Report for Augusta Resource Corporation

Final Report for Phase 1.

July 6, 2007

Jeffrey S. Fehmi
University of Arizona
School of Natural Resources
Biosciences East Rm. 325
P.O. Box 210043
Tucson, AZ 85721-0043

(520) 621-7268 Fax (520) 621-8801
jfehmi@email.arizona.edu
http://cals.arizona.edu/~jfehmi/

ROSEMONT COPPER
Resourceful.

Memorandum

To: Tom Furgason
Cc: Bev Everson
From: Kathy Arnold
Doc #: 8.6.6-007/09
Subject: **Transmittal of Electronic Copies of Reports**
Date: March 3, 2009

Rosemont is pleased to transmit electronic copies of the reports SWCA for your review:

1. Results of Phase 2 Hydrogeologic Investigations and Monitoring Program
2. University of Arizona Project Reports – Phase 1, Interim Phase 2, and Phase 2 Final
3. APP Application Document by Tetra Tech Volumes 1, 2, 3, 4, and 5

These reports were previously transmitted to the Forest Service on February 27, 2009.

Executive Summary:

The target of the Rosemont mine reclamation effort is to prevent soil loss from the site, reclaim its capacity for productive use, and return the site to a higher functioning plant community. The uplands in the prospective site of the Rosemont mine, are not currently at their highest potential as a plant community. The most visible evidence of a degraded plant community is the substantial cover of Alligator or One-seed Juniper and Velvet or Honey Mesquite. These trees, while being native species, encroach upon sites that have had a lower than normal fire frequency often combined with historical overgrazing by cattle. Once the canopy cover of these species gets above about 25%, soil erosion and soil loss often becomes a serious issue and the overall site becomes unstable. The proposed seed mixes should reclaim the site to a condition more like its ideal plant community.

Prospective seed mixes: Twenty-nine species (four overlapping mixes of eleven species each) were chosen for greenhouse evaluation in the next phase of this project. All selected species are natives and represent the highest condition native plant communities across the range of conditions expected on the site. The species chosen for testing represent a range of functional types of plants including: warm-season perennial grasses, cool-season perennial grasses, annual grasses, perennial forbs (broadleaved flowering plants), annual forbs, and shrubs. This array of plants maximizes the ability to select a successful mix at the end of the greenhouse testing but also will allow the final mix to have all the components of a resilient and productive system. All species chosen for inclusion are currently available from large-scale commercial seed vendors.

Rainfall scenarios: Three rainfall scenarios were chosen based on an evaluation of storm-by-storm rainfall data from two rain gauges near the site. The average scenario was an average rainfall year rather than the average daily rainfall over the 31 year period. Having a sufficiently large storm size and appropriate interval between storms is critical for plant germination and establishment. Similarly the low rainfall scenario is a characteristic low rainfall year from center of the range encompassing the bottom 20% of total rainfall years and the high rainfall scenario is a high rainfall year from center of the range encompassing the top 20% of rainfall years. For this project, the monsoon was considered to be from the beginning of July to the end of September or a little more than 90 days. Once the monsoon season trial is complete, the plants will be not given water again for at least two months before the start of the winter season growth period. This will mimic the normal dry period between seasons. For this project the winter season was considered to be from the beginning of December to the end of March or a little more than 120 days. The selected watering schedules will be tested prior to use.

Soil/surface amendments: The amendments chosen for evaluation are tackified straw and tackified straw combined with slow-release fertilizer. Tackified straw, straw that has been glued or tackified onto a field site, is a popular amendment for regional reclamation efforts and ameliorates some of the harsh surface conditions common to the site. The second amendment, slow-release fertilizer, will provide a temporary source of nutrients in the surface soil where the plants will be establishing.

Florida fire: An initial evaluation of paired seeded and unseeded sites within the footprint of the Florida fire showed little response to the seeding but the plants were out of season and difficult identify. The evaluation will be followed up at the end of the monsoon season when the main species planted, warm-season perennial grasses, are readily identifiable.

Other recommendations: Initiate an invasive species survey and invasive species management plan on the mine site.

Introduction:

This report describes the results of the first of a four phase project supporting the revegetation portion of the Rosemont mine reclamation plan. Phase one of this project includes: the evaluation of plant materials for further greenhouse testing, evaluation of possible rainfall scenarios for use in greenhouse testing, and evaluation of soil/surface amendments for use in greenhouse testing. Phase two is the actual greenhouse testing of the results discussed here. Phase three is the field testing and development of planting methods for the seed mixes and amendments selected in phase two. Finally, phase four is the long term monitoring of phase three and the adaptive adjustments required. This project and evaluation is solely concerned with upland plant communities; no evaluation of riparian plant communities was undertaken.

Definition of reclamation:

Reclamation of disturbed lands has been variably defined but typically includes two facets: return of ecological function and return of productive use (Whisenant, 1999). Regaining ecological function can be seen as a short-term goal because of the need to keep the soil, water, and nutrients on site. Ecological function is also an important long-term goal because the resultant plant community needs to be self sustaining and self repairing. Regaining productive use not only includes returning some potential economic value (e.g. grazing or recreation) but also supporting aesthetic and conservation concerns. Using non-native species would not support the productive use of the land both by causing conservation concerns and having liability for unwanted plants escaping the site.

The reclamation goal assumed for this report is to return the site to a resilient, diverse, native plant community as close to the historical norm as possible given the availability of plant materials.

Overview of current site conditions:

Current vegetation cover and plant community types were assessed by WestLand Resources (2007) and are only briefly touched on here along with informal observations of the site by Dr. Fehmi. The WestLand report is not a complete flora (listing of every plant species thought to occur on the site) but rather an assessment of the main plant communities on site at the time of the survey.

The prospective site of the Rosemont mine (hereafter the Rosemont Site) is visibly degraded from the ideal plant communities when the current plant communities are compared to the Natural Resources Conservation Service (NRCS) descriptions of the historical climax communities of this area (discussed in the next section). The most visible evidence of a degraded plant community is the substantial cover of Alligator or One-seed Juniper (*Juniperus deppeana* and *J. monosperma*) and Velvet or Western-honey Mesquite (*Prosopis velutina* and *P. glandulosa*). These trees, while being native species, increase upon sites that have had a lower than normal fire frequency often combined with historical overgrazing by cattle. Once the canopy cover of these species gets above about 25%, soil erosion and soil loss often becomes a serious issue and the overall site becomes unstable. Without additional research, it is not possible to say where in the progression to

destabilization the Rosemont site falls, but future reduction of Mesquite and Juniper cover would be recommended regardless of land use.

Given the history of human disturbances in this region, and on the Rosemont site, as well as the high tree cover currently present, historical overgrazing and fire suppression are reasonable assumptions (WestLand Report 2007). There is visible evidence of small-scale mining activities being common in the past on the site as well as evidence of unregulated recreational use, especially by off-road vehicles. Current grazing intensity appears moderate, but both grazing and recreational carrying capacity could be improved by reduction of the woodlands and increasing the extent of the upland grasslands.

Historical climax community

The NRCS has divided the US into regions of similar soil, climate, and vegetation. Within each region, they have further divided the areas by soil type, topographical position (slope, upland, etc.), and rainfall (see NRCS 2006). For each of these divisions, they have prepared an Ecological Site Description which, among much other information, contains an extended list of the plants and compositions expected on sites in their historical climax condition (ideal condition).

To determine the ideal condition of the upland areas within the Rosemont site, five Ecological Site Descriptions (ESDs) were chosen for evaluation. The specific ESDs were chosen based on the soil descriptions provided in the TetraTech draft report (2007) and those of the soil survey (Richardson et al 1979). The ESDs selected were: Loamy Slopes 12-16 inches of precipitation, Loamy Slopes 16-20 inches of precipitation, Loamy Upland 12-16 inches of precipitation, Sandy Loam Upland 16-20 inches of precipitation, and Clay Loam Upland 16-20 inches of precipitation (see http://esis.sc.egov.usda.gov/ and appended to this report). All five ecological site descriptions fall within Major Land Resource Area: 041 - Southeastern Arizona Basin and Range. The information in the ESDs also allows the relative ranking of the plant functional and structural groups which allows allocation of the plant species into ranks of relative importance.

