AECOM

Memorandum

To	Alistair Kent	Page	1
CC	Project team		
Subject	Tailings Seepage Collection Pond Water Balance		
From	Ryan Mills (AECOM) and Justin Stockwell (Lorax)		
Date	November 16, 2009	Project Number	112359

Introduction

This memorandum summarizes the results of mixing calculations conducted to estimate the relative contributions of source waters reporting to the tailings seepage collection pond. The purpose of this task was as follows:

- to refine the hydrogeological conceptual model of groundwater flow for the tailings seepage collection pond;
- to support water balance development for the seepage collection pond; and
- to provide a conceptual model upon which to base the contribution of source waters to the seepage collection pond.

Key Objectives of Task

The key objectives of this task were to:

- To identify the relative contribution of specific source waters reporting to the tailings seepage collection pond.

Task Methodology

Potential sources of water reporting to the seepage collection pond include tailings porewater seepage (e.g., MW09-4), Dome Creek (e.g., Station D1), tailings dam seepage (e.g., well MW09-21) and lateral groundwater seepage (e.g., well MW09-24). Water quality data from samples collected between September 1st and 3rd, 2009 were plotted on a Piper plot (Figure 1) and Schoeller diagram (Figure 2) to visually represent the geochemical signature of potential source waters reporting to the seepage collection pond.

Two distinct geochemical sources are present: seepage from the tailings mass (MW09-04) and relatively dilute groundwater (MW09-24). Well MW09-04 represents porewater seepage emanating from the tailings mass. Well MW09-24 is presumed to represent groundwater flowing laterally into the seepage collection pond from the regional groundwater system. Water from these two-wells appears to represent end-members for mixing in the seepage collection pond.

Tailings seepage travels from the tailings mass and through the tailings dam before discharging to the seepage collection pond. Data from several wells along this flowpath suggest that tailings seepage undergoes dilution and reduction processes as it travels toward the seepage collection pond. Reduction processes are apparent from the behaviour of arsenic, iron, manganese, nitrogen, and sulfur, supporting the notion that tailings seepage does not behave conservatively as it travels from the tailings mass through the tailings dam and into the seepage collection pond. Reduction processes are less apparent as seepage approaches the seepage collection pond. Nonetheless, seepage from the tailings mass is not behaving "conservatively" as it travels toward the seepage collection pond. As a result, a conservative mixing model can not be applied to source waters from the tailings mass (*e.g.*, MW09-04) to quantify their contribution to the seepage collection pond.

Monitoring well MW09-21 is located at the base of the tailings dam near the seepage collection pond and represents net seepage emanating from the dam, which is a mixture of seepage from the tailings mass and lateral groundwater flow (dilution). While reducing conditions are evident within groundwater sampled from this well, it may be reasonable to apply a conservative mixing model to select parameters.

For the purposes of this evaluation, it was assumed that water reporting to the seepage collection pond is represented by two sources: 1) regional groundwater (i.e., MW09-24); and 2) net seepage emanating from within and under the dam (i.e., MW09-21). The mixing of these two source waters is apparent in that the seepage collection pond exhibits a chemical signature on the Piper plot that is intermediate between these two source waters (Figure 1).

