Golder Associates

TECHNICAL MEMORANDUM

DATE 17 July 2014

PROJECT NO. 14514150095.508
No.

TO Carol Fries
Lydian International Ltd

CC

FROM Golder Associates (UK) Ltd

EMAIL

AMULSAR GOLD PROJECT: ESTIMATE OF NITRATE AND AMMONIA CONCENTRATIONS IN MINE WATER AS A PRODUCT OF BLASTING

The planned use of ammonium nitrate based blasting agents at the Erato and Tigranes-Artavazdes pits at the Amulsar site has the potential to affect groundwater and surface water quality in the vicinity of the mine. The purpose of this Technical Memorandum is to estimate the potential concentrations of nitrogen in mine water based on the proposed use of explosives.

1.0 WATER QUALITY ASSESSMENT

1.1 Environmental Risks Associated with ANFO and Similar Nitrogen Based Explosives

Ammonium nitrate fuel oil (ANFO) is highly soluble and may, therefore, pose a risk to groundwater and surface water through the release of nitrogen compounds (ammonia, nitrite and nitrate) if not appropriately managed.

The risk posed to the environment is not the same for all nitrogen based blasting agents. Revey (1996) reproduces data from a previous study indicating the following rates of leaching from explosive in wet environments (Table 1).

Table 1: Percentage of Nitrates Leached from Explosives (Watson, 1991 *in* Revey, 1996)

Time (hr)	ANFO[1]	"Water Resistant" ANFO	Water Gel	Emulsion
0.1	~25%	-	-	-
1	>50%	~25%	-	-
6	-	-	24.6%	0.6%
144	-	-	>75%	1.2%

Notes: 1: ANFO = Ammonium nitrate fuel oil explosive

Forsyth *et al* (1995) list the following mechanisms for the release of nitrates to the environment from blasting agents:

- Spillage during transport or charging;
- Dissolution (leaching) of explosive in wet blast holes; and
- Undetonated explosive in rock after the blast.

A study of potential environmental impacts of ANFO was published by Defence R&D Canada – Valcartier (DRDC Valcartier) in 2010. The detonation of ANFO explosive in wet environments is often incomplete (DRDC, 2010 and Revey, 1996). Due to its high solubility, in wet environments a significant proportion of ANFO can be lost due to dissolution prior to ignition. Revey (1996) indicates exposure of ANFO to water

Golder Associates (UK) Ltd
Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds, Nottinghamshire NG12 5BL, UK
Tel: [+44] 0115 937 1111 Fax: [+44] 0115 937 1100 www.golder.com
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Company Registered in England No. 1125149 At Attenborough House, Browns Lane Business Park, Stanton-on-the-Wolds, Nottinghamshire NG12 5BL
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leads to a loss of nitrate of approximately 25% after 10 mins and 50% after 1 hour. Furthermore, studies have shown (Davis *et al,* 1996) that even under dry conditions combustion is incomplete.

In wet environments, water resistant emulsions (in which the ammonium nitrate and/or other oxidising nitrate salts are surrounded by an oil or wax fuel phase) or ANFO-emulsion mixtures can be used in place of dry bulk ANFO or granules. However, ANFO-emulsion mixtures may be subject to poor detonation if the wrong emulsion mixes are used or charges are left too long prior to detonation (DRDC, 2010). Revey (1996) indicates that nitrate release from emulsions is considerably lower than ANFO but, even so, emulsions will leach given sufficient exposure time. This conclusion is supported by field data presented in Cameron *et al* (2007), which demonstrated much reduced release of nitrogen compounds into pit water using emulsion explosives. However, even using emulsion, the pit water ammoniacal nitrogen concentration reported in that study was up to 10 mg/l, indicating that use of emulsion mitigates but does not remove environmental risk.

In addition to dissolution in wet environments, DRDC (2010) list the following factors influencing detonation performance and loss of ANFO based on an evaluation of existing research:

- Type of ANFO (bulk, packaged, mixtures of bulk and packaged, ANFO-emulsion mixtures);
- Physical characteristics of ANFO particles;
- Storage and handling controls;
- Blast design considerations (drilling and loading practices, charge cutoffs or precompression failures); and
- Loading controls (e.g. spillage and blow back during pneumatic loading of bulk ANFO).

