



June 8, 2005

Ms. Cheryl Woodall  
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10600 N.E. 51st Circle  
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**SUBJECT: TRANSMITTAL – AZURITE TAILINGS REPROCESSING REPORT**

Dear Cheryl:

Attached please find one (1) copy of the report “Azurite Mine Tailings Reprocessing Testwork” by James A. Bradbury, P.E., Chief Metallurgist, N.A. Degerstrom Laboratories (Degerstrom), Spokane, Washington. The following provides a brief summary of the results, discussion and conclusions.

This testwork examines the technical viability of removing acid producing sulfide minerals from the Azurite Mine tailings as an alternative remedial method to conventional encapsulation. Cascade Earth Sciences (CES) elected to test both gravity and flotation separation methods on the tailings. Bench testing was completed by Degerstrom. CES obtained three representative tailings samples with a volume of 5 gallons each at testpit locations TP2, TP13, and TP19 (See Figure 1). CES assumed that the oxidized tailings surface would not contain sulfide minerals, and this portion was excluded from testwork. The samples were reduced to original particle size by drying and utilizing a ring pulverizer. Each was then separated into two split samples by riffle splitter. One split sample was processed by gravity methods in a Knellson concentrator; the other was processed by bench flotation. Tailings from each method were analyzed for paste pH, arsenic cadmium, copper, iron, lead, selenium, zinc, sulfur forms, and acid-based accounting (ABA).

**RESULTS**

Detailed process results are provided in the attached report, and reprocessed tailings analyses are provided in Tables 1 and 2. Results of tailings analyses are summarized as follows:

- Sulfide Recovery and Efficiency – Only about 40% of the sulfides were removed from the tailings; gravity recovery was actually more efficient than flotation. This was unexpected and very unusual.
- Base Metal Recovery – Although over half of the sulfide minerals were attached to the reprocessed floatation tailings, all base metals sulfides were attached to the flotation concentrates.
- Tailings Quality – The reprocessed tailings, both gravity and flotation, exceeded most Human Health and Ecological criteria for arsenic, copper, iron, lead, selenium, and zinc (See Table 1).
  - Paste pH ranged from 4.3 to 5.9 su in gravity tailings; 5.2 to 6.8 su in flotation tailings.
  - Arsenic ranged from 435 to 860 milligrams per kilogram (mg/kg) in gravity tailings; 141 to 575 mg/kg in flotation tailings.
  - Cadmium ranged from 0.7 to 1.6 mg/kg in gravity tailings; 0.2 to 0.5 mg/kg in flotation tailings.

- Copper ranged from 1,120 to 1,210 mg/kg in gravity tailings; 103 to 153 mg/kg in flotation tailings.
- Iron ranged from 145,000 to 151,000 mg/kg in gravity tailings; 141 to 575 mg/kg in flotation tailings.
- Lead ranged from 295 to 350 mg/kg in gravity tailings; 195 to 206 mg/kg in flotation tailings.
- Selenium ranged from <2 to 3 mg/kg in gravity tailings; 1 to 4 mg/kg in flotation tailings.
- Zinc ranged from 129 to 200 mg/kg in gravity tailings; 59 to 114 mg/kg in flotation tailings.
- Total sulfur ranged from 4.58 to 6.23 % in gravity tailings; 6.95 to 8.05 % in flotation tailings.
- Acid base potential (ABP) ranged from -134 to -163 t CaCO<sub>3</sub>/Kt in gravity tailings; -193 to -197 t CaCO<sub>3</sub>/Kt in flotation tailings, a consequence of low sulfide recovery.
- No samples exceeded RCRA criteria following toxicity characterization leaching procedure (TCLP) or synthetic precipitation leaching procedure (SPLP) test procedures (See Table 2).