The above ESDs were used to select candidate species which were then checked for commercial availability. Those that were commercially available were then sorted into four mixes based upon their proportional representation by functional group in the ideal condition plant community. Having four different mixes with overlapping species will allow a comprehensive test as well as giving a flexible and robust list of species to choose from for the field trial mix.

Plant species to be tested for reclamation during the greenhouse phase:

Plant list:

Species list for greenhouse testing

Common Name	Scientific Name
whitethorn acacia*	*Acacia constricta*
catclaw acacia*	*Acacia greggii*
red threeawn	*Aristida purpurea var. longiseta*
fourwing saltbush*	*Atriplex canescens*
desert marigold	*Baileya multiradiata*
cane beardgrass*	*Bothriochloa barbinodis*
sixweeks needle grama	*Bouteloua aristidoides*
sideoats grama*	*Bouteloua curtipendula*
blue grama*	*Bouteloua gracilis*
Rothrock grama*	*Bouteloua rothrockii*
false mesquite	*Calliandra eriophylla*
Arizona cottontop	*Digitaria californica*
bottlebrush squirreltail	*Elymus elymoides*
plains lovegrass*	*Eragrostis intermedia*
Mexican gold poppy	*Eschscholzia californica ssp. mexicana*
tanglehead*	*Heteropogon contortus*
curly mesquite	*Hilaria belangeri*
orange caltrop	*Kallstroemia grandiflora*
prairie Junegrass	*Koeleria macrantha*
green sprangletop*	*Leptochloa dubia*
big purple tansyaster	*Machaeranthera tanacetifolia*
muttongrass	*Poa fendleriana*
whitestem paperflower	*Psilostrophe cooperi*
skunkbush sumac*	*Rhus trilobata*
desert senna	*Senna covesii*
desert globemallow	*Sphaeralcea ambigua*
gooseberryleaf globemallow	*Sphaeralcea grossulariifolia*
sand dropseed*	*Sporobolus cryptandrus*

Table 1. Plant species selected for greenhouse testing. All species are natives, represent the ideal plant community, and are commercially available. A total 503 native species were evaluated in the preparation of this list.

*these species were mentioned in the WestLand (2007) report characterizing the plant communities on the Rosemont site. The other species likely occur but are not mentioned in the report.

Criteria for mix development

The species mixes for greenhouse testing (candidate mixes) need to have the following characteristics:

1. The candidate mixes must only contain native plants.
2. The natives selected must be common to the site/local area.
3. They must be expected to occur across the range of conditions and soil types predicted during reclamation.
4. The members represent plants of the ideal (historical climax) community rather than any current or former degraded state.
5. Each candidate mix must include all of the structural and functional groups in proportion to those found in the historical climax community.
6. All of the species tested in the greenhouse must have robust commercial availability.

Overall, 503 plant species were considered for inclusion in the candidate mixes.

Native plants. The species selected for the seed mixes must be natives. This was a requirement of Augusta Resources Corp as part of the seed mix development. The use of native plants has become the standard for reclamation due to a variety of factors. Natives are often better adapted to survive in local conditions than plants imported from elsewhere. This can be important when conditions are harsher and more variable than common. The semi-desert grassland characteristic of the Rosemont site has uncommonly harsh and variable conditions compared to most of the ecological communities in North America. Plants established for reclamation purposes must also fit within the ecological community in a cohesive way. If an imported species has the potential to takeover and form a near monoculture or to aggressively move into new sites, then it is not a suitable species. For natives, it is apparent that they will fit within the ecological structure of a plant community – they have been doing it all along. For imported plants, it has been difficult to predict which will become invasive and there are often long lag periods between introduction and invasive behavior.

Invaders can have many desirable characteristics, but their overall impact on the system properties tends to be detrimental. Invaders often form dense stands which offer fewer ecosystem services and less resilience when compared to the diverse communities of natives they often replace.

Natives common to the site and local area: The concept of native is some what dependent on the context. For plant species to be selected for inclusion in a candidate mixfor this project, they must be presumed to have occurred, or occur presently, on the actual Rosemont site. This is somewhat different than the concept of a species being native to North America or native to the arid west. Restricting species for consideration solely to those expected on the actual site did not greatly limit the number of species. These communities are diverse and the ESDs referenced an average of 300 plant species for each of the five communities evaluated.

Selected species must occur across the range of predicted conditions and soil types: The species selected must have the right range of tolerance to be able to grow on the conditions across the range of those found on the site. While a more specific mix might be developed for some specific condition (e.g. a sandy north facing slope), the application of the mix should be robust with respect to the conditions across the entire Rosemont site. This did not greatly limit the number of species to choose from. The expected upland plant communities across the Rosemont site have a broad species overlap and candidate mixes were selected with preference for species that occurred in most or all the expected conditions.

Ideal (historical climax) community: While it may be easier to establish plants common to disturbed sites, these weedy plants do not offer the required services for long-term reclamation. The plants selected should offer the maximum potential for erosion control (and other ecosystem services), long-term sustainability, and productive reuse. While the Rosemont site self-maintains its current plant community, even in the absence of mining, it would require substantial improvement (Juniper and Mesquite removal) for long-term sustainability. This makes the current condition unsuitable as a target for plant species inclusion and composition. Further, the effort required to establish any native species will be similar therefore the best target is to use species from ideal plant community – of which most, if not all, currently occur on the site but in low abundance.

Structural and functional groups: For a plant community to be self-sustaining, self-repairing, and resistant to invasion (resilient), it must have a breadth of species as well as structural and functional diversity. This diversity includes plants that grow at different times of the year, e.g. warm-season and cool-season perennial grasses, which offer better resistance to erosion (among other desirable services) than choosing a group of plants that are solely active for a short period of each year. A combination of annual grasses, perennial grasses, and forbs create stability in a plant community by being able to fill the various sized patches of space, nutrients, and moisture. This is especially important in recovery from disturbance and the resistance to plant invasion. Shrubs, vines, cacti, and other succulent plants can be important for a variety of reasons. Many of these species common to the semi-desert grassland are import in that they provide safe sites (e.g. areas under prickly pear are not grazed by large mammals) or nurse sites critical for long-term maintenance of diversity. These species are also important bridge foods for wildlife during the frequent dry periods. Some broadleaved plants fix nitrogen which is important in these nitrogen-poor systems.

Commercial availability: A high degree of seed availability was a requirement for species tested in this project. This is important in that the size and frequency of reclamation required for the mine can preclude wild collected seed for most species. Common commercial availability is critical for having the plant materials available when needed by the project. The seed must also be of high quality (known germination rate), and be certified free of noxious weeds which will be true of most seed purchased from a commercial seed vendor. Having similar sources of available seed (and getting seeds with similar properties) is also critical for being able to transfer the greenhouse results to the field trial and then from the field trial to the actual mine reclamation.

Selected mixes:

Common name	Scientific Name	Functional type
Mix 1		
sideoats grama	*Bouteloua curtipendula*[2]	WSPG
blue grama	*Bouteloua gracilis*[2]	WSPG
green sprangletop	*Leptochloa dubia**[,2]	WSPG
Rothrock grama	*Bouteloua rothrockii**[,2]	WSPG
sand dropseed	*Sporobolus cryptandrus**[,2]	WSPG
sixweeks needle grama	*Bouteloua aristidoides*	AG
bottlebrush squirreltail	*Elymus elymoides*	CSPG
desert marigold	*Baileya multiradiata*	PF
big purple tansyaster	*Machaeranthera tanacetifolia*	AF
whitethorn acacia	*Acacia constricta*	SH
skunkbush sumac	*Rhus trilobata*	SH
Mix 2		
cane beardgrass	*Bothriochloa barbinodis*	WSPG
Arizona cottontop	*Digitaria californica*	WSPG
sideoats grama	*Bouteloua curtipendula*[2]	WSPG
blue grama	*Bouteloua gracilis*[2]	WSPG
tanglehead	*Heteropogon contortus**	WSPG
sixweeks needle grama	*Bouteloua aristidoides*	AG
plains lovegrass	*Eragrostis intermedia*	CSPG
desert senna	*Senna covesii*	PF
Mexican gold poppy	*Eschscholzia californica ssp. mexicana*	AF
false mesquite	*Calliandra eriophylla*	SH
whitestem paperflower	*Psilostrophe cooperi*	SH
Mix 3		
cane beardgrass	*Bothriochloa barbinodis*	WSPG
Arizona cottontop	*Digitaria californica*	WSPG
curly mesquite	*Hilaria belangeri*	WSPG
red threeawn	*Aristida purpurea var. longiseta*	WSPG
sixweeks needle grama	*Bouteloua aristidoides*	AG
muttongrass	*Poa fendleriana*	CSPG
prairie Junegrass	*Koeleria macrantha*	CSPG
gooseberryleaf globemallow	*Sphaeralcea grossulariifolia*	PF
orange caltrop	*Kallstroemia grandiflora*	AF
catclaw acacia	*Acacia greggii*	SH
fourwing saltbush	*Atriplex canescens*	SH
Mix 4		
red threeawn	*Aristida purpurea*	WSPG
sand dropseed	*Sporobolus cryptandrus**[,2]	WSPG
sideoats grama	*Bouteloua curtipendula*[2]	WSPG
Rothrock grama	*Bouteloua rothrockii**[,2]	WSPG
sixweeks needle grama	*Bouteloua aristidoides*	AG
desert senna	*Senna covesii*	PF
desert marigold	*Baileya multiradiata*	PF
desert globemallow	*Sphaeralcea ambigua*	PF
Mexican gold poppy	*Eschscholzia californica ssp. mexicana*	AF
whitethorn acacia	*Acacia constricta*	SH

