RECLAIMING A GOLD MINE[1]

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Abstract: An open-pit gold mine in the Mother-Lode mining region of the Sierras was essentially closed according to an accepted mine closure plan. However, because one element of the plan was not completed, due to technical disagreements, the entire mine site is now being re-examined, conceptually resulting, in revisions to the closure plans for the entire site. Elements of the mine include open-pits, a pit lake, waste rock piles, tailings pile, and a site wide surface water drainage system. Concerns to be re-addressed include: off site migration of dissolved metals in groundwater, stormwater sediment transport, revised criteria for side slope gradients of waste rock piles, disposition of pit lakes, and other complex issues.

Additional Key Words: mine drainage, water treatment

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[1] Paper presented at the 2005 Annual Meeting of the American Society of Mining and Reclamation, Breckenridge, CO, June 19-23, 2005, Published by ASMR, 3134 Montavesta Rd, Lexington, KY 40592

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Proceedings America Society of Mining and Reclamation, 2005 pp 1244-1255
DOI: 10.21000/JASMR05011244
https://doi.org/10.21000/JASMR05011244

Introduction

The Jamestown Mine was operated until 1994 and closed with the exception of capping the tailings pile. Disagreements on the effectivence of the proposed cap and subsequently other elements resulted in a legal complaint filed against the property owners, including the County, by the California State Water Resources Control Board (SWRCB). The Parties have cooperated to develop the following approach to manage environmental concerns at the Jamestown Mine site in Toulumne County (Site) based on the California State Water Resources Control Board (SWRCB) Containment Zone Policy (CZ), 92-49.

Containment Zone Regulations

In October 1996, Amendments were made to SWRCB Resolution 92-49, which were codified in Water Code Section 13304. This amended Resolution indicated that, if "background" water quality is unachievable, cleanup levels shall be consistent with the maximum benefit of the State. The Containment Zone Policy also indicated that it is not unreasonable to affect present and anticipated future beneficial uses in considering cleanup and while not permitting dischargers to avoid responsibilities recognizing that, in some cases, compliance with water quality objectives cannot reasonably be achieved within a reasonable time frame. In order to implement a CZ, the Water Code indicates that RWQCB must adopt a Cleanup and Abatement Order.

Rationale For Designation

A wide range of reclamation/remedial actions could be implemented at the Jamestown mine site to attempt to meet water quality goals. The water quality goals are the State of California, Department of Health Services, Drinking Water Standards, Primary and Secondary Maximum Contaminant Levels of Constituents, August 2003. The proposed conceptual plan for reclamation and long term management of mining units within a designated CZ at the Site is described further below. The Site consists of a fracture flow-dominated hydrogeologic environment with most of the groundwater flowing along the primary fault structures and fractures. The predominant fault is the Melones Fault, striking northwest and dipping to the east, part of the regional Mother Lode gold bearing mineralized zone. There is very limited groundwater flow in the thin layer of colluvial soil cover and in unaltered and unfractured bedrock according to previous hydrologic investigations and aquifer tests of monitoring wells. The Harvard Pit located at the southern Site boundary acts as a sink and collects groundwater flowing through fractures in bedrock surrounding the pit. As long as the water level in the pit is below the static water level, the gradient in the surrounding area would be towards the pit.

Proposal Overview

As part of the approved Management Plan, mitigation measures are proposed to reduce or remove the potential for significant impacts at the Jamestown Mine, as described below. The proposed plan includes several measures to reduce pollutant mass and potential impacts to groundwater within the CZ.

Minesite Description

Location

The Jamestown Mine is located approximately 75 miles southeast of Sacramento and 30 miles west of Yosemite National Park in central California. The Site currently consists of three open pits known as the Harvard, North Crystalline and South Crystalline, the Tailings Management Facility (TMF) and Rock Storage Area (RSA), and ancillary facilities. (Fig. 1)

