**Mount Polley Mining Corporation**
IMPERIAL METALS CORPORATION

# Annual Review of Anaerobic Biological Reactor

# 2011

## INTRODUCTION

A one hundred gallon per minute (GPM) anaerobic biological reactor (ABR) was commissioned and constructed at Mount Polley Mining Corporation (MPMC) in December 2009. The objective of this ABR is to reduce metal and sulphate concentrations thereby providing a better opportunity for meeting water quality discharge requirements. The ABR feed flow is the toe drain of the existing Tailings Storage Facility (TSF) along the Main embankment of the Dam. From the outflow, water passes through a series of retention ponds before returning to the Main Seepage Pond (from which it is pumped back into the dam).

## TIMELINE

*2009*

The ABR was commissioned on December 16th, 2009. It was constructed by covering the bottom of the pond, including the pipes on the bottom of the northwest side of the ABR, with layers of organic material (manure, woodchips, and straw), which act as a carbon and energy source for microbes. The organic material was sealed in by rocks, which maintain the layer structure and provide microbe habitat, and the rocks were covered with water to act as an oxygen barrier. The system was activated with an inflow of approximately 100GPM.

*2010*

The system was active with an estimated 100 GPM until August 11th 2010, when the system was shut down for just over one month. From September 20th to the end of October approximately 10 GPM was allowed to report to the ABR, then through most of November 100 GPM was once again flowing into the ABR.

*2011*

The ABR continued to be active at 100 GPM until September when a propane heating system was commissioned at the ABR inflow, and the inflow was reduced to a rate of 4 GPM. Heat was applied to increase the temperature of inflow water from 7°C to 20°C, thereby allowing the organic section of the ABR to acclimate, in hopes of promoting the activity of remedial microbial. The heating system ran until mid-November before being winterized and shut off. After the heating system was shut off, inflow was increased to 50 GPM.

## SAMPLING METHODOLOGY

To monitor any changes in the water quality after passing through the ABR samples are taken at the inflow (ABR-IN), within the pond (ABR-INTERFACE)., and at the outflow (ABR-OUT) of the ABR.

ABR-IN is sampled at the toe drain, which represents the source. Previously, a series of pumps were run for several days to draw down the level of the main seepage pond below the input of the toe drain. Sample access was at the foundation drain location below the main tailings dam. This is also identified as sample location E5 on the MPMC effluent permit. An inflow sampling port was installed at the end of April when the new heating system was installed, providing more convenient access, and more accurate data on inflow water quality.

ABR-OUT is accessed through the gate of the ABR on the South East side and the sample is taken in front of the outlet culvert during non-freezing periods. In the winter months, the sample is taken from the other side of the "Gavin Lake Rd" in the outlet ditch (for safety reasons). ABR-Interface samples are taken at four general locations within the body of water in the ABR in the area of the pond where the piping is situated (refer to Figure 1). In addition to samples, profiles are taken at interface locations to measure the changes in pH, conductivity, temperature, redox potential, and dissolved oxygen from surface to bottom.

In 2011, 10 samples were taken at ABR-IN and 14 samples were taken at ABR-OUT. Three sets of ABR-INTERFACE samples (at different combinations of locations) were collected both at the surface by hand, and at the bottom using a "Van Dorn" sampler. These samples were sent to an independent laboratory (ALS Laboratory Group (ALS)) for analysis and reporting.

# RESULTS

## Water Quality Parameters

A comparison of average results for key parameters at ABR-IN and ABR-OUT is presented in Table 1. Highlighted cells indicate an increase in a parameter. Samples taken prior to the installation of the new ABR-IN valve (before mid-April) were not included in calculations and discussion. Similarly, data from samples taken while the heater was running (August 31$^{st}$ to mid-November) were also not included, because water was not flowing out of the ABR, and all of the water was circulating within the pond. Results for individual samples taken in 2011 at ABR-IN and ABR-OUT are presented in Tables 2 and 3, respectively. Results for the key parameters from all the ABR Interface samples are listed in Table 4. To assess if the water quality is appropriate for discharge, the BC Water Quality Guidelines (BCWQG) for aquatic life are used.

*Sulphate*

Sulphate levels at ABR-OUT were relatively constant between 415 and 558 mg/L. Compared to ABR-OUT, results at ABR-INTERFACE were similar in June and slightly lower in August. With the exception of August, ABR-OUT sulphate levels were lower than ABR-IN levels. The low record of 201 mg/L at ABR-IN in August, however, results in a lower annual average at ABR-IN than ABR-OUT. All results were above the 30-day BCWQG, but below the maximum BCWQG.

*Nitrate*

Nitrate levels were consistently higher at ABR-IN than ABR-INTERFACE and ABR-OUT. A significant decrease between the average results of ABR-IN and ABR-OUT was observed. All results were below the BCWQG.

*Phosphorus (Total)*

With the exception of August, when ABR-OUT and ABR INTERFACE 1-B (bottom) were higher than ABR-IN, ABR-OUT and ABR-INTERFACE reported lower values of total Phosphorus.

