FINAL
PIT LAKE GEOCHEMISTRY REPORT

MOUNT HOPE PROJECT

April 2010

2910/R1

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MAY 18 2010

BUREAU OF MINING
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LIST OF ACRONYMS

ABA	acid-base accounting
ARD	acid rock drainage
CNI	Call and Nicholas, Inc.
DRZ	damaged rock zone
EDCM	Empirical Drainage Chemistry Model
EURN	Eureka AgriMet Station
ft amsl	feet above mean sea level
gpm	gallons per minute
HCT	humidity cell test
HFO	hydrous ferric oxide
JBR	JBR Environmental Consultants, Inc.
kt/yr	kilotons per year
NCDC	National Climatic Data Center
NDEP	Nevada Department of Environmental Protection
NPR	neutralizing potential ratio
PAG	potentially acid generating
PRISM	Parameter-Elevation Regressions on Independent Slopes Model
SI	saturation index
SLERA	Screening Level Ecological Risk Assessment
SRK	SRK Consulting U.S., Inc.
su	standard units
SWS	Schlumberger Water Services
TDS	total dissolved solids
tpd	tons per day
USBR	United States Bureau of Reclamation

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EXECUTIVE SUMMARY

This report provides a description of the Mt. Hope project pit lake geochemical evaluation conducted for Eureka Moly, LLC in support of project permitting. This evaluation included a comprehensive review and update of pit lake model inputs, conceptual model, and model implementation. Expected (base) case and multiple sensitivity cases were developed and run to predict an expected pit lake chemistry and a range of results to evaluate model sensitivities.

An abundance of historical geologic and geochemical information has been developed from exploration (and early small-scale mining) in the Mount Hope molybdenum deposit since the late 1800s. Systematic drilling and sampling since the 1970s has resulted in a comprehensive geologic data set for the ore body. Data indicate a relatively inert ore body with low sulfur and carbonate content; only 16 percent of the ultimate pit wall is predicted to be potentially acid generating, with the remaining 84 percent classified as non-acid generating rock. Recent geochemical testing confirms this, including rinse testing indicating some material types having elevated concentrations of zinc, cadmium, fluoride, and manganese in sample leachates. For this reason, the pit lake is not expected to be significantly affected by sulfide oxidation and acid generating reactions in the pit walls, but rather by rinsing of weathered, non-acid generating rock.

Hydrogeologic data indicate a low-permeability system with low expected groundwater flux rates into the pit. As such, the water balance model for the Mount Hope pit lake (Interflow and Montgomery, 2010) predicts the final pit lake will act as a groundwater and surface water hydraulic sink, or "terminal lake", that is, no discharges from the pit lake are expected to occur either to groundwater or surface water. Groundwater at the site has moderate alkalinity, low metals concentrations, elevated fluoride, and neutral pH.

Given the expected low groundwater inflow of relatively good quality water, combined with a relatively unreactive ore body and host rock, it is expected that the pit lake will develop slowly. The pit lake chemistry will be influenced predominantly by groundwater inflow chemistry, solute release from the pit wall rocks, and evapoconcentration.

The geochemical model described in this document was used to predict pit lake chemistry at time steps ranging from 5 to 200 years after cessation of dewatering, by mixing waters from the various inflow sources, evapoconcentrating the mixture, and then allowing the resulting water to equilibrate with specified mineral and gas species.

Comprehensive and site-specific, hydrologic and geochemical data sets were used to develop inputs for the flow and geochemistry models. The conceptual model and model inputs represent an accurate yet conservative prediction of expected chemistry of the post-closure pit lake. Conservative aspects of the modeling include:

- The method of estimating the exposed areas of potentially acid generating wall rock resulted in greater areas than will likely exist.
- A minimal number of mineral phases (six) were included as solubility controls in the model; this assumption is conservative in terms of some metals concentrations.
- Both fractured pit wall and accumulated material on pit benches was considered in deriving estimates of pit wall porosity and grain size distribution; the effect was a very conservative level of scaling laboratory chemical data for estimating pit wall runoff chemical concentrations.
- Adsorption of trace metals was limited to hydrous ferric oxide surfaces; other mechanisms of co-precipitation and adsorption, which in nature act to limit trace constituent concentrations, have not been included in the modeling.

Uncertainties and natural variability inherent in natural systems were evaluated by a wide range of sensitivity analyses. These included both hydrologic and geochemical parameters.

Model results indicate an alkaline pit lake will develop with a consistently neutral pH, low to moderate alkalinity, and relatively low metals. Concentrations of fluoride, cadmium, manganese and antimony are predicted to be slightly elevated above Nevada reference standards; however, because the lake is predicted to act as a hydraulic sink, these reference standards are only presented for comparative purposes. These model predictions are consistent for all sensitivity analysis simulations indicating a low sensitivity of input parameter variability on the overall model results.

Also, the model-predicted concentrations of manganese and cadmium, in particular, are likely over-estimated as a result of the conservative assumptions listed above regarding adsorption and co-precipitation reactions; specifically, adsorption of these constituents to aluminum oxide, organic matter, calcite and clay minerals will most likely result in reduced concentrations. Lower concentrations would be more consistent with observed concentrations in analogous runoff waters associated with porphyry molybdenum deposits (Climax Mine, CO and Questa Mine, NM).

1 INTRODUCTION

Eureka Moly, LLC (Eureka Moly) is currently developing mine plans to extract molybdenum ore from the Mount Hope deposit near Eureka, Nevada (Figure 1.1) with mining and milling operations anticipated to last about 44 years. The location of the proposed mine facilities are shown in Figure 1.2. During operations, dewatering will keep the pit operational and any collected water will be used within the process circuit. At the end of open pit mining operations, groundwater levels will recover slowly and the combination of surface runoff within the pit catchment and groundwater inflow will eventually form a terminal sink pit lake. This report provides the approach, inputs and results of a pit lake geochemical evaluation conducted by Schlumberger Water Services USA, Inc. (SWS) as part of the planning and baseline characterization for the project for the purposes of predicting post closure water quality that may occur in this pit lake.

1.1 Scope and objective

Preliminary pit lake modeling was conducted by SRK Consulting U.S., Inc. (SRK), and the results of that work were presented in the *Pit Lake Geochemistry Report for the Mount Hope Project* (SRK, 2009), completed by SRK in January 2009. That preliminary work has been reviewed by SWS, and much of the data have been adopted for the current evaluation. Similarly, written sections of this report have relied on the SRK report, and are cited accordingly.

Montgomery and Associates (Montgomery) of Tucson, AZ, was retained by Eureka Moly to develop a local hydrologic model to simulate pit dewatering and pit lake formation after cessation of mining. The local model is linked to a regional hydrologic model, developed by Interflow Hydrology Inc (Interflow), for the purpose of evaluating the effects of pit dewatering during operations on the regional groundwater resources. The results of the hydrologic pit lake filling model are presented in the report, *Hydrogeology and Numerical Flow Modeling, Mt. Hope* Area (Interflow and Montgomery, 2010), prepared by Interflow and Montgomery, and provide the hydrologic framework for the geochemical pit lake modeling presented in this report.

The scope of this current evaluation was to review and update the preliminary geochemical model based on the updated hydrogeological characterization and pit lake water balance. The main objective of this evaluation was to predict the future Mount Hope pit lake water quality. These results were used to evaluate ecological risks and impacts to the environment as described in the *Mount Hope Project Pit Lake Screening-Level Ecological Risk Assessment* (SLERA) (SRK, 2010).

In order to accomplish these objectives, the following tasks were completed by the Eureka Moly project team:

- Development of a hydrologic and geochemical conceptual model (Montgomery, SWS)
- Geological modeling to estimate the geology of final pit walls (Eureka Moly, SRK)
- Laboratory geochemical characterization tests to provide a source term for chemical rinsing from exposed pit wall rock (SRK)
- Baseline water quality analysis of groundwater collected from pumping wells and on-site monitoring wells (Eureka Moly, Montgomery, SRK)
- Hydrogeological assessment of groundwater conditions in the vicinity of the pit, including estimates of pit filling rate, groundwater inflow, pit wall runoff, direct precipitation and evaporation rates from the pit lake over time (Montgomery)
- Development and implementation of a geochemical pit lake model to predict pit lake water quality over time, considering sensitivity of multiple hydrologic and geochemical parameters on model results (SWS)

The scope of this report includes comparison of predicted pit lake water quality results to Nevada water quality reference criteria.

1.2 Overview of pit lake geochemical modeling practices

Prediction of long-term water quality for post-mine pit lakes is necessary for the evaluation of open pits that will collect water. Several approaches have been developed for these predictions in recent years, which rely upon various mass loading, mixing, and reaction methods.

The geochemistry of a pit lake depends on several factors, including:

- the potential for rock exposed in the pit walls to contribute alkalinity, acidity, metals, and other solutes to the pit lake during filling
- groundwater (and/or surface water) chemistry
- local climate, including both precipitation and evaporation
- the bathymetry (or geometry) of the lake as it affects potential for seasonal stratification and mixing
- surface water management
- secondary mineral precipitation or trace element sorption within the lake

There is no single model or method that can be applied to evaluate the complex hydrological and geochemical system of a pit lake, although there is general agreement that the factors described above must be quantified (to the extent possible in a forward-looking model of a proposed facility) and used to predict the evolution of water quality throughout the pit-filling process (Kempton et al., 1996). It is widely accepted that the predictive effort is only as representative as the conceptual model or hypothesis that is tested using the analytical or numerical solution tool or code (Nordstrom, 2004). A description of the conceptual model for the Mount Hope pit lake simulations is provided below. There is also general scientific professional consensus regarding the analytical and numerical modeling approaches used to calculate water balance and chemistry, which rely on well-known hydrologic and geochemical codes such as MODFLOW, PHREEQC, MINTEQA2, and WATEQ.

Methods of estimating the chemistry and flows contributing to the pit lake must account for unique, site-specific geological and hydrological factors and thus vary substantially between sites. These factors include groundwater geochemistry, mineralogy and physical stability of the post-mining pit wall, direct precipitation, surface water inflows, precipitation onto the pit walls, groundwater flux into the mine pit, flushing of the pit walls upon lake inundation, and mineral precipitation, and sorption as a function long-term chemical evolution. The current evaluation relied heavily on site-specific data and characterization.

The extent to which sampling represents the range of mineralization and geochemical variation in the pit walls (Price and Errington, 1995); the use of analytical methods to represent the post-mining environmental conditions (including mineralogy) (Banwart et al., 2004; White et al., 1999; Kwong and Ferguson, 1997; Lapakko, 2003; Price, 1997); and the ability to calibrate laboratory-based predictions to field-scale analogs are all important considerations (Bowell and Parshley, 2005). More importantly, the need to consider uncertainty in the estimates developed for these inputs has been addressed by numerous authors (Neuman and Weirenga, 2003; Castendyk and Webster-Brown, 2007). Concern about inadequate representation of uncertainty is a key issue raised in public review of pit lake chemistry predictions (Maest et al., 2005). All of the aforementioned considerations were taken into account for this study.

As the understanding of post-mine pit lake hydrogeochemistry has grown, so have efforts to quantitatively represent the temporal variation in hydrogeochemical processes while accounting for the inherent variability in estimates used for model inputs. Models that relied on more simplistic and deterministic (single value) estimates of input parameters (groundwater flux rates, groundwater chemistry, etc.) have been abandoned (where data permit) for more comprehensive models that address the range of possible values for key parameters, through sensitivity or stochastic analysis methods. The relative merit of various approaches must be weighed for each site-specific set of factors.

While any geochemical prediction of future water quality is inherently constrained by some uncertainty regarding future conditions (water chemistry, groundwater flow, climate variability, etc.), state of the art modeling practices incorporate an understanding of the magnitude of uncertainty into geochemical models. This is reflected in the current evaluation through the comprehensive sensitivity analyses (Section 5). Uncertainty in future climate variability is reflected in the hydrologic sensitivity analyses evaluating variation in precipitation and evaporation rates.

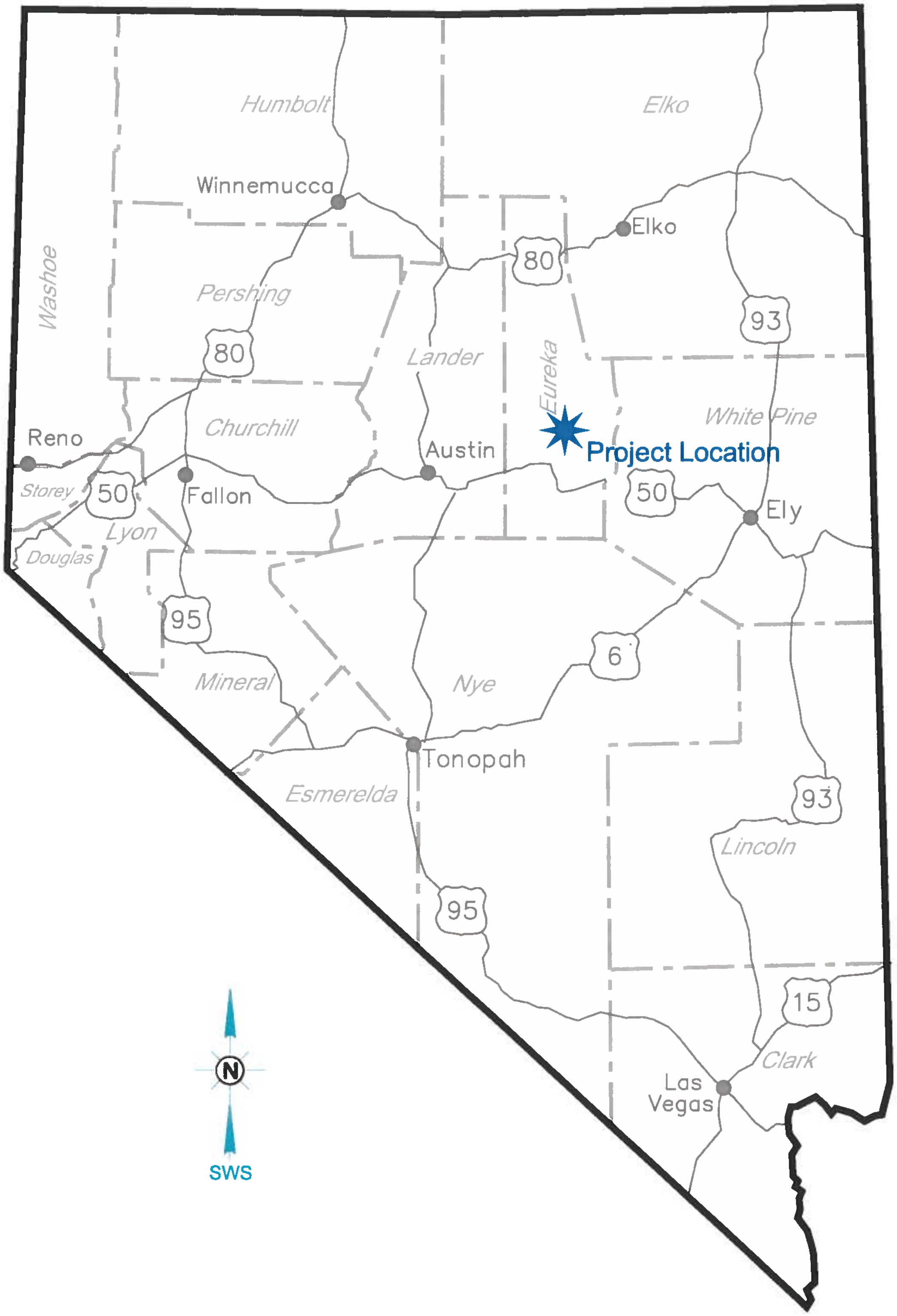
1.3 Mount Hope pit lake conceptual model and modeling approach

The geochemical pit lake model for the Mount Hope open pit was developed to predict the composition of pit lake water through time after pit dewatering is stopped. As the pit lake fills, water from various sources will mix, and water will evaporate from the pit lake surface. A local, and associated regional, groundwater model has been developed to predict the pit filling water balance. The water balance modeling results demonstrate that evaporative loss would be the only outflow from the Mount Hope pit lake, which is predicted to be a terminal lake or "hydraulic sink" (Interflow and Montgomery, 2010). Site-specific and geochemical test data were used to estimate the chemistry of inflowing waters to the pit. Only a small portion of the pit wall rock is considered potentially acid-generating; the pit wall rock runoff chemistry is dominated by rinsing non-acid generating rock types. Geochemical reactions with rock and air result in an evolving pit lake water chemistry. The geochemical model simulates these processes and provides a tool for simulating alternative scenarios that represent the potential variability of the lake chemistry within a reasonable range of hydrologic and geochemical inputs. Multiple scenarios were developed to evaluate the sensitivity of geochemical and hydrologic variability on the predicted pit lake chemistry.

Modeling performed for the Mount Hope pit lake was based on state of the art practices, which included:

- Developing a rigorous, site-specific conceptual hydrogeochemical model as a basis for model development which addresses uncertainty in model inputs.
- Developing geologic interpretation of the mine pit area based upon logging of exploration drill core and surface mapping, and applying this interpretation to the final pit shell.
- Collecting site-specific monitoring data to represent groundwater chemistry.
- Using site-specific kinetic geochemical test data to estimate solute mass release from pit wall rock based on mineralogical and static geochemical characterization.
- A comprehensive evaluation of uncertainty through sensitivity analyses of various key hydrologic and geochemical model parameters.
- Simulation of precipitation of mineral phases that are kinetically and thermodynamically reasonable for the simulated conditions based on both empirical evidence (observations from this and similar deposits) and published literature.

These components are described in Sections 3, 4 and 5.



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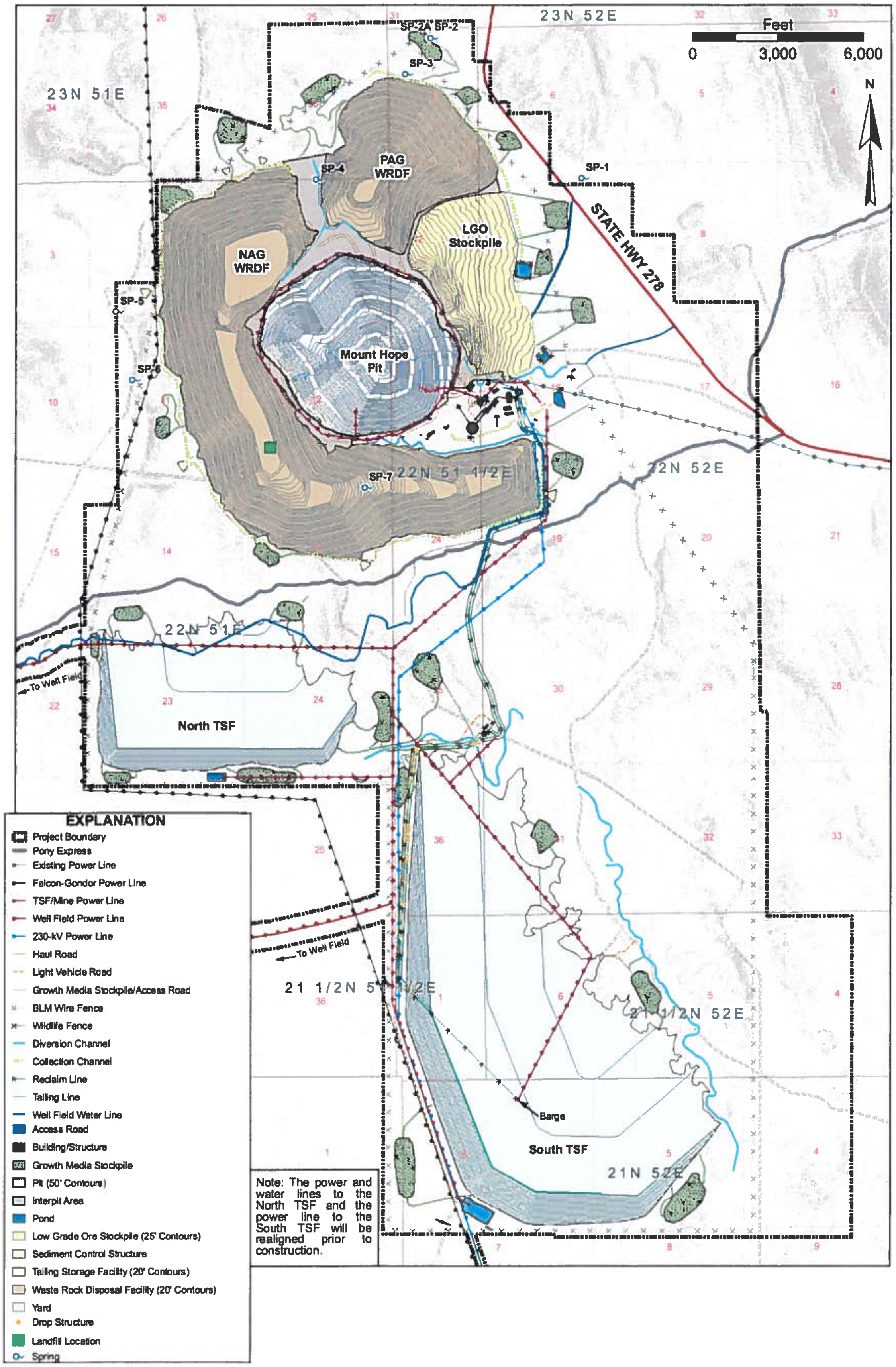
SITE LOCATION MAP

CLIENT:	EUREKA MOLY, LLC	PROJECT:	MOUNT HOPE
JOB:	2910	DRAWN:	RN CHECKED: PR
DATE:	APRIL 2010	FIGURE:	1



Note: The power and water lines to the North TSF and the power line to the South TSF will be realigned prior to construction.

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PROPOSED MINE FACILITIES (FINAL BUILD-OUT)

CLIENT: EUREKA MOLY, LLC		PROJECT: MOUNT HOPE	
JOB: 2910		DRAWN: RN	CHECKED: PR
DATE: APRIL 2010		FIGURE: 1.2	

P:\2910 - MT HOPE 2009\CAD\2910-R-APRIL-2010\FIGURE-1.2.DWG

2 SITE DESCRIPTION

The following report sections relied on the SRK (2009) report, with some modification to account for updates to the project. The geologic/geochemical block model projections to the pit shell were conducted by SRK and are detailed in the SRK (2009) report.

2.1 Location

The Mount Hope Project is located in central Nevada about 23 miles north of the town of Eureka as shown in Figure 1.1. The project site is located in the central Great Basin section of the Basin and Range Physiographic Province, with a maximum elevation of about 8,380 feet above mean sea level (ft amsl). It is adjacent to Diamond Valley to the east, Kobeh Valley to the southwest, and Pine Valley to the north and northeast. The project area, at final buildout is shown in Figure 1.2.

2.2 Mining overview

Eureka Moly currently plans to use open pit hard rock mining methods to deliver molybdenum sulfide ore to a conventional flotation mill. The current mine plan is to deliver 60,625 tons per day (tpd) of ore on average to the plant during years 1 through 32, and simultaneously stockpile lower grade ore. During years 32 to 44 (year 32 is a transition year), the stockpiled ore will be processed at an average rate of 60,625 tpd (22,100 kt/yr). The total material mining rate is planned to average 261,600 tpd (95.5 million tons per year) (Independent Mining Consultants, Inc., 2007).

