Comparison of Pre-Mining Geochemical Predictions to Operating Conditions for New Afton Tailings

Emily O'Hara and Scott Davidson
New Afton Mine, Canada

ABSTRACT

New Afton is a block cave mine that sustains processing of an average of 14000 tonnes per day of ore. The mine produces an average of 80,000 ounces of gold and 750,000 pounds of copper annually over a 12 year mine life. New Afton is located near Kamloops, BC which is hosted by a grassland ecosystem classified as semi-arid, with annual average precipitation of 305mm and evaporation of 608mm.

Prediction of acid rock drainage (ARD) and metal leaching (ML) for tailings supernatant and leachate is typically carried out early in the permitting process when access to tailings samples is often limited to those generated from metallurgical testing programs which often do not reflect the range of geological conditions that are present in an ore body or surrounding waste rock. Early prediction of potential effects, is essential to ensure mitigation programs can be effectively developed and implemented. New Afton has a variety of practices available to understand and control potential effects of ARD or ML. With 2 years of operating conditions, comparisons are now being carried out to reflect on the predicted versus actual conditions. This paper examines the comparison of pre-mining geochemical predictions with actual observed conditions while also commenting on some of the challenges in linking the two.

The New Afton ore body is classified as having low acid generating potential, with a high neutralizing capacity. The predicted Net Neutralizing Potential (NNP) for tailings samples is between 177 and 263 tCaCO3/1000t, with paste pH between 8 and 8.6. Predicted tailings supernatant ranged between 7.85 and 9.28 and actual supernatant at the Tailings Storage Facility (TSF) has ranged between 7.83 and 9.79, over the last 2 years of operation. Additional tailings samples have been taken based on "actual" conditions, and humidity cell tests (HCTs) are in progress to determine the variability between the pilot plant samples. The two original humidity cells generated from metallurgical testing have been running for 6 years with no evidence of acidic conditions and pH results between 7.81 and 8.33. However, humidity cells, and tailings supernatant indicate that low level metal leaching may occur under neutral or high pH conditions.

Keywords: Tailings, Permitting, ARD, ML

INTRODUCTION

New Afton is located approximately 10km west of Kamloops in British Columbia, on the historic Afton Mine site. Kamloops is approximately 350km North East of Vancouver. The site is within the Interior Plateau region of British Columbia that lies in the rain shadow of the Coastal Mountains (Rescan, 2007). Precipitation in this area is very low, on average receiving 305mm per year with annual evaporation rate of 608mm (Environment Canada, 2014). The New Afton site is zero discharge, with all runoff being contained onsite. New Afton uses the "block cave" mining method.

The New Afton ore body is an alkalic porphyry copper-gold deposit comprised predominately of hypogene mineralization, with lesser amounts of supergene mineralization and intermediate mesogene mineralogy located in upper elevations of the deposit. The hypogene type ore has constituted over 85% of the mill feed to date, as the block cave mining sequence extracts ore from the lower levels of the current mining lift. The proportion of mesogene ore and supergene ores has gradually increased, as ore from higher levels in the block cave are extracted.

Pyrite is the main sulphide gangue mineral with the concentration of up to 0.5% in hypogene ore. Mesogene samples include higher proportion of carbonates (13% compared to 2-3% for the other ore types). A pyrite "halo" surrounds the ore zone, with sulphur values ranging between 0.02% and 8.1% (Rescan, 2006). Arsenic mineralization in the ore is found to be primarily tennantite with some tetrahedrite, and only trace amounts of arsenopyrite.

New Afton does not suffer from significant ARD/ML issues due to three main factors; low precipitation, low acid generating capacity and high neutralizing capacity. The block cave mining method does not generate significant waste rock, and all waste rock bought to surface is disposed of in the old Afton Pit. As waste rock generation is low, and disposal is fully controlled, the primary geochemical focus is acid rock draining and metal leaching (ARD/ML) potential of the tailings. While ARD potential for the tailings is very low, some metal leaching has been seen to occur at neutral or higher pH.

Tailings Dam Design

The New Afton tailings storage facility (TSF) is made up of five dams. Two dams were constructed at final elevation, and three were constructed as started dams to be raised throughout the mine life. The three construction dams use the centerline method of dam construction. New Afton also has the ability to use Pothook Pit for tailings deposition. Seepage ponds are located at the base of each of these dams, with pumping capacity to return water to the tailings impoundment.