*Aluminum (Dissolved)*

In general, dissolved Aluminum concentrations at ABR-OUT and ABR-INTERFACE were the equal to, or slightly lower than ABR-IN concentrations, resulting in the average annual decrease in Aluminum between ABR-IN and ABR-OUT. All results were below the BCWQG.

*Arsenic (Total)*

Arsenic levels were consistently lower at ABR-INTERFACE than ABR-IN, and lower at ABR-OUT than ABR-INTERFACE. All results were below the BCWQG.

*Cadmium (Total)*

Cadmium results were below MDL for all results except the June value of 0.00012 mg/L at ABR-IN, which exceeds the BCWQG. This, and the fact that higher MDLs were generally used at ABR-IN, caused the annual average decrease between ABR-IN and ABR-OUT.

*Copper (Total)*

Copper levels were consistently lower at ABR-INTERFACE and ABR-OUT than ABR-IN. All results were below the BCWQG.

*Iron (Total)*

ABR-OUT was lower than ABR-IN in June, July and August, but higher in May and December, resulting in an annual average increase between ABR-In and ABR-OUT. For ABR-INTERFACE, results were below MDL in June, but in August were much higher, ranging from 0.078 to 0.327 mg/L. These values exceed the ABR-OUT result, and fluctuate around the ABR-IN value of 0.131 mg/L. All results were below the BCWQG.

*Lead (Total)*

All ABR-OUT results were below MDL, showing an annual average decrease between ABR-IN and ABR-OUT. ABR-INTERFACE results were lower than ABR-IN, or below MDL. All results were below the BCWQG.

*Magnesium (Total)*

The results for all sites fluctuate between 20 and 25 mg/L, with the exception of the 11.5 mg/L record at ABR-IN in August. Excluding this sample shows basically no change between average concentrations at the three sites.

*Manganese (Total)*

Manganese concentrations consistently decrease from ABR-IN, across ABR-INTERFACE (from sits 1 to 4), to ABR-OUT, where the lowest values were recorded. ABR-INTERFACE-1 in August and all the results from ABR-IN exceed the BCWQG.

*Molybdenum (Total)*

Molybdenum concentrations at ABR-OUT and ABR-INTERFACE were consistently lower than ABR-IN concentrations. All results were below the BCWQG.

*Nickel (Total)*

Nickel levels were at ABR-OUT and ABR-INTERFACE were consistently lower that ABR-IN levels, except in August when both ABR-IN and -OUT were below MDL and ABR-INTERFACE was higher (slightly below typical ABR-IN values). All results were below the BCWQG.

*Selenium (Total)*

Selenium results were lower at ABR-OUT and ABR-INTERFACE than ABR-IN, except for July. Despite the decrease in Selenium between ABR-IN and –OUT, all results exceed the BCWQG.

*Zinc (Total)*

Zinc concentrations at ABR-OUT and ABR-INTERFACE were consistently lower than ABR-IN concentrations, with many results below MDL at all sites. All results were below the BCWQG.

For the in situ parameters, pH does not change, and conductivity shows a slight increase between ABR-IN and ABR-OUT. Temperature decreased, which is a function of the weather.

When compared with the 2010 results of the remedial effects of the ABR, the 2011 results show increased removal of metals and other parameters. In 2010, aluminum, Arsenic, Copper, Manganese, Nickel and Phosphorus all showed greater that 20% increases between ABR-IN and ABR-OUT. In 2011, all of these parameters decreased by greater than 20% between ABR-IN and ABR-OUT. Note that when the outliers in the Sulphate and Molybdenum data (discussed above) are removed, neither exhibits significant change in concentration, which was similar in 2010. The remaining parameters had similar outcomes in 2010 and 2011.

## Heating Results

Table 5 shows the water quality on the bottom of the ABR-INTERFACE before and after heat application, and compares it to the water quality at ABR-IN. In general the heat was successful in further removing metals and other parameters of concern from the water. Aluminum and

Nickel showed little improvement because they were already below MDL prior to heat application. Iron levels improved, but it remain the only parameter which the ABR causes to increase. The selenium concentration improved, but still exceeds the BCWQG. One of the main reasons for introducing heat to the system was to attempt to reduce Sulphate levels, because thus far the ABR has been unsuccessful, however, heat did not appear to induce the desired levels of sulphate reduction.

### ABR-INTERFACE Profiles

Tables 6 and 7 show the results from profiles completed at interface locations in 2011. Due to issues with equipment, some data gaps exist, however, some general trends can be observed. pH decreases between the surface and bottom. Conductivity decreases towards the bottom, indicating that more metals are removed through microbe activity toward the organic layer. Temperature is higher on the surface, which is mostly due to surface solar heating, as most of the profiles were completed in the summer months. Redox potential decreases between the surface and bottom, indicating that there are lower oxygen levels towards the bottom. This is confirmed by the dissolved oxygen levels which decrease from 80 to 100% on the surface, to 0% on the bottom. These results show that there is in fact an anaerobic environment on the bottom of the ABR, but only at the very bottom.

