DEVELOPMENT AND IMPLEMENTATION OF RECLAMATION PRACTICES AT HOMESTAKE'S McLAUGHLIN MINE[1]

by

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Abstract. The McLaughlin Mine is a world class epithermal gold deposit located in the coastal ranges of Northern California. Reclamation planning commenced with environmental baseline studies and initial project facility design. California law requires the designation of a postmining land use and the preparation and approval of a reclamation plan prior to initiation of mining. The McLaughlin Mine Reclamation Plan provides for a postmining land use of approximately 10,000 acres as an environmental studies field station. Mine waste rock dumps are designed to facilitate reclamation in annual increments concurrent with pit development. Grasses and woody plant species and planting methods were chosen before mine construction based on literature review and on-site test plots. Reclamation performance criteria were adopted and annual performance monitoring implemented. Seed mixes and woody plant species and planting methods were modified following several years of use based on performance monitoring data. Plant succession is evident in reclaimed areas during the first five years following planting. Approximately 1,325 acres have been reclaimed since commencing project construction in 1983, with approximately 136 acres of mine waste rock dump reclamation completed in 1985 through 1990.

Additional Key Words: Reclamation Planning, Monitoring, Performance Standards.

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Introduction

Homestake Mining Company's McLaughlin Mine is a world class gold deposit located in the coastal ranges of northern California, approximately 70 air miles north of San Francisco. The area was identified as an exploration target by Homestake in 1978 and confirmed by drilling to be a commercial deposit in 1980. The McLaughlin Mine ore body contains 20 million tons of gold ore averaging 0.152 ounces per ton and contains approximately 3,000,000 ounces of gold. The Mine was planned, engineered, constructed, and brought into production by March of 1985. Mining is by open pit methods moving approximately 50,000 tons of waste rock, low-grade and high-grade ores per day to provide a millfeed of 6,200 tons per day. The Mine produced 267,000 ounces of gold in 1990. The accompanying waste rock disposal facilities have a capacity of 160 million tons and cover approximately 385 acres. The development of a reclamation plan and the selection of methods for the reclamation of the waste rock disposal areas is the subject of this paper.

Environmental Setting

The mine is located at the juncture of Lake, Napa and Yolo Counties, on a ridge, at an elevation of approximately 2,000 feet above sea level. The ridge defines the boundary between Napa and Yolo Counties and acts as the watershed divide, placing the Mine at the headwaters of two drainages.

The climate is Mediterranean with an average annual rainfall of 30 inches with precipitation occurring predominately between October and April. The months of June through September are dry with little or no measurable precipitation. The growing season begins in October with the first winter rains and continues through the winter and spring months until precipitation declines in May and June. Maximum growth occurs in April and May.

Summertime temperatures are typically in the 90°F range with peak temperatures exceeding 105°F. Winter temperatures are moderate with typical daytime temperatures in the 40°F range with seasonal lows in the 20's. Snowfall occurs several times per year, with a typical snowfall averaging less than 3 inches.

The project site is remotely located and sparsely settled. The closest community is 15 miles to the north and is centered around Clear Lake, the state's largest natural lake. The economy and land use of this area is seasonal tourism and agriculture with pears, walnuts, and grapes being the predominant produce.

The Napa Valley is located south of the project with the economy and land use centered around the premium wine grape industry, both for agriculture and tourism. To the east lies the Sacramento Valley with an agriculturally based economy consisting primarily of field crops and orchards.

Vegetation at the site is a mixture of plant communities including Cismontane Introduced Grasslands, Blue Oak Woodland, Serpentine Chaparral and Northern Interior Cypress Forest. The Serpentine Chaparral and Northern Interior Cypress Forest are largely restricted to, or associ-

ated with, soils derived from serpentinitic parent rock. Serpentine soils have physical and chemical characteristics that limit plant growth including calcium deficiency, excess magnesium, elevated levels of nickel and chromium, and a clay consistency which contributes to soil instability.

Reclamation Authority and Regulation

Reclamation is regulated by the California Surface Mining and Reclamation Act which is administered by the local county and city governments. The Act requires designation of a postmining land use and the preparation and approval of a mining and reclamation plan prior to the initiation of mining. The reclamation plan must specify final land form and topography; postmining hydrology; topsoil salvage, storage and replacement; seedbed preparation and fertilization; species to be planted and planting methodology; erosion and sedimentation control, and maintenance of revegetated areas. The Act also allows local governments to require the determination of reclamation costs and the posting of financial assurances.

