Dalhousie University

Chemical Engineering Department

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Investigation of a potential Mine
Water Stratification in the 1B Mine Pool

Performed at
Cape Breton University
1250 Grand Lake Rd.
Sydney NS B1P 6L2
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Abstract

This report investigates a potential mine water Stratification in the 1B Mine Pool. Samples from 30 selected wells within the 1B Mine Pool was analyzed for a potential stratification development within the Mine Pool.
The electrical conductivity and the temperature which are the most important parameters were measured per every meter from the water level to the bottom of each well using the Solinst and the Sphor measuring device (the first measures both parameters up to a depth of 100.34 m and the latter only measures temperature up to a depth of 300 m.)
It was concluded that, although there is an observed differentiation in the wells there is no observed stratification in the 1B mine pool at Neville Street in Glace Bay N.S.
It is recommend that since stratification cannot be used as a possible remediation, the passive mine water treatment plant which is currently running be replaced by an active mine water treatment system plant. It is more effective for highly polluted mine waters and the 1B mine pool is a highly polluted area

TABLE OF CONTENTS

List of Figures

List of Tables

Acknowledgements

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I will also thank my two other colleagues Beth Maclellan and Wadzanai Chimhanda for making the field sampling and data collection useful for this report a success. This project was funded by DEVCO and Cape Breton Development Corporation.

1.0 Introduction

Abandoned or orphaned mines are flooded with water when pumping is ceased. As Nuttal stated in her paper “Hydro chemical stratification in flooded underground mines”, the flooding can develop to a temporarily stagnant bodies of water (Nuttal and Younger, 2003) introducing the possibility of stratification or layering. This phenomenon is defined by Wolersdorfer (2008) as separation of water into horizontal layers of different physical or chemical characteristics. Wolkersoderfer (2008) pointed out that even though stratification can be a consequence of changes in chemical properties such as sulphate and sodium chloride content or the physical properties such as temperature, viscosity and density, the stratification is always due to density differences. Stratification can also be differentiated as either stable or unstable depending on the temperature and density change within layers (Gebhart et al., 1988). If there is a high density difference coupled with a low temperature difference within the stratified layer then the stratification is assumed stable (Wolkersdorfer, 2006).

The 1B mine pool which is of concern in this study is defined as a profound body of water within the 1B hydraulic system consisting of former mine working Collieries (MGI LTD. 2005). When mining sites were closed in Glace Bay and Dominion NS, water was filling the mine sites and dewatering pumps were installed to discharge the water into the environment; Atlantic Ocean. However in 1985, the dewatering pumps in the 1B colliery were shut down and this began the uncontrolled flooding of the abandoned mine sites (wolkersodorfer, 2009). In 2003, a mine water management system prevented the flooded mines to discharge into the Atlantic Ocean. The existing problem was that since the pumping in the area started, the pumped mine water quality has deteriorated. As Wolkersdorfer stated, this is proven by increasing iron and aluminum content and also low pH (Wolfersdorfer, 2009).

DEVCO and CBDC are currently working on a remediation project that can solve the problem. Dr. Christian Wolkersdorfer the appointed chair of mine water remediation at CBU and my supervisor has the task of researching how to extract and remediate water from the mines. Stratification is one of the potential remediation methods that is been investigated for the 1B mine pool. If stratification is observed and is stable, dewatering pumps can be lifted or lowered to access the better quality mine water (Wolkersdorfer, 2009).

The objective of this report is to study and analyze the data collected from 30 selected wells situated within the 1B mine pool focusing on a potential mine water stratification and how it can be used as an effective remediation if present. Results from previous works by Wolkersdorfer (2009) showed that no stable stratification was observed within the 1B mine pool however, he only sampled 15 wells whilst this year the 1B mine pools data was updated by sampling and taking information from 30 wells. Another point that can arise is that the water actually settles with time and form a stable stratified layer. This report is intended to provide recommendations on using stratification as a potential remediation method or rather looking into other alternatives in solving the environmental problems the flooded mines has introduced and also saving underground water for productive use.

2.0 Field Equipments and Procedure

The field equipments used in the field and the procedure used to collect the data needed from the 30 wells is explained in this section. Both the equipments and the procedure are standards used in mine water sampling and monitoring. Figure 1 below shows the sampling site in the Glace Bay and Dominion area where the 1B mine pool colliery is situated. All the sampling sites are highlighted with green dots. It can be observed that the wells are not on the same level geographically and this means that the data cannot be scaled and analyzed as a whole but individually.