## **DISCUSSION**

The cause for poor sulfide mineral separation probably lies in the unusual treatment process used to fixate cyanide prior to disposal. Cyanide is an extremely effective pyrite depressant during flotation. Normally, residue cyanide degrades rapidly as tailings acidify through natural oxidation, and pyrite is not depressed during re-processing. At the Azurite Mill, it appears that operators added ferrous sulfite to fixate cyanide for health and safety purposes. Ferrous iron rapidly oxidizes to ferric iron, which then precipitates insoluble and relatively non-degradable ferri-cyanate/cyanide minerals. This precipitate appears to have remained in the tailings and acts as a pyrite depressant that inhibits flotation. Analyses of tailings prior to reprocessing (Site Inspection, CES 2005) illustrates up to 3.5 mg/kg weak acid dissociable (WAD) cyanide residue, which further verifies cyanide availability for depression.

To test this hypothesis, a small split of tailings was subjected to strong-acid leaching at a pH of 1.5 to dissolve ferri-cyanate/cyanides and degrade cyanide/cyanate through volatilization. This was followed by lime addition to raise the pH to 7, and the slurry was then subjected to non-selective flotation. Pyrite recovery using this procedure was nearly complete, indicating that the depression problem can be overcome. Additional testing is necessary to optimize re-processing. A literature search illustrated that this problem had been encountered in Africa during “re-mining” of old gold tailings for profit. The solution was to leach the tailings in pH 3 acid for several hours prior to flotation.

## **SUMMARY AND CONCLUSIONS**

This reprocessing testwork was not intended to compare costs of reprocessing with other closure methods. The intention was only to determine if the tailings are amenable to simple, nonselective bulk sulfide flotation or gravity separation methods. The initial flotation tests yield poor recovery. We believed that the trace amounts of cyanide fixated by addition of ferrous sulfite were depressing pyrite. The tailings were treated with acid to dissolve and volatilize the metalocyanide minerals. Following this step, flotation was greatly enhanced and sulfide mineral recoveries were excellent.

Since bench testing has been completed and it is clear that sulfide minerals can be removed, it will now be a minimum cost addition to the Engineering Evaluation / Cost Analysis (EE/CA) to compare this approach to alternative closure methods. Because we have no data relative to tailings quality after acid leach-flotation reprocessing, numerous assumptions must be made. Results of evaluating this alternative in the EE/CA must be tempered with the understanding that additional testwork is necessary.

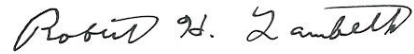
If you have any questions, please do not hesitate to contact us at (509) 921-0290. We look forward to continue representing the USFS with the AML program.

Respectfully Submitted,  
**CASCADE EARTH SCIENCES**



Dustin G. Wasley, PE  
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Att: Figure 1. Azurite Mine Layout and Sampling Locations  
Table 1. Gravity and Flotation Analytical Results for Re-Processed Tailings  
Table 2. TCLP and SPLP Analytical Results for Re-Processed Tailings  
Azurite Mine Tailings Reprocessing Testwork