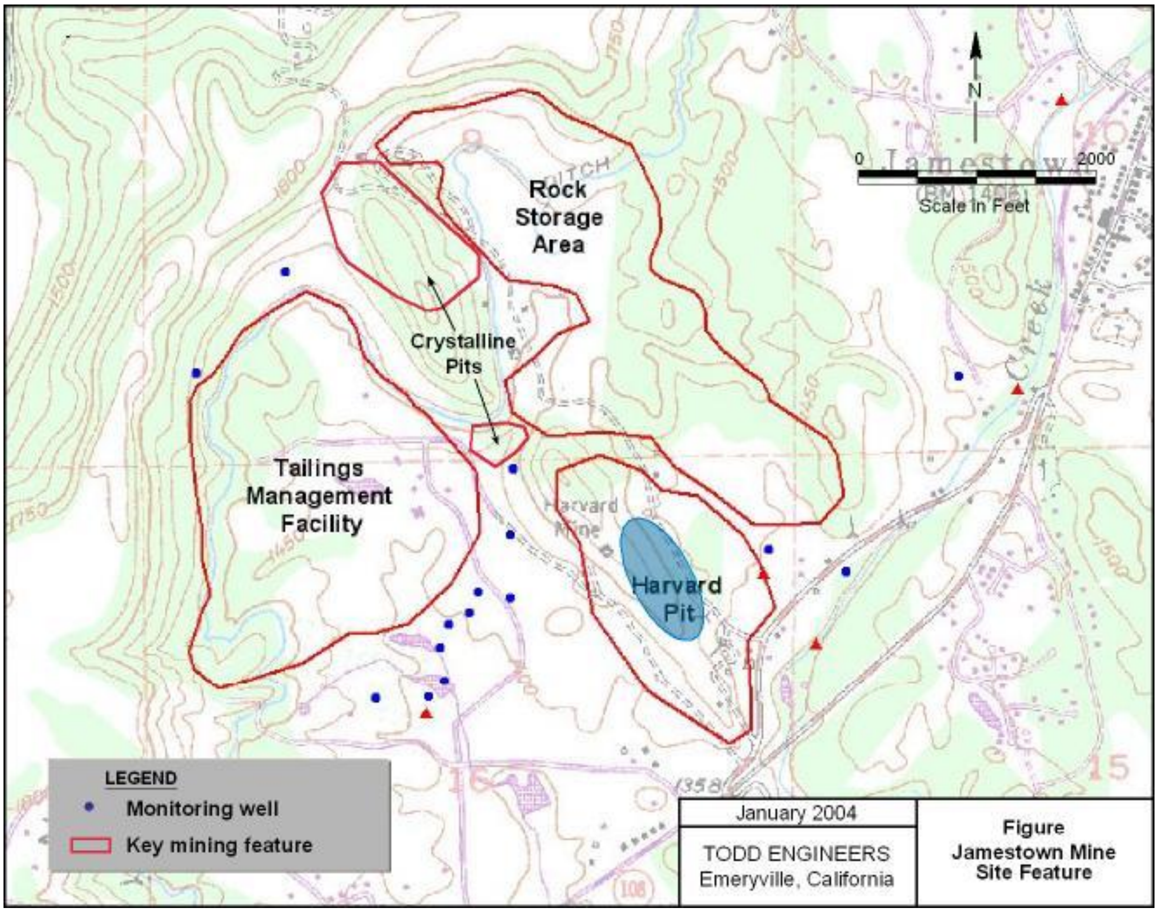

Figure 1. Jamestown Mine Site Features

Site History

Mining at the Site began in the 1850s, when placer gold was discovered in Woods Creek. Sonora Mining Company (SMC) began its plans for the California Gold Project in 1983/1984 and construction of the Jamestown Mine commenced in 1986. Development of the Harvard Pit was initiated together with the construction of the mill facilities, TMF, and the RSA.

Ore milling and the production of gold concentrate began in 1987 with the extraction and processing of approximately 6,000 tons of ore per day. The extraction of gold concentrate was by froth flotation techniques. Free gold was removed from the ore using gravity separation. The concentrate was hauled to a leaching facility near Yearington, Nevada for processing.

In the summer of 1988, the Harvard Pit was mined to an elevation of 1,340 feet mean sea level (msl), at which point the groundwater table was encountered. Mine dewatering was thereafter accomplished by pumping from a pit floor sump as well as dewatering wells that intersected flooded historic workings underlying the pit. The historic underground mines were located in hard, stable hanging wall metamorphic rocks (slates and shists) and footwall metavolcanic rocks (serpentine and greenstone) and metamorphosed diorites and gabbro. The dewatering system was progressively lowered with the pit pumping rates ranged from 50 to 150 gallons per minute. Water treatment was not required based on laboratory analysis, and the water was discharged to detention ponds. The Harvard Pit was ultimately mined to an approximate elevation of 840 feet msl, or to a depth of approximately 640 feet at completion in 1994. (Fig. 2) The Crystalline and South Crystalline Pits were mined from 1990 to 1993. After mining of the Crystalline Pit ceased, it was partially backfilled with waste rock from the Harvard Pit. The South Crystalline Pit was partially backfilled after closure in mid 1994. Active mining at the Jamestown Mine ceased in July 1994, and the mine has remained in a reclamation and maintenance phase since then.