Postmining Land Use

The McLaughlin Mine Reclamation Plan specifies a postmining land use which provides for the conversion of the approximately 10,000 acre site to an environmental studies field station at the conclusion of mining. This decision was based on an evaluation of postmining assets which revealed that a valuable educational resource will result from the project in the form of accumulated environmental data. Between 3 and 4 million dollars were expended for the environmental baseline studies and the ongoing comprehensive monitoring program will produce another twenty plus years of useful data including aerial photography updated annually, surface and ground water quality data, aquatic ecology, wildlife surveys, vegetation and sensitive plant surveys, and more. In addition, physical facilities including laboratories, commercial power, roads, water supply and sanitation facilities will be in place and available at the site. The field station will be made available for the use of regional public schools, colleges, and universities. The postmine land use as an environmental studies field station provides for productive use of the land and facilities while preserving the opportunity for future mining.

Reclamation Plan

In addition to specifying the post mining land use, the Reclamation Plan provides specific reclamation goals and specifies the reclamation methods to be implemented to achieve those goals. Reclamation goals are to:

- Minimize Erosion.
- Stabilize Disturbed Areas With a Permanent Diverse Vegetative Cover.
- Maximize Productive Land Use
- Protect Water Quality.

These goals are met through preconstruction engineering and planning of project components to facilitate implementation of the reclamation plan; through preconstruction research and literature review to identify reclamation methods best suited for use at the site; by the identification of soils suitable for reclamation and the stockpiling of these

soils during construction; by implementation of the reclamation plan during mining operations; and by annual monitoring to evaluate reclamation. Rather than commencing reclamation at the end of the mine life, the reclamation plan provides for reclamation of the waste rock disposal areas concurrently with mining operations. Reclamation efforts are monitored annually with collected data utilized to evaluate and modify reclamation methods for use in following years.

Preconstruction Reclamation Planning

Reclamation planning at the McLaughlin Mine began with the collection of baseline environmental data for vegetation, soils, sensitive plants, climatic conditions, and land use. These data were tabulated and mapped to provide a useful format for planning purposes. These baseline data laid the foundation for further planning and engineering decisions. Detailed reclamation planning incorporated the baseline environmental studies, revegetation and reclamation experience, research conducted by numerous agencies, private firms, and academic institutions in California.

Facility Siting

As the facilities were engineered, the project baseline information was utilized to develop siting criteria and to evaluate siting alternatives. Project facilities that had siting flexibiilty such as pipelines, transmission corridors, and roads, were adjusted to the extent possible to avoid sensitive plant populations and serpentine soils which are more difficult to reclaim. Environmental sensitivity was considered in the siting of all facilities and appropriate mitigation measures designed and incorporated into the project to minimize environmental impacts.

Facility Design and Construction

Those facilities with less flexibility in siting, such as the waste rock disposal areas, were designed and constructed to facilitate reclamation and closure. The waste rock or overburden disposal areas are designed with an overall slope of 4H:1V to assure mass stability under seismic loading. The facilities are constructed in 50 to 100 ft. lifts with benches of varying widths constructed at the toe of each lift. Interbench slopes are constructed at a slope of 2.5H:1V to provide a slope conducive to revegetation. Topsoil was salvaged from areas disturbed during construction and stockpiled for later placement on final slopes in the waste rock disposal facility.

Species Selection

Species selections for grass seed mixes were based on research completed through the University of California at Davis, experience gained from twenty years of revegetation at the nearby Geysers Geothermal Steam Field electric generation facilities, state highway revegetation work completed by the California Department of Transportation, assistance provided by the California Division of Mines and Geology, and by a master's thesis research project on grass species that was conducted at the site.

Two seed mixes were developed, one for nonserpentine soils, and one for serpentine soils recognizing the particular

limitations of this soil type for revegetation. Table 1 lists the seed mixes currently in use, which are composed of annual and perennial grasses and each include a legume.

Native woody species indigenous to the site were reviewed for reclamation potential taking into consideration soil types, seed collection potential from surrounding native plants, nursery propagation potential, and expected survival rates following transplanting into disturbed soils as tublings. Woody species chosen for planting are listed in Table 2.

Topsoil, Fertilizer, and Soil Amendments

Topsoil was identified and salvaged during project construction and stockpiled at various locations for reclamation use. Additional topsoil is salvaged from open pit development for direct placement on final slopes and benches of the waste rock disposal facilities during mining operations. Topsoil is placed on the reshaped slopes of the waste rock disposal facility at an average depth of 1.4 feet. The topsoil is then trackwalked to provide a firm soil surface while also providing microhabitats in the indentations remaining from the dozer grouzer bars.

Fertilizer specifications were developed from previous experience on northern California soils of similar types. The soils generally have sufficient potassium, but are deficient in nitrogen, phosphorus, and sulfur. A 16-20-0 NPK fertilizer was specified at a rate of 400 lbs. per acre.