WSPG = warm-season perennial grass
CSPG = cool-season perennial grass
AG = annual grass
PF = perennial forb
AF = annual forb
SH = shrub

Table 2. Mixes selected for testing. Each mix contains each of the six functional groups and is included in proportion to its representation in the ideal community (discussed in the next section).

Mix 1 is essentially the US Forest Service (USFS) recommended mix with the addition of the other functional groups to the warm-season perennial grasses. Indian wheat (*Plantago ovata* also called *P. insularis*) was a component of the USFS mix but was not selected here because it is not common to the site and is not thought to be a native plant. Mixes 2 and 3 are combinations of plants common to the site and often used for reclamation. Mix 4 is based on the mineland reclamation mix advocated by seed companies and used on mines in the area. The mixes have overlap (most species appear in more than one mix) which will allow generalization of the testing results.

Proportions and seeding rate

	Warm Season Perennial Grasses	Cool Season Perennial Grasses	Annual Grasses	Perennial Forbs	Annual Forbs	Cacti and Succulents	Shrubs and Vines	Trees	Nitrogen Fixing Plants
LS12-16	57.2	5.7	5.7	4.9	8.3	13	2.8	2.4	6
LS16-20	84	1.7	0.5	1.9	6.5	2.2	1.7	1.6	0.9
LU12-16	73.8	0.1	4.5	3.3	6.8	8.7	2.1	0.6	4
SLU16-20	87.4	1.5	3	2	4.4	0.8	0.1	0.9	0.8
CLU16-20	79.2	0.1	5.1	2.5	7.6	3.8	0.8	1	2.2
Average	76.32	1.82	3.76	2.92	6.72	5.7	1.5	1.3	2.78

Table 3. Values are the percent composition by weight. LS12-16 is the Ecological Site Description (ESD) for Loamy Slopes with 12-16 inches of rainfall. The ESDs for Loamy Uplands (LU), Sandy Loamy Upland (SLU) and Clay Loam Uplands (CLU) are also included.

Each ESD was used to evaluate the distribution of ecological types by the range of weights expected species composition. The final proportions were 82% warm-season perennial grasses, 2% cool-season perennial grasses, 4% annual grasses, 3% perennial forbs, 7% annual forbs, and 2% shrubs. In addition, about 3% of the mix should be nitrogen fixing plants; these plants only occur among forbs and shrubs. The final proportions used for the mixes did not include trees which are discussed in a later section.

These average proportions by functional type were used to select the number of plants within each group for the mixes with the majority being warm-season perennial grasses. These proportions also formed the basis for the seeding rate for each species. The rate was assumed to be 50 seeds (PLS) per square foot (the USFS/BLM recommended rate – this will be adjusted, if needed, based on the results of the greenhouse trials). Using the number of seeds per pound, 50 seeds per sf, and the above proportions, the amount of seeds required can be calculated.

Availability checking

General availability was verified in two ways. First the prospective species, outlined in the following sections, were checked against the list of available reclamation plant materials maintained by the Tucson Plant Materials Center (see http://plant-materials.nrcs.usda.gov/pubs/azpmsarseedlist0501.pdf). Plant species were either categorized as commonly available (C), for having four or more listed sources supplying seed. Species were listed as being uncommonly available (U) if they had three or fewer listed sources. Available species were used to construct an initial list of species which was further culled by checking their availability in current seed catalogs. Three companies catalogs were checked (Granite Seed, Pawnee Buttes Seed, and Curtis & Curtis Seed).

Once the amounts per acre were calculated and the general availability was verified, the land area for reclamation for each year (provided by TetraTech 2007) was used to estimate the total seed requirement. This seed requirement was sent to the above three seed companies to verify that the quantities required could be met. All the species in the plant list (which includes all the species in the mixes) have been verified as available this year in the required quantities. Given the common availability of these species in past years, future availability seems reasonable.

The lack of immediate commercial availability of any species does not mean that species cannot be considered or used for reclamation. This requirement was established both to take the complications out of later seed acquisition but more to allow the work done in the greenhouse phase to apply to the later phases of the project.

Seed availability varies depending on demand, the weather (if it has been a good year for the plant to produce seeds), and the general desirability of the species (perceived future demand). The final seed mix must be flexible with alternate species and a rationale for substitution (e.g. functional groups), in case vagaries in future seed availability necessitate changes in the seed mix.

Functional group assessments - Warm-season perennial grasses:

Warm-season perennial grasses

Common Name	Scientific Name	Available
poverty threeawn	*Aristida divaricata*	
Havard threeawn	*Aristida havardii*	
red threeawn	*Aristida purpurea var. longiseta*	C
Wright threeawn	*Aristida purpurea var. wrightii*	
spidergrass	*Aristida ternipes*	
cane beardgrass	*Bothriochloa barbinodis*	U
sprucetop grama	*Bouteloua chondrosioides*	U
sideoats grama	*Bouteloua curtipendula*[2]	C
black grama	*Bouteloua eriopoda*	U
blue grama	*Bouteloua gracilis*[2]	C
hairy grama	*Bouteloua hirsuta*	U
purple grama	*Bouteloua radicosa*	
slender grama	*Bouteloua repens*	
Rothrock grama	*Bouteloua rothrockii**[,2]	U
Arizona cottontop	*Digitaria californica*	C
fall witchgrass	*Digitaria cognata*	
spike pappusgrass	*Enneapogon desvauxii*	U
tanglehead	*Heteropogon contortus**	U
curly mesquite	*Hilaria belangeri*	U
green sprangletop	*Leptochloa dubia**[,2]	C
Arizona muhly	*Muhlenbergia arizonica*	
vine mesquite	*Panicum obtusum*	U
sand dropseed	*Sporobolus cryptandrus**[,2]	C

* observed on site per WestLand Resources report 2007

[2] species used by USFS in nearby seedings

Table 4. Species were included in this list if they occurred in all five of the ecological site descriptions. Available C means it is available from 4 or more suppliers. Available U means it is available from 3 or fewer suppliers. Plants that are not commercially available could be wild collected or grown under contract.

A total of 62 warm-season perennial grass species were evaluated for this category. These species are commonly advocated as being the best at conserving soil and preventing erosion. Based on the analyses of the species composition, this group will be 82% of the final plant community by weight. A number of the species that seem sparsely available based on published information (e.g. vine mesquite, black grama, hairy grama, and sprucetop grama) are not actually available in commercial quantities. The warm-season perennial grasses selected for testing are those that were verified as available this year (as described in the previous section) from the above list of species common to the site.

Warm-season grasses germinate, grow, and set seed during the monsoon season (approx July – September). The conditions tend to be hot with variable, often intense, rainfall. (See the later section on rainfall.)