Although the DRDC study focuses on management of ANFO explosives, similar issues apply to emulsion explosives.

1.2 Sources of Nitrogen from Blasting at Amulsar

ANFO explosives will be used at the open pits for the Amulsar project. DRDC (2010) report a typical composition of ANFO explosives as 94% ammonium nitrate and 6% fuel oil based on its stoichiometric composition. However, the composition of commercial ANFO formulations will vary depending on the manufacturer (DRDC, 2010). For example, Dyno Nobel's ANFO comprises >90% ammonium nitrate and <10% fuel oil; Orica's ANFO 94/6 comprises >90% ammonium nitrate, <10% fuel oil and <1% "non-hazardous" ingredients; and Nordex Explosives Ltd's NorAnfo comprises 94.33% ammonium nitrate and 5.67% fuel oil.

On this basis, the quantity of nitrogen as ammonium and nitrate contained in the explosives is shown in

Table 2: Mass of Nitrogen as a Function of Explosive Mass

Constituents	**Mass (AMU)**	**ANFO composition**		
		wt %	**kg/tonne explosives**	**kg/tonne (expressed as N)**
NH_4NO_3		94	940	
NH_4	18.04		212	164.5
NO_3	62.00		728	164.5
$NaNO_3$				
Na	22.99			
NO_3	62.00			

Lydian International Ltd (Lydian) provided the information in Table 3 regarding projected annual explosives consumption during the mine operation. The information also contains the mass of waste (barren) rock removed during each year of the mine life.

Table 3: Projected ANFO use at Amulsar Over the Mine Life

Year of Operation	Ore Production (tpa)	Barren Rock (tpa)	Ratio of Ore to Barren Rock	ANFO Use (tonnes/yr)
1	9,240,000	24,959,820	0.37	12,480
2	9,240,000	32,302,060	0.29	16,150
3	9,240,000	42,748,780	0.22	21,370
4	9,240,000	42,339,160	0.22	21,170
5	9,240,000	43,088,640	0.21	21,540
6	9,240,000	42,067,310	0.22	21,030
7	9,240,000	43,179,030	0.21	21,590
8	9,240,000	39,268,700	0.24	19,630
9	9,240,000	29,582,770	0.31	14,790
10	9,240,000	30,253,970	0.31	15,130
11	9,240,000	16,159,600	0.57	8,080

Water management assessments for the open pit and barren rock storage facility (BRSF) (GRE, 2014a, 2014b, 2014d) consider a nine-year mine life. Values (flow or seepage rates) from GRE (2014a, 2014b, 2014d) have been applied in Year 2 onward. For the BRSF, it is assumed that run-off in the operational years following the last year for which output has been provided from the seepage assessment (2022) is the same as that in 2022.

At the point of discharge to groundwater, it is assumed that the source term will have proportions of ammonium and nitrate equal to the explosive composition. Ammonium is likely to undergo nitrification during leaching and subsequent surface/subsurface transport.

1.3 Estimates of Rates of Nitrogen Release to the Environment

The following are estimates of nitrogen loss from nitrogen based mine explosives:

- Revey (1996): 1.2% leaching from emulsion explosives in water after 144 hours.
- Pommen (1983): Case study of one mine, with reference to a study of a second site. One percent of nitrogen content of ANFO released, 6% from slurry, assumed to be nearly entirely nitrate with only small, but acknowledged that this is a function of pathway length to the discharge point and capacity of nitrification to occur.
- Ferguson and Leask (1988): Open pit mining, case study of five mines.
  - In dry conditions, 0.2% of nitrogen from ANFO released;
  - In mines using greater than 20% slurry explosives the authors proposed 0.94% of nitrogen contained in ANFO and 5.1% of nitrogen contained in slurry.
- Wiber et al (1991): 5 to 15% loss of nitrogen from ANFO, even with consideration of good practice.
- Sharpe (2007): 5 to 15% loss of nitrogen from ANFO, but this could be reduced to 2% to 5% is best practices were followed.
- Morin and Hutt (2008): Underground mining, case study of one mine, 12 – 28% of explosive nitrogen content, 40 % to 46% NH_3, 2.9% - 4.0% Nitrite, 51.3% to 56%.

