Mine Water Balance for a Semi-Arid Climate: Overcoming Challenges to Maintain Operations

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ABSTRACT

Development of a mine water balance model (WBM) is an essential part of early permitting work and operational planning. New Afton is situated in a semi-arid climate, where its WBM predicted a zero-discharge and net loss facility. Challenges when situated in a semi-arid environment, include significant losses at various stages of the mining cycle and the requirement to supplement the process with freshwater. Water management onsite is essential for all mining operations, and minimizing water losses is essential for arid and semi-arid climates. Freshwater use is highly material to local communities of interest, in particular our First Nations partners. Another challenge that needed to be overcome was that New Afton's water license allows for 139m^3/h of freshwater to be pumped from Kamloops Lake, although it had initially applied for 290 m3/hr.

Prior to full operation, two significant water losses were not completely understood. These included void loss in the Tailings Storage Facility (TSF) and ventilation losses from underground. Void losses account for on average 137m^3/h when operating at 12,000 tonnes per day. This value was unable to be determined with accuracy until tailings had been produced from the mill, after operation had commenced. Ventilation losses were not expected to be significant, and thus weren't considered when the initial WBM was developed. Due to the extremely dry climate in Kamloops, ventilation losses were first monitored in 2013. Throughout the year, dry air that is pumped underground is vented as warm humid air due to equipment use and water sprays for dust control. Water losses through ventilation on average were found to range from 10 to 18 m^3/h. Quantification of these losses was critical to being able to determine actual operation freshwater demands and allow New Afton to amend its permit.

Keywords: Mine, water, arid, climate

INTRODUCTION

New Afton is in its third year of operation, with commercial production reached in June 2012. The scheduled throughput for the mill was 11,000 tons per day, however, this throughput was exceeded early during commercial production. The mine currently operates at a rate of approximately 14,000 tons per day, with opportunity for increased throughput. It is currently licensed to withdraw 139m³/h, or 1,218,000m³ annually from Kamloops Lake.

Located in a semi-arid climate with on average 278mm of precipitation annually, water management is an essential part of New Afton's operating considerations. Water use at the mine site is a significant area of concern for local First Nations and the general community. Managing water quality is also of a very high interest. New Afton minimizes its water use through the following management strategies:

- Recycling of process water in the mill facilities
- Using chemical dust suppressant for dust control
- Recycling all water drawn from underground dewatering
- Maintaining a "zero discharge" water balance.

As part of permit applications prior to operation, New Afton completed a water balance model depicting pre-construction, construction, early operation, full operation and closure. Based on these water balance models, it was estimated that approximately 290m³/h of makeup water from Kamloops Lake would be required, to account for contingencies and increases in production. However, as part of regulatory applications, it was also mentioned that 139m³/h was required for base case, and thus this was the awarded withdrawal rate granted by the government. Following commencement of operations it was realized that the water balance developed for the permitting contained two significant omissions and that the permitted withdrawal rate was insufficient for continuous uninterrupted operations. In November 2013, an application was submitted to increase the licensed water withdrawal rate from 139m³/h to 212m³/h to ensure the operation has sufficient water for continuous operations.

METHODOLOGY

Following the commencement of operations, and as part of its Mines Act permit, New Afton was required to develop an operational water balance for the site. During the development of the operational water balance it was quickly noticed that tailings void losses had not been included along with ventilation system losses. The development of the operational water balance was conducted by BGC Engineering Inc. (BGC) and was based on a combination of process design details and operational data. In July 2013, BGC provided the following water balance based on actual inputs and estimated monthly averages from the first year of operations.