The relevance to TSF design to geochemistry is the use of tailings sands as construction material. Raw tailings are processed using cyclones to produce a not acid generating (NAG) construction sand. Should the tailings be considered potentially acid generating (PAG), this method of construction would be less appropriate.

TESTING PROGRAM

Tailings geochemical prediction often has significant limitations primarily due to the availability of representative tailings samples. During the early stages of permitting and economic assessment, tailings samples are generated as part of metallurgical, laboratory based, pilot plant testing programs to determine which mill flow sheet will provide the best results. These tests are designed based on expected geological conditions and availability of core samples and may be designed and conducted in a fashion that does not reflect the proposed process. It is the remains from this test work that is then available for predictive testing.

Tailings Geochemistry Tests

Static Tests

Three samples based on ore type were selected for static acid base accounting (ABA) testing during the permitting process. The three samples were based on the three ore types, mesogene, hypogene and supergene with the results being demonstrated in Table 1.

Table 1 Historic Laboratory and Pilot Plant Tailings Samples

	Static Tests Only			**Static and HCTs**	
	JUN 20-06 LCT Hypogene Tails	**JUN 21-06 LCT M2 Mesogene Tails**	**JUN 22-06 LCT MS1 Mesogene/Supergene Tails**	**Tails Rougher 2092P6**	**Tails Final 2092P6**
Paste pH	8.3	8.2	8.3	8.6	8.5
%S (Total)	0.15	0.18	0.12	0.52	0.42
%S (Sulphide)	0.13 (Calc)	0.14 (Calc)	0.11 (Calc)	0.33	0.27
%S (Sulphate) Carbonate Leach	0.01	<0.01	0.02	0.02	0.05
%S (Sulphate) HCL Leachable	0.02	0.04	0.01	0.02	0.01
Measured NP (kg $CaCO_3$/t)	57	269	193	267	276
SNNP (kg $CaCO_3$/t)	53	264	190	252	264
SNPR	15.2	53.8	61.8	17.6	22.3
As ppm	5.6	37.2	64.7	1090	772
Cu ppm	1055	1650	2210	7890	6380
Se ppm	1	1	1	4	4

As per ore quality at New Afton, the tailings samples have been shown to be heavily neutralizing with the potential for acid generation being very low. Most of the Bulk NP is likely associated with the carbonate-based minerals, based on CaNP levels (Rescan, 2007).

Follow-up Static Tests

The mine permit for New Afton does not contain any geochemical monitoring program requirements for tailings. Since operation of the TSF began only 5 static samples have been taken in order to provide more representative data for the composite tailings. The grab sample program will continue throughout the life of mine to ensure continued understanding of tailings conditions. Samples will be selected based on mill feed characteristics. The ore feed is a blend of the 3 primary types so the collection of blended samples will provide a better understanding of actual conditions than analyses run on pure ore materials.

Table 2 Actual Tailings Samples 2014

	Static Tests Only		Static and HCTs		
	JUN 25-14 Whole Tailings	**JUN 25-14 Tailings Cyclone Underflow**	**Q2 2014 Overflow Tailings (SCOF)**	**Q2 2014 Underflow Tailings (STUF)**	**Q2 2014 Final Tailings (FTML)**
Paste pH	8.1	8.3	7.8	8.7	8.5
%S (Total)	0.9	0.74	0.73	0.35	0.55
%S (Sulphide)	0.82	0.71	0.69	0.31	0.52
%S (Sulphate) Carbonate Leach	0.08	0.03	0.04	0.04	0.03
%S (Sulphate) HCL Leachable	0.07	0.01	0.03	0.03	0.04
Measured NP (kg $CaCO_3$/t)	112	101	170	144	162
SNNP (kg $CaCO_3$/t)	88.6	79.1	149.4	135.3	147.0
SNPR	4.8	4.6	8.2	16.5	10.8
As ppm	36.5	38.5	25.3	35.8	32.5
Cu ppm	1730	1740	901	1980	1400
Se ppm	1.41	1.46	1.33	1.01	1.15

The ore type is predominately hypogene, however concentrations of each ore type will vary throughout the mine life. Table 3 shows the mill feed by ore type for April to August 2014 to illustrate the current level of variability. BCKGR is partially mineralized ore, and is treated as hypogene for processing requirements.