Serpentine soils have a calcium/magnesium imbalance with a significant calcium deficiency. Hydrated lime (CaO) is applied at a rate of 1,000 lbs. per acre as a calcium supplement to these soils. Application is accomplished by mixing the lime with water in a hydroseeder and spraying the mixture on the areas to be reclaimed prior to the application of seed and fertilizer.

Soil amendments and application rates are shown in Table 3.

Reclamation Methodology

Grasses

Reclamation methods were reviewed for use at the site with the objective of finding the methods that provided the best application for site specific conditions. Soil contact with seed and fertilizer was a primary objective for determining application methods. Mulches were reviewed for effectiveness of erosion control and enhancement of seed germination.

Seeding and fertilizing by hydroseeder provided the most reasonable means of application on long and steep slopes while assuring direct seed contact with the soil.

Straw mulch was chosen because of its longer fiber length and subsequent greater erosion protection capability. Seeding is completed just prior to the period of heaviest precipitation. Maximum protection from both raindrop impact and sheet erosion is critical for reclamation success. The straw mulch also provides additional insulation necessary to maintain surface soil

Table 1. Grass and legume species and seeding rates used to revegetate serpentine and nonserpentine soils at the McLaughlin Mine, Lower Lake, CA.

Plant Species	Seeding Rate (Pure Live Seed Lbs/Acre) Soil Type Serpentine	Nonserpentine
'Blando' brome (*Bromus Mollis*)	15	15
'Alta' tall fescue (*Festuca Arundinaceae*)	8	5
'Luna' pubescent wheatgrass (*Agropyron Tricophorum*)	10	8
'Berber' orchard grass (*Dactylis Glomeratus*)	0	8
'Wilton' rose clover (*Trifolium Hirtum*)	0	10
'Panoche' red brome (*Bromus Rubens*)	10	0
Lana Vetch (*Vicia Dasycarpha*)	8	0
Annual ryegrass (*Lolium Multiflorum*)	0	5
Total	51	51

temperatures essential for seed germination and also retains soil moisture between precipitation events to minimize adequate surface mortality. Straw is available from regional agricultural activitities.

Fully seeded straw is used to provide an annual nurse crop of wheat, oats, or barley, depending on regional straw availability. The annual nurse crop is quickly established providing early season erosion protection.

The organic matter remaining after the first season's growth provides additional mulch for soil protection. This mulch adds organic matter as it decomposes.

Straw is applied by a conventional straw blower with the addition of a long hose extension to reach the bottom of the slopes and to minimize wind loss. Straw is tackified using 90 lbs. of tackifier per acre applied through a hydroseeder.

Woody Species

Woody species seed is collected from plants in the immediate area and grown in tublings in a local nursery. The plants are then transplanted using a collar and screen planting method developed by staff for Pacific Gas and Electric Co. The method utilizes 1 quart cottage cheese containers with the bottom removed, forming a collar to contain the seed or seedling. The collar serves to concentrate available moisture to the root zone while providing protection from burrowing rodents. The collar also provides a point of attachment for an aluminum screen which provides animal browse protection for the young plants during initial establishment. A polypropylene mat is installed around the plant to minimize weed and grass growth which outcompete the young plants for available water and nutrients. The mat is porous, black in color and decomposes after several years.

Plants are watered initially, and may receive one to two supplemental waterings during the first growing season if precipitation is light or sporadically distributed. General irrigation of any type is not practiced.

Planting Season

Grasses are seeded prior to the winter rainy season, generally by October 15. This provides maximum opportunity for early gentle soaking rains and warm temperatures necessary for germination and initial root development prior to the onset of heavy winter precipitation and reduced soil temperatures.

Early winter rains can be sporadic with 30 days or more between precipitation events. The use of straw mulch conserves soil moisture needed for germination and subsequent survival between precipitation events.

As soil temperatures drop in late October and November, germination declines and revegetation success is visibly affected. Straw mulch provides the insulation necessary to maintain warmer surface soil temperatures when daytime temperatures are warm and night time temperatures drop to near freezing.

Table 2. Woody Species Used in Reclamation at the McLaughlin Mine, Lower Lake, CA.

Scientific Name	Common Name
Quercus durata	Leather Oak
Quercus wislizenii	Interior Live Oak
Quercus lobata	Valley Oak
Quercus douglasii	Blue Oak
Quercus dumosa	Scrub Oak
Pinus sabiniana	Foothill Pine
Cupressus macnabiana	Macnab Cypress
Juglans hindsii	Black Walnut
Rhamnus californica	Coffeeberry
Cercis occidentalis	Redbud
Cornus sericea var. occidentalis	Western Dogwood
Umbellularia californica	Bay
Hetermolele arbutifolia	Toyon
Adenostoma fasciclatum	Chamise

Table 3. Soil Amendments and Mulch Application Rates Used in Reclamation at the McLaughlin Mine, Lower Lake, CA.