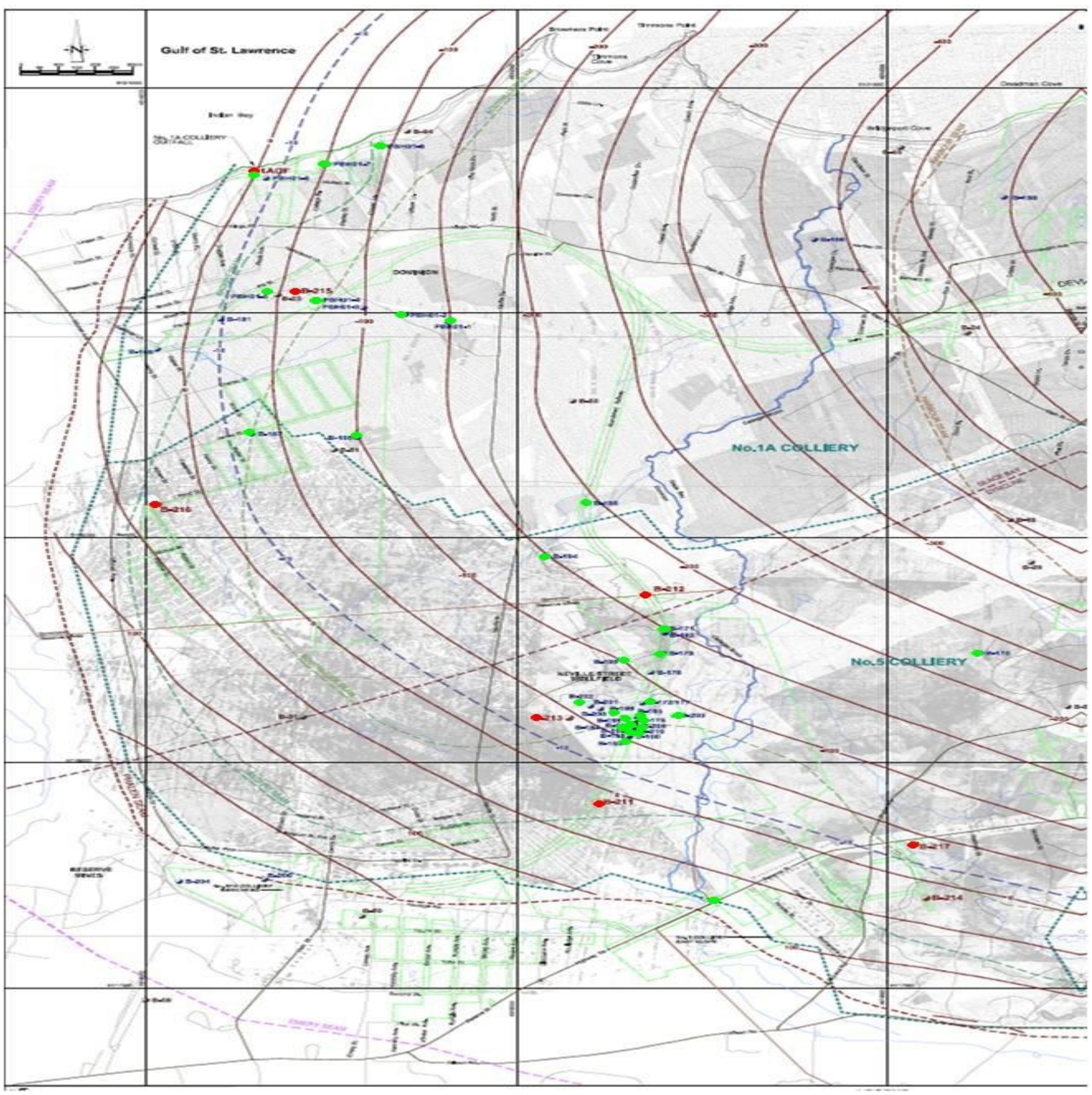


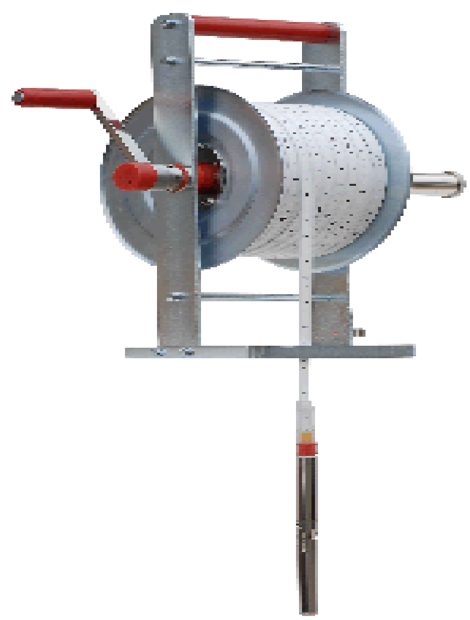
Figure 1: Sampling point maps for the 1B colliery

