SWCA
ENVIRONMENTAL CONSULTANTS

Memorandum

To: File

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From: Chris Garrett, SWCA

Date: June 26, 2013

Re: Estimates of Explosive Residue, Potential Nitrogen Concentrations in Water, and Applicable Standards

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The purpose of this memo is to estimate the approximate amount of explosive residue that may be present at the site, to roughly estimate the concentrations that could occur in stormwater runoff and the pit lake, and to clarify which surface water standards are appropriate for consideration.

Amount of Explosive Residue

The explosive reaction that occurs involving ammonium nitrate and fuel oil ideally generates only water, carbon dioxide gas, nitrogen gas, and heat. It is the rapid release and expansion of these gases that creates the explosive power of the mixture. However, the reaction is seldom completely efficient, and nitrogen can remain as a residue in waste rock and in the blast zone. Early literature analyzed explosive use in coal mines in Canada and suggested that 1 to 6 percent of the total nitrogen could remain as residue (Pommen 1983). The lower end of this range (1%) is typically associated with the dry use of ammonium nitrate, while the higher end of this range (6%) is typically associated with the use of a slurry form of ammonium nitrate. The slurry form of the explosive is usually used in wet environments; only dry use of ammonium nitrate fuel oil explosive is expected to be used by Rosemont. Further studies of these same mines and additional mines clarified that the total nitrogen loss depended largely on the form of the explosive used, and suggested that use of ammonium nitrate-fuel oil under dry conditions has significantly less residue, as little as 0.2 percent of the total nitrogen (Ferguson and Leask 1988).

Approximately 20,100 tons of ammonium nitrate would be used for blasting each year for the Rosemont Project). By weight, ammonium nitrate is approximately 35 percent nitrogen. The total nitrogen being imported to the site in the form of ammonium nitrate is therefore approximately 14 million pounds per year.

For the purposes of this analysis, a range of results will be used representing 0.2 to 1 percent explosive residue. It can be estimated that from approximately 28,000 pounds per year of nitrogen (0.2 percent residual) to 140,000 pounds per year of nitrogen (1 percent residual) would remain either in the mine pit or in waste rock.

Ferguson and Leask (1988) further estimate that nitrogen residue is likely to consist of approximately 87% nitrate, 11% ammonia, and 2% nitrite.

Potential Nitrogen Concentrations in Water

Making useful predictions of actual nitrogen concentrations in water due to explosive residue is difficult, as there simply are too many factors that are either unknown or could vary widely. The approach used here is to make a reasonable range of predictions, but biased towards being more conservative (i.e., higher nitrogen concentrations rather than lower nitrogen concentrations).

Potential Concentration of Nitrogen in Surface Water Runoff

Approximately 1,100 acre-feet of water (as measured at the Highway 83 bridge in Barrel Canyon) are expected to annually runoff the site after closure and enter the downstream watershed. However, not all of this water is in contact with the waste rock/tailings facilities. Based on post-closure stormwater modeling, only about 33% of the stormwater contacts the waste rock/tailings facility.

Table 1. Percentage of Stormwater Contacting Waste Rock or Tailings Facility Post-Closure

Contributing Area	Percent Contribution to Annual Flows at Highway 83 Bridge[1]	Potential Contact with Waste Rock/Tailings Facility?
McCleary Canyon	23.2%	No
Scholefield Canyon	31.6%	No
Lower Barrel Canyon	1.3%	No
North Waste Rock Area	9.3%	Yes
South Waste Rock Area	23.4%	Yes
Lower Trail Canyon	11.5%	No

[1] See Attachment 3 of Tetra Tech (2012)

Exposure of this surface water to waste rock in the waste rock facility is one pathway through which nitrogen residue from explosives could impact surface water. For the most part, this water would only contact waste rock in limited ways. After closure, the surface of the waste rock/tailings landform would be covered with approximately one foot of salvaged soil, and the runoff would be contacting this soil instead of waste rock. The soil would not have been subjected to explosives use.

However, there are some areas over which stormwater runoff might still contact waste rock. Some of the longer slopes potentially could only have rock cover, and no soil cover due to erosion concerns. On these slopes stormwater runoff could contact waste rock that could contain nitrogen residue from explosives. Stormwater then flows through channels along the facility benches until it reaches drop structures and is routed into the downstream watershed. These channels are very likely to have only waste rock present, and represent a pathway for exposure of stormwater runoff to explosives residue.

What percentage of the waste rock, and therefore nitrogen residue, might come into contact with stormwater? This is impossible to answer directly, since it would be a comparison of surface area (the exposure area of the channels and slopes) with volume (of the entire waste rock pile). However, we can make a conservative estimate. The waste rock and tailings facility is approximately 2,500 acres in size for the Preferred Alternative. Assuming a depth of 1 foot, and an approximate bulk density of 1.5 tons per cubic yard, the surface shell of the waster rock/tailings facility would represent about 6 million tons of waste rock. This represents about one half of one percent of the entire 1.2 billion tons of waste rock in the facility.

As discussed, in reality only a portion of the surface waste rock would have any possibility of contacting stormwater. However, for the purposes of demonstrating the high end of the potential nitrogen concentration in runoff, we shall increase this by an order of magnitude and use an assumption that 5% of the total nitrogen residue could end up in surface water. This represents from 1,400 to 7,000 pounds per year of nitrogen residue that could end up in surface water. If all of this nitrogen residue were to enter stormwater runoff on an annual basis, the concentration would be approximately 1.4 to 43.2 milligrams per liter (mg/L) of nitrogen.