## CONCLUSIONS AND RECOMMENDATIONS

Results from the ABR thus far have shown positive effects in reduction of metals. All of the key parameters analyzed in this reports showed significant decreases in concentration through the action of the ABR, with the exception of Sulphate, Lead, Magnesium, and Selenium. The application of heat appears to further reduce parameters, albeit minimally for Sulphate.

In 2012, a focus on parameters of concern that are not currently being reduced to desired levels is recommended.

- **Sulphate**: In winter, when the ABR is under ice cover, the strong Sulphur smell may indicate sulphate processes are active. Yet, a closed sample that smells of sulphur initially loses this odour with time. It has been hypothesized that sulphate levels have not been reduced is because it is re-precipitating with Iron. Further research precipitation processes and covers (that provide darkness and an oxygen barrier) should be considered.
- **Selenium**: the ABR is currently reducing Selenium levels, but not to the level required for discharge. Options for further reduction should be considered.
- **Magnesium & Lead**: while neither of these parameters exceed BCWQG, understanding why they remain stable/increase may provide insight into the functioning of the ABR.

A final recommendation for next year is to carry out more consistent interface profiling and sampling (sampling the same interface point(s) each time to allow for better result comparisons).

## TABLES AND FIGURES

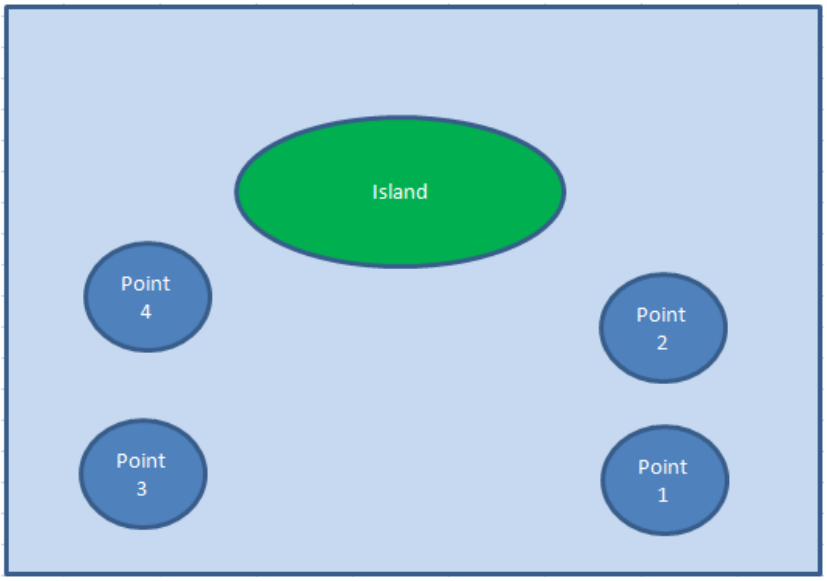


**Figure 1**: ABR-INTERFACE sample site locations (↑SE)

**Table 1**: 2011 average results from ABR-IN and ABR-OUT

| Parameter | ABR-IN | ABR-OUT | Decrease | % Reduction |
|---|---|---|---|---|
| Conductivity (in situ) (µs/cm) | 1121 | 1211 | -90 | -8.01 |
| pH (in situ) | 8.03 | 8.03 | 0.00 | -0.04 |
| Temperature (in situ) (°C) | 7.5 | 10.3 | -2.9 | -38.17 |
| Sulfate ($SO_4$) (mg/L) | 471 | 499 | -28.2 | -6.00 |
| Nitrate (as N) (mg/L) | 1.186 | 0.025 | 1.161 | 97.89 |
| Phosphorus (Total) (mg/L) | 0.0557 | 0.0318 | 0.0239 | 42.93 |
| Aluminum (Dissolved) (mg/L) | 0.0022 | 0.0017 | 0.0004 | 19.60 |
| Arsenic (Total) (mg/L) | 0.0019 | 0.0015 | 0.0004 | 22.85 |
| Cadmium (Total) (mg/L) | 0.00007 | 0.00002 | 0.00005 | 66.50 |
| Copper (Total) (mg/L) | 0.0044 | 0.0022 | 0.0022 | 50.86 |
| Iron (Total) (mg/L) | 0.04533 | 0.0996 | -0.0542 | -119.64 |
| Lead (Total) (mg/L) | 0.00029 | 0.00003 | 0.00026 | 91.31 |
| Magnesium (Total) (mg/L) | 21.6 | 23.3 | -1.760 | -8.15 |
| Manganese (Total) (mg/L) | 1.086 | 0.776 | 0.310 | 28.54 |
| Molybdenum (Total) (mg/L) | 0.185 | 0.138 | 0.0469 | 25.33 |
| Nickel (Total) (mg/L) | 0.00082 | 0.00037 | 0.00045 | 54.80 |
| Selenium (Total) (mg/L) | 0.0018 | 0.0010 | 0.0008 | 44.76 |
| Zinc (Total) (mg/L) | 0.0048 | 0.0026 | 0.0021 | 44.86 |