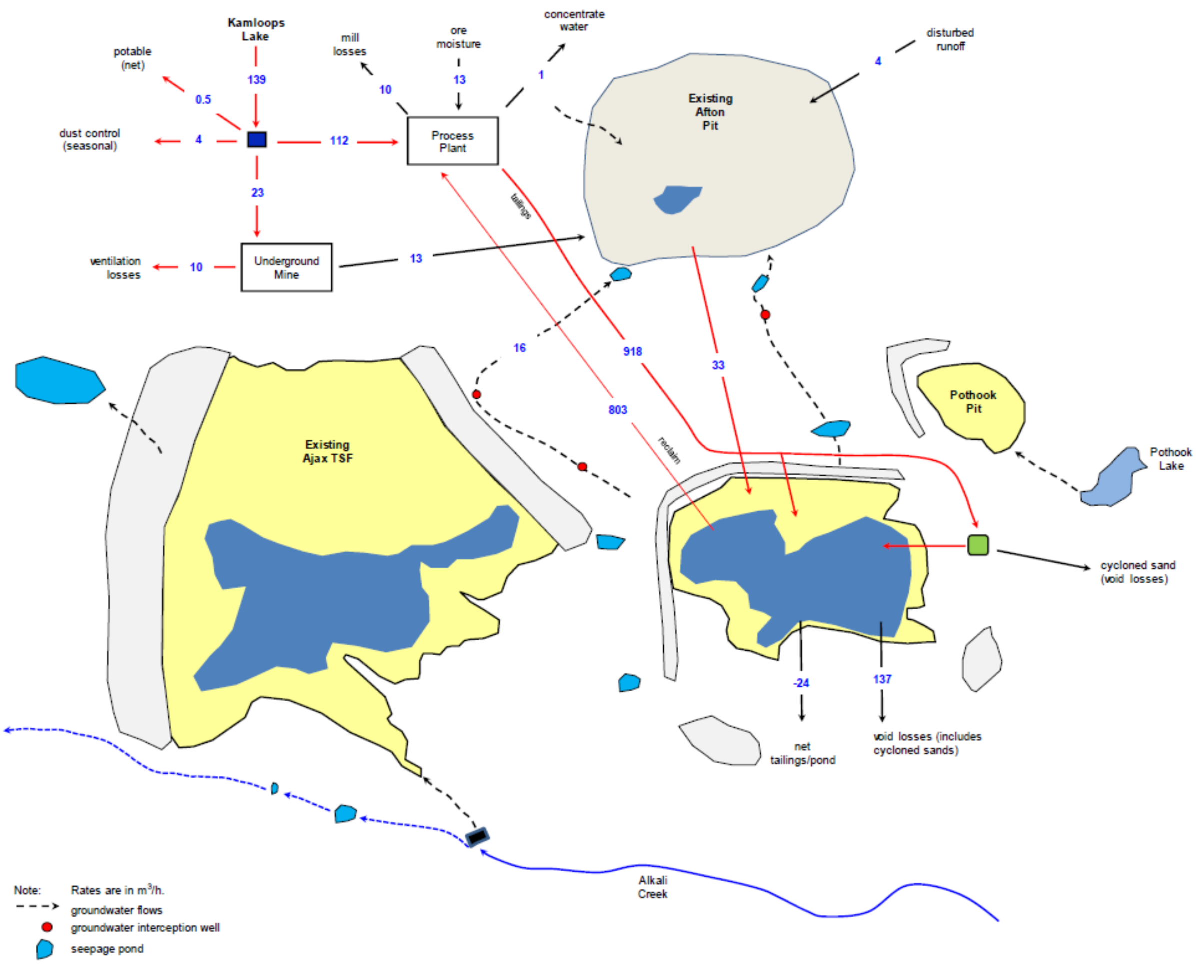

Figure 1 New Afton Average Annual Flows Life-of-Mine (BGC, 2013)

Tailings Void Losses

Tailings void losses is the volume of water that is lost in tailings voids during placement of tailings into the storage facility. Void losses are calculated through the following formula, which is derived from the dry unit weight equation (Budhu, 2007) (Nomenclature for all formulas can be found at the end of this publication):

$$void\ loss = \left(\frac{1}{\rho_s} - \frac{1}{SG}\right) \cdot tailings\ tonnage$$

The current assumption is that the final settled dry density of the tailings will be 1.47t/m³, however it is expected that realized final dry densities may range between 1.4t/m³ and 1.60t/m³ (BGC, 2013).

The settled dry density will vary throughout the life of the project due to ongoing consolidation, so estimating an average for the sake of developing a water balance needs to take this into consideration. Table 1 demonstrates the variation in void losses over the given range of settled dry densities at a production rate of 12 000 tonnes per day. It can be seen from this table that a relatively small change in the settled dry density of the tailings has a substantial impact on the volume of water being lost.

