

August 7, 2006

Project E050451

Mr. Michael L. Sykes  
West Virginia Conservation Agency  
HC 63 Box 535  
Romney, West Virginia 26757

**Re: Bench Scale Testing Report  
Richard Mine Drainage (RM-MON-1)**

Dear Mr. Sykes:

GAI Consultants, Inc. (GAI) appreciates the opportunity to submit this bench scale testing report for the Richard Mine Drainage Project. This report summarizes the procedures utilized to collect and analyze the AMD discharge at the Site.

The following are included as part of this letter report:

- Two tables with bench scale results
- Photographs of bench scale testing
- Laboratory results of the Richard Mine discharge

Five copies of this letter report have been forwarded to Mr. T.J. Burr of the NRCS.

The purpose of the Project is to determine the type and extent of treatment necessary to restore the Deckers Creek reach downstream of the Site to a warmwater fishery. A cursory examination of the habitat afforded by the stream indicates the benthic community is nonexistent due to gross deposition of predominantly iron with staining from aluminum and manganese. Historic chemical analysis of the discharge from the Richard Mine confirms that iron concentrations dominate the character of the drainage, and that aluminum is also present in concentrations that limit aquatic life. Manganese concentrations are likely not limiting aquatic life at present, and if iron and aluminum and associated mineral acidity were eliminated, would likely not be a threat to restoration of this reach of Deckers Creek. The limits to which these two contaminants must be brought is unknown, without detailed eco-risk assessment and hazard quotient calculations, but the success of neutralization of acidity and removal of iron (and concomitant removal of aluminum) by pH elevation (to at least neutral range) has been sufficient for the recovery of many acid mine drainage polluted reaches and even entire watersheds. There may indeed be subtle acid sources or other contaminants further downstream of the Site, which may compromise the

intended water use (warm-water fishery). If the Richard Mine Drainage to Deckers Creek is indeed neutralized and iron concentration reduced to approximately 1.5 mg/l, then other sources of acidity, metals, or even industrial or fecal pollution, may limit the recolonization of aquatic life. In a very general assumption, neutralizing acidity and reduction of total iron to 1.5 mg/l is the very minimum effort which would possibly allow restoration of the watershed to this intended use. Indeed, where dilution of the Richard Mine Drainage by Deckers Creek would result in a total iron concentration of 1.5 mg/l, even more iron could be allowed from this point source. Realistically, since only limited sampling with limited flow volumes of both stream and mine discharge are available, dilution scenarios cannot be relied upon at all times of the year. **Therefore, the goal of the bench scale testing should be to determine the type and extent of treatment necessary to reduce total (hot) acidity to zero, and total iron to less than 1.5 mg/l.**

On June 15, 2006, GAI personnel visited the Site to obtain samples for analysis.

After collection of a sample from the 18-inch PE pipe in 5 five gallon cubitainers, the following were collected for laboratory analysis:

- Two 500 ml samples with no preservatives.
- Two 500 ml samples preserved with 1 ml of HNO<sub>3</sub>.
- Two 500 ml samples preserved with 1 ml of HNO<sub>3</sub> after field filtering with a peristaltic pump and a GeoTech high capacity low pH 0.045 micron filter. Tygon tubing and filter were dedicated to this sample and duplicate. The sample was drawn from cubitainer 1/5.
- A 100 ml sample preserved with 1 ml of H<sub>2</sub>SO<sub>4</sub>.

The cubitainers were then purged of air and placed on ice in coolers for transport.

The following field measurements were obtained for the four drainages associated with the Site. The flow for the cumulative discharge was measured at the concrete culvert under the roadway approximately halfway to Deckers Creek (denoted #5).

Sample	pH	pH w/ H <sub>2</sub> O <sub>2</sub>	T°(C)	s.c. (µmho)	ORP (mV)	DO (mg/l)	Flow (gpm)	Description
1	4.06	3.25	13.6	1855	247	0	377.3 (pipe flow)	18" PE pipe
2	3.47	3.44	11.7	663	403	Ns	7.5 (estimated)	Portal
3	3.56	3.34	14.9	1333	364	Ns	1.8 (500 ml/4.5s)	Upper 12" pipe
4	3.59	3.35	15.4	1408	362	Ns	0.5 (500 ml/15s)	Lower 12" pipe
5							390.3 (pipe flow)	42" concrete pipe

The field pH, temperature and conductance was determined with an Oakton pH/Con 10.  
The field DO was determined with a Hach OX-2P (modified Winkler chemical kit).  
The field ORP was determined with a Hach ORP pen.

