ROSEMONT COPPER
redefining mining.

Memorandum

To: File

From: Holly Lawson

Doc #: 069/12

Subject: **Rosemont Reclamation Treatments**

Date: July 18, 2012

Introduction

The Rosemont Copper Project is located in the northern portion of the Santa Rita Mountains, located in arid Southeast Arizona. This area is located within the basin-range complex composed of mountains that rise in elevation to over 10,000 feet above sea level separated by basins. The area exhibits vegetation differences based on slope aspect, elevation, and other features. Precipitation is highly variable both temporally and spatially, making some years and locations more likely to produce positive results. Disturbed lands that disrupt hydrological processes leave the land vulnerable to erosion. Reclamation must prioritize stability and conservation of soil resources in order to establish vegetation. Vegetation provides a permanent form of erosion control while bringing the land back to a productive state. Revegetation will be able to support the post-mining land uses of ranching, wildlife habitat, and recreation by utilizing native species that concur with the land use. Reclamation treatments provide temporary amendments to promote vegetation establishment while providing erosion control.

Vegetation is affected by a number of environmental factors and topographic features. The Rosemont area receives an average annual precipitation that varies from 14 – 16 inches, depending on elevation. Current elevation of the Rosemont area varies from 4400 feet above sea level to over 6000 feet. Typically, the lower elevations receive less precipitation than higher elevations, as paralleled by the plant community. Lower elevations are characterized by a semi-desert grassland plant community while the upper elevations transition into a Madrean oak woodland. The shape of the land or topography affects the way that water flows, leaving different vegetation types on different slopes. A convex slope allows water to run-off the slope, contributing to less infiltration, and less available soil moisture for vegetation. Vegetation that can withstand less soil moisture, like grass, cacti, and succulents are suitable functional groups for convex slopes. A concave slope often collects run-on or allows more time for water to infiltrate, leaving more soil moisture in the soil. Shrubs, trees, and grasses that prefer more soil moisture are often found on concave slopes. Additional factors like soil, slope gradient, and slope aspect also determine the vegetation type.

Soils

During University of Arizona greenhouse and reclamation test plot studies, the Arkose and Gila Conglomerate (Gila) soils were evaluated. The greenhouse results indicated that the Arkose soil produced less biomass than Gila soil, but was able to support at least a limited plant community. The Gila soil produced good potential for revegetation with higher densities, biomass, and diversity than the Arkose soil. Vegetation placed on Arkose soil was predicted to improve over time as soil develops. Both studies revealed that Gila soil more consistently produced a healthier plant community with higher densities of vegetation, biomass, and species diversity. Gila conglomerate is the preferred soil type to use during revegetation and will be placed in areas importance, for visual or ecological purposes.

Soil texture may be modified to produce stable soils and successful revegetation. There is a trade off between erosion potential and revegetation. The Arkose soil on the lower test plot contained more fine particles than the upper test plot, allowing it to retain a higher amount of soil moisture and nutrients necessary for plant growth. When Arkose contained a sufficient amount of fine particles, it produced promising revegation that was comparable to the Gila soil. Arkose soil did not produce a healthy plant community at the upper site from 2010 – 2011. The Arkose soil on the upper test plot contained a high amount of large particles, contributing to a coarser texture, which retained less than a third of the soil moisture that the Arkose soil at the lower test plot. While fine particles retain the moisture, they are also more vulnerable to erosion. Coarse fragments provide protection from erosion by providing ground cover while aggregates form to stabilize the soil. The pores, or spaces between the soil and rocks, allow for water and air movement and also provide habitat for microorganisms that help plants absorb nutrients. It is for these reasons that a mixture of fine particles and coarse particles, or a soil texture similar to a gravelly sandy loam, is the ideal soil texture for reclamation. Alternatively or additionally, organic mulch may be applied to the soil.

Slope Aspect

There is a strong slope effect in Southern Arizona that influences soil and vegetation type. North-facing slopes receive less sun and therefore less evaporation, making soil moisture more available than other slope aspects. During soil development, the amount of water available to weather and break down parent materials is a key factor. As a result, soils are deeper on north-facing slopes than on south-facing slopes. The deeper soils, with more available soil moisture, and less sunlight support more shrubs and trees. As time passes, trees and shrubs decompose, adding organic matter and nutrients into the soil. In contrast, the south-facing slopes receive more sunlight, higher rates of evaporation, and have less available soil moisture. Shallower soils with fewer nutrients and a high exposure to sunlight contribute to additional cacti and succulents observed on south-facing slopes. Slope effects in the Rosemont area can clearly be seen in Figure 1, with shrubs and trees occurring on the north-facing slopes, and grasslands occurring on all other slope aspects.

