NOTICE OF DECISION – Bureau of Mining Regulation and Reclamation

Web Posting: 12/24/2015

Deadline for Appeal: 01/04/2016

WPC Permit No. NEV0086018
Twin Creeks Mine – North Project
Newmont USA Limited dba Newmont Mining Corporation

The Administrator of the Nevada Division of Environmental Protection (the Division) has decided to issue Water Pollution Control Permit NEV0086018 to Newmont USA Limited dba Newmont Mining Corporation. This Permit authorizes the construction, operation, and closure of approved mining facilities in Humboldt County, Nevada. The Division has been provided with sufficient information, in accordance with Nevada Administrative Code (NAC) 445A.350 through 445A.447, to assure that the waters of the State will not be degraded by this operation, and that public safety and health will be protected.

The Permit will become effective 9 January 2016. The final determination of the Administrator may be appealed to the State Environmental Commission pursuant to Nevada Revised Statute (NRS) 445A.605 and NAC 445A.407. All requests for appeals must be filed by 5:00 PM, 4 January 2016, on Form 3, with the State Environmental Commission, 901 South Stewart Street, Suite 4001, Carson City, Nevada 89701-5249. For more information, contact Shawn Gooch at (775) 687-9557 or visit the Bureau of Mining Regulation and Reclamation website at http://ndep.nv.gov/bmrr/bmrr01.htm.

Written comments were received during the public comment period from Glenn C. Miller, Ph.D., of Reno, Nevada, for Great Basin Resource Watch (GBRW). The text of all comments, in some cases excerpted, and the Division responses (in *italics)* are included below as part of this Notice of Decision.

GBRW, Written Comment 1:

The Vista Pit Lake model (Geomega, 2015) appears to contain a systematic underestimate for the loading of sulfate and metals leached from wall rock. This arises from calculating load as the product of that mass of rock that will completely oxidize with the constituents released by samples only partially oxidized in humidity cell tests.

The mass of oxidized wall rock was estimated from the modified Davis-Ritchie model (Fennemore et al., 1998). This model oxidation rate was calibrated to measured oxidation rates in humidity cell tests on Vista Pit rock, then it used Vista Pit wall rock characteristics (e.g., fracture density, sulfide sulfur content, duration of exposure, etc.; See Figure 4-2 in Geomega 2015) to estimate the thickness of completely oxidize rock over time using. The product of the thickness of this fully oxidized zone [m], the area of exposed wall rock [m^2], and density [kg/m^3] yields the mass of completely oxidized rock [kg].

However, the mass of sulfate and other constituents leached from each kg of oxidized rock was estimated from the total amount of sulfate leached from rock samples in humidity cell tests. Specifically, total the leachate released over time was estimated in the lake model using "chemical release functions"—equations fit to humidity cell leachate concentrations. The problem is that the humidity cell tests were not run long enough to completely oxidize the sulfide S, so the mass of constituents leached in humidity cell tests corresponds to partial oxidation. Thus the chemical release functions thus underestimate the amount of sulfate and other constituents that would leach by complete oxidation.

For example, consider rock sample TWD-1173 (862-883), which:

- Is net-acid generating (i.e., has a Net Neutralizing Potential < 0, termed "Code 3" in Table 2-3 "List of humidity cell tests used in the Vista VIII pit lake model, Geomega 2015),
- Has an acid-generating potential of 173 Tons CaCO3/1000 tons rock (based on sulfide sulfur measured by loss at 550 degree C (Table 3.1, in IML 2013),
- Was subjected to 34-week humidity cell tests (Table 3.3 in IML 2013),
- Leached a cumulative 57,246 mg SO4 from the 1-kg rock sample over the 34-week test (Table in "Section 4 – HCT Leachate Analysis", in IML 2013)

Total sulfide S in this 1-Kg sample =
[173 Tons CaCO3/1000 tons rock] x
[(1%S) / (31.25 Tons CaCO3/1000 tons rock)] x
[10,000 mg S / 1%S]
= 55,360 mg S/kg rock.

