

**APPENDIX B**  
**GENESIS PROJECT GEOCHEMISTRY**

## **APPENDIX B**

### **GENESIS PROJECT GEOCHEMISTRY**

#### **INTRODUCTION**

This section summarizes the geochemical characterization and geochemical modeling of the Genesis Project, conducted by Geomega, Inc. (Geomega) for Newmont Mining Company (Newmont). This review evaluates potential long-term environmental impacts of the Proposed Action and No Action alternatives associated with the Genesis Project. The Proposed Action involves expansion of mining activities and complete backfilling of the Bluestar and Beast pits, and partial backfilling of the Genesis pit, as described in Chapter 2 – “Proposed Action and Alternatives” of this Draft EIS. The No Action alternative would involve no change to the existing approved plan of operations. Under this alternative, backfilling of mine pits would not occur and a pit lake (about 40 acres) would form in the Genesis pit when dewatering of the Betze/Meikle-Post and Leeville mines is discontinued.

As part of the permitting process, geochemical properties of waste rock and pit wall rock were evaluated to assess geochemical effects to water resources, including groundwater, surface water, and for the No Action alternative, a pit lake that would develop in the Genesis pit. Newmont contracted Geomega to conduct the geochemical characterization of rock and to run numerical models to predict future environmental impacts resulting from each of the two alternatives (Geomega 2008a, 2008b, 2008c).

Predictive models generally incorporate integrated components that include water balance and chemical mass balance. The water balance typically includes surface water and groundwater flow components that estimate the movement of water in and out of the system. Chemical inputs to the system are generally derived from site-specific testing and are evaluated using geochemical models that can assess the contribution of precipitation/dissolution and adsorption/desorption reactions on chemical mass balance and transport.

The following sections present a review of geochemical inputs to the modeling completed to evaluate the Proposed Action and No Action alternatives.

#### **GEOCHEMICAL CHARACTERIZATION**

Geochemical inputs for the pit lake and flow/transport groundwater modeling were derived from pit wall rock and waste rock characterization studies conducted by Geomega (2008a). The objective of these studies is to:

- Assess the acid generating and acid neutralizing potential of exposed pit wall rock and waste rock; and
- Characterize potential leachate chemistry of wall rock and waste rock to provide geochemical inputs to the predictive models.

Under both alternatives, geochemical inputs to the models were derived from the same sampling and analytical data set.

The geochemical characterization involved a robust testing and analysis program that included:

- Net carbonate value (NCV) classification;
- Acid-Base Accounting (ABA);
- Whole rock chemistry;
- Mineralogy;
- Biological Acid Production Potential (BAPP);
- Peroxide Acid Generation;
- Paste pH;
- Meteoric Water Mobility Procedure (MWMP);
- Humidity cell;
- Field oxidation tests; and
- Batch attenuation testing.

The two primary lithological materials found at the Genesis Project site were classified by alteration type into six categories based on percent sulfide sulfur (SS) and percent carbonate carbon (CC) as shown in **Table B-1**.

<b>TABLE B-1</b>			
<b>Lithology and Alteration Classification</b>			
<b>Lithology</b>	<b>Alteration Type</b>	<b>Sulfide Sulfur (%)</b>	<b>Carbonate Carbon (%)</b>
Siliciclastic rocks	Oxidized siliceous (OS)	<0.2	--
Siliciclastic rocks	Unoxidized siliceous (US)	>0.2	--
Carbonate rocks	Oxide carbonate (OC)	<0.2	>0.5
Carbonate rocks	Unoxidized carbonate (UC)	<0.2	>0.5
Carbonate rocks	Oxide carbonate decalcified (OCD)	<0.2	<0.5
Carbonate rocks	Unoxidized carbonate decalcified (UCD)	>0.2	<0.5

Source: Geomega 2008c.

Genesis wall rock and waste rock from various lithologies, alteration types, depths, and locations were further classified following Newmont's standard net carbonate value (NCV) classification system, as shown in **Table B-2**. About 15,000 samples collected from 3,400 boreholes at the Genesis Project site were submitted for NCV analysis.

The NCV classification was used to describe exposed pit wall rock and backfill material to be placed in the Genesis and West Genesis pits. **Table B-3** shows the percentage of each type of material predicted to be exposed in the ultimate pit surface (UPS) or used as pit backfill. Based on the NCV classification, acidic and slightly acidic waste rock would comprise five percent of the proposed Genesis pit backfill and two percent of the West Genesis pit backfill for the Proposed Action. Acidic and slightly acidic mine pit wall rock that would be exposed for the Proposed Action and No Action alternatives are 14 and 11 percent, respectively, of the total pit wall surface.

<b>Code</b>	<b>Classification</b>	<b>NCV Range ( % )</b>	<b>Alteration Type</b>
1	Acidic	-5 < NCV ≤ -1	US, UCD
2	Slightly acidic	> -1 NCV ≤ -0.1	US, UCD
3	Inert/neutral	> -0.1 NCV < 0.1	US, OS, UCD
4	Slightly basic	≥ 0.1 NCV < 1	US, OS, UCD
5	Basic	≥ 1 NCV < 5	US, OS, OC
6	Highly basic	NCV ≥ 5	OC, OCD, UC

US = Unoxidized siliceous; UCD = Unoxidized carbonate decalcified; OS = Oxidized siliceous; OC = Oxide carbonate; OCD = Oxide carbonate decalcified; UC = Unoxidized carbonate.

<b>Classification</b>	<b>NCV Range ( % )</b>	<b>No Action</b>	<b>Proposed Action</b>		
		<b>Genesis Wall Rock (%)</b>	<b>Genesis Wall Rock (%)</b>	<b>Genesis Backfill (%)</b>	<b>West Genesis Backfill (%)</b>
Acidic	-5 < NCV ≤ -1	8	9	3	1
Slightly acidic	> -1 NCV ≤ -0.1	3	5	2	1
Inert/neutral	> -0.1 NCV < 0.1	5	6	8	12
Slightly basic	≥ 0.1 NCV < 1	51	39	40	68
Basic	≥ 1 NCV < 5	8	5	12	16
Highly basic	NCV ≥ 5	25	36	35	2

NCV = Net Carbonate Value

Newmont performed multiple static and kinetic tests to evaluate and validate the NCV criteria applicable to identifying potentially acid generating (PAG) rock. Additional NCV testing of 187 individual and 34 single lithology composite samples, combined with Acid Base Accounting results (Acid Generation Potential – AGP; Acid Neutralization Potential – ANP; and Net Neutralization Potential – NNP) for the 34 composite samples, demonstrated that approximately 29 percent of wall rock and waste rock samples from the Genesis complex can be expected to meet Bureau of Land Management (BLM) guidelines for non-acid generating rock. Due to the uncertainty about potential acid generation for the remaining samples, additional kinetic testing was performed (Geomega 2008a).