The field pH was then measured after addition of 10% by volume 3% hydrogen peroxide solution. Three of the samples did not exhibit substantial pH change with oxygenation.

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Only the #1 sample had dramatic pH depression, indicating that iron was in the ferrous state in Sample #1, and ferric state in the balance of the drainage. It appears that #2 was completely oxygenated from the iron deposits and low flow, and the two smaller pipes were nearly fully oxygenated given the low flow.

Flow at #1 was measured by determining precise uncompromised pipe diameter, water depth, and velocity at 60% depth using the Marsh-McBirney Flow-Mate 2000 (Diameter = 1.45, depth of flow = 0.28, velocity = 3.76 fps). Flow was estimated at #2 given its laminar low flow. Flow at #3 and #4 was measured by graduated vessel and stopwatch. Flow at #5 was measured by determining precise uncompromised pipe diameter, water depth, and velocity at 60% depth using the Marsh-McBirney Flow-Mate 2000 (Diameter = 3.5, depth of flow = 0.21, velocity = 3.69 fps). The flows measured and calculated are reasonable in that the sum of the individual flows (387.1 gpm) approaches the measured flow at the cumulative flow (390.3 gpm) for an error of one percent.

Bench Titration commenced on June 26, 2006 at the REIC Laboratories in Beaver, West Virginia. The analyses were conducted by Mr. Ben Faulkner of Bratton Farm with Messrs. Claude Scott, Ivan Leef, and Jason Clark of REIC Laboratories.

Cubitainer 1 was brought to the general chemistry suite and examined. Photo 1 indicates a shallow iron precipitate in the bottom of the cubitainer. Analytical result of the separate sample grabbed at the time of collection of the cubitainers was 179 mg/l total iron. Cubitainer 2 was analyzed before being allowed to warm in the laboratory and the dissolved iron was measured to be 90.6 mg/l. This indicates that iron readily precipitates irrespective of oxidation. This loss of iron was expected and unavoidable in transporting the unpreserved cubitainer sample to the laboratory. (This exercise reinforces the need for preserving the total metals and filtered dissolved metals samples to prevent precipitation).

This dissolved iron concentration of 90.6 mg/l will be the starting point for titration of the sample to remove iron. Typically, dissolved iron is used for bench titrations as it indicates the percentage of iron that has oxidized from ferrous to ferric iron without further settling. It also eliminates from consideration the portion of iron that is suspended and will eventually settle, given temperature, agitation, and detention time variables.

Three titrations of water from cubitainer 1 were performed utilizing the three predominant neutralizers used at modern acid mine drainage chemical treatment plants.

For each titration, four 1000 ml beakers were set up on magnetic stirring apparatus. 1000 ml of unpreserved sample were measured with graduated cylinder into each beaker and moderate stirring initiated at 9:42 for the first trial, caustic soda or 20% sodium hydroxide. The calibrated bench pH meter was used to measure each pH and the elapsed time of stirring (aeration). Beaker A served as the vessel to achieve a target pH of 5.0. Stirring of all four beakers was initiated simultaneously. This provided insight as to the stability of the solution and whether additional aeration would provide oxidation of iron and concomitant depression of pH. By comparing the initial pH of beaker A (3.15) with the pH of beaker D after 26 minutes of aeration (3.24), it is clear that additional aeration of the mine water did not depress pH. This trend was verified by subsequent aeration exercises when ammonia and calcium oxide agents were used. In each of these cases, pH values did not substantially decrease with the addition of oxygen in the form of moderate stirring for up to 55 minutes. This laboratory exercise likely exceeds the extent of agitation and oxidation that could be accomplished in a modern AMD treatment plant.

Addition of chemical oxidants such as hydrogen peroxide or sodium hypochlorite might accomplish this, but both reagents are quite expensive, and are typically added in a modern plant only when limited contact time necessitates their use. Similarly, the use of chemical flocculants was not evaluated in this exercise. This is very difficult to do in a bench scale test, as the ambient temperature of mine water in the laboratory seldom approaches that in the field, and these physical reactions with chemical polymer bonds are often temperature and agitation dependent. Measuring the addition of very minute concentration of chemical flocculants is very difficult under bench scale conditions. The goal was to maintain near target pH at a minimum of 60 seconds, or the approximate residence time in a rapid mix tank of a modern AMD treatment plant. The beaker was then allowed to aerate and pH was recorded after several minutes before a 10ml sample was withdrawn from the sample and analyzed for dissolved metals. After all beakers were titrated to a steady pH near the target pH, and sampled, the beakers were poured into Imhoff cones to measure precipitation rates and volumes. These data are presented in Tables 1 and 2 for each neutralizer. Photographs of the apparatus, including Imhoff cones to measure settleable solids (or precipitate volume) are attached.