2.3 Climate

The climate of the area is semi-arid with warm summers and cold winters. Annual normal precipitation as computed by the National Climatic Data Center (NCDC) for the period from 1971 through 2000 is 9.14 inches at the Diamond Valley U.S. Department of Agriculture station, which is at an elevation of about 5,970 ft amsl. At the Eureka station, which has an elevation of about 6,545 ft amsl, the 1971-2000 annual average precipitation is 12.06 inches. The temporal distributions of precipitation are similar at both stations with May being the wettest month and July among the driest. According to the Parameter-elevation Regressions on Independent Slopes Model (PRISM) developed by the Spatial Climate Analysis Service (2006) at Oregon State University, 1971-2000 annual normal precipitation is about 14.94 inches at the center of the Mount Hope open pit (Interflow and Montgomery, 2010).

Two weather stations that measure pan evaporation are located near Mount Hope. During the period from 1948 through 2002, annual pan evaporation averaged about 51.5 inches at the Ruby Lake station, located at an elevation of 6,010 ft amsl about 46 miles to the northeast of the site. At the Beowawe University of Nevada Ranch station, located at an elevation of

5,740 ft amsl, about 22 miles northwest of the site, annual pan evaporation averaged 51.2 inches during the period from 1972 through 2002. Due to freezing conditions, pan evaporation is not measured in the winter months (November through March) at either station. A lake evaporation rate was calculated as part of the hydrological analysis using the average value from these stations and applying a pan coefficient of 0.73 (Interflow and Montgomery, 2010). The water balance results used in the base case scenario used a mean annual evaporation rate of 37.46 inches.

2.4 Surface water hydrology

The Mount Hope pit straddles the divide between Diamond, Kobeh, and Pine Valleys. Much of the mine area immediately surrounding the open pit drains into the Diamond Valley. Kobeh Valley, the largest of the three basins in the area, is an alluvial basin bounded on the east by Whistler Range, on the north by the Roberts Mountains, on the west by the Simpson Park Range, and on the south by the Monitor Range and Mahogany Hills. Pine Valley is located north of the proposed mine and is bounded on the north and west by the northeast trending Cortez Mountains, on the south by the Roberts Mountains, and on the northeast by the Sulphur Springs Range.

Drainage from Mount Hope occurs via ephemeral surface water flows, which sometimes form swales or tributaries that radiate away from the mountain. Virtually all of the surface water flows in the study area are ephemeral; containing water only during storms or intense snowmelt. Garden Pass Creek originates at the topographic divide between Pine Valley and Diamond Valley. The northern and eastern faces of Mount Hope drain into Garden Pass Creek. Tyrone Creek drains the south face of the mountain and joins Garden Pass Creek southeast of the mountain just upstream of where the latter cuts through the Sulphur Spring Range and empties into Diamond Valley. Two ephemeral surface water swales or tributaries drain the western face of Mount Hope and join to become a relatively well-defined tributary that persists a substantial distance to the south into Kobeh Valley. The only connection of Mount Hope to Pine Valley to the north is a small portion of one storage area located in the uplands above the Henderson Creek drainage; however, this area does not connect to Henderson Creek via a defined drainage.

2.5 Geology

The geology of the project area was mapped and described by Westra and Riedell (1996) and the following discussion is based on their observations and interpretations.

The Mount Hope project area is located on the eastern side of Mount Hope near the leading edge of the Roberts Mountains thrust. During the Devonian-Mississippian Antler orogeny, east-vergent thrust faults placed allochthonous siliceous sedimentary (western) assemblage rocks over autochthonous carbonate rocks of the eastern assemblage. The western assemblage in the project area is represented by sedimentary rocks of the Ordovician Vinini Formation that underlies the majority of the project area. The Vinini Formation crops out to the south and west of Mount Hope and consists mainly of shale, siltstone, chert with rare interbeds of quartzite and sandy limestone.

The eastern assemblage carbonate rocks from the Silurian and Devonian are exposed in the Sulphur Springs Range northeast of Mount Hope and have been interpreted as windows through the Roberts Mountains thrust (Roberts et al, 1967). A window to the carbonate eastern assemblage does not occur in the project area, and drilling to depths in excess of 2,000 ft have not encountered the eastern carbonate assemblage.

Following cessation of the Antler orogeny, clastic sediments derived from erosion of the Antler orogenic belt were deposited in a foreland basin east of the highlands. In the project area, this overlap assemblage is represented by the Permian Garden Valley Formation and consists of sandy limestone, sandstone and conglomerate that crop out in the Sulphur Spring Range and on the southeastern edge of Mount Hope. In the latter location, the basal unit of the Permian Garden Valley Formation has been preserved.

The Paleozoic sequence was intruded by the Mount Hope igneous complex during Eocene and Oligocene time (approximately 38 million years ago). This igneous complex consists of andesitic and high-silica rhyolite hypabyssal plugs emplaced within the Mount Hope and Garden Pass areas and as rhyolite ash flows at Mount Hope and in the Henderson Summit area (Westra and Riedell, 1996). Magmatism occurs within an east-northeast trending belt that extends from central Nevada to north central Utah (Stewart et al, 1977; Shawe et al, 1978). A single magnetic high across this area (Mabey, 1996) and similar chemistry and mineralogy of the igneous rocks suggest that they share a common magmatic source (Westra and Riedell, 1996).

The initial phase of igneous activity in the area is marked by intrusion of an early quartz porphyry phase as evidenced only by autoliths. Following this initial event, ash-flow eruptions formed the variably welded Mount Hope Tuff that comprises the northwest portion of the volcanic complex. The tuffs are distinguished from the other volcanic units with an abundance of broken quartz and feldspar grains, shards and pumice and sparse lithic fragments. Following the ash-flow eruption, rhyolite vent breccias form steeply dipping ring-dikes that were emplaced in the caldera fracture zone (Riedell, 1996). Similar to the tuffs, the rhyolite vent breccia contains abundant broken quartz and feldspar grains, but is distinguished from the tuff by an absence of shards and pumice and an increase in size and abundance of lithic fragments.

The core of the Mount Hope complex consists of nonfragmental rhyolite quartz porphyries which intrude both the Mount Hope tuff and rhyolite vent breccia. These porphyries contain subhedral to euhedral quartz, K-feldspar and plagioclase phenocrysts with an aphanitic groundmass that becomes coarser with depth. Along the margins of the complex, the porphyry occurs as a chilled border phase with prolific xenoliths of Vinini Hornfels. The main phase of the quartz porphyry is exposed in the west central portion of the complex and as numerous dikes cutting the Vinini Formation. Subsequent porphyry phases include an aplitic quartz porphyry with a distinctively sugary groundmass; a very coarse grained quartz porphyry and granite porphyry with phenocrysts greater than 3 millimeters in size; and minor dikes of fine-grained granite or aplite (Riedell, 1996).

2.5.1 Mineralization and alteration

Hydrothermal alteration and mineralization in the Mount Hope area is related to the intrusion of the Mount Hope igneous complex, the effects of which are widespread throughout the area and extend into the adjacent sedimentary wall rocks. Igneous and sedimentary rocks in the region are host to a porphyry molybdenum deposit that exhibits distinctive zoned alteration and mineralization patterns. Alteration zones are well developed within the deposit and can be correlated between the various host lithologies. Riedell and Westra (1996) classified the effects of alteration based on secondary mineral assemblages, regardless of host, into the following categories (arranged from periphery to core of the hydrothermal system): weak argillic-propylitic, argillic, potassic-phyllic, potassic, high silica, and biotite.

Argillic alteration is widespread and well developed in the Mount Hope Tuff and rhyolite vent breccia in the eastern half of the complex. Clays and carbonates replace plagioclase and form distinctive orbicular aggregates associated with sulfide mineralization. Argillically altered Vinini Formation is a gray to brown biotite-sericite hornfels. Within the argillic zone, lead, zinc, silver and manganese values are anomalously high and occur in distinct haloes. High grade zinc-rich mineralization occurs where this zone intersects carbonates of the Garden Valley Formation. Hydrothermal fluids recrystallized the carbonate and produced isolated lenses of retrograde altered garnet-pyroxene skarn.

Molybdenum mineralization, in the typical grade range of 0.04-0.08 percent molybdenum by weight, occurs within the potassic-phyllic and potassic zones and within a thin zone near the top of the biotite alteration zone. However, ore grade molybdenum mineralization is generally associated with the potassic zone. Mineralization occurs in a stockwork of quartz-molybdenite+K-feldspar+fluorite veins with lesser "blue quartz" veins (thermally or structurally shocked quartz) and molybdenite "paint" (fine grained sulfide grains) on late fractures. Disseminated molybdenum is rare. The geometry of the molybdenum mineralization suggests two stacked molybdenum shells lying side by side where the highest molybdenum grades are encountered in a zone of spatial overlap between the two hydrothermal systems (Westra and Riedell, 1996).

The main alteration types for the Mount Hope Project include:

1. Argillic – Ar: replacement of primary silicates by clay minerals, most varied of the alteration types
2. Phyllic – Ph: an assemblage of quartz, sericite and pyrite ± calcite
3. Potassic – Po: dominance of potassium feldspar, biotite and co-existing sulfides
4. Biotite – Bo: similar to potassic alteration with a greater abundance of biotite, only associated with the Tqpa rock type
5. Silicic – Si: heavily silicified rock, occasionally complete replacement by silica
6. Hornfels – Hnfls: contact metamorphism of fine-grained siliceous sedimentary rocks of the Vinini Formation.

Two other alteration types that occur at the site, but are not captured in the current mine model include; skarn (contact metamorphism of eastern assemblage carbonate rocks) and propylitic alteration (an assemblage of carbonate, epidote, chlorite and sulfide associated with weakly argillized zones). Further geochemical information concerning these geologic types can be found in *Mount Hope Project Waste Rock and Pit Wall Rock Characterization Report* (Waste Rock Characterization Report) (SRK, 2008).

2.5.2 Local petrology

In this report, the term lithology type refers to the basic lithological description of the rock and alteration type refers to the type of mineral assemblage that has been formed as a result of hot saline water (that formed the ore mineralization) contacting a pre-existing lithological rock and modifying the mineralogy and geochemistry of that rock by hydrothermal alteration. The term "geologic type" connotes a unique combination of lithology type and alteration type.

Although the geology of the region is complex, the lithologies controlling the evolution of the pit lake geochemistry are dependant only on the lithology types in the vicinity of the proposed open pit. These lithologies have been categorized into four groups for the purposes of modeling:

- Vinini Formation (including Hornfels)
- Early-phase Quartz Porphyry
- Intermediate-phase Quartz Aplite Porphyry
- Rhyolite (including tuffs and plug breccias)

2.5.3 *Final pit geologic/geochemical block model*

The final, exposed open pit shell was discretized based on both geologic and geochemical projections of the block model, as shown in Figures 2.1 and 2.2, respectively. The geologic model, as described below, was constructed using geologic interpretation from exploration boreholes. A geochemical "block model" was prepared based on laboratory test data of historical assay pulps, as described further below. The purpose of the discretization was to provide an estimate of the areas of the material types which will be exposed on the open pit walls at the end of mining. This information is used for geochemical pit lake modeling, as described in Section 3.3.2. A description of this process is summarized below.

Geologic modeling

A three-dimensional geological model was created for the pit walls using Mintec's MineSight® mining software (Independent Mining Consultants, Inc., 2007). The model is based on mineral exploration holes drilled by Exxon. Data from these drill holes were used by Call and Nicholas Incorporated (CNI) to generate a series of geological shapes that define the lithology type and alteration of the deposit. The set of shapes developed to describe lithology are laterally and vertically extensive. However, the set of shapes developed to describe alteration are confined to the pit dimensions defined by the Exxon exploration program. The "Exxon pit" is smaller than the pit that is currently being proposed by Eureka Moly. Consequently, the alteration type was extrapolated from the drillhole data to the edge of the final pit wall; details are provided in Appendix A of SRK (2009). The projections of lithology and alteration types which will be exposed in the final pit shell are presented in Figure 2.1. A total of 17 geologic (lithology-alteration) types were identified in the final pit shell.

Geochemical modeling

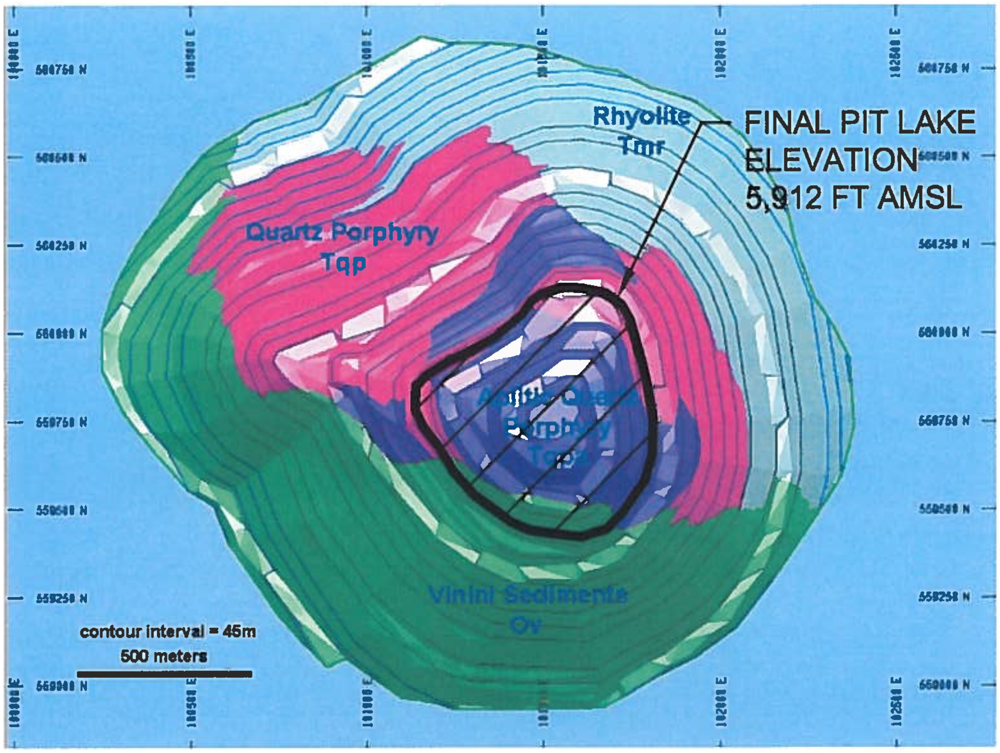
As described in the *Waste Rock Characterization Report* (SRK, 2008), acid base accounting (ABA) results including total sulfur and total carbon for almost 3,000 historical assay pulps were entered into the Mine Site® software to produce an ABA block model for the deposit. ABA characteristics of waste rock and pit wall rock (i.e., neutralizing potential ratio [NPR] and total sulfur values) were used to generate a three-dimensional shape that defines the distribution of potential acid generating (PAG) material throughout the deposit. However, because this PAG shape is based on data from historical assay pulps from the Exxon drill holes, approximately 30 percent of the pit material is undefined with respect to acid generating potential. Consequently, the PAG shape was extrapolated to the edge of the final proposed pit shell. During extrapolation, if the outermost drill location was defined as PAG, then the three-dimensional shape defining the PAG material was unconstrained and was extended from this location to the final pit wall. This approach results in a very conservative estimate of PAG material that will be exposed in the final pit walls, especially those areas to the south that may be unaltered. The projected PAG material on the final pit walls is depicted in Figure 2.2; details are provided in Appendix A of SRK (2009).

The geologic-geochemical material types were defined by overlaying the "PAG" shape (Figure 2.2) over the geologic (lithology and alteration) shapes (Figure 2.1). The result was that nine of the 17 geologic types were further subdivided into PAG and non-PAG geochemical types. Therefore, a total of 26 geologic-geochemical types will be exposed in the final pit shell. The combination of geologic- and geochemical-type will be referred to in this document as "material type". The percentage of exposed surface area for each material type is summarized in Table 2.1. (If the material is not designated as PAG, it is non-PAG material.) These data (Table 2.1) represent the surface area of the entire pit shell from the pit bottom (4,700 ft amsl) to the pit rim (6,800 ft amsl (lowest point) to 8,150 ft amsl (highest point)), in plan-view (2-dimensional projection). These areas are appropriate for evaluating contact with incident precipitation to the pit walls. The total, plan view surface area of the exposed pit shell is 728 acres, of which 118 acres (16 percent) are conservatively estimated to consist of PAG material (SRK, 2009). The actual or 3-dimensional areas were also calculated to evaluate contact of pit walls with the rising lake water; the total, actual surface area is 1,074 acres. Both 2-D (plan view) and 3-D (actual) exposed areas of each material type were calculated at incremental, discrete pit elevations for the purpose of geochemical modeling. These results are provided in Appendix A.

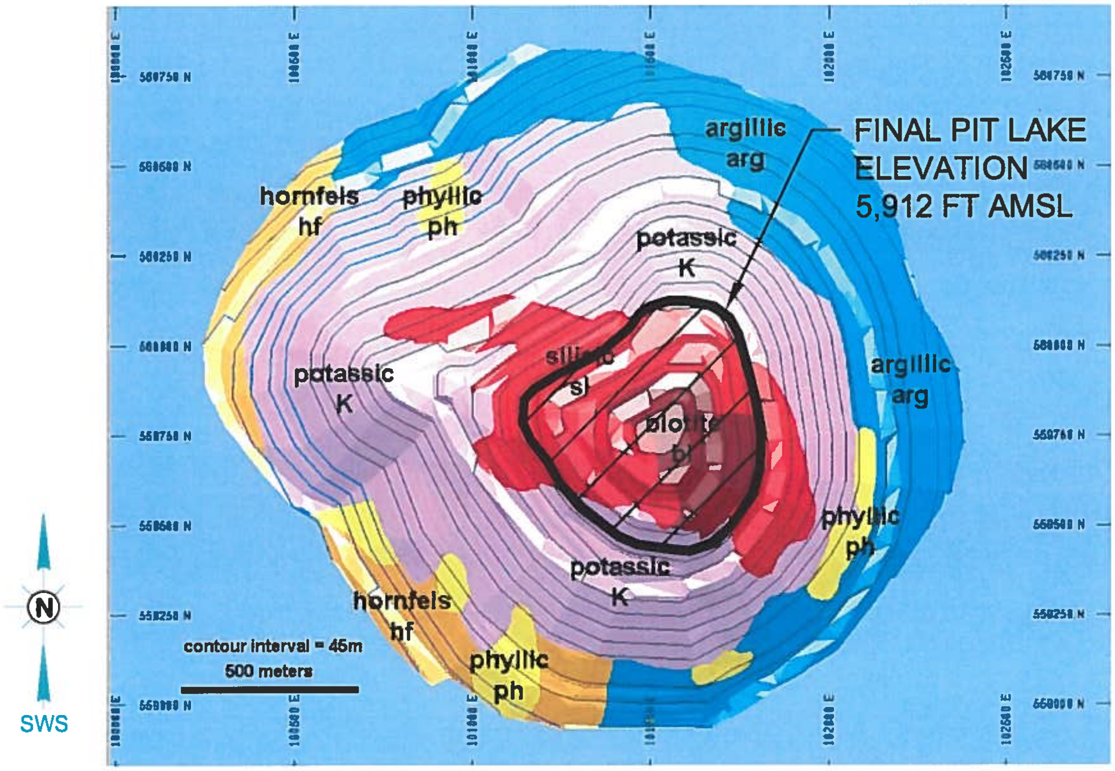
Table 2.1 Final pit wall material type percentages

Lithology Type	Material Type	Total Pit Surface Area (acres)	Percent Pit Wall Exposure
Early Phase Quartz Porphyry	Silica Quartz Porphyry	38	5.2%
	Potassic Quartz Porphyry	129	18%
	Potassic Quartz Porphyry (PAG)	5.3	0.73%
	Phyllic Quartz Porphyry	4.9	0.67%
	Phyllic Quartz Porphyry (PAG)	0.50	0.069%
	Argillic Quartz Porphyry	0.86	0.12%
	Biotite Quartz Porphyry	0.060	0.0082%
Intermediate Phase Quartz Aplite Porphyry	Silica Quartz Aplite Porphyry	55	7.5%
	Potassic Quartz Aplite Porphyry	18	2.5%
	Biotite Quartz Aplite Porphyry	26	3.5%
Rhyolite	Potassic Rhyolite	29	3.9%
	Potassic Rhyolite (PAG)	4.3	0.59%
	Phyllic Rhyolite	3.4	0.46%
	Argillic Rhyolite	69	9.5%
	Argillic Rhyolite (PAG)	69	9.4%
Vinini	Silica Vinini	6.4	0.87%
	Potassic Vinini	146	20%
	Potassic Vinini (PAG)	4.3	0.59%
	Phyllic Vinini	23	3.1%
	Phyllic Vinini (PAG)	3.1	0.43%
	Argillic Vinini	34	4.7%
	Argillic Vinini (PAG)	13	1.8%
	Biotite Vinini	0.79	0.11%
	Biotite Vinini (PAG)	0.20	0.027%
	Hornfels Vinini	28	3.8%
	Hornfels Vinini (PAG)	19	2.6%
Total		**728**	**100%**