2.1 Field Equipments

Stratification sampling needs a measuring meter that can get information with depth and also onsite. For the electrical conductivity and the temperature data, a Solinst 107 TLC meter was used. It accurately measures the electrical conductivity (±1μS cm^{-1}), the temperature (±0.1°C) and depth/ level (±2 m) using a probe attached to a 100m flat tape displaying the results on an LCD display.

Figure 2 shows the Solinst 107 TLC meter used. Most of the wells we measured had a depth below 100m which is the length of the Solinst TLC 107 meter however the 1B shaft and well B-175 are deeper than 100m. Another water level meter model Sphor which only measures the temperature was used. The probe is attached to a 300m flat tape and it also displays the temperature measurement. This instrument was also used for the B-175 well and the 1B shaft. Both instruments were perfect for the parameters we had to measure since they are portable and are on-site meters since the electrical conductivity and temperature change quickly after a sample has been taken.

Solinst 107 TLC



Sphor water level meter

Figure 2: Solinst TLC 107 and Sphor meter used for the stratification data

2.2 Procedure

There are two types of stratification that can be analyzed, thermal and chemical stratification. The temperature data will be used to analyze the thermal stratification and the electrical conductivity will be used to analyze the chemical stratification. The electrical conductivity measures the ability for the water to conduct electricity. Wolkersdorfer (2006) showed how the calculation of the electrical conductivity based on the physical and electrical properties of the ions that are generally found in mine water systems is very close to the measured electrical conductivity. In addition, the example Wolkersdorfer used in his book calculated a value of 1091µS cm^{-1} and it was very close to the measured electrical conductivity of 1086 µS cm^{-1}. This makes it clear that the chemical stratification can be analyzed measuring the electrical conductivity data.

The procedure used to measure the electrical conductivity and temperature was the same for all wells. The Solinst probe is lowered in the well and once it gets in contact with the surface of the water, the meter beeps. The TOC is recorded and the parameters were measured 0.1m and 0.5m below the water surface. From that point on, each 1m reading was measured until the bottom of the well is reached. The depth of the wells data from 2009 was used to know exactly when to stop reading the parameters and bring back the probe. Some of the wells were not measured last year and with those wells, we had to observe and evaluate the tension on the tape. Once we reached the bottom of the well, no tension can be felt on the tape.

This is done with all the wells except well B-175 and the 1B mine shaft were both the Solinst meter and the sphor had to be used. The Solinst meter was used to get the electrical conductivity and temperature data to the depth of 100m and the sphor is used to the actual depth of the well and the shaft.

I then inputted all the stratification data into the stratification database where the graphs were developed for both electrical conductivity and temperature with depth.

3.0 Results and Discussions

All the data collected was inputted in the stratification database in excel and sigma plot 11. All the 13 wells that stratification data was collected were analyzed individually. It will be difficult to discuss all 13 wells in this report and since all the wells are within the vicinity of the 1B mine pool the characteristics of the colliery can be better explained with the wells analyzed together. To better understand the results, well B-186 will be discussed.

Stratification occurs when there is a density difference in layers of water extending over a large area. On a depth dependent graph, the density difference is explained when the parameters (el. Cond., temp) change vertically with a large horizontal extent.

With well B-186, there is no defined stratification with either parameter. The electrical conductivity shows a big jump at 20 m below surface level from 700 to 3800 µS cm^{-1}, this is shown in the figure below. The rest are gradual changes in the parameters and this just shows a differentiation with depth but not a distinct stratification between water layers. This identifies either unstable stratification or unexplained water behavior. The figure below shows the results of well B-186 with both parameters and it better explains how the parameters relate with depth. The highlighted portion with the oval shape shows an extended horizontal line which shows an example of a density difference with water layers.