Twenty humidity cell tests were performed on representative lithologies, and the observed acid generation potential was used to evaluate the NCV classification system. **Table B-4** provides test results for NCV, paste pH, MWMP, ABA, BAPP, Peroxide Acid Generation, field oxidation, and mineralogy (alteration type) which were compared to the final pH and net alkalinity from the humidity cell tests to determine the appropriate criteria for classification of PAG material. Prediction results were compared to net alkalinity from humidity cell tests because they reflect more conservative conditions than field oxidation tests and they better represent longer-term potential of fully oxygenated samples to generate acidity (Geomega 2008a).

Newmont's standard NCV classification system (**Table B-2**) was relatively good (90 percent accuracy) at predicting the acid generating potential of most Genesis waste rock samples, but the humidity cell test results did not fully confirm the NCV classifications for "slightly basic" (Code 4) or "inert/neutral" (Code 3) (Geomega 2008a). Specifically, composite samples 7 and 8 (Code 3 and 4, respectively) produced acidity during the humidity cell testing, while eight composite samples (5, 6, 11, 15, 16, 19, 20 and 23) from Codes 3 and 4 did not produce acidity. The NCV data show 100 percent correlation for Codes 1 and 2 (PAG rock with NVC < -0.1 %) and Codes 5 and 6 (non-PAG rock with NCV > 1.5 %).

The addition of the paste pH predictor for samples where the paste pH  $\geq 6$  and NCV  $\geq 0$  % increases the predictive accuracy to 100 percent and was chosen over the other tests due to its ease of analysis. Comparison of the other tests to humidity cell net alkalinity showed the following predictive accuracies:

- MWMP based on sulfate minus net alkalinity being greater than 250 mg/L (100%)
- ABA NCV (80%)
- PAG pH (85%)
- BAPP pH (80%)
- NCV + PAG pH (90%)
- NCV + paste pH + PAG pH = MWMP (sulfate and alkalinity basis) (100%).

Using the NCV + paste pH classification system, material would be classified as PAG if one of the two following conditions occurs:

- NCV < 0 percent ; or
- NCV  $\geq 0$  percent and paste pH < 6.

Non-PAG material would be classified as follows:

- NCV  $\geq 0$  percent and paste pH  $\geq 6$ .

Based on this classification system and the Genesis plan of operations, a total of six percent waste rock (28 million tons) would be classified as PAG rock for the Proposed Action.

**Table B-4. Comparison of Humidity Cell and Paste pH Test Results with Other Tests for Waste Rock for Genesis Composite Samples.**

Waste Rock Composite ID	Location	Alteration Type	NCV Type	Static Test Results							Kinetic Test Results					
				NCV <sup>a</sup> (% CO <sub>2</sub> )	NCV <sup>b</sup> (% CO <sub>2</sub> )	Paste pH	MWMP	Acid-Base Accounting		Peroxide Acid Generation	BAPP	Humidity Cell Test Class		Field Oxidation Class after 26 months		
						pH (su)	Extract pH <sup>c</sup> (su)	NP/AP <sup>a</sup>	NCV <sup>a</sup> (ppt CaCO <sub>3</sub> )	Final pH <sup>d</sup> (su)	Final pH <sup>d</sup> (su)	Final pH <sup>c</sup> (su)	Net Alkalinity <sup>f</sup> (mg/kg)	pH (su)	Net Alkalinity (mg/kg)	
1	Bluestar	OC	Code 6	No 12.41	No 13.9	No 8.84	No 8.24	No no AP	No 282	No 8.42	---	No 7.11	No 801.63	7.36	No 1827	
3	Genesis 2	OC	Code 5	No 2.94	No 4.1	No 8.57	No 8.26	No 70.3	No 66.8	No 10.02	No 7.52	No 7.55	No 567.9	7.46	No 2170	
4	Genesis 3	OC	Code 6	No 13.9	No 15.9	No 8.63	No 8.32	No no AP	No 314.8	No 7.93	---	No 7.98	No 786.26	7.31	No 2656	
5	Bobcat	OCD	Code 3	Uncertain 0.07	Uncertain 0	No 7.51	No 8.19	Uncertain no AP	Uncertain 1.5	No 6.94	No 3.64	No 7.94	No 501.27	7.25	No 1828	
6	Bobcat	OCD	Code 4	Uncertain 0.26	Uncertain 0	No 7.28	No 8.11	Uncertain no AP	Uncertain 5.8	No 7.44	No 3.66	No 7.46	No 692.52	7.26	No 1838	
7	Genesis 1	OCD	Code 3	Uncertain 0.06	Uncertain 0	Yes 5.66	Yes 7.4	Uncertain no AP	Uncertain 1.3	No 4.67	Yes 3.43	Yes 4.45	Yes -85.56	7.17	No 1080	
8	Genesis 1	OCD	Code 4	Uncertain 0.21	Uncertain -0.1	Yes 5.3	Yes 7.18	Uncertain no AP	Uncertain 4.7	No 4.81	Yes 3.46	Yes 3.79	Yes -129.56	7.21	No 832	
10	Genesis 2	OCD	Code 6	No 5.22	Uncertain 0	No 8.07	No 8.79	No no AP	No 118.6	No 7.88	---	No 7.61	No 743.8	7.63	No 2657	
11	Genesis 3	OCD	Code 3	Uncertain 0.05	Uncertain -0.1	No 6.8	No 7.92	Uncertain no AP	Uncertain 1.1	No 6.49	No 3.67	No 7.74	No 219.17	7.37	No 1470	
15	Bobcat	OS	Code 3	Uncertain 0.01	Uncertain 0	No 7.43	No 8.65	Uncertain no AP	Uncertain 0.2	No 6	No 3.55	No 7.59	No 487.54	7.31	No 1552	
16	Bobcat	OS	Code 3	Uncertain 0	Uncertain 0	No 7.04	No 8.61	Uncertain no AP	Uncertain 0	No 5.54	No 3.53	No 7.7	No 185.33	7.27	No 1332	
19	Genesis 1	OS	Code 3	Uncertain 0.05	Uncertain 0	No 7.01	No 8.54	Uncertain 1.9	Uncertain 1.2	No 4.89	Yes 3.48	No 7.84	No 146.31	7.25	No 1254	
20	Genesis 1	OS	Code 3	Uncertain -0.07	Uncertain -0.1	No 6.99	No 8.39	Uncertain 0.1	Uncertain -1.6	No 5.34	No 3.59	No 7.83	No 333.32	7.24	No 1582	
21	Genesis 1	OS	Code 5	No 1.52	Yes -0.2	No 7.2	No 8.31	No 9.6	No 34.7	No 5.75	No 3.73	No 7.02	No 179.17	7.46	No 1612	
23	Genesis 2	OS	Code 4	Uncertain 0.32	Uncertain 0.3	No 7.47	No 8.67	Uncertain no AP	Uncertain 7.3	No 7.67	No 3.58	No 7.22	No 707.17	7.36	No 1650	

**Table B-4. Comparison of Humidity Cell and Paste pH Test Results with Other Tests for Waste Rock for Genesis Composite Samples.**