Final Pit Wall Lithologies



Final Pit Alteration Assemblages



▨ PIT LAKE

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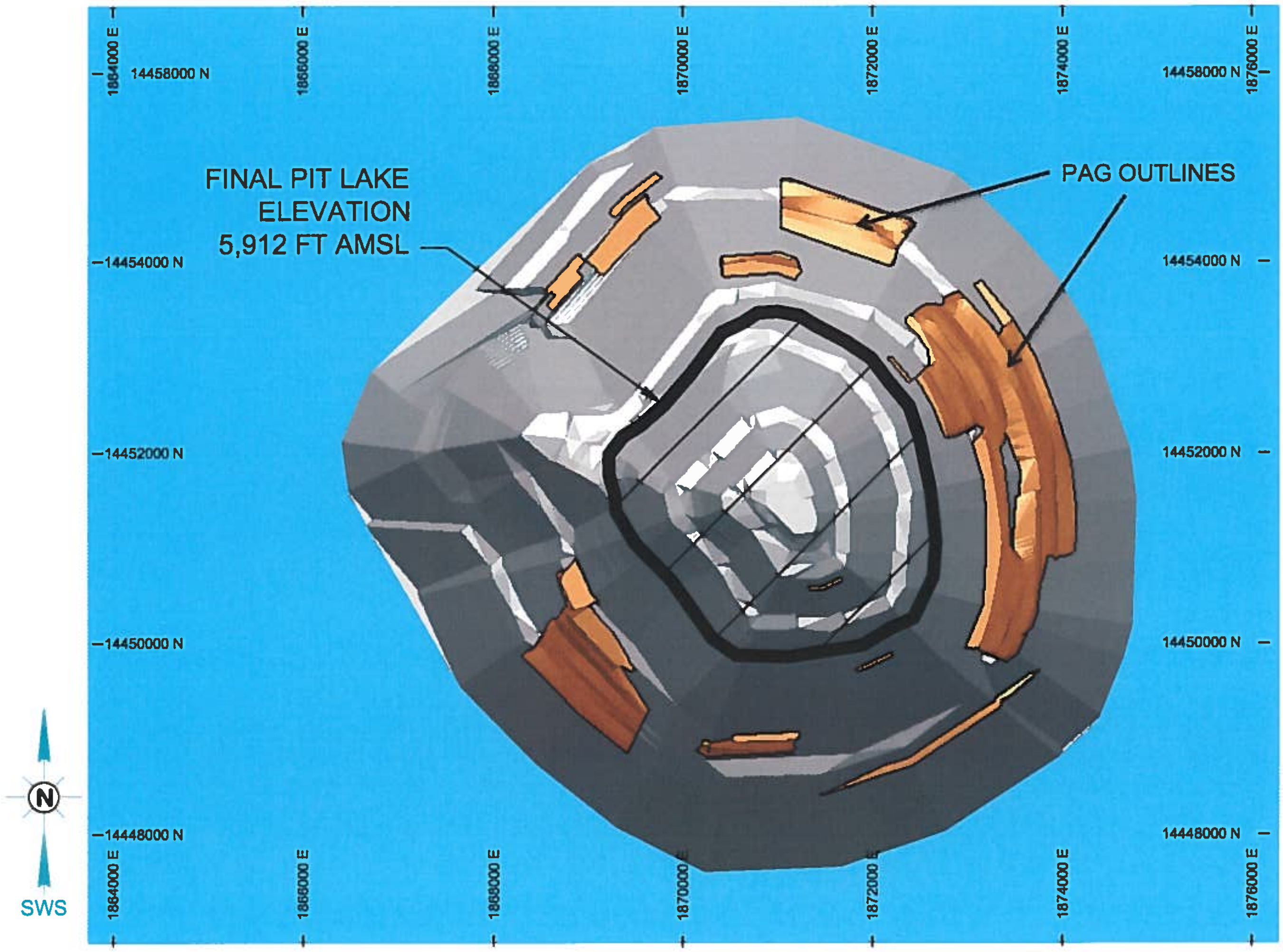
WATER SERVICES

GEOLOGIC MATERIAL TYPES EXPOSED IN THE FINAL PIT SHELL			
CLIENT:	EUREKA MOLY, LLC	PROJECT:	MOUNT HOPE
JOB:	2910	DRAWN:	RN CHECKED: PR
DATE:	APRIL 2010	FIGURE:	2.1

P:\2910 - MT HOPE 2009\CAD\2910-R-APRIL-2010\FIGURE-2.1.DWG



▨ PIT LAKE

🟨 PAG MATERIAL (PROJECTED) ON PIT WALLS

PAG: POTENTIALLY-ACID GENERATING (SRK, 2009a)

P:\2910 - MT HOPE 2009\CAD\2910-R-APRIL-2010\FIGURE-2.2.DWG

Schlumberger
WATER SERVICES

PAG MATERIAL (PROJECTED) IN THE FINAL PIT SHELL

CLIENT: EUREKA MOLY, LLC		PROJECT: MOUNT HOPE	
JOB: 2910		DRAWN: RN	CHECKED: PR
DATE: APRIL 2010		FIGURE: 2.2	

3 MODEL APPROACH AND COMPONENTS

The conceptual model developed for the Mount Hope pit lake geochemical predictions takes into account unique and site-specific geological, geochemical, and hydrologic factors. The approach and components used to estimate the relative flow volumes and chemistry of pit inflows/outflows are described in this section. The geochemical pit lake modeling, which incorporates these components, is detailed in Section 4. Sections 3 and 4 describe the "base case", or most-likely modeling scenario. Sensitivity analyses on the base case condition have been conducted, and are described in Section 5. Modeling results are presented in Section 6.

3.1 Conceptual model

Figure 3.1 depicts the various hydrologic and geochemical processes considered in the modeling approach. As the pit fills, water and solutes from various sources mix in the pit lake and pure water is evaporated from the pit lake surface. A local-scale groundwater flow model was developed for the Mount Hope pit area (Interflow and Montgomery, 2010). This model was used to prepare a post-closure, pit filling water balance. The results serve as the basis for volumetric mixing calculations in the geochemical model. Inflowing waters included in the Mount Hope pit lake simulations include direct precipitation onto the pit lake surface, pit wall runoff, and groundwater inflow. The capture zone for pit wall runoff was defined in the hydrologic model as the upper pit shell. Precipitation captured outside and above this zone will be diverted away from the pit lake, and is therefore not included in the model. The only outflow from the pit lake is evaporation from the pit lake surface.

The modeling approach for this analysis conceptualized the pit lake as a completely mixed reactor that results in seasonal mixing of inflowing waters with specific chemical compositions. Observations from other pit lakes in Nevada (e.g., Mag, Sleeper, Fortitude, McCoy Cove, and Big Springs) indicate seasonal turnover due to the wind-driven turbulence and seasonal changes in temperature (pers. comm., Beale, 2008).

Site-specific geochemical test data and measured water quality data were used to estimate the chemistry of inflowing waters to the pit. In addition to the inflows described in association with the water balance, the geochemical model considers addition of solute introduced during pit wall submergence (i.e., flushing of solutes from the pit wall as the lake rises and lake water inundates the damaged rock zone (DRZ) of the wall). Geochemical reactions within the lake and with the atmosphere result in an evolving pit lake water chemistry.

3.2 Pit lake water balance

Montgomery & Associates developed a local-scale groundwater flow model for the Mount Hope pit area. The model was constructed to evaluate potential impacts of pit dewatering on regional groundwater levels and post-closure pit-lake formation. Details regarding model construction, calibration, and modeling results are presented in Interflow and Montgomery (2010). The model was also used to evaluate the post-closure water balance for the pit lake, including the relative rates of inflows/outflows from the pit. The water balance considered the following flow components on an annual basis:

- direct precipitation onto the pit lake
- pit wall runoff
- groundwater inflow to the pit
- lake evaporation

Seven time steps during the pit filling period were selected to represent points in time during filling and at near-equilibrium. These time steps were used for geochemical modeling and are presented in Table 3.1, and on Figure 3.2.

A summary of the base case results is provided in Appendix B. The pit water balance was used to predict a pit lake filling curve (Figure 3.2), with annual pit lake elevations for 1,580 years after pit dewatering stops. The water balance indicates that the maximum water level in the pit lake will be 5,912 ft amsl, or 1,212 ft deep (the base of the pit is at approximately 4,700 ft amsl); and pit lake elevation equilibrium will be reached in approximately 1,000 years. The pit lake will be approximately 82 percent filled (by depth) in 200 years.

Because the final equilibrium pit lake water level elevation is estimated to be below the surrounding groundwater potentiometric surface, the pit lake is considered to act as a "terminal lake" or "hydraulic sink", i.e., the groundwater gradient will be towards the pit throughout filling and under long-term equilibrium conditions. Similarly, the final pit lake elevation will reach equilibrium well below the physical elevation of the pit rim (6,800 ft amsl); therefore, no potential overflow of surface water from the pit lake is predicted to occur into the surrounding drainages.

Table 3.1 Geochemical modeling time step summary

Timestep	Time (years)	Pit Lake elevation* (ft amsl)	Pit lake depth* (ft)	Pit lake volume* (ft^3)	Percent pit lake filled by depth* (%)	Percent pit lake filled by volume* (%)
1	5	4,935	235	1.47E+08	19%	3%
2	10	5,029	329	2.78E+08	27%	6%
3	20	5,149	449	5.13E+08	37%	11%
4	50	5,349	649	1.10E+09	54%	24%
5	100	5,524	824	1.84E+09	68%	41%
6	150	5,627	927	2.38E+09	77%	53%
7	200	5,697	997	2.80E+09	82%	62%

** predicted values (base case model)*

For each time step in the model (5, 10, 20, 50, 100, 150, and 200 years), the water volumes for the various inflow/outflow components (shown in the bullet list above) are derived from the hydrologic water balance. These volumes and mixing percentages are presented in Table 3.2. As shown in the table, the annual lake volume at the end of each time step is carried forward into the subsequent time step for mixing. Therefore, total inflows to the model include:

(1) existing pit lake (from the previous time step), (2) direct precipitation; (3) pit wall runoff; and (4) groundwater inflow. The only outflow from the model is lake evaporation.

Table 3.2 Time step summaries of water balance flow volumes and percentages

Time Period (years)	Units	INFLOW VOLUME					OUTFLOWS
		Lake Volume*	Direct Precipitation	Pit Wall Runoff	Groundwater Inflow	Total Inflows	Lake Evaporation
0–5	ft^3	0.00E+00	4.77E+06	6.03E+07	9.36E+07	1.59E+08	-1.20E+07
	%	0%	3%	38%	59%	100%	
5–10	ft^3	1.47E+08	8.79E+06	5.91E+07	8.53E+07	3.00E+08	-2.21E+07
	%	49%	3%	20%	28%	100%	
10–20	ft^3	2.78E+08	2.48E+07	1.16E+08	1.57E+08	5.75E+08	-6.21E+07
	%	48%	4%	20%	27%	100%	
20–50	ft^3	5.13E+08	1.12E+08	3.37E+08	4.19E+08	1.38E+09	-2.81E+08
	%	37%	8%	24%	30%	100%	
50–100	ft^3	1.10E+09	2.67E+08	5.37E+08	6.01E+08	2.50E+09	-6.69E+08
	%	44%	11%	21%	24%	100%	
100–150	ft^3	1.84E+09	3.32E+08	5.18E+08	5.31E+08	3.22E+09	-8.32E+08
	%	57%	10%	16%	17%	100%	
150–200	ft^3	2.38E+09	3.78E+08	5.04E+08	4.86E+08	3.75E+09	-9.48E+08
	%	64%	10%	13%	13%	100%	

*Note: * For each annual time step the water balance predicts a lake volume. This lake volume forms the antecedent conditions for the subsequent time step. In this subsequent time step, the lake volume is considered as a volumetric percentage of the total (including all other flow components). The process is repeated for each time step.*

The rates and relative proportions of inflows to the pit are dependent on the water level in the pit. During the initial phase of filling (0 to 5 years), the bulk of the water will come from groundwater inflow (almost 60 percent) and from pit wall runoff (approximately 38 percent); the relative percentages of these components will vary as filling proceeds. During the early filling period, up to approximately 50 years, the chemistry of the lake is predominately influenced by these inflows (Figure 3.2).

As the lake elevation increases, the rate of pit wall water runoff and groundwater inflow into the pit will slow as the lake approaches hydrologic equilibrium. During later periods of filling and equilibrium, the pit lake water quality will be most significantly affected by evapoconcentration, which becomes increasingly significant as the pit lake grows in surface area and other inflows decrease. The chemistry then becomes more influenced by evaporative concentration of constituents present in the lake. After 50 years, evaporation from the pit lake is the largest single component of the water balance (other than the existing pit lake water), and therefore the effect of evaporative concentration has been evaluated over the period from 50 to 200 years (Figure 3.2). The geochemical modeling predictions were conducted to 200 years post-closure; this model time period was agreed upon by BLM and Eureka Moly.

3.3 Water balance components chemistry

Each of the water balance inflow/outflow components was assigned a representative water chemistry. The following components were considered, and described in detail in this section:

- direct precipitation
- pit wall runoff and submergence
- groundwater inflow
- lake evaporation

3.3.1 Direct precipitation to the lake

Rain and snow will fall directly on the pit lake surface. The chemical composition of direct precipitation to the pit lake was estimated using the PHREEQC code by equilibrating pure water with atmospheric gasses (oxygen and carbon dioxide) at a temperature of 10°C. The estimated precipitation chemistry is presented in Table 3.3.

Table 3.3 Direct precipitation chemistry

Analyte	Units	Modeled Direct Precipitation
pH	su	5.6
pe	V	4
Temperature	°C	10

pe: oxidation-reduction potential

Due to the small contribution to the overall pit lake water balance, the chemical composition of the direct precipitation component is expected to have a small effect on the overall water quality of the pit lake.

3.3.2 Pit wall runoff/submergence

The pit walls exposed in the proposed Mt Hope pit comprise 26 material types. The bottom of the pit is dominated by aplite quartz porphyry (14 percent of the total exposed pit wall surface area); quartz porphyry (24 percent) is exposed in the middle to northwest portions of the lower pit walls; Vinini Formation (38 percent) is exposed in the south to west, middle to upper pit walls; and rhyolite tuff (24 percent) is exposed around the north and east, upper pit walls. The bottom of the pit exposes silicic/biotite altered rocks (18 percent); a large portion of the middle benches consist of potassic-altered rock (46 percent); hornfels (6 percent) is exposed in the upper southwest to northwest Vinini Formation; small, discrete areas of phyllic alteration (5 percent) are in the mid-upper walls; and argillically-altered material (25 percent), mainly rhyolite tuff, is exposed in the upper pit rim from the northwest around to the east and southern portions of the pit wall. Based on the geochemical block model analysis, a total of 16 percent of the final exposed pit walls are predicted to consist of PAG material. The majority of this material (9 percent) is within the argillic rhyolite tuff, in the upper portion of the north and east pit walls.

Solutes will be rinsed and flushed from the pit wall to the lake through time. These solutes are generated from the in-situ weathering of the minerals comprising each material type exposed in the pit wall. This process is implemented in the model in two ways: 1) pit wall runoff; and, 2) pit wall submergence.

Pit wall submergence represents the flushing of the fractured pit wall (and raveled material that accumulates on benches) during inundation by the pit lake. This input contributes additional solute mass to the pit lake but no additional water, and therefore is not included in the water balance. The volume of pit wall rock contributing solute through the "submergence" term is calculated outside the water balance as the actual pit wall surface area submerged between timesteps, multiplied by the estimated thickness of the DRZ (1.8 meters), multiplied by an estimated fracture density of 10 percent (damaged rock zone parameters are estimated based on studies conducted by Siskind and Fumanti [1974]). This calculated volume of submerged rock mass is considered one "pore volume" of submerged rock, as follows:

$$\text{Pore Volume} = \text{Surface Area}_{(\text{pit wall})} \times \text{DRZ thickness} \times \text{fracture density}$$

Based on experience with other pit lakes in dry climates, the Mount Hope base case modeling scenario allows for 10 pore volumes of flushing from the submerged zone to account for accumulation of solute from the DRZ. The amount of accumulation is site specific and depends on climate, reactivity of pit wall minerals, and time; sensitivity analyses were conducted on this term to account for site-specific variability. Also, it is assumed in the model that after the initial inundation and flushing of pit wall rock, further accumulation of mineral salts due to atmospheric weathering of pit wall material below the lake level does not occur. Mass loading to the lake from the pit wall is simulated to occur only once in the model upon initial submergence, in the time step that that portion of pit wall is inundated.

During the period of dewatering, the pit walls will be exposed to air and will weather to form secondary minerals, including soluble salts. As the pit wall rinses (pit wall runoff) and is flushed (pit wall submergence), soluble salts and other weathering products will dissolve into these source waters. The pit wall runoff and submergence chemistries are based on geochemical kinetic test results designed to estimate the chemistry of waters in contact with site materials that have weathered over time in the natural environment. Thirty-one humidity cell tests (HCTs) of site materials were completed and used for this purpose. Detailed descriptions and results of the HCT tests are provided in the *Mount Hope Project Waste Rock and Pit Wall Rock Characterization Report* (SRK, 2008). The material types, and their corresponding HCTs, are summarized in Table 3.4. HCT leachate chemistry, averaged throughout the duration of the testing cycles, was used for modeling and the data are presented in Appendix C. If constituents were not detected at the method detection limits, values were set to zero in the model so that unrealistic concentrations of these constituents were not predicted as an artifact of the long periods of evapoconcentration.

Various methods exist for correlating weathering/oxidation time in an HCT test (in weeks) to actual weathering rates in the field (on the order of several to 100s of years). The relationship is dependent on site-specific variables including, but not limited to, climate, pit geometry, wall rock mineralogy, wall rock density, porosity, etc. Phase I Mount Hope HCTs were run for 57 to 70 cycles (weeks), and Phase II HCT data through 67 weeks were available (SRK, 2008). Weekly HCT data were averaged (arithmetic) over the entire testing cycles, and were used to estimate runoff and flushing chemistry for the base case scenario. This approach accounts for the higher concentrations associated with first flush (early time), as well as the potential of high concentrations in the late time for some acid-generating material types. The early and late time HCT results are were used to perform sensitivity analyses. If values for a parameter were not detected at the method detection limit (non-detects), those values were set to one-half the method detection limit for averaging; however, if all values for a single parameter were below detection, then the average value was set to zero for modeling purposes.

Table 3.4 Material types and representative HCTs

Exposed material types in final pit shell		Representative HCT tests
Quartz Porphyry	Silica Quartz Porphyry	26
	Potassic Quartz Porphyry	30
	Potassic Quartz Porphyry (PAG)	7, 29
	Phyllic Quartz Porphyry	16
	Phyllic Quartz Porphyry (PAG)	14
	Argillic Quartz Porphyry	2, 17
	Biotite Quartz Porphyry	30
Quartz Aplite Porphry	Silica Quartz Aplite Porphyry	13, 22
	Potassic Quartz Aplite Porphyry	23
	Biotite Quartz Aplite Porphyry	23
Rhyolite	Potassic Rhyolite	25
	Potassic Rhyolite (PAG)	28
	Phyllic Rhyolite	25
	Argillic Rhyolite	1, 8
	Argillic Rhyolite (PAG)	3, 4, 27
Vinini	Silica Vinini	12
	Potassic Vinini	5
	Potassic Vinini (PAG)	6
	Phyllic Vinini	19
	Phyllic Vinini (PAG)	24
	Argillic Vinini	18, 9
	Argillic Vinini (PAG)	31
	Biotite Vinini	5
	Biotite Vinini (PAG)	6
	Hornfels Vinini	19
	Hornfels Vinini (PAG)	24

The chemistry of the pit wall runoff and submergence contributions to the evolving pit lake will vary over time due to the changing composition of the exposed pit wall surface as the pit is progressively inundated. As the lake rises, the exposed/submerged wall rock material types will vary according to their distribution in the pit wall relative to the pit lake elevation. As described more fully in Section 2.5.3, the Mount Hope final pit wall was divided into 26 material types, and their relative abundances (areas of exposure) at discrete elevation steps were calculated according to the final pit wall geology map (Appendix A). Pit wall runoff chemistry was weighted as a function of exposed, plan-view surface areas above the pit lake elevation; and pit wall submergence chemistry is a function of actual or 3-D exposed areas below the pit lake elevation. The solutions defined from the geochemical tests for each of the wall rock material types were mixed in their appropriate proportions (based on pit wall exposure) to yield final solution chemistries representative of the total pit wall runoff and submergence term, respectively, at each selected time step. The resultant chemistry of runoff/submergence water reporting to the pit is then calculated as the weighted sum of each water type associated with each exposed material type. Material types with a greater exposure therefore have a greater influence on the net pit wall leachate chemistry.

The runoff and submergence chemistries were then adjusted to account for the differences in both (1) the rock to water ratios and (2) the grain sizes of the humidity cell tests (laboratory-scale) versus the pit wall rock (field-scale). A complete discussion of scaling calculations is provided in Section 3.4.

3.3.3 Groundwater

At closure, after pit dewatering activities have ended, groundwater will flow naturally back into the open pit. During the initial 5 years of filling, groundwater inflow is expected to account for approximately 60 percent of the total flow to the open pit. In subsequent years, groundwater makes up a smaller component (13 to 30 percent) of the water balance.

To account for spatial variation in groundwater chemistries, the groundwater inflow component to the pit lake model was subdivided into four quadrants:

1. Northwest quadrant, represented by water quality from pumping well PDT-2 (7/20/2009)
2. Northeast quadrant, represented by water quality from pumping well PDT-3 (7/2/2009)
3. Southwest quadrant, represented by water quality from pumping well PDT-1 (6/2/2009)
4. Southeast quadrant, represented by water quality from piezometer 231P (2/26/2008).

These well locations and the approximate quadrant "boundaries" are shown on Figure 3.3. Quantity of flow from each quadrant was determined using the MODFLOW Hydrogeologic Unit Flow package with the predictive pit lake model (Interflow and Montgomery, 2010).

The PDT- series wells were installed in 2008/2009 for hydrologic testing and sampling. Details regarding well construction, well testing, and sampling are included in the Interflow and Montgomery (2010) report. The final water quality samples, collected during the pumping tests from each PDT well, were used for the geochemical model, representing stabilized water quality, drawing from the largest capture zone. Water samples from pumping well PDT-4, located in the southeast quadrant, were not used to represent post-dewatering groundwater inflow chemistry. PDT-4 was drilled into historical mine (zinc) adits and water quality samples from this well are representative of mine adit water. These adits will be mostly mined out by the open pit and the final pit lake elevation will be below the elevation of these workings. Therefore, PDT-4 water quality is not representative of groundwater which will recover to the pit during the post-dewatering closure period. Piezometer 231P was selected as a replacement water sample to represent groundwater quality from this quadrant. The water quality sample from 231P is similar in quality to the PDT wells and other wells in the quadrant. The groundwater data used for modeling are presented in Appendix D. For groundwater data, only dissolved metals concentrations were considered for input to the model (total metals concentrations are not representative of water moving through the aquifer). If a parameter was reported below the analytical detection limit for that parameter, the value for that parameter was set to zero in the model.

The relative inflow contribution from each quadrant was estimated using the local groundwater model. These percentages are presented with the base case water balance results in Appendix B. Roughly 32, 26, 20, and 22 percent of the groundwater flow is contributed from the northwest, northeast, southwest and southeast quadrants, respectively. Variability in these estimates is evaluated in sensitivity modeling.

3.3.4 Lake evaporation

Evaporation from the pit lake surface is simulated in the model by removal of pure water from the water body. The volume of water removed at each time step in the model was calculated based on the cumulative amount of evaporation occurring on an annual basis, as predicted by the pit lake water balance (Appendix B). A lake evaporation rate of 37.46 inches/year was used in the hydrologic modeling, based on measured pan data and applying a pan coefficient of 0.73 (Interflow and Montgomery, 2010). Sensitivity for this parameter was assessed as part of the pit lake hydrological model, and has been evaluated within the geochemical modeling sensitivity runs (Section 5.1).

3.4 Laboratory to field scaling calculations

(The following discussion has been adapted from SRK [2009]):

It has been widely discussed that laboratory static (meteoric water mobility procedure) and kinetic (HCT) test data should be scaled for prediction of solute release at the field scale (Li et al., 2006; Maest et al., 2005). For example, the inability of heap leach operations to reproduce high rates of laboratory metal leaching from column tests in full scale leach piles has been well documented (Kul'tin, 1997; Bowell, 2001; Antonijevic and Bogdanvic, 2004; Lizama et al., 2005).

Although many different approaches have been taken to address scaling factors when applying laboratory leachate data to field scale models, the fundamental factors and processes that lead to these differences are universal. The rate of oxidation, and subsequent solute release via dissolution or desorption, from weathering rock is directly related to several factors, which include the:

- duration of rock-water interaction (residence time of water)
- ratio of rock to water
- surface area of the minerals
- ambient temperature of rock-water system
- chemistry of the lixiviant leaching solution
- reactivity of the minerals present in the rock (minerals which will oxidize or dissolve).

