Long Lake Seep Passive Treatment System Quarterly Report

3rd Quarter 2015/2016

Prepared for:

Ministry of Environment

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Table of Contents

1.0 Summary

In accordance with Mine Permit condition 3(b) (approving the Long Lake Seep Passive Treatment System) and the Ministry of Environment *"Authorization to Bypass the Works*" (dated August 25, 2015), is a report summarizing the operation of the treatment system for the third quarter of the 2015-2016 monitoring year (Q3) covering October 1 through December 31, 2015. Sampling of chemical parameters takes place once per month at 6 sites associated with the treatment system. Results from sampling along with observations from routine inspections provide the information necessary to evaluate system performance. The 6 sites sampled include:

- Water pumped into the system from the 2 South minepool (inflow or INF)
- In the biochemical reactor (BCR) where sulphate is biochemically reduced to sulphide
- The sulphide polish cell (SPC) in which sulphide is sequestered by sacrificial iron
- The aerobic lagoon (AL) where dissolved oxygen is diffused into the water, removing excess nutrients and precipitates metals
- The system settling pond (SP) in which suspended materials settle out
- A location 100m downstream of the confluence from settling pond #1 (SPD) and SP mixing known as Biocell downstream (BDS)

System flow rates combined with field observations and results from laboratory analyses are compiled to interpret system performance. During Q3, the system continued to perform effectively and meet its treatment criteria. Key observations made included:

- The inflow rate to the (BCR) remained at 4.0 L/s (Chart 1) with a total of 31, 795 m^3 of water treated through the system.
- The average sulphate concentrations observed at the inflow and BCR were 588 mg/L and 365 mg/L respectively resulting in an average quarterly reduction efficiency of 38% from the BCR (Chart 8)
- Sulphate concentrations discharged from the SP averaged 294 mg/L resulting in a system reduction of 50.0% averaged through the quarter
- The system removed roughly 8,900 kg of sulphate from potentially entering Long Lake via the seeps

On August 25, 2015, the Ministry of Environment renewed the "Authorization to Bypass the Works" with a one year extension allowing effluent from the treatment system to be discharged downstream of the SPD discharge point. Since this time, there have been no observed permit limit exceedances in observed at BDS (Figure 1).

2.0 Results and Observations

The attached (Charts 1 through 14) illustrate and provide detailed comments on the treatment system performance including physical parameters, flow rates and chemical parameters since commencement of the system in late 2012. A summary of observations include:

- pH throughout the system remained at a suitable range of 6.5 – 8.0
- A suitable ORP for sulphate reduction was observed at the BCR
- The aerator and mixers were successful in diffusing dissolved oxygen to the system
- Water temperatures steadily declined at all locations with a maximum observed in October in the AL at 15.95°C and a minimum of 2.20°C in December; also in the AL. As expected, sulphate reduction efficiency through the system correlated with the temperature decline
- Sulphate concentrations observed at the inflow increased slightly through the quarter ranging from 550 - 645 mg/L
- The overall sulphate reduction through the system during Q3 was slightly greater than Q3 2014. Average reductions and efficiencies were: -294 mg/L and 50% in Q3 2015 and -288 mg/L and -44.7% in Q3 2014

It is noted that reduction efficiencies have been higher during the fall months compared to the summer months in the last 2 years. This is an unexpected observation as reduction efficiencies should be greater in warmer weather due to increased microbial activity. Another observation which was unexpected was found in sulphide concentrations in the BCR. When the microorganisms reduce sulphate, it is expected that sulphide concentrations would increase proportionately. However, during the colder periods with higher reduction efficiencies, sulphide concentrations are observed to decrease compared to warmer months. A suspectedcause of this anomaly may be associated with increased precipitation at the mine site. As the treatment system is designed open to the atmosphere, it is conceivable that heavy precipitation may dilute water within the system resulting in biased results. Adversely, low precipitation during the summer and increased temperatures may evaporate water from the system prior to discharge resulting in higher observed sulphate concentrations that may bias reduction efficiency.

Figure 1: BDS Results (Red) vs SPD Permit Limits (Green)

Studies are ongoing to develop the relationship between the 2 South mine pool water elevation and flow rate at the Long Lake Seep. Figure 2 illustrates the relationship to mine pool water elevation and the effect on seep flow. The groundwater level measured at well MW004 appears to have the most direct relationship with flow at the seep. Water elevations fluctuate seasonally, rising steadily through the fall to early spring and decrease throughout the drier months, directly related to infiltration from precipitation. During Q3, the larger seep into Long Lake began to discharge as mine pool water elevations increased. It was noted that flow did not begin until November 18 resulting in the longest period of flow cessation since the treatment system has been active. Additional information will be required to determine how this relationship might inform the necessary long term flow rate through the treatment system.