Morin and Hutt (2008) refer to groundwater flow through the mine and drainage along a floor ditch via gravity to the discharge location. This strongly indicates that blasting was occurring in saturated rock, although ANFO and other powder explosives were used. It is considered likely that the significant discrepancy in the proportion of nitrogen loss between the Fergusson and Leask (1988) and Morin and Hutt (2008) studies is associated with the use of ANFO in saturated conditions in the latter study, resulting in much higher rates of dissolution of the explosives prior to blasting and greater quantity of undetonated explosives (as indicated by Revey, 1996).

1.4 Estimation of Nitrogen in Mine Water at the Amulsar Mine

A methodology similar to that proposed by Ferguson and Leask (1988) has been used to estimate nitrogen in mine water at Amulsar.

Based on the studies quoted above, it is assumed that 2% to 5% of dry ANFO will contribute to nitrogen in mine water. This is based on discussions in Revey (1996) of leaching from emulsion explosives and in DRDC (2010) on limitations of emulsion-ANFO mixtures in wet environments.

It is assumed that with good management practices, nitrogen will only be released on wet days, when run-off (from rainfall or snowmelt) will transport blasting residues to the pit sump(s). On dry days, the majority of explosive residual will be contained in the blasted rock and transported via mine trucks either to the BRSF or to the heap leach facility (HLF). It has been assumed that run-off (and thus nitrogen release to the pit sumps) occurs on 30% of the days of the year at Amulsar (representing snowmelt during the spring months and intermittent rainfall events during the summer and autumn). It is assumed that the remaining 70% of the explosive residual will be transported to the HLF and BRSF or Tigranes/Artavazdes pit backfill area in proportion with the mass of ore and barren rock mined. The following proportions have been assumed:

- 30% of the explosive residues are transported by run-off to the pit sump(s); and
- 70% of the explosive residues are transported to the HLF and BRSF/pit backfill based on tonnage, according to the proportions shown in Table 3.

It is assumed that as ammonium nitrate is highly soluble, residual explosives are rapidly leached into pit run-off, BRSF infiltration or HLF leach solution. Depending upon the rock type, ammonium may partition slightly onto the solid phase, reducing leaching to groundwater. However, as ammonium partition coefficients can be very low in some materials, this effect has been neglected.

1.4.1 Pit Sumps

The concentration of nitrate and ammonium in water in the pit sumps is affected by a number of processes. This memorandum refers to pit sump water collectively over the mine life since the explosives use data and the outputs of the pit run-off model (GRE, 2014a) do not differentiate between mining of the Artavazdes/Tigranes pit and or Erato pits.

The quantity of ANFO used in the open pits increases over the first and second year of the mine life, is at a maximum and is approximately constant in years three to seven of the mine life and declines thereafter. Nitrogen loading will therefore be highest in the middle years of operation.

The volume of water in the pits will increase over the mine life as the area of the pits increases. The increased volume of water will provide greater dilution as the mine life proceeds, reducing ammonium and nitrate concentrations as a result of dissolution of ANFO residues. Backfilling of the pits commences in Year 5, such that the area contributing to run-off does not increase in the later years of mining. Annual total pit water volumes calculated by GRE (2014a) are shown in Table 4.

Table 4: Annualised Total Pit Dewatering Flows, GRE (2014a)

Mine Year	Annualised Flow Rate m^3/year
1	88,060
2	133,390
3	163,480
4	255,520
5	234,890
6	249,080
7	252,310

Mine Year	Annualised Flow Rate m^3/year
8	238,620
9	211,210

Decreasing run-off rates toward the end of the mine life will coincide with decreasing ANFO use. Calculations of annual mean ammonium and nitrate concentration in pit sump water (Attachment 1) indicate that on an annual basis, average ammonium and nitrate concentrations will be highest at the start of the mine life with an annual mean between 181 mg N/l and 453 mg N/l (for both nitrate and ammonium as nitrogen). Annual mean concentrations decrease and stabilise later in the mine life at approximately 70 mg N/l to 180 mg N/l.