Humidity cells are not designed to predict field chemistry, but rather to optimize the rates of oxidation reactions and to compare the relative kinetics of acid generating and neutralizing processes. By design, laboratory static and kinetic tests consistently show higher release rates for various solutes than field conditions, because a test simulating actual release rates at actual time scales cannot be completed expediently in order to facilitate predictive studies. The reactivity of minerals present in the rock is the principal unknown in a humidity cell experiment. The duration of rock-water interaction, the ratio of rock to water, the surface area of the minerals, and the chemistry of the leach solution are all fixed by the method (or can be determined), and can be used to correct solute release for scale when these parameters are also known for the field conditions. Less is quantitatively known about these parameters at the field scale, however, although approximations can be made by mapping fracture densities, doing sieve analyses to determine *in situ* particle gradation, and measuring in-situ water flow. Precipitation falling onto an outcrop contacts rock surfaces for variable amounts of time, for example, and the ratio of rock to water is determined by the intensity and duration of the event. In contrast, contact time and the ratio of rock to water are relatively more constant for pit wall inundation, but for both groundwater and surface water, the relative surface area exposed to reaction per unit time will vary significantly at Mount Hope depending upon the site-specific characteristics of fracture density, fracture permeability and geometry that control water flux.

In spite of these challenges, kinetic test data are often the best source of information available for prediction of future solute release as a result of weathering in mined rock. The difficulty for most modeling efforts is to determine a practical way to scale kinetic test cell results so that they approximate future field conditions. At Mount Hope, scaling factors were constrained to the extent possible by incorporation of all available site-specific data and observations (e.g., grain size distribution of tested materials and physical characteristics of pi t wall materials).

Simple calculations which normalize humidity cell leachate based on surface area and rock-water ratio can be used to address one portion of the scale related differences, as has been done for other pit lake models in Nevada. For example, the Pipeline pit lake model (Geomega, 2003) incorporated analysis of fracture density to predict surface area and the Davis-Ritchie pyrite oxidation model to predict depth of weathering to predict mass available for reaction, along with design of leaching studies to include coarse rock that more closely corresponds to field scale particle size. Comparison of *in situ* field scale data collected in a pilot scale pit wall leach test and laboratory leaching allowed further calibration of a proprietary pyrite oxidation model (PITQUAL) that predicted water quality as a function of time. PTI used a somewhat different approach at Robinson, which relied heavily on calibration to *in situ* leaching conditions for existing pit lakes (PTI, 1994) and on measurements of porosity and particle size distributions in core samples from existing pit walls to calibrate the pyrite oxidation model. In a model currently being developed for Round Mountain (WMC, 2008), the characteristics of the weathered pit rind has been conservatively estimated using particle size analysis of run-of-mine rock from the existing mine site. However, the way rock breaks defines the site specific surface area and the extent to which fracture flow controls the rock-water leaching ratio is highly variable and strongly dependent upon the characteristics of the individual ore deposit.

There are particle size and porosity data for a range of materials available in reference literature. Because there are no existing facilities at Mount Hope, it is not possible to measure these parameters *in situ*. In the absence of such data, the best alternative is to adjust laboratory data using a scaling factor based on literature values constrained by available site-specific understanding of the site geology, and provide sensitivity analyses which are consistent with published estimates. Several published studies describing the differences between lab and field solute release rates, as discussed in the following section, were reviewed for the Mount Hope modeling effort (SRK, 2009). Many of these studies used laboratory methods that were designed to mimic field conditions as closely as possible, unlike the more standardized methods typically used for mine site evaluation (e.g. HCT using ASTM protocols), and therefore may actually under predict the differences between laboratory and field scale leaching.

3.4.1 Literature review of scaling factors

Sverdrup and Warfvinge (1995) have suggested that a two to five order of magnitude difference between field and laboratory release rates is caused by:

- Generation of inhibiting weathering products in the field (such as Al hydroxides) which cause field rates to be two to five times slower than lab rates.
- Lower ambient field temperatures, compared to typical laboratory temperatures that are approximately 25 °C, can cause field rates to be 2 to 10 times slower than lab rates.
- Partial or incomplete wetting of field materials, which can reduce field rates to values that are 4 to 10 times slower than laboratory rates.

Drever and Clow (1995) have described additional factors relating to the scaling discrepancies between field and laboratory release rate determinations. They report field rates that are two to eight orders of magnitude slower than laboratory or theoretical rates, which they attribute to:

- Formation of secondary layers on mineral surfaces in field conditions, such as aluminum or ferric hydroxide coatings.
- Presence of inhibiting solutes (such as aluminum ions) under field conditions that are not present in laboratory lixiviants.
- The influence of saturated geochemical conditions on critical mineral phase kinetics during laboratory kinetics which are not present under variably saturated conditions in the field.

Schnoor (1990), described field rates that are typically one to two orders of magnitude slower than laboratory rates, even when using laboratory methods designed to eliminate the factors discussed above.

Ritchie (1994), suggested that sulfide oxidation rates under “optimized conditions” (e.g. laboratory columns) are three orders of magnitude (or greater) faster than field values.

Smith and Beckie (2003) report field weathering rates that are several times to several orders of magnitude slower for field rates.

Li et al. (2006 and 2008) describe “chemical, physical, and microbiological heterogeneity that results in the formation of concentration gradients [which]....can lead to a scale dependence of the rates and thus potentially to discrepancies between laboratory and field rates.” In complex systems with multiple species that flow in single pores and fractures under the influence of both diffusion and advection, significant flow and concentration gradients result in rate discrepancies between the lab and field scale. Of particular importance is the need to scale rate of mass release per unit reactive surface area and volume of leachate, because of the influence these factors have on the scale dependent gradients. Efforts by Li et al. (2006) to upscale geochemical reaction rates using pore scale network modeling to study anorthite and kaolinite reactions associated with changing carbon dioxide concentrations indicate that pore-scale concentrations of reactive species and reaction rates vary spatially by up to four orders of magnitude when reactant concentrations are high.

A non-peer reviewed article by Morin and Hutt (2005) proposes various approaches to the issue of scaling laboratory leachate data and uses a generic conceptual model at the microscale, mesoscale, and full scale to demonstrate that physical factors like water flowpaths, sequences of minerals, and sampling location affect drainage chemistry. In this study, increases in scaling factors (e.g., volume, kinetic rate, residence time, and solid: liquid ratio) cause aqueous concentrations to increase until a maximum equilibrium level is attained. The “scale transition” represents the general break between kinetically-determined and equilibrium-determined concentrations in mg/L. Morin and Hutt provide equations for calculating scale transition.

However, a considerable amount of site data or estimates are necessary to apply this method, and the element by element approach does not take into account the common-ion effect or aqueous interference of elements in solution that leads to saturation and precipitation, ion-exchange or adsorption-desorption reactions.

Maest et al. (2005) discuss the need to scale data, and suggest that laboratory oxidation and weathering rates are two to three orders of magnitude greater than in the field, requiring correction for differences in surface area and rock-water ratio for proper modeling application.

In general, these scaling studies suggest that laboratory derived concentrations are one to three orders of magnitude higher than field conditions.

3.4.2 Scaling Mount Hope laboratory data

Rates of solute release were calculated using scaled HCT data to represent both the pit wall runoff and submergence terms. The approach used to scale the data is described below, and example calculations are shown in detail in the worksheets provided in Appendix E.

The HCT leachate data were scaled in two steps:

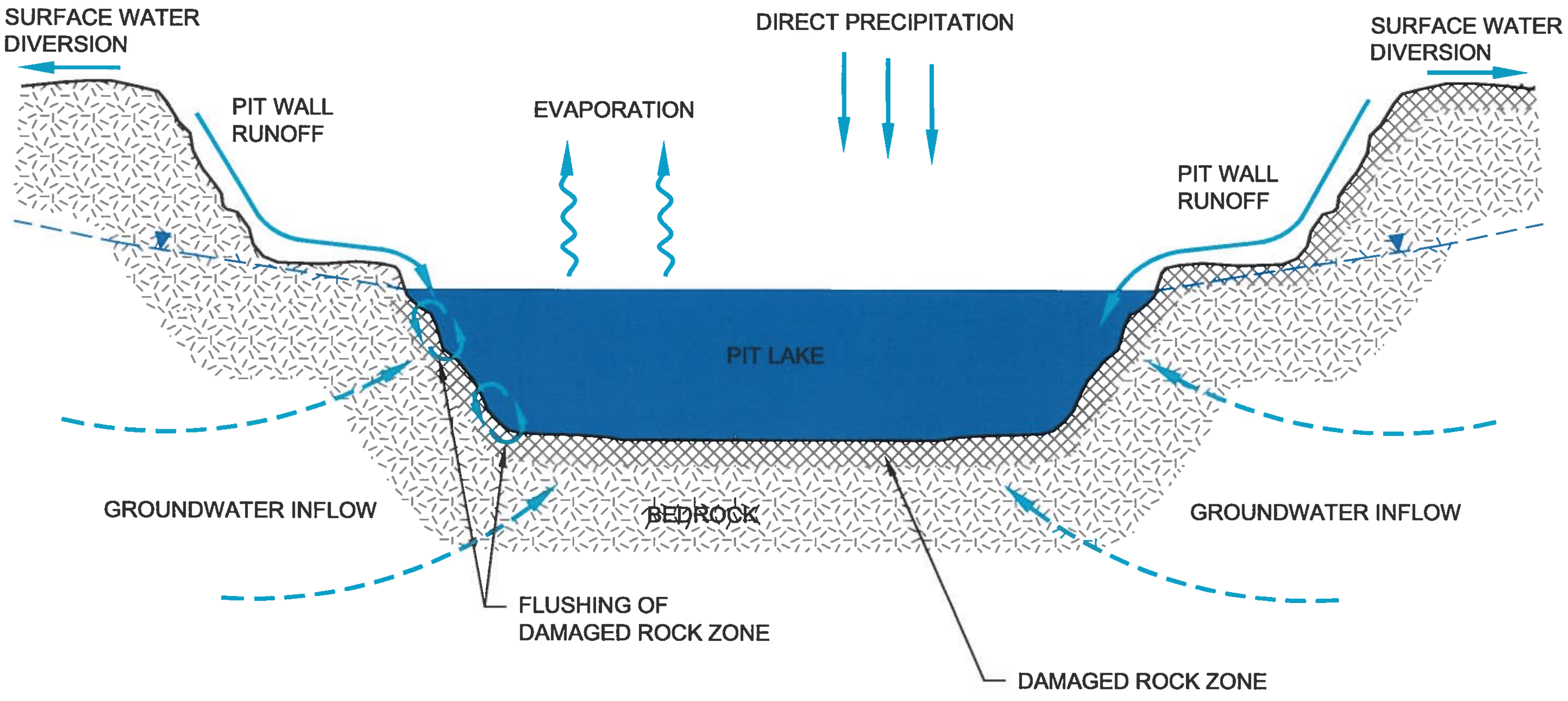
In the first step, the HCT data were normalized to account for the mass of rock in the test cell, the volume of leachate collected during the weekly rinse, and the specific surface area of material in the cell, based on the grain size distribution (Appendix E).

Grain size distribution analyses were conducted on splits from the 31 HCT materials. The surface area (in m^2/kg) were calculated using the Grain 3.0 spreadsheet (MDAG Grain 3.0©,^{TM} from MDAG Publishing (www.mdag.com), which calculates surface areas based on sieve analyses assuming spherical grains. A specific gravity of 2.7 was used. The specific surface area estimates ranged between 5.7 and 101 m^2/kg, with a median value of 27 m^2/kg. The grain size distribution data and calculations are included in Appendix F.

In the second step (Appendix E), the normalized HCT data are scaled to pit wall characteristics in terms of mass of rock involved in the reactions, volume of water interacting, and an estimate of pit wall grain size distribution. The mass/volume of the pit wall is approximated by pit wall rock density (2,430 kg/m^3) and estimated porosity (25 percent). The relatively high porosity for the pit wall (of 25 percent) is intended to represent both wall fracturing (~10 percent), and the porosity of finer grained materials which will accumulate on the benches over time (>25-30 percent).

As described above, the grain size distribution in the pit wall is a factor that cannot be measured for the Mount Hope pit. The degree to which areas of the pit wall will decrepitate is a function of geology (lithology and alteration type), climate, slope stability issues, and time. In the period immediately following mining, the pit walls are likely to be stable and the benches clean, and the grain size distribution would be dominated by very large material. Over time, and particularly for fine-grained, clay-altered rocks, the degree of decrepitation may be significant with grain size distributions similar to those found in laboratory test cells. To obtain a reasonable estimate of pit wall grain size, representing the two scenarios described above, a literature review was performed to obtain grain size data for waste rock materials. Five estimates (Munroe, et al., 1999; Shaw, et al., 2002) for specific surface areas of waste rock material, based on grain size distributions, were averaged to obtain a "representative" value for the pit wall of 4.0 m^2/kg. This estimate is considered to be conservative, as it accounts for fine grained materials on the benches as well as the in-situ porosity of the pit walls. These calculations are provided in Appendix F. To account for variable degree of decrepitation in different types of rock, a scaling factor of 6.8 (calculated based on the ratio of the median value of measured HCT grain size data (27 m^2/kg) to the waste rock material estimate (4.0 m^2/kg)) was applied to each material type. By this method, materials which had a higher degree of decrepitation in the laboratory cells would also degrade more in the environment.

The approach used for Mount Hope is based on available, site-specific information. This method is considered to be conservative as a result of the high specific surface area estimate for the pit walls. The net scaling correction is approximately 30 percent decrease total correction, well below most values reported in the reviewed literature. Scaled HCT data for each material type are presented in Appendix G. To evaluate sensitivity on the scaling correction, the model has been run using both unscaled data, and data which have been (arbitrarily) scaled down one order of magnitude.



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PIT LAKE GEOCHEMICAL CONCEPTUAL MODEL

CLIENT: EUREKA MOLY, LLC		PROJECT: MOUNT HOPE	
JOB: 2910		DRAWN: RN	CHECKED: PR
DATE: APRIL 2010		FIGURE: 3.1	

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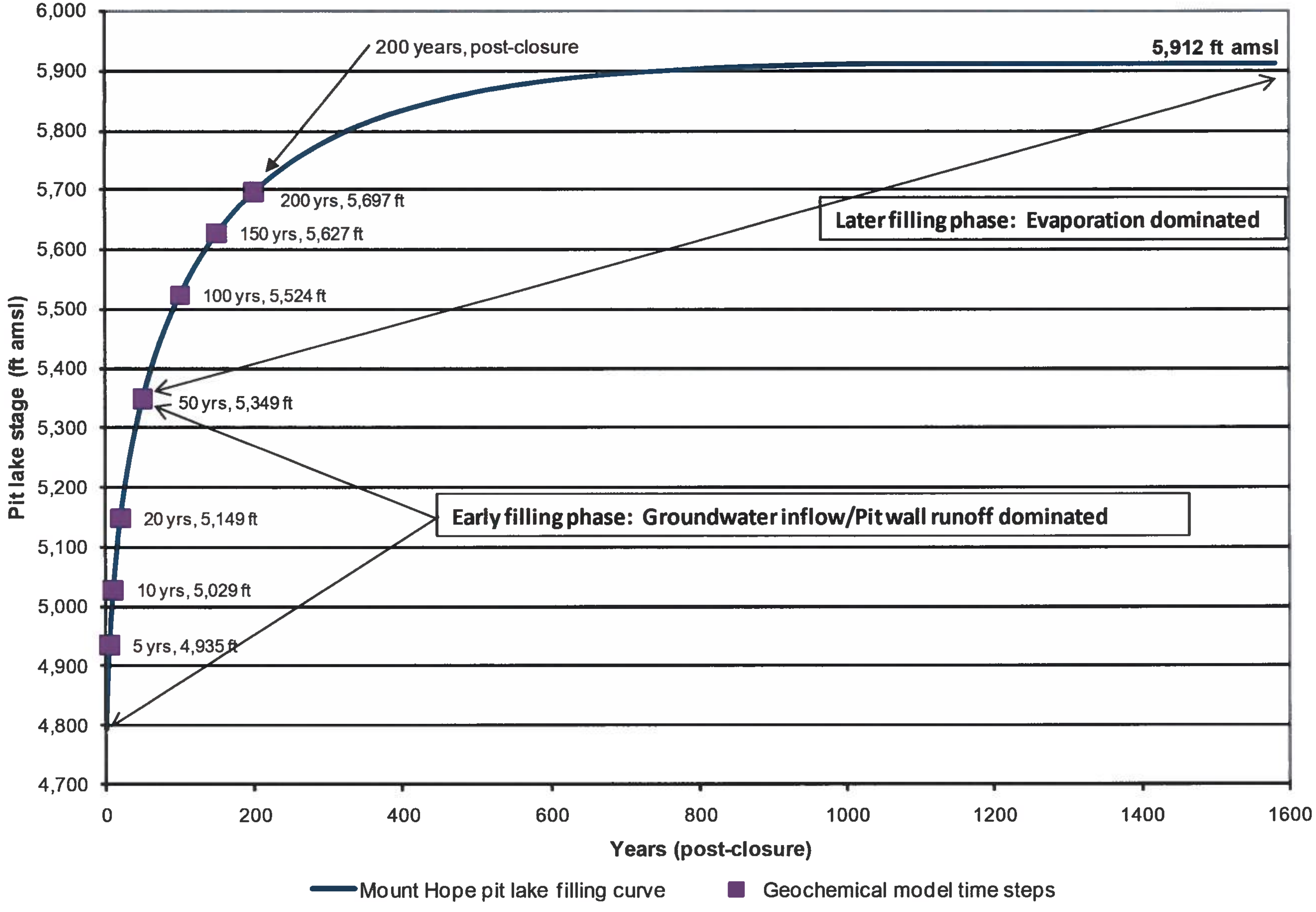

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PIT LAKE FILLING CURVE - BASE CASE MODEL	
CLIENT: EUREKA MOLY, LLC	PROJECT: MOUNT HOPE
JOB: 2910	DRAWN: RN CHECKED: PR
DATE: APRIL 2010	FIGURE: 3.2

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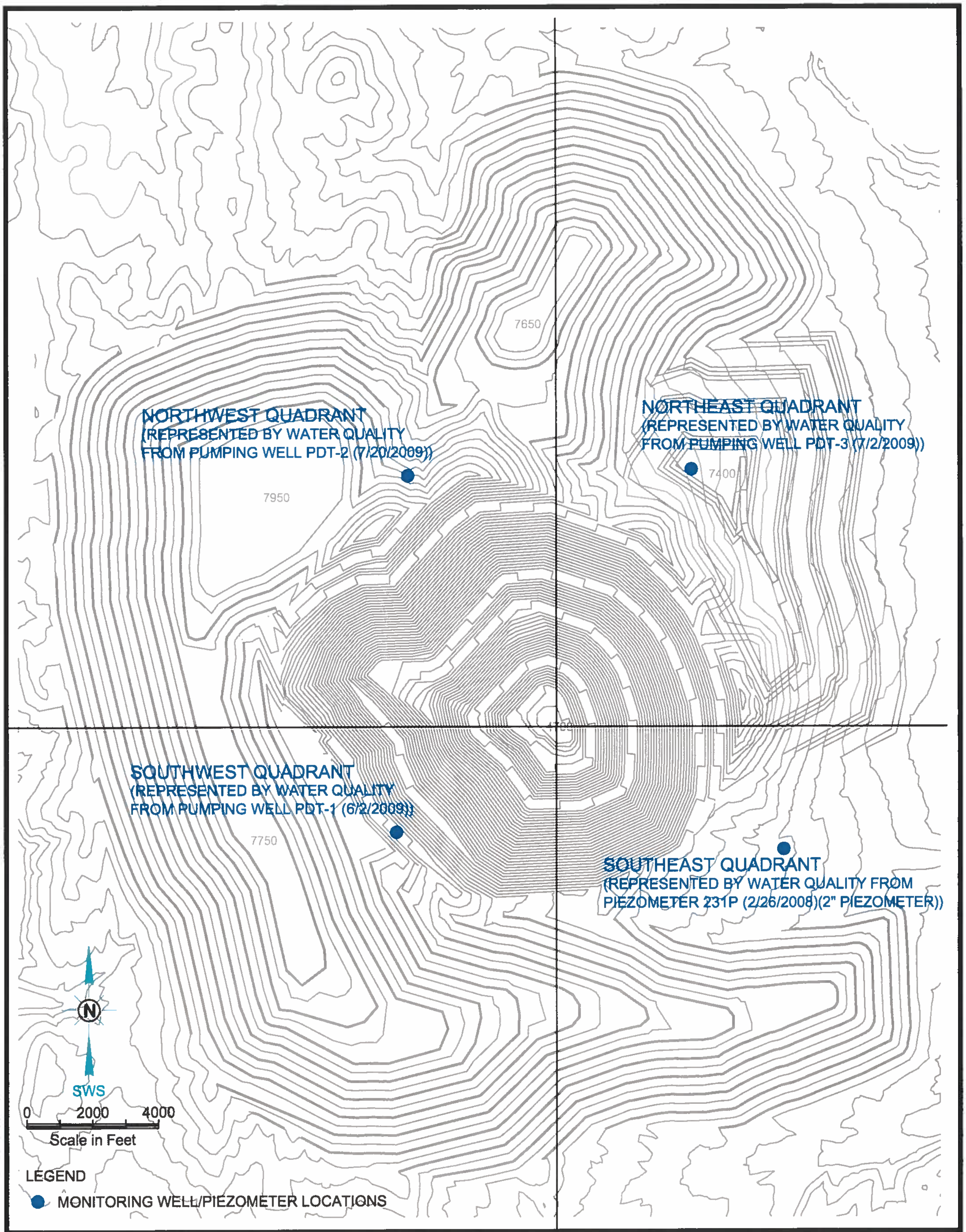

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GROUNDWATER QUADRANTS AND WATER QUALITY SAMPLE LOCATIONS

CLIENT:	EUREKA MOLY, LLC	PROJECT:	MOUNT HOPE
JOB:	2910	DRAWN:	RN CHECKED: PR
DATE:	APRIL 2010	FIGURE:	3.3

4 GEOCHEMICAL MODELING

The conceptual model developed for the pit lake system was implemented using the geochemical thermodynamic equilibrium code; PHREEQC (Parkhurst and Appelo, 1999). The model was used to predict pit lake chemistry at specific time steps after dewatering operations cease and filling begins. The chemistry of pit water was predicted by mixing waters from different sources, evapoconcentrating the mixture, and then allowing the resulting water to equilibrate with specified mineral and gas species. Details of the modeling code, processes and assumptions are provided in this section.

4.1 Pit lake modeling

The geochemical model PHREEQC (Parkhurst and Appelo, 1999) was used for all geochemical speciation, mixing, and reaction modeling conducted for this assessment. This code is publically available through the United States Geologic Survey, has been rigorously tested, and has been used in numerous pit lake geochemical predictions. PHREEQC is an industry standard tool used worldwide for conducting geochemical calculations to predict the chemistry of natural or impacted waters in the environment. This software uses thermodynamic equilibrium and speciation calculations to determine the concentration of mixed solutions as they evolve after allowing for mineral precipitation and trace element sorption under imposed gas and redox conditions. The resulting model output contains the aqueous concentrations of simulated elements, the speciation of the aqueous solutes, the solubility of relevant minerals, and the relative magnitude of sorption based on number of available sites and competition between solutes based on ionic strength and pH.