Table 3 Ore Composite by Type April – August 2014

	Tons	Supergene	Hypogene	Mesogene	BCKGR
April 2014	366,941	2.2%	75.9%	8.9%	13.0%
May 2014	392,151	2.5%	74.2%	8.1%	15.3%
June 2014	380,528	2.2%	73.9%	8.1%	15.9%
July 2014	400,030	1.8%	76.5%	8.8%	12.9%
August 2014	413,887	1.4%	75.4%	9.1%	14.1%

Figure 1 shows the expected mill feed as a function of ore type over the life of mine. It can be seen that the relative portion of mesogene and supergene ore increases later in the mine life.

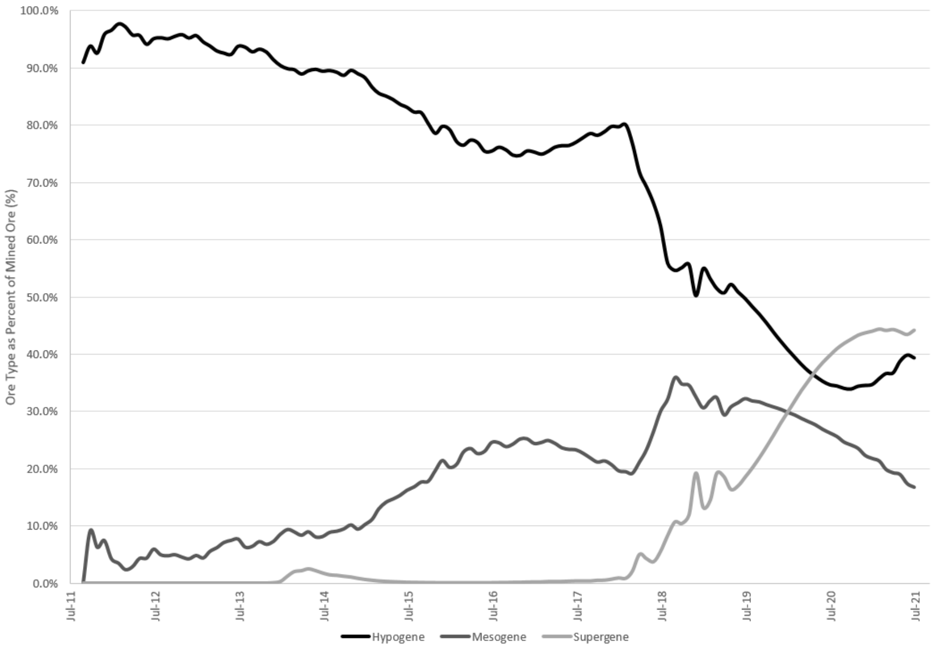

Figure 1 Mill Feed by Ore Type over Life of Mine

Initial Kinetic Tests

New Afton started two humidity cell tests (HCTs) on the 29th May 2008. Initial characterization results are shown above for the two HCTs in Table 1. The two samples were generated during two stages of a pilot plant, rougher and final tails (Rescan, 2012a) and these tests have been running for 329 weeks. The samples for the HCT tests were generated from mesogene ore material. Hypogene ore was also selected for pilot plant testing, however it is believed that there was not enough sufficient tailings produced from this ore type to allow for kinetic testing. Table 4 demonstrates the mineralogy of the tailings samples. No arsenic or antimony bearing mineral phases were identified in these mesogene tailings samples by Rietveld X-Ray Diffraction (XRD), however tennantite and tetrahedrite are considered the main contributing arsenic compound in mesogene ore (Rescan, 2012b).

Table 4 Rietveld X-Ray Diffraction Mineralogy for Tailings Humidity Cell Tests

Mineral	Ideal Formula	2092P6 Final Tls Sands	2092P6 Ro Tls Sands
Dolomite (wt.%)	$CaMg(CO_3)_2$	32.6	32.6
Muscovite, total (wt.%)	$KAl2AlSi_3O_{10}(OH)_2$	21.4	22.3
Plagioclase (wt.%)	$NaAlSi_3O_8$-$CaAl_2Si_2O_8$	18.3	17.2
Quartz (wt.%)	SiO_2	16.9	16.3
K-feldspar (wt.%)	$KAlSi_3O_8$	6.1	6.5
Kaolinite (wt.%)	$Al_2Si_2O_5(OH)_4$	3.4	3.6
Calcite (wt.%)	$CaCO_3$	1	1
Anatase (wt.%)	TiO_2	0.5	0.5

A secondary issue with the samples taken for initial HCT tests is that the feed sample was not representative of witnessed feed grade since operation, even considering mesogene ore feed. The feed grade in the pilot plant test was approximately 2% copper, which is around double what has been seen on average. The tails grade was also disproportionately high, as the pilot plant was targeting a specific concentrate grade not attempting to optimize recovery. This has resulted in elemental content of tailings being higher than average feed grade. For example, the As values for the tails used in the HCTs was 1090 ppm and 772ppm, whereas for 2014 the As values in Final Mill tailings (FTML) ranged between 7.4ppm and 58.5ppm. These are not seen as an error in sample collection, but a challenge when dealing with limited sample availability.