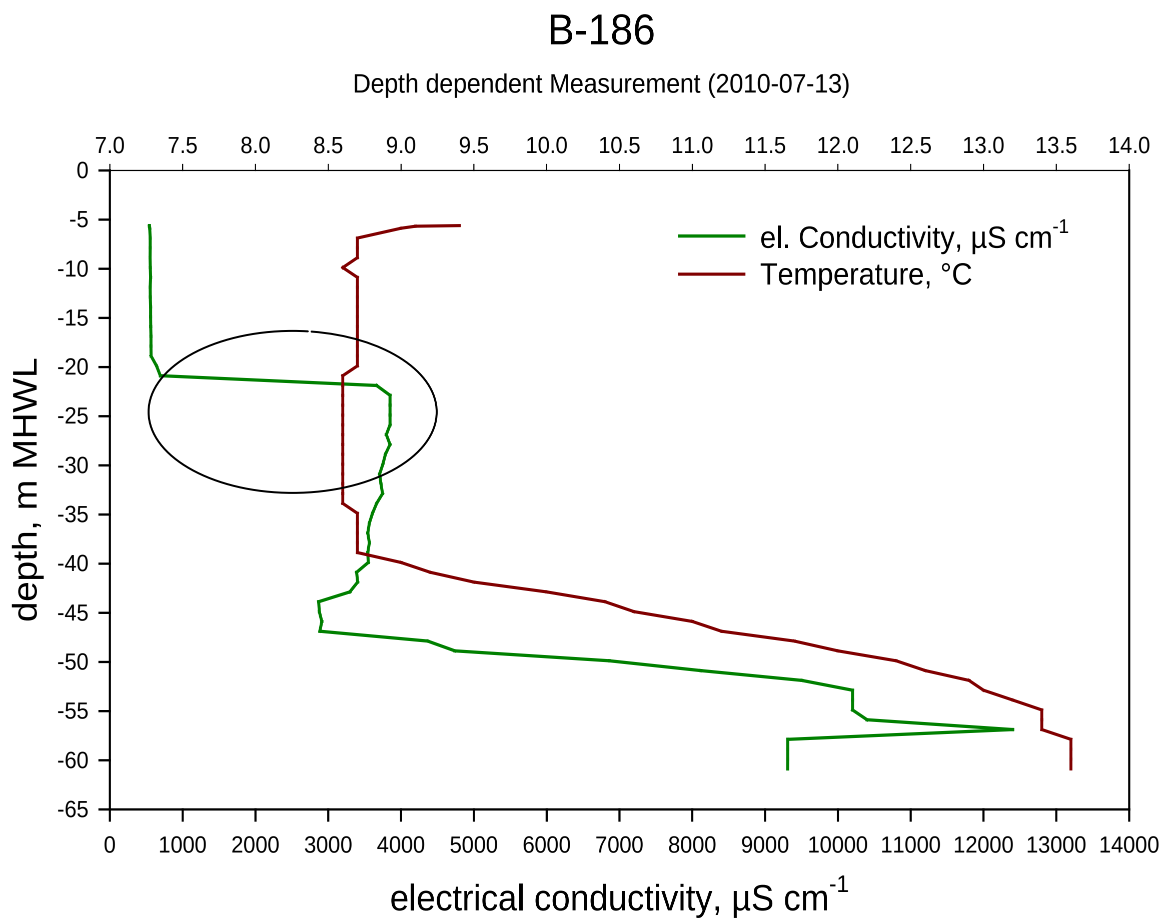


Figure 3: Electrical conductivity- Depth- Distribution for well B-186

3.1 Temperature-Depth-Distribution in the 1B mine pool

Figure 3 shows the temperature-depth-distribution in the 1B mine pool and as can be observed, there is no defined and consistent pattern in the distribution. Each well that was measured has its own pattern and there is no actual stratified well. However all the wells showed a differentiation in the water layers within the well. The upper water column in the wells had temperatures between 8 to 10 ^{o}C except the PBH01-1, 2,4,5,7 and 8 wells which have temperatures between 11 to 14.5 ^{o}C. The lower water column shows temperatures between 9 to 16 ^{o}C and as Wolkersdorfer stated in his 2009 report that in all cases, the temperatures are warmer than the expected temperature due to the geothermal gradient which is only 1.4 to 1.7 K/100 m based on Mackenzie et al (1985).