The PHREEQC model for Mount Hope used the modified MINTEQv4 thermodynamic database supplied with the v2.15.02 version of PHREEQC (released March 31, 2008). This database is widely used for geochemical modeling and was selected for this study because it includes the full range of elements for consideration in this pit lake evaluation as well as key sorption reactions for iron oxyhydroxides.

4.2 Model limitations

This discussion of model limitations is adapted from SRK (2009). Defining assumptions and model boundaries are a necessary part of the pit lake geochemical modeling process. Specific boundaries and assumptions of the model include:

1. Modeling was set up to simulate the pit lake for a 200-year time period.
2. The geochemical model framework was defined by the hydrological model and site water balance, which specifies volumes of inflow from pit wall runoff, groundwater, precipitation and loss from evaporation.
3. The model is defined by the elements, mineral phases, gas phases, and chemical species specified in the model input files.
4. The model is limited to thermodynamic equilibrium reactions and does not simulate the effects of reaction kinetics and rates.
5. The model relies on an external database of thermodynamic constants for mineral phase precipitates and sorbed surface complexes. These thermodynamic constants are valid at 25° C and one atmosphere of pressure, although changes in constants are negligible within the temperatures and pressures expected in the Mount Hope pit lake.
6. The model does not consider the effects associated with the formation and precipitation of mineral species other than those specified. Due to kinetic constraints, a portion of the potentially oversaturated mineral phases will not actually precipitate. A select suite of minerals is therefore specified that are allowed to precipitate, based on relevance for the environment in question, site-specific knowledge, experience in evaluating kinetic constraints and relevance of key phases for given styles of mineralization, and literature review (Eary, 1999). The model assumes that mineral phases that form within the pit lake are removed from the system as sediments.
7. Modeling was performed under the assumption that the pit lake will be fully mixed. The early lake will not stratify; however, as the lake deepens, seasonal stratification will develop. The lake is expected to mix seasonally throughout the majority of the depth of the lake. This will result in annual mixing of the lake waters.

4.3 Model development and progression

The PHREEQC model consists of several components including the input data file, the thermodynamic database, the executable code, and the output file. The input file consists of a series of logic statements and commands that define each of the components of the system (as described below) and explains how these components interact. The input file is read by the executable code and commands are executed in a stepwise manner.

The geochemical modeling process involved a series of solution mixing, chemical reactions, and mineral surface adsorption modeling to predict the pit lake composition at each selected time step. A logic flow diagram for the structure of the input code is shown as Figure 4.1 and discussed below. Specific steps included:

1. Developing individual, charge-balanced water chemistries which are representative of contact waters. A charge balance is a comparison of the sum of the cations compared to the sum of the anions, which confirms the electroneutrality requirement for natural waters. The geochemical model was used to modify the concentration of an element in order to correct for slight differences in the charge balance. Chloride and sodium were used to adjust the charge balance of the input waters because these elements do not play critical roles in geochemical reactions of concern for the pit lake simulations; sulfate and calcium were used (rarely) where chloride and sodium concentrations were insufficient to allow for charge balance. Final, charge-balanced concentrations were compared to original values to verify that concentrations were not significantly modified from original, laboratory values.

2. Selecting appropriate time steps that represent different stages of filling the post-closure pit lake.
3. Mixing the individual inflow components according to proportions from the pit lake water balance model. Components include:
    - direct precipitation
    - pit wall runoff, in proportion to the material types exposed in the pit wall above the lake elevation
    - groundwater, divided into four quadrants
4. Add constituent load to represent pit wall submergence, in proportion to the material types exposed in the pit wall below the lake elevation.
5. Removing pure water from the pit lake to account for evaporation in quantities estimated from the pit lake water balance (then restore the mixture in the model to 1 kilogram of water).
6. Equilibration of the pit lake water with likely mineral phases available for reaction (ferrihydrite, gypsum, gibbsite, barite, rhodochrosite and hydrated zinc carbonate ($ZnCO_3{:}H_2O$)). Based on evaluation of actual pit lakes, these mineral phases are commonly in equilibrium with pit lake waters (Eary, 1999) and affect solubility control on iron, sulfate, aluminum, barium, manganese and zinc concentrations. It was assumed that these phases were in equilibrium in the pit lake waters, with saturation indices (SIs) of 0. Additional discussion (chemical precipitation) is provided below.
7. A moderately oxygenated pit lake was simulated by assuming a pe value of 4.5 V, which is a typical value for a body of water with a pH around 7.5 that experiences periodic overturn and intermittent equilibration with the atmosphere, followed by periods of isolation from atmospheric oxygen (approximately, pe = 12 – pH) (Garrels and Christ, 1965). To simulate the pit lake at this pe, oxygen concentrations were adjusted. Additional discussion (atmospheric gas) is provided below.
8. Carbon dioxide partial pressure was set to slight oversaturation ($pCO_2 = 10^{-3.0}$ atm), based on observations at existing pit lakes (Eary, 1999).
9. Adsorption of specific species (antimony, arsenic, barium, lead, cadmium, copper, nickel, calcium, phosphate, zinc, beryllium, and sulfate) onto ferrihydrite according to Dzombak and Morel (1990). The mass of available ferrihydrite was limited to that precipitated by the mixed pit water under modeled conditions (i.e., no additional ferrihydrite from bedrock was included). Additional discussion (adsorption) is provided below.

This procedure was then repeated for each time step. For each subsequent timestep, the pit lake (volume and water quality) derived in the previous timestep was mixed with the inflows for the next timestep.

4.3.1 Chemical precipitation

The model assumes that surface and groundwater entering the pit lake will mix evenly and completely within the pit lake as filling proceeds. The solutes in these waters will react with each other and may form chemical precipitates, if the concentrations and geochemical conditions (pe, pH, pCO_2, pO_2, and ionic strength) allow super-saturation to occur. Precipitates will settle to the bottom of the pit lake and be removed from future chemical interactions as a sediment layer accumulates on the lake bottom.

As the pit lake forms and waters become progressively more evapoconcentrated, certain dissolved solutes may become oversaturated and precipitate as mineral phase solids. Due to kinetic constraints, all oversaturated mineral phases will not actually precipitate. Appropriate minerals must therefore be specified that are allowed to precipitate, based on relevance for the environment in question, site specific knowledge, experience, and literature review (Eary, 1999).

The suite of minerals chosen is based on an understanding of the types of minerals commonly observed in post mine lake settings with strong evaporative stress. The relative saturation of all minerals was calculated by comparing the calculated concentration of dissolved ion pairs with their theoretical, thermodynamic limit. Where these values were equal, the saturation index was zero and the solution was said to be at equilibrium with that mineral. At equilibrium, any amount of the mineral that dissolves will precipitate to maintain the relative solute:mineral balance. The minerals that are allowed to form in the Mount Hope pit lake model include ferrihydrite, gypsum, gibbsite, barite, rhodochrosite, and hydrated zinc carbonate ($ZnCO_3$:H_2O). This small number of mineral phases represents a conservative approach in that other, more obscure phases may in reality precipitation from the lake, resulting in removal of dissolved constituents.

4.3.2 Atmospheric gas equilibrium and lake stratification

Pit lakes in Nevada tend to stratify and mix seasonally. Typically, a thermocline or a halocline will form in a large body of water such as a pit lake, making turnover events difficult to predict or simulate (Bowell, 2002; Parshley and Bowell, 2003), although numerous pit lakes in Nevada have been shown to remain oxygenated throughout the water column. Stratification resulting from the development of a thermocline or halocline may result in the isolation of bottom waters where consumption of most (if not all) available oxygen is likely, while more buoyant and less saline surface water maintains near-atmospheric levels of oxygen and carbon dioxide. Early pit lakes are dynamic and tend not to stratify seasonally and are well mixed. As the Mount Hope pit lake begins to stratify seasonally, however, it will still undergo mixing in late fall, resulting in a completely mixed lake. Because the pit continues filling throughout the 200 year simulation, redox has been fixed along with carbon dioxide gas activity at near atmospheric conditions. Oxygen gas activity is then calculated within the model.

4.3.3 Adsorption

Trace metals will be removed from the pit lake water via sorption to freshly generated mineral precipitates of iron oxides (in addition to particulate iron that is flushed into the lake from the pit wall). As these particulates form, they will adsorb trace metals and remove them from the pit lake water. These particulates are assumed to settle out of the pit lake water column and become entrained in the sediment mass on the pit lake floor. The model assumes that the adsorbed trace elements are buried and isolated from further interaction with the overlying water column.

Sorption processes have been included in this model because many dissolved trace element concentrations are controlled by sorption to oxide and clay minerals in natural waters (Jenne, 1998). Although several mineral phases incorporating trace elements have saturation indices that suggest potential for mineral precipitation, empirical knowledge of the pit lake environment suggests that they should not be allowed to form. Trace element concentrations are mostly controlled by adsorption onto common mineral phases or through a process of co-precipitation.

This controlling feature is simulated numerically in the model by including sorption of certain trace elements onto charged hydrous ferric oxide (HFO) surfaces. The amount of potential sorption is influenced not only by the mass of available substrate, but also by the pe and pH conditions that influence solute speciation and the net charge of the HFO surface. HFO was selected for this modeling effort because it is a common sorption substrate in oxygenated natural waters, and the trace element sorption thermodynamic properties of these reactions are well defined by numerous empirical studies. Aluminum oxide, organic matter, calcite and clay minerals will most likely also influence sorption, but less is known about accurately representing these processes in a hydrogeochemical model, and therefore, they have conservatively been removed from consideration as sorption substrates. Further, preliminary calculations indicate that HFO will form from the pit lake as filling proceeds.

The mass of HFO used in the model is assumed to be identical to the mass of the mineral phase ferrihydrite precipitated in preliminary iterations of the model. The chemical properties of the HFO mass consist of default values that are derived from scientific literature (Dzombak and Morel, 1990), as reported by Parkhurst and Appelo (1999). The default HFO (strong-sites) material characteristics reported by Dzombak and Morel (1990) included 0.005 mole of strong sorption sites per mole of iron, and HFO (weak-sites) material was estimated to have 0.2 mole weak sites per mole of iron; their surface area estimate of 53,300 m^2/mole was also used in the pit lake model.

As with mineral phase precipitation, the adsorbed mass of trace elements removed through this mechanism is assumed in our conceptual model to be permanently removed from the system following settling of the HFO substrate into the bottom of the pit lake, where it is incorporated into the sediment and thus unavailable for subsequent desorption reactions.

The effects of co-precipitation, defined as the incorporation of small amounts of trace elements into the body of a more abundant precipitating mass, were conservatively not included in this modeling effort, although these processes will act to reduce certain trace metal concentrations. Co-precipitation can become significant under conditions where the saturation indices of a mineral are elevated and temperatures are elevated, neither of which will likely occur in the predicted pit lake system. However, for certain trace elements of concern such as cadmium, co-precipitation, even at low rates, may significantly reduce overall concentrations.

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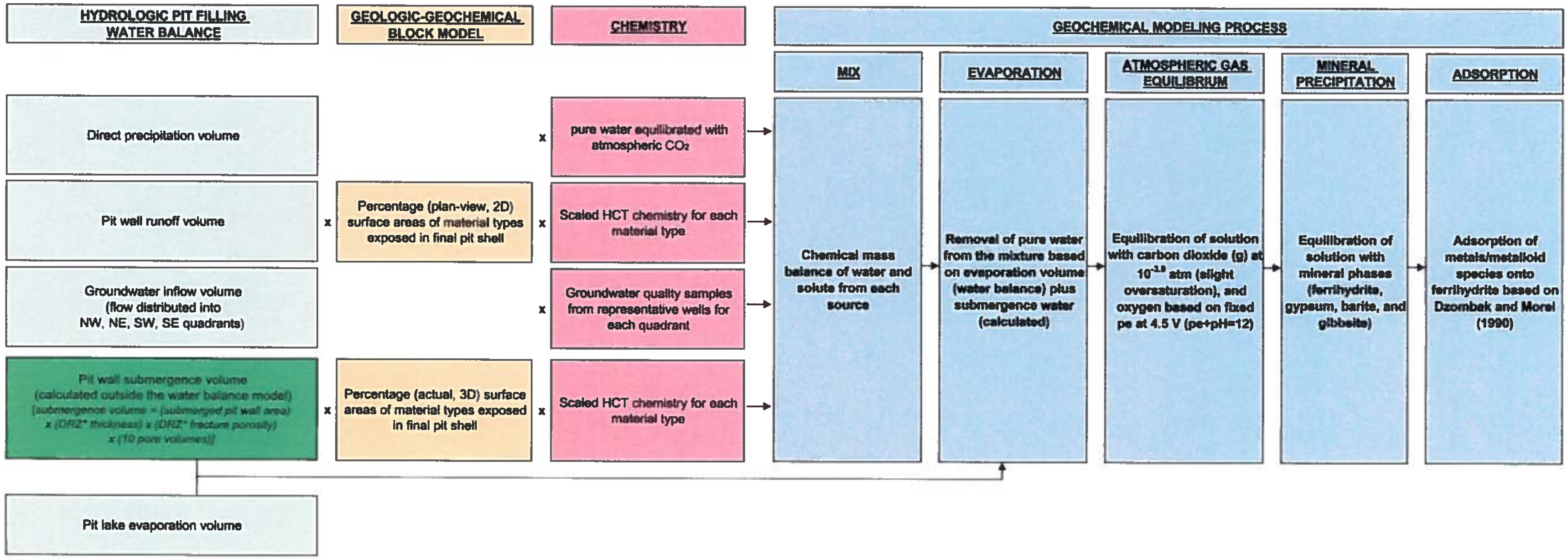

*DRZ = pit wall Damaged Rock Zone (thickness, 1.8m; porosity, 10%)

** Flow diagram represents one timestep

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GEOCHEMICAL MODELING FLOW DIAGRAM

CLIENT:	EUREKA MOLY, LLC	PROJECT:	MOUNT HOPE		
JOB:	2910	DRAWN:	RN	CHECKED:	PR
DATE:	APRIL 2010	FIGURE:	4.1		

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5 SENSITIVITY ANALYSIS

A series of model runs was conducted to evaluate the sensitivity of key model parameters and assumptions on predicted water chemistry results. Sensitivity analyses were performed by varying input parameters and evaluating the response compared to the base case scenario. The types and range of sensitivity analyses are described below, and include:

- hydrologic parameter variability
- pit wall runoff/submergence chemistry scaling effects
- HCT leachate data variability
- groundwater chemistry data variability
- atmospheric CO_2(g) equilibrium assumptions

The influence of each parameter on pit lake chemistry predictions is described in Section 6.

5.1 Hydrologic sensitivity evaluation

The relative percentages of inflow/outflow water volumes in the geochemical model were derived from the local pit filling hydrologic model (Interflow and Montgomery, 2010). The base case results from the hydrologic model were used in development of the base case geochemical model. Several sensitivity runs were conducted to evaluate the local hydrologic model (Interflow and Montgomery, 2010); these same sensitivity runs have been applied to the geochemical model to evaluate the potential effects on predicted water quality. In addition, a sensitivity run on the groundwater inflow component was added to evaluate the potential impacts to pit lake water quality based on varying the groundwater inflow rate. This modified water balance was prepared by SWS (MS Excel spreadsheet model) by modifying the base case water balance provided in Interflow and Montgomery (2010). The hydrologic data sensitivity runs are:

- *Pit wall runoff coefficient (high and low stage)* – the runoff coefficient that defines the percentage of precipitation on the pit walls that reaches the lake was set at 30 percent for the base case, and varied between 20 and 40 percent for the sensitivity runs (Interflow and Montgomery, 2010).
- *Lake evaporation rate (high and low stage)* – the free surface evaporation rate used in the base case model was 37.46 in/yr; this value was varied to 30.79 in/yr and 42.08 in/yr for sensitivity runs (Interflow and Montgomery, 2010).

- *Precipitation rate (high and low stage) – the precipitation rate for the base case model was 14.94 in/yr; this value was varied by +15 percent (17.18 in/yr) and -15 percent (12.70 in/yr) for sensitivity runs (Interflow and Montgomery, 2010).*
- *Lake conductance (high and low stage)* – lake conductance is 0.64 ft^2/day for lake cell bottoms and 0.32 ft^2/day for lake cell sides; these values were varied to plus/minus an order of magnitude for the sensitivity runs (Interflow and Montgomery, 2010).
- *Specific yield (high and low stage)* – the specific yield values were set to 0.5 to 3.0 percent (based on lithology); these values were varied to plus/minus a factor of 3 for the sensitivity runs (Interflow and Montgomery, 2010).
- *Multi-variable (high and low stage)* – the multi-variable runs combined variations on runoff coefficient, evaporation rate, lake conductance, precipitation, and specific yield at the values set in the individual runs (Interflow and Montgomery, 2010).
- *Groundwater inflow (high and low stage)* – the base case water balance predicted an initial groundwater inflow rate of 285 gallons per minute (gpm), decreasing to 133 gpm at 200 years post-closure; these estimates were varied by one half order of magnitude initial decrease (143 – 77 gpm), and one-half order of magnitude initial increase (1425 – 491 gpm).

The terms "high" and "low" refer to the pit lake water level (stage) that results from that sensitivity run. The values and ranges applied to the modeling are presented in Table 5.1. The resulting annual water balance volumes for each of these runs are compiled in Appendix H. A summary of the relative proportions of inflow components (at the five year time step) for each of these runs is presented in Table 5.2.

Table 5.1 Hydrologic modeling sensitivity runs

Input Parameter	Minimum Stage	Base Case	Maximum Stage
Pit wall runoff coefficient	20%	30%	40%
Lake evaporation	42.08 in/yr	37.46 in/yr	30.79 in/yr
Precipitation	-15%(12.70 in/yr)	14.94 in/yr	+15% (17.18 in/yr)
Lake conductance	decrease 10x	0.64 ft^2/day (bottom) 0.32 ft^2/day (side)	increase 10x
Specific Yield	decrease 3x	0.5 – 3.0 %	increase 3x
Multi-variable (runoff, evaporation, ppt, specific yield, lake conductance)	compilation of above	-	compilation of above
Groundwater inflow rate	143-77 gpm	285–133 gpm	1,425–491 gpm

As shown in Table 5.2, the hydrologic water balance sensitivities performed by Montgomery reflect a range of relative groundwater inflow rates for years 0 to 5, between 48 and 68 percent (base case is 59 percent); similarly, the range of relative pit wall runoff rates vary between 29 and 49 percent (base case is 38 percent) (Interflow and Montgomery, 2010). A greater variability in percent inflow components is reflected in the additional (high/low groundwater inflow) sensitivity scenarios. Relative groundwater inflow varies from 43 to 87 percent in those runs; while pit wall runoff varies from 12 to 54 percent. The relative contribution of direct precipitation varies between 2 and 3 percent for all model runs (base case is 3 percent).

Table 5.2 Percent inflows/outflows (years 0-5) for hydrologic sensitivity models

Model Run	Average (0-5 years) total inflow rate (gpm)	Direct Precipitation (%)	Pit wall runoff (%)	Groundwater inflow (%)	Total Inflows	Evaporation (as percent total inflow)
Base Case	454	3%	38%	59%	100%	-8%
Runoff – High stage	508	3%	45%	52%	100%	-7%
Runoff – Low stage	394	3%	29%	68%	100%	-8%
Evaporation – High stage	451	3%	38%	59%	100%	-6%
Evaporation – Low stage	451	3%	38%	59%	100%	-8%
Lake conductance – High stage	499	3%	34%	63%	100%	-7%
Lake conductance – Low stage	351	3%	49%	48%	100%	-8%
Sp. Yield – High stage	475	3%	36%	61%	100%	-7%
Sp. Yield – Low stage	438	3%	39%	58%	100%	-8%
Precipitation – High Stage	479	3%	41%	55%	100%	-7%
Precipitation – Low Stage	424	3%	34%	63%	100%	-8%
Multi-variable – High stage	637	3%	41%	56%	100%	-6%
Multi-variable – Low stage	268	3%	37%	60%	100%	-10%
Groundwater Inflow – High stage	1440	2%	12%	87%	100%	-4%
Groundwater Inflow – Low stage	322	3%	54%	43%	100%	-7%

**High- and low-stage refer to resulting pit lake elevation of the sensitivity run, compared to the base case.*

5.2 Geochemical modeling sensitivities

Various sensitivity runs were performed based on varying chemical inputs to the model, and modeling assumptions. These runs are described below, and summarized in Table 5.3.

Table 5.3 Geochemical modeling sensitivity runs

Sensitivity	Sensitivity (1)	Base Case	Sensitivity (2)
Pit wall runoff chemistry scaling	1 order of magnitude decrease	~ 30 percent decrease	Unscaled
Pit wall submergence flushing	5 pore volumes	10 pore volumes	20 pore volumes
HCT chemistry data	Late time (average last 10 weeks)	Average all data	Early time (average first 4weeks)
Groundwater chemistry data	Average chemistry (4 samples)	4 quadrant inflows 4 well samples	High TDS groundwater sample
Atmospheric $CO_2(g)$ equilibrium	pCO_2, $10^{-2.5}$ atm	pCO_2, $10^{-3.0}$ atm	pCO_2, $10^{-3.5}$ atm

5.2.1 Pit wall runoff/submergence chemistry scaling

As described in Section 3.4, laboratory kinetic data (HCT leachate chemistry) was scaled to estimate solute release from the pit walls at the field scale. Specifically, for the base case geochemical model, the HCT chemistry data was scaled based on estimates of water:rock ratios and grain surface areas in the test cells and pit wall, respectively. The net scaling results in approximately 30 percent decrease of HCT leachate concentrations to pit wall runoff concentrations. To evaluate sensitivity on the scaling correction, the model was run using:

- unscaled HCT data, to represent a very conservative case
- HCT data scaled down one order of magnitude, to bracket the scaling effect

In addition, sensitivity analyses were conducted on the number of pore volumes of solute released during pit wall inundation and flushing, as described in Section 3.3.2. Based on experience with other pit lakes in dry climates, the Mount Hope base case modeling scenario allows for 10 pore volumes of flushing from the submerged zone to account for accumulation of solute from the DRZ. The amount of accumulation is site-specific and depends on climate, reactivity of pit wall minerals, and time. Two sensitivity analyses were conducted on this term using 5 and 20 pore volumes of solute, respectively, to account for the variability in actual accumulation and subsequent flushing of weathering products from the pit wall materials.

5.2.2 HCT chemistry data

As presented in the characterization report (SRK 2008), solute release chemistry changes over time in the humidity cells in response to mineral-water reactions. In the initial flushing stages of the humidity cells, high concentrations of sulfate and cations such as aluminum, iron, calcium and magnesium and in some cases cadmium and zinc were observed due to dissolution of secondary minerals. Over time these concentrations decreased except where sulfide oxidation occurs and then a low pH coupled with high metal and sulfate concentrations are observed. This effect was observed in 12 of 31 HCTs, representing about 16 percent of the final, exposed pit wall. After 60 weeks, most cells effluents had reached steady element release rates.

