Manganese Resource Recovery Final Technical Report

DEP File No. OSM PA (AMD-04)

Stream Restoration Inc. and BioMost, Inc.

June 2008

MANGANESE RESOURCE RECOVERY

FINAL REPORT

Brief Description of Project Work through Grant and Partnership Contributions

- Conducted influent and effluent pre-recovery water monitoring of 4 Horizontal Flow Limestone Beds (HFLBs) located within the Slippery Rock Creek Watershed;
- Compiled all available influent and effluent water monitoring of the 4 HFLBs to evaluate treatment efficiency and to estimate the quantity of manganese-bearing material potentially available for recovery;
- Researched available technologies to evaluate potential methods of resource recovery;
- Conducted bench-scale tests to assist with development of a recovery method;
- Developed a method for the recovery of manganese-bearing material from a limestone (aggregate) bed (Patent-Pending Application # US61/137,556);
- Conducted full-scale recovery of the manganese-bearing material from the De Sale Phase 2 passive treatment system (online continuously since 9/2000), Venango Twp., Butler Co.; an estimated 30 tons (as-recovered) was removed from the site;
- Conducted bench-scale and then full-scale post-recovery processing of a portion of the recovered manganese-bearing material;
- Conducted post-recovery water monitoring of influent and effluent of the De Sale Phase 2 HFLB to determine the impact of the recovery effort on the HFLB functionality;
- Submitted numerous samples of recovered material for laboratory analyses, including sieve analysis (particle-size distribution), X-ray diffraction (mineral identification), X-ray fluorescence and ICP (major oxides - bulk chemical analyses), and elemental analyses;
- Compiled laboratory analyses of recovered material for characterization;
- Conducted and compiled preliminary market research to identify and to evaluate potential uses;
- Demonstrated use of recovered manganese as a colorant in ceramic glazes including the creation of numerous ceramic items (bowls, cups, mugs, plates, vases, etc.);
- Demonstrated use of recovered manganese as a colorant in ceramic tile;
- Demonstrated use of recovered manganese as a colorant in bricks and concrete;
- Created Clean Creek Products, as part of Stream Restoration Inc. (non-profit), to market recovered manganese and iron (low-pH) as raw materials as well as products made utilizing the materials with a portion of all proceeds to be returned to watershed groups;
- Created a variety of marketing materials including flyers, handouts, and a new website www.cleancreek.org to market recovered manganese and iron as raw materials as well as products made utilizing the materials;
- Participated in numerous public events to conduct education/outreach and marketing related to resource recovery;
- Provided information upon request to national/international and regional magazines & newsletters, local newspapers, online publications; co-authored article with PA DEP for US EPA publication; provided articles for local watershed newsletter;
- Presented a professional paper and power points at local/regional/national meetings/conferences concerning the recovery effort;
- Compiled photo log of project activities;
- Submitted electronic updates, status reports, and a final report; administered contract.

Funding Source: $205,957.00 grant from the PA Department of Environmental Protection Bureau of Abandoned Mine Reclamation

PUBLIC-PRIVATE PARTNERSHIP

Bench-Scale Testing; Resource Recovery Process Research & Development; Full-Scale Recovery Implementation; Water Monitoring; Marketing Research; Project Management
BioMost, Inc., 434 Spring Street Ext., Mars, PA 16046
DENHOLM, Clifford, Environmental Scientist; GROTE, Tom, Facilitator; DANEHY, Timothy, QEP; BUSLER, Shaun, GISP; DANEHY, Sylvia, Office Manager; DUNN, Margaret, PG (724) 776-0161

Landowner: De Sale Phase 2 Passive Treatment System
TERWILLIGER Family, 128 McJunkin Rd, Boyers, PA 16020

Development of Ceramic Glazes and Pottery Creations
Pottery Dome, 2347 Leesburg-Grove City Road, Mercer, PA 16137
ISENBERG, Robert, Ceramic Artist; HAMILTON, Lois, Owner (866) 570-5001

MEC-Clay Studios, Bratenahl Village Community Center
10300 Brighten Road, Bratenahl, OH 44108
ESCH, Pam; MORRISON, Carl; CLAGUE, Sarah, Ceramic Artists (216) 346-7006

Brick Manufacturing Experimentation
Redland Brick Inc. – Harmar Plant, 230 Rich Hill Road, Cheswick, PA 15217
MCINTYRE, Glen, 412-828-8046

Project Funding & Management
PA Dept. of Environmental Protection, Bureau of Abandoned Mine Reclamation
PO Box 8476, Harrisburg, PA 17105-8476
VARANO, Carol, PE, Grant Project Advisor (717) 783-1311

Grant Administration, Education/Outreach
Stream Restoration Inc. (non-profit), 434 Spring Street Ext., Mars, PA 16046
DENHOLM, Clifford, Environmental Scientist; GROTE, Tom, Facilitator; DANEHY, Timothy, QEP; BUSLER, Shaun, GISP; DANEHY, Sylvia, Office Manager; DUNN, Margaret, PG (724) 776-0161

In-Kind Contributions
- **Terwilliger Family** (donated use of property & permission for recovery effort)
- **Giberson Enterprises** New Jersey (reduced equipment rental rates)
- **Quality Aggregates Inc.** Boyers Quarry, PA (donated use of scalehouse)
- **Pottery Dome** (donated extra time & materials for test glazes)
- **MEC-Clay Studios** Ohio (donated additional time & materials for test glazes)
- **Redland Brick Inc**. - Harmer Plant (donated time & materials for test samples)
- **BioMost, Inc.** (donated additional time & resources for recovery effort & final report)
- **Stream Restoration Inc.** (donated additional time & resources in education/outreach)

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Marketing Materials

Clean Creek Products flyer *(2 pages)*
Clean Creek Products leaflet *(1/3 page)*
Clean Creek Products Manganese Oxide *(front)* Iron Oxide *(back)* Information Sheet
Clean Creek Products website *(selected printouts - 11 pages)*

Professional Publication

Denholm, C., T. Danehy, S. Busler, R. Dolence, M. Dunn, 2008, Sustainable Passive Treatment of Mine Drainage: Demonstration of Manganese Resource Recovery: *2008 proc.* ASMR, p. 285-297.
Power point presented at 2008 National Mtg. American Soc. of Mining & Reclamation (ASMR)
(CD with PowerPoint attached to back cover)

News Items

National, Regional, and Local Periodicals, Newspapers, Newsletters (Online & Printed)

"Make This Holiday Season A Bit More 'Green'", The Point North, 11/2008, cover/p. 18-19.
"Mine Drainage Sludge: Helping the environment?", Reclamation Matters, Iss. 2, 2008, cover/p. 24-27.
"Passive Systems Treat AMD While Allowing Recovery of Metal Oxides", *US EPA Technology News and Trends*, 07/2008, p.1-2. [Authors: Scott Roberts (PA DEP), M. Dunn (SRWC), C. Denholm (SRI)]
"Diss. Metal From Mine Drainage Used to Make Pottery by Cranberry Co.", *PA Env. Digest*, 5/9/08
"Company Discovers New Uses For Byproducts Of Acid Mine Drainage", *US EPA Envirobytes*, 5/2/08
"Lois Hamilton's dome of wonders", The Rock, Spring 2008, p. 32-33.
"Pottery Helping the Environment? Are you Kidding!?", The Point North, April 2008, p.18-19.
"Glazed With What Oozed", Sierra, March/April 2008, p. 8.
"Free Oxides", *Clay Art*, 3/29/08
"Resource Recovery With A Twist", *Abandoned Mine Posts*, 2/26/08
"Potter finds gold in stream slime", *The Herald*, 2/2/08
"Clean stream effort yields pottery glazes", *The Butler Eagle*, 2/4/08
"Perfect Pigment - Potters find stream residue quite colorful", *The Eagle*, 2/1/08
"River Comes Clean", Pittsburgh Quarterly, Fall 2007, p. 37.
"Passive Treatment Systems in Slippery Rock Watershed Yield Black Glaze", *PA Env. Digest*, 4/27/07

Slippery Rock Watershed Coalition (monthly newsletter)

"The Point North Magazine Points to the SRWC, Clean Creek Products", *The Catalyst*, July 2008
"Creativity Abounds at the NCECA Conf." & "Introducing Clean Creek Products", *The Catalyst*, 4/08
"Boscov's Green Day", *The Catalyst*, March 2008
"2007 Year in Review", *The Catalyst*, February 2008
"Manganese Recovery at De Sale Phase 2", *The Catalyst*, November 2007
"Black Glaze – Green Technology", *The Catalyst*, April 2007
"Manganese Recovery", *The Catalyst*, June 2006

Water Quality Data

De Sale 1: Raw *(PTS influent)*; WL *(HFLB influent)*; HFLB *(HFLB & PTS effluent)*
De Sale 2: Up *(raw PTS influent)*; Wetland *(HFLB influent)*; OUT/HFLB *(HFLB & PTS effluent)*
De Sale 3: DEP Raw *(raw PTS influent)*; SP2 *(HFLB influent)*; HFLB *(HFLB & PTS effluent)*
Erico: ST 63E *(raw PTS influent)*; WL2@PP2 *(HFLB influent)*; HFLB *(HFLB & PTS effluent)*

Manganese Data

RJ Lee – XRD, XRF, and Elemental Analyses
ACT Labs – XRF, Elemental, and XRD Analyses
Ferro CGPM Analytical Services Lab – Food Safety Testing

MANGANESE RESOURCE RECOVERY: FINAL REPORT

submitted to

PA Department of Environmental Protection
Bureau of Abandoned Mine Reclamation

EXECUTIVE SUMMARY

Stream Restoration Incorporated (SRI), a non-profit organization, received a grant from the Pennsylvania Department of Environmental Protection through the Bureau of Abandoned Mine Reclamation to expand work being conducted by SRI, the Slippery Rock Watershed Coalition, and BioMost, Inc. in the recovery of manganese-bearing material as an economic resource from passive mine drainage treatment components.

Selected major accomplishments of the multi-faceted project are briefly outlined below.

Successful development through bench tests, online research, and full-scale field demonstration of an effective "unique-but-practical" method that

(1) **optimizes treatment performance** by rehabilitating the passive component;

(2) **reuses limestone** eliminating need for removal/replacement of treatment medium;

(3) **decreases, by ~50+%, rehabilitation costs** for limestone-based components;

(4) **recovers manganese "ore"** defining a new "natural" resource created by natural processes using limestone and compost, which can be used to develop "green" products.

Successful recovery of manganese precipitates of

(1) **substantial quantity (~30 tons)** after 7 years of accumulation in the Horizontal Flow Limestone Bed (a passive treatment component) at the De Sale Phase 2 Restoration Site, Slippery Rock Creek Watershed, Venango Twp., Butler Co.;

(2) **acceptable quality**

a. **having 25% MnO, 22% SiO_2, 10% Al_2O_3, 4% Fe_2O_3, 11% CaO, 24% LOI** from generalized results of bulk chemical analysis (wt. %) on raw, as-recovered, material;

b. **containing less silver, arsenic, barium, bismuth, chromium, lead, etc. and more cobalt, nickel, yttrium, zinc, and zirconium than commercially-available manganese material** from generalized description of elemental analysis of 40 parameters on raw, as-recovered, material;

c. **with initial commercial processing indicating the ability to readily significantly decrease moisture content from ~20% to ~2% with subsequent increase in the weight percent of manganese-bearing material** based on preliminary, post-recovery, testing of bulk raw material by a commercial toll processing facility;

d. **with ceramic glazes being considered as safe for food use** with lead (below detection to 0.3 ppm) and cadmium (below detection) based on ceramic glaze leachability tests (ASTM C738-94) [US FDA action levels for similar ceramic items: 2 ppm lead; 0.5 ppm cadmium (US FDA CPG 711707 Sec. 545.450 & 545.400)];

Successful use of recovered manganese material as a colorant in ceramic glazes that

(1) **supports and helps to sustain local businesses** by providing income to a local potter through sale of hand-made items, to a local brew pub by increased patronage and with the sale of 300 mugs, and to a local highly-respected boutique by sale of unique, "green" pottery;

(2) **supports and helps to sustain a local watershed group** by donating a portion of all sales for watershed restoration activities, currently deposited into trust funds;

(3) **supports and expands the watershed stewardship concept** by allowing the general public to personally contribute to restoration activities through purchase of pottery items and to learn about the restoration efforts through interviews and articles requested by the Sierra Club and US EPA and through other local and regional magazines and online newsletters (~20 articles total);

(4) **supports continued development of "recycled" products and the development of new "natural" resources** by demonstrating to the general public that materials formerly considered as valueless have value;

(5) **supports the purchase of "Made in the USA" products** by providing a source of manganese material developed in the USA, as all commercially-available manganese material is currently imported.

Successful completion of a preliminary evaluation for other potential uses and a more in-depth evaluation and marketing of pigments/colorants beyond hand-made ceramics by

(1) **providing the opportunity to conduct preliminary research into various commercial uses of manganese; thereby, enabling an informed decision to target appropriate markets** with compilation of a list of ~85 potential commercial users (~20 contacted during project) that included suppliers to, and manufacturers of, tile, linoleum, brick, concrete, paint, and cosmetic industries using pigments/colorants and also manufacturers of agricultural and water treatment products;

(2) **enabling the creation of marketing materials including an e-commerce website, Clean Creek Products (www.cleancreek.org)** with the initial targeted market for pigments/colorants resulting in requests, after acquiring satisfactory results from further testing, of ~20 tons each of recovered manganese material by two large pigment/colorant suppliers to the ceramic industry.

Even though much has been accomplished, the effort is still in the preliminary development stage. To continue to expand the use of the recovered material and to sustain the performance of passive systems, future necessary efforts include not only continued implementation and refinement of the recovery and beneficiation (field and/or commercial) processes but also documentation of the degree and duration of the improvement in system treatment performance. Also imperative is continued and expanded market development, which hinges on further testing of materials, conducting a cost-benefit analysis including material processing methods, and determining the consistency in material quality and availability at other potential sites.

COMPREHENSIVE TIMELINE

Abbreviations: BioMost, Inc. (**BMI**); Bureau of Abandoned Mine Reclamation (**BAMR**); Clean Creek Products (**CCP**); De Sale 1 (**DS1**); De Sale 2 (**DS2**); De Sale 3 (**DS3**); Erico Bridge (**EB**); Horizontal Flow Limestone Bed (**HFLB**); Pennsylvania Department of Environmental Protection (**PA DEP**); Request for Proposal (**RFP**); Slippery Rock Watershed Coalition (**SRWC**); Stream Restoration Incorporated (**SRI**); Vertical Flow Pond (**VFP**)

Date	Description
07/19/04	PA DEP solicitation of proposals for OSM PA(AMD-04) posted in *PA Bulletin*
07/19/04	Letter requesting copy of RFP No. OSM PA(AMD-04) submitted to BAMR
01/20/05	Copy of RFP No. OSM PA(AMD-04) received from BAMR
02/09/05	PA DEP/BAMR pre-proposal conference for RFP No. OSM PA(AMD-04)
03/01/05	Addendum No. 1 to RFP No. OSM PA(AMD-04) issued from BAMR
04/18/05	Manganese Resource Recovery Technical Submittal
12/01/05	Received approval for funding through the Environmental Stewardship and Watershed Protection (Growing Greener) Fund and from PA DEP BAMR Federal Abandoned Mine Reclamation Fund
12/06/05	SRI submitted detailed budget sheets for OSM PA(AMD-04) Manganese to BAMR
04/20/06	DEP Grant Agreement signed
05/02/06	Fully-executed grant agreement received from BAMR for OSM PA(AMD-04) Manganese
06/--/06	“Manganese Recovery” article in SRWC monthly newsletter *The Catalyst*
07/05/06	Status Report submitted to PA DEP
10/11/06	Status Report submitted to PA DEP
01/15/07	Status Report submitted to PA DEP
02/02/07	Letter from PA DEP requesting updated timeline and Problem Identification Report
03/23/07	Revised timeline and Problem Identification Report submitted to PA DEP
03/28/07	Water monitoring and system inspections conducted at DS1, DS2, DS3, and EB
04/--/07	“Black Glaze – Green Technology” article in SRWC monthly newsletter *The Catalyst*
04/19/07	Status Report and Reimbursement Request (1st) for OSM PA(AMD-04) Manganese submitted to BAMR
04/23/07	2 samples of hand-collected manganese material sent for analysis to Actlabs
04/26/07	Water monitoring and system inspections conducted at DS1, DS2, DS3, and EB
04/27/07	“Passive Treatment Systems in Slippery Rock Watershed Yield Black Glaze” article in *PA Environment Digest*
05/15/07	Collection of manganese-coated limestone aggregate from DS2 for bench-scale testing; bench-scale testing initiated
05/23/07	Water monitoring and system inspections conducted at DS1, DS2, DS3, and EB
05/29/07	Status Report and Reimbursement Request (2nd) for OSM PA(AMD-04) Manganese submitted to BAMR
06/13/07	Bench-scale testing completed
07/10/07	Status Report and Reimbursement Request (3rd) for OSM PA(AMD-04) Manganese submitted to BAMR
07/26/07	3” gasoline-powered water pump purchased
08/01/07	Document #: GR4100033910 – Response to information request for Manganese Resource Recovery for DEP File No. OSM PA(AMD-04) submitted to BAMR
08/20/07	Installed HFLB by-pass from wetland spillway; excavated wash pit #1; pumped water from existing constructed wetland to fill wash pit; installed large “felt sock” (filter bag) on HFLB drain pipe
08/21/07	Trench (sump) dug along east side of HFLB to dewater component; constructed frames

	to support totes used to dewater and transport recovered material; initiated manganese recovery using Flip Screen
08/22/07	Constructed frames to support dewatering and bulk-hauling totes; continued use of Flip Screen to recover manganese
08/23/07	“Dry Processed” stone placed in trench; recovered dry and wet material
08/24/07	Recovered material
08/27/07	Began to decant wash pit #1; wash pit #2 constructed
08/28/07	Decanted wash pit #2; greased Volvo/ Flip Screen; reset screen; processed stone in wash pit #2; progress drawings updated; recovered manganese
08/31/07	Recovered manganese from wash pits # 1 & 2
08/31/07	Status Report and Reimbursement Request (4th) for OSM PA(AMD-04) Manganese submitted to BAMR
09/04/07	Greased excavator; recovered manganese pumped from wash pits # 1 & 2
09/05/07	Pumped recovered material from wash pit #2 to totes 12, 8, 9, 10, 11, 1, 3; transported selected totes to Quality Aggregates scalehouse at the Boyers Quarry to determine bulk weight (~1720 lbs/tote)
09/06/07	Greased excavator and Flip Screen; unloaded pallets; prepped freshwater; fixed oil leak; fixed HFLB emergency spillway
09/07/07	Hauled manganese to loading site
09/10/08	Loaded air-dried material from stockpiles into totes for offsite haulage
09/11/07	Hauled 17 totes; removed by-pass; leveled HFLB; cleaned/graded
09/21/07	Status Report with Reimbursement Request (5th) for OSM PA(AMD-04) Manganese submitted to BAMR
Fall 07	“River Comes Clean” article in *Pittsburgh Quarterly* magazine Fall 2007 issue
10/01/07	Samples collected of recovered manganese material
10/11/07	Meeting with potter Bob Isenberg at Pottery Dome (near Grove City, PA)
10/26/07	Status Report with Reimbursement Request (6th) for OSM PA(AMD-04) Manganese submitted to BAMR
11/--/07	“Manganese Recovery at De Sale Phase 2” article in SRWC monthly newsletter *The Catalyst*
11/07/07	Grant Extension Request filed with BAMR
11/14/07	30 samples of recovered material submitted for analysis to Actlabs
11/30/07	Status Report and Reimbursement Request (7th) for OSM PA(AMD-04) Manganese submitted to BAMR
12/10/07	Manganese Resource Recovery Project deadline extended from 12/31/07 to 6/30/08
01/04/08	Status Report and Reimbursement Request (8th) for OSM PA(AMD-04) Manganese submitted to BAMR
01/07/08	Site inspection and water monitoring conducted at DS2; low-pH Fe recovered from surface of drained VFP
01/09/08	Budget Revision Request submitted to BAMR
01/30/08	Request to modify budget approved by BAMR
02/--/08	Project in “2007 Year in Review” article in SRWC monthly newsletter *The Catalyst*
02/01/08	“Perfect Pigment” article in *Slippery Rock Eagle*
02/02/08	“Potter finds gold in stream slime” article in *The Herald*
02/04/08	“Clean Stream Effort Yields Pottery Glazes” article in *Butler Eagle*
02/15/08	Status Report and Reimbursement Request (9th) for OSM PA(AMD-04) Manganese submitted to BAMR
02/26/08	“Resource Recovery With A Twist” article in *Abandoned Mine Posts* website
02/26/08	Ceramic bowls sent to Ferro Color for analysis
03/--/08	“Boscov’s Green Day” article in SRWC monthly newsletter *The Catalyst*

03/04/08	Ceramic bowl samples sent to Ferro Color & Glass Performance Materials for analysis
03/06/08	Reimbursement Request (10th) for OSM PA(AMD-04) Manganese submitted to BAMR
03/11/08	Additional ceramic bowl samples sent to Ferro for analysis
03/18/08	Manganese samples collected from totes
03/18/08	Samples received from BMI at RJ Lee*Group*
3/19-3/21	SRI/CCP attends National Council on Education for the Ceramic Arts conference in Pittsburgh, PA (>3000 attendees)
03/21/08	Reimbursement Request (10th-Rev.) for OSM PA(AMD-04) Manganese sent to BAMR
03/28/08	"Free Oxides" article on Clayart Blog
04/--/08	"Glazed With What Oozed" article in Sierra Club's *Sierra* magazine
04/--/08	"Pottery Helping the Environment? Are You Kidding" article in *The Point North* magazine
04/--/08	"Creativity Abounds at the NCECA Conference" and "Introducing Clean Creek Products" articles in SRWC monthly newsletter *The Catalyst*
Spring 08	"Lois Hamilton's Dome of Wonders" article in Slippery Rock University alumni magazine *The Rock*
04/01/08	Laboratory report from RJ Lee*Group* for samples received on 03-18-08 completed
04/01/08	Status Report and Reimbursement Request (10th–Rev2) for OSM PA(AMD-04) Manganese submitted to BAMR
04/15/08	Status Report and Reimbursement Request (11th) for OSM PA(AMD-04) Manganese submitted to BAMR
05/02/08	"Company Discovers New Uses For Byproducts of Acid Mine Drainage" article in US EPA *Envirobytes* newsletter
05/09/08	"Dissolved Metal From Mine Drainage Used to Make Pottery by Cranberry Company" article in *PA Environment Digest*
05/12/08	Manganese & iron samples sent to Custom Processing Services for drying & screening
06/01/08	Custom Processing Services sends letter confirming receipt of samples of manganese slurry, manganese residual, and iron oxide
06/06/08	Status Report and Reimbursement Request (12th) for OSM PA(AMD-04) Manganese submitted to BAMR
06/10/08	Sent manganese material samples from totes 11 and 25 to Geochemical Testing Inc. (Somerset, PA)
06/15/08-06/18/08	SRI/CCP exhibits and presents professional paper on recovery efforts at the American Society of Mining and Reclamation conference in Richmond, VA
06/24/08	Totes taken to custom processing
06/25/08	Spec sheets for iron & manganese oxides received from Standard Ceramic Supply Co.
06/27/08	Status Report and Reimbursement Request (13h) for OSM PA(AMD-04) Manganese submitted to BAMR
07/--/08	"Passive Systems Treat AMD While Allowing Recovery of Metal Oxides" article in US EPA's *Technology News and Trends* newsletter
07/--/08	"The Point North Magazine Points to the SRWC, Clean Creek Products" article in SRWC monthly newsletter *The Catalyst*
07/02/08	Custom Processing Services email - drying process underway on sample materials
07/04/08	SRI/CCP displays pottery at Harrisville Community Days in Harrisville, PA
08/11/08-08/14/08	SRI/CCP displays pottery at PA Abandoned Mine Reclamation Conference, State College, PA
-----2008	"Mine Drainage Sludge: Helping the Environment?" in American Society of Mining and Reclamation magazine *Reclamation Matters,* Issue 2 of 2008
11/--08	"Make This Holiday Season a Bit More 'Green'" article in *The Point North* magazine

INTRODUCTION

The extraction and use of natural resources have occurred throughout human history. In Pennsylvania, coal has been mined for over 200 years. The first known commercial coal mine was opened in 1761 on Coal Hill now known as Mt. Washington in Pittsburgh, PA. While coal has fueled our economy, heated our homes, and provided countless kilowatt-hours of electricity, historical mining activities have left a legacy of scarred landscapes and polluted streams throughout the world. Forty-five of Pennsylvania's sixty-seven counties have abandoned mine lands. In Pennsylvania, abandoned mine drainage is the largest non-point source of stream impairment. According to the 2006 Pennsylvania Integrated Water Quality Monitoring and Assessment Report, over 4,600 miles of streams have been degraded due to mine drainage. Metal precipitates coat the bottom of streams destroying the habitat of the macroinvertebrates that are so extremely important to the aquatic food chain. In some cases, only the most tolerant of species are able to survive in such severely degraded streams. While in many other cases, entire streams have been completely decimated and are essentially lifeless.

Within the last 20 years, government agencies, watershed groups, nonprofits, universities, and private industry have developed and implemented passive systems to treat these abandoned discharges in a cost-effective manner. Combining remining, land reclamation, and the installation of passive treatment systems have resulted in restoring barren land to productive farmland and in returning streams that had been lifeless for decades to healthy aquatic habitats capable of supporting reproducing fish populations.

In order to sustain these dramatic improvements in water quality, long-term operation and maintenance of these passive systems must be addressed. Thousands of tons of metal precipitates are being retained within about 300 systems every year. The accumulated metal solids will need to be periodically removed in order to maintain effective treatment of the mine drainage. These metal solids have the potential to be either a liability or an asset. The question then becomes "What to do with the metal precipitates that are removed?"

One approach to address this issue is to develop markets for these "by-products" of passive systems. Passive systems are essentially concentrating the metals within the treatment components, which could be viewed as creating a mineral deposit or ore. These "ore" bodies have the potential of being "mined" in order to extract the metals for economically viable purposes as opposed to being buried or placed in a landfill.

A contract was received from the Pennsylvania Department of Environmental Protection Bureau of Abandoned Mine Reclamation (PA DEP BAMR) to expand upon work being conducted by BioMost, Inc., Stream Restoration Inc. and participants in the Slippery Rock Watershed Coalition under a grant through the Southern Alleghenies Conservancy to pursue the recovery of manganese from passive treatment components and to evaluate potential markets for this material. The approach consisted of multiple phases. First, bench-scale testing and research was conducted as the first step in developing a recovery process prior to conducting the full-scale recovery effort.

Samples of the recovered material were collected and sent for analysis to determine mineral phases and chemical constituents. Market development and research was conducted to determine potential uses and demands for these recovered materials. Test products were created in addition to marketing materials such as flyers, informational sheets, brochures, and a website.

This report documents the progression of the project with selected data and photographs and provides preliminary conclusions and recommendations for the recovery of manganese from passive treatment systems. In addition, while not part of the scope of work, this report also documents some of the initial results investigating the potential use of iron minerals that form at low pH within certain passive components.

PASSIVE TREATMENT OF MANGANESE-BEARING MINE DRAINAGE

Passive systems typically use no electricity, require limited maintenance, and use environmentally-friendly materials, such as limestone aggregate and spent mushroom compost and other organic material in a series of constructed ponds, beds, ditches, and wetlands. As with any type of system, the goal is to provide economical, long-term, effective treatment. Passive components are selected based upon the often variable water quality and flow rate of the mine drainage, preferred chemical and/or biological processes, and available construction space.

One of the many effective components available to designers of passive treatment systems is the Horizontal Flow Limestone Bed **(HFLB)**. An HFLB is an open (not buried), bed of limestone aggregate, which is commonly installed as the final component in a passive treatment system. The HFLB serves two major purposes. First, the HFLB provides an alkalinity “boost” to the final effluent, which adds buffering capacity to the stream, which in many cases is needed to lessen the impact of other acidic sources downstream. Second, the HFLB has been demonstrated to be effective in removing dissolved manganese.

Historically, removal of dissolved manganese from mine drainage has been problematic and thought to require active chemical treatment in order to raise the pH above ≈9. With the development of passive technology, dissolved manganese has been observed to form solids at a much lower pH (6 to 7). The exact mechanism is not completely understood at this time, but biogeochemical factors such as low dissolved ferrous iron, high dissolved oxygen, available surface area, sufficient alkalinity, presence of certain microorganisms, and autocatalytic processes appear to play a significant role. The availability of certain nutrients, dissolved organic carbon, and other factors may also be important, depending upon the role and type of the microorganisms in the removal process. Recent investigations have indicated that fungi may play a more important role than bacteria especially if the water has extremely high concentrations of dissolved manganese. [Based on recent (ca. 6/2008) communication of initial findings by Dr. Cara Santelli, Harvard University, who collected and analyzed samples from several HFLBs in the Slippery Rock Creek Watershed including De Sale Phase 2.]

The HFLB, as well as many other effective passive components, accumulates metal precipitates, sediment, vegetative debris, etc. Over time, the accumulation of these materials can result in decreased treatment efficiency as the treatment media becomes plugged and permeability decreases.

PREVIOUS RELATED EFFORTS

As previously noted, this project expands upon earlier work by the partnership effort to investigate recovery and use of manganese oxides from passive treatment systems. The scope of work conducted under the previous grant included the installation and monitoring of steel slag and limestone test tanks to evaluate manganese removal and recovery. In addition, manganese oxides were collected from existing passive treatment components by hand and, when applicable, by flushing. While results varied, in general, grab samples of the material collected directly from several HFLBs indicated that the material was about 50% manganese on an as-received basis with a loss-on-ignition of about 20%, which typically accounts for water, volatiles, and organic matter. These samples contained much higher concentrations of manganese than those samples collected by flushing of the treatment media. X-ray diffraction conducted on the grab samples revealed that the manganese material was a mixture of todorokite (monoclinic mineral; general formula: $(K,Na,Ba)(Mn,Al,Zn)_6O_{12}\bullet 3H_2O$) and birnessite (hexagonal mineral; general formula: $(Na,Ca)Mn_7O_{14}\bullet 3H_2O$). In addition to conducting analyses, potential uses of manganese oxides were identified including use in ceramic glazes. The success of this previous project and the knowledge gained encouraged further investigation to develop a method for recovery and to continue pursuit of an economical use of recovered products.

PROJECT LOCATION

The project area is within the Slippery Rock Creek headwaters in western Pennsylvania about 50 miles north of Pittsburgh. (See Location Map.) The locations of the passive systems online within the headwaters are shown on the attached map. For this project, water samples were collected at the influent and effluent of the Horizontal Flow Limestone Beds included in the De Sale Phase 1, De Sale Phase 2, De Sale Phase 3 and Erico Bridge Passive Treatment Systems. The full-scale field recovery process for manganese-bearing material was conducted at the De Sale Phase 2 Passive Treatment System. Located in Venango Township, Butler County, De Sale Phase 2 lies north of State Route 58 about 2 miles west of the town of Eau Claire at latitude 41° 08’ 40” and longitude 79° 49’ 55”. The manganese-coated limestone utilized for the bench-scale testing was also collected from this site.

SLIPPERY ROCK CREEK TARGET AREA

Goff Station (2001)
Four Vertical Flow Systems
Acid Removed: 7,298 lbs/mo
Fe Removed: 417 lbs/mo
Al Removed: 367 lbs/mo
Bat Hibernaculum
Naturally-Functioning Wetlands