Figure 2. Harvard Pit

Site Characterization Information

As context for this proposal and consistent with the CZ requirements, Site characterization information was summarized and the key concerns are groundwater quality.

The RWQCB has identified the primary constituents of concern and range of concentrations in groundwater at the Site as:

- Arsenic; 0.002 – 0.025 mg/L
- Sulfate; 150 – 2000 mg/L
- Nitrate; 0 – 170 mg/L
- Magnesium; 20 – 160 mg/L
- Sodium; 0 – 150 mg/L
- Calcium; and 40 – 220 mg/L
- TDS. 200 – 4000 mg/L

Pre-mining Water Quality Data

Groundwater studies conducted in the Jamestown Mine area prior to mine operations indicated that water quality was highly variable and closely associated with the bedrock type and associated mineralization. In general, pre-mining TDS results show a zone of high TDS extending along the main fault zone.

Past and Ongoing Actions

Past actions at the Site have taken place consistent with the 1990-Revised Reclamation Plan and the 1995 Mine Closure Plan.

- The storm water runoff detention ponds (DP-6) (Fig. 3) are being used as wetland habitats similar to the wildlife pond in the northeast corner of the property. The ponds continue to attenuate storm water runoff, and provide clarification of the runoff (elevation of 1370 feet MSL) prior to discharge to Woods Creek, (elevation of 1340 feet MSL) if necessary. (Fig. 4)

- Closure activities at the Crystalline and South Crystalline pits was largely completed in 1994. These activities consisted of partially backfilling the pits with mine waste rock up to an elevation which would allow gravity drainage from the pits, grading and placing a soil cover on the waste rock, and revegetating the soil cover and the accessible portions of the pit perimeter with grass.

- The mill site and crusher pad areas were reclaimed as grassland areas. The fuel tanks and buried pipes were removed. The concrete slab curbs were inspected for hydrocarbon contamination and were steamed cleaned as necessary and then broken up and buried.

- The tailings dam at the TMF has been revegetated to minimize erosion. (Fig. 5)

Figure 3. Detention Pond

Figure 4. Woods Creek

Figure 5. Tailings Dam

- The TMF Leachate Collection and Recovery System (LCRS) currently discharges approximately 200 gpm continuous flow. Presently, this water is managed by pumping the water back up to the TMF. In addition, the TMF underdrain produces approximately 35 gpm continuous flow, which is also conveyed to the Process Water Retention Pond (PWRP). During the first five years after construction of the TMF cover system, we assume that the LCRS and under-drain will discharge to the PWRP and this water will be managed through a combination of spray evaporation and blending/discharge.

- The RSA area has been reclaimed during operations and at present is 90 percent (Fig. 6) complete. The slopes of the RSA were contoured so that the slopes were adequate toplace the soil cover for revegetation. Revegetation was conducted consistent with theRevegetation Master Plan

Management Plan

A Management Plan for proposed cleanup actions has been developed to be consistent with the requirements of the Containment Zone presented in the Application Requirements for Designation of a Containment Zone (RWQCB 1997). Presented here is a brief summary of the plan.

Figure 6. Rock Storage Area

Task 1: Site Management

The parties will establish a Site management and maintenance plan for the Jamestown Mine site for a projected 30-year period.

Task 2: Water Monitoring Program

The existing monitoring program will incorporate analysis of the new monitoring wells installed as part of the Site Management Plan, storm water management sampling, monitoring related to the RSA, monitoring of the Crystalline Pit well and monitoring of the Harvard Pit. The program also includes surface water monitoring. Specific locations of additional monitoring location requires approval of the Regional Water Quality Control Board.

Task 3: Groundwater Monitoring Well Installation

A Work Plan will be prepared to document the objectives, rationale, and methods for installing additional groundwater monitoring wells at the Site following selection of specific well locations. All monitoring wells will be screened in the metamorphic and metal volcanic host rocks that underlie the pits, tailings facilities and rock storage areas. Analytical laboratory testing will include the following parameters: pH, EC, TDS, calcium, sodium, potassium, chloride, sulfate, bicarbonate, carbonate, nitrate, ammonia, arsenic, magnesium and TOC. This Work Plan will also include a Health and Safety Plan. This subtask will also include Site visits and related work to ensure proper selection of and access to well locations.