Total sulfur oxidized during the humidity cell test =
[57,246 mg SO4/kg rock] x [32.1 mg S/96 mg SO4]
= 19,100 mg S/kg rock .

The fraction of the total sulfide S oxidized over the 34-week test =
[(19,100 mg S/kg rock) / (55,360 mg S/kg rock)] x 100% = 35%.

Thus if the Vista Pit Lake model estimates sulfate release from wall by multiplying the mass of rock that completely oxidized (kg rock), by the sulfate released from rock that only partially oxidized in a humidity cell test (mg SO4/kg rock), then the model has introduce a systematic underestimate of solute release in the pit lake model.

Using the example above, where 35% of the sulfide S oxidized in the humidity cell test, the Vista Pit Lake model would underestimate actual sulfate release from wall rock by a factor = [(55,360 mg S/kg rock assumed by oxidation model) / (19,100 mg S/kg rock actually leached in kinetic test)] x 100% = 290 %.

The 7 humidity cell tests on net-acid generating rock in the Vista Pit wall rock (i.e., Net Neutralizing Potential < 0 tons $CaCO_3$/ Ton rock; Geomega 2015) appear to have oxidized on average ~35% of the sulfide S, so that actual sulfate release from this wall rock would be (100%/35%), or 2.9 times greater than estimated by the pit lake model.

For the 4 rock samples classified as "uncertain" in terms of their acid generating potential (called "Code 2" in Geomega 2015) that also contained detectable sulfide S (i.e., samples with > 0.01% sulfide S), the humidity cells tests appear to have oxidized on average only 14% of the sulfide S. Thus the actual sulfate release from this wall rock would be (100%/14%) or ~7 times greater than estimated in the pit lake model.

Other constituents that are leached out of the wall rock in proportion to the sulfide oxidation would be underestimated by similar amounts, i.e., an underestimate of ~2.9 times from Code 1 rock, and an underestimate of ~7 times from Code 2 rock.

As a conceptual check on this model assumption, consider that the mass of sulfate release in a humidity cell test on a sulfide-bearing rock sample will depend upon the duration of the test, at least until the sulfide is completely oxidized. Of the Vista Pit wall-rock samples that initially contained detectable sulfide sulfur, none were run long enough to completely oxidize the sulfide S. Thus the longer that humidity cell tests were run, the greater would be the estimate of sulfate loading from wall rock. A model that will systematically predict increased constituent concentrations in proportion to the arbitrary duration of a laboratory tests is not properly formulated.

Division Response 1:

The humidity cell test (HCT) is the method required by the Division and the U.S. Bureau of Land Management (BLM) to simulate long-term weathering of rocks in an accelerated time frame. The HCT method is a more reliable means to determine the extent to which sulfide minerals in the rock will oxidize than to simply assume full oxidation of all sulfide minerals. In practice incomplete oxidation of sulfide minerals is common in HCTs and in nature.

The Division minimum duration for HCTs is 20 weeks and HCTs can be terminated only with Division approval. The Vista VIII humidity cell tests were run for 28 to 57 weeks, well beyond the minimum duration. Approval from the Division and BLM was received before termination of each HCT. Each HCT was terminated after the Division concurred that the chemical response of the particular rock sample to the accelerated weathering environment had been sufficiently characterized for incorporation into the pit lake model.

In the Vista VIII pit lake model, the HCT results were used to develop chemical release functions (CRFs) to predict leachability until the rock zone is submerged. The length of rock exposure was determined from the groundwater model. Once the rock zone is inundated, the diffusion of oxygen through water is very limited as it is almost four orders of magnitude slower than similar diffusive transfers in air (Tremblay & Hogan 2001). This factor considerably diminishes the rate of sulfide oxidation and acid generation in subaqueous conditions.