Table 1 Void Losses for Various Settled Dry Densities (BGC, 2013)

Settled Dry Density (t/m^3)	**Void Loss (m^3/h)**
1.40	176
1.47	159
1.55	141
1.60	131

Bathymetric surveys are carried out annually throughout the life of mine in order to provide data on the existing field settled dry densities and are used to update the water balance model. The surveys are conducted using a boat equipped with a GPS system and a sonar unit. The 2013 bathymetric survey resulted in an estimated settled dry density of 1.47 t/m^3 which matched the water balance value of 1.47 t/m^3.

Ventilation Losses

Ventilation losses were not calculated during the permitting process, as this was not expected to be a significant pathway for water loss. Operations personnel realized though that the ventilation system in the summer months was pushing warm to hot dry air underground while in the winter months the air was cold and dry. Exhaust from the underground was found to be warm humid air throughout the year. Table 2 demonstrates the monthly averages for temperature and relative humidity at the ventilation intake, exhaust and the Kamloops Airport weather station.

Table 2 Ventilation System Temperature and Relative Humidity

Average Monthly Results					
	1981-2010	2013-2014			
Month	**Kamloops Airport Temp (°C)**	**Intake Temp (°C)**	**Intake RH (%)**	**Exhaust Temp (°C)**	**Exhaust RH (%)**
January	-2.8	-2.7	90.0	13.3	80.4
February	0.1	-6.8	72.3	12.5	76.8
March	5.2	2.9	64.8	12.9	78.7
April	9.9	7.6	55.4	13.9	81.2
May	14.6	12.8	59.6	16.1	86.3
June	18.4	16.1	53.9	17.7	85.5
July	21.5	21.9	42.3	20.0	83.7
August	20.9	20.3	53.8	20.2	90.4
September	15.6	13.7	58.1	18.7	84.9
October	8.5	-	-	-	-
November	2.1	-2.0	90.2	13.6	77.6
December	-2.7	-5.7	88.5	12.8	76.6

Ventilation losses are estimated through the monitoring of relative humidity and temperature at intake fans, exhaust fans and the portal. These readings are recorded hourly on a data logger and retrieved monthly. The water holding capacity for air is estimated based on the August-Roche-Magnus formula (Lawrence, 2005) as shown below:

$$e_s(T) = 6.1094e^{\left(\frac{17.625T}{T+243.04}\right)}$$

For this estimation, it is assumed that there is constant standard atmospheric pressure.

Figure 2 shows the calculated water losses that occurred throughout the monitoring period in 2014. This includes water loss from the ventilation fans only, with another $2m^3/h$ approximately lost from the mine portal. Table 3 contains a monthly summary of the average calculated water losses from the ventilation system.