*Results below MDL are reported as 0.5*MDL

**Table 2** ABR-IN 2011 Sample Results  Date format below

| Date | 5-Apr-11 | 11-May-11 | 18-May-11 | 9-Jun-11 | 13-Jul-11 | 3-Aug-11 | 31-Aug-11 | 5-Oct-11 | 31-Oct-11 | 5-Dec-11 |
|---|---|---|---|---|---|---|---|---|---|---|
| Conductivity (in situ) (µs/cm) | 1274 | 1295 | 1303 | 1218 | 1214 | 791 | 1120 | 940 | 907 | 907 |
| pH (in situ) | 7.78 | 7.79 | 7.68 | 7.95 | 8.32 | 8.25 | 8.25 | 8.09 | 8.16 | 8.16 |
| Temperature (in situ) (°C) | 7.7 | 7.5 | 7.3 | 8.7 | 7.4 | 7.1 | 11.7 | 7.3 | 6.8 | 6.8 |
| Sulfate ($SO_4$) (mg/L) | 545 | 562 | 549 | 545 | 513 | 201 | 471 | 307 | 279 | 453 |
| Nitrate (as N) (mg/L) | 1.41 | 1.56 | 1.51 | 1.44 | 1.6 | 0.037 | 1.64 | 0.063 | <0.050 | 0.968 |
| Phosphorus (Total) (mg/L) | 0.0989 | 0.0345 | 0.0391 | 0.039 | 0.0358 | 0.13 | 0.0328 | 0.853 | 0.104 | 0.0558 |
| Aluminum (Dissolved) (mg/L) | <0.003 | <0.003 | <0.003 | 0.0038 | 0.0031 | <0.003 | 0.0075 | <0.0030 | <0.0030 | <0.003 |
| Arsenic (Total) (mg/L) | 0.00422 | 0.0017 | 0.00177 | 0.00164 | 0.00173 | 0.00282 | 0.00172 | 0.00245 | 0.00257 | 0.00175 |
| Cadmium (Total) (mg/L) | <0.00038 | <0.00012 | 0.00012 | <0.00015 | <0.00012 | <0.00004 | <0.00015 | <0.000040 | <0.000050 | <0.0002 |
| Copper (Total) (mg/L) | 0.503 | 0.00387 | 0.00419 | 0.00413 | 0.00637 | 0.00061 | 0.00363 | 0.0017 | 0.00056 | 0.00722 |
| Iron (Total) (mg/L) | 1.64 | <0.030 | <0.030 | 0.031 | 0.034 | 0.131 | <0.030 | 0.102 | 0.113 | 0.046 |
| Lead (Total) (mg/L) | 0.00112 | 0.000078 | 0.000197 | 0.000297 | 0.000267 | 0.000296 | 0.00006 | 0.000091 | <0.000050 | 0.000592 |
| Magnesium (Total) (mg/L) | 24.3 | 24.6 | 24.5 | 24.9 | 22.9 | 11.4 | 21.2 | 13.7 | 13.5 | 21.2 |
| Manganese (Total) (mg/L) | 0.941 | 0.867 | 0.872 | 0.834 | 0.821 | 1.96 | 0.751 | 1.53 | 1.8 | 1.16 |
| Molybdenum (Total) (mg/L) | 0.18 | 0.171 | 0.181 | 0.199 | 0.187 | 0.188 | 0.181 | 0.163 | 0.179 | 0.184 |
| Nickel (Total) (mg/L) | 0.00126 | 0.00072 | 0.00109 | 0.00143 | 0.0008 | <0.00050 | 0.0006 | <0.00050 | <0.00050 | 0.00064 |
| Selenium (Total) (mg/L) | 0.00301 | 0.00246 | 0.00242 | 0.00186 | 0.00252 | <0.00050 | 0.00246 | <0.00050 | <0.00050 | 0.00143 |
| Zinc (Total) (mg/L) | 0.012 | 0.004 | 0.0065 | 0.0085 | 0.0066 | <0.0030 | 0.0176 | <0.0030 | <0.0030 | <0.0030 |