Lehman lovegrass (*Eragrostis Lehmanniana*), a non-native, invasive, warm-season perennial grass, is already present on the site in small amounts and could become an issue if it increases in area. This seems likely because Lehman lovegrass does especially well on disturbed areas and is a prolific seed producer. Another warm-season perennial grass, Buffelgrass (*Pennisetum ciliare*), is somewhat of a concern because it has invaded surrounding lands but the Rosemont site is on the upper edge of the potential range of buffelgrass due to this species' limited cold tolerance. However, cold tolerant varieties of buffelgrass occur in Mexico and Texas and may eventually be introduced (accidentally) into Arizona. Buffelgrass is a listed noxious weed in Arizona. Buffelgrass tends to be less dominant in areas with livestock grazing while Lehman lovegrass can become more dominant with livestock grazing. There are numerous other invasive warm season grasses that could become a problem on the site.

An invasive species management plan that includes regular surveys would be required to prevent invasive plants from reaching a threshold where they become difficult to control. The reclamation effort seems likely to be blamed for any invasive species issues on the site, so a solid assessment of what species are there before any reclamation takes place would be helpful. Controlling these species is recommended despite the likely reinvasion from neighboring invaded sites.

Functional group assessments – Cool-season perennial grasses

Cool-season Perennial grasses

Common Name	Scientific Name	ESDs	available
bottlebrush squirreltail	*Elymus elymoides*	5	C
densetuft hairsedge	*Bulbostylis capillaris*	3	
pinyon ricegrass	*Piptochaetium fimbriatum*	3	
plains lovegrass	*Eragrostis intermedia*	2	U
prairie Junegrass	*Koeleria macrantha*	2	C
muttongrass	*Poa fendleriana*	1	U

Table 5. Only one species occurred in all five of the ecological site descriptions (ESDs). Available C means it is available from 4 or more suppliers. Available U means it is available from 3 or fewer suppliers. Plants that are not commercially available could be wild collected or grown under contract.

Cool season perennial grasses are expected to be less important on the site than the warm-season perennial grasses. Cool-season grasses germinate, grow, and set seed during the cooler and wetter winter months (approx. December to March). They are typically dormant through the summer. However, they add resiliency to the plant community through giving additional protection from erosion outside the monsoon season. This resiliency is especially important in the first few years after reclamation plant establishment. All of the cool-season grasses listed as available were verified as commercially available.

Functional group assessments – Annual grasses

Annual grasses

Common Name	Scientific Name	ESDs	Available
sixweeks threeawn	*Aristida adscensionis*	5	
prairie threeawn	*Aristida oligantha*	5	
sixweeks needle grama	*Bouteloua aristidoides*	5	U
sixweeks grama	*Bouteloua barbata*	5	
Arizona brome	*Bromus arizonicus*	5	
feather fingergrass	*Chloris virgata*	5	
Mexican lovegrass	*Eragrostis mexicana*	5	
southwestern cupgrass	*Eriochloa acuminata var. acuminata*	5	
Mexican sprangletop	*Leptochloa fusca ssp. uninervia*	5	
annual muhly	*Muhlenbergia fragilis*	5	
littleseed muhly	*Muhlenbergia microsperma*	5	
annual witchgrass	*Panicum capillare*	5	
Mexican panicgrass	*Panicum hirticaule*	5	
Arizona signalgrass	*Urochloa arizonica*	5	
sixweeks fescue	*Vulpia octoflora*	5	
red sprangeltop	*Leptochloa panicea ssp. brachiata*	4	
prairie trisetum	*Trisetum interruptum*	4	
mat grama	*Bouteloua simplex*	3	
desert lovegrass	*Eragrostis pectinacea var. miserrima*	3	
spreading lovegrass	*Eragrostis pectinacea var. pectinacea*	3	
pitscale grass	*Hackelochloa granularis*	3	
gray fescue	*Vulpia microstachys var. ciliata*	3	
fragile grass	*Aegopogon tenellus*	2	
spreading lovegrass	*Eragrostis pectinacea*	2	
sweet tanglehead	*Heteropogon melanocarpus*	2	
little barley	*Hordeum pusillum*	2	
Bigelow bluegrass	*Poa bigelovii*	2	
poverty dropseed	*Sporobolus vaginiflorus*	2	
Pacific fescue	*Vulpia microstachys var. pauciflora*	2	
little grapefern	*Botrychium simplex*	1	
Parry grama	*Bouteloua parryi*	1	
red sprangletop	*Leptochloa panicea*	1	
sticky sprangletop	*Leptochloa viscida*	1	
twoflower fescue	*Vulpia microstachys var. microstachys*	1	

Table 6. Species are listed with their occurrence in the ecological site descriptions (ESDs). Available U means it is available from 3 or fewer suppliers. Plants that are not commercially available could be wild collected or grown under contract.

Annual grasses do not live beyond a single year. They have various strategies but sixweeks needle grama (*Bouteloua aristidoides*) grows and sets seed in the spring. Annual grasses add the capability to quickly fill gaps in the ecological community. The annual grasses from all five ESDs were included in the above list to see if that would increase the availability of this functional group. Only one annual grass appropriate for this site, sixweeks needle grama, is readily available.

Functional group assessments – Perennial Forbs

Perennial forbs

Common Name	Scientific Name	Available
trailing four o'clock	*Allionia incarnata*	
slimleaf bursage	*Ambrosia confertiflora*	
desert anemone	*Anemone tuberosa*	
Indianroot	*Aristolochia watsonii*	
shrubby ayenia	*Ayenia microphylla*	
greeneyes	*Berlandiera lyrata*	
Castilleja	*Castilleja linariaefolia*	U
leatherweed croton	*Croton pottsii*	
Cooley bundleflower	*Desmanthus cooleyi*	
bluedicks	*Dichelostemma capitatum*	
spreading dyschoriste	*Dyschoriste schiedeana var. decumbens*	
spreading fleabane	*Erigeron divergens*	
hairy evolvulus	*Evolvulus arizonicus*	
Arizona snakecotton	*Froelichia arizonica*	
hogpotato	*Hoffmannseggia glauca*	
ragged jatropha	*Jatropha macrorhiza*	
spiny goldenhead	*Machaeranthera pinnatifida*	
tufted evening-primrose	*Oenothera caespitosa*	
orange talinum	*Phemeranthus aurantiacus*	
velvetseed milkwort	*Polygala obscura*	
shrubby purslane	*Portulaca suffrutescens*	
slimflower scurfpea	*Psoralidium tenuiflorum*	
twinleaf senna	*Senna bauhinioides*	
silverleaf nightshade	*Solanum elaeagnifolium*	
gooseberryleaf globemallow	*Sphaeralcea grossulariifolia*	C
brownplume wirelettuce	*Stephanomeria pauciflora*	
big talinum	*Talinum paniculatum*	
branched noseburn	*Tragia ramosa*	
American vetch	*Vicia americana*	U
Texas zinnia	*Zinnia grandiflora*	C

Table 7. Species were included in this list if they occurred in all five of the ecological site descriptions. Available C means it is available from 4 or more suppliers. Available U means it is available from 3 or fewer suppliers. Plants that are not commercially available could be wild collected or grown under contract.

Perennial forbs are the most diverse group occurring on the site with potentially 160 different species. Perennial forbs have diverse strategies. This group could be supplemented with field collected seed, if needed. Despite the putative availability from published information, Castilleja, Amercian vetch, and Texas zinna, are not commercially available this year from the seed vedors queried. This left only gooseberryleaf globemallow (*Sphaeralcea grossulariifolia*) in the perennial forb functional group. In addition to the plants on this list which occurred in all five ecotypes, the list of 160 perennial forbs was reviewed and desert marigold (*Baileya multiradiata*), desert senna (*Senna covesii*) and desert globemallow (*Sphaeralcea ambigua*) were found to be common to one or more types and available commercially.