As described in Section 3.3.2, the base case pit lake model uses average HCT leachate concentrations to represent flushing, over time, from pit wall rocks. This approach accounts for the higher concentrations associated with first flush (early time), as well as the potential of high concentrations in the late time for some acid-generating material types. Sensitivity analyses have been completed to evaluate the response of the model to a change in how the HCT data are used to represent groundwater chemistry.

Sensitivity runs were completed using:

- early-stage release rates, based on average release rates from the first four weeks of testing
- late-stage release rates, based on an average of the final 10 weeks of HCT data

The HCT results for early- and late-stage leaching are compared to the average HCT input values in Appendix I.

5.2.3 Groundwater chemistry data

As described in Section 3.3.3, the groundwater inflow component to the pit lake model was subdivided into four quadrants, northwest, northeast, southwest and southeast (Figure 3.3). Each of these quadrants is represented by groundwater quality data from representative pumping wells/piezometer from each quadrant. The groundwater quality data are presented in Appendix D. The relative proportion of groundwater inflow from each quadrant was estimated based on the local hydrologic model (Interflow and Montgomery, 2010).

To evaluate the potential influence of groundwater chemistry data, the following sensitivity runs were performed:

- average groundwater chemistry data – this sensitivity may also be viewed as equal portions of groundwater inflow from the four quadrants
- high total dissolved solids (TDS) groundwater data – of the four groundwater quality samples, the sample with the highest TDS and generally higher trace metals concentrations (PDT-3, 7/2/2009) was used to represent water quality from all quadrants.

These sensitivity runs are intended to evaluate uncertainty in the proportion of inflows from the four quadrants, as well as variability in the groundwater quality surrounding the pit.

5.2.4 Atmospheric $CO_2(g)$ equilibrium

For the base case model, carbon dioxide partial pressure was set to slight oversaturation ($pCO_2 = 10^{-3.0}$ atm), based on observations at existing pit lakes (Eary, 1999) (Section 4.3). Based on the temperature, pH, stratification, and degree of atmospheric equilibrium within the pit lake, the partial pressure of carbon dioxide gas may vary. To evaluate the sensitivity of this value on the results, the following sensitivity runs were conducted:

- fix pCO_2 to $10^{-3.5}$ atm, to represent equilibrium with atmospheric carbon dioxide that would likely occur early in the pit lake when it is well mixed and relatively small (at standard temperature and pressure)
- fix pCO_2 to $10^{-2.5}$ atm, to represent over-saturation with respect to atmospheric carbon dioxide that might occur locally in a deeper, stratified lake (e.g., late summer conditions).

This range of values is reasonable, and has been observed in existing pit lakes (Eary, 1999).

5.2.5 Additional sensitivity evaluations

In addition to the evaluations described above, additional modeling parameters were varied to confirm whether the model results were sensitive, and whether additional evaluation was necessary. These parameters included:

- *Fixed pe value*. This modeling parameter defines the oxidation state of the pit lake; this parameter was set to 4.5 V for the base case, and was varied between 2 and 10 V for this evaluation.
- *HFO adsorption parameters*. The values for number of adsorption sites per mole and surface area of the sites were set to default values for the base case (Dzombak and Morel, 1990). These values were varied based on previous Mount Hope pit lake modeling (SRK, 2009) and reported values (various sources for other pit lake models).

These evaluations served to verify that the model results were insensitive to variation in these parameters. Therefore, further investigation, literature review, and sensitivity runs were not pursued.

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6 MODEL RESULTS

The base case simulation for the Mount Hope pit lake was designed to predict the most likely condition of future pit lake water quality. Input parameters were varied from the base case to evaluate the sensitivity of the model to key parameters during the first 200 years of filling (Section 5).

The base case results for each model time step are presented in Table 6.1 and the range of results based on the hydrologic and chemistry sensitivities, respectively, are summarized in Tables 6.2 and 6.3; results are described in the following sections. The tabulated model results were compared to Nevada Department of Environmental Protection (NDEP) reference values; the reference values are a compilation of Nevada drinking water primary and secondary standards, action levels, and beneficial use standards, and are consistent with Federal Maximum Contaminant Levels (MCLs) (also shown in tables for reference). Because the pit lake is expected to act as a hydraulic sink (Interflow and Montgomery, 2010), there will be no discharge from the pit to either groundwater or surface water; therefore, the standards are presented for reference purposes only. Pit lake water quality predictions were evaluated in terms of ecological risk, and are presented in a separate SLERA report (SRK, 2010).

The tabulated data are presented in Appendix J with plots showing the change in key constituent concentrations over time for all model scenarios. These plots show the range of results and variation of the constituents depending on the model scenario.

6.1 Base case results

The base case scenario results are presented in Table 6.1. For the base case, the pH is predicted to be neutral to slightly alkaline, with a pH of approximately 7.7 standard units (su), throughout pit filling to 200 years post-closure. Total alkalinity is predicted to be present initially at approximately 55 mg/L as $CaCO_3$, and will increase with time. Sulfate concentrations are predicted to be moderate, ranging between 134 and 214 mg/L over the simulated time period. Iron and aluminum concentrations are predicted below standard detection limits as a result of precipitation of secondary hydroxide mineral phases.

Most trace metals/metalloid concentrations are low or below analytical detection; however, concentrations of fluoride, cadmium, and manganese are predicted to be present above Nevada reference standards during early pit lake filling and throughout the modeling period. In general, constituent concentrations in the pit lake are predicted to increase over time due to evapoconcentration. Antimony concentrations are initially low, but are predicted to increase to just above the reference standard due to this evapoconcentration effect in the late stages of pit filling (by 50 years).

Table 6.1 Mount Hope predicted pit lake water quality results

Parameter/ Analyte	Nevada Reference Standards	USEPA Drinking Water MCLs	Pit Lake (Time 5yr) (Base Case)	Pit Lake (Time 10yr) (Base Case)	Pit Lake (Time 20yr) (Base Case)	Pit Lake (Time 50yr) (Base Case)	Pit Lake (Time 100yr) (Base Case)	Pit Lake (Time 150yr) (Base Case)	Pit Lake (Time 200yr) (Base Case)
pH, std units	**6.5 - 8.5***	**6.5 - 8.5***	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Major Ions									
Alkalinity, as $CaCO_3$	**ns**	**ns**	55	55	55	56	57	58	59
Chloride	**400***	**250***	8.2	8.3	8.4	8.8	9.5	10.1	10.8
Fluoride	**4.0 (2.0*)**	**4.0 (2.0*)**	3.1	3.0	3.0	3.0	3.2	3.4	3.7
Nitrate, as N	**10**	**10**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorus	**ns**	**ns**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulfate, as SO_4^{2-}	**500***	**250***	134	136	142	155	175	194	214
Calcium	**ns**	**ns**	46	46	47	50	54	58	62
Magnesium	**150***	**ns**	7.3	7.4	7.6	8.1	8.9	9.6	10.4
Potassium	**ns**	**ns**	4.5	4.6	4.7	5.1	5.7	6.3	6.8
Sodium	**ns**	**ns**	26	27	28	30	34	38	42
Metals/Metaloids									
Aluminum	**0.2***	**0.05-0.2***	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	**0.006**	**0.006**	0.0056	0.0057	0.0058	0.0062	0.0067	0.0072	0.0076
Arsenic	**0.01**	**0.01**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Barium	**2**	**2**	0.014	0.014	0.013	0.012	0.011	0.011	0.010
Beryllium	**0.004**	**0.004**	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	**ns**	**ns**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	**ns**	**ns**	<0.05	<0.05	<0.05	<0.05	0.053	0.059	0.065
Cadmium	**0.005**	**0.005**	0.033	0.034	0.037	0.043	0.051	0.059	0.067
Chromium	**0.1**	**0.1**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	**ns**	**ns**	0.009	0.009	0.010	0.011	0.013	0.014	0.016
Copper	**1.0* (1.3**)**	**1.0* (1.3**)**	0.015	0.0149	0.016	0.016	0.018	0.018	0.018
Iron	**0.6***	**0.3***	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	**0.015****	**0.015****	0.00045	0.00043	0.00045	0.00048	0.00051	0.00052	0.00053
Lithium	**ns**	**ns**	0.0042	0.0045	0.0048	0.0057	0.0069	0.0079	0.0090
Manganese	**0.10***	**0.05***	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Mercury	**0.002**	**0.002**	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Molybdenum	**ns**	**ns**	0.074	0.078	0.083	0.094	0.11	0.12	0.13
Nickel	**0.1**	**ns**	0.023	0.023	0.025	0.028	0.034	0.038	0.043
Selenium	**0.05**	**0.05**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	**0.1***	**0.1***	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	**ns**	**ns**	0.22	0.22	0.22	0.23	0.24	0.26	0.28
Thallium	**0.002**	**0.002**	0.00055	0.00056	0.00058	0.00063	0.00069	0.00075	0.00083
Tin	**ns**	**ns**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	**ns**	**ns**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc	**5.0***	**5***	2.7	2.7	2.9	3.3	3.5	3.5	3.5

STANDARDS PRESENTED ARE NOT APPLICABLE TO THE PIT LAKE WATER. FOR REFERENCE PURPOSES ONLY.

Nevada Reference Standards are based on Nevada primary and secondary drinking water standards, action levels and beneficial use standards.
* Based on secondary standard. ** Based on lead and copper action levels ns = no standard
Exceedences of the Nevada Reference Standards are highlighted.
USEPA Drinking Water Maximum Contaminant Levels (MCLs) are also shown for reference only.
All concentrations are in milligrams per liter, unless otherwise noted.
< Analyte concentration result is below typical analytical detection limits. Value shown is the detection limit.

Base case and sensitivity results for key constituent concentrations over time are presented in Figure 6.1 (pH, alkalinity) Figure 6.2 (fluoride, sulfate), Figure 6.3 (cadmium, manganese), and Figure 6.4 (antimony, zinc).

Fluoride concentrations are predicted to be relatively stable throughout early pit filling, at a concentration of approximately 3 mg/L, and then increasing during late-stage filling due to evapoconcentration in the lake. The sources of fluoride to the pit include both groundwater (approximately 39 percent by mass) and pit wall rock rinsing (approximately 60 percent by mass). About half of the fluoride contribution from the wall rocks (32 percent by mass) is leached from the quartz aplite porphyry material, exposed near the bottom of the pit. For this reason, there is an initial spike in fluoride concentration at the five year time step, as this geologic unit is being inundated by the rising pit lake (Figure 6.2).

The major source of antimony to the pit lake is groundwater inflow (95 percent by mass). Antimony concentrations in representative groundwater samples range from below analytical detection (PDT-1) to 0.015 mg/L (PDT-3) (above the Nevada reference standard). The pit lake antimony concentrations are predicted to increase to just slightly above the standard due to evapoconcentration after approximately 50 years.

In contrast, the primary source of cadmium, manganese and zinc is pit wall rock flushing. These constituents were reported at low concentrations (manganese and zinc) or below the analytical detection limit (cadmium) in each of the representative groundwater samples, and therefore there is little or no loading from groundwater predicted in the modeling for these constituents. Of the pit wall rocks, the major contributing area for these constituents is the PAG-classified, argillic rhyolite tuff (75 percent of the cadmium load, 38 percent of the manganese load, and 69 percent of the zinc load to the pit lake); this material is located high on the north to east pit walls. Other significant contributing areas of these constituents include the phyllic quartz porphyry (15 percent of the cadmium load), and the argillic Vinini sediments (40 percent of the manganese load, and 11 percent of the zinc load).

It should be reiterated that these predicted concentrations are considered conservatively high because some mechanisms of co-precipitation and adsorption (other than HFO), which would normally attenuate trace constituent concentrations, have not been included in the modeling. These reactions were not included because thermodynamic data are not available (or not thoroughly defensible) to define the behavior in the geochemical model. For example, a potential mechanism for manganese removal, adsorption to organics, is not considered in the geochemical model; similarly, co-precipitation of cadmium with calcite, which would limit cadmium concentrations, is also not considered in the modeling.

6.2 Hydrologic model sensitivity results

The results of the hydrologic sensitivity runs are included in Appendix J, and summarized for the 200 year time step in Table 6.2. In addition, plots of key constituents are presented in Appendix J. Overall, the results of the hydrologic modeling sensitivity runs are consistent with the base case model results, predicting a neutral to slightly alkaline pit lake (pH ranging from 7.4 to 8.0 su), low to moderate alkalinity (30 to 109 mg/L as $CaCO_3$), and low sulfate concentrations (ranging from 170 to 263 mg/L). Consistent with the base case model results, most trace metals/metalloid concentrations are low or below analytical detection while concentrations of fluoride, antimony, cadmium, manganese, and (rarely) zinc are predicted to be present above Nevada reference standards. The ranges of these constituents, at the 200 year time step, compared to the base case results, are as follows:

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Table 6.2 Base case and hydrologic sensitivity results summary

Parameter/ Analyte	Nevada Reference Standards	USEPA Drinking Water MCLs	(Base Case)	(Runoff-High)	(Runoff-Low)	(Evap-High)	(Evap-Low)	(LakeCond-High)	(LakeCond-Low)	(SpecificYield-High)	(SpecificYield-Low)	(Precip - High)	(Precip - Low)	(Multivariate-High)	(Multivariate-Low)	(GWinflowHigh (1120gpm))	(GWinflowLow (56gpm))	Minimum	Maximum
			Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)		
pH, std units	**6.5 - 8.5***	**6.5 - 8.5***	7.7	7.6	7.9	7.7	7.8	7.8	7.6	7.8	7.7	7.7	7.8	7.5	7.9	8.0	7.4	7.4	8.0
Major Ions																			
Alkalinity, as $CaCO_3$	**ns**	**ns**	59	43	85	53	64	63	45	61	58	49	72	34	92	109	30	30	109
Chloride	**400***	**250***	10.8	9.3	13.0	9.4	12	11.1	9.9	11	10.8	9.6	12.3	7.4	15	13	8.6	7.4	15
Fluoride	**4.0 (2.0*)**	**4.0 (2.0*)**	3.7	3.7	3.7	3.2	4.1	3.7	3.9	3.7	3.7	3.5	3.9	3.1	4.6	2.8	4.1	2.8	4.6
Nitrate, as N	**10**	**10**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorus	**ns**	**ns**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulfate, as SO_4^{2-}	**500***	**250***	214	213	214	186	234	212	221	213	214	204	224	178	263	170	231	170	263
Calcium	**ns**	**ns**	62	54	74	54	69	64	57	63	62	56	70	44	86	74	51	44	86
Magnesium	**150***	**ns**	10.4	9.5	11.8	9.0	11.5	10.6	9.9	10.5	10.4	9.5	11.5	7.7	14	11	9.3	7.7	14
Potassium	**ns**	**ns**	6.8	6.7	7.0	6.0	7.5	6.8	7.0	6.8	6.8	6.5	7.2	5.6	8.5	5.6	7.2	5.6	8.5
Sodium	**ns**	**ns**	42	42	42	36	46	41	43	42	42	40	44	35	52	33	45	33	52
Metals/Metaloids																			
Aluminum	**0.2***	**0.05-0.2***	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Antimony	**.006**	**0.006**	0.0076	0.0065	0.0092	0.0066	0.0085	0.0079	0.0068	0.0078	0.0076	0.0068	0.0087	0.0052	0.011	0.0094	0.0058	0.0052	0.011
Arsenic	**0.01**	**0.01**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Barium	**2**	**2**	0.010	0.010	0.010	0.011	0.009	0.010	0.010	0.010	0.010	0.010	0.010	0.011	0.009	0.013	0.009	0.0090	0.013
Beryllium	**0.004**	**0.004**	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	**ns**	**ns**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	**ns**	**ns**	0.065	0.073	0.053	0.057	0.071	0.062	0.075	0.063	0.065	0.066	0.063	0.063	0.069	<0.05	0.089	<0.05	0.089
Cadmium	**0.005**	**0.005**	0.067	0.076	0.053	0.059	0.073	0.064	0.078	0.065	0.067	0.069	0.064	0.066	0.068	0.022	0.092	0.022	0.092
Chromium	**0.1**	**0.1**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	**ns**	**ns**	0.016	0.018	0.013	0.014	0.018	0.016	0.019	0.016	0.016	0.017	0.015	0.016	0.017	0.005	0.022	0.0054	0.022
Copper	**1.0* (1.3**)**	**1.0* (1.3**)**	0.018	0.018	0.018	0.018	0.019	0.018	0.019	0.018	0.018	0.019	0.018	0.014	0.018	0.013	0.014	0.013	0.019
Iron	**0.6***	**0.3***	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	**0.015****	**0.015****	0.00053	0.00058	0.00044	0.00054	0.00052	0.00051	0.00061	0.00052	0.00053	0.00058	0.00048	0.00044	0.00045	0.00034	0.00052	0.00034	0.00061
Lithium	**ns**	**ns**	0.0090	0.0103	0.0072	0.0079	0.0098	0.0086	0.0104	0.0088	0.0090	0.0092	0.0086	0.0089	0.0093	0.0030	0.0124	0.0030	0.012
Manganese	**0.10***	**0.05***	1.4	2.5	0.67	1.6	1.2	1.2	2.3	1.3	1.4	1.9	0.93	3.7	0.62	0.40	5.3	0.40	5.3
Mercury	**0.002**	**0.002**	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0	<0.0002	<0.0002	<0.0002	<0.0002
Molybdenum	**ns**	**ns**	0.13	0.14	0.12	0.12	0.15	0.13	0.15	0.13	0.13	0.13	0.13	0.12	0.15	0.068	0.16	0.068	0.16
Nickel	**0.1**	**ns**	0.043	0.050	0.034	0.038	0.047	0.041	0.051	0.042	0.043	0.045	0.041	0.043	0.043	0.014	0.060	0.014	0.060
Selenium	**0.05**	**0.05**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	**0.1***	**0.1***	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	**ns**	**ns**	0.28	0.24	0.34	0.24	0.31	0.28	0.27	0.29	0.28	0.25	0.32	0.19	0.42	0.37	0.23	0.19	0.42
Thallium	**0.002**	**0.002**	0.00083	0.00077	0.00089	0.00072	0.00090	0.00082	0.00081	0.00083	0.00082	0.00077	0.00089	0.00065	0.00107	0.00081	0.00079	0.00065	0.00107
Tin	**ns**	**ns**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	**ns**	**ns**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc	**5***	**5***	3.5	5.7	1.8	4.1	3.1	3.1	5.7	3.3	3.5	4.8	2.5	4.9	1.7	1.2	6.9	1.2	6.9

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* Based on secondary standard. ** Based on lead and copper action levels *ns = no standard*

Exceedences of the Nevada Reference Standards are highlighted.

USEPA Drinking Water Maximum Contaminant Levels (MCLs) are also shown for reference only.

All concentrations are in milligrams per liter, unless otherwise noted.

< Analyte concentration result is below typical analytical detection limits. Value shown is the detection limit.

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Table 6.3 Base case and chemistry modeling sensitivity results summary

Parameter/ Analyte	Nevada Reference Standards	USEPA Drinking Water MCLs	Base Case	Unscaled HCT data	Scaled -10x HCT data	5 PVs flushing	20 PVs flushing	Early HCT data	Late HCT data	(Avg GW chemistry)	(High TDS GW)	(pCO_2 $10^{-3.5}$)	(pCO_2 $10^{-2.5}$)		
			Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Pit Lake (Time 200 yr)	Minimum	Maximum
pH, std units	**6.5 - 8.5***	**6.5 - 8.5***	7.7	7.6	7.9	7.7	7.7	7.6	7.6	7.7	7.7	8.2	7.3	7.3	8.2
Major Ions															
Alkalinity, as $CaCO_3$	**ns**	**ns**	59	45	86	59	59	42	44	58	58	54	65	42	86
Chloride	**400***	**250***	10.8	11	10.0	10.8	10.8	14	10.0	11.4	11.1	10.8	10.8	10.0	14
Fluoride	**4.0 (2.0*)**	**4.0 (2.0*)**	3.7	4.8	1.9	3.6	3.9	4.2	3.4	3.8	4.0	3.7	3.7	1.9	4.8
Nitrate, as N	**10**	**10**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphorus	**ns**	**ns**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Sulfate, as SO_4^{2-}	**500***	**250***	214	273	117	213	215	299	245	216	224	214	214	117	299
Calcium	**ns**	**ns**	62	67	56	62	63	71	59	62	69	62	62	56	71
Magnesium	**150***	**ns**	10.4	12	8.2	10.4	10.5	13	9.4	10.5	10.7	10.4	10.4	8.2	13
Potassium	**ns**	**ns**	6.8	8.6	3.9	6.8	7.0	14	4.1	6.8	10.5	6.8	6.8	3.9	14
Sodium	**ns**	**ns**	42	54	21	42	42	54	23	43	37	42	42	21	54
Metals/Metaloids															
Aluminum	**0.2***	**0.05-0.2***	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.000
Antimony	**0.006**	**0.006**	0.0076	0.0079	0.0072	0.0076	0.0077	0.0082	0.0075	0.0075	0.0132	0.0076	0.0076	0.0072	0.013
Arsenic	**0.01**	**0.01**	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Barium	**2**	**2**	0.010	0.008	0.015	0.010	0.010	0.0078	0.009	0.010	0.010	0.010	0.010	0.0078	0.015
Beryllium	**0.004**	**0.004**	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Bismuth	**ns**	**ns**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron	**ns**	**ns**	0.065	0.098	<0.05	0.063	0.069	0.080	<0.05	0.065	0.065	0.065	0.065	<0.05	0.10
Cadmium	**0.005**	**0.005**	0.067	0.10	0.010	0.067	0.067	0.085	0.10	0.067	0.067	0.065	0.067	0.010	0.10
Chromium	**0.1**	**0.1**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cobalt	**ns**	**ns**	0.016	0.024	0.0024	0.016	0.016	0.031	0.006	0.016	0.016	0.016	0.016	0.002	0.031
Copper	**1.0* (1.3**)**	**1.0* (1.3**)**	0.018	0.019	0.0053	0.018	0.018	0.0075	0.009	0.019	0.017	0.019	0.015	0.0053	0.019
Iron	**0.6***	**0.3***	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead	**0.015****	**0.015****	0.00053	0.00065	0.00015	0.00052	0.00053	0.00044	0.00031	0.00054	0.00050	0.00047	0.00048	0.00015	0.00065
Lithium	**ns**	**ns**	0.0090	0.0135	0.0013	0.0090	0.0090	0.042	0.0073	0.0090	0.0090	0.0090	0.0090	0.0013	0.042
Manganese	**0.10***	**0.05***	1.4	2.5	0.56	1.4	1.4	2.9	1.5	1.4	1.4	0.5	3.5	0.53	3.5
Mercury	**0.002**	**0.002**	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0	<0.0002	<0.0002	<0.0002	0.00025
Molybdenum	**ns**	**ns**	0.13	0.19	0.039	0.13	0.14	0.35	0.10	0.13	0.13	0.14	0.13	0.039	0.35
Nickel	**0.1**	**ns**	0.043	0.064	<0.01	0.043	0.044	0.056	0.021	0.043	0.043	0.041	0.044	<0.01	0.064
Selenium	**0.05**	**0.05**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	**0.1***	**0.1***	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Strontium	**ns**	**ns**	0.28	0.29	0.27	0.28	0.28	0.32	0.27	0.32	0.17	0.28	0.28	0.17	0.32
Thallium	**0.002**	**0.002**	0.00083	0.00098	0.00059	0.00083	0.00084	0.00103	0.00065	0.00081	0.0024	0.00083	0.00083	0.00059	0.0024
Tin	**ns**	**ns**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vanadium	**ns**	**ns**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Zinc	**5***	**5***	3.5	6.2	0.79	3.5	3.5	7.2	4.4	3.6	3.7	1.5	5.1	0.79	7.2

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* Based on secondary standard. ** Based on lead and copper action levels *ns = no standard*
Exceedences of the Nevada Reference Standards are highlighted.
USEPA Drinking Water Maximum Contaminant Levels (MCLs) are also shown for reference only.