Also, certain reactions and mineral relationships in the rock may prevent complete sulfide oxidation in HCTs. For example, one of the Valmy Code 3 samples [TWD-01620 (806-847)] should have been acid generating based on negative net neutralization potential (NNP of -60 ppt $CaCO_3$), but after 57 weeks, the leachate pH was still 6.2 standard units (SU). The mineral liberation analyses (MLA) indicated that iron oxide had formed around pyrite grains preventing further oxidation. Consequently, if complete sulfide oxidation were assumed in the pit lake model, the sulfate release from the pit wall rock would have been overestimated.

<u>GBRW, Written Comment 2:</u>

The Vista Pit Lake model appears to have underestimated the thickness of the wall rock zone that has enhanced permeability from blasting. The model assumed that blasting enhanced porosity in wall rock from the exposed surface in to a depth of 3.6 ft, where this fracture depth was based on a rock porosity study after blasting in competent igneous rock… *[Siskind and Fumanti, 1974].* This assumed fracture depth in the Vista Pit lake model is several times smaller than was measured by an EPA study, which measured permeability in blast-face wall rock at the Golden Sunlight Mine in Montana. Specifically, this EPA study found iron staining (indicative of active oxidation) to a depth of ~10 ft, a rind of high permeability rock to a depth of ~20 ft, and propagation of blast fracturing to a depth of 50 ft from the face (McCloskey 2015). The discrepancy suggests that the oxidation model applied to the Vista pit could have underestimated the thickness of the enhanced-permeability zone by a factor of ~5.6 (i.e., 20 ft / 3.6 ft), and possibly by a factor as high as 13.9 (i.e., 50 ft/3/6 ft).

A related wall-rock oxidation effect that was omitted from the Vista Pit lake water quality study is oxidation and constituent leaching from rock fall onto pit benches. A recent literature review of modeling and management methods for mine pit lakes identifies "typical pit walls with high amounts of rubble," so that "that much of the rain that falls on the other pit walls will not take a rapid path to the water surface but will encounter significant amounts of rubble of variable grain size and in fracture zones in the pit walls" (Castendyke et al., 2015). While the volume of rubble may be small relative to fractured wall rock back from the pit walls, the rubble may be smaller fragments and thus react more quickly than rock within the pit walls.

<u>Division Response 2:</u>

The referenced core drilling and water injection testing characterized the open pit highwall at Golden Sunlight Mines, Inc by McCloskey and Bless (2005). The Precambrian sedimentary rock was reported to be rubble for approximately the first 3 feet. While this may be different from the Vista VIII wallrock, the Division concurs that using a fracture depth based on the Siskind and Fumanti (1974) results from a granite quarry is also inaccurate. Therefore, in response to the comment the Division has modified Part I.B.1 of the Permit to require a revised pit lake study that incorporates a thicker blast-induced fracture depth appropriate for the Vista VIII wallrock.

The HCT method is conducted on small particles (<6.3 mm), relative to typical in-pit rubble size. Therefore, the greater reactivity of rubble compared to pit wallrock has already been incorporated into pit lake model.

GBRW, Written Comment 3:

The Vista Pit Lake model appears to have underestimated the rate of sulfide S oxidation in wall rock by applying a correction for the effects of low moisture. Based on the publication cited for the wall-rock oxidation model (Fennemore et al., 1998), it includes "water rate-liming effects" to account for semi-arid conditions in Nevada, and this factor produces a "3-fold reduction in oxidized wall rock thickness in arid environments" relative to rates measured in humidity cell tests.

The idea of including the effect of moisture limits to oxidation at the Vista Pit is certainly reasonable, because numerous studies do demonstrate that the rate of pyrite oxidation decreases with decreasing humidity. At relative humidity below 30%, reactive pyrite will "probably remain unchanged"; but "the rate of oxidation increases greatly in the area of 60%" relative humidity (Howie 1992). This increase in oxidation rate when relative humidity increases above ~60% is consistent with the report that liquid water condenses on pyrite at relative humidity greater than 70% (Borek (1994). A study under humid but unsaturated conditions found that pyrite oxidized quickly for a brief period, but soon slows and "approaches the rates reported by humidity cell studies" (Jerz and Rimstidt, 2004; measured at 96.7% RH). The problem is that although field studies of near-surface hydrology suggest that a thin surface layer is often too dry to support oxidation, nearly all of the zone included in the pit-wall-rock oxidation model will remain humid enough to support oxidation at rates comparable to what is measured in humidity cell tests.