Functional group assessments – Annual Forbs

Annual Forbs

Common Name	Scientific Name	available
New Mexico copperleaf	*Acalypha neomexicana*	
carelessweed	*Amaranthus palmeri*	
bluestem pricklypoppy	*Argemone pleiacantha*	U
wheelscale saltbush	*Atriplex elegans*	
fewflower beggartick	*Bidens leptocephala*	
Coulter spiderling	*Boerhavia coulteri*	
hairy bowlesia	*Bowlesia incana*	
redmaids	*Calandrinia ciliata*	
partridge sensitive pea	*Chamaecrista nictitans*	
New Mexico thistle	*Cirsium neomexicanum*	
miner's-lettuce	*Claytonia perfoliata ssp. perfoliata*	
golden corydalis	*Corydalis aurea*	
Cryptantha	*Cryptantha*	
rattlesnake carrot	*Daucus pusillus*	
western tansymustard	*Descurainia pinnata*	
wedgeleaf draba	*Draba cuneifolia*	
miniature woollystar	*Eriastrum diffusum*	
sorrel buckwheat	*Eriogonum polycladon*	
Mexican gold poppy	*Eschscholzia californica ssp. mexicana*	U
Arizona blanketflower	*Gaillardia arizonica*	
annual goldeneye	*Heliomeris longifolia var. annua*	
camphorweed	*Heterotheca subaxillaris*	
cutleaf morning glory	*Ipomoea costellata*	
orange caltrop	*Kallstroemia grandiflora*	U
warty caltrop	*Kallstroemia parviflora*	
poorman pepperweed	*Lepidium virginicum var. medium*	
foothill deervetch	*Lotus humistratus*	
maresfat	*Lotus salsuginosus var. brevivexillus*	
yellow tansyaster	*Machaeranthera gracilis*	
big purple tansyaster	*Machaeranthera tanacetifolia*	U
lipstick plant	*Plagiobothrys arizonicus*	
woolly Indianwheat	*Plantago patagonica*	
Portulaca	*Portulaca*	
straighttube devilsclaw	*Proboscidea althaeifolia*	
annual devilsclaw	*Proboscidea parviflora*	
sawtooth sage	*Salvia subincisa*	
prostrate sida	*Sida abutifolia*	
sleepy catchfly	*Silene antirrhina*	
golden crownbeard	*Verbesina encelioides*	

Table 8. Species were included in this list if they occurred in all five of the ecological site descriptions. Available U means it is available from 3 or fewer suppliers. Plants that are not commercially available could be wild collected or grown under contract.

Annual forbs had limited availability except for those species that are popular in wildflower mixes. Bluestem pricklypoppy (*Argemone pleiacantha*) was not available this year but the other three species were. The addition of charismatic flowers will benefit the public acceptability of the final plant community. A total of 126 annual forbs were evaluated.

Functional group assessments – Shrubs and vines

Shrubs

Common Name	Scientific Name	ESDs	available
false mesquite	*Calliandra eriophylla**	5	U
shrubby buckwheat	*Eriogonum wrightii*	5	
range ratany	*Krameria erecta*	5	
spreading ratany	*Krameria lanceolata*	5	
wait-a-bit	*Mimosa aculeaticarpa var. biuncifera**	5	
velvetpod mimosa	*Mimosa dysocarpa**	5	
prairie acacia	*Acacia angustissima**	5	
yerba de pasmo	*Baccharis pteronioides*	4	
longleaf Mormon tea	*Ephedra trifurca*	4	
broom snakeweed	*Gutierrezia sarothrae*	4	
burroweed	*Isocoma tenuisecta*	4	
skunkbush sumac	*Rhus trilobata*	4	C
catclaw acacia	*Acacia greggii**	3	C
fourwing saltbush	*Atriplex canescens*	3	C
threadleaf snakeweed	*Gutierrezia microcephala*	3	
turbinella oak	*Quercus turbinella*	3	
whitethorn acacia	*Acacia constricta**	2	C
mintbush lippia	*Aloysia wrightii*	2	
Pringle manzanita	*Arctostaphylos pringlei*	2	
pointleaf manzanita	*Arctostaphylos pungens*	2	
desert hackberry	*Celtis ehrenbergiana*	2	
knifeleaf condalia	*Condalia spathulata*	2	
Mexican crucillo	*Condalia warnockii*	2	
Mexican crucillo	*Condalia warnockii var. kearneyana*	2	
rayless brittlebush	*Encelia frutescens*	2	
turpentine bush	*Ericameria laricifolia*	2	U
ocotillo	*Fouquieria splendens*	2	
Lycium	*Lycium*	2	
pale wolfberry	*Lycium pallidum*	2	
rough menodora	*Menodora scabra*	2	
whitestem paperflower	*Psilostrophe cooperi*	2	U
threadleaf groundsel	*Senecio flaccidus*	2	
threadleaf groundsel	*Senecio flaccidus var. flaccidus*	2	
desert zinnia	*Zinnia acerosa*	2	C
graythorn	*Ziziphus obtusifolia*	2	

Table 9. Common species are listed with their occurrence in the ecological site descriptions (ESDs). Available C means it is available from 4 or more suppliers. Available U means it is available from 3 or fewer suppliers. Plants that are not commercially available could be wild collected or grown under contract.
* Nitrogen fixing plants

A total of 65 shrubs and vines were evaluated. Of the available species, false mesquite (*Calliandra eriophylla*) and the two acacias fix nitrogen which is a critical component of system stability. False mesquite seems an important part of the plant community because it is listed as a co-dominant species for two of the five ESDs. Turpentine bush (*Ericameria laricifolia*) and desert zinnia (*Zinnia acerosa*) were not available, and the local practice has

been to add foothill palo verde (*Parkinsonia microphylla*) which is common to only one of the ecological sites. Shrubs are important to the ecological system through being able to hold soil and resources during times when other plants are senescent or not present.

Functional group assessments – Cacti and succulents

Cacti and Succulents

Common Name	Scientific Name	ESDs	available
Palmer agave	*Agave palmeri*	5	
cane cholla	*Cylindropuntia spinosior*	5	
spinystar cactus	*Escobaria vivipara*	5	
Engelmann pricklypear	*Opuntia engelmannii*	5	
soaptree yucca	*Yucca elata*	5	U
Parry agave	*Agave parryi*	4	
Chihuahua pineapple cactus	*Echinomastus intertextus*	4	
sacahuista	*Nolina microcarpa*	4	
brownspine pricklypear	*Opuntia phaeacantha*	4	
banana yucca	*Yucca baccata*	4	U

Table 10. Common species are listed with their occurrence in the ecological site descriptions (ESDs). Available U means it is available from 3 or fewer suppliers. Plants that are not commercially available could be wild collected or grown under contract.

Prickly pear (*Opuntia* spp.) and Cholla (*Cylindropuntia* spp.) readily reestablish from joints broken from the main stems. This makes them quite likely to establish in the recovered soils replaced on the areas for reclamation because of their current presence on the site and the plan to move surface soils without stockpiling them. These species may in fact become so common as to require a control strategy at some later date. They offer little protection from soil erosion but can be important for supporting wildlife.

The seeds of cacti tend to be long lived and may germinate several years after being deposited in the soil. No cacti have been included in the species mix due in part to limited seed availability. Also, cacti typically offer little protection from erosion and survive well when planted from container stock. Container stock availability was not specifically evaluated but based on personal experience much is readily available. These species could be successfully transplanted into containers from the site before disturbance takes place and maintained for later replanting.

Agave species are also not recommended in the species mix but could be added as container stock at a later date. These species are important as a seasonal food for the lesser long-nosed bat which is an endangered species. Most cacti are state protected plants (http://www.azsos.gov/public_services/Title_03/3-03.htm).

Functional group assessments – Trees

Trees

Common Name	Scientific Name	ESDs
oneseed juniper	Juniperus monosperma[1]	5
alligator juniper	Juniperus deppeana[1]	3
Arizona white oak	Quercus arizonica	3
Emory oak	Quercus emoryi	3
blue palo verde	Parkinsonia florida	2
honey mesquite	Prosopis glandulosa var. torreyana[1]	2
velvet mesquite	Prosopis velutina[1]	2
Mexican palo verde	Parkinsonia aculeata[1]	1
Mexican blue oak	Quercus oblongifolia	1

Table 11. Species are listed with their occurrence in the ecological site descriptions (ESDs).

[1]Species thought to be invasive

A total of 10 tree species were evaluated. Trees are not recommended except for landscaping considerations; this area was historically a grassland/shrubland. Mesquites and junipers should not be considered for planting because of their detrimental effects on ecosystem stability. When native plant communities have a strong increase of mesquite (velvet or honey) or juniper (alligator or one seed) to higher canopy levels (above 25%), erosion can accelerate and the site can become unstable. This happens when there is both an absence of fire and an available seed source. Mesquites are thought to be further spread through cattle consuming seeds and pods, and then distributing the seeds in their feces.