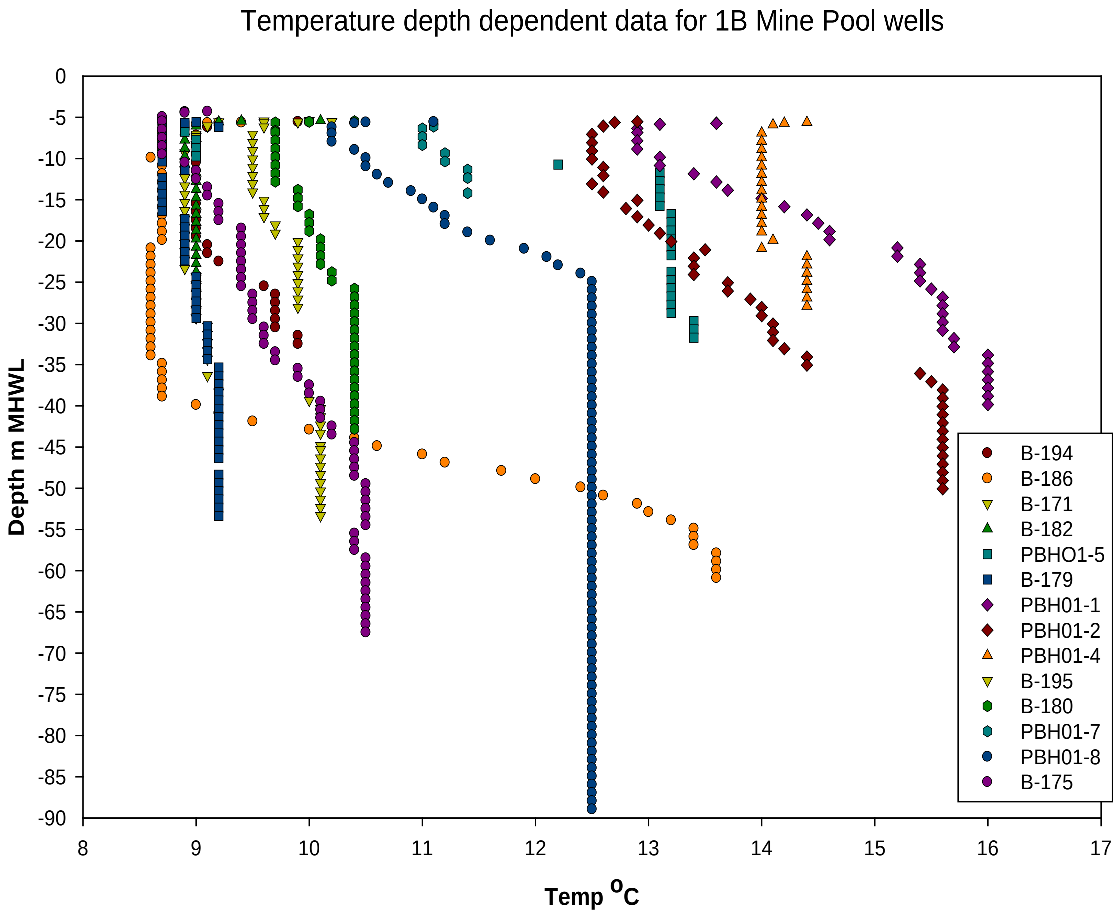


Figure 4: Temperature-Depth-Distribution for 1B Mine Pool

3.2 Electrical Conductivity-Depth-Distribution in the 1B mine pool

Figure 4 shows the el. Cond.-Depth-Distribution in the 1B mine pool and just like the temperature distribution, there is no clear stratification pattern. Analyzing the data, the upper water column is more clustered than the lower water column. The el. Conductivity ranges between 300 to 2000 µS/cm in the upper water column except the PBH01- 1, 2, 4, 5, 7, 8 wells which range widely between 50 to 4000 µS/cm also the lower water column has a random trend of higher el. Conductivity between 2000 to 15700 µS/cm.