Due to low sulphur content and high neutralization potential, these HCTs were not expected to become acid generating. Metal leaching rates were not predicted for these samples. Figures 2, 3 and 4 demonstrate pH, arsenic and copper results seen for the two original tailings HCTS. While other metal concentrations have been decreasing, arsenic values have been increasing since week 258. It is believed that this increase could be the result of cleaning of fines that had accumulated under the screen which were then placed back on top of the solid sample. A spike in arsenic was also seen at a similar time in some waste rock cells following similar cell maintenance.

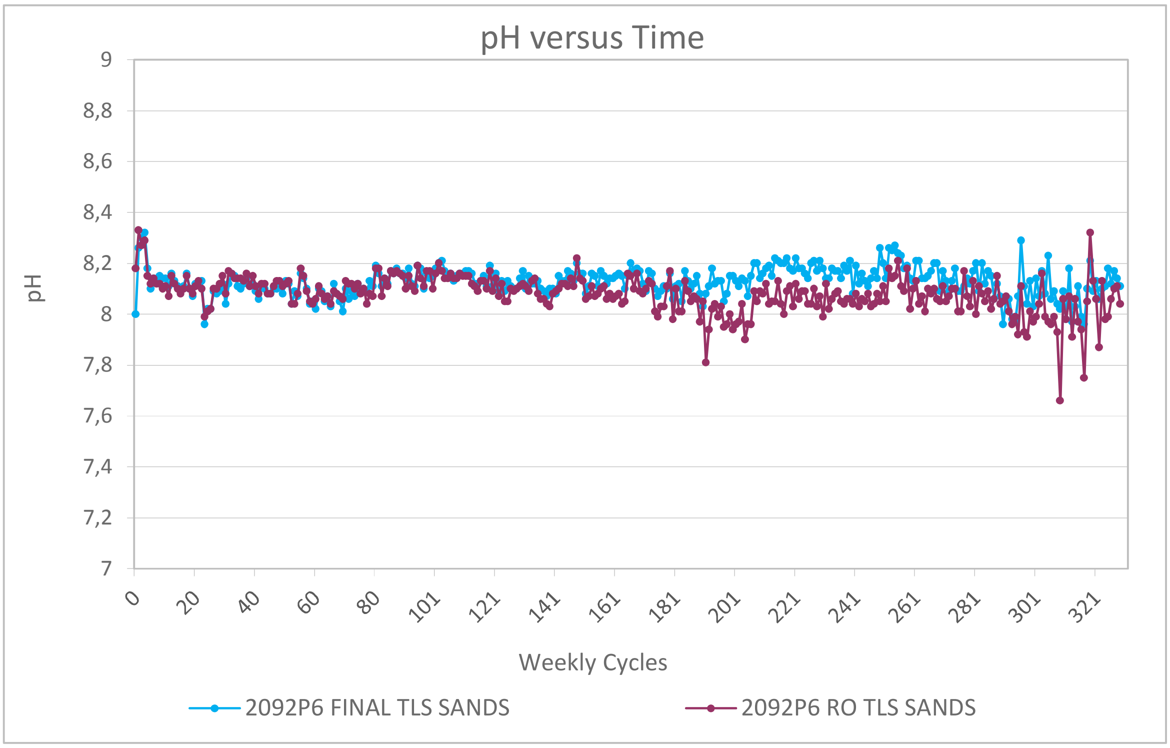

Figure 2 Pre-Operations HCTs pH vs Time

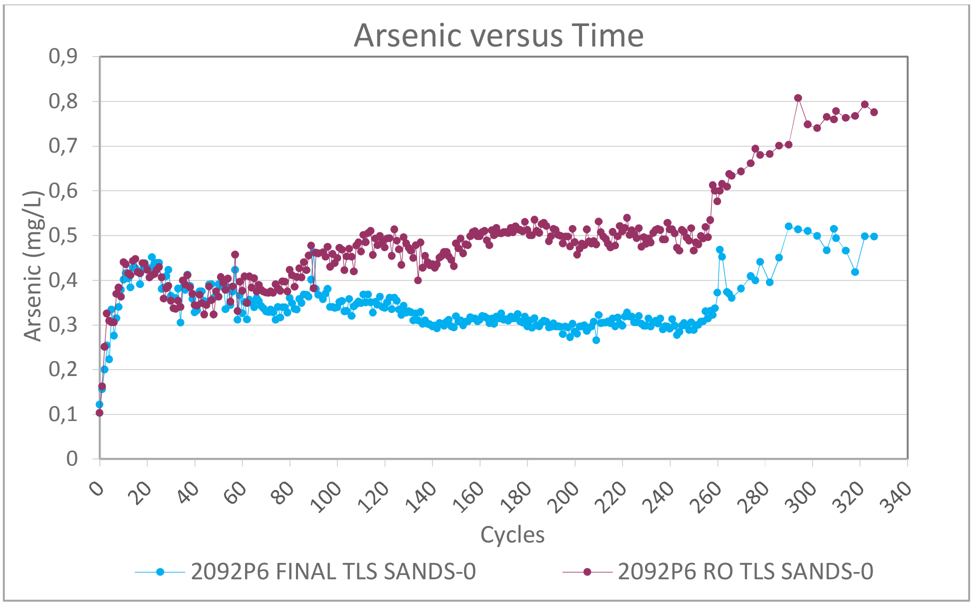

Figure 3 Pre-Operations HCTs Arsenic vs Time

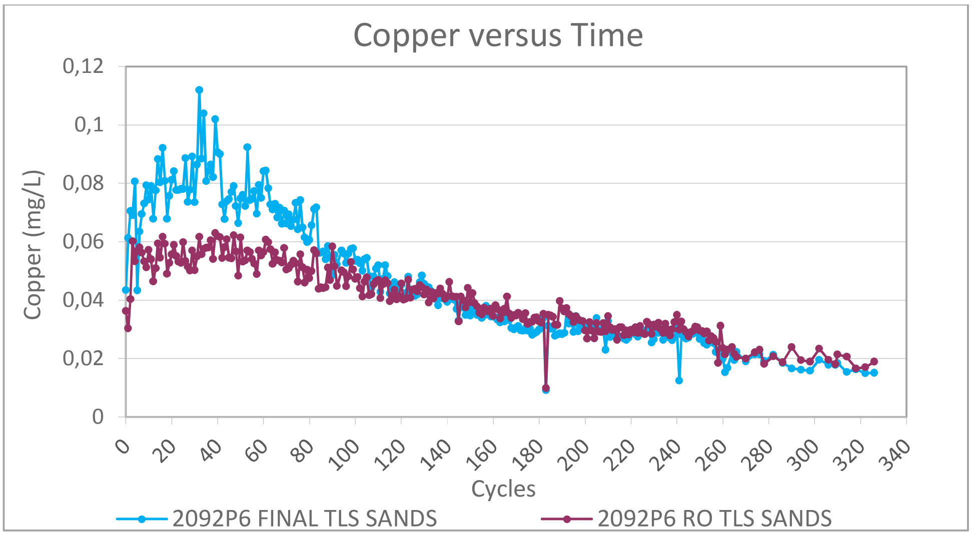

Figure 4 Pre-Operations HCTs Copper vs Time

Secondary Kinetic Tests

In the second quarter of 2014, a weighted composite of tailings was collected for Final Tailings (FTML), Secondary Tailings Underflow (STUF) and Secondary Tailings Overflow (SCOF). FTML is the total tailings that is sent from the mill to the TSF, STUF is the tailings sands that are used for dam construction, and SCOF is the fine slimes that are sent to the center of the TSF. This composite was collected over a 4 month period, in order to obtain required weights of samples for humidity cell testing.

There is currently not sufficient data to estimate time to ARD onset with the new humidity cells, as high loadings of sulphate is being exhibited due to initial flushing. The secondary humidity cells are intended to be continued throughout the life of mine. Additional HCT testing will be initiated later in the mine life when there is a higher portion of mesogene and supergene ore in the mill feed as these will reflect the final tailings produced during the mine.