Waste Rock Composite ID	Location	Alteration Type	NCV Type	Static Test Results							Kinetic Test Results					
				NCV <sup>a</sup> (% CO <sub>2</sub> )	NCV <sup>b</sup> (% CO <sub>2</sub> )	Paste pH	MWMP	Acid-Base Accounting		Peroxide Acid Generation	BAPP	Humidity Cell Test Class		Field Oxidation Class after 26 months		
						pH (su)	Extract pH <sup>c</sup> (su)	NP/AP <sup>a</sup>	NCV <sup>a</sup> (ppt CaCO <sub>3</sub> )	Final pH <sup>d</sup> (su)	Final pH <sup>d</sup> (su)	Final pH <sup>c</sup> (su)	Net Alkalinity <sup>f</sup> (mg/kg)	pH (su)	Net Alkalinity (mg/kg)	
26	Genesis I/3	UCD	Code 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes		Yes
				-1.85	-1.5	4.11	3	0	-42.1	2.44	2.2	2.24	-11648.86	5.26	-3771	
27	Genesis I	UCD	Code 2	Yes	Yes	Yes	Yes	Uncertain	Uncertain	Yes	Yes	Yes	Yes		No	
				-0.54	-0.4	4.68	4.75	0.1	-12.4	3.25	3.3	2.81	-803.2	6.92	443	
30	Genesis I	US	Code 1	Yes	Yes	No	Yes	Uncertain	Yes	Yes	Yes	Yes	Yes		No	
				-1.75	-0.5	6.1	6.48	0.1	-39.7	2.42	2.22	2.33	-3361.64	6.72	368	
31	Genesis I	US	Code 2	Yes	Uncertain	No	Yes	Uncertain	Uncertain	Yes	Yes	Yes	Yes		No	
				-0.44	0.4	6.8	7.61	0.6	-10	2.89	3.48	2.62	-1009.49	7.07	735	
34	Genesis I	US	Code 5	No	No	No	No	No	No	Yes	Yes	No	No		No	
				2.41	0.9	6.99	7.53	3.2	54.7	3.32	3.43	6.66	181.34	7.12	1203	

<sup>a</sup>Newmont Metallurgical Services

<sup>b</sup>SVL Analytical Inc.using a modified Sobek method with a Hot DI Water Rinse

<sup>c</sup>McClelland Laboratories Inc.

<sup>d</sup>Little Bear Laboratories Inc.

NOTES:

Alteration types: OS (oxide siliceous), US (unoxidized siliceous), OC (oxide carbonate), OCD (oxide carbonate decalcified), UC (unoxidized carbonate), UCD (unoxidized carbonate decalcified). See Table B-2 for NCV Type descriptions.

NP = Neutralization Potential; AP = Acidification Potential; NNP = Net Neutralization Potential; NCV = Net Carbonate Value; MWMP = Meteoric Water Mobility Procedure; BAPP = Biological Acid Production Potential;

su = standard units; ppt = parts per thousand; TCaCO<sub>3</sub>/k = tons calcium carbonate per kiloton; %CO<sub>2</sub> = percent carbon dioxide; mg/kg = milligrams per kilogram. "----" = not tested.

"Yes" = Yes for acid generating potential (cells are shaded); "No" = No for acid generation potential; "Uncertain" = uncertain acid generation potential.

Composite IDs are shaded when the NCV < 0 or the NCV ≥ 0 and paste pH < 6 criteria predicts acid generation.

The following criteria are used to determine "Yes", "No", and "Uncertain":

NP:AP --- "Yes" = 0; "No" > 3; "Uncertain" > 0 and ≤ 3.

NNP --- "Yes" < -20; "No" > +20; "Uncertain" ≥ -20 and ≤ +20.

NCV --- "Yes" NCV < -0.1; "Uncertain" -0.1 ≥ NCV < 0.9; No" NCV ≥ 0.9.

MWMP --- MWMP extract pH is "Yes" if the Sulfate - Net alkalinity > 250 mg/L.

Peroxide Acid Generation --- "Yes" <4.5; "No" ≥ 4.5.

Paste pH --- "Yes" < 6.0; "No" ≥ 6.0.

Humidity Cell --- "Yes" pH < 5.0 or net alkalinity <0; "No" pH ≥ 5.0 or net alkalinity ≥ 0.

BAPP --- "Yes" < 3.5; "No" ≥ 3.5. Note: False Positive test if PAG pH is >4.5.

Field Oxidation Tests --- "Yes" net alkalinity <0; "No" net alkalinity ≥ 0.

Source: Geomega 2008a (Modified from Table 4-10 of Newmont Genesis Project, Characterization of Wall Rock and Waste Rock Chemistry)

## NO ACTION ALTERNATIVE

The geochemical characterization and modeling conducted under the No Action alternative assumed no expansion or backfilling of the existing Genesis pit. Objectives of the study include:

- Predict chemistry of Genesis pit lake water;
- Assess potential future impacts to groundwater adjacent to the pit; and
- Identify potential effects to human health and/or biota.

### Hydrologic Inputs to Pit Lake

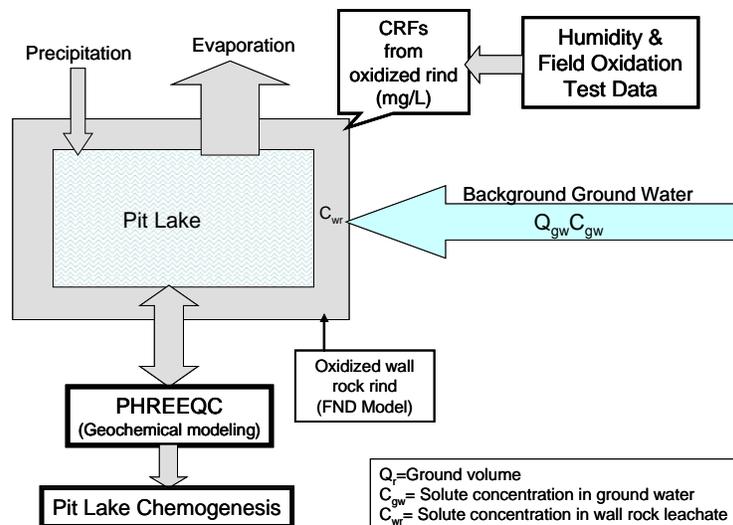
Water inflows and outflows associated with the Genesis pit are expected to come from the following sources:

- Meteoric precipitation (rain and snow) falling on the pit lake surface;
- Surface runoff from pit walls (incident precipitation);
- Groundwater flow through the pit walls; and
- Evaporation.

It was assumed for the model that surface runoff from outside the Genesis pit would be collected by storm water diversion systems and diverted around the pit. A schematic showing various components of the water balance is shown on **Figure B-1**.

Since 1990, Newmont has contracted with Hydrologic Consultants, Inc. (HCI) to develop, maintain, and update a numerical model that simulates groundwater flow in the northern Carlin Trend (i.e., Carlin Trend Model) (HCI 2007). The Carlin Trend Model provides predicted groundwater fluxes into and out of the Genesis pit lake for the chemical modeling conducted by Geomega (2008b). Meteoric precipitation (11.5 in/yr) and evaporation (45.5 in/yr) used in the model were also provided from the HCI (2007) model. Surface water runoff from the pit walls was excluded from model simulation because the volume of water from this source was considered negligible to the water balance and pit lake chemistry (Geomega 2008b). This was consistent with assumptions by HCI (2007) that pit wall runoff was negligible in the context of the entire pit lake water balance. While the total contribution of water volume from this source may be negligible, the solute loading associated with wall rock leaching for hundreds of years could influence overall pit lake chemistry and is addressed later in this appendix.