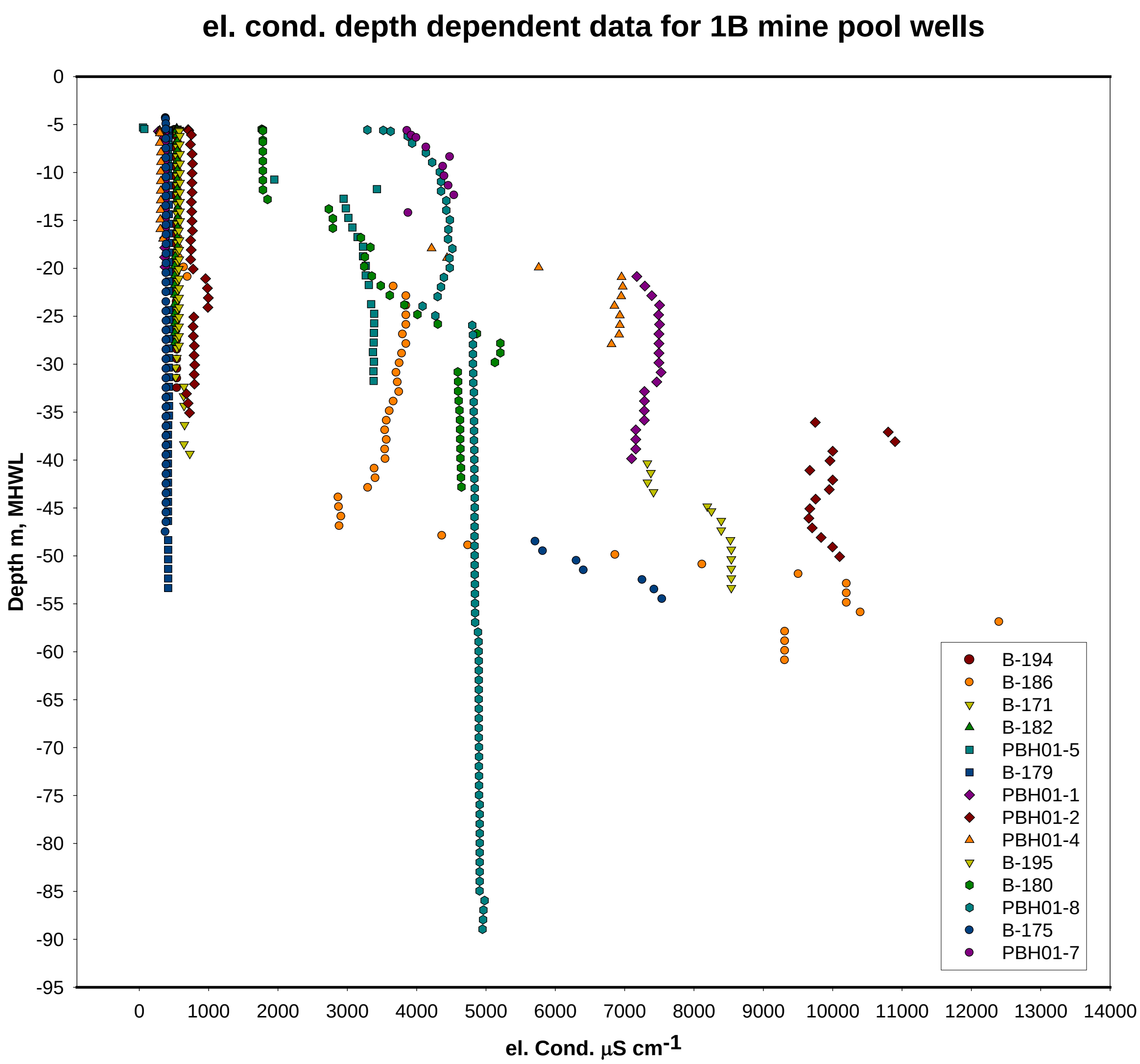


Figure 5: Electrical Conductivity-Depth-Distribution for 1B Mine Pool

3.3 1B shaft temperature and el. Cond.-depth distribution

Whilst doing my research on stratification in underground mines, I realized that all the journals or books written on stratification used the shafts profile as its point of discussion. With all the locations that experienced stratification, there was a defined vertical and horizontal layer with the parameters and a consistent pattern over the years of sampling. For example, Josef Zeman *et al* (2008) showed in their paper “Mine Water Stratification at Abandoned Mines and its Geochemical Model” how the temperature and the resistivity (which is inversely related to the el. Conductivity i.e. conductivity is the reciprocal (inverse) of resistivity) distributed with depth over three years. This is shown in figure 6. The stratification is well defined and two layers of stratification is visually clear on the graphs. Over the years, the trend is constant but slightly shifting to the left or the right. This shows that there is both a defined and stable stratification.