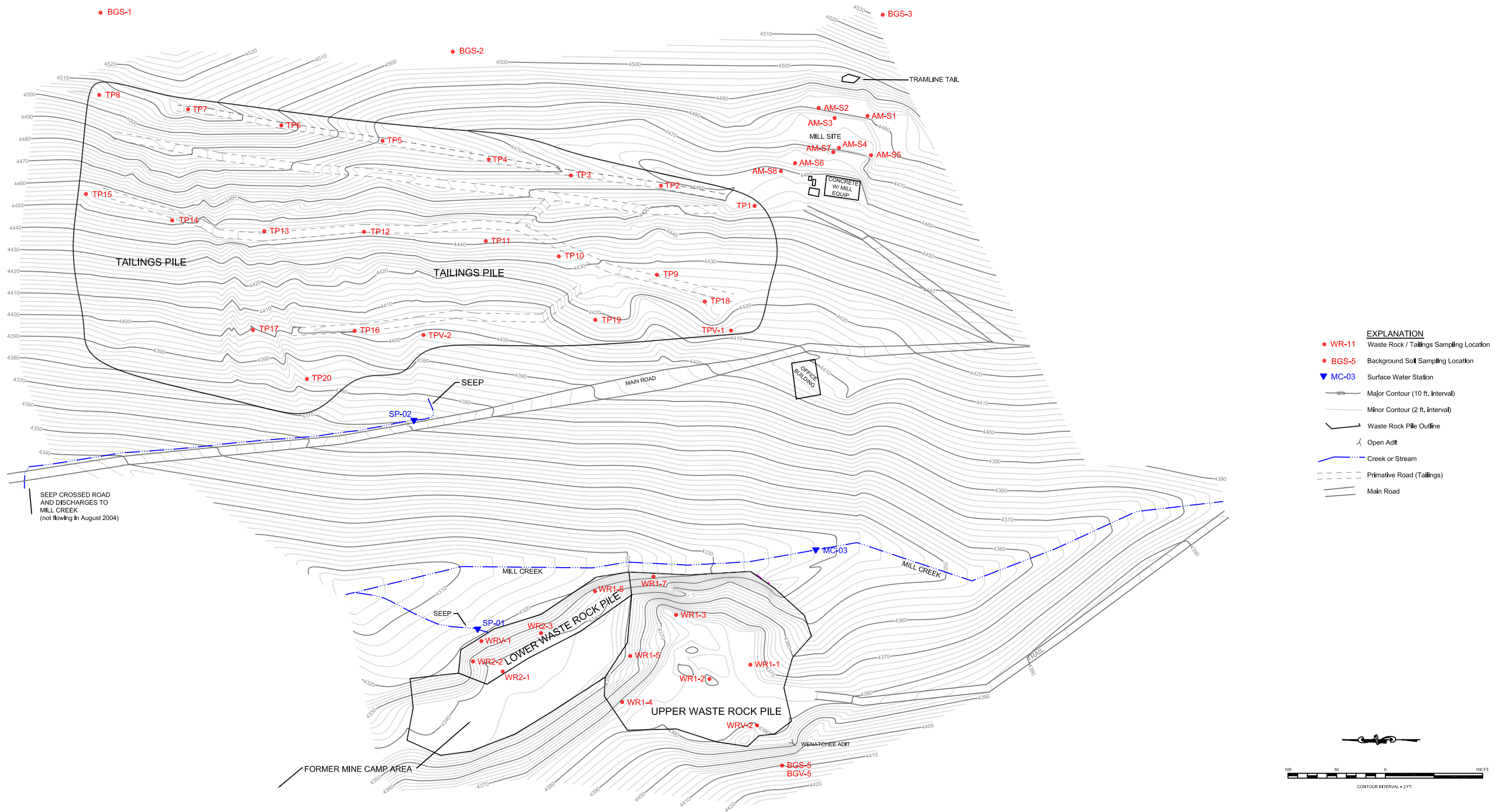


Figure 1. Azurite Mine Layout and Sampling Locations

PROJECT NUMBER: 2423008	<b>AZURITE MINE</b> <b>SITE INSPECTION</b> USDA FOREST SERVICE OKANOGAN NATIONAL FOREST HARTS PASS, WASHINGTON <b>CES</b> CASCADE EARTH SCIENCES A Valmont Industries Company
DATE: 02/07/05	
CONTRACT NUMBER: 2423008P2.dwg	
PROJECT MANAGER: 6DWG	
REVISION:	

**Table 1. Gravity and Flotation Analytical Results for Re-Processed Tailings  
Azurite Mine Site Inspection, Mt. Baker-Snoqualmie National Forest, Washington**