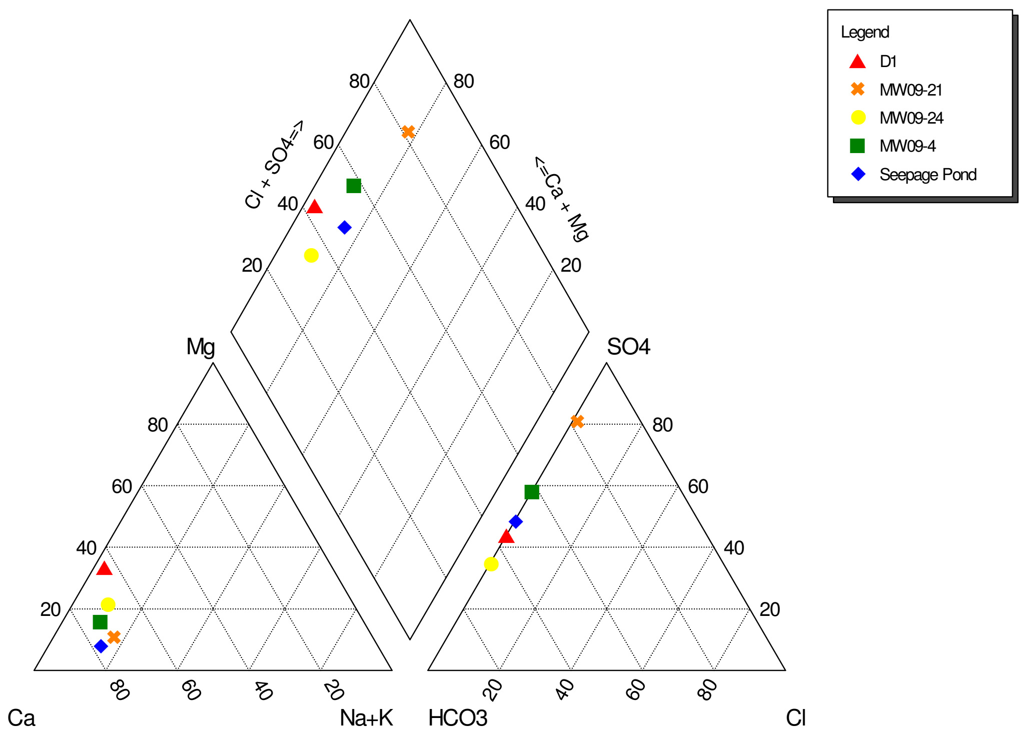

Figure 1. Piper Plot of Potential Sources Reporting to Seepage Collection Pond

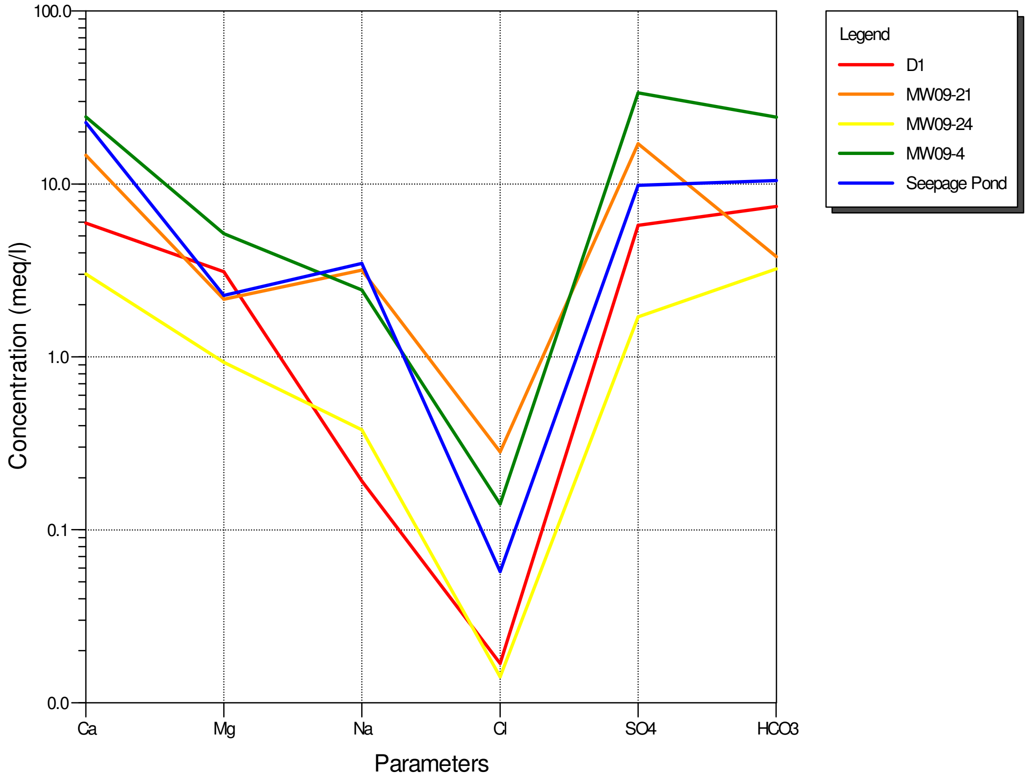

Figure 2. Schoeller Diagram Illustrating Potential Sources Reporting to Seepage Collection Pond