Chemical mass entering the Genesis pit lake is derived from the solutes dissolved in background groundwater, and solutes leached from the oxidized rind of the pit walls as incoming groundwater passes through the rind and enters the pit (**Figure B-1**). Background groundwater chemistry was defined by groundwater data collected at monitoring well GEN-39 (**Table B-5**), which is located within the current Genesis pit (Geomega 2008b). Well GEN-39 was selected to represent background groundwater because: (1) the well is completed in a mineralized zone of the Genesis pit; and (2) Genesis pit infilling will come mostly from carbonate rocks of the same formation (Geomega 2008b; HCI 2007).



**Figure B-1. Schematic of Pit Lake Modeling Components for No Action Alternative**

Chemical inputs used to predict the contribution of wall rock leachate to chemical mass loading were derived from humidity cell and field oxidation tests, calculated chemical release functions (CRFs), and the Fennemore-Neller-Davis (FND) pyrite oxidation model (**Figure B-1**).

### Humidity Cell and Field Oxidation Testing

From 533 rock samples, 34 composite samples were established. From this set of composite samples, 20 samples representing all NCV types were selected and used in the humidity and field oxidation testing to evaluate the rate of pyrite oxidation and leaching behavior of metals and major ions.

### Chemical Release Functions

The mass flux of any given constituent to groundwater passing through the oxidized rind of the Genesis pit walls is defined by the chemical release functions and the thickness of the wall rock oxidation rind (**Figure B-1**). Chemical release functions are empirically derived from curves fit to pore volume versus solute release data obtained from humidity cell and field oxidation testing (Geomega 2008b).

### Oxidation Modeling

The extent of wall rock oxidation was estimated using the FND pyrite oxidation model (Fennemore *et al.* 1998). The FND model simulates sulfide oxidation reactions based on transport of oxygen and water within each NCV type, accounting for enhanced oxidation rates due to the presence of macrofractures in the pit walls. The FND model uses site-specific input parameters including wall rock fracture density, wall rock particle size, rock porosity, wall rock pyrite density, mass of oxygen per mass of sulfur consumed, wall rock thickness, oxygen diffusion rate through pore space, and oxygen diffusion rate through particles to estimate the thickness of wall rock oxidation rind and, thereby, the mass of wall rock contributing solute mass.

Parameter	Concentration in milligrams per liter (mg/L) unless otherwise noted			
	Influent Groundwater	Predicted Final Chemistry of Pit Lake using Field Oxidation Test	Predicted Final Chemistry of Pit Lake using Humidity Cell Test	Nevada Municipal or Domestic Supply
Alkalinity	135.0	426.1	418.0	NS
Aluminum	<0.037	0.085	0.083	NS (0.05*)
Antimony	0.009	0.079	0.079	0.146 (0.006*)
Arsenic	0.400	2.921	2.942	0.05 (0.01*)
Boron	0.08	0.66	0.90	NS
Barium	0.06	0.017	0.017	2.0
Beryllium	<0.002	0.007	0.007	0.004
Calcium	39.20	7.14	7.37	NS
Cadmium	<0.002	<0.002	<0.002	0.005
Chloride	26.0	190.4	190.3	250
Chromium	<0.008	0.042	0.043	0.1
Copper	<0.004	0.035	0.036	NS (1.3*)
Fluoride	0.40	3.14	3.13	NS (4.0*)
Iron	<0.019	<0.019	<0.019	NS (0.3*)
Lead	<0.002	0.013	0.013	0.05 (0.015*)
Mercury	<0.0002	0.0012	0.0012	0.002
Magnesium	15.5	112.6	112.6	NS
Manganese	0.05	<0.05	<0.05	NS (0.05*)
Nickel	<0.016	0.606	0.606	0.0134
Nitrate-N	0.52	4.09	4.07	10
pH (std. units)	7.99	8.65	8.64	5.0-9.0 (6.5-8.5*)
Potassium	3.00	22.62	22.56	NS
Selenium	<0.048	0.181	0.181	0.05
Silver	<0.005	0.028	0.030	NS (0.1*)
Sodium	29.5	215.7	215.7	NS
Sulfate	47.0	342.2	342.1	250
Thallium	0.003	0.026	0.026	0.013 (0.002*)
Zinc	<0.004	0.036	0.044	NS (5.0*)

from Groundwater Monitoring Well GEN-39. Shaded cells exceed at least one of the water quality standards in the last column. Source: Geomega 2008b.

based on modeling using chemical release functions based on 12-month field oxidation test results; these are maximum concentrations after 436 years of groundwater recovery, except for barium and calcium which are based on 25 years of infilling. Shaded cells exceed at least one of the water quality standards in the last column. Source: Geomega 2008b.

based on modeling using chemical release functions based on humidity cell test results; these are maximum concentrations after 436 years of groundwater recovery, except for barium and calcium which are based on 25 years of infilling. Shaded cells exceed at least one of the water quality standards in the last column. Source: Geomega 2008b.

<sup>4</sup> NS = no standard. State water quality standards are from Nevada Administrative Code 445A.144. Values with an asterisk (\*) are federal primary or secondary drinking water standards from 40 CFR Parts 141 & 143.

## Pit Lake Modeling

In the pit lake model, influent water from all sources and the respective chemical masses are proportionally mixed with the existing volume of water in the pit lake from the previous year. Effluent from evaporation is removed as pure water. The resulting solution composition is imported into the geochemical model PHREEQC (**Figure B-1**) which allows for equilibration of the solution with atmospheric gases and potential and/or existing solid phases, and simulation of adsorption reactions involving amorphous ferric hydroxide (AFH).

Solubility controls or equilibrium phases incorporated into the geochemical model include carbon dioxide ( $\text{CO}_2$ ), oxygen ( $\text{O}_2$ ), barite ( $\text{BaSO}_4$ ), calcite ( $\text{CaCO}_3$ ), ferrihydrite ( $\text{Fe}(\text{OH})_3$ ), gibbsite ( $\text{Al}(\text{OH})_3$ ), gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ), manganite ( $\text{MnO}(\text{OH})$ ), and otavite ( $\text{PbCO}_3$ ).

