy Clay Loam
R2623	TS-4	0	10	25.1	1.3	8.3	5.7	1.37	70	8	22	Sandy Clay Loam
R2624	TS-4	10	20	26.6	1.6	9.4	7.0	1.51	68	11	21	Sandy Clay Loam

*= Below Reporting Limits

$^+$ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

$^+$ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.1.6 Topsoil / Overburden Pile

Twenty-seven samples from five boreholes were analyzed from the Topsoil/Overburden Pile. Overall, it was noted that soils in the Topsoil/Overburden Pile were somewhat variable, productive soils. Black shale fragments are consistently interspersed throughout the pile, along with precipitated gypsum ($CaSO_4$) crystals approximately 1-2 inches in length. Extensive erosion features, including piping, rills, and gullies were observed from the surface of the Topsoil/Overburden Pile. The origin of materials located within the Topsoil/Overburden Pile is unknown, but it is likely a mix of topsoil, alluvium, and slightly weathered shale. Salinity was slightly elevated in seventeen samples, and moderately elevated in ten samples. Thirteen samples exhibited moderately high proportions of sand, while one sample was high in sand (above suitability threshold). One sample was high in clay, while two samples were moderately high in clay. The Topsoil/Overburden Pile was somewhat well mixed, and average values should approximately represent on the ground conditions at any point across the pile.

Table 7 St. Anthony Mine - Soil and Geologic Materials Characterization
Topsoil / Overburden Pile

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	Paste		Lime Estimate	% Organic Matter	ppm						
				pH	EC mmhos/cm			NO_3-N	P	K	Zn	Fe	Mn	Cu
R2559	T/O-1	0	25	7.5	3.6	very high	0.8	6.00	1.86	134.50	0.31	10.03	2.36	1.70
R2560	T/O-1	25	50	7.4	3.8	very high	0.7	6.30	1.69	145.60	0.45	14.50	3.09	1.90
R2561	T/O-1	70	90	7.8	2.7	very high	0.8	3.00	2.19	109.10	1.45	4.36	1.94	6.49
R2576	T/O-2	0	20	7.8	4.6	very high	0.7	4.80	1.53	215.60	0.18	13.12	3.83	2.14
R2625	T/O (shale)	-	-	7.6	3.2	high	1.0	2.50	0.86	218.50	0.12	5.34	0.79	0.91
R2562	T/O-3	0	5	7.7	3.6	very high	0.8	0.42	2.23	109.90	0.19	4.14	0.54	1.23
R2563	T/O-3	5	10	7.6	3.9	very high	0.6	4.70	1.64	125.00	0.18	4.94	0.49	1.25
R2564	T/O-3	10	15	7.6	4.0	very high	0.7	6.00	1.18	107.10	0.19	6.76	0.42	1.68
R2565	T/O-3	15	20	7.6	4.0	very high	0.8	9.60	1.94	135.00	0.30	8.62	0.83	1.19
R2566	T/O-3	20	25	7.7	2.4	high	0.8	3.20	2.38	118.90	0.15	6.08	0.83	1.35
R2567	T/O-3	25	30	7.8	3.2	high	0.8	3.20	2.06	85.70	0.18	3.27	0.30	1.66
R2568	T/O-3	30	35	7.6	3.5	very high	0.7	4.90	1.53	117.80	0.23	10.08	2.10	1.38
R2569	T/O-3	35	40	7.7	4.0	very high	0.7	5.80	1.79	112.90	3.60	9.76	1.54	1.48
R2570	T/O-3	40	45	7.6	3.6	very high	0.9	7.10	0.74	115.40	0.56	11.59	2.69	4.76
R2571	T/O-3	50	55	7.8	4.1	very high	0.7	9.20	2.30	117.90	0.23	10.69	1.20	2.05
R2572	T/O-3	55	60	7.7	4.6	very high	0.7	9.40	1.48	123.90	0.29	8.48	1.43	1.49
R2573	T/O-3	65	70	7.8	4.6	very high	0.7	1.30	1.74	115.00	0.19	29.15	5.03	1.79
R2574	T/O-3	70	75	7.7	3.8	high	0.7	4.70	1.62	108.70	0.19	15.45	2.12	0.90
R2575	T/O-3	75	80	8.0	2.1	high	0.7	30.50	2.95	131.70	0.18	14.33	1.08	1.41
R2577	T/O-4	0	10	7.7	2.7	very high	0.8	3.60	1.51	168.70	0.20	10.11	2.88	1.13
R2578	T/O-4	30	40	7.8	4.1	very high	0.8	8.60	1.88	148.40	1.16	8.99	2.93	5.22
R2579	T/O-5	0	5	7.8	4.0	high	0.7	7.50	2.30	101.20	0.10	2.91	0.49	0.87
R2580	T/O-5	5	10	7.8	3.7	high	0.7	13.50	2.53	102.50	0.13	3.81	0.67	0.61
R2581	T/O-5	10	15	7.8	4.1	high	0.7	4.20	2.56	112.30	0.15	4.53	0.46	1.16
R2582	T/O-5	15	20	7.9	3.9	very high	0.6	4.70	2.06	104.90	0.20	6.65	1.24	2.88
R2583	T/O-5	20	25	7.8	2.8	very high	0.7	3.90	2.99	101.10	0.11	5.41	0.68	1.23
R2584	T/O-5	25	29	7.9	3.7	very high	0.9	7.40	2.11	118.50	0.28	9.58	1.15	2.19
	Average			7.7	3.6	very high	0.7	6.52	1.91	126.14	0.43	8.99	1.60	1.93