**Table 3** ABR-OUT 2011 Sample Results

| Date | 2-Feb-11 | 8-Mar-11 | 5-Apr-11 | 11-May-11 | 8-Jun-11 | 13-Jul-11 | 3-Aug-11 | 31-Aug-11 | 5-Oct-11 | 1-Nov-11 | 5-Dec-11 | 12-Dec-11 | 20-Dec-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conductivity (in situ) (µs/cm) | 1203 | 1217 | 1033 | 1212 | 1228 | 1217 | 1191 | 1178 | 1198 | 1224 | 1215 | 1221 | 1194 |
| pH (in situ) | 7.43 | 7.97 | 7.72 | 8.45 | 7.99 | 8.6 | 7.97 | 7.8 | 7.71 | 7.85 | 7.75 | 7.66 | 7.78 |
| Temperature (in situ) (°C) | 1.8 | 17.2 | 4.2 | 10.1 | 15 | 16.4 | 17.2 | | 10 | 3.5 | 1.8 | 1.4 | |
| Sulfate ($SO_4$) (mg/L) | 508 | 527 | 415 | 558 | 542 | 525 | 505 | 480 | 483 | 473 | 453 | 456 | 452 |
| Nitrate (as N) (mg/L) | <0.05 | <0.05 | 0.129 | <0.05 | <0.05 | <0.05 | <0.05 | <0.050 | 0.054 | <0.050 | <0.05 | <0.05 | <0.05 |
| Phosphorus (Total) (mg/L) | 0.0914 | 0.0799 | 0.0723 | 0.02 | 0.0127 | 0.0154 | 0.0168 | 0.048 | 0.0422 | 0.0436 | 0.0491 | 0.0529 | 0.0556 |
| Aluminum (Dissolved) (mg/L) | <0.003 | <0.003 | 0.0038 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | 0.0031 | <0.0030 |
| Arsenic (Total) (mg/L) | 0.00158 | 0.00154 | 0.00133 | 0.00141 | 0.00123 | 0.00142 | 0.00128 | 0.00182 | 0.00166 | 0.00165 | 0.00162 | 0.00166 | 0.00165 |
| Cadmium (Total) (mg/L) | <0.00005 | <0.00005 | <0.00006 | <0.000050 | <0.000050 | <0.000040 | <0.000050 | <0.00010 | <0.000070 | <0.000030 | <0.000050 | <0.000050 | <0.000050 |
| Copper (Total) (mg/L) | 0.00163 | 0.00233 | 0.0046 | 0.00241 | 0.00177 | 0.00243 | 0.00271 | 0.00219 | 0.00305 | <0.0025 | 0.00237 | 0.00179 | 0.00165 |
| Iron (Total) (mg/L) | 0.093 | 0.081 | 0.293 | 0.074 | <0.030 | <0.030 | 0.063 | 0.092 | 0.121 | 0.202 | 0.185 | 0.19 | 0.155 |
| Lead (Total) (mg/L) | <0.00005 | <0.00005 | 0.00011 | <0.00005 | <0.00005 | <0.00005 | <0.00005 | <0.000050 | 0.000145 | <0.000050 | <0.00005 | <0.00005 | <0.00005 |
| Magnesium (Total) (mg/L) | 22.9 | 24 | 19.2 | 23.4 | 24.6 | 25.2 | 24.3 | 22.3 | 22.3 | 23.8 | 22.3 | 23.2 | 20.4 |
| Manganese (Total) (mg/L) | 1.22 | 1.2 | 0.948 | 0.788 | 0.472 | 0.332 | 0.413 | 0.452 | 0.144 | 0.145 | 0.796 | 1.2 | 1.43 |
| Molybdenum (Total) (mg/L) | 0.16 | 0.142 | 0.129 | 0.15 | 0.156 | 0.163 | 0.165 | 0.127 | 0.109 | 0.102 | 0.111 | 0.112 | 0.11 |
| Nickel (Total) (mg/L) | <0.0005 | <0.0005 | 0.00063 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | 0.00059 | 0.00058 | 0.00051 | 0.00052 | 0.00057 |
| Selenium (Total) (mg/L) | <0.001 | <0.0005 | 0.00079 | 0.00155 | 0.00119 | 0.00125 | 0.00122 | 0.00092 | 0.00078 | 0.00069 | 0.00065 | 0.00057 | 0.00062 |
| Zinc (Total) (mg/L) | <0.003 | <0.003 | 0.0052 | <0.003 | 0.0042 | <0.003 | <0.003 | <0.0030 | <0.0030 | <0.0030 | <0.003 | 0.0042 | 0.004 |