Tailings Water Quality Tests

TSF water quality is of significant interest to regulators, and local communities of interest. While the water contained in the TSF is reused within the milling process, and the water is understood to be contaminated, monthly monitoring is carried out to ensure a good understanding of this water quality.

Laboratory Supernatant Analysis

Both fresh and 7-day aged supernatant analysis was carried out for the lock cycle test bulk tailings samples for hypogene tails, mesogene tails and a mesogene/supergene blended tails. A sample of these results are shown in Table 5.

Table 5 Lab Tested Tailings Supernatant Results and Actual New Afton TSF Supernatant

		Laboratory Test						Actual
		LCT H2 Hyp Tails Sol'n		LCT M2 Mes Tails Sol'n		LCT MS1 Mes/Sup Tails Sol'n		SW17 - TSF
	Units	Fresh	7-Day Aged	Fresh	7-Day Aged	Fresh	7-Day Aged	Average 2012-2014
TSS	mg/L	700	412	140	124	3240	32	38
pH	pH	8.93	8.34	8.85	7.85	9.28	8.87	8.58
Acidity	Mg/L as $CaCO_3$	<2	<2	<2	<2	<2	<2	2.5
Alkalinity	Mg/L as $CaCO_3$	152	138	170	170	261	204	92
Conductivity	uS/cm	548	554	692	663	647	665	7700
SO_4	mg/L	69	86	97	110	78	99	4448
As – Total	mg/L	0.0085	0.0072	0.0561	0.0488	0.328	0.142	0.023
Cu – Total	mg/L	3.17	1.1	0.185	0.0958	6.33	0.412	0.03
Mo - Total	mg/L	0.0141	0.017	0.0205	0.0242	0.00482	0.0128	0.1585
Pb - Total	mg/L	0.0121	0.0104	0.00112	0.0012	0.0572	0.0068	0.0013
Se – Total	mg/L	<0.003	<0.003	0.006	0.005	<0.003	0.003	0.0416
As – Dissolved	mg/L	0.0079	0.008	0.04	0.0474	0.134	0.123	0.021
Cu – Dissolved	mg/L	0.718	0.592	0.0034	0.0054	0.178	0.0037	0.004
Mo - Dissolved	mg/L	0.0184	0.0202	0.0211	0.0231	0.01416	0.017	0.1549
Pb - Dissolved	mg/L	0.00832	0.0082	0.0001	0.0001	0.0043	0.0003	<0.0005
Se – Dissolved	mg/L	<0.0003	<0.0003	0.006	0.006	0.006	0.005	0.044

Monthly Water Quality Samples

New Afton monitors tailings supernatant monthly as per permit requirements. Table 5 shows monthly averages when compared against the laboratory supernatant tests. pH at the TSF has ranged between 7.83 and 10.4. Higher pH results are likely associated with lime that is added to the mill process, rather than neutralization that is occurring. The major difference between the laboratory and field tests has been conductivity and sulphate. Figure 5 and Figure 6 demonstrate the pH, conductivity, sulphate and alkalinity results seen at the New Afton TSF since operation commenced.