In one field study under conditions analogous to Nevada mines (i.e., unvegetated surfaces in semi-arid climates), the surface layer (0 to 0.4 inch depth) dries out within ~2 - 3 days after a precipitation event to below levels that will support appreciable oxidation (Ishizuka et al., 2005). (Oxidation slows dramatically when relative humidity drops below 70% [Howie 1992], which in the above study was associated volumetric moisture ~0.01 [vol water/vol soil].) However, in the slightly deeper zone (2-inch depth), relative humidity remained in the 75-95% range that supports rapid oxidation, and volumetric moisture never dropped below 0.05. A separate study of bare dune sands in arid New Mexico demonstrates the same behavior over a deeper depth interval. The driest soil is generally the top layer (0–2 in. depth), where moisture averages of 1.4 – 3.4 vol. %; but soil is wetter in the 10-15 cm interval (7.4 – 8 vol% moisture), and all samples from below 12 inches, average moisture was > 4% (Ritsema and Dekker, 1994). Thus the field oxidation tests used to estimate the reduction in pyrite oxidation in semi arid climate (described in Fennemore et al., 1998, and applied in Geomega 2015) appears to have measured this surface-drying effect, but it has little relevance to oxidation rates at more than a few inches from the wall-rock surface.

These moisture profiles in the published studies cited above indicate that there is some net recharge from meteoric water in the semi-arid climates. This is consistent with the regional groundwater model used for the Twin Creeks Mine (Itasca 2015), which assumes 3% of precipitation is recharge in the upper pit benches (i.e., above 4510 ft amsl). But as with the studies cited above for bare desert soil, given the flat surfaces and absence of roots to transpire water, actual net infiltration to the unvegetated pit-benches should be many times greater than the average applied in the regional model for store-and-release behavior in vegetated soil.

It seems probably that virtually the entire thickness of the wall rock zone estimated to undergo complete oxidation (i.e., the range from 1.8 to 49 ft in the various units; Geomega 2015, pg. 10) should contain moisture and humidity at levels high enough to avoid appreciably limiting the rate of sulfide S oxidation. Thus applying the moisture-limiting factor to wall rock several feet from the air surface, as done in the Vista Pit lake model, has probably underestimated the overall wall-rock oxidation rate.

Division Response 3:

The Division concurs that incorporating the effect of moisture limits to the oxidation model at the Vista VIII pit is certainly reasonable, because numerous studies demonstrate that the rate of pyrite oxidation decreases with decreasing humidity or moisture content (Borek, 1994; Fennemore et al., 1998; Schmieder et al., 2012). However, the Division also concurs that this effect may have been overestimated in the current pit lake model due to the likelihood that the drier zone is thin. Therefore, in response to this comment the Division has required in Part I.B.1 of the Permit that the base case for next pit lake study revision shall not include the effect of moisture limits; however, a sensitivity assessment is required to evaluate the effect of varying the moisture effect.

GBRW, Written Comment 4:

The figure of thickness of oxidized wall rock is labeled in ft, but the y-axis should be labeled in meters to be consistent with the text (Geomega 2015, Figure 4-2).

Division Response 4:

Comment noted.

GBRW, Written Comment 5:

The water quality study for the Vista Pit lake (Geomega 2015) do not include the formulas that describe the "chemical release functions." These should be included in order to support the estimates of constituent leaching from wall rock and load to the pit lake.

Division Response 5:

The Division concurs. To illustrate the fit between the derived CRFs and the HCT data, the Division requires that the next revision of the pit lake model shall include a plot for each chemical parameter showing the derived CRF curve and all of the HCT data obtained for that parameter.