### Pit Lake Modeling Results for No Action Alternative

Groundwater modeling (HCI 2007a) predicts that the Genesis pit lake will begin to form approximately 113 years after dewatering ceases at the Leeville Mine in year 2018, and that infilling will start in about year 2130 and be 90 percent complete within the first 216 years, with complete filling after 436 years. The model predicts the Genesis pit lake will evolve to an alkaline lake (pH ~ 8.6) and contain some chemical constituents above state and/or federal drinking water standards (**Table B-5**). The drinking water standards are used only for comparative purposes as groundwater in the Project area is not used for drinking. The following constituents in influent groundwater exceed drinking water standards (**Table B-5**):

- Antimony
- Arsenic
- Thallium

The following constituents are predicted to exceed drinking water standards for modeled maximum concentrations in the final pit lake (all of which would occur after 436 years of groundwater recovery, except for barium and calcium, which would reach maximum concentrations after 25 years recovery) (**Table B-5**):

- Aluminum
- Antimony
- Arsenic
- Beryllium
- Nickel
- Selenium
- Thallium
- Sulfate
- pH

The Genesis pit lake would be a terminal lake during groundwater recovery and, therefore, most constituent concentrations would increase with time due to the effects of evapoconcentration. Model results indicate there would be a small amount of groundwater throughflow (1 to 2 gal/min) after the pit

lake reaches steady-state conditions (HCI 2007a). This low rate of groundwater flux is well within the margin of error of model results and is a minor percentage of regional groundwater flow; therefore, the modeled throughflow condition at the Genesis pit may not occur (HCI 2007a). The groundwater throughflow condition is based on model results where regional groundwater would flow from the Genesis Project area toward the Betze/Post-Meikle mine area where water levels are predicted to be approximately 20 feet lower than at the Genesis Project area.

Model results using humidity cell or field oxidation test data as chemical inputs were similar due to the dominant contribution from groundwater (**Table B-5**). Removal of constituents via adsorption to amorphous ferric hydroxide was predicted to be minimal because of the low influent flux of iron. The model predicted precipitation of barite, calcite, and otavite, which controlled the concentrations of barium, calcium, and cadmium, resulting in a decreasing concentration trend for these elements. These results and conclusions are consistent with other pit lake modeling studies for lakes that form in carbonate buffered systems (Eary 1998).

Because the Genesis pit lake is predicted to be a sink for at least 400 years, it is unlikely there would be adverse impacts from the lake on adjacent groundwater. However, the creation of a large, open water body with elevated levels of numerous chemical constituents, including metals, could pose a risk to both human health and biota. As noted above under the *Hydrologic Inputs to Pit Lake* section, omission of wall rock runoff as a source of chemical mass loading could bias the prediction of water quality, resulting in an underestimation of solute concentrations. This omission however, does not affect the primary conclusions of the modeling that the pit lake will evolve to contain some constituents above background groundwater quality and above state and/or federal drinking water standards.

## PROPOSED ACTION ALTERNATIVE

The Proposed Action for the Genesis project would deepen and expand the Genesis pit, create a smaller pit immediately west of the Genesis pit (West Genesis), and backfill a portion of both pits with waste rock. The bottom elevation of the Genesis and West Genesis pits are planned to be 4640 and 4829 feet above mean sea level (amsl), respectively. The Genesis and West Genesis pits would be backfilled primarily with non-PAG waste rock. Any PAG waste rock would be isolated in “cells” above an elevation of 5370 feet amsl which is above the pre-mining groundwater level of 5267 feet amsl. Dewatering associated with mining at Meikle, Betze/Post, and Leeville will lower the water table >1,100 feet below the base of the Proposed Action Genesis Pit by year 2018, and backfill in the Genesis pit is not expected to begin refilling with groundwater until year 2054. The lower portion of the Genesis and West Genesis pits (below 5225 feet amsl) will eventually become inundated with groundwater after mine dewatering activities cease.

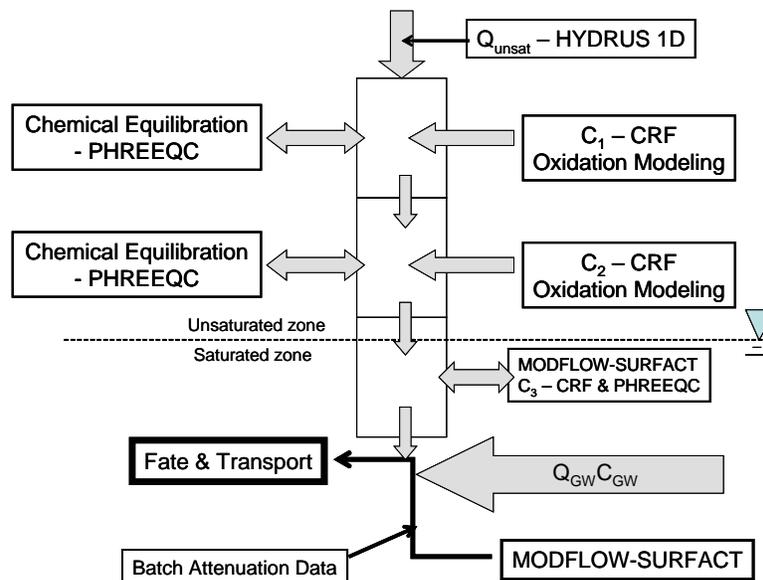
Newmont and Geomega evaluated the following: (1) potential impacts to groundwater resulting from placement of waste rock into the deepened and expanded pits, which would eventually become inundated with groundwater; and (2) potential impacts to groundwater from placement of waste rock in dry pits and waste rock disposal facilities at ground surface.

A combination of numerical models including unsaturated zone, saturated flow, oxidation, geochemical, and transport modeling were coupled to evaluate potential impacts from solute loading under the Proposed Action (i.e., changes to existing mine plan) to groundwater in and near the Genesis Project area. Two numerical models were employed:

- HYDRUS 1D – quantify infiltration through waste rock disposal facilities and backfilled pits under unsaturated conditions, and assess the efficacy of cover materials placed over the backfill.
- MODFLOW-SURFACT – evaluate chemical fate and transport under variable saturated and completely saturated conditions.

Numerical model inputs and outputs were supported with oxidation modeling (Davis-Ritchie), geochemical modeling (PHREEQC), and additional geochemical data from batch tests (Geomega 2008a, 2008c).

As was the case in the pit lake model, groundwater quality will depend on chemical mass loading to water moving through the waste material. **Figure B-2** is a schematic diagram of hydrologic and geochemical components of the modeling. These generalized components are used to develop modeling of pit backfill and waste rock disposal facilities.



**Figure B-2. Schematic of Waste Rock Modeling Components for Proposed Action**

### Unsaturated Zone Loading Modeling

Unsaturated zone modeling was conducted to quantify the amount and timing of infiltration through the backfill materials and to assess the effects of reduced infiltration resulting from placement of a cover on top of the backfill. Results from the unsaturated zone modeling are used as inputs to both the local-scale groundwater model and the geochemical models to predict chemical mass loading during the period when backfilled waste rock is unsaturated.

### *HYDRUS-1D Modeling*

As shown in **Figure B-2**, water flux into each cell in the unsaturated zone is estimated with HYDRUS-1D. Details of the hydrologic input parameters used for the Hydrus modeling are provided by Geomega (2008c). To simulate unsaturated flow through backfill, a one-dimensional soil column with a total depth of 730 feet was created to represent the thickest backfill profile; then observation points were specified at several depths to evaluate infiltration within the backfill. Additional simulations were also performed to evaluate the effect of placing a capillary cover over the backfill.