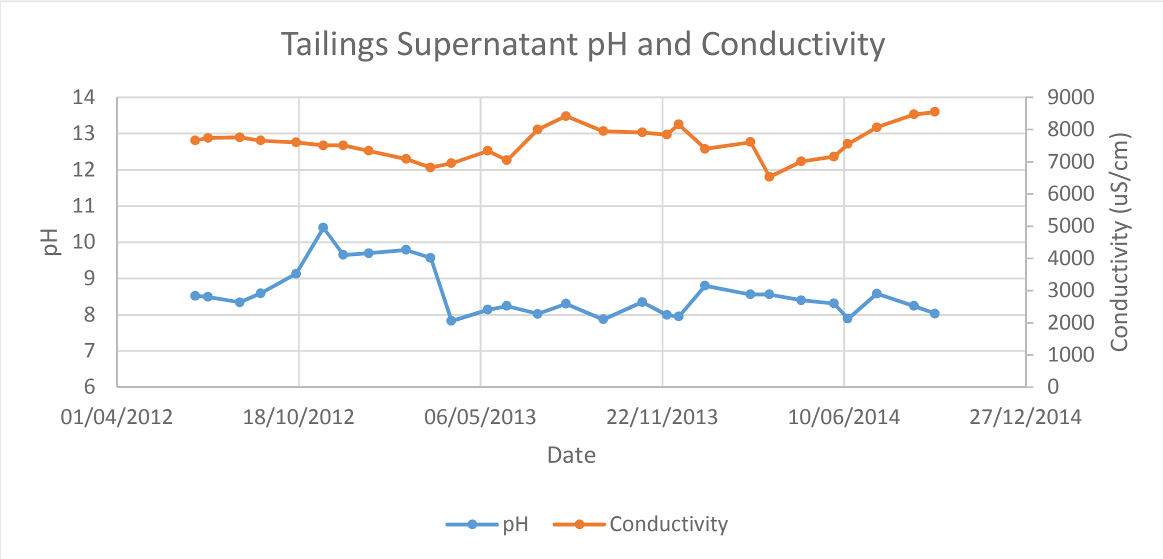

Figure 5 Actual Tailings Supernatant pH and Conductivity

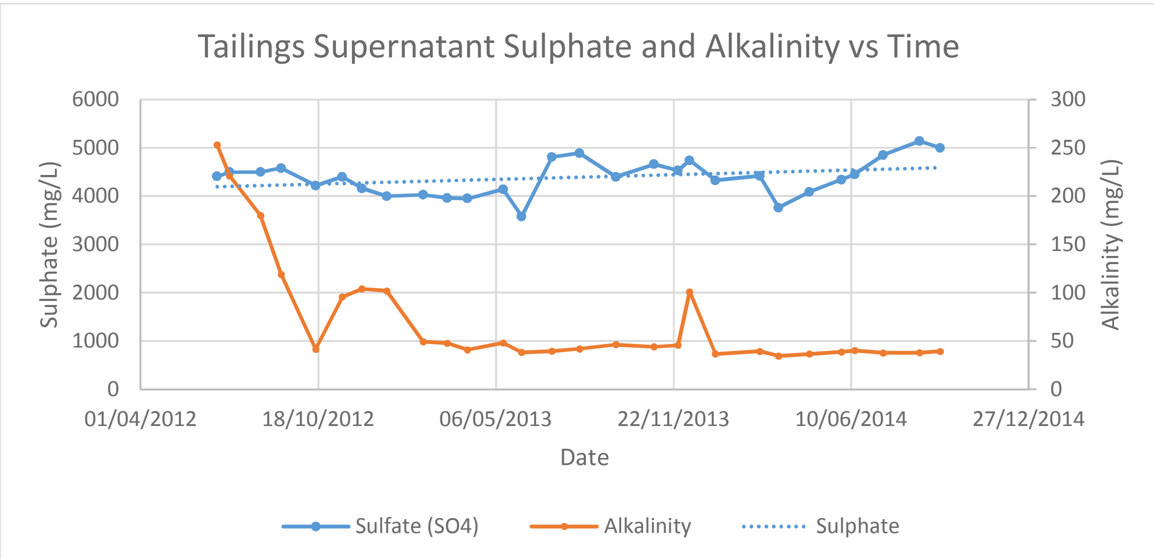

Figure 6 Actual Tailings Supernatant Sulphate vs Time

RESULTS AND DISCUSSION

Overall, kinetic, static and supernatant test results indicate that New Afton should not expect tailings to become acid generating, or have significant issues with ML. Both lab and mill produced tailings demonstrated low acid potential and high neutralizing potential, which was expected based on ore properties. The pre-operation humidity cells are an outlier in comparison to other test results with respect to elemental content.

Operational characterization programs have been developed in order to ensure that there is adequate characterization of the tailings that are being produced over the life of mine. The development of these operational characterization programs is important given with the need to validate or refute the representative nature of the pre-mining characterization samples.

Humidity Cell Results

Humidity cells to date indicate neutral pH and generally low metal loadings. BC Fresh Water Aquatic Life (BCFWAL) concentration guidelines have seen exceedances for antimony, arsenic, copper and selenium. Metal loadings have generally been decreasing throughout testing, however arsenic has seen increasing concentrations since week 250. The samples used in these HCTs, as provided by the pilot plant do not represent actual conditions, with As values in the Final Tails pilot plant sample being greater than 10 times the maximum seen during 2014 operations when the mill feed was primary hypogene ore.

It is expected that these samples were used for HCTs, as no other testing would provide sufficient sample weight to run HCTs. However, there was no documented discussion during permitting or reporting regarding the appropriateness of these samples, so it cannot be determined if these anomalies were picked up prior to initiating the tests.