Run-off is not distributed evenly across the year. The run-off model (GRE, 2014a) indicates that negligible run-off will occur in winter months when the temperature is sub-zero. Run-off is highest during the spring snow melt, and nitrogen loading is also initially high during this period due to accumulation of nitrogen mass over the winter months. The annual fluctuation in nitrate and ammonium concentrations in response to changes in run-off will result in minimum concentrations in June, when the spring flush event has passed and run-off rates remain high. Calculations (Attachment 1) indicate concentrations at the pit sump may be between 12 mg N/L and 30 mg N/L in June. Nitrate and ammonium concentrations are expected to be highest in autumn, following the summer dry period and before the influence of autumn rainfall is seen in the pit run-off model. The actual concentrations during this period are highly dependent on the accumulated mass of ammonia and nitrate, environmental degradation over the summer months, and the quantity of mine water inflow. Concentrations in excess of 1,000 mg N/l are theoretically possible in small volumes of mine water. .

The volume of water in the pit sump is likely to be largest in spring, following the spring snow melt. This is the period of the year when it is most likely that significant standing water will be present in the base of the pits and therefore infiltration from the pit sump to groundwater will be highest. Although ammonium and nitrate concentrations in the pit sump will potentially be very high in early autumn, the volume of run-off from the pits in these months can be more readily managed and the volume of water in the pit sump (and therefore infiltration rates) will be low.

1.4.2 Pit Backfill

The concentration of nitrate and ammonium in water infiltrating to groundwater from the base of the Tigranes/Artavazdes pit backfill has been calculated on the following basis:

- Modelling of infiltration from the pit backfill has indicated that a pulse of discharge occurs from the barren rock mass arising from the period of infiltration during the uncovered period (i.e. prior to reclamation and construction of the store-and-release cover);
- It is assumed that the ammonium and nitrate in the barren rock is released into this initial pulse of discharge; and
- It is assumed that development of preferential pathways through the pit backfill results in only a proportion of the rock mass contacting infiltrating water. A channelization factor between 10% and 25% has been assumed.

For the Artavazdes pit, the volume of the initial pulse is calculated as the sum of infiltration from the base of the backfill over the first 20 years following the end of backfill operations (GRE, 2014b). For the Tigranes pit, the initial pulse is calculated as the infiltration from the base of the backfill over the first 17 years following the end of backfill operations (GRE, 2014b).

Calculations (Attachment 1) indicate that ammonium and nitrate concentrations in seepage discharging from the base of the backfill will range between approximately 70 mg N/l and 440 mg N/l. Modelling of the backfill seepage (GRE, 2014b) indicates that the annual average seepage rate from the pit backfill footprint does not exceed 1 L/s (combined from both Artavazdes and Tigranes backfill areas) during or following mine operations.

1.4.3 BRSF

The concentration of ammonium and nitrate in fluids within the BRSF engineered facility has been calculated assuming:

- The mass of nitrate and ammonium in barren rock delivered annually to the BRSF is released into infiltration the same year; and
- Development of preferential pathways through the barren rock results in only a proportion of the rock mass contacting infiltrating water. A channelization factor between 10% and 25% has been assumed.

The volume of seepage (infiltration to groundwater) from the base of the BRSF during the operational period has been calculated by GRE (2014d).

Calculations (Attachment 1) indicate that annual average concentrations of ammonium and nitrate in fluids within the engineered containment system for the BRSF will range from 13 mg N/l to 420 mg N/l. Concentrations are predicted to be highest during the early years of operation of the BRSF, when the small footprint area results in a low volume of infiltration to the facility. Seepage from the BRSF will vary seasonally, whilst loading rates will be less dependent on the time of year. This will result in seasonal fluctuations in concentration outside the range stated above. The seasonal range in flow (Figure 1) indicates that this will be typically no more than a two-fold change from the annual average concentrations. Concentrations are likely to be highest in winter and late summer and lowest in April and May.