	Application Rate (Pounds Per Acre) Soil Type	
	Serpentine	Nonserpentine
Fertilizer, 16-20-0	400	400
Straw Mulch	4,000	4,000
Tackifier, A-Z Tack	90	90
Hydromulch Wood Fiber	500	500
Hydrated Lime	1,000	0

Woody Plants are planted in December and January when soil moisture is high and ambient air temperatures are cool. Precipitation occurring in December through April provides needed moisture for initial plant establishment.

Performance Standards and Annual Monitoring

Performance standards for the McLaughlin Mine utilize percent cover criteria as the measure of reclamation success as illustrated in Table 4. Monitoring of reclamation success incorporates two inspections for percent cover in the first growing season and an annual inspection thereafter. The first inspection is completed several months following planting and is an evaluation of mulch application and nurse crop establishment, requiring a 70% cover criteria, including mulch. The percent cover standard is based on sediment loss as function of soil cover with 70% cover providing the optimal level of erosion control protection. The second evaluation is completed at the end of the first growing season and is conducted in April or May. This inspection evaluates the first year's success which is critical to erosion control, surface stabilization and establishment of perennials and natives in following years. This evaluation also requires a 70% cover including mulch.

Annual inspections are conducted in following years to document a sustained 70% level of cover and the establishment of a permanent diverse vegetative community.

Consideration is given to serpentine slopes in the development of performance standards, recognizing the respective reclamation challenges provided by the different soil types. Disturbed serpentine soils do not readily support seeded species even with the addition of lime as a calcium supplement. The performance criteria reflect the requirements of 25% cover standard in years following the initial application of seed and mulch.

Monitoring data are reported annually in the McLaughlin Mine Annual Environmental Monitoring Report published in October of each year. The data are used to evaluate and modify, where needed, the reclamation methods employed.

Successional Patterns

Successional patterns are evident in the first five years following reclamation as illustrated in Table 5. Generally, the first year plants present include the species from the fully seeded straw (oats, barley, or wheat depending on straw species used) and seeded annuals including 'Blando' brome and annual rye. The second year monitoring documents a reduction in the annuals and the emerging presence of the seeded perennials. Clovers which are absent in the first year also become well established in the second year. The third year exhibits the first signs of native species, both shrubs and grasses invading from surrounding seed sources. The fourth and fifth year show perennial seeded species and an increase in native species present.

Table 4. McLaughlin Mine Reclamation Performance Standards.

First Inspection, Two to Three Months Following Seeding
70% Cover (including mulch)
Second Inspection, End of First Growing Season
Topsoiled Areas 70% Cover (including mulch) Nontopsoiled Areas 40% Cover (including mulch) Serpentine Soils 25% Cover (including mulch)
Annual Inspection
Percent Cover Estimated Annually for Sustained Level

Table 5. General Plant Succession by Year in Reclaimed Areas at the McLaughlin Mine, Lower Lake, CA.

Year	
1	**Annual Grasses and Mulch Species** Annual Rye, Blando Brome, Mulch Species (oats, barley, wheat)
2	**Annual Grasses, Emerging Perennial Grasses, Clover** Mulch Species absent, Blando Brome, Annual Rye, seed mix perennial grasses become evident, clover.
3	**Perennial Grasses, Emerging Native Species** Seeded perennial grasses well established. Native species dependent on surrounding seed source but include both shrubs and grasses.
4 & 5	**Increasing Abundance of Native Species**

Conclusion

The McLaughlin Mine Reclamation Plan incorporates a unique postmining land use as an environmental studies field station, providing for productive use of the site and facilities while maintaining the potential for future mining.

Development of the reclamation plan incorporated existing information, experience and resources to provide a plan employing techniques and materials proven to be successful in the local region of northern California. Annual performance monitoring and comparison of results to adopted performance criteria provide a feedback loop for evaluation and modification of reclamation methods.

Annual Monitoring has demonstrated successional patterns in reclaimed areas during the first five years following planting. Continued monitoring will confirm the long-term successional patterns developing in reclaimed areas and provide additional information for evaluation of reclamation techniques. Annual monitoring, evaluation and fine tuning of reclamation methods will continue throughout the life of the project.

Overall reclamation success has been excellent, with performance criteria being met in all cases, with the exception of occasional rilling in limited areas. Woody species establishment has also met expectations for plant establishment.

Approximately 1,325 acres have been reclaimed since commencing project construction in 1983 with approximately 136 acres of mine waste rock disposal facility reclamation completed in 1985-1990.

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