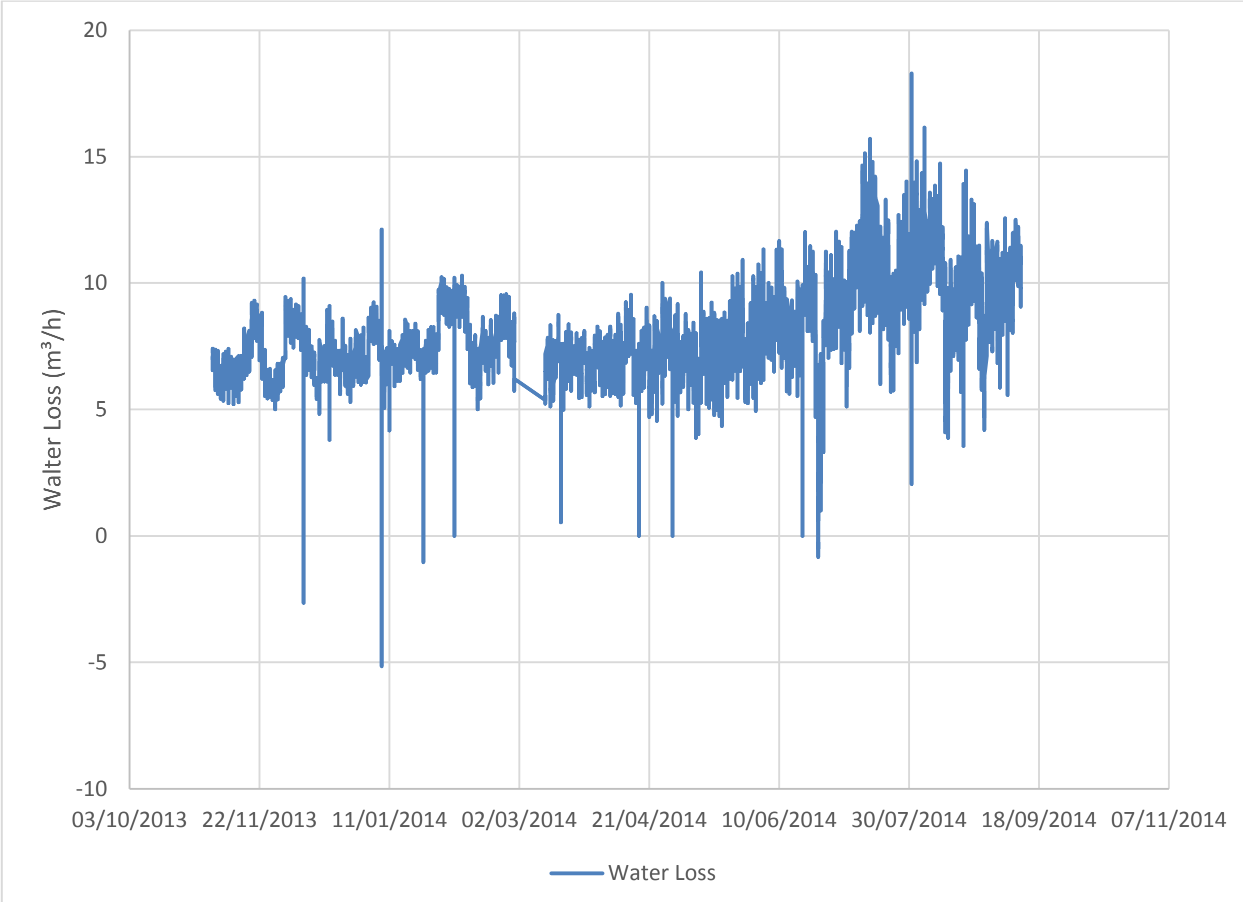

Figure 2 Calculated Ventilation System Water Loss

Table 3 Ventilation System Average Calculated Water Loss (m^3/hr)

Month	Average Calculated Water Loss (m^3/h)
January	9.2
February	10.2
March	9.6
April	9.9
May	9.8
June	11.1
July	12.9
August	12.8
September	13.5
October	-
November	8.5
December	9.1

Water Requirements

Fresh water is required throughout site for showers and bathrooms, underground dust suppression and mill operations. The semi-arid climate at New Afton requires the application of significant dust control measures. Often this would be the continual application of water to roads and bare surfaces, however New Afton has implemented the following controls to assist in the reduction of surface dust:

- Recycled asphalt application on high traffic areas
- Progressive reclamation to provide vegetative cover to bare surfaces
- Application of flocculant to exposed tailings sands during snow free period
- Application of Magnesium Chloride to roadways during dusty months.

The majority of makeup water is provided to the mill process, with on average 112m^3/h being used. Current testing is being completed to determine the effect of dissolved metals and salinity on gold and copper recovery, which could put further demands on the freshwater requirements within the mill.

The current major shortfall for water requirements is the ability to maintain a large enough pond volume on the Tailings Storage Facility (TSF). A sufficient volume of water within the pond is required in order to ensure sufficient settling time for fine particulate prior to being recycled back into the processing plant. Based on operating experience at New Afton, the minimum required tailings pond operating volume is approximately 1 Mm^3 at a throughput of 14,000 tpd. The original estimated minimum tailings pond volume for the design throughput of 11,000 tpd was 500,000 m^3, however, it was found even at volumes above this that there was insufficient settling time within the pond.

Figure 3 shows the estimated New Afton tailings pond free water volumes for different throughputs, based on the inclusion of measured ventilation system and tailings void losses. The figure shows the steep decline in free water within the tailings pond based on throughput.