Task 4: Domestic Well Analysis

Selected domestic water wells located downgradient of the Site will be monitored for potential groundwater quality impacts.

Task 5: Basin Analysis

A groundwater basin analysis will be conducted through the accumulation, integration, and evaluation of groundwater data to determine groundwater movement within the Jamestown mine area drainage basin and to identify and locate chemicals of concern within the basin from groundwater sample analyses. This analysis will include a re-examination of the previously conducted mine-closure studies.

Task 6: Safety Review and Risk Assessment

With respect to environmental issues, a safety review will be performed to ensure that Site access does not allow for unauthorized entry and the potential for injury. A screening level human and/or ecological health risk assessment may be completed to support the CZ program, if necessary.

Task 7: Groundwater Performance Criteria and Contingency Plan

Groundwater performance criteria will be established to verify the effectiveness of the CZ. The criteria specified by the RWQCB will be used to evaluate the possible need for contingency measures. Since the constituents of concern (arsenic, calcium, magnesium, nitrate, sodium, sulfate, and TDS) at the Site are naturally occurring, pre-mining (before any mining occurred at the site) conditions need to be considered when developing performance criteria. The impact of Site mining activities on groundwater will need to be determined by evaluating whether there are increased concentrations of these naturally occurring constituents, such as sulfate, total dissolved solids, or arsenic caused by mining activities.

Task 8: Storm Water Management

The objective of the storm water management system is to collect storm water runoff on the mine site and channel the storm water flows to detention basins. The collection of storm water runoff reduces the infiltration of water and thereby reduces potential mobilization of contaminants of concern in the mine features such as the TMF, RSA and crystalline pits. Secondly the storm water management system reduces erosion and transport of sediments. The Stormwater Management Plan will be expanded to include additional storm water control measures and a description of the existing meteorological station operation. Scheduled monitoring and inspections would be incorporated into the Storm Water Management Plan.

Task 9: Tailings Management Facility and Process Water Retention Pond Closure

The TMF will be rough graded to achieve an approximate three percent surface slope, creating definitive drainage areas. The top one-foot of tailings soil obtained from topsoil stockpiles, will then be compacted and contoured per the grading and drainage design. The entire TMF will be hydro-seeded (native grasses) and trees will be planted.

The existing dam will be benched and graded. One foot of surface cover soil (from overburden stockpiles or reclaimed soil from dam removal) will be placed on the dam surface. This area will also be hydro-seeded with native grasses and trees will be planted. After 5 years, we expect the flow of water from the TMF Leachate Collection and Recovery System will have diminished to approximately 25 gpm (assumption) and ground water will continue to drain from the TMF under-drain system. This flow will continue to be managed by spray evaporation, and water quality of the seepage water will be sampled and analyzed according to the schedule in the water-monitoring program specified by the RWQCB.

Task 10: Rock Storage Area

The Low-Grade Ore Pile north of DP-5 will be benched and graded to establish a maximum slope of 1.75:1, in accordance with Title 27. One foot of topsoil from the overburden topsoil storage area will be placed upon the graded ore pile and compacted. This topsoil will be vegetated with native grasses and planted with trees to minimize surface erosion and encourage evapotranspiration. The existing vegetated cover over the RSA will be improved by additional hydroseeding and tree planting. This will further reduce erosion and sediment transport while increasing the evapotranspiration rate of the cover system. The species of native plants is specified in the mine closure plan. Additional erosion control fabric and lined drainage channels will be installed in selected locations.

Task 11: Crystalline Pits

The conceptual approach for closure and management of the North and South Crystalline Pits is consistent with the 1984 Reclamation Plan and the 1995 Mine Closure Plan for the Jamestown Mine. The approach addresses surface grading (re-contouring), storm water management, maintenance of a native vegetation cover, access control, and annual maintenance and reporting.

Paved drainage channels will provide increased capacity to convey the design storm, and will require less maintenance than unlined ditches, with the lifetime estimated to exceed 30 years. The drainage channels discharge to the detention ponds, which are sampled on a regular basis according to the Stormwater Monitoring Plan. Revegetation of bare spots with native grasses will provide wildlife habitat and better blend in visually with surrounding topography and enhance evapotranspiration.