The model domain was given an atmospheric boundary condition with ponding for the upper boundary, and a free drainage or unit gradient boundary ( $dh/dz = 0$ ) for the lower boundary condition. The moisture content at initial conditions was set slightly above the residual moisture content for each material type. Model simulations were initially run for a 35-year period, and then for an additional 35 years using the final water content within the soil profile from the initial run. In cases where breakthrough was not achieved during the 70-year simulation, additional periods were simulated to achieve breakthrough at the bottom of the soil profile. To evaluate the sensitivity of unsaturated soil hydraulic parameters, four different soil profiles were evaluated, including compacted waste rock, waste rock in the middle of lift, waste rock in the bottom of lift, and coarse waste rock.

Two additional simulations (compacted waste rock and coarse waste rock) were performed to evaluate the performance of a capillary cover emplaced on the top of the backfill profile. The capillary cover was parameterized based on native soil in the vicinity of the study area, where the dominant soil is of the Bucan-Humdum Association, which varies from silt loam to clay. The cover simulations considered two feet of native soil cover underlain by one foot of coarse waste rock, with backfill material below the coarse waste rock.

### *Hydrus 1-D Results*

A total of six simulations were performed with four different waste rock profiles and the two end-member profiles with two feet of native soil cover. Simulations were run until breakthrough occurred at the bottom of the waste rock profile and seepage or flux rates reached a pseudo-steady-state. Results ranged from a relatively rapid breakthrough of 8.4 years in the coarse waste rock profile, to 187 years in the compacted waste rock profile with cover (Geomega 2008c). Steady-state seepage rates varied from 0.07 ft/year in the compacted waste rock profile with cover, to 0.67 ft/year in the coarse waste rock profile. These steady-state seepage rates calculated at the bottom of the backfill column range from 8 to 67 percent of annual precipitation; annual precipitation in the vicinity of the backfill is approximately one ft/year. The breakthrough curves for waste rock exhibit an oscillatory behavior once breakthrough has occurred, which is indicative of moisture fronts derived from large storm (and infiltration) events. Pulses of moisture act as the driving force for deeper, unsaturated water movement, and similar patterns are apparent for the moisture content profile (Geomega 2008c).

Profiles with the highest saturated hydraulic conductivities resulted in the fastest breakthrough times and the highest steady-state water seepage rates. The backfill never becomes fully saturated for any material type and not more than 30 percent saturated throughout the simulation for the middle of lift waste rock properties (Geomega 2008c). Comparison of the two cover scenarios indicates that the two end-member soil profiles (compacted waste rock vs. coarse waste rock) with a two-foot native soil

cover yielded similar steady-state seepage rates, within 0.01 ft/year. However, the simulations differ in breakthrough time, due to different properties of the underlying waste rock profiles. Soil cover simulations reduced infiltration of precipitation by 83 percent for the compacted waste rock and by 88 percent for the coarse waste rock profile. These results highlight the importance of adequate parameterization for soil at or near the surface. Once water infiltrates beyond the depth available for potential evaporation, it will be retained initially as soil storage, but will eventually infiltrate through the waste rock profile and recharge groundwater.

### *Oxidation Modeling*

Blasting, excavation, and translocation activities during open pit mining will result in the exposure of mineralized rock to the atmosphere. Sulfide minerals such as pyrite, stable under reducing conditions, may oxidize and leach solutes when exposed to the atmosphere (oxygen) and water. In the backfilled waste rock placement, as sulfide oxidation in shallow portions of the backfill becomes diminished, oxygen migrates farther down into the backfill profile, leading to propagation of the oxidation reaction front. However, the advancement of this front is primarily limited by the rate of oxygen diffusion through pore spaces and within waste particles (Davis and Ritchie 1986).

In environments with high permeability (such as backfill waste rock), other transport processes (e.g., convection and advection) can also be significant (Geomega 2008c). Diffusion, advection, and convection transport processes are significantly affected by the moisture content of waste materials, and oxygen transport under water-filled porosity (saturated conditions) is inhibited (Geomega 2008c). Under saturated conditions, groundwater flow rates and oxygen content determine the advancement of the oxidation front. Propagation of the oxidation front will also be affected by the rate of oxygen consumption (i.e., rate of sulfide oxidation) and the availability of sulfide minerals (Geomega 2008c).

The waste rock proportion based on the NCV classification (Codes 1 to 6) for each mining stage was used to construct a NCV spatial distribution of Genesis waste rock associated with the current mine plan. For waste rock containing more than one NCV type, a probability function was used to assign the NCV type for each model cell. The north-south cross-section through the Genesis backfilled waste materials was then used to select representative PAG and non-PAG vertical columns in the oxidation simulations. These vertical columns were chosen because they contained relatively more vertical model cells in the cross-section (seven and eight layers for PAG and non-PAG, respectively), and represented the waste rock proportion in the Genesis backfilled materials. The simulations were conducted using a modification of the Davis-Ritchie approach (Davis and Ritchie 1986) to account for oxygen diffusion, advection, and convection terms. The input parameters used in the oxidation modeling are presented by Geomega (2008c). The oxidation model utilized a cell discretization of 100 × 100 × 3.28 feet for each cell or layer. The oxidation and geochemical model for the Beast Waste Rock Disposal Facility was simulated using a cell discretization of 18 × 3.28 × 3.28 feet (5.5 × 1 × 1 meters).

Samples with particle size <6.3 millimeters (mm) (80% <2 mm) and <2.4 mm were used in the humidity cell and field oxidation tests, respectively. These particle sizes are generally much smaller than the rocks that comprise the bulk of the waste rock. However, smaller particles are more reactive in terms of oxidation kinetics and were, therefore, included because they provide a conservative upper boundary in

defining waste rock oxidation and chemical mass loading algorithms. Chemical input in each cell is defined by the chemical release function for each NCV type from humidity cell and field oxidation test data, in combination with oxidation modeling.

#### *Oxidation Modeling Results*

Sulfide oxidation rates for each cell or layer in the PAG and non-PAG columns generally show similar trends using both humidity cell and field oxidation. The upper two or three layers in the PAG and non-PAG columns were completely oxidized, while the subsequent layers remained unoxidized due to limited oxygen transport into deeper layers (Geomega 2008c).

In the modeled PAG column, sulfide oxidation in the top layer reached 99 percent after 64 and 138 years using humidity cell and field oxidation data, respectively. For the second layer, sulfide oxidation reached approximately 30 percent after 425 years, using both humidity cell and field oxidation data. For the third layer, sulfide was not oxidized or only reached 6 percent after 425 years, using humidity cell and field oxidation data, respectively. Sulfide in the subsequent deeper layers (layers 7, 8, 9, and 10) remained unoxidized.

In the modeled non-PAG column, sulfide oxidation in the top layer reached 99 percent at 194 and 104 years using humidity cell and field oxidation data, respectively. For the second layer, sulfide oxidation reached 99 percent after 334 and 298 years using both humidity cell and field oxidation data, respectively. For the third layer, sulfide oxidation reached ~99 percent after 335 and 425 years, using humidity cell and field oxidation data, respectively. For the fourth layer, sulfide was not oxidized or reached 8 percent after 425 years with field oxidation and humidity cell data, respectively. Sulfide oxidation in the subsequent deeper layers (layers 9, 10, 11, and 12) remained unoxidized.