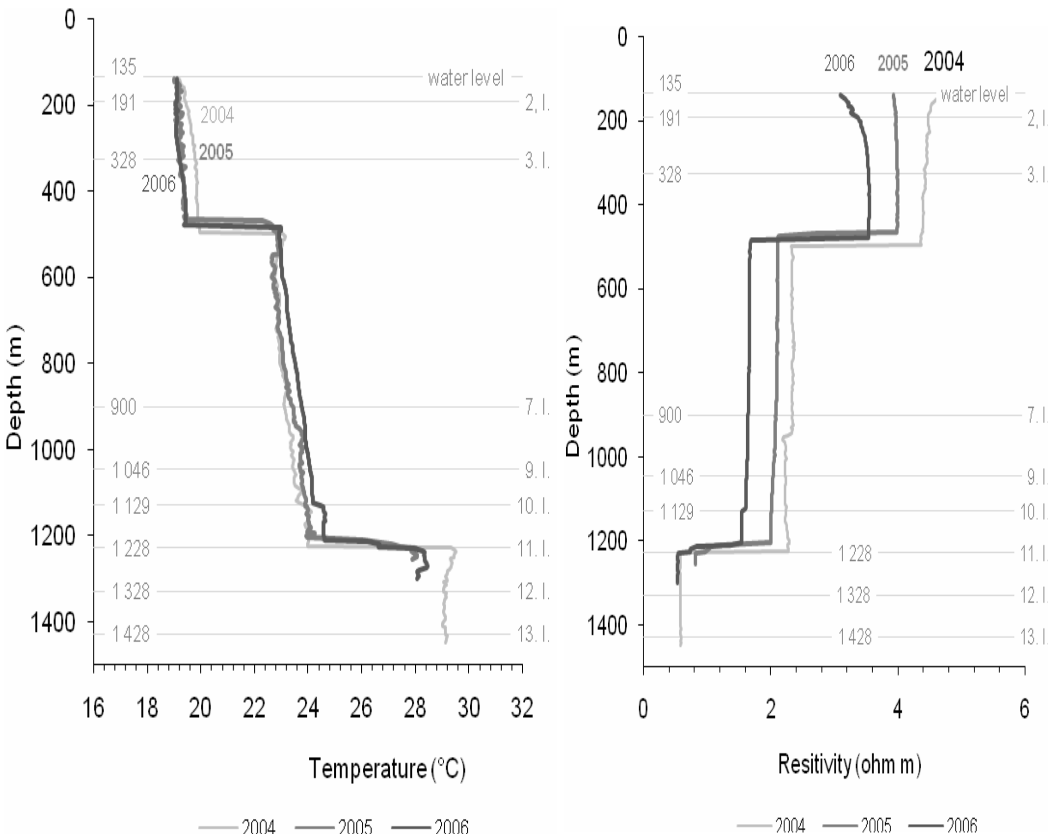


Figure 6: "Stratification of mine water on shaft Jindich II in Rosice-Oslavany coal field six and more years after flooding. (Zeman et al, 2008)" Temperature and Resistivity (el. Cond. Reciprocal)-Depth-Distribution.

Figure 7 shows the 1B shaft distribution and like the well data, it does not show any stratification trend. The 1B shaft was not sampled in the previous years therefore I am not able to compare the trend over the years. In addition, if there is a visible trend over the years but no sign of stratification then it really does not help with the investigation.

For completion, table 1 shows the comparison between 2009 and 2010 stratification results between the wells that were measured in both years. The highest values observed in the wells are included in the table. The el. Conductivity in all the wells but B-179 increased over the one year span and the temperature was relatively constant.

Table 1: Electrical Conductivity and Temperature highest value in 2009 and 2010 stratification results.

Wells	**Electrical Conductivity**		**Temperature**	
	2009	**2010**	**2009**	**2010**
B-194	4677	>4000	11.9	10
B-186	5233	12400	13.6	13.6
B-171	5256	8538	9.7	10.1
B-182	469	552	9.0	9.0
PBH01-5	2346	3387	13.2	13.4
B-179	599	429	9.2	9.2
PBH01-1	323	7525	15.7	16.0
PBH01-2	4771	10900	15.6	15.6
PBH01-4	3990	6930	14.2	14.4
B-180	4845	5207	10.4	10.4