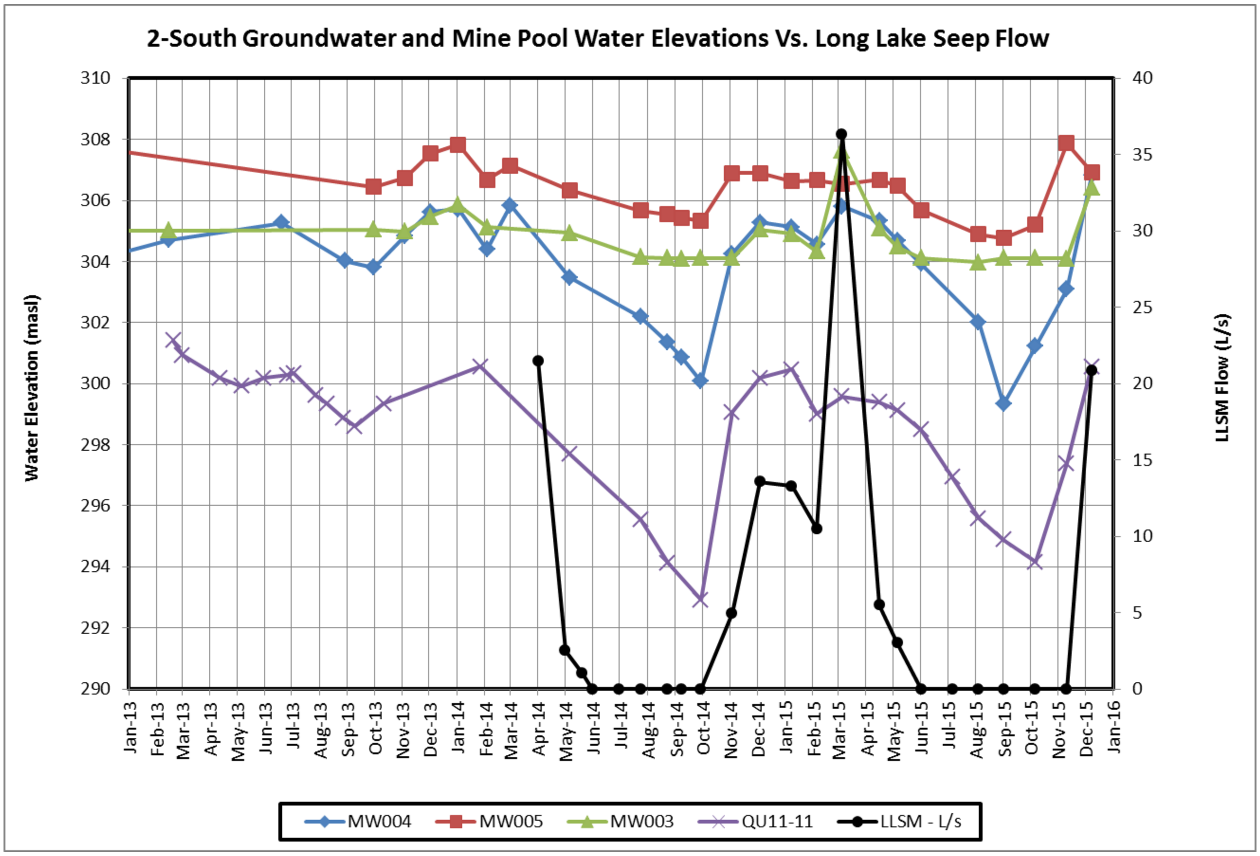

Figure 2: 2 South Groundwater and Mine Pool Water Elevation Vs. Long Lake Seep Flow

3.0 Operations

During the 3rd quarter of 2015 the following maintenance work was completed:

- Ongoing electrical related maintenance to the mixers in the aeration lagoon
- Mixer 1 was successfully restored by removing accumulated build up

Bench Scale Testing:

A three phase bench–scale testing regime has been designed and initiated by Golder Associates in order to evaluate potential improvements in sulphate treatment performance, including:

- Improving sulphate reduction during winter months
- Extending the life of the substrate in the BCR and SPC
- Increasing the BCR inflow rate

The bench system was constructed and initiated at the Quinsam mine site in July 2014. As summarized by Golder Associates, the objectives of the three phases are as follows:

- Phase 1: Evaluate the effects of different liquid carbon amendments on sulphate reduction in the BCR unit process (Q2-Q3 2014/15)
- Phase 2: Evaluate different mechanisms for sulphide sequestration / treatment with the preferred liquid carbon amendments selected during Phase 1 of testing (Q2 2015/16)
- Phase 3: Evaluate the effects of the winter temperatures on the performance of the most effective process configuration determined by Phase 1 and Phase 2 testing. (Q4 2015/16)

Phase 1 of testing was performed July through November 2014. The principal objective of the Phase 1 bench scale testing was to determine influences of different liquid carbon amendments on sulphate reduction in the BCR unit process. The carbon amendment tests included comparison of three carbon sources; MicroC 4200, molasses and methanol. As Phase 1 of bench testing was performed through different seasons, evaluation during different ambient temperatures was accomplished. Phase 1 was separated into two periods with different inflow rates and ultimately, lower holding retention time (HRT) within the cells. Some of the conclusions drawn from Phase 1 included:

- The target effluent sulphate removal concentration of 300 mg/L was consistently achieved in all test cells with an HRT of 13 days during Period 1.
- During Period 2, most test cells achieved the target effluent concentration of 300 mg/L with the HRT of about 7 days. On the two occasions when the control effluent was greater than the target

concentration, molasses supplementation improved sulphate removal sufficiently to achieve the target concentration.

