MONITORING THE BEHAVIOUR OF SLUDGE IN THE VADOSE ZONE[1]

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Abstract: The Fire Road Mine coal mine in eastern Canada has been a source of acid mine drainage since the mid 1980's. Lime neutralization treatment has been ongoing and lime treatment costs and mine water acidity levels have dropped significantly over time. Placement of the resulting treatment sludge back onto and into the backfilled mine site may be a factor in reducing the mine water acidity. One of the originally defined benefits of placing the sludge back into the waste rock was that the sludge would fill up the void spaces and possibly decrease the rate of oxygen diffusion to the waste rock that was above the ground (mine) water elevation. This would possibly reduce the rate of acid generation.

There were questions about how far the sludge migrated into the vadose zone and the characteristics of that sludge over time. Excavations in the early 1990’s indicated that the sludge only dried out near the surface but remained moist at depth. Discussions ensued about variations in conductivity over time being an indication of reduced moisture content in the sludge as it dewatered over time.

Geophysical research projects have been conducted since 2001 to identify variations in conductivity across the backfilled mine sites by the University of New Brunswick, Department of Earth Sciences. The geophysical surveys have been useful for corroborating the decrease in acidity as identified by annual and biannual groundwater well monitoring surveys. The geophysical surveys have

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also been instrumental in identifying the distribution and changing conductivity of the lime treatment sludge in the waste rock.

During the early Spring of 2016 ground water chemistry, apparent conductivity (EM31) and electrical resistivity (ERI) surveys along with test pit trenching were conducted to provide information as to:

1. Is the groundwater acidity continuing to decrease?
2. Is sludge still present in the vadose zone?
3. Why are some previously highly conductive zones becoming less conductive over time?
4. Does the sludge dry out and become less conductive over time?
5. For future investigations, is the benefit of depositing sludge in the vadose zone temporary, or is it long term.

The ground water well monitoring survey illustrated (Figure 1) that acidity levels continued to decrease across the mine site.

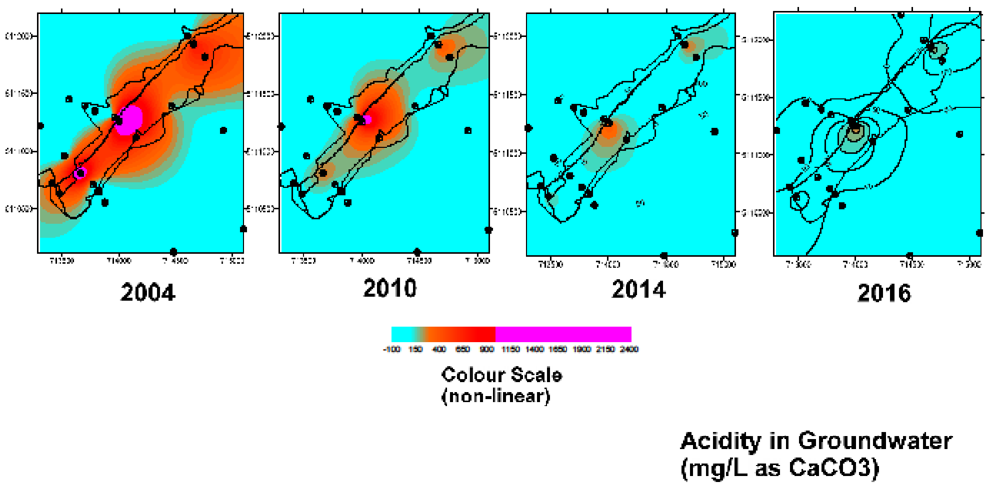

Figure 1 Decreasing acidity in groundwater as determined from monitoring wells across the Fire Road mine site 2004- 2016.

Apparent conductivity and electrical resistivity surveys were re-acquired in areas that had not been surveyed or received sludge deposition for more than a decade by the University of New Brunswick, Department of Earth Sciences. Then, test pits were excavated to allow in-situ measurements of electrical resistivity and sampling for water content in areas where sludge is present or absent. This data was compared to the conductivity /resistivity survey results acquired from surface surveys. This information was also compared to soil texture and soil chemistry from the finer material collected at selected intervals along the test pit wall.

Electromagnetic apparent conductivity (EM31) (Figure 2) and electrical resistivity imaging (ERI) surveys have been instrumental in identifying the locations of highly conductive mine water and what we had postulated is the treatment sludge, which had settled out in the vadose zone during disposal. However, the conductivities of these zones varied across the site, across seasons and over time. Observations from previous geophysical surveys over several seasons indicated that the sludge may dry out and become less conductive.

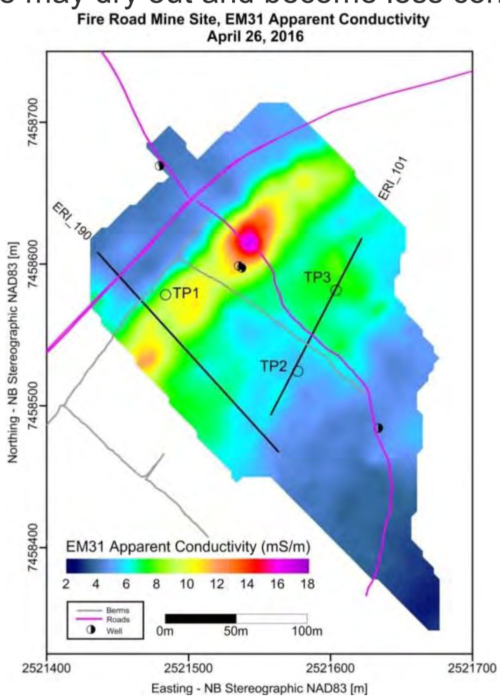

Figure 2 Apparent Conductivity (EM31) in 2016. Note the locations of the test pits (TP1, TP2, TP3) and ERI survey lines 101 and 109.

Along with results of the 2016 geophysical surveys, areas of known sludge deposition history were identified.   Test pit locations were selected on the basis of known sludge deposition based on surface and geophysics information (test pit 1), location of no evidence of sludge deposition (test pit 2) and area of uncertain deposition of some undetermined amendment (test pit 3), as indicated in Figure 2. Test pits (trenches) were excavated to determine presence/ absence of fine grained material in the waste rock void spaces, soil texture and chemistry including pH, major cations and cation exchange capacity. Not surprisingly, test pit 1 had the highest calcium content and the highest conductivity, the soil texture of test pit 2 with no amendment had very little fine grained material in the void spaces between the waste rock, and the unknown material fine material in test pit 3 with the moderate conductivity level contained higher magnesium levels. The surprising result was the consistent low pH (3.5-4) of the fine grained material across all test pits.

ERI results support the hypothesis that resistivity imaging can identify areas where sludge is likely resident in the vadose zone. This information was beneficial to determining the behaviour of the sludge in the vadose zone and initiated discussions about the whether the benefits of sludge in this zone are temporary or long term. Improving the mine water chemistry to "zero lime demand" is the ultimate goal for mine water treatment at this mine.

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