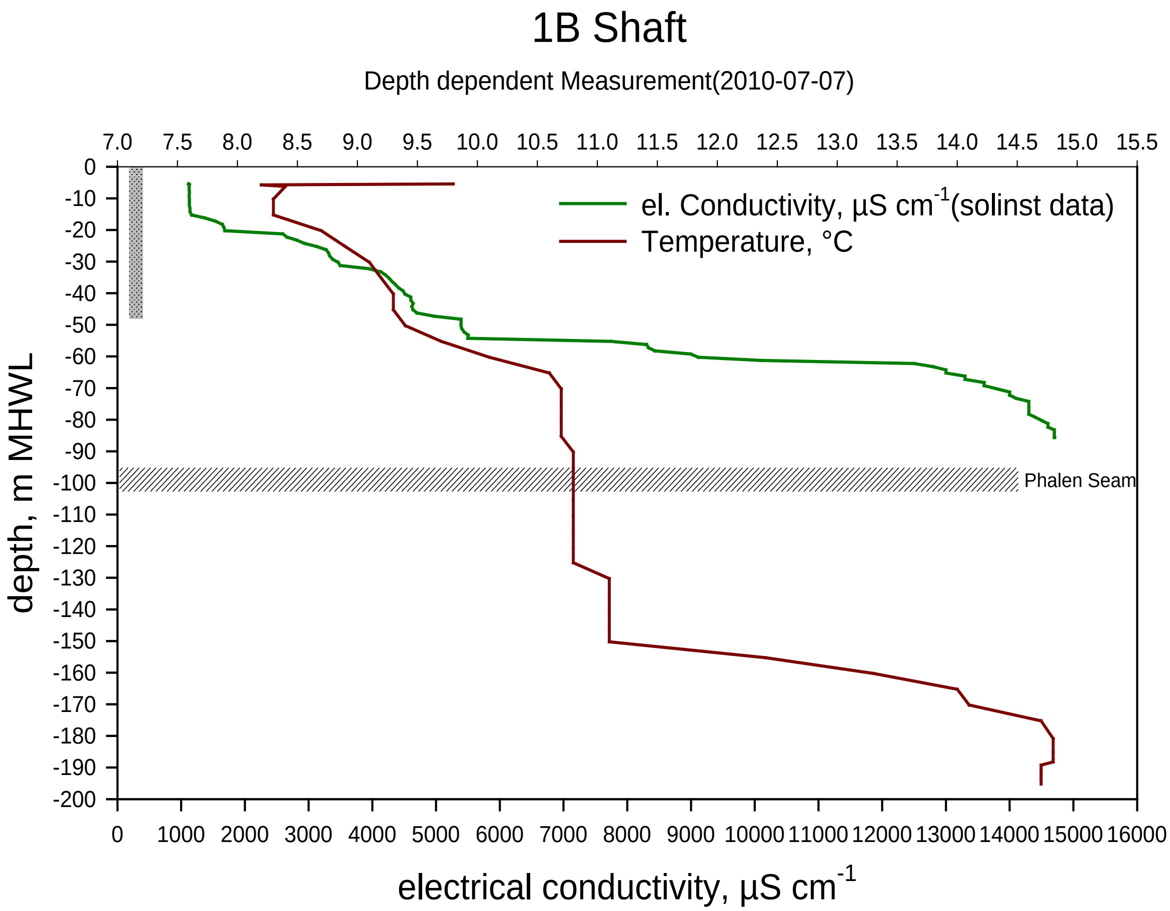


Figure 7: 1B shaft Temperature and el. Cond.-Depth Distribution

4.0 Conclusion

The results over the two years of investigation have shown that there is no sign of stratification in the 1B mine pool either stable or not. It is safe to conclude that the idea of using stratification as a potential remediation for the 1B colliery will not work. Lifting the pumps in the wells to pump good quality water will definitely pick up bad quality water. Wolkersdorfer (2009) stated that the pump will pump bad quality water independent of its vertical position in the well therefore the wells showing vertical differentiation will consequently pick up bad quality water.

5.0 Recommendation

As the conclusion stated, there is no observed stratification within the 1B mine pool and lifting the pumps in the wells will not solve the problem of the deteriorating mine water quality. There is currently a passive mine water treatment plant stationed in the 1B mine pool and as observed by Wolkersdorfer (2010) the plant design criteria of 15-18 mean residence time and less than 1mg/L Fe_{total} was not met. However, observing the increase in electrical conductivity and acidity which is not discussed in this report but was measured during the sampling period.

An active treatment involves the usage of electricity and chemicals in contrast; a passive treatment uses natural occurring energy sources e.g. solar and potential energy. A passive treatment is more economically friendly but if in the case of a highly polluted mine water, it is better to use an active treatment to solve the problem and alleviate maintenance issues. It is recommended that the passive treatment plant be replaced by an active mine water treatment plant which is commonly used for highly polluted mine water.

6.0 Reference

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Figure 6: Zeman, J., Šupíková, I., Cerník, M. (2008) Mine Water Stratification at Abandoned Mines and its Geochemical Model, 3-4

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