Rainfall scenarios

The nearest rain gauges with publicly available daily precipitation data were Agricultural Research Service (ARS) research equipment on the Santa Rita Experimental Range (SRER; less than 10 miles from the mine site). This data is available at http://www.tucson.ars.ag.gov/dap/DataCatalogueOld.htm. Gauges 5-6 were chosen as being nearest in elevation to the Rosemont site and are close enough together to be realistically averaged. Averaging widely separated gauges was not chosen because it would give less of a local picture of plant available water because the storm cells in the summer monsoon are often local in effect. The ARS data contains a complete data record for a period of 31 years (1976-2006). This data was used instead of the longer SRER records of monthly rainfall because daily weather records were needed.

The rainfall within a day was summed into a single precipitation amount. Runoff was discounted because the sites could both loose water due to runoff as well as gain water due to runon. These processes are probably not equal but the reclamation scenario seems to incorporate minimal expected runoff, especially given the readily drained nature of the expected surface soils. Water will be given to the potted soils at a rate of approximately 1 gallon per hour for the fraction of an hour it takes to meet the daily precipitation amount prescribed by its scenario (low, average, high). Excess water (unlikely) will be allowed to drain freely from the bottom of the pots.

The average rainfall scenario was an average rainfall year rather than the average daily rainfall over the 31 year period. This is an important distinction because the daily average would be smaller amounts distributed over many days. The average year will have normal sized storms at a normal interval. Having a sufficiently large storm size and appropriate interval between storms is critical for plant germination and establishment.

Similarly the low rainfall scenario is a characteristic low rainfall year from center of the range encompassing the bottom 20% of total rainfall and the high rainfall scenario is a high rainfall year from center of the range encompassing the top 20% of rainfall years. The year 1980 was selected as the representative low rainfall year, the year 1991 was selected as the representative average rainfall year, and the year 1990 was selected as the representative high rainfall year.

The greenhouse watering schedules derived from this analysis will be tested before use to ensure they meet the plant growth assumptions of the Rosemont site. Minor adjustments may be needed.

Rank (low to high)	Year	Average precip. (mm)	
1	1995	228.9	
2	2004	277.6	
3	1989	280.3	
4	1980	285.0	Low year
5	2002	292.5	
6	2006	293.5	
7	1996	305.9	
8	1976	309.5	
9	2005	311.2	
10	2003	311.9	
11	1986	336.4	
12	1997	338.5	
13	2001	344.4	
14	1979	365.9	
15	1991	398.4	Ave. year
16	1977	422.9	
17	1994	423.0	
18	1982	428.1	
19	1985	431.7	
20	1981	448.1	
21	1993	449.8	
22	1999	488.4	
23	1992	500.4	
24	2000	507.7	
25	1998	515.9	
26	1987	522.2	
27	1988	523.4	
28	1990	532.3	High year
29	1978	569.2	
30	1983	581.2	
31	1984	735.5	
	average	411.6	

Table 12. This is a range from 9 to 28 inches (228.9 to 735.5 mm) of rainfall. The average is approximately 16 inches (400 mm) with common amounts between 12 and 20 inches (300 to 500 mm).

Figure 1. The low year – 1980.

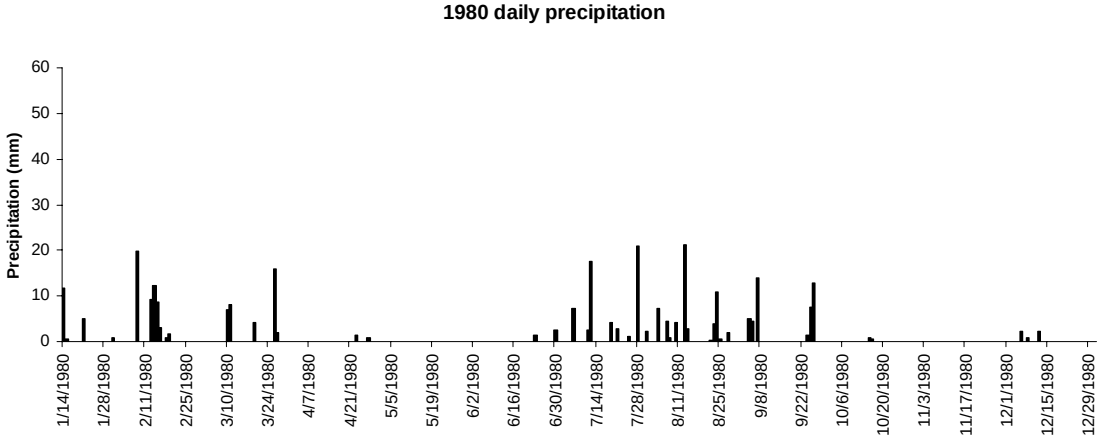


Figure 2. The average year – 1991

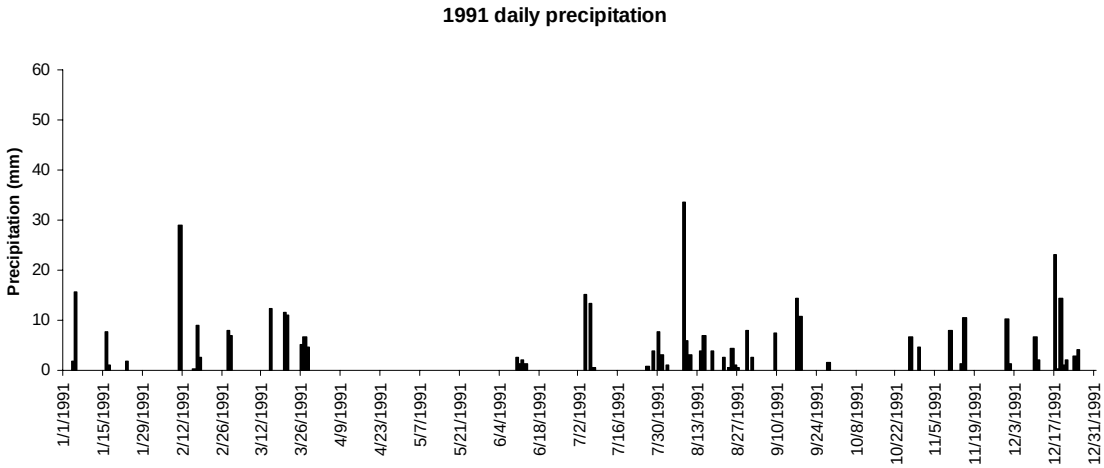
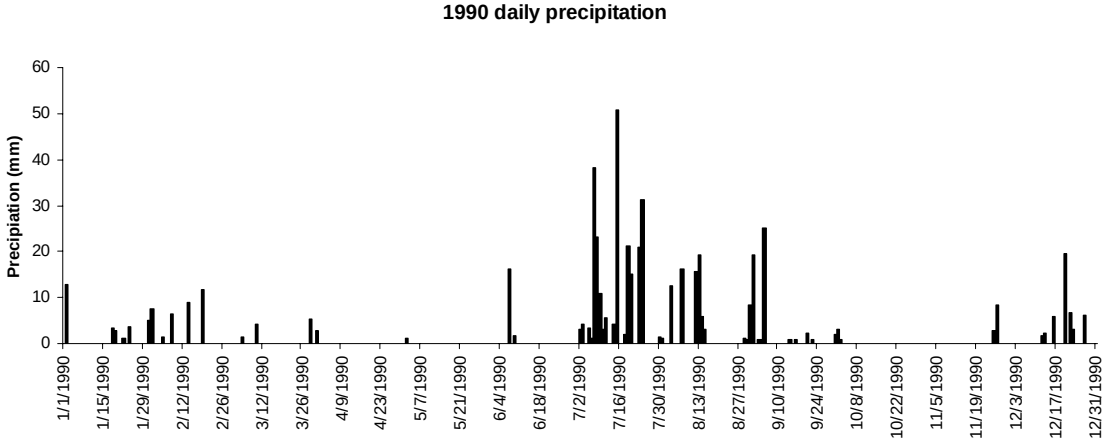


Figure 3. The high year – 1990



Developing a water schedule for the Monsoon season

Using the three characteristic years (high, average, and low), a watering schedule must be developed for the greenhouse. The three monsoon seasons were graphed together and the germinating rains are aligned so that all the plants will start at the same time. This avoids unnecessary complications entailed with too specifically mimicking a rainfall year. Monsoonal rains are characterized by short, often intense rains. Monsoonal rains are typically convective storms where humid air near the surface is heated by the sun, rises, cools and creates a shower. The humidity from these storms come from the Gulf of Mexico and is moved by the return flow from the jet stream flowing across the northern part of North America. Monsoon rains are unpredictable and unreliable. The monsoon (warm) season at the Rosemont site is hot with average day time highs of 89° F and lows of 58° F (temperatures based on the weather station at Sonoita).