Beakers B, C and D were used to achieve approximate pH values of 5.5, 6.0, and 6.5, respectively. Once the first titration (with caustic) was accomplished, analytical results of dissolved metals (with ICP apparatus) were made available, indicating that iron was not being removed from this particular mine water to single digit concentrations until above pH 7.0. Therefore, another beaker (E) was prepared to titrate to this pH. For quality assurance, addition of neutralizer was replicated on the subsequent beaker. For example, the addition of 1.51 ml of caustic was necessary to elevate the pH of beaker A (target of pH 5.0) to pH 5.12. After measuring the initial pH of beaker B, and noting the aeration time, this same volume of caustic was added to beaker B and the pH recorded (pH 5.16)

which provided good assurance of method by replication. In a similar manner, each subsequent beaker was measured, and then brought up to the pH of its predecessor and pH noted before increasing the volume (or weight in the case of calcium oxide) of neutralizer.

Having rapid access to precise laboratory analysis provided information that allowed for reduced titration and sampling effort. For example, it was clear that pH 7.0 would have to be reached or exceeded to obtain iron concentrations approaching the target of 1.5 mg/l. Similarly, the resolubilization of aluminum was indicated in beaker E (pH 7.0) where more aluminum (0.107 mg/l) was present than in the previous beaker trial (beaker D with pH 6.24 and dissolved aluminum of 0.072 mg/l). It was clear this was the titration endpoint for neutralization and optimal metal removal before oxidation.

Calcium oxide is usually the clean winner for many chemical treatment plants as this reagent generally produces desirable metal precipitates and tight flocculants in a reasonable time period. The Richard Mine discharge proved to be no exception as chemical grade calcium oxide was used to elevate pH. It also became clear that the mine drainage responded reliably to pH 6.50 to 6.56 based on the replication of beakers C and D with 0.40 grams of reagent per 1000 ml of mine water. With the addition of only 0.05 g of additional reagent to beaker D, the pH jumped to a sustained pH of 7.84 and resultant dissolved iron concentrations of less than 1 mg/l (0.158 mg/l). Within three hours of settling time, the green flocculant (ferrous iron) had converted to red (ferric) iron and had decreased in volume by nearly 50%. This is remarkable when compared to similar volumes of floc of the same age for solutions of lesser pH where there was much less metal removal. Flocculant volume in the laboratory is an indication at best and cannot be used to provide reliable estimates of actual volumes of precipitates in the field. There are just too many variables and dissimilarities between the physical conditions in the laboratory and field trials. These Imhoff cones do provide some indication of time of settling and a means of comparison of volumes between the three neutralizers. For example, beaker D (pH 7.84) with calcium oxide exhibited 170 ml of solids after three hours, compared to 240 ml of solids in beaker E (caustic soda titrated to pH 7.12) after 3 hours. This is the same volume of precipitate after 3 hours of beaker E for ammonia but 8 mg/l total iron remained in this solution. Calcium Oxide is clearly superior for pH adjustment and sludge formation.

Clearly, the addition of approximately 0.45 g of calcium oxide to 1000 ml of mine water resulted in a product that would be neutralized, stable, and nearly iron free after a reasonable retention time. Retention time is a critical consideration for the Site, as level land for retention ponds is at a premium at the Site. Piping the drainage to a site downstream where a calcium oxide plant could be erected and maintained along with approximately 3 hours retention time (absolute minimum of 63,000 gallons of volume available before cleanout) is indicated.

The data presented herein provides the necessary means to compute the "treatability" of the discharge during subsequent phases of the Project. The information obtained during the bench scale test can be utilized to calculate costs for the various active treatment methods discussed in the Phase I Evaluation of AMD Problem Report (found under separate cover). In addition, the amount of sludge generation can be calculated.

GAI appreciates the opportunity to submit this report and looks forward to discussing it during our August 24<sup>th</sup> meeting.

Respectfully submitted,  
GAI Consultants, Inc.

Bryce D. Good, P.E.  
Project Manager

BDG/ejb

Attachments