360 acre-feet = 444 million liters of water

1,400 – 7,000 pounds of nitrogen = 636 – 3,180 million milligrams of nitrogen

Resulting concentration in annual runoff = 1.4 – 7.2 milligrams/liter of nitrogen

Estimated concentration of nitrate as N = 1.2 – 6.3 mg/L

Estimated concentration of ammonia as N = 0.15 – 0.8 mg/L

Estimated concentration of nitrite as N = 0.03 – 0.14 mg/L

Potential Concentration of Nitrogen in Pit Lake

Another pathway of exposure would be to assume that nitrogen residue would remain within the pit itself, and if it persisted and built up through the life of the mine, would eventually end up in the pit lake. What percentage of nitrogen residue might remain in the pit instead of the waste rock pile? Again, this is difficult or impossible to calculate with any certainty.

An estimate can be made by comparing the tonnage of rock associated with the near surface of the pit, versus the tonnage of waste rock. Tetra Tech previously made estimates of the thickness of the "blast affected wall rock" in the pit (i.e., the rock that has increased fracture density due to blasting) and estimated it to be 6 feet deep (Tetra Tech 2010). The rough surface area of the pit can be estimated from simple geometry. The pit is roughly conical in shape, with the bottom at an elevation of 3,050 feet above mean sea level (amsl), the pit rim ranging in elevation from approximately 5,650 feet amslto 4,350 feet amsl, and a diameter ranging from 2,600 to 3,300 feet across. Using an average depth of 1,950 feet and an average diameter of 2,975 feet, the surface area of the resulting cone is about 11.5 million square feet, which gives an approximate blast zone volume of 69 million cubic feet. Using the same bulk density as used above (1.5 tons/cubic yard), the tonnage of the rock comprising the pit walls that may have been affected by explosive residue is about 4 million tons. This represents about 0.3 percent of the 1.2 billion tons of waste rock removed from the pit. However, for the purposes of demonstrating the high end of the potential nitrogen concentration in runoff, we shall increase this by an order of magnitude and use an assumption that 3% of the total nitrogen residue could end up remaining in the pit.

The eventual volume of the pit lake would be approximately 100,000 acre-feet; however this will take hundreds of years to develop fully. Based on the estimated pit lake elevation 20 years after closure of the mine (3,600 feet amsl), the expected volume of the pit lake would only be approximately 1,000 acre-feet.

Over a 21 year life of the mine, approximately 17,600 to 88,200 pounds of nitrogen residue would be produced. The concentrations below assume that the entire mass of nitrogen residue over the life of the mine accumulates in the pit, does not degrade, and then reports to the developing pit lake. If all of this nitrogen residue were to enter the pit lake, the concentration would be approximately 6.7 to 201 mg/L of nitrogen.

1,000 acre-feet = 1.2 billion liters of water

17,600 – 88,200 pounds of nitrogen = 8 - 40 billion milligrams of nitrogen

Resulting concentration in pit lake = 6.7 – 33.3 milligrams/liter of nitrogen

Estimated concentration of nitrate as N = 5.8 – 29 mg/L

Estimated concentration of ammonia as N = 0.74 – 3.7 mg/L

Estimated concentration of nitrite as N = 0.13 – 0.67 mg/L

That residual nitrogen from explosives use remains present in the environment has been documented and is reasonable to consider. However, the purpose of these estimates is not to make a reliable estimate for regulatory purposes. The purpose is rather to make a reasonable guess in order to gain understanding of how significant an issue explosive residue would be when compared to applicable standards.

Applicable Water Quality Standards

Arizona Numeric Aquifer Water Quality Standards

Arizona numeric aquifer water quality standards exist for nitrate as N (10 mg/L), nitrite as N (1 mg/L), and nitrate + nitrite as N (10 mg/L). No standard exists for ammonia.

Arizona Numeric Surface Water Quality Standards – Stormwater Runoff

Arizona numeric surface water quality standards depend on the water use of the receiving water. In this case, the applicable standard for stormwater runoff would be the acute standard for aquatic and wildlife uses in ephemeral waters (A.A.C. R18-11-109). These standards are:

Nitrate – No standard

Nitrite – No standard

Ammonia – No standard

Arizona Numeric Surface Water Quality Standards – Pit Lake

The Arizona numeric surface water quality standards do not apply to the pit lake. However, they are used in the EIS analysis in order to provide context for assessing potential impacts to wildlife. Both the acute and chronic standards for warmwater aquatic and wildlife (A.A.C.. R18-11019) are used in the EIS.

Nitrate – No standard

Nitrite – No standard

Ammonia - acute – 6.95 – 8.4 mg/L. The acute ammonia standard is pH dependent. The range was estimated based on the pH of 8.0 – 8.1 predicted in the pit lake geochemical model (Tetra Tech 2010).

Ammonia – chronic – 0.773 to 2.43 mg/L. The chronic ammonia standard is not only pH dependent, but it is temperature dependent as well. The range was estimated using the range of pH given above, as well as a range of temperatures from 0 to 30 degrees Celsius.

References

Ferguson, K.D. and Leask, S.M. 1988. The Export of Nutrients from Surface Coal Mines. Environment Canada Regional Program Report 87-12. March.

Pommen, L.W. 1983. The Effect on Water Quality of Explosives Use in Surface Mining, Volume 1: Nitrogen Sources, Water Quality, and Prediction and Management of Impacts. MOE Technical Report 4. British Columbia Ministry of the Environment. May.

Tetra Tech. 2010. Geochemical Pit Lake Predictive Model – Revision 1. November.

Tetra Tech. 2012. Baseline & Post Mine Hydrology and Sediment Delivery at USGS Gage for Barrel Alternative Technical Memorandum. July 11.