#### *Waste Rock Chemistry Modeling*

Potential impacts from solute transport mechanisms were evaluated with an aqueous geochemical model (PHREEQC) that utilized time- and space-varying water fluxes from the numerical vadose zone flow and groundwater flow models (Geomega 2008c). PHREEQC was used to evaluate the effects of geochemical transformation processes along the transport path, to provide estimates of water quality and quantity expected to discharge from the selected PAG and non-PAG waste rock columns, and ultimately the backfilled waste rock. Waste rock chemistry modeling simulated geochemical transformations anticipated to occur in the backfilled waste rock within each layer of the two selected reaction columns (PAG and non-PAG) over 425 years.

#### *Unsaturated Zone Modeling Results*

Solute loading from waste rock material was incorporated into the linked oxidation and geochemical models using site-specific, empirically derived chemical release functions. The chemical release functions represent concentrations of each solute as a function of oxidation, derived from a plot of the oxidized percent of sulfide (e.g., sulfate released in the humidity cell or field oxidation tests divided by sulfide content in the associated sample) versus the concentration of each constituent released per kilogram rock. Seepage and flux of water into each cell through the vadose zone was simulated with HYDRUS-1D and linked to the oxidation model and PHREEQC to simulate geochemical evolution (e.g., leaching,

precipitation, oxidation, complexation, and sorption) along the flow path through the backfilled waste rock (**Figure B-2**). Equilibrium phases incorporated into the PHREEQC geochemical model include iron (Fe), aluminum (Al), iron-arsenic (Fe-As), and manganese (Mn) oxides/oxyhydroxides (ferrihydrite, gibbsite, scorodite, manganite, bixbyite); copper (Cu), nickel (Ni), thallium (Tl), zinc (Zn), and cadmium (Cd) hydroxide; secondary calcite (); fluorite (); gypsum/anhydrite ()() or ); epsomite (); barite (); jarosite-K (  $(\text{OH})_6$ ); and alunite (  $(\text{OH})_6$ ). Results for individual cells were used as input into the coupled Saturation Zone Model described below to estimate constituent loading to groundwater.

### Saturated Zone Modeling

Initial water volumes, flows, recharge, and material porosities were taken from the groundwater flow modeling inputs and results described previously under the No Action scenario. The flux of water into each cell through the vadose zone or local groundwater was simulated with MODFLOW. The saturated zone model was coupled to the results from the unsaturated zone model both with and without chemical attenuation based on the batch attenuation results presented below. Details on the coupling of the various models are presented by Geomega (2008c).

### Batch Attenuation Testing

The waste rock disposal facilities and/or pit backfill at the Genesis Project would be placed atop the carbonaceous Roberts Mountain Formation and, therefore, water exiting the bottom of the PAG cells would infiltrate through the carbonate-rich material. To supplement initial waste rock characterization and assess potential natural attenuation of solutes in the vadose and groundwater systems, batch tests using site-derived materials were conducted to determine partition coefficients. Groundwater from Leeville well HDDW-10, spiked with a known concentration of multiple solutes, was mixed and equilibrated with a known quantity of carbonate rock representative of rock beneath and downgradient of the Genesis pit. After a 24-hour equilibration period, the batch water was separated from the solids and analyzed to determine the fraction of each element in solution (EPA 1999).

### Results of Batch Tests

Batch test results show that most of the elements tested including arsenic, cadmium, lead, silver, mercury, antimony, chromium, copper, nickel, and zinc were sorbed by the bedrock carbonate. Freundlich and Langmuir isotherms were used to calculate partition (attenuation) coefficients ( ) for arsenic, antimony, and mercury for input to the groundwater transport model (Geomega 2008c). For cadmium, lead, chromium, copper, silver, thallium, nickel, selenium, manganese, and zinc, the test results indicate that the carbonate bedrock contained considerable attenuation capacity for these metals. However, most results could not be described using either the Freundlich or Langmuir isotherms, and attenuation of these elements was not modeled. Boron was only slightly adsorbed (0 to ~ 20%) by bedrock material.

### Predicted Chemistry of Groundwater from Mine Pit Backfill for Proposed Action

Chemical composition of water flowing through mine pit backfill was simulated over a period of 425 years. Impacts to groundwater were evaluated under two scenarios: one in which attenuation of solutes was not invoked, and the second in which attenuation for parameters derived from batch testing was applied. Modeling with no attenuation predicted that the behavior of solutes could be grouped into three general categories:

- Solutes dominated by the oxidation or leaching trend: arsenic, antimony, boron, cadmium, chromium, fluoride, lead, magnesium, manganese, mercury, nickel, nitrate, potassium, selenium, silver, sodium, sulfate, thallium, and zinc.
- Solutes reported to be controlled by equilibration with solid phases: alkalinity, aluminum, barium, calcium, copper, and iron.
- Solutes controlled by background water concentrations: chloride.

Predicted waste rock pore water at the base of the modeled PAG and non-PAG columns is neutral to slightly basic, with pH values ranging from about 6.5 to 8.0 standard units.

Solute concentrations in the PAG columns for constituents in the first group listed above were above background groundwater concentrations during vadose zone loading, but were predicted to generally decrease to concentrations close to those associated with background groundwater (represented by well GEN-39) after groundwater rebound infiltrates the pit and dilutes the pore water. Concentrations for constituents in the second group listed above were controlled by precipitation of solid phases that included gibbsite, ferrihydrite, secondary calcite, and barite. Precipitation of these phases is expected under neutral pH and oxidizing conditions. In summary, solute chemistry predicted to discharge from the base of the selected PAG and non-PAG columns in the Genesis pit would be neutral to slightly basic, and generally exceed background water quality. Solute concentrations simulated using humidity cell data generally release higher concentrations than those calibrated using field oxidation data.

As the water table rebounds, the chemical mass released during vadose loading would enter the groundwater system. Upon saturation by recovering groundwater, the predicted groundwater chemistry was applied to the local-scale MODFLOW model to simulate transport away from the backfilled pit, to potential receptors. The predicted chemistry was applied to waste rock cells in the groundwater model as a plane, once the layer becomes saturated. Waste rock cells were assigned concentrations representative of either PAG or non-PAG leachate chemistry, depending on their position relative to their deposition according to the mine plan. The backfilled Genesis and West Genesis pits were treated as a solute source during the simulation, where the solutes predicted from geochemical modeling were applied as prescribed concentration boundary conditions in the transport model. Concentrations of 28 solutes were monitored along the primary flow directions using hypothetical multilevel observation wells at the north and south ends of the model domain.