The critical period for plant establishment is the first rain fall of sufficient intensity and duration which allows germination. Once germination has occurred, the plants then are dependent on semi-regular rainfall to allow continued growth and for their adventitious roots to keep ahead of the drying front in the soil. If the newly germinated seedlings cannot keep roots in the zones where moisture occurs in the soil, they die. For many native plants that grow during the monsoon season, the majority of the viable seeds will germinate during the first germinating rains. If the germinating rains are not quickly followed by other rainfall events, then new seeds would have to be added for recruitment during that season. Most invaders have seeds that have more variable germination than natives and will have some recruitment despite inconsistent rainfall.

For this project the monsoon was considered to be from the beginning of July to the end of September or a little more than 90 days. This is the primary growing season for warm-season plants.

Monsoon season watering schedule

Day	low rainfall scenario	average rainfall scenario	high rainfall scenario
1			15
2		15	15
3	10	15	15
4	10	15	15
7	5	8	11
10	5	8	11
13	5	8	11
16	5	8	11
19	5	8	11
22	5	8	11
25	5	8	11
28	5	8	11
31	5	8	11
34	5	8	11
37	5	8	11
40	5	8	11
43	5	8	11
46	5	8	11
49	5	8	11
52	5	8	11
55	5	8	11
58	5	8	11
61	5	8	11
64	5	8	11
67	5	8	11
70	5	8	11
73	5	8	11
76	5	8	11
79	5	8	11
82	5	8	11
85	5	8	11
88	5	8	11
91	5	8	11
94	5	8	11
total	170	285	390

Table 13. Values are in millimeters (mm) of water. Watering 170 mm equals 6.7 inches, 285 mm equals 11.2 inches, and 390 mm equals 15.4 inches.

Once the monsoon season trial is complete, the plants will be not given water again for at least two months before the start of the winter season growth period. This will mimic the normal dry period between seasons.

Winter season

The winter rains are characterized by the frontal systems more typical of the weather patterns that develop in the rest of the country. These storms are often several days in duration and are more of a gentle soaking rain compared to the intense rainfall events of the monsoon season. These storms are pushed into Arizona from the pacific by the jet stream when it flows across the more southern part of North America during the winter. Winter rains tend to be more predictable and consistent than monsoon rains. The temperatures are cool with average highs of 61° F and lows of 30° F.

As long as sufficient rain falls, plants are able to establish in the winter. Similar to the monsoon, if the rainfall does not occur on a regular interval, plants may germinate and then die before rains fall again. However, winter season plants tend not to all germinate during the first period when there is enough moisture; more will germinate with each rain. This makes establishing plants in winter season (cool-season plants) more reliable but they contribute substantially less to erosion prevention than the warm-season perennials.

For this project the winter season was considered to be from the beginning of December to the end of March or a little more than 120 days.

Winter season watering schedule

Day	low rainfall scenario	average rainfall scenario	high rainfall scenario
1	5	5	5
4		3	3
7	5	5	5
10			3
13	5	5	5
16		3	3
19	5	5	5
22			3
25	5	5	5
28		3	3
31	5	5	5
34			3
37	5	5	5
40		3	3
43	5	5	5
46			3
49	5	5	5
52		3	3
55	5	5	5
58			3
61	5	5	5
64		3	3
67	5	5	5
70			3
73	5	5	5
76		3	3
79	5	5	5
82			3
85	5	5	5
88		3	3
91	5	5	5
94			3
97	5	5	5
100		3	3
103	5	5	5
106			3
109	5	5	5
112		3	3
115	5	5	5
118			3
121	5	5	5
total	105	135	165

Table 14. Values are in millimeters (mm) of water. Watering 105 mm equals 4.1 inches, 135 mm equals 5.3 inches, and 165 mm equals 6.5 inches.

Amendments

The two amendments selected for evaluation in the greenhouse were tackified straw and tackified straw with a slow-release fertilizer. These amendments were selected based on an assessment of the expected surface materials and the likely conditions at the time of plant establishment. The potential surface materials (referred to as growth media or cap material in other reports) were sampled and evaluated in the laboratory by Tetra-tech and again by the University of Arizona after sample materials were delivered for the greenhouse evaluation. The laboratory reports for the sample materials are available upon request. The amendments were also selected so that they could be surface applied coincident with seeding.

Amendments are typically intended to ameliorate physical conditions (e.g. cover the surface with straw), increase resource retention (e.g. incorporate organic matter into the soil) or augment nutrients critical to successful plant establishment and growth (e.g. add fertilizer). Many amendments do some combination of these (e.g. manure or compost). The three materials to be used for reclamation at the Rosemont site are: Gila Conglomerate, Glance Conglomerate, and Arkose. These soils contain varying levels of organic matter and reasonable levels of macro- and micro-nutrients. This is not surprising since they currently support productive plant communities. There were two primary issues expected to be ameliorated with amendments during reclamation: 1) the harsh conditions at the soil surface for seed germination and establishment due to the climate and lack of soil cover, and 2) the limited nutrient availability in the surface soil layers (the layers important for plant establishment) due to soil mixing during movement and application as well as nutrient losses from exposure in the interval before reclamation and rainfall.

Amelioration of physical conditions: Plant residues such as straw, wood chips, sawdust, and paper mill sludge primarily alter the physical conditions by prevention of particle detachment by rain drops; insulation of the soil surface from direct drying by sunlight, wind, and heat; and by direct retention of water. These materials are typically very low in nitrogen and do not contribute to a quick infusion of nutrients into the soil but can add organic mater to the soil over the longer term. However in the semi-desert grassland, the soil moisture at the amendment-soil contact interface is generally insufficient to incorporate the organic matter into the soil within the time frame that the plant establishment must occur.

This type of amendment is typically spread by broadcasting, spraying, or blowing the materials across the site. It is targeted to stay on the soil surface rather than being incorporated into the soil. On sites with little surface roughness, it can be easily lost to wind. The primary way to prevent loss is to limit the amount of exposure to dry windy periods by timing the additions to just before rains expected to establish plants (which can be difficult in Arizona and impossible with large sites). Alternately, the materials can be held on the site with the addition of a tackifier agent that adheres the pieces together and to the ground.

Straw is a common amendments in current use and was selected for evaluation in this project. It should alleviate some of the hot/dry conditions at the soil surface which will enhance seed germination and retain soil moisture through reducing evaporation. The

straw will be applied after the seeds have been spread. Certified weed free straw is readily available and will be used. The expected application rate will be 2 tons per acre which is a standard rate.

The tackifying agent selected (product name - Envirotac), a commercially available poly acrylamide synthetic, will also being used for dust control at the Rosemont site. The alternative would be an organic plant based tackifying agent, but the efficiencies of having the same synthetic agent for dual use is compelling. Synthetic agents last longer and are in common use for straw tackification in reclamation. The application rate is expected to be 4.4 lbs per acre (dry weight) of Envirotac but the rate will be refined in consultation with the manufacturer as needed.

Augmentation of nutrients critical to successful plant establishment and growth: Chemical and natural fertilizers can be applied at rates that specifically match known mineral deficiencies in the soil. These can be in both quick-release and slow-release forms. They typically provide little or no physical protection to the soil and are aimed solely at mineral nutrition of plants. These amendments can be sprayed or broadcast on the site at the time of seeding or afterward, but quick-release fertilizers can be quickly leached from the soil and work best when the plant growth occurs at the same time as fertilizer availability. Incorporating quick-release fertilizers into the soil can improve their uptake by plants. For the application on the Rosemont site, the desired fertilizer would need to be applied on the surface at the time of seeding. Quick-release fertilizers would likely be lost before the plants could be large enough to take up the nutrients. Also, seedlings are especially sensitive to fertilizers and may be burned or killed by application of quick-release fertilizers with the seeds. This limits fertilizers for this project to slow-release forms.