To estimate the relative contribution of each distinct water source to the tailings seepage collection pond, the following formula was solved in an attempt to reduce the residual to zero:

$Q_{Seepage\ Pond} \times C_{Seepage\ Pond} = Q_{MW09-21} \times C_{MW09-21} + Q_{MW09-24} \times C_{MW09-24}$; where

$Q_{Seepage\ Pond}$ is the total volume of seepage pumped out of the pond (assumed to be 1 to solve equation);

$C_{Seepage\ Pond}$ is the concentration of each parameter as measured at the seepage pond water quality sampling location on a given date;

$Q_{MW09-21}$ is the relative contribution of seepage from the tailings facility (MW09-21) to the seepage collection pond;

$C_{MW09-21}$ is the concentration of each parameter as measured at MW09-21 on a given date;

$Q_{MW09-24}$ is the relative contribution of regional groundwater (MW09-24) to the seepage collection pond; and

$C_{MW09-24}$ is the concentration of each parameter as measured at MW09-24 on a given date.

Key Assumptions

The key assumptions used as input to the task were:

- Tailings seepage collection pond is dictated by the mixing of two distinct waters (regional groundwater and net seepage through the tailings dam);
- The chemistry of groundwater in MW09-21 is representative of net seepage emanating through the base of the tailings dam, while MW09-24 is representative of regional groundwater;
- There is no attenuation, dissolution or other chemical reactions occurring along the pathway between these wells and the seepage collection pond;
- The seepage collection pond is well mixed;
- Conductivity, total dissolved solids (TDS), sulphate, calcium, sodium and strontium are suitable indicator parameters for estimating the total loading source waters to the seepage collection pond; and
- The relative contribution from each source water does not change with time.

Information Provided by Others

The following information, provided by others and/or in previous studies, was:
- Surface water quality database (EDI)
- Seepage pond pumping rates (YTG)

Key Results

Table 1 summarizes the results of the seepage pond mixing calculations for the September 2009 groundwater sampling event.

Table 1. Results of Seepage Collection Pond Mixing Calculations

Parameter	Measured Concentrations (mg/L)			Modelled Mixing Ratios	
	MW09-21	MW09-24	Seepage Pond	Fraction MW09-21	Fraction MW09-24
Conductivity	1790	378	1420	0.738	0.262
Total Dissolved Solids	1420	255	983	0.625	0.375
Sulfate	818	81.7	471	0.529	0.471
Dissolved Calcium	293	60.4	210	0.643	0.357
Dissolved Sodium	73.1	8.7	69.2	0.939	0.061
Dissolved Strontium	1.00	0.295	0.65	0.504	0.496
			Average	0.66	0.34
			Median	0.63	0.37
			Minimum	0.50	0.06
			Maximum	0.94	0.50

Using the average mixing ratios for all parameters under consideration, approximately 66% of the flow reporting to the seepage collection pond originates from the tailings pond and the remaining 34% originates from regional groundwater. Based on the measured seepage pond pumping rate in September 2009 of 466 m^3/day (5.4 L/s), approximately 309 m^3/day (3.6 L/s) originates from beneath the tailings facility and the remaining 157 m^3/day (1.8 L/s) originates from the regional groundwater flow system. A portion of the groundwater originating from the regional groundwater flow system may be the result of leakage through the bottom of the unlined diversion ditch north of the tailings facility and seepage collection pond. A strong downward gradient has been observed in the relatively permeable materials forming the base of the diversion ditch on the inferred groundwater flow path upstream of the seepage collection pond.

Recommendations

It is recommended that the results of this evaluation be incorporated into the conceptual model for groundwater and surface water flow in the area downstream of the tailings impoundment.

These mixing ratios should be re-evaluated in the event that additional groundwater and surface water data becomes available to verify the accuracy of these calculations as mixing ratios may change on a seasonal basis in response to changes in infiltration.

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Encl.