Task 12: Harvard Pit

The purpose of this task is to define and evaluate potentially appropriate in-situ treatment methods that could be used to reduce the TDS and arsenic levels in the Harvard Pit water. Although TDS and arsenic, are the primary constituents of concern, other constituents will also be removed or reduced by the pit water treatment. The evaluation of alternatives for mass reduction from the pit must be a step-wise process. It is likely the data review and bench scale testing will need to be completed to evaluate the potential for mass removal from the pit lake.

Work Plan

The objective of this subtask is the preparation of a work plan that will guide completion of future subtasks. The work plan preparation will include a review of the 1990 Revised Reclamation Plan and the 1995 Mine Closure Plan. These subtasks include:

- Pit water modeling (geochemical, dynamic systems, and limnology);

  The goals of the data review and modeling are to define the probable sources and sinks of Site constituents (e.g. TDS and arsenic) in the pit water, and to determine the extent to which water in the Harvard Pit will experience seasonal turnover or become permanently stratified.

- Evaluate in-situ treatment options
  Methods used for in situ treatment of surface waters, such as, pit lakes generally employ one or more of these mechanisms to remove the target analyte from solution. Two remedial options are described here for the in situ treatment that could effectively remove arsenic and/or sulfate from the Harvard Pit water column and sequester these constituents in the pit sediments. These options include: Removal of Arsenic by Chemical Coagulation; and In Situ Redox Manipulation for Removal of Arsenic and Sulfate.

  The objective of the coagulation testing is to determine the efficacy of chemical coagulation processes involving the adsorption of dissolved arsenic to iron oxyhydroxides for decreasing arsenic concentrations in the Harvard Pit.

  The objective of the in-situ test is to determine the feasibility of redox manipulation for removing arsenic and sulfate. The efficacy of this option relies on the formation of arsenic sulfides and possibly iron sulfides under reducing conditions and removal of the arsenicsulfur species from the Pit Lake by sedimentation within the pit.

- Implementation of laboratory-scale bench tests to test treatment alternatives.
  There are three main processes that can be used for decreasing the mass of dissolved chemicals (contaminants) from surfacewaters, including: chemical/biological degradation/ transformation, chemical precipitation, and adsorption to solids.
- Defining a treatment verification monitoring program.
- Full-scale implementation of selected treatment alternative.

Summary

The State Water Resource Control Board and the Mine property owners are cooperating to develop a revised closure plan that will result in the successful remodeling of the closed gold mine.

Acknowledgements

Evaluation and preliminary design of the post closure remedial plans for the mine site have been developed by a team of consulting companies retained by the mine property owners and operators. The technical consulting team is cooperating with the Central Valley Regional Water Quality Control Board of the California State Water Quality Control Board of the California State Water Resource Control Board, to negotiate an acceptable revised closure plan.

Literature Cited

California State Water Resources Control Board. 1996. Containment Zone Policy (Final Functional Equivalent Document), Amendment of SWRCB Resolution No. 92-49, Policies and Procedures for Investigation and Cleanup and Abatement of Discharges Under Water Code Section 13304.

De Dycker, P.M. and Associates, Inc. Water, Waste and Land Inc. 1994.   Harvard Pit Water Modeling Summary, Sonora Mining Company.

DNE Knight Piesold. 1995. Mine Site Closure and Post Closure Maintenance Plan. *In:* Volume I of III, Main Report. Sonora Mining Company.

Julihn, C. E. and Horton, F.W. 1939. California, Tuolumne and Mariposa Counties, Mother Lode District (South), Miners of the Southern Mother Lode Region, Part II-Tuolumne and Mariposa Counties. *In:* Mineral Industry Survey of the United States, U.S. Department of the Interior, Bureau of Mines Bulletin 424.

Marshack, Jon B. 2000. A Compilation of Water Quality Goals. RWQCB, Central Valley Region.

Sonora Mining Corp., Envirocon, Inc. 1990. Revised Reclamation Plan, Sonora Mining Corp., Jamestown Mine, for Toulumne County Planning Department.

Sonora Mining Corp., Schmidt, Kenneth, Robertson, Steffen, and Kristen Inc. 1985. Jamestown Mine. Proposed Groundwater Monitoring Plan, for the State of California Regional Water Quality Control Board.