Fertilization will only increase the levels of macro-nutrients (Nitrogen (N), Phosphorus (P), and Potassium (K) – the three numbers given when referring to fertilizers) for a short period (months rather than years). Long-term repair of the site is dependent on re-establishing the plant based source of nitrogen and restarting the nutrient cycling in the soil. More importantly when considering fertilizers, native plants are adapted to low nitrogen conditions and adding too much will encourage non-natives to colonize the site. While fertilization is a common part of reclamation, selecting plants that will establish and grow with the existing conditions seems a more sustainable approach.

The fertilizer selected for evaluation is a natural, slow-release formula (7-2-3; product name – Biosol). It will be applied at the rate of 1500 lbs per acre in conjunction with the straw and tackifier. The straw and tackifier will have the same rates listed above. Biosol, an organic product, can be applied dry, will not burn the emerging seedlings, and has the potential to increase the microbial activity important for healthy soil. It will primarily provide a temporary source of nutrients in the surface soil where the plants will be establishing.

Amendments with multiple advantages: Manures, composts, and biosolids can offer some small amount of physical protection as well as improve soil condition and mineral nutrition. These amendments are typically broadcast or sprayed onto the soil after seeding. Some come as a liquid or semi-liquid others come as solids. To get those at the highest quality – that do not contain harmful bacteria or heavy metals – one is in direct competition with the retail trade due to the limited supply. These amendments can contain

varying amounts of nitrogen which at higher levels can reduce plant growth of natives and encourage weeds. Incorporation this kind of amendment into the soil can greatly improve its effect.

These amendments can provide both short- and long-term benefits. The organic matter content, especially plant lignins, controls how slowly these amendments decompose in the soil. The more slowly they decompose the longer the release of nutrients (albeit in small amounts). The other, quickly released, components of this kind of amendments are taken up by plants (which only occurs if active growth is occurring), volatilized, or leached from the site. For surface applied manures and biosolids, the particle size is typically small enough so that the organic matter can be carried into the soil by rainfall. The addition of organic matter can improve infiltration, increase water holding capacity, and enhance microbial activity and nutrient cycling.

Chicken manure and fish pellets, which are commonly available as fertilizers, release most of their nutrients on the first rainfall. Biosolids release nutrients somewhat more slowly. Composts and cow manure both contain substantial amounts of slowly decaying organic matter. Cow manure can be easier to apply with commercial equipment due to the small and consistent particle size compared to most compost. Dehydrated or composted cow manure is safe, and unproblematic to ship and store. This manure typically is 2-2-2 (N-P-K) from diary animals and 2-1-2 from range fed animals. The application rate could be expected to be 3500 lbs (dry weight) per acre.

Any of the amendments could be successfully used in reclamation. The alternatives chosen were the best in terms of efficiency and expected plant requirements.

Florida Fire Assessment

The Florida fire occurred on July 7 - July 21, 2005 in the Santa Rita mountains. The fire burned about 23,000 acres and came within 5 miles of the southern edge of the Rosemont site. The USFS had an active reseeding program after the fire and the success or shortcomings of this effort may offer insight on reseeding for the mine.

The USFS seeded the following species on the areas marked in Figure 4.

30%	Sideoats grama	(*Bouteloua curtipendula*)	WSPG
15%	Blue grama	(*Bouteloua gracilis*)	WSPG
2%	Rothrock grama	(*Bouteloua rothrockii*)	WSPG
12%	Green sprangletop	(*Leptochloa dubia*)	WSPG
11%	Alkali Sacaton	(*Sporobolus airoides*)	WSPG
11%	Sand dropseed	(*Sporobolus cryptandra*)	WSPG
3%	Small-flowered fescue	(*Vulpia microstachys*)	AG
16%	Indian wheat	(*Plantago insularis*)	PF

The listed percentage represents the amount by weight for the mix. The mix was seeded at a rate of not less than 50 seeds per square foot through aerial broadcasting.

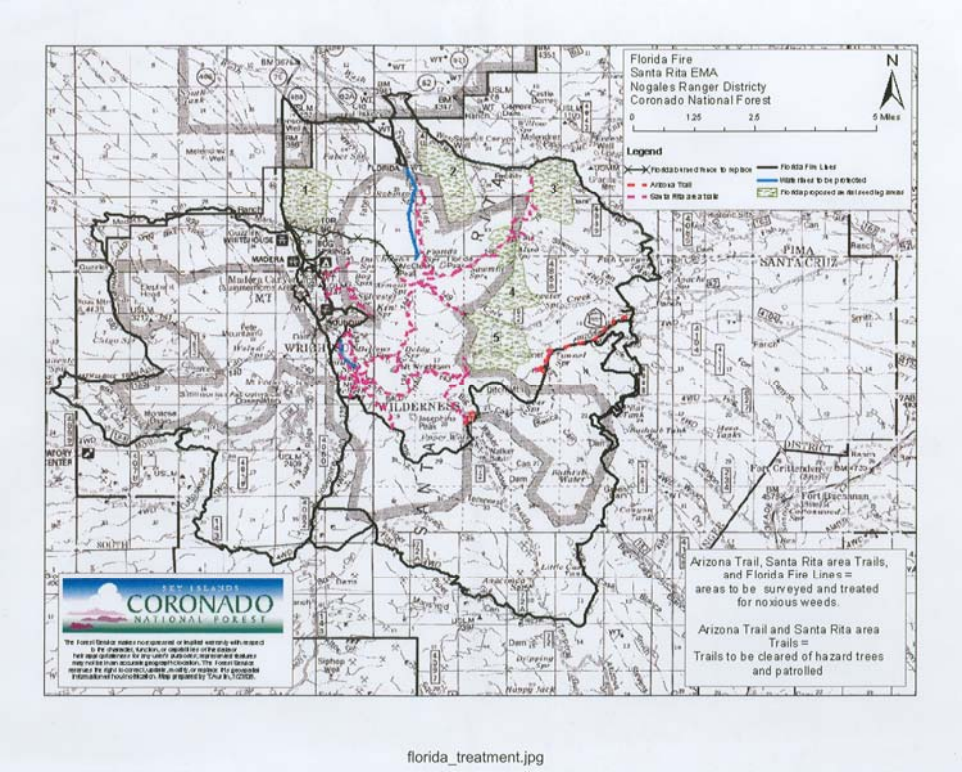


Figure 4. Map of the Florida Fire and reseeding (provided by the Coronado National Forest).

A preliminary survey of six sites (three seeded and three adjacent unseeded) showed little evidence of the seeded species. The sites had substantial vegetation other than the seeded species. Based on this preliminary site assessment, it did not seem that the seeding after the fire made a substantive impact on the species composition. The timing of the visit was during the dormant period for the species that were seeded and senescent plants can be difficult to identify based solely on the vegetative characteristics. The sites should be more formally sampled at or near the end of the monsoon season when these plants can be most accurately identified. The sites surveyed were in areas 1, 4, and 5 in Figure 4. These would be the sites proposed for later formal assessment.

The formal assessment would be to identify any plants of the species seeded within 5 randomly located 1 X 10 meter transects on each of the 6 sites. While the species composition before seeding and fire are unknown, the comparison of adjacent seeded and unseeded areas will at least offer some basis to determine if seeding had an effect.

Literature cited:

NRCS. 2006. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. (http://soils.usda.gov/survey/geography/mlra/)

Richardson, M. L., Clemmons, S. D. Walker, J. C. 1979. Soil survey of Santa Cruz and parts of Cochise and Pima Counties, Arizona. US Govt. Doc

Tetra Tech. 2007. Survey of salvage topsoil resources for the Rosemont mining area.

Tucson Plant Materials Center, 2001. Commercial sources of conservation plant materials, USDA-NRCS http://plant-materials.nrcs.usda.gov/pubs/azpmsarseedlist0501.pdf

Westland Resources. 2007. Draft report on the upland plant communities for the prospective site of the Rosemont mine.

Whisenant, S. 1999. Repairing Damaged Wildlands: A Process-Oriented, Landscape-Scale Approach, Cambridge University Press