- Molasses amendment outperformed both MicroC 4200 and methanol amendment with respect to improved sulphate mass percentage removal during Period 2.

The test was suspended in late November due to freezing temperatures and the system reestablished in July-September 2015 (Phase 2) to continue bench scale testing. The objective of Phase 2 was to evaluate different mechanisms for sulphide treatment and sequestration using molasses as a carbon amendment. Sulphide removal mechanisms in the demo scale system include:

- Sulphide sorption to the BCR media,
- Sulphide sequestration in the SPC by sacrificial iron
- Hydrogen sulphide off-gassing to the atmosphere
- Sulphide conversion to elemental sulphur

Upon discovery that sulphate concentrations often increase after the AL, it was an important step to understand how to better sequester sulphide in the system to inhibit the reproduction of sulphate. Testing has occurred in two stages (2a and 2b) during which three test cells have been configured to simulate BCR cells with secondary cells to simulate the SPC. Potential nitrogen limiting was observed during Phase 1 of testing therefore amendment of urea as a nitrogen source has been incorporated along with phosphorus to optimize sulphate reduction in this testing. Phase 2a included addition of nutrients such as carbon, phosphorus and nitrogen along with sulphide treatment using iron (ferric and ferrous chloride). Ferric and ferrous chloride was added in different locations to observe the effects of injection point. Ferrous chloride was more suitable choice as ferric chloride has a tendency to produce ferric oxy-hydroxides that may cause clogging. One system saw iron addition into the influent (directly into simulated BCR) and one added into the effluent (directly into simulated SPC). Sulphide concentrations were measured to determine relative reduction, indicative of sequestration. The third test cell was used to evaluate effects of nitrogen addition on its own.

Figure 3: Construction of Phase 2a Bench System

Phase 2b was designed to evaluate the potential of mitigating reproduction of sulphate as treated water passes through the AL on the demonstration-scale treatment system. Different sulphide treatment processes were performed including some combination of acidification, aeration, and oxidation of BCR effluent. These tests were performed in a laboratory setting with collection of effluent obtained directly from the simulated BCR cells. Effluent water was separated into 3 tests (A, B and C); each treated differently. Test A consisted of lowering pH to values of 6.5 and 6.0 using HCl and aeration using an aerating stone for duration of 30 minutes. This test studied the effect of off gassing sulphide in a gaseous form. Test B consisted of lowering pH to values of 6.5 and 6.0 using HCl and encouraging oxidation with the addition of hydrogen peroxide. This test studied the effect of oxidation of sulphide to elemental sulphur and sulphate. The products of both aeration and oxidation are strongly dependent on pH where less sulphate is created with lower pH values. Test C consisted of oxidation using hydrogen peroxide without the addition of HCl. More sulphate is predicted to form as pH values are higher than Test B. Some conclusions drawn from Phase 2 were:

- Amendment of carbon and nutrients to the BCR influent improved sulphate reduction between 20-38% compared to no additions
- Iron addition sequestered up to 99% of sulphide
- Aeration of BCR effluent removed 95% of sulphide with minimal conversion to sulphate (3% increase in sulphate relative to effluent) after 30 minutes of aeration
- Oxidation of BCR effluent with 3% peroxide removed 93-95% of sulphide. However, a noticeable amount of sulphide was converted to sulphate (18-39% increase in sulphate relative to effluent)

4.0 Conclusion

The Long Lake Seep Treatment System continues to achieve the performance objectives established for the demonstration phase(s) through Q3 including: adequate sulphate reduction, metals sequestration, nutrient reduction and discharging within permit limits at the site BDS.

Results and observations from bench scale testing have provided and will continue to provide supplemental information on potential improvements aiding in extension of media life, increased sulphate reduction and compliance of discharge water with respect to permit limits. Phase 3 of the bench scale testing that will be applied to the demo scale system during Q4 2015/2016 with the addition of molasses as a carbon source to retain efficient sulphate reduction during colder ambient temperatures.

Quarterly reports on the treatment system will continue to highlight system performance, trending and observations made by Quinsam personal. Ongoing studies and bench scale testing will be implemented as necessary to gain a better understanding and optimize system functionality.