It is expected that the metal leaching that is occurring under neutral pH is associated with these high metal concentrations and has not been identified as a risk to operation or closure of the New Afton TSF. As results are received for the operating tailings HCTs, it is expected that metal loadings will be lower than those seen in the pre-operations test results.

Tailings Supernatant

It is expected that differences in tailings supernatant results can be explained by the addition of lime in the milling process, processing of the historic Teck Ore Stockpile, and the circulating loads due to the reuse of process water. Lime addition was not included in pre-testing, as it was not expected to be required. This lime addition would contribute to the increased conductivity seen in the supernatant water. The added lime also results in the suppression of pyrite during the flotation circuit resulting in more pyrite reporting to the tailings waste stream. Weathering of the pyrite in the cyclone sands used to construct the impoundment will result in some increases in sulphate concentrations. Early in operation, New Afton processed approximately 129,000 tons of historic ore from the Afton Mine which was operated by Teck and closed around 1995. This ore was significantly weathered and oxidized, which could explain the increase in sulphate loading from the start of the TSF operation. No leachate tests were completed on this ore however. New Afton expects that concentrations will increase throughout life of mine, as metals and nutrients are circulated throughout the process.

It is difficult to make significant comparisons of aging tests versus actual supernatant due to variances in operating conditions, and the recycling of process water. No discussion around scale-up or estimations were completed for the permitting report.

ARD and ML Management

New Afton has the ability to manage ARD through draw control and blending, should a high pyrite or high arsenic zone be identified. To date, this practice has not been necessary and draw control has been based primarily on ore grade requirements and maintaining cave operations. Waste rock was generated primarily through the development of the access declines to construct the underground mine although some waste rock is generated from the base of columns within the block cave. All waste rock produced from the underground mine is disposed of in the historic Afton open pit.

If waste rock is to be used onsite for construction, it must first be tested and meet the requirements of New Afton's M229 permit as NAP waste rock. These conditions include a paste pH of greater than six or NPR greater than two. The open pit is the final location for all PAG waste rock, however, standard practice since operations began has been that all waste rock is disposed of within the historic open pit.

CONCLUSION

Prediction of ARD and ML is an essential part of the permitting process to ensure that environmental effects are planned for and managed correctly however, geochemical characterization programs are often based on small samples that are available at the time of testing. These samples may not always reflect the actual operating conditions, and in the case of New Afton HCTs the samples chosen are statically significantly different to witnessed operating conditions. Scaling up tailings samples is particularly difficult, due to the limited availability of samples produced during the laboratory metallurgical testing process. These challenges do not indicate that these tests should not be completed, but that ongoing checks and verification of the results is important. Lessons learned from the permitting aspect of New Afton, is that documentation for reasons behind sample selection is essential and verification of appropriateness of sample should be carried out. A review of As levels was completed in 2012, however no reasoning for why As levels were significantly higher in the samples was provided. It was recommended that additional tailings HCTs be set up based on actual tailings samples to provide a comparison.

In New Afton's case, it is expected that metal leaching will demonstrate lower concentrations than those predicted through the initial humidity cells. While pre-operation research is valuable, it is important for companies to continue to improve and increase their knowledge of ARD and ML based on actual operating conditions in order to confirm or refute the initial predictions. This ensures that adequate resources are available as needed to control ARD/ML after the mine has closed.

While New Afton does not expect to see any detrimental effects from changes in predictions, there has been significant benefit in repeating ARD/ML tests based on mill produced tailings. This allows New Afton to have greater confidence when communicating to regulators and communities of interest that potential effects are well understood and managed.

ACKNOWLEDGEMENTS

The authors appreciate the work that Rescan Environmental (ERM) completed as part of the permitting process and in setting up the HCTs. There was also ongoing reporting associated with these HCTs which has provided significant information to the New Afton site.

It is appreciated that New Gold Inc has allowed the time to prepare this paper and provide significant management review.

REFERENCES

Rescan Environmental Services Ltd. (Rescan) (2012a) *New Afton Humidity Cells Report 2012,* Prepared for New Gold Inc. by Rescan Environmental Services Ltd., pp. 3-15.

Rescan Environmental Services Ltd. (Rescan) (2012b) *Assessment of Elevated Arsenic in Tailings Humidity Cell Leachate,* Prepared for New Gold Inc. by Rescan Environmental Services Ltd., pp. 1-10.