Laboratory Sample ID	Client Sample ID	Top Depth (ft)	Bottom Depth (ft)	meq/L				SAR	%			Texture
				Ca	Mg	Na	K		Sand	Silt	Clay	
R2559	T/O-1	0	25	25.0	13.3	7.9	0.6	1.80	36	34	30	Clay Loam
R2560	T/O-1	25	50	24.6	13.4	9.0	0.6	2.07	40	30	30	Clay Loam
R2561	T/O-1	70	90	12.5	12.4	6.7	0.4	1.90	60	20	21	Sandy Clay Loam
R2576	T/O-2	0	20	27.3	2.1	8.5	9.4	1.32	36	24	40	Clay
R2625	T/O (shale)	0	1	28.7	1.8	4.8	0.4	0.90	16	34	50	Clay
R2562	T/O-3	0	5	24.6	0.9	7.0	7.7	1.20	52	26	22	Sandy Clay Loam
R2563	T/O-3	5	10	24.9	0.9	8.0	8.4	1.33	46	24	30	Sandy Clay Loam
R2564	T/O-3	10	15	25.9	1.1	8.2	9.8	1.34	34	30	36	Clay Loam
R2565	T/O-3	15	20	25.9	1.2	7.9	7.5	1.32	44	26	30	Clay Loam
R2566	T/O-3	20	25	11.8	0.8	5.8	6.7	1.38	58	20	22	Sandy Clay Loam
R2567	T/O-3	25	30	18.0	0.6	7.9	9.8	1.42	56	20	24	Sandy Clay Loam
R2568	T/O-3	30	35	26.4	1.4	7.7	9.2	1.28	40	28	32	Clay Loam
R2569	T/O-3	35	40	25.4	1.2	8.0	9.3	1.32	42	28	30	Clay Loam
R2570	T/O-3	40	45	25.3	1.6	7.9	8.3	1.31	36	30	34	Clay Loam
R2571	T/O-3	50	55	23.1	1.5	8.8	7.0	1.46	64	12	24	Sandy Clay Loam
R2572	T/O-3	55	60	29.8	1.4	8.5	8.1	1.33	48	24	28	Sandy Clay Loam
R2573	T/O-3	65	70	27.3	1.7	8.5	10.3	1.32	48	26	26	Sandy Clay Loam
R2574	T/O-3	70	75	23.6	1.2	7.9	6.8	1.35	54	24	22	Sandy Clay Loam
R2575	T/O-3	75	80	14.1	2.1	4.5	1.4	1.31	70	18	12	Sandy Loam
R2577	T/O-4	0	10	26.2	4.7	8.2	10.8	1.29	32	28	40	Clay
R2578	T/O-4	30	40	24.8	1.8	8.3	6.8	1.37	58	20	22	Sandy Clay Loam
R2579	T/O-5	0	5	25.0	1.5	8.3	9.1	1.36	56	20	24	Sandy Clay Loam
R2580	T/O-5	5	10	21.9	3.1	8.1	6.7	1.44	64	16	21	Sandy Clay Loam
R2581	T/O-5	10	15	25.3	1.3	9.0	8.6	1.42	60	16	24	Sandy Clay Loam
R2582	T/O-5	15	20	22.7	1.2	8.6	7.3	1.43	58	20	22	Sandy Clay Loam
R2583	T/O-5	20	25	24.0	0.7	7.7	7.8	1.32	64	12	24	Sandy Clay Loam
R2584	T/O-5	25	29	25.6	1.4	7.2	6.1	1.28	60	20	21	Sandy Clay Loam
	Average			23.7	2.8	7.7	6.8	1.39	49	23	27	Sandy Clay Loam