Figure 1. Slope aspect effects in the Rosemont area.

Elevation & Slope Effects

While slope aspect contributes to changes in vegetation, elevation interactions further determine plant communities. Lower elevations around of the Rosemont site are associated with semi-desert grassland. Due to the lower precipitation rate and slightly higher temperatures, perennial grasses, forbs, cacti and drought-adapted shrubs and trees compose the plant community. In higher elevations in the west and southwest portion of the footprint, more precipitation, some in the form of snow, and lower temperatures contribute to a mixture of semi-desert grassland mixed with Madrean oak woodland. As seen in Figure 2, plant communities change at lower elevations on the northern slope as compared to the southern slopes. The additional sun exposure, higher temperatures, and less available moisture on the southern slopes prevent trees and shrubs from establishing at lower elevations. On the contrary, the retention of soil moisture on the northern slopes, allow species that require more water to occur at lower elevations.

In accordance to Whittaker & Niering's (1968) observations, the desert grasslands will occur on the Rosemont landform on northern slopes up to ~4000-feet in elevation and up to ~5700-feet in elevation on the southern slopes. Since the grassland at the Rosemont site is a semi-desert grassland, grasses are currently observed and expected to occur between trees and shrubs at elevations greater than 4000-feet. According to the species listed in Figure 2, open oak woodland corresponds with the Madrean oak woodland at the Rosemont site. A Madrean oak woodland is targeted from 5400- to over 6000-feet in elevation on northern slopes and over 5800-feet in elevation on southern slopes. Gentle, gradual slopes on the top of the Rosemont landform located higher elevations are suitable to produce an oak woodland mixed with grass between trees and shrubs.

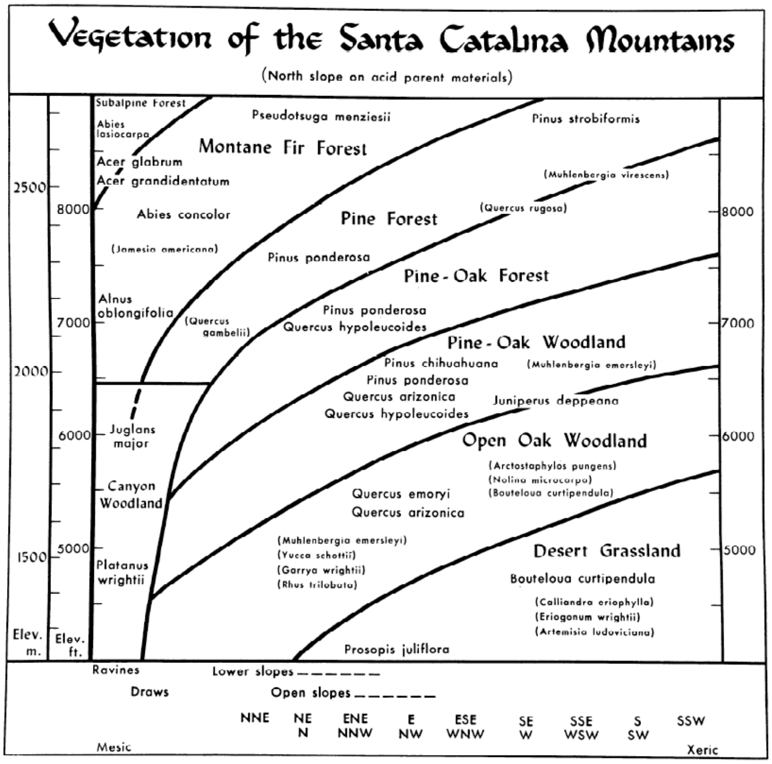

Figure 1.– Vegetation pattern of the northeast side of the Santa Catalina Mountains, Arizona, on acid parent materials (quartz diorite, etc.) near the Oracle Road, based on 180 vegetation samples. Major species are indicated by their areas of maximum importance; dominants of lower strata are indicated in parentheses. A corresponding diagram for the south side of the range is given by Whittaker & Niering (1964, 1965).