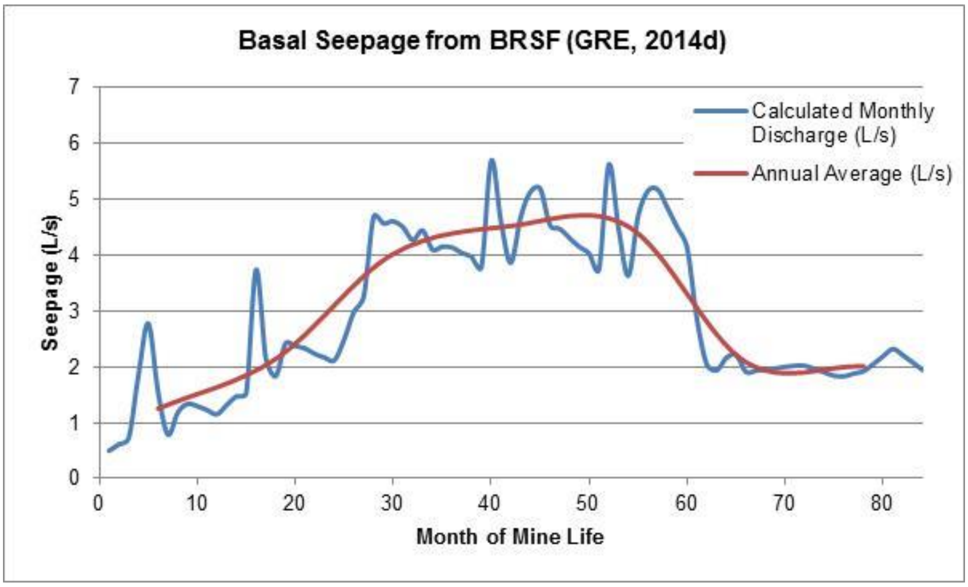

Figure 1: Calculated monthly seepage from the BRSF (GRE, 2014d), and annual average seepage

1.4.4 HLF

Calculations indicate that the mass of nitrate and ammonium transported to the HLF over the mine life will be between approximately 10,640 kg N/year and 26,600 kg N/year for both nitrate and ammonium (Attachment 1).

The HLF leach solution will be recycled throughout the mine life. Make-up water will be added as required to maintain the total solution volume. The concentration of ammonium and nitrate in the HLF leach solution will be a function of the mass of ANFO residue transported to the facility, and the concentration of ammonium and nitrate in waters used as make-up water. The storage pond used to supply make-up water will receive water from a number of sources including the pit sumps and BRSF run-off. Make-up water may also be sourced from the Arpa River. The concentration of ammonium and nitrate in the HLF solution will be a function of the proportion of water from each source in the makeup water supply, and the ammonium and nitrate concentrations in each of these sources. This analysis is outside the scope of this memorandum.

1.4.5 Summary of Results

The calculations are presented in Attachment 1 and results are summarised in Table 5.

Table 5: Calculated Concentrations of Nitrate and Ammonium (as N) in Mine Water

	Nitrate Concentration (mg N/l)*		Ammonium Concentration (mg N/l)*	
Area	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Pit Sumps	12 - 30	>1,000*	12 - 30	>1,000*
Pit Backfill Fluids	70	440	70	440
BRSF Fluids	13	420	13	420

* Significant uncertainty in this high concentration, low volume sump water.

The ranges shown in Table 5 in the case of the pit sumps reflect seasonal fluctuations in water quality, as well as the range attributable to uncertainty regarding the proportion of ANFO which will contribute to nitrogen in mine water. Maximum concentrations are predicted for early autumn; minimum concentrations are predicted in June. For the pit backfill seepage and fluids within the BRSF engineered containment system, the range presented incorporates uncertainty regarding the degree of contact between the barren rock and infiltrating water and the proportion of ANFO which will contribute to nitrogen in mine water.

1.5 Conclusions and Recommendations

Calculated concentrations indicate that there is the potential for both ammonium and nitrate concentrations to exceed the Republic of Armenia Surface Water MAC of 0.4 mg/l ammonium as N and 2.5 mg/l nitrate as N, in water infiltrating to ground from the pit sumps, and from the Tigranes-Artavazdes pit backfill. In the absence of relevant groundwater standards, and due to the fact groundwater reports to surface water in the form of springs, surface water MACs provide suitable standards for the project. In the pit sumps, the concentration will be highest in early autumn, when the volume of water in the pit sump is likely to be the least, and will be lowest in spring when the volume of water in the pit sump is likely to be the greatest.