**Table 4**: ABR-INTERFACE results (2011)

| Interface Location | 1-S | | 1-B | | | 2-S | 2-B | | 3-B | 4-S | 4-B | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **08-JUN-11** | **24-OCT-11** | **08-JUN-11** | **02-AUG-11** | **24-OCT-11** | **24-OCT-11** | **02-AUG-11** | **24-OCT-11** | **02-AUG-11** | **08-JUN-11** | **08-JUN-11** | **02-AUG-11** |
| Conductivity (µs/cm) | 1210 | 1180 | 1230 | 1130 | 1180 | 1180 | 1100 | 1180 | 1150 | 1210 | 1220 | 1160 |
| pH | 7.96 | 8.29 | 7.89 | 7.83 | 8.27 | 8.28 | 7.94 | 8.29 | 7.87 | 8.07 | 7.98 | 7.87 |
| Temperature (in situ) (°C) | | 7.1 | | | | 7 | | | | | | |
| Sulfate ($SO_4$) (mg/L) | 541 | 472 | 554 | 479 | 471 | 468 | 471 | 432 | 505 | 543 | 499 | 530 |
| Nitrate (as N) (mg/L) | <0.050 | <0.050 | <0.050 | 0.068 | <0.050 | <0.050 | <0.050 | <0.050 | 0.059 | <0.050 | <0.050 | 0.065 |
| Phosphorus (Total) (mg/L) | 0.0305 | 0.045 | 0.0187 | 0.485 | 0.0462 | 0.0459 | 0.0465 | 0.0452 | 0.0669 | 0.0145 | 0.0161 | 0.0306 |
| Aluminum (Dissolved) (mg/L) | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | 0.0075 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 |
| Arsenic (Total) (mg/L) | 0.00133 | 0.00169 | 0.00134 | 0.00206 | 0.00165 | 0.00172 | 0.00216 | 0.00164 | 0.00161 | 0.00129 | 0.00137 | 0.00156 |
| Cadmium (Total) (mg/L) | <0.000050 | <0.000040 | <0.000050 | <0.000070 | <0.000030 | <0.000030 | <0.000060 | <0.000030 | <0.000060 | <0.000050 | <0.000050 | <0.000060 |
| Copper (Total) (mg/L) | 0.0018 | 0.00182 | 0.00126 | 0.00457 | 0.00201 | 0.00198 | 0.00209 | 0.00242 | 0.00256 | 0.00221 | 0.00161 | 0.00251 |
| Iron (Total) (mg/L) | <0.030 | 0.18 | <0.030 | 0.327 | 0.191 | 0.192 | 0.115 | 0.209 | 0.082 | <0.030 | <0.030 | 0.078 |
| Lead (Total) (mg/L) | 0.000164 | <0.000050 | <0.000050 | 0.000135 | <0.000050 | <0.000050 | 0.000062 | 0.000061 | <0.000050 | <0.000050 | <0.000050 | <0.000050 |
| Magnesium (Total) (mg/L) | 25.4 | 24 | 25.6 | 22.9 | 24 | 22.6 | 21.6 | 23.7 | 23.2 | 25.3 | 24.7 | 23.4 |
| Manganese (Total) (mg/L) | 0.479 | 0.168 | 0.932 | 1.06 | 0.166 | 0.169 | 1.11 | 0.17 | 0.632 | 0.49 | 0.615 | 0.604 |
| Molybdenum (Total) (mg/L) | 0.157 | 0.103 | 0.153 | 0.142 | 0.102 | 0.103 | 0.131 | 0.104 | 0.147 | 0.156 | 0.153 | 0.15 |
| Nickel (Total) (mg/L) | <0.00050 | 0.00051 | <0.00050 | 0.00078 | 0.00056 | 0.00054 | 0.00051 | 0.00056 | <0.00050 | <0.00050 | <0.00050 | 0.00054 |
| Selenium (Total) (mg/L) | 0.00121 | 0.00069 | 0.00117 | 0.00149 | 0.00068 | 0.0007 | 0.00132 | 0.00069 | 0.0013 | 0.00121 | 0.00113 | 0.00156 |
| Zinc (Total) (mg/L) | <0.0030 | <0.0030 | <0.0030 | 0.0034 | <0.0030 | <0.0030 | 0.0031 | <0.0030 | <0.0030 | <0.0030 | <0.0030 | <0.0030 |

**Table 5** Assessment of effect of heat on ABR function (2011)

| Sample Location | ABR-IN | ABR-INTERPHASE-B | | ABR-INTERPHASE-B | % Reduction |
|---|---|---|---|---|---|
| Date Sampled | 2 months prior to heat application | 02-AUG-12 | | 24-OCT-12 | |
| Nitrate (as N) | 1.52 | 0.0640 | HEAT ADDED | 0.0050 | 92 |
| Phosphorus (P)-Total | 0.0374 | 0.1573 | | 0.0457 | 71 |
| Sulfate (SO4) | 529 | 496 | | 452 | 9 |
| Aluminum (Al)-Dissolved | 0.00345 | 0.0015 | | 0.0015 | 0 |
| Copper (Cu)-Total | 0.0053 | 0.0029 | | 0.0022 | 24 |
| Iron (Fe)-Total | 0.0325 | 0.1505 | | 0.2000 | -33 |
| Lead (Pb)-Total | 0.0003 | 0.0001 | | 0.0001 | 38 |
| Molybdenum (Mo)-Total | 0.1930 | 0.1425 | | 0.1030 | 28 |
| Nickel (Ni)-Total | 0.0011 | 0.0006 | | 0.0006 | 8 |
| Selenium (Se)-Total | 0.0022 | 0.0014 | | 0.0007 | 52 |
| Zinc (Zn)-Total | 0.0076 | 0.0033 | | 0.0015 | 54 |