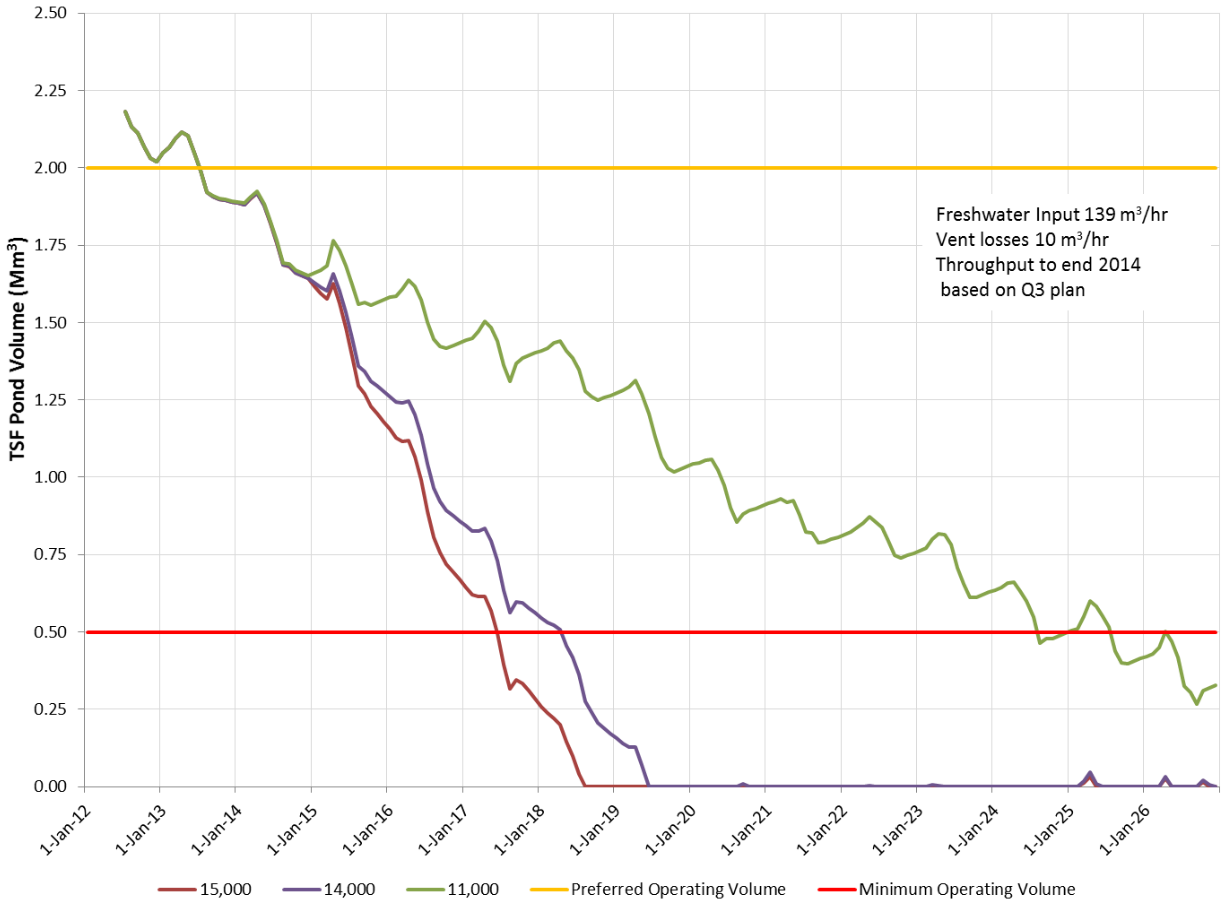

Figure 3 Estimated Tailings Pond Free Water Volume Based on Throughput

CONCLUSION

The reliability of water balances for mines operating in a semi-arid climate is critical to ensure uninterrupted operations. Water balances modelled prior to operation are often based on a variety of factors that can easily have significantly different results once operation commences. This can be due to a variety of reasons, and doesn't always imply that errors were made in the assumptions during the development of these models. As water balance models are an integral part of all levels of mine permitting, it is essential to have a level of confidence and that sufficient resources are made available to best develop this model. Errors or omissions in a water balance may have significant impacts on mine operations over the life of mine.

In the case for New Afton, insufficient care was taken to ensure all reports and applications had a single freshwater requirement and thus, the water volume allocated only accounted for the minimum requirements for an 11,000 tons per day operation, with no level of contingency. The omission of ventilation system losses and water contained within the tailings pores significantly affect the estimated free water balance for the mine. New Afton has continued to increase its throughput above the original mine plan resulting in an additional shortfall of water volume. The mine has applied to increase its licensed water allocation, however this is an ongoing project that faces many delays through the regulatory process.

NOMENCLATURE

r_s	settled dry density
SG	specific gravity
$e_s(T)$	saturation vapor pressure (hPa)
T	temperature (degrees Celsius)

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