Concentrations of ammonium and nitrate in fluids within the engineered containment of the BRSF are predicted to exceed the Republic of Armenia maximum acceptable concentration (MAC) of 0.4 mg/l as N and 2.5 mg/l as N, respectively. The calculation is based on an average annual discharge flux and concentrations may be higher distributed across the year.

The predicted concentration of ammonium and nitrate in the HLF will be a function of the relative contribution of water from a range of sources, including the pit sumps and BRSF underdrain system, to make-up water applied to the heap. The calculated nitrogen mass load associated with the ore should be considered in water quality assessments for the HLF leach solution.

In order to mitigate against the risk of nitrogen loading from partial detonation of explosives, it is recommended that industry best practice is followed. This includes use of appropriate explosives use for the environmental conditions, appropriate handling techniques during transport and storage to minimise explosives loss, immediate containment and clean-up of any spillages, appropriate charge loading procedures to minimise explosives loss, and appropriate procedures to manage blasting to minimise misfires. Revey (1996) provides specific guidelines for ANFO storage, transportation, and use that reduce spillage, ANFO loss to groundwater, and maximize the detonation of ANFO in blasts.

1.6 References

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H. Garrick

Hollie Garrick
Hydrogeologist

Carl Nicholas
Project Manager

CHG/DB/CN/np

ATTACHMENT 1

Prepared by:	HG	15/02/2012
Checked by:	GDLT	16/02/2012
Updated by:	JB	21/06/2013
Checked by:	GDLT	27/06/2013
Updated by:	HG	14/07/2014
Checked by:	GDLT	16/07/2014

This spreadsheet should be viewed in conjunction with the accompanying technical memorandum which describes derivation of input parameters applied in the calculation.

Calcuation input parameters are shown in green 🟩

Source data:

Pit runoff

GRE, 2014a. Technical Memorandum. Amulsar Pit Dewatering Model. Ref 13-1064, July 2014
Spreadsheet accompanying memorandum, summed by year

ANFO use

Received by email from Carol Fries, 23/06/2014

Pit base and wall areas for backfill infiltration

DXF files "Backfill design" received from AMC, 10/60/2014
Base and wall areas measured in GIS.

Total open waste infiltration to Tigranes and Artavazdes backfill

GRE, 2014b. Technical Memorandum. Amulsar Pit Backfill Seepage Model. Ref. 13-1064. July 2014
Spreadsheet accompanying memorandum
Sum of infiltration (flux x timestep length), years 1 to 17 for Tigranes and 1 to 20 for Artavazdes

Seepage rate from the BRSF

GRE, 2015d. Technical Memorandum. Amulsar BRSF Seepage Model. Ref. 13-1064. 14 July 2014
Spreadsheet accompanying memorandum, sum of total seepage per mine year from monthly flows as L/s

CALCULATION OF WATER QUALITY IMPACTS FROM BLASTING RESIDUE

Calculation of Nitrogen Mass Loading

Explosives Usage During Mine Operation:

		0.5 kg/t	100%	0%
Year of Operation	**Total Rock Removal tpa**	**Explosives Use t/yr**	**ANFO t/yr**	**Emulsion t/yr**
1	24959817	12480	12480	0
2	32302058	16151	16151	0
3	42748778	21374	21374	0
4	42339155	21170	21170	0
5	43088641	21544	21544	0
6	42067311	21034	21034	0
7	43179027	21590	21590	0
8	39268698	19634	19634	0
9	29582771	14791	14791	0
10	30253970	15127	15127	0
11	16159601	8080	8080	0

Proportion of explosive lost:

	Min (fraction)	**Max (fraction)**
ANFO	0.02	0.05
Emulsion	0.005	0.03

Ammonium and nitrate in explosives kg N/tonne:

	Nitrate (kg N/t)	**Ammonium (kg N/t)**
ANFO	164.5	164.5
Emulsion	159.8	140.0

Mass of explosives and nitrogen compounds lost:

	ANFO (t/yr)		**Emulsion (t/yr)**		**Nitrate (kg/yr)**		**Ammonium (kg/yr)**	
Year of Operation	Min	Max	Min	Max	Min	Max	Min	Max
1	249.6	624.0	0	0	41056	102641	41056	102641
2	323.0	807.6	0	0	53134	132834	53134	132834
3	427.5	1068.7	0	0	70317	175794	70317	175794
4	423.4	1058.5	0	0	69644	174109	69644	174109
5	430.9	1077.2	0	0	70876	177191	70876	177191
6	420.7	1051.7	0	0	69196	172991	69196	172991
7	431.8	1079.5	0	0	71025	177563	71025	177563
8	392.7	981.7	0	0	64593	161483	64593	161483
9	295.8	739.6	0	0	48661	121652	48661	121652
10	302.5	756.3	0	0	49765	124412	49765	124412
11	161.6	404.0	0	0	26581	66452	26581	66452

Distribution of nitrogen compounds across Mine Facilities:

Year of Operation	**Approx proportion of ore in mined mass**	**Pit Area**	**Heap Leach Pad**	**Waste Dump**
1	0.4	0.30	0.26	0.44
2	0.3	0.30	0.20	0.50
3	0.2	0.30	0.15	0.55
4	0.2	0.30	0.15	0.55
5	0.2	0.30	0.15	0.55
6	0.2	0.30	0.15	0.55
7	0.2	0.30	0.15	0.55
8	0.2	0.30	0.16	0.54
9	0.3	0.30	0.22	0.48
10	0.3	0.30	0.21	0.49
11	0.6	0.30	0.40	0.30

Pit Area	**Nitrate (kg N/yr)**		**Ammonium (kg N/yr)**	
Year of Operation	min	max	min	max
1	12317	30792	12317	30792
2	15940	39850	15940	39850
3	21095	52738	21095	52738
4	20893	52233	20893	52233
5	21263	53157	21263	53157
6	20759	51897	20759	51897
7	21308	53269	21308	53269
8	19378	48445	19378	48445
9	14598	36496	14598	36496
10	14929	37324	14929	37324
11	7974	19936	7974	19936

Heap Leach Pad	**Nitrate (kg N/yr)**		**Ammonium (kg N/yr)**	
Year of Operation	min	max	min	max
1	10639	26598	10639	26598
2	10639	26598	10639	26598
3	10639	26598	10639	26598
4	10639	26598	10639	26598
5	10639	26598	10639	26598
6	10639	26598	10639	26598
7	10639	26598	10639	26598
8	10639	26598	10639	26598
9	10639	26598	10639	26598
10	10639	26598	10639	26598
11	10639	26598	10639	26598

Barren Rock Storage/Backfill		**Nitrate (kg N/yr)**		**Ammonium (kg N/yr)**	
Year of Operation	Destination	min	max	min	max
1	Waste Dump	18100	45251	18100	45251
2	Waste Dump	26554	66386	26554	66386
3	Waste Dump	38583	96457	38583	96457
4	Waste Dump	38111	95278	38111	95278
5	Waste Dump	38974	97436	38974	97436
6	Backfill	37798	94496	37798	94496
7	Waste Dump	39078	97696	39078	97696
8	Backfill	34576	86440	34576	86440
9	Backfill	23423	58558	23423	58558
10	Waste Dump	24196	60490	24196	60490
11	Waste Dump	7967	19919	7967	19919
Total to Barren Rock Storage		231565	578913	231565	578913
Total to Backfill		95798	239494	95798	239494

Calcuation of Water Quality Impacts

Barren Rock Storage Facility

	Min	Max
Channelisation factor	0.1	0.25

		Nitrate as N (mg/L)		**Ammonium as N (mg/L)**	
Year of Operation	Liquid discharge (m3/yr)	min	max	min	max
1	-	-	-	-	-
2	39428	67	421	67	421
3	67473	57	357	57	357
4	126788	30	188	30	188
5	142584	27	171	27	171
6	142302	0	0	0	0
7	65716	59	372	59	372
8	63423	0	0	0	0
9	63423	0	0	0	0
10	63423	38	238	38	238
11	63423	13	79	13	79

Pit Area

Open Pit: Release from Pit Sump

Pit inflow rates taken from GRE Memorandum "Amulsar Pit Dewatering Model", July 2014, and accompanying spreadsheet