**Table 6** ABR-INTERPHASE 1 and 2 2011 profile results

| Parameter | Depth (m) | ABR 1 (W) | | | | ABR 2 (S) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 08-Jun-11 | 05-Jul-11 | 02-Aug-11 | 24-Oct-11 | 14-Jun-10 | 08-Jun-11 | 05-Jul-11 | 02-Aug-11 | 24-Oct-11 |
| pH | 0.0 | 8.44 | 8.8 | | 7.64 | 6.9 | 8.31 | 8.82 | | 7.61 |
| | 0.5 | 8.42 | 8.81 | | | | 8.3 | 8.82 | | |
| | 1.0 | 8.4 | 8.96 | | | | 8.29 | 8.86 | | |
| | 1.5 | 8.39 | 8.83 | | | | 8.29 | 8.81 | | |
| | 2.0 | 8.23 | 8.31 | | | 6.1 | 8.1 | 8.46 | | |
| | 2.5 | 7.88 | 8.08 | 7.53 | | | 8.21 | 8.07 | | |
| | 3.0 | 7.84 | 7.89 | | | | 8.31 | 7.99 | | |
| | 3.5 | | | | | 5.7 | 7.96 | 7.93 | 7.47 | |
| | 4.0 | | | | | | 7.97 | 7.91 | | |
| | 4.5 | | | | | | 7.84 | 7.91 | | |
| | | | | | | | | | | |
| Conductivity | 0.0 | 751 | 829 | | 1204 | 196.4 | 758 | 827 | | 1212 |
| (uS/cm) | 0.5 | 751 | 829 | | | | 756 | 828 | | |
| | 1.0 | 751 | 825 | | | | 755 | 823 | | |
| | 1.5 | 751 | 812 | | | | 750 | 812 | | |
| | 2.0 | 733 | 780 | | | 196.4 | 714 | 777 | | |
| | 2.5 | 699 | 742 | 515 | | | 685 | 742 | | |
| | 3.0 | 680 | 716 | | | | 673 | 720 | | |
| | 3.5 | | | | | 196.7 | 665 | 709 | 515 | |
| | 4.0 | | | | | | 660 | 703 | | |
| | 4.5 | | | | | | | 698 | | |
| | | | | | | | | | | |
| Temperature | 0.0 | 14.6 | 15.6 | | 7.1 | 15.7 | 14.8 | 15.6 | | 7.0 |
| (°C) | 0.5 | 14.7 | 15.7 | | | | 14.7 | 15.7 | | |
| | 1.0 | 14.6 | 15.3 | | | | 14.7 | 15.2 | | |
| | 1.5 | 14.6 | 14.2 | | | | 14.6 | 14.5 | | |
| | 2.0 | 12.8 | 12.2 | | | 10.1 | 13.4 | 12 | | |
| | 2.5 | 10.6 | 10 | 15.6 | | | 11.2 | 9.7 | | |
| | 3.0 | 9.3 | 8.7 | | | | 9.4 | 8.8 | | |
| | 3.5 | | | | | 7.6 | 8.8 | 8.36 | 14.5 | |
| | 4.0 | | | | | | 8.6 | 8.2 | | |
| | 4.5 | | | | | | 8.4 | 8 | | |
| | | | | | | | | | | |
| Redox (mV) | 0.0 | | -23.7 | | | 20 | | -26.2 | | |
| | 0.5 | | -22.9 | | | | | -25.3 | | |
| | 1.0 | | -24.9 | | | | | -24.5 | | |
| | 1.5 | | -23.6 | | | | | -24.2 | | |
| | 2.0 | | -23.8 | | | -240 | | -24.2 | | |
| | 2.5 | | -24.8 | -37 | | | | -25.3 | | |
| | 3.0 | | -25.9 | | | | | -26.3 | | |
| | 3.5 | | | | | -250 | | -27.6 | -27.3 | |
| | 4.0 | | | | | | | -28.5 | | |
| | 4.5 | | | | | | | -32.8 | | |
| | | | | | | | | | | |
| DO (mg/L) | 0.0 | 8.18 | 9.85 | | 5.04 | 0.66 | 8.17 | 9.69 | | 5.17 |
| | 0.5 | 8.18 | 9.79 | | 5.08 | | 7.83 | 9.6 | | 5.16 |
| | 1.0 | 8.23 | | | 5.01 | | 7.82 | 10.17 | | 5.13 |
| | 1.5 | 7.89 | 9.08 | | 5.00 | | 7.77 | 9.52 | | 5.12 |
| | 2.0 | 4.41 | 3.94 | | 4.95 | 0.31 | 5.94 | 4.58 | | 4.96 |
| | 2.5 | 1.8 | 1.74 | 2.46 | 4.93 | | 4.98 | 1.7 | | 4.86 |
| | 3.0 | 1.61 | 0.42 | | | | 4.24 | 0.66 | | 4.95 |
| | 3.5 | | | | | 0.29 | 1.79 | 0.5 | 3.11 | |
| | 4.0 | | | | | | 1.3 | 0.23 | | |
| | 4.5 | | | | | | 0.17 | 0.04 | | |
| | | | | | | | | | | |
| DO (%) | 0.0 | 80.8 | 99.3 | | 41.5 | | 80.8 | 97.7 | | 42.5 |
| | 0.5 | 80.8 | 98.8 | | 41.7 | | 77.9 | 95.6 | | 42.4 |
| | 1.0 | 81.2 | 101.8 | | 41.2 | | 77.4 | 101.9 | | 42.3 |
| | 1.5 | 77.7 | 89.1 | | 41.1 | | 76.7 | 93.5 | | 42.2 |
| | 2.0 | 41.9 | 36.5 | | 40.9 | | 57.4 | 42.2 | | 40.8 |
| | 2.5 | 16.2 | 15.3 | 25.1 | 40.6 | | 45.5 | 15 | | 39.8 |
| | 3.0 | 14.1 | 3.7 | | | | 37.3 | 5.8 | | 40.8 |
| | 3.5 | | | | | | 15.4 | 4.3 | 30.9 | |
| | 4.0 | | | | | | 11.2 | 1.9 | | |
| | 4.5 | | | | | | 1.4 | 0.4 | | |