<u>GBRW, Written Comment 6:</u>

It seems like the Vista Pit lake water quality model assumes that some of the constituents that leach from wall rock on the down-gradient side of the Vista Pit will never enter the pit lake, but will instead just flow south and west into the aquifer (Geomega 2015, Section 5.1). However, the text is not clear on this conceptual assumption. The water-quality model report needs to be better explain this important assumption, and illustrated which wall-rock zones were assumed to have only outflow and thus not contribute any solutes to the pit lake.

<u>Division Response 6:</u>

The Division concurs that the next revision of the pit lake study shall illustrate more clearly the three dimensional boundaries in the model between the pit lake inflow and outflow zones, as they vary in time through the pit filling process. In addition, the revised pit lake study shall clarify whether the flow direction and magnitude at any given time is discretized on a small scale or represented in a few large zones.

<u>GBRW, Written Comment 7:</u>

The Vista Pit Lake water quality model does not include an assessment of uncertainty in predictions or sensitivity of predictions to model parameters. Without some estimate of accuracy or uncertainty, it is difficult to assess model.

<u>Division Response 7:</u>

The Division concurs that the next pit lake model revision shall include sensitivity assessments for important model input parameters, including but not necessarily limited to thickness of the blast-induced fracture zone, magnitude of moisture correction for a semi-arid environment, the spatial volume of the pit outflow zone, and the magnitude of the pit outflow rate.

References:

Borek, S. L., 1994. Effect of Humidity on Pyrite Oxidation. In Alpers, C.N., Blowes, D.W. (eds). Environmental Geochemistry of Sulfide Oxidation. American Chemical Society Symposium Series, American Chemical Society: Washington, DC, p. 31-44.

Castendyke, D.N., Eary, L.E., and Balistrieri, L.S., 2015. Modeling and Management of Pit Lake Water Chemistry 1 :Theory. Applied Geochemistry, Vol. 57, pp. 267-288.

Fennemore, G.G., Neller, W.C., and Davis, A., 1998. Modeling Pyrite Oxidation in Arid Environments. Environ. Sci. Technol. 32:2680-2687.

Geomega, 2015. Newmont Vista VIII: Pit Lake Chemogenesis. Prepared for Newmont Mining Corporation. Boulder, CO: Geomega Inc.

Howie F. M., 1992. Pyrite and Marcasite. In: Care and Conservation of Geological Material: Minerals, Rocks, Meteorites and Lunar Finds (ed. F. M. Howie), pp. 70–84. Butterworth.

Ishizuka, M., Mikami, M., Zeng, F. J., Gao, W., and Yamada, Y., 2005. Measurements of Soil Water Content Using Time Domain Reflectometry Sensor and Water Vapor in the Surface Soil Layer at the Gobi Site in the Taklimakan Desert, J. Meteorol. Soc. Jpn., 83(6), 987–999, doi.

Itasca, 2015. Model Predictions of Pit-Lake Infilling at Vista Phase 8 Pit. Lakewood, CO: Itasca Denver, Inc.

Jerz J. K. and Rimstidt J. D., 2004. Pyrite Oxidation in Moist Air, Geochimica et Cosmochimica Acta 68, 701-714.

McCloskey, A.L., Bless, D., 2005. Prevention of Acid Mine Drainage Generation from Open- Pit Highwalls-Final Report. EPA/600/R-05/060 July 2005.

Schmieder, P.J., Taylor, J.R., Bourgeot, N., 2012. Oxygen Consumption Techniques to Quantify Acidity Generation Rates. International Acid and Metalliferous Drainage Workshop, Beijing, China.

Siskind, D., Fumanti, R., 1974. Blast-produced Fractures in Lithonia Granite. US Bureau of Mines Report of Investigation 7901, Washington, DC.

Ritsema, C. J., and L. W. Dekker, 1994. How Water Moves in Water Repellent Sandy Soil, 2, Dynamics of Fingered Flow, Water Resour. Res., 30, 2519–2531.

Tremblay, G.A. and Hogan, C.M., 2001. MEND Manual, Volume 4. Prevention and Control. MEND Report 5.4.2d.