Annual Average Concentration:

Year of Operation	Pit inflow (m3/year)	Nitrate as N (mg/L)		Ammonium as N (mg/L)	
		min	max	min	max
1	0	-	-	-	-
2	88055	181	453	181	453
3	133386	158	395	158	395
4	163478	128	320	128	320
5	255521	83	208	83	208
6	234887	88	221	88	221
7	249083	86	214	86	214
8	252309	77	192	77	192
9	238620	61	153	61	153
10	211214	71	177	71	177
11	0	-	-	-	-

Annual Distribution

Month	Flow (m3/month) Mine Year 2*	Nitrate Load Released (kg N)		Ammonium Load Released (kg N)		Nitrate as N (mg/L)		Ammonium as N (mg/L)	
		Min	Max	Min	Max	min	max	min	max
1	0	0	0	0	0	-	-	-	-
2	0	0	0	0	0	-	-	-	-
3	0	0	0	0	0	-	-	-	-
4	0	0	0	0	0	-	-	-	-
5	28293	7970	19925	7970	19925	282	704	282	704
6	43905	1328	3321	1328	3321	30	76	30	76
7	998	1328	3321	1328	3321	1331	3329	1331	3329
8	7370	1328	3321	1328	3321	180	451	180	451
9	2450	1328	3321	1328	3321	542	1356	542	1356
10	358	1328	3321	1328	3321	3706	9266	3706	9266
11	4681	1328	3321	1328	3321	284	709	284	709
12	0	0	0	0	0	-	-	-	-

*Runoff model Year 1

Month	Flow (m3/month) Mine Year 8*	Nitrate Load Released (kg N)		Ammonium Load Released (kg N)		Nitrate as N (mg/L)		Ammonium as N (mg/L)	
		Min	Max	Min	Max	min	max	min	max
1	0	0	0	0	0	-	-	-	-
2	0	0	0	0	0	-	-	-	-
3	0	0	0	0	0	-	-	-	-
4	0	0	0	0	0	-	-	-	-
5	67827	10654	26634	10654	26634	157	393	157	393
6	146270	1776	4439	1776	4439	12	30	12	30
7	1962	1776	4439	1776	4439	905	2263	905	2263
8	16586	1776	4439	1776	4439	107	268	107	268
9	8441	1776	4439	1776	4439	210	526	210	526
10	702	1776	4439	1776	4439	2531	6327	2531	6327
11	10522	1776	4439	1776	4439	169	422	169	422
12	0	0	0	0	0	-	-	-	-

*Runoff Model Year 7

Backfilled pit: seepage from backfill

	Min	Max
Channelisation factor:	0.1	0.25

	Tigranes				Artavazdes					Nitrate as N (mg/L)		Ammonium as N (mg	
Year of Operation	Pit wall area km2	Pit base area km2	wall backfill infiltration Total (m)	base backfill infiltration total (m)	Pit wall area km2	Pit base area km2	wall backfill infiltration rate (m)	base backfill infiltration total (m)	Total water (m3)	min	max	min	max
Period of infiltration to open waste	0.36	0.018	0.11	0.33	0.32	0.077	0.11	0.71	136406	70	439	70	439

Summary

	Nitrate Concentration (mg N/l)		Ammonium Concentration (mg N/l)	
	Min	Max	Min	Max
BRSF fluids	13	421	13	421
Pit Sump	12 - 30	6300 - 9300	12 - 30	6300 - 9300
Pit Backfill seepage	70.2	439	70.2	439

Nitrogen Content of Explosives

		ANFO			Emulsion		
Components	**Molecular Mass**	**%**	**kg/tonne explosives**	**kg/tonne (expressed as N)**	**%**	**kg/tonne explosives**	**kg/tonne (expressed as N)**
NH4NO3		94%	940		80%	800	
NH4	18.0383		212	164.5		180	140
NO3	62.0049		728	164.5		620	140
NaNO3					12%	120	
Na	22.9898					32.5	
NO3	62.0049					87.5	20
Mineral Oil		6%	60		6%	60	

GFW's	
N	14.0067
H	1.0079
O	15.9994
Na	22.9898
Al	26.981