All concentrations are in milligrams per liter, unless otherwise noted.
< Analyte concentration result is below typical analytical detection limits. Value shown is the detection limit.

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- fluoride – ranging between 2.8 and 4.6 mg/L; base case, 3.7 mg/L
- antimony – ranging between 0.0052 and 0.011 mg/L; base case, 0.0076 mg/L
- cadmium – ranging between 0.022 and 0.092 mg/L; base case, 0.067 mg/L
- manganese – ranging between 0.40 and 5.3 mg/L; base case, 1.4 mg/L
- zinc – ranging between 1.2 and 6.9 mg/L; base case, 3.5 mg/L

The following sensitivity runs predicted generally lower trace constituent concentrations:

- pit wall runoff coefficient – low stage
- lake evaporation rate – high stage
- multi-variable – high stage
- groundwater inflow rate – high stage

The following sensitivity runs predicted generally higher trace constituent concentrations:

- pit wall runoff coefficient – high stage
- lake evaporation rate – low stage
- multi-variable – low stage
- groundwater inflow rate – low stage

The groundwater inflow rate (low stage) and the multi-variable (low stage) scenarios resulted in the most variability and highest trace constituent concentrations, compared to the base case. The geochemistry model results were generally insensitive to changes in specific yield and lake conductance estimates.

6.3 Geochemical modeling sensitivity results

Sensitivity runs were performed based on varying chemical inputs to the model and geochemical modeling assumptions (Section 5.2). The results of these sensitivity runs are included in Appendix J, and summarized for the 200 year time step in Table 6.3. In addition, plots of key constituents are presented in Appendix J. Results for each run are described below.

6.3.1 Pit wall chemistry scaling sensitivity

To evaluate sensitivity on the scaling correction, the model was run using:

- unscaled HCT data, to represent a very conservative case
- HCT data scaled down one order of magnitude, to bracket the scaling effect

This range in scaling magnitude is consistent with, but conservative in comparison to a literature review of scaling factors, which suggested that laboratory data are approximately one to three orders of magnitude greater than field data.

Results of these two scenarios are included in Appendix J, and summarized for the 200 year time step in Table 6.3. In addition, plots of key constituents are presented in Appendix J. The unscaled data scenario predicts, at 200 years, a stable, neutral lake pH of 7.6 su, with an alkalinity of approximately 45-48 mg/L as $CaCO_3$. The scaled sensitivity run (one order of magnitude decrease) results in more alkaline water (pH of 7.9 su) with higher alkalinity (67–86 mg/L as $CaCO_3$).

Similar to the base case run, most trace metal/metalloid concentrations are low or below analytical detection. Consistent with the base case, the unscaled sensitivity run predicts concentrations of fluoride, antimony, cadmium, and manganese above Nevada reference standards during early pit lake filling and throughout the modeling period, while concentrations of zinc increase to just above the reference standards in later stages of pit filling due to evapoconcentration. In the scaled sensitivity run, only antimony, cadmium and manganese were predicted to exceed standards.

These two scenarios result in the widest range of pit lake water quality results, demonstrating the influence of the pit wall runoff chemistry on the lake water quality. The range of scaling presented in the sensitivity runs (unscaled to one order of magnitude decrease) represents a conservative level of scaling compared to the range of magnitude (up to 8 orders of magnitude decrease) supported by the literature review (Section 3.4.1).

A third sensitivity run was included to evaluate the influence of solute released during pit wall inundation and flushing (“submergence” term) (Section 3.3.2 and 5.2). The base case assumed a total of 10 pore volumes of solute released, and these sensitivity evaluations halved and doubled that estimate, respectively. The results of this run are presented in Appendix J and summarized in Table 6.3. Results of this sensitivity run are very similar to the base case scenario, both in concentrations and in constituents predicted to exceed reference standards (fluoride, antimony, cadmium, and manganese). This result demonstrates that the model predictions are not overly sensitive to the estimate of solute loading from the pit wall submergence term.

6.3.2 HCT chemistry sensitivity

The base case pit lake model uses average leachate concentrations to represent flushing over time from pit wall rocks. Two sensitivity runs were completed using early-stage release rates and late-stage release rates, respectively (Section 5.3). Results of these two scenarios are included in Appendix J, and summarized for the 200 year time step in Table 6.3.

As expected, sensitivity results based on early stage leaching from humidity cell tests (i.e., first flush) predict slightly lower pH conditions (7.6 su), lower alkalinity (42-48 mg/L as $CaCO_3$), and higher sulfate, fluoride, and metals (antimony, cadmium, manganese, molybdenum, and zinc) concentrations in the final pit lake chemistry. This result reflects rinsing of the salts and mobile minerals that are naturally present in the rock. Under field conditions, some of these solutes are rinsed from the pit wall during operations and pumped out of the pit; therefore, this sensitivity run is considered conservative compared to expected conditions.

Over time, minerals in the pit wall rock will weather producing secondary mineral phases, including products of prolonged sulfide oxidation and evaporation, which store acidity, metals and sulfate in secondary mineral phases. In particular, HCT materials identified as PAG produced elevated sulfate and metals concentrations and reduced pH in long-term HCT tests (SRK, 2008); this material conservatively makes up approximately 16 percent of the pit walls. Pit lake predictions based on late stage leaching are generally similar to the base case scenario. Concentrations of metals are similar, or lower, than the base case scenario with the exception of cadmium and zinc which are slightly higher. These sensitivity results indicate that elevated concentrations (due to long-term sulfide oxidation) in some late-stage HCT data do not significantly impact the overall pit lake chemistry.

6.3.3 Groundwater chemistry sensitivity

The groundwater inflow component to the pit lake model was subdivided into four quadrants, represented by groundwater quality data from a specific pumping well/piezometer from each quadrant (Section 3.3.3). Two sensitivity runs were conducted to evaluate uncertainty in the proportion of inflows from the four quadrants, as well as variability in the groundwater quality surrounding the pit (Section 5.4). The runs used average groundwater chemistry data and high TDS groundwater data, respectively, to represent the groundwater inflow term. The results of these runs are presented in Appendix J and summarized in Table 6.3. Results of these sensitivity runs were similar to the base case scenario, both in concentrations and in constituents predicted to exceed reference standards (fluoride, antimony, cadmium, and manganese). The high TDS groundwater model predicted slightly higher concentrations of fluoride, antimony and thallium, reflecting the higher concentrations in the PDT-3 groundwater sample. This result demonstrates that the model predictions are not overly sensitive to the estimated proportions of groundwater inflow from the four quadrants, or the variability in groundwater quality from the quadrants.

6.3.4 Atmospheric CO_2 (g) equilibrium sensitivity

For the base case model, the pCO_2 was set to slight oversaturation ($10^{-3.0}$ atm), based on observations at existing pit lakes (Eary, 1999) (Section 4.3). To evaluate the sensitivity of this estimate on the pit lake water quality predictions, the carbon dioxide partial pressure was varied from atmospheric equilibrium ($pCO_2 = 10^{-3.5}$ atm) to a higher degree of oversaturation ($pCO_2 = 10^{-2.5}$ atm). As would be expected, the carbon dioxide gas equilibria has a noticeable affect on the lake pH; the lake that is over-saturated with CO_2 (g) reflects a lower pH (7.3 su), while the lake equilibrated to atmospheric levels results in an alkaline lake (pH of 8.2 su). Other constituents, including levels of fluoride, antimony, and cadmium are consistent with base case modeling results. Concentrations of manganese and zinc are affected because these constituents are controlled in the model by carbonate mineral solubility. This sensitivity run indicates that while the lake pH is affected, the overall condition (neutral to slightly alkaline) of the lake is maintained, and the pit lake water quality is consistent with the base case.

6.4 Summary of model results

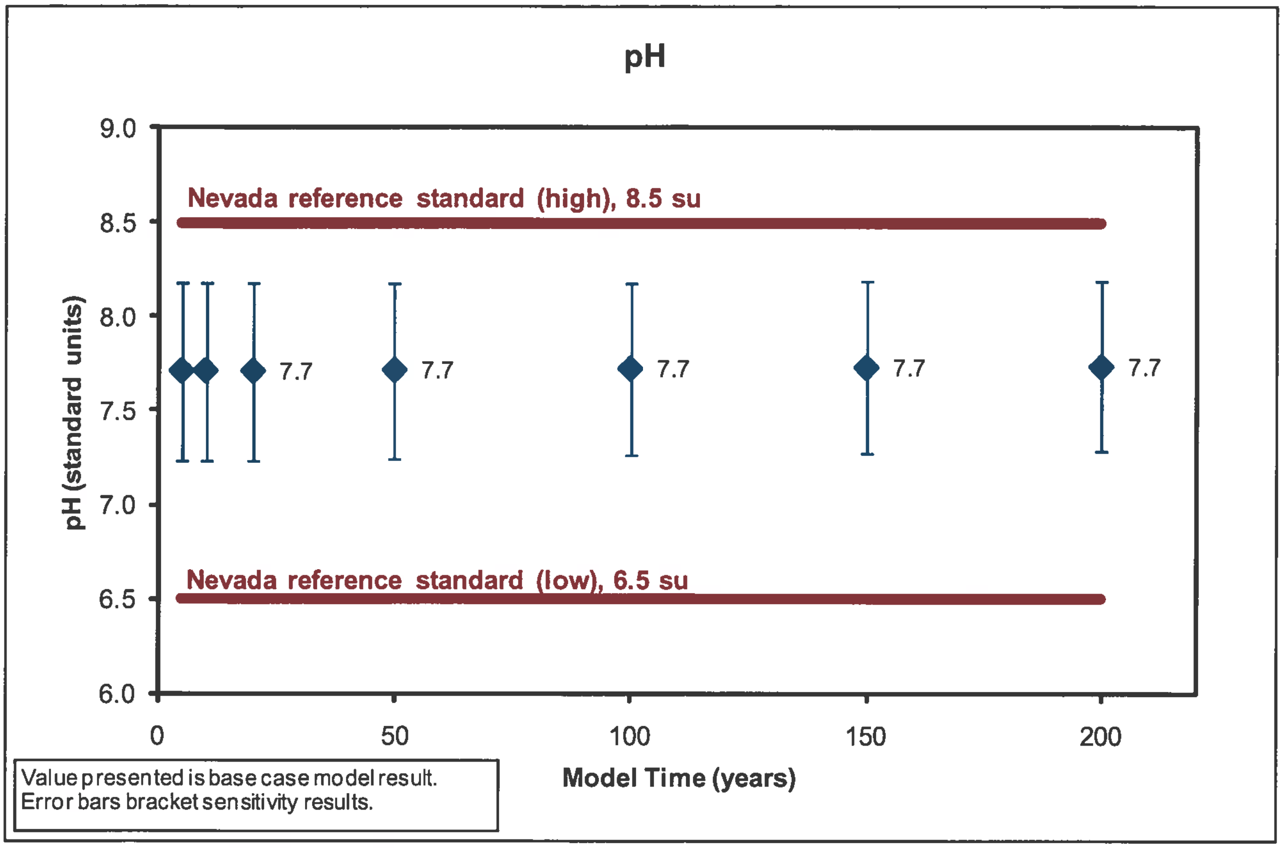
The relatively low groundwater inflow to the pit predicted by the groundwater model results in a long pit filling time. This results in pit walls being exposed to weathering and potential oxidation for a considerable time period. Although the actual groundwater inflow rate is low, as a relative proportion compared to other inflows (direct precipitation and pit wall runoff), groundwater makes up the majority of inflow, particularly in the first several years where it is estimated to approach 60 percent of the inflows to the lake. The next highest relative inflow is pit wall runoff, estimated to make up approximately 38 percent of inflows during that period. The quality of groundwater that is expected to enter the lake is well-buffered and overall good quality with the exception of fluoride, which is elevated; antimony is also present at low to moderate levels in groundwater. Materials exposed in the proposed pit walls show variable mass release characteristics, are generally not acid-generating, but can contain elevated cadmium, manganese, and zinc. Given these hydrologic and geochemical conditions, it would be expected that groundwater chemistry would be the major influence on the ultimate pit lake quality, with secondary influence from chemical mass release from the pit wall material.

The base case scenario represents the most likely pit lake water quality. For the base case, the pH is predicted to be neutral to slightly alkaline throughout pit filling to 200 years post-closure. Total alkalinity is predicted to be present at moderate concentrations, and will increase with time. Most trace metals/metalloid concentrations are low or below analytical detection;

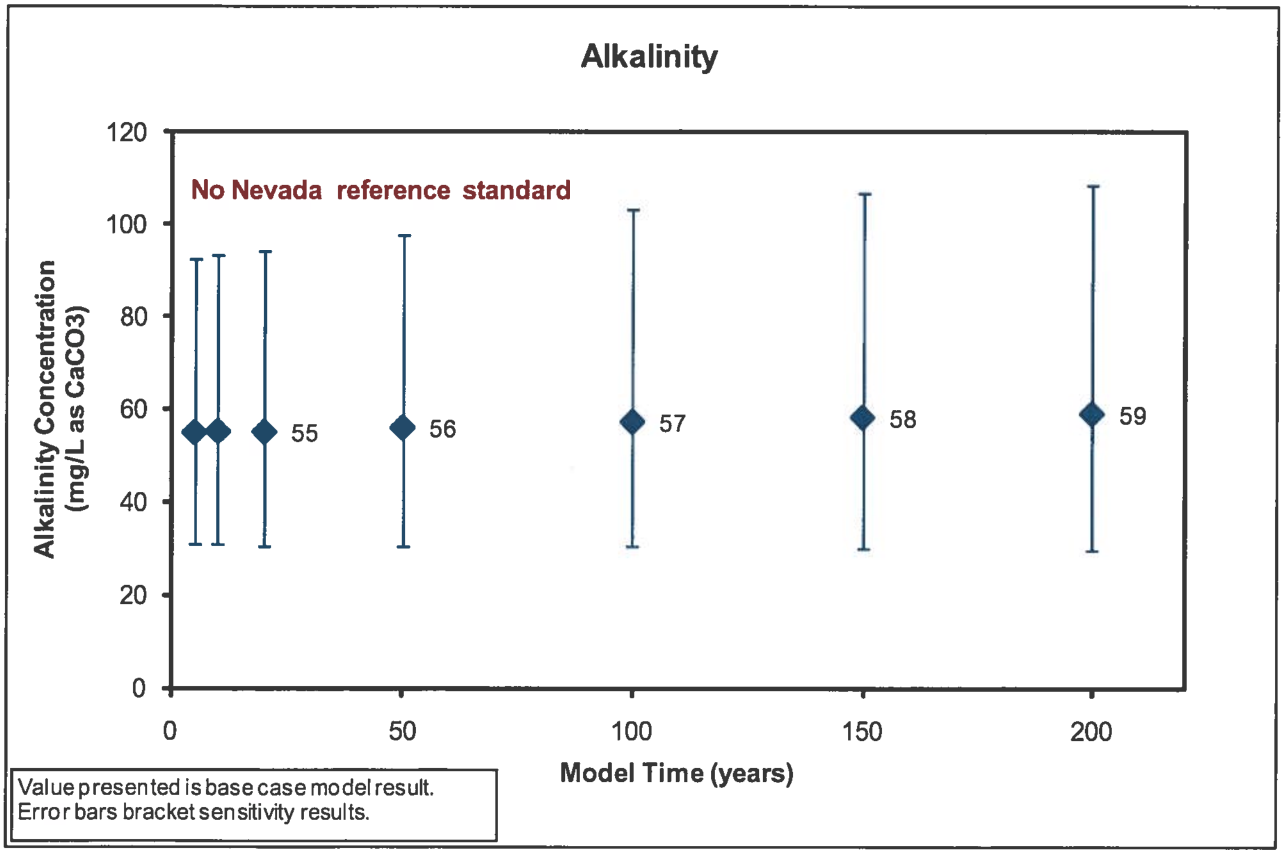
however, concentrations of fluoride, antimony, cadmium, and manganese are predicted to be above Nevada reference standards. The source of cadmium and manganese loading is pit wall runoff, while fluoride and antimony are present in both pit wall runoff and ambient groundwater. It should be noted that these predicted concentrations are considered conservative because some mechanisms of co-precipitation and adsorption, which will attenuate trace constituent concentrations, have not been included in the modeling.

Sensitivity analyses were completed to evaluate the effect of natural variation and uncertainty in hydrologic and geochemical parameters on predicted pit lake chemistry. As expected, changes in inputs do result in slight variations in predicted pit lake chemistry; however, the overall geochemical nature of the pit lake (neutral to alkaline pH, measureable alkalinity, low to moderate sulfate) remains consistent in all model runs. Similarly, the model runs consistently predict the same constituents as being elevated in predictable concentrations relative to the magnitude varied of the parameter being tested.

A comparison of the base case prediction to the various sensitivity analyses reveals that the model is most sensitive to (1) the relative percentage of groundwater inflow to the pit, (2) pit wall runoff chemistry scaling, and (3) changes in the pit wall leaching (HCT chemistry). Sensitivity analysis results also indicate that predicted pit lake chemistry is not overly sensitive to other uncertainties in the hydrologic parameters, groundwater chemistry data/inflow volumes and/or equilibration with atmospheric carbon dioxide.



Value presented is base case model result.
Error bars bracket sensitivity results.



Value presented is base case model result.
Error bars bracket sensitivity results.

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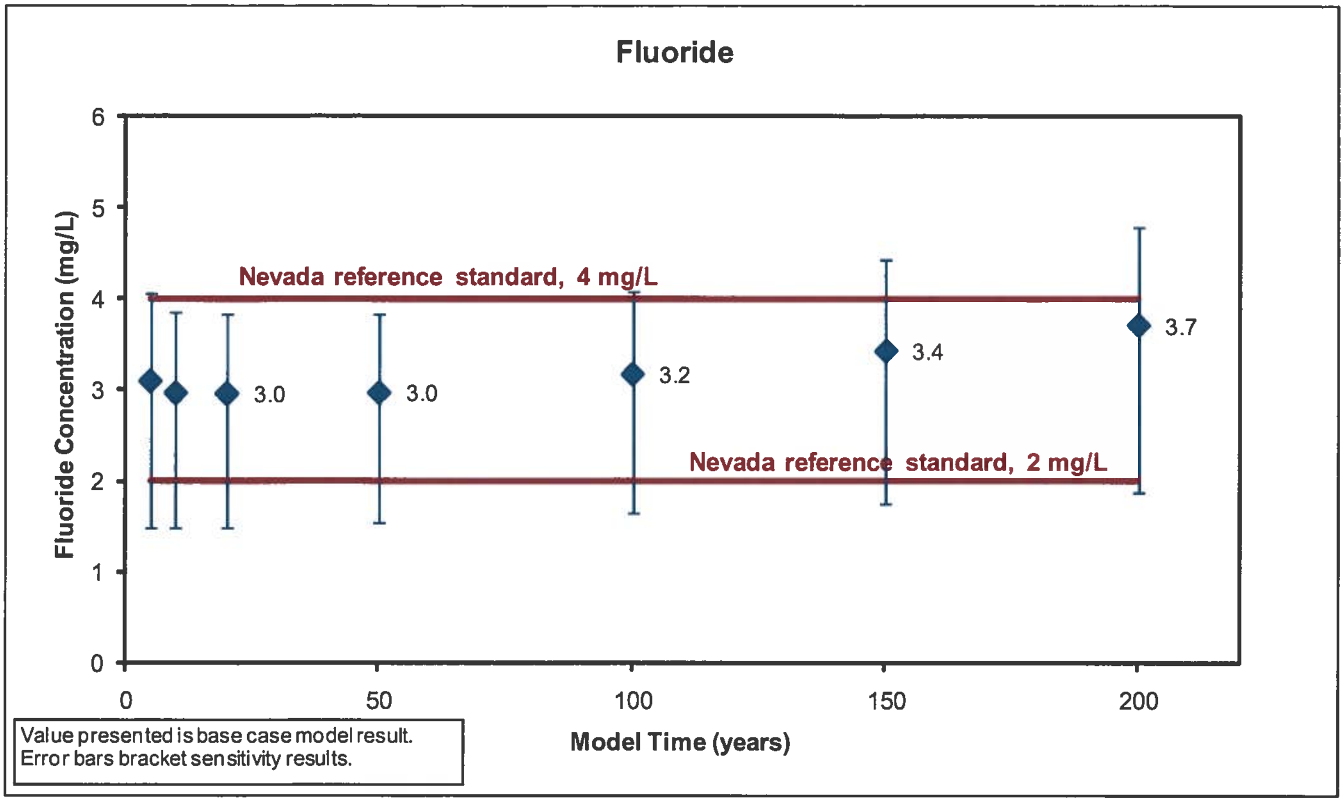
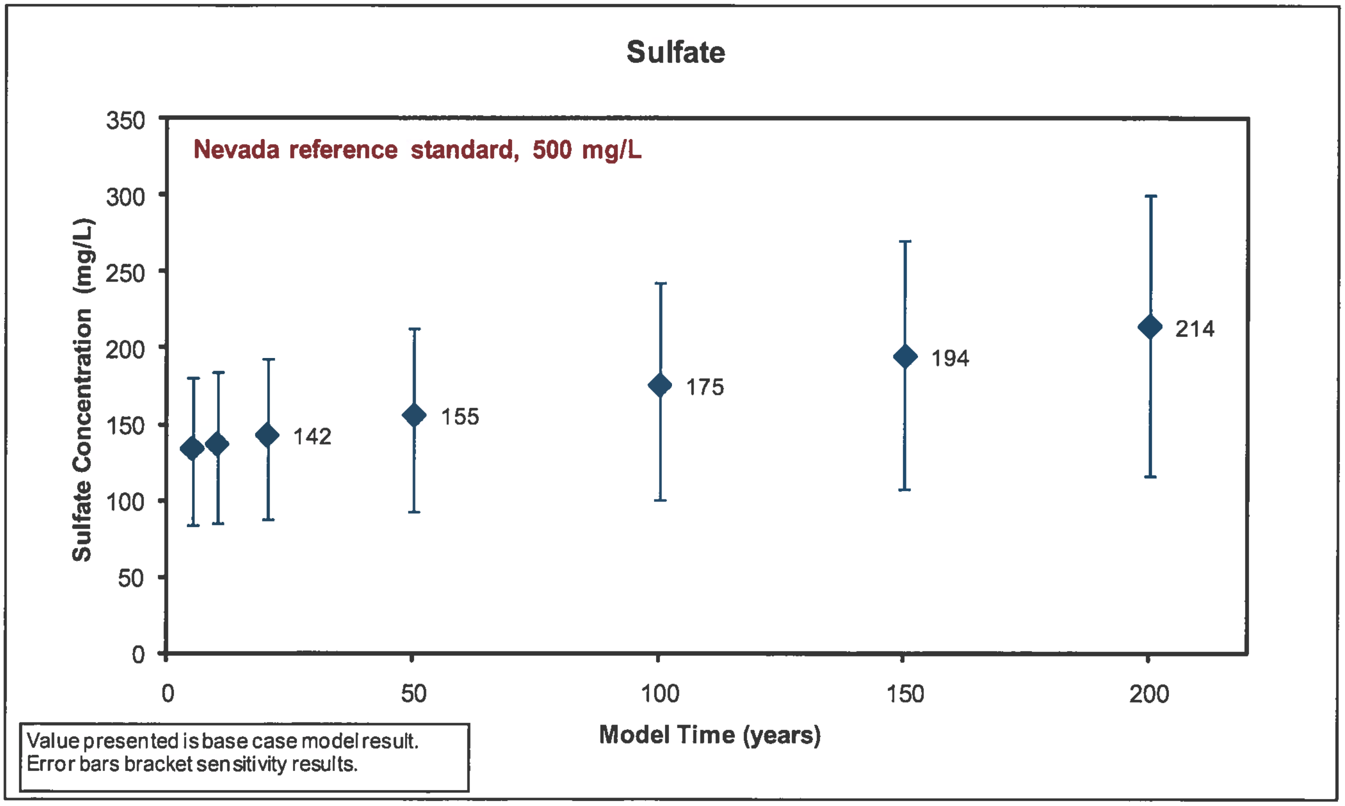
pH AND ALKALINITY RESULTS

CLIENT:	EUREKA MOLY, LLC	PROJECT:	MOUNT HOPE
JOB:	2910	DRAWN: RN	CHECKED: PR
DATE:	APRIL 2010	FIGURE:	6.1

P:\2910 - MT HOPE 2009\CAD\2910-R-APRIL-2010\FIGURE-6.1.DWG



Value presented is base case model result.
Error bars bracket sensitivity results.