Groundwater quality predicted by the modeling was compared to water quality measured at Well DS-66. Well DS-66 is screened in the lower plate carbonates, immediately downgradient from the Genesis pit. **Table B-6** lists the concentration of 28 solutes in groundwater measured at DS-66, and the maximum predicted solute concentrations, in any model layer, for the entire simulation. Fourteen of the 28 solutes evaluated in this investigation were either not analyzed or not detected at DS-66, including

aluminum, boron, cadmium, chromium, copper, lead, mercury, nickel, phosphorous, tin, selenium, silver, thallium, and zinc. Eleven of the remaining 14 solutes exceed the measured solute concentrations at DS-66, at either the north or south monitoring location, for a portion of the simulation period, including alkalinity, calcium, chloride, fluoride, iron, magnesium, manganese, nitrogen, potassium, sodium, and sulfate. However, at the end of the simulation, predicted concentrations of potassium and sodium fall below those measured at DS-66. Due to dilution by background water and attenuation, transport of arsenic and barium is limited and these constituents never exceed the solute concentrations measured at DS-66, at either the north or south monitoring locations during the entire simulation period.

### **Predicted Chemistry of Groundwater from Waste Rock Disposal Facilities for Proposed Action**

Modeling was also conducted to predict the fate of solutes that might be leached from waste rock disposal facilities constructed above ground surface. Leachate exiting the base of waste rock piles would travel several hundred feet through unsaturated carbonate-rich bedrock before mixing with the recovered groundwater table.

Model results for the waste rock disposal facilities also predict that some constituents would be elevated at the base of the waste rock pile. Predicted pH values are in the range of 7.4 to 8.0 standard units for solute discharging from the base after initial interaction with the carbonate bedrock (i.e., calcite). Predicted concentrations for arsenic, antimony, and mercury in leachate leaving the PAG cells are approximately 40, 12, and 0.05 mg/L, respectively, all of which exceed drinking water standards for groundwater. After reacting with calcite at the base of the waste rock disposal facility, constituent behavior, similar to that predicted for pit backfill, can be grouped into two general categories:

- Solutes dominated by the oxidation or leaching trend.
- Solutes controlled by equilibration with solid phases.

Analytes included in the first group listed above are: antimony, arsenic, boron, cadmium, chloride, chromium, fluoride, magnesium, mercury, nitrate, potassium, selenium, silver, sodium, sulfate, and zinc. These elements showed increasing concentrations over time, associated with maximum oxidation/leaching of the top several layers of waste rock. Solute in the second group are primarily influenced by precipitation/dissolution of equilibrium phases and/or adsorption to precipitated solids and/or bedrock. The solutes influenced by mineral precipitation or sorption include alkalinity, aluminum, barium, calcium, copper, iron, lead, manganese, nickel, and thallium. In the simulated results, ferrihydrite, gypsum, gibbsite, bixbyite, fluorite, barite,  $\text{Cu}(\text{OH})_2$ ,  $\text{Ti}(\text{OH})_3$ , and  $\text{Ni}(\text{OH})_2$  were precipitated.

Batch tests showed that the Roberts Mountains carbonate rock that would be present beneath the waste rock disposal facilities acts as an attenuator for some dissolved metals and other constituents. For those constituents that follow Freundlich sorption isotherms, and could be assigned a distribution coefficient (e.g., arsenic, mercury, and antimony), the predicted vadose zone pore water concentrations are negligible within the first 100 to 200 feet of carbonate rock. Therefore, the Geomega (2008c) analysis predicts no potential impacts to groundwater from any of the simulated solutes. Other metals (with the exception of boron) that did not follow sorption isotherms in the batch testing showed near-total sorption onto the carbonate rock and, therefore, may also be rapidly attenuated.

**Table B-6. Summary of Predicted Potential Impacts to Groundwater Quality**

Parameter	Groundwater Quality Well DS-66 <sup>1</sup>	Max. Predicted Conc. in Groundwater for Entire Simulation	Solute Plume Behavior <sup>2</sup>	Attenuation Invoked <sup>3</sup>	Percent Mass Attenuated <sup>4</sup>	Max. Conc. Tested <sup>5</sup>
Silver	<0.005	0.014	-	N	67 - 96	0.06
Aluminum	<0.1	0.028	-	N	N/A	-
Alkalinity, total (as CaCO <sub>3</sub> )	150	253	A	N	N/A	-
Arsenic	1.8	0.40	B	Y	69 - 95	90
Boron	<0.1	1.4	-	N	0 - 20	220
Barium	0.16	0.099	B	N	N/A	-
Calcium	37	80	A	N	N/A	-
Cadmium	<0.005	0.0058	-	N	97 - 100	1
Chloride	15	41	A	N	N/A	-
Chromium	<0.005	0.016	-	N	95 - 100	1.9
Copper	<0.005	0.13	-	N	91 - 100	1.8
Fluoride	0.6	2.5	D	N	N/A	-
Iron	0.01	0.015	D	N	N/A	-
Mercury	<0.0001	0.0001	-	Y	100	0.96
Potassium	7	12	C	N	N/A	-
Magnesium	6.5	27.5	A	N	N/A	-
Manganese	0.005	0.094	A	N	71 - 98	3.8
Sodium	53	58	C	N	N/A	-
Nickel	<0.01	0.02	-	N	94 - 99	2.7
Nitrate as N	0.05	0.85	A	N	N/A	-
Lead	<0.004	0.011	-	N	87 - 100	0.95
pH (standard units)	8.4	7.4 - 7.9	N/A	N	N/A	-
Phosphorous	N/A	0.005	-	N	N/A	-
Antimony	<0.05	0.01	-	Y	73 - 79	9.2
Selenium	<0.005	0.039	-	N	35 - 96	1
Sulfate	51	111	D	N	N/A	-
Thallium	<0.005	0.005	-	N	45 - 98	0.44
Zinc	<0.02	0.045	-	N	98 - 100	14

All units in mg/L unless otherwise noted.

<sup>1</sup> Water quality measured on 8/14/1992.

<sup>2</sup> See section 5.6.1 of Geomega 2008c.

A: solute concentrations always exceed concentrations measured at DS-66.

B: solute concentrations always below concentrations measured at DS-66.

C: solute concentrations exceed DS-66 for a short duration during its peak.

D: solute concentrations are initially below DS-66 but increase above DS-66 later in simulation.

<sup>3</sup> Attenuation was only invoked in the transport model for analytes for which an isotherm could be fit.

<sup>4</sup> The range, in percent, of mass attenuated during batch tests at various concentrations.

<sup>5</sup> The maximum aqueous concentration applied during batch attenuation tests.

N/A = not analyzed.

## Discussion of Model Results for Proposed Action Alternative

Based on experience at numerous mine sites, there will be oxidation of sulfide minerals and the production of acid rock drainage (ARD) if water and oxygen enter the PAG cells (Davis and Ritchie 1986). Neutralization of ARD and attenuation of metals and other constituents will occur in underlying carbonate rock; this is the primary chemical reaction employed by passive and active ARD treatment systems (Cravotta and Trahan 1999; Gusek and Wildeman 2002; Nordstrom 1982; Skousen et al. 1998). The outputs of geochemical models reviewed above concerning metals migration and attenuation are generally supported by current literature. Batch testing using site-derived materials, and evaluation of potentially analogous sites, provide an additional level of validation to the predicted results (Geomega 2008c).

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