Sample ID	Sample Date	Sample Depth (feet)	Solids % CLPSOW390, PART F, D-98	Paste pH USDA No. 60 (21A) su	Arsenic, Total M6020	Cadmium, Total M6020	Copper, Total M6020	Iron, Total M6020	Lead, Total M6020	Selenium, Total M6020	Zinc, Total M6020	Sulfur Forms M600/2-78-054 3.2.4			ABAs M600/2-78-054 1.3		
												Total Sulfur ASTM D-4239-85C	Pyritic Sulfur Calculated	Sulfate Sulfur	Acid Generation Potential	Acid Neutralization Potential	Acid-Base Potential
												%			t CaCO <sub>3</sub> /Kt		
<b>Gravity Tailings:</b>																	
AM-TP5-2-GT	9/20/2004	1.1 - 9.8	99.6	5.7	751	1.6	1,120	151,000	350	< 2	193	5.57	4.44	1.13	174	23	-151
AM-TP13-2-GT	9/22/2004	0.5 - 8.0	99.3	4.3	860	1	1,130	145,000	350	< 5	200	4.58	3.20	1.38	143	9	-134
AM-TP19-2-GT	9/21/2004	1.2 - 7.6	99.5	5.9	435	0.7	1,210	151,000	295	3 B	129	6.23	5.40	0.83	195	32	-163
<b>Mean</b>			99.5	5.3	682	1.1	1,153	149,000	332	2.2	174	5.5	4.3	1.1	171	21.3	-149
<b>Flotation Tailings:</b>																	
AM-TP5-2-FT	9/23/2004	1.1 - 9.8	99.7	5.8	460	0.5	147	163,000	195	3 B	87	7.43	6.53	0.9	232	35	-197
AM-TP13-2-FT	10/6/2004	0.5 - 8.0	99.8	5.2	575	0.4 B	153	165,000	206	4 B	114	6.95	5.89	1.06	217	24	-193
AM-TP19-2-FT	10/5/2004	1.2 - 7.6	99.6	6.8	141	0.2 B	103	167,000	203	1 B	59	8.05	7.49	0.56	252	55	-197
<b>Mean</b>			99.7	5.9	392	0.4	134	165,000	201	1.5	87	7.5	6.6	0.8	234	38.0	-196
<b>Standards</b>																	
WA - Method A Indust. Soil Cleanup Levels - Human Receptors <sup>1</sup>				2-12.5	20	2	NS	NS	1,000	NS	NS	NS	NS	NS	NS	NS	NS
WA - Ecological Receptors (p=plant, b=soil biota, w=wildlife) <sup>2</sup>				NS	NS	4 p	50 b	NS	50 p	0.3 w	86 p	NS	NS	NS	NS	NS	NS
EPA Indust. PRGs - Human Receptors <sup>3</sup>				NS	1.6	450	41,000	100,000	800	5,100	100,000	NS	NS	NS	NS	NS	NS
EPA - Ecological Receptors (m=mammal, b=bird, i=invertebrate, p=plant) <sup>4</sup>				NS	37 p	29 p	61 i	NS	NS	NS	120 i	NS	NS	NS	NS	NS	NS
ORNL - Ecological Receptors <sup>5</sup>				NS	9.9	4	60	NS	40.5	0.21	8.5	NS	NS	NS	NS	NS	NS

**STANDARD NOTES:**

- 1 = Washington Department of Ecology MTCA (WAC 173-340) Industrial criteria, Table 745-1 (Ecology, 2001).
  - 2 = Washington Department of Ecology MTCA (WAC 173-340) Industrial criteria, Table 749-3 (Ecology, 2001).
  - 3 - EPA Region 9 Industrial Preliminary Remediation Goals - (EPA, 2002).
  - 4 - EPA Ecological Soil Screening Levels - Lowest Criteria Listed (EPA, 2000)
  - 5 - ORNL = Oak Ridge National Laboratory Preliminary Remediation Goals for Ecological Endpoints August 1997
- NS = No standard  
Paste pH criteria is a Dangerous Waste/RCRA Hazardous Waste designation

**GENERAL NOTES:**

All analysis was conducted by ACZ Laboratories, Inc., Steamboat Springs, CO following digestion by M3050B  
Sulfur, Pyritic was calculated from the difference between Sulfur, Total and Sulfur, Sulfate  
mg/kg = Milligrams per kilogram  
su = Standard Units  
< value = Analyte not detected above indicated Method Detection Limit (MDL).  
B = Analyte detected between MDL and Practical Quantification Limit (PQL).  
Bolded values indicate that the value exceeds one or more standard; corresponding criteria also bolded.  
Mean values calculated using one half the MDL if results were below the MDL.  
t CaCO<sub>3</sub>/Kt = tons of calcium carbonate needed to neutralize 1000 tons of waste/soil. Negative number indicates lack of CaCO<sub>3</sub>, positive value indicates excess (no need).  
Mean values calculated using one half the MDL if results were below the MDL.

**Table 2. Toxicity Characteristics Leaching Procedure (M1311, TCLP) & Synthetic Precipitation Leaching Procedure (M1312, SPLP) Results for Re-Processed Tailings  
Azurite Mine Site Inspection, Mt. Baker-Snoqualmie National Forest, Washington**

Sample ID	Sample Date	Sample Depth (feet)	Arsenic, TCLP M6010B	Arsenic, SPLP M6010B	Barium, TCLP M6010B	Barium, SPLP M6010B	Cadmium, TCLP M6010B	Cadmium, SPLP M6010B	Chromium, TCLP M6010B	Chromium, SPLP M6010B	Lead, TCLP M6010B	Lead, SPLP M6010B	Mercury, TCLP M7470	Mercury, SPLP M7470	Selenium, TCLP M6010B	Selenium, SPLP M6010B	Silver, TCLP M6010B	Silver, SPLP M6010B
mg/L																		
<b>Gravity Tailings:</b>																		
AM-TP5-2-GT	9/20/2004	1.1 - 9.8	< 0.04	< 0.04	0.149	0.031	< 0.005	< 0.005	< 0.01	< 0.01	0.08 B	< 0.04	< 0.0002	< 0.0002	< 0.04	< 0.04	< 0.005	< 0.005
AM-TP13-2-GT	9/22/2004	0.5 - 8.0	< 0.04	< 0.2	0.047	0.03 B	< 0.005	< 0.03	< 0.01	< 0.05	0.33	0.4 B	< 0.0002	< 0.0002	< 0.04	< 0.2	< 0.005	< 0.03
AM-TP19-2-GT	9/21/2004	1.2 - 7.6	< 0.04	< 0.04	0.139	0.028	< 0.005	< 0.005	< 0.01	< 0.01	0.04 B	< 0.04	< 0.0002	< 0.0002	< 0.04	< 0.04	< 0.005	< 0.005
<b>Flotation Tailings</b>																		
AM-TP5-2-FT	9/23/2004	1.1 - 9.8	< 0.04	< 0.04	0.064	0.024	< 0.005	< 0.005	< 0.01	< 0.01	< 0.04	< 0.04	< 0.0002	< 0.0002	< 0.04	< 0.04	< 0.005	< 0.005
AM-TP13-2-FT	10/6/2004	0.5 - 8.0	0.04 B	< 0.04	0.053	0.02	< 0.005	< 0.005	< 0.01	< 0.01	0.18 B	< 0.04	< 0.0002	< 0.0002	< 0.04	< 0.04	< 0.005	< 0.005
AM-TP19-2-FT	10/5/2004	1.2 - 7.6	< 0.04	< 0.04	0.082	0.021	< 0.005	< 0.005	< 0.01	< 0.01	< 0.04	< 0.04	< 0.0002	< 0.0002	< 0.04	< 0.04	< 0.005	< 0.005
<b>Applicable Standards</b>																		
RCRA TCLP Disposal Limits			5		100		1		5		5		0.2		1		5	

**GENERAL NOTES:**

Analysis was conducted by ACZ Laboratories, Inc., Steamboat Springs, CO

mg/L = Milligrams per liter

< value = Analyte not detected above Method Detection Limit (MDL)

B = Analyte detected between MDL and Practical Quantification Limit (PQL)