Figure 2. Elevation & Slope Effects (Whittaker & Niering, 1968)

Seed Mix

The native species seeded will be modified according to the slope. Some native species that require more moisture will be placed on north-facing slopes, while species that can withstand drier conditions will be placed on the south-facing slopes. The seeding rate will be increased on the Arkose soil due to lower plant establishment and biomass produced during greenhouse and field tests. In addition to the Rosemont Copper seed mix (Table 1), trees and shrub seeds will be added to the north-facing slopes and drainages at a rate comparable to reference areas. Trees may also be transplanted in addition to seeding. Species that established during the high rainfall scenarios of the greenhouse study (Fehmi *et al* 2008) will also be added to the base Rosemont seed mix. Additional species include Tanglehead (*Heteropogon contortus*), Sand Dropseed (*Sporobolus cryptandrus*), Cane Beardgrass (*Bothriochloa barbinodis*), and Skunkbush Sumac (*Rhus trilobata*). For south-facing slopes, agave and other succulent and cacti seeds will be added to the seed mix in clusters to emulate pre-disturbance conditions. The seed mix in Table 1 will be used on east- and west-facing slopes to emulate a grassland. Grasses will occur on all slope directions, but may be out-competed for light and moisture by shrubs and trees. Grasses are expected to establish quickly, within 2 -3 years, while shrubs and trees may require additional time. Additional volunteer species are expected when soil is directly replaced from native ground. The seed mix may be modified according to concurrent reclamation monitoring results.

Table 1. Rosemont Copper Seed Mix

Rosemont Copper Seed Mix	Scientific Name	Group	Species Composition
Arizona cottontop	*Digitaria californica*	WSPG	14.0%
Blue grama	*Bouteloua gracilis*	WSPG	14.0%
Curly mesquite	*Hilaria belangeri*	WSPG	14.0%
Green sprangletop	*Leptochloa dubia*	WSPG	14.0%
Plains Lovegrass	*Eragrostis intermedia*	WSPG	14.0%
Sideoats grama	*Bouteloua curtipendula*	WSPG	14.0%
Bottlebrush squirreltail	*Elymus elymoides*	CSPG	3.3%
Mexican gold poppy	*Eschscholzia californica ssp. Mexicana*	AF	8.3%
Desert marigold	*Baileya multiradiata*	PF	4.3%
Fairy Duster	*Calliandra eriophylla*	SH	0.1%
TOTAL			100.0%

Drainages

To mimic natural drainages in the area, trees and shrubs will be placed within the drainages. Drainages in the area sustain trees and shrubs in areas of deposition, where fine soils, nutrients, and organic matter accumulate. The additional, intermittent water that passes through the drainages and use of trees and shrubs that can quickly utilize available moisture will imitate pre-disturbance conditions. Additional erosion features, like check dams or use of large rocks, will prevent soil loss and stabilize the drainage.

Other Features

The Sonoran Talussnail, *Sonorella magdalenensis*, is petitioned for the Endangered Species Act protection. Talussnail habitat consist of rocky hillsides or talus slopes that consist of broken rock slides at least several meters thick with stable moisture and large interstitial spaces, in which the talus snails move from the surface down to at least 1 meter depth (WestLand, 2010). Talus slopes, consisting of loose Bolsa quartzite rock, are located near the open pit.

Talus slopes will be placed on the 2:1 slopes located on the west portion of the Rosemont landform. Northwest- and northeast-facing talus slopes will provide talus snail habitat with stable moisture conditions. Lichens or other snail forage will be established to support the snails. Mulch will be blown onto the surface of the talus slopes to preserve moisture while talussnail forage establishes.

Mulch Treatments

Certified weed-free wheat straw mulch will be used to aid vegetation establishment while providing erosion protection. Mulch can be applied by blowing it onto the surface of the soil or incorporating into the soil. These methods were tested on the reclamation test plots and were preferable to bare soil (no mulch) treatments. While it was possible to establish vegetation without the use of mulch, it appears that treatment would only be favorable during above-average precipitation years without extreme temperatures. Due to the variable climate and high possibility of erosion as a result of high-intensity monsoon storms, mulch will be used as a form of erosion protection.

Surface mulch provided favorable results when applied at the rate of 1 ton per acre. There is a trade-off between using surface mulch to establish vegetation as compared to using it for erosion protection. While increasing the rate provides more erosion protection, young seedlings cannot break through the mulch barrier to intercept sunlight. The majority of the Rosemont seed mix is perennial grasses, which are composed of small seeds with a limited amount of energy stored inside. The seed mix was not able to break through the surface mulch when applied at the rate of 2 tons per acre (1.3 inches thick), but at the rate of 1 ton per acre (0.67 inches thick), surface mulch provided favorable results. Wheat straw was found to provide the most protection against environmental conditions while utilizing the least amount of organic matter. Surface mulch is easily blown onto any soil type, the application is quick, but is vulnerable to wind. To fasten the mulch to the ground, a tackifier will be sprayed onto the mulch to keep it in place until vegetation can establish. A minimum of 1 ton of mulch per acre is recommended for erosion control, but a slightly increased rate of 1.25 tons per acre is recommended to retain moisture on south-facing slopes. The rate may be increased for areas with higher potential for erosion, or decreased on north-facing slopes if there is less potential for erosion.