**Table 7** ABR-INTERPHASE 3 and 4 2011 profile results

| Parameter | Depth (m) | ABR 3 (N) | | | | ABR 4 (E) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 14-Jun-10 | 08-Jun-11 | 05-Jul-11 | 02-Aug-11 | 14-Jun-10 | 08-Jun-11 | 05-Jul-11 | 02-Aug-11 |
| **pH** | 0.0 | 6.39 | 9.21 | 8.81 | | 6.4 | 8.3 | 8.84 | |
| | 0.5 | | 8.75 | 8.83 | | | 8.28 | 8.85 | |
| | 1.0 | | 8.65 | 8.85 | | | 8.28 | 8.87 | |
| | 1.5 | | 8.56 | 8.76 | | | 8.26 | 8.81 | |
| | 2.0 | 6.05 | 8.36 | 8.19 | | 5.7 | 8.11 | 8.1 | |
| | 2.5 | | 8.13 | | | | 8.1 | 8.12 | 7.54 |
| | 3.0 | | | | | | | | |
| | 3.5 | 5.8 | | | 7.71 | 5 | | | |
| | 4.0 | | | | | | | | |
| | 4.5 | | | | | | | | |
| | | | | | | | | | |
| **Conductivity** | 0.0 | 196.6 | 768 | 829 | | 195.9 | 750 | 835 | |
| **(uS/cm)** | 0.5 | | 765 | 830 | | | 749 | 835 | |
| | 1.0 | | 763 | 824 | | | 749 | 825 | |
| | 1.5 | | 759 | 810 | | | 748 | 815 | |
| | 2.0 | 196.6 | 749 | 778 | | 198 | 717 | 770 | |
| | 2.5 | | 708 | | | | 693 | 738 | 515 |
| | 3.0 | | | | | | | | |
| | 3.5 | 196.4 | | | 515 | 196.9 | | | |
| | 4.0 | | | | | | | | |
| | 4.5 | | | | | | | | |
| | | | | | | | | | |
| **Temperature** | 0.0 | 15.96 | 14.7 | 15.7 | | 15.71 | 14.9 | 15.6 | |
| **(°C)** | 0.5 | | 14.6 | 15.7 | | | 14.7 | 15.6 | |
| | 1.0 | | 14.6 | 15.2 | | | 14.6 | 15.5 | |
| | 1.5 | | 14.6 | 14.1 | | | 14.5 | 14.1 | |
| | 2.0 | 9.22 | 13.1 | 11.7 | | 12.88 | 11.9 | 11.2 | |
| | 2.5 | | | | | | 10.3 | 9.5 | 16.1 |
| | 3.0 | | | | | | | | |
| | 3.5 | 8.98 | | | 16 | 7.7 | | | |
| | 4.0 | | | | | | | | |
| | 4.5 | | | | | | | | |
| | | | | | | | | | |
| **Redox (mV)** | 0.0 | 9.4 | | -25 | | 340 | | -22.5 | |
| | 0.5 | | | -23.3 | | | | -21.5 | |
| | 1.0 | | | -22.3 | | | | -21.1 | |
| | 1.5 | | | -21.7 | | | | -21.3 | |
| | 2.0 | -222 | | -22 | | -145 | | -22.7 | |
| | 2.5 | | | | | | | -24.4 | -26.1 |
| | 3.0 | | | | | | | | |
| | 3.5 | -235 | | | -27 | -195 | | | |
| | 4.0 | | | | | | | | |
| | 4.5 | | | | | | | | |
| | | | | | | | | | |
| **DO (mg/L)** | 0.0 | 1.2 | | 9.89 | | 1 | 7.73 | 9.7 | |
| | 0.5 | | | 9.85 | | | 7.71 | 9.43 | |
| | 1.0 | | | 10.1 | | | 7.71 | 10.13 | |
| | 1.5 | | | 8.82 | | | 7.06 | 8.62 | |
| | 2.0 | 0.9 | | 3.17 | | 0.66 | 4.36 | 2.51 | |
| | 2.5 | | | | | | 3.94 | 2.16 | 3.72 |
| | 3.0 | | | | | | | | |
| | 3.5 | 0.8 | | | 3.39 | 1 | | | |
| | 4.0 | | | | | | | | |
| | 4.5 | | | | | | | | |
| | | | | | | | | | |
| **DO (%)** | 0.0 | | | 99.7 | | | 76.6 | 97.9 | |
| | 0.5 | | | 98.7 | | | 76.4 | 95 | |
| | 1.0 | | | 100.8 | | | 76 | 100.6 | |
| | 1.5 | | | 86 | | | 69 | 83.9 | |
| | 2.0 | | | 29.63 | | | 40.6 | 22.9 | |
| | 2.5 | | | | | | 35.3 | 18.9 | 37.9 |
| | 3.0 | | | | | | | | |
| | 3.5 | | | | 34.4 | | | | |
| | 4.0 | | | | | | | | |
| | 4.5 | | | | | | | | |