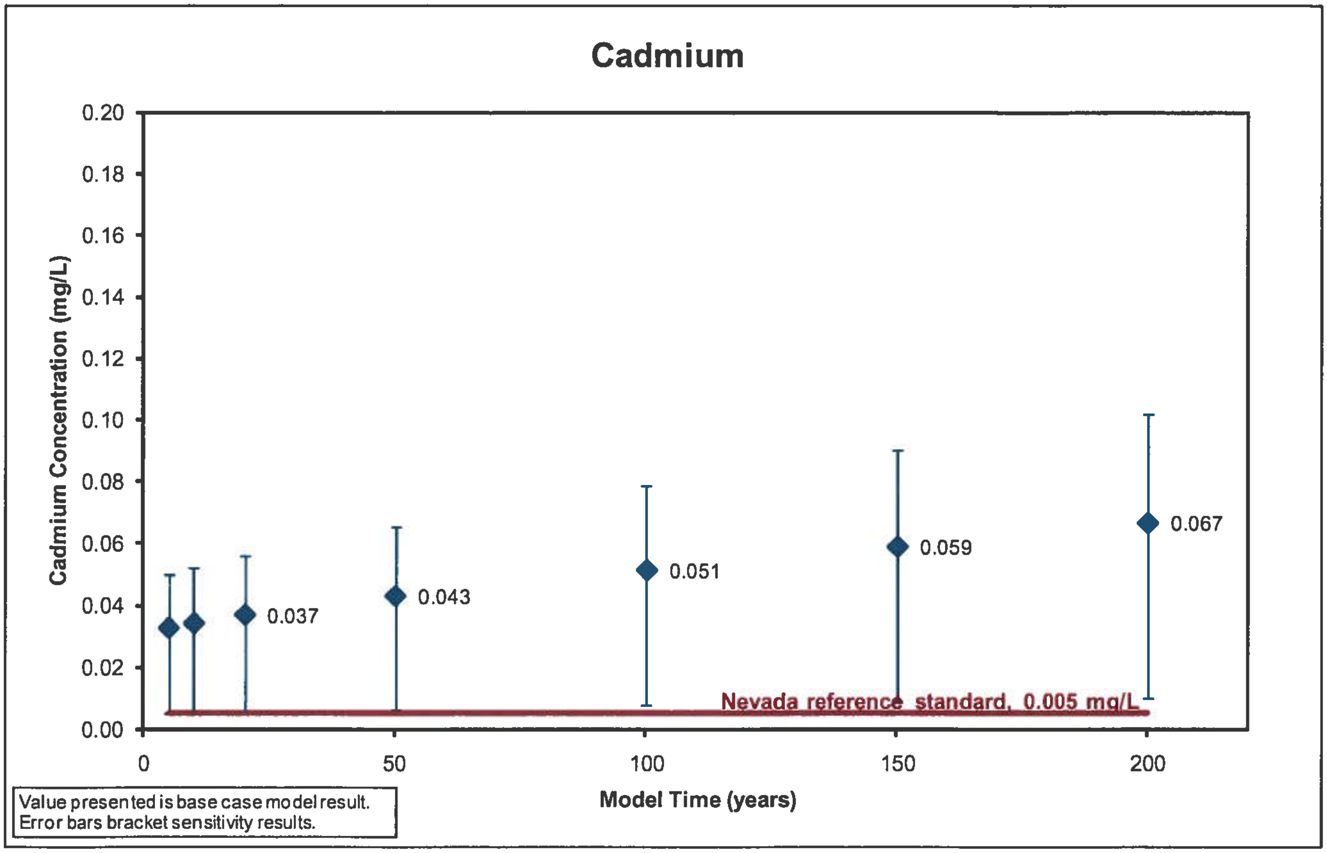
Value presented is base case model result.
Error bars bracket sensitivity results.

P:\2910 - MT HOPE 2009\CAD\2910-R-APRIL-2010\FIGURE-6.2.DWG

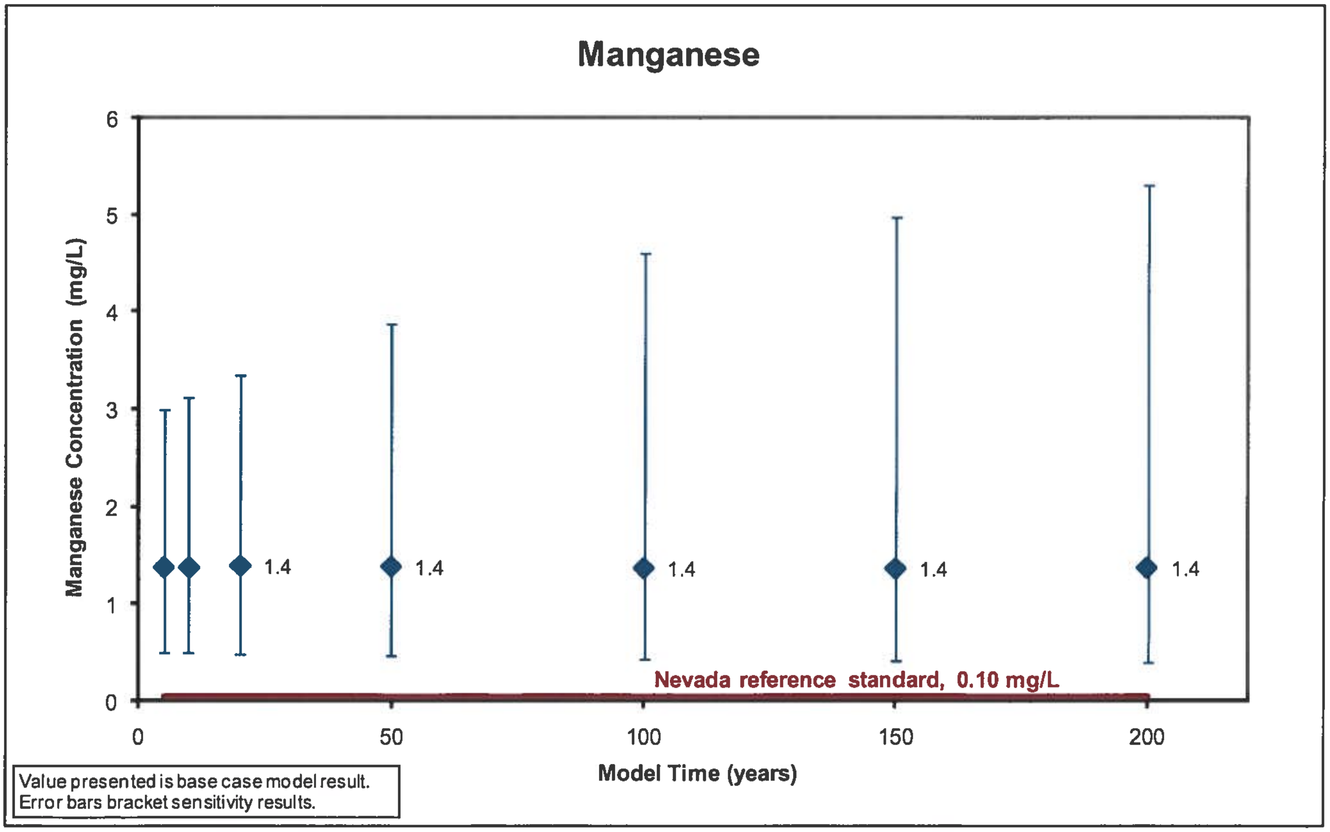
Schlumberger
WATER SERVICES

FLUORIDE AND SULFATE RESULTS

CLIENT: EUREKA MOLY, LLC		PROJECT: MOUNT HOPE	
JOB: 2910		DRAWN: RN	CHECKED: PR
DATE: APRIL 2010		FIGURE: 6.2	



Value presented is base case model result.
Error bars bracket sensitivity results.



Value presented is base case model result.
Error bars bracket sensitivity results.

P:\2910 - MT HOPE 2009\CAD\2910-R-APRIL-2010\FIGURE-6.3.DWG

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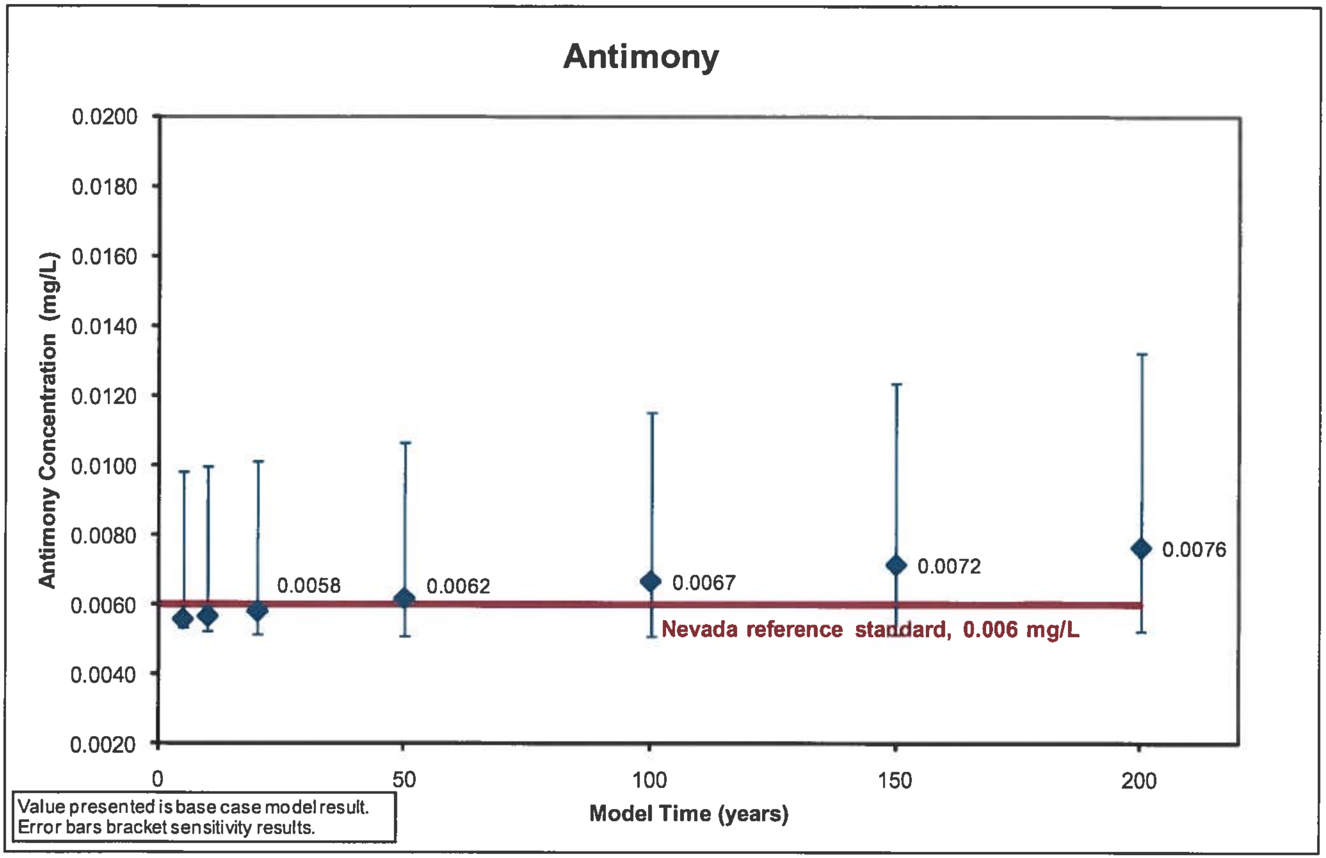
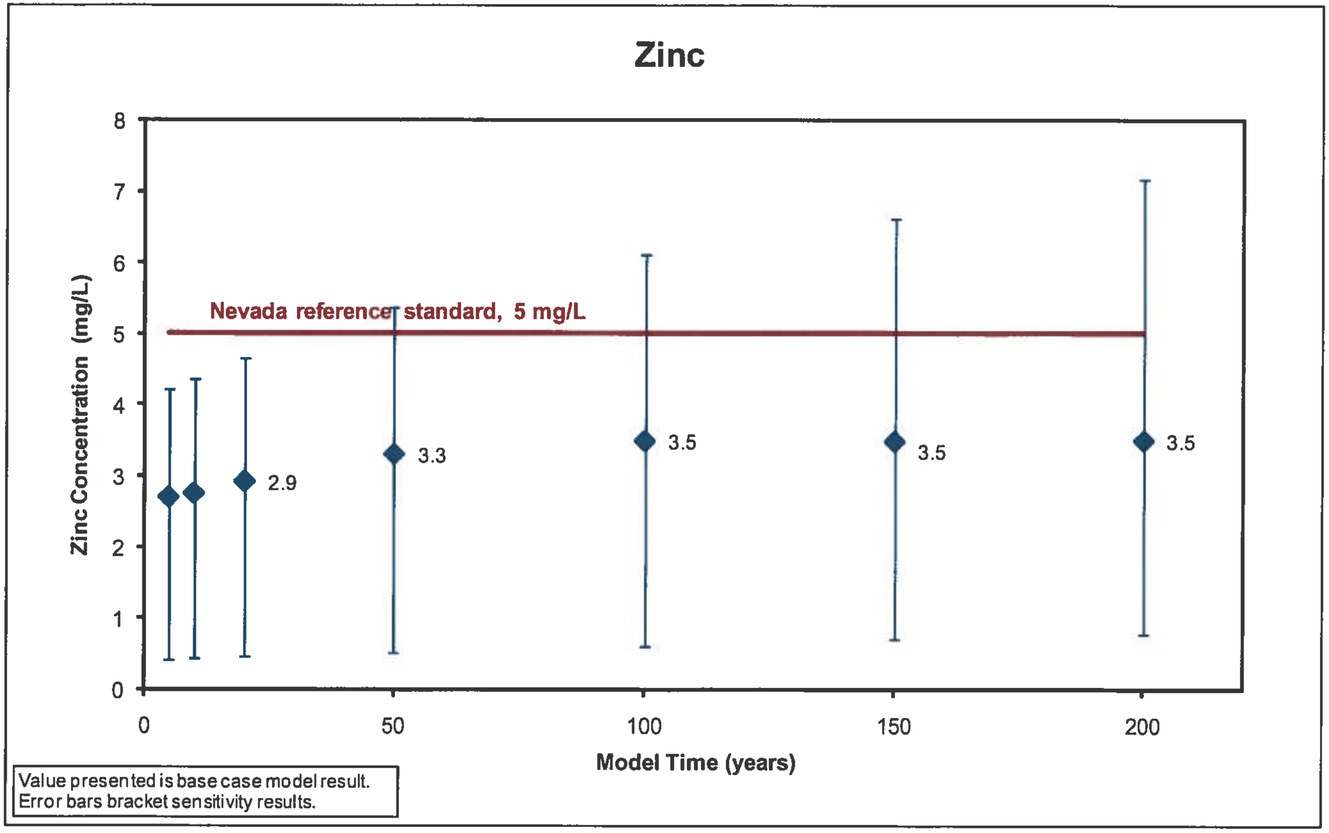
CADMIUM AND MANGANESE RESULTS

CLIENT: EUREKA MOLY, LLC
PROJECT: MOUNT HOPE
JOB: 2910
DRAWN: RN
CHECKED: PR
DATE: APRIL 2010
FIGURE: 6.3



Value presented is base case model result.
Error bars bracket sensitivity results.



Value presented is base case model result.
Error bars bracket sensitivity results.

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WATER SERVICES

ANTIMONY AND ZINC RESULTS

CLIENT: EUREKA MOLY, LLC	PROJECT: MOUNT HOPE
JOB: 2910	DRAWN: RN CHECKED: PR
DATE: APRIL 2010	FIGURE: 6.4

P:\2910 - MT HOPE 2009\CAD\2910-R-APRIL-2010\FIGURE-6.4.DWG

7 SUMMARY AND IMPLICATIONS FOR MINING

Post-closure water quality of the Mount Hope pit lake was evaluated based on the revised, local hydrogeologic model for the pit (Interflow and Montgomery, 2010). The water balance model predicts the final pit lake will act as a groundwater and surface water hydraulic sink, or "terminal lake", that is, that both groundwater and surface water gradients will be directed towards the pit both during filling and under long-term equilibrium conditions. Based on this result, no discharge from the lake is expected to occur.

The conceptual model developed for the Mount Hope pit lake geochemical predictions takes into account unique and site-specific geological, geochemical, and hydrologic factors. The conceptual model for pit filling includes direct precipitation onto the pit lake surface, pit wall runoff, and groundwater inflow. In addition, the geochemical model considers addition of solute introduced during pit wall submergence (i.e., flushing of solutes from the pit wall as the lake rises and lake water inundates the damaged rock zone of the wall). Detailed site-specific geological and geochemical data were used to characterize the influence of pit wall runoff and flushing (submergence), accounting for reaction with oxidized and weathered pit walls; scaled laboratory kinetic test data were used for this purpose. Only a small portion of the pit wall rock is considered potentially acid-generating; therefore, the pit wall rock runoff chemistry is dominated by rinsing of non-acid generating rock types. The only outflow from the pit lake is evaporation from the pit lake surface.

The geochemical model was used to predict pit lake chemistry at several time steps, ranging from 5 to 200 years post-closure, by mixing waters from the various inflow sources, evapoconcentrating the mixture, and then allowing the resulting water to equilibrate with specified mineral and gas species.

The base case simulation for the Mount Hope pit lake was designed to predict the most likely condition of future pit lake water quality. Because the pit lake is expected to act as a hydraulic sink, there will be no discharge from the pit to either groundwater or surface water; however, the pit lake water quality results have been compared to Nevada reference standards, for reference purposes only. These pit lake water quality predictions have been evaluated in terms of ecological risk, and are presented in a separate SLERA report (SRK, 2010).

The pH of the pit lake is predicted to be neutral to slightly alkaline, with a pH of approximately 7.7 su, throughout pit filling to 200 years post-closure. Total alkalinity is predicted to be present initially at moderate concentrations of approximately 55 mg/L as $CaCO_3$, and will increase with time. Sulfate concentrations are predicted to be low, ranging between 134 and 214 mg/L over the modeled time period.

Iron and aluminum concentrations are predicted to be below standard detection limits as a result of precipitation of secondary hydroxide mineral phases. Most trace metals/metalloid concentrations are low or below analytical detection; however, concentrations of fluoride, cadmium, and manganese are predicted to be present above Nevada reference standards during early pit lake filling and throughout the modeling period. Antimony concentrations are initially low, but are predicted to increase to just above the reference standard due to this evapoconcentration effect in the late stages of pit filling (by 50 years). In general, constituent concentrations in the pit lake are predicted to increase over time due to evapoconcentration.

Key model variables were modified from the base case to evaluate their sensitivity on predicted pit lake chemistry during the first 200 years of filling. The results of the pit lake water quality predictions were not overly sensitive to these runs in that the pit lake predictions were consistently neutral to slightly alkaline (pH greater than 7.0) with low to moderate alkalinity, and similar constituents of concern identified as exceeding reference standards throughout pit filling. In addition, some of the sensitivity runs identified zinc and thallium (the high TDS groundwater sensitivity model) as slightly exceeding reference standards during late-stage filling due to evapoconcentration in the pit lake. Results of these sensitivity runs do indicate that predicted pit lake water chemistry is mostly influenced by the chemistry of the groundwater and pit wall runoff. This is reflected in the model sensitivity to groundwater inflow contribution, pit wall runoff chemistry scaling, and the use of early-stage versus average HCT concentration data to represent pit wall runoff.

The sources of fluoride to the pit include both groundwater and pit wall rock rinsing. About half of the fluoride contribution from the wall rocks is leached from the quartz aplite porphyry material, exposed near the bottom of the pit. The primary source of antimony is groundwater inflow. In contrast, the only source of cadmium and manganese is pit wall rock flushing. The major contributing area for these constituents is the PAG-classified, argillic rhyolite tuff; this material is located high in the pit on the north to east pit walls.

It should be noted that these predicted concentrations are considered conservative because:

- The amount of PAG material exposed on the pit walls is a conservatively high estimate, due to limited available data in the vicinity of the final pit shell (Section 2.5.3).
- The specific surface area estimate for the pit walls is based on grain size data from waste rock piles; this is considered to be a conservative approximation that takes into consideration the range of grain-size material present in the fractured pit walls as well as the fine-grained materials which, over time, accumulate on pit benches. The effect is in a conservative level of scaling (30 percent decrease) for pit wall runoff chemistry (Section 3.4.2).
- Only a limited number of minerals were allowed (by the model setup) to precipitate in the pit lake, resulting in conservatively high concentrations of some dissolved constituents (Section 4.3.1).
- Various mechanisms of co-precipitation and adsorption, which in nature act to limit trace constituent concentrations, have not been included in the modeling either by design, to maintain conservative assumptions, or because thermodynamic data are not available (or thoroughly defensible) to define the behaviour in the geochemical model (Section 4.3.3).

Overall, water in the proposed pit lake is expected to be of generally good quality over the first 200 years of pit filling, with moderate, long-term alkalinity, low metals concentrations, and neutral to slightly alkaline pH.

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