Incorporated mulch, or mulch mixed into the soil, provided favorable revegetation results but is not practical for all soil textures. Mulch was first blown onto the soil surface, followed by a rotary tiller to mix the mulch into the soil. This technique worked well for the Gila soil, but proved difficult on the coarse Arkose soil at the upper test plot. No additional efforts were necessary for wind protection as it was anchored into the ground. According to the Rosemont weather station, wind primarily comes from the west so incorporated mulch is recommended on west-facing slopes of the Rosemont landform.

Drainages are vulnerable to erosion as flowing water is directed into a concentrated area to flow down stream. Due to potential water flow that could occur in the drainages, proper protection is necessary to prevent or minimize erosion. Trees and shrubs should be seeded or transplanted on the banks of the drainages to prevent displacement. Lightweight organic mulch will easily flow downstream, so gravel mulch appears to be more favorable to withstand erosion. Like organic mulch, gravel mulch has been proven to provide protection from environmental conditions (retains soil moisture, reduces evaporation, reduces seed predation) and will relieve stress from transplanting.

Fertilizer

No fertilizer is planned at this time. Fertilizer has been shown to promote invasive species and require multiple applications and maintenance. While fertilizer provides a temporary source of nutrients, seeding native vegetation that is adapted to low nutrients will promote a self-sustainable, self-repairable ecosystem. If nutrients are below levels that native vegetation needs to establish, a process-oriented approach will be initiated. Cattle, livestock, the addition of organic material or soil development products like microbe inoculation may be utilized to commence the nutrient cycle.

References

Fehmi, JS., TM Kong, and L Wood. 2008. *Phase II – Project Report Final.* University of Arizona, School of Natural Resources. December 17, 2008.

Whittaker, Niering. 1968. *Vegetation of the Santa Catalina Mountains, Arizona III. Ecological Classification and Floristic Relations on the North Slope.* Journal of Arizona Academy of Science, 5: 3 – 21.

Rosemont Reclamation Treatments

Slope Aspect	Soil Type	Amendments	Vegetation	Comments
East – Facing	Arkose	Seedbed preparation, Surface Mulch (1 ton/acre [t ac^{-1}])	-Rosemont seed mix -Increased seeding rate -Trees & shrubs will be added above 6000' elevation	Widely scattered trees and shrubs may be planted for aesthetic purposes.
East – Facing	Gila Conglomerate	Seedbed preparation, Surface Mulch (1 t ac^{-1})	-Rosemont seed mix -Trees & shrubs will be added above 6000' elevation	
North – Facing	Arkose	Seedbed preparation, Surface Mulch (1 t ac^{-1})	-Rosemont seed mix -Increased seeding rate -Trees & shrubs will be added above 5400' elevation	Tree canopy cover will ideally be visually similar to surrounding areas. Additional species that require higher amounts of soil moisture may be added to the seed mix.
North – Facing	Gila Conglomerate	Seedbed preparation, Surface Mulch (t ac^{-1})	-Rosemont seed mix -Trees & shrubs will be added above 5400' elevation	
South – Facing	Arkose	Seedbed preparation, Surface Mulch (1.25 t ac^{-1})	-Rosemont seed mix -Increased seeding rate -Cactus & succulents will be added up to 5800' in elevation -Trees & shrubs will be added above 5800' elevation	Species that naturally occur in clusters will be placed onto the landform in groups. Species diversity within the clusters may be different than surrounding reclaimed areas.
South – Facing	Gila Conglomerate	Seedbed preparation, Surface Mulch (1.25 t ac^{-1})	-Rosemont seed mix -Cactus & succulents will be added up to 5800' in elevation -Trees & shrubs will be added above 5800' elevation	

Slope Aspect	Soil Type	Amendments	Vegetation	Comments
West – Facing	Arkose	Seedbed preparation, Surface Mulch (1 ac^{-1})	-Rosemont seed mix -Increased seeding rate -Trees & shrubs will be added above 5800' elevation	
West – Facing	Gila Conglomerate	Seedbed preparation, Incorporated Mulch (2 t ac^{-1})	-Rosemont seed mix -Trees & shrubs will be added above 5800' elevation	
Drainages		Gravel mulch	- Transplanting and seeding vegetation on banks will prevent damage or movement downstream	Sandy soils mixed with large particles placed to depth will aid infiltration
Top of Landform		Seedbed preparation, Surface Mulch (1.25 t ac^{-1})	-Rosemont seed mix -Trees & shrubs dispersed at a rate similar to reference area	Additional land uses on top of landform may require vegetation modifications
Species of Concern Habitat				
Talus Slopes	Bolsa Quartzite	Surface Mulch (1 t ac^{-1})	Lichens and other talussnail forage	Vegetation surrounding talus slopes may be necessary to support talussnail habitat