*= Below Reporting Limits

+ Values in red are sufficiently elevated to be excluded as surficial growth media unless mixed

+ Values in orange are moderately elevated, and may require special consideration in the reclamation plan

3.2 Additional Soil-Vegetation System Observations

Both disturbed and undisturbed areas within the project area were observed, specifically to obtain information on locally successful vegetation species and the corresponding edaphic systems.

3.2.1 Disturbed Soil Systems

The extent to which disturbed systems were supporting vegetation (both seeded and volunteer) varied greatly across the project area. Areas with visible salt deposits and salt crusts (such as several Waste Piles) were supporting little to no vegetation. Areas with approximately 6 to 8 inches of disturbed topsoil overlying visibly salty geologic materials supported diminutive and sparse vegetation.

Slope angle largely influenced vegetation. Because of how the dump facilities were constructed, materials are either generally flat to gently sloping or approaching angle of repose. Little to no vegetation was observed growing on angle of repose slopes, even when materials seemed suitable for use in reclamation (topsoil/alluvial materials). Only on flat areas (less than 10% slopes) were suitable patches of vegetation observed.

3.2.2 Native (Undisturbed) Soil Systems

Native soils in the region vary greatly, particularly in depth and age. Deeper and older alluvial soils in the main drainage channels and alluvial fans are not particularly useful when attempting to estimate the required depth of cover materials on reclamation and were excluded. Therefore, small pockets of residually weathering topsoil with shaley and sandy geologic parent materials were targeted as a proxy to estimate cover requirements.

Native systems observed supporting vegetation sufficient to minimize erosion ranged in depth from 1-4 feet. Vegetation was noticeably diminished in areas with 12-18 inch topsoil depths and mostly productive in areas with topsoil greater than 2 feet. Deeply incised rills and gullies were visible in these native areas, even on relatively shallow slopes (less than 20%) with no topographic variation to concentrate overland flow; demonstrating the high potential for erosion in local soil and geologic systems.

4.0 Technical Discussion

4.1 General Overview

Soils in the project area generally have elevated levels of salt and high proportions of sand. Targeted sampling of unique or unadulterated geologic materials (such as Sample R2585 - Table 5; EC=42.1) provides the bounds for which conditions could be encountered within the reclaimed system. Material types (and corresponding suitability as a top/sub soil) have distinctive colors in the field:

- Brown materials (soils and alluviums) are typically slightly saline and have some potential to exhibit textural extremes, but are most often within all suitability criteria. These materials are most suited to serve as a reclamation planting media.
- White materials (weathered or crushed sandstone) are typically very saline, and inappropriate for use as a rooting media. These materials should be buried if possible (a minimum of 4 feet), to avoid the upward mobilization of soluble salts and contamination of overlying rooting media.
- Grey materials (shale and weathered carbonaceous sand, silt, and clay stone) are typically slightly to moderately elevated in salts, occasionally display low pH's, and exhibit high

erosivity. These materials should be avoided for use as a planting media, but will act sufficiently as a subsoil rooting media.

- Black materials (coal, shale, and carbonaceous sandstone) are typically elevated in salts, exhibit unsuitably low pH's for native arid western vegetation, and are moderately to highly erosive. These materials should be avoided for use as a planting media, but will act sufficiently as a subsoil rooting media.

Reclamation will be challenging, and a variety of best management practices should be implemented to ensure reclamation success. Observations suggest that at a minimum, 2 feet of suitable cover material should be utilized for reclamation, preferably deeper (especially if reclaiming the white saline sandstone encountered within Waste Piles 1, 2, 3, 4, and 7). Observations also suggest that best management practices will need to be used to control erosion, even on shallow slopes.

4.2 Findings from Field and Laboratory Analysis

4.2.1 Waste Piles 1, 2, 3, 4, and 7

Field observations indicated that these Waste Piles consist of large quantities of saline sandstone (white materials), shale, coal, and carbonaceous sandstone (black materials), and shale (grey materials). Laboratory results from Waste Piles 1, 2, 3, 4, and 7 demonstrated that these piles are comprised of materials that exhibit unsuitable subsoil / rooting media conditions. The potential for moderate to exceptionally high salinity, and slight to extreme acidity is possible.

Sodium levels have the potential to be elevated. Samples from this sampling effort suggest that sodium elevations correspond with elevated salinity, balancing the salt to sodium ratio and diminishing the negative effects of sodium presence. Agronomic samples from the 2007 MWH Materials Characterization Report exhibited SAR values up to 19.1 in Non-Economical Material Storage Areas, Shaft Area Ponds, and Mine Dump and Shaft Pads.

Sampling results from 2018 characterization efforts indicate that the upper and middle portions of these piles are not suitable growth media; Yet drilling logs from previous sampling efforts indicate that brown alluvial materials or soils may comprise the lower portions of Pile 4 (although no sampling was conducted to these depths during the 2018 efforts). The lower portions of Pile 4 may be suitable for use as a reclamation growth media or for direct revegetation, but sampling should be conducted if the lower portions of Pile 4 are to be used as a revegetation planting media.

4.2.2 South Topsoil Pile

The South Topsoil Pile is comprised more of crushed carbonaceous sandstone (black materials) and shale (black and grey materials), than topsoil (brown materials). This Pile exhibited laboratory results approaching thresholds for salinity, along with slightly to strongly acidic pH's, in addition to high proportions of sand (relative to other potential Borrow Areas). This pile should be considered the least desirable of the identified potential sources for use as a reclamation planting media. It would be suitable for use as a rooting media.

4.2.3 Topsoil / Overburden Pile

The Topsoil/Overburden Pile is likely comprised of mostly topsoil, but with a considerable shale component (grey and black materials) mixed throughout, with occasional concentrated pockets of weathering shale. Laboratory testing parameters were comparable to other potential sources of growth media, yet extensive erosion features were observed on the pile (8-10 foot deep gullies). This is likely due to the poor consolidation and the erosive nature of the shale material. This pile would be more suited for use on flatter reclamation surfaces (less than 10% slopes) or as a subsoil.

4.2.4 Borrow South, Borrow West, Lobo Tract Borrow, and North Topsoil Pile

Borrow South, Borrow West, Lobo Tract Borrow, and North Topsoil Pile can all be considered comparable in quality for use as a reclamation growth media. Each Pile exhibits at least one or more samples with elevated salinity or sand content, but when averaged are suitable for use as a cover material / planting material. Averaging of laboratory values are applicable for these locations, because they are predominantly undisturbed systems that can be definitively characterized, and will be significantly mixed through salvage, transportation, final placement, and grading.

4.3 Addressing Reclamation Challenges

4.3.1 Erosion

The erosive nature of locally available growth media, due to elevated sand content, will require best management practices to stabilize the reclamation surface. The proportion of sand found in most soils across the project area will result in poorly structured and non-cohesive soils, especially following disturbance from earth moving and reclamation activities. In addition to direct erosion control measures (i.e., mulching, hydro-seeding, wood chip waddles, etc.), an effort should be made to adjust slope length and minimize steepness wherever possible. By considering the erosive nature of available materials, conservative planning and design will increase the likelihood of a favorable reclamation outcome on the project.

4.3.2 Salinity

The moderate salinity consistently found throughout local soils will exacerbate drought stress, particularly during the critical period of germination and establishment. There is no impact threshold with salinity; impacts exist on a continuum, meaning any increase in salinity is a direct increase is plant-water stress. Deeper soil systems have the potential to capture and store more plant available water, increasing the likelihood of a successful reclamation effort.

Relatively deeper soils will also limit the upward migration of soluble salts from underlying salty and acidic geologic materials, such as the white sandstone, black coal, and grey shale. Erosion control efforts, such as mulching, contouring, waddles, etc., will provide additional benefits in mitigating salinity by aiding in soil moisture retention through limiting surface evaporation and facilitating greater infiltration.

4.3.3 Acidity

The slight to extreme acidic conditions (in black and dark grey materials) encountered on Borrow South, South Topsoil Pile, and Piles 1, 2, and 3, are challenging to overcome in arid rangeland reclamation systems. Native arid western vegetation is not adapted for acidic soil conditions and will likely result in diminutive vegetation or a lack of germination. Acidity was localized to areas with black materials (coals, shales, and carbonaceous sandstones). The degree and extent of acidity can be managed by ensuring any black materials are buried at least 2 feet below adequate cover materials, or excluded from salvage.

5.0 Summary

Local soils and site conditions present significant hurdles to overcome when considering reclamation planning and design. Industry best management practices and conservative reclamation planning will be crucial when attempting to establish vegetation and stabilize reclaimed slopes. Any adversity in climatic conditions will exacerbate these challenges. Expectations for reclamation timelines and overall potential should be tempered, as even favorable weather coupled with conservative best management practices may likely be insufficient to ensure site-wide reclamation success. Reseeding and regrading of erosive areas will likely be required at some point during the liability period.

Table 8 provides a ranking of the relative suitability of Borrow Areas for use as growth media, the recommended minimum thickness, and the soil and geologic material types noted in each location.

Table 8 St. Anthony Mine - Materials Characterization - 2018

Growth Media Borrow Source Summary

Potential Growth Media Borrow Source	Rank by Preference	Placement Suitability	Recommended Minimum Thickness	Material Types Observed
North Topsoil Pile	1	Cover / Planting Media	24 inches	Topsoil
West Borrow	2	Cover / Planting Media	24 inches	Topsoil
				Alluvium
Lobo Tract	3	Cover / Planting Media	24 inches	Topsoil
				Alluvium
Borrow South	4	Cover / Planting Media	24 inches	Topsoil
				Alluvium
Topsoil / Overburden Pile	5	Cover / Planting Media (on < 10% slopes) Subsoil / Rooting Media	24-36 inches	Topsoil
				Alluvium
				Shale
				Coal
				Gypsum Precipitates
South Topsoil Pile	6	Subsoil / Rooting Media	N / A	Topsoil
				Alluvium
				White Saline Sandstone
				Black Carbonaceous Sandstones
				Shale
				Coal

The information gathered through field efforts and laboratory testing will be utilized to update the existing reclamation plan to reflect site conditions and developing site-specific strategies for achieving successful revegetation and slope stabilization.

6.0 References

Dillinger J.K. Geologic Map of the Grants 30' x 60' Quadrangle, West-Central New Mexico. 1990.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. Field book for describing and sampling soils, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Soil Survey Staff. 2014. Soil Survey Field and Laboratory Methods Manual. Soil Survey Investigations Report No. 51, Version 2.0. R. Burt and Soil Survey Staff (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service.

New Mexico Mining and Minerals Division. Closeout Plan Guidelines for Existing Mines. April 30, 1996.

MWH. Materials Characterization Report – Saint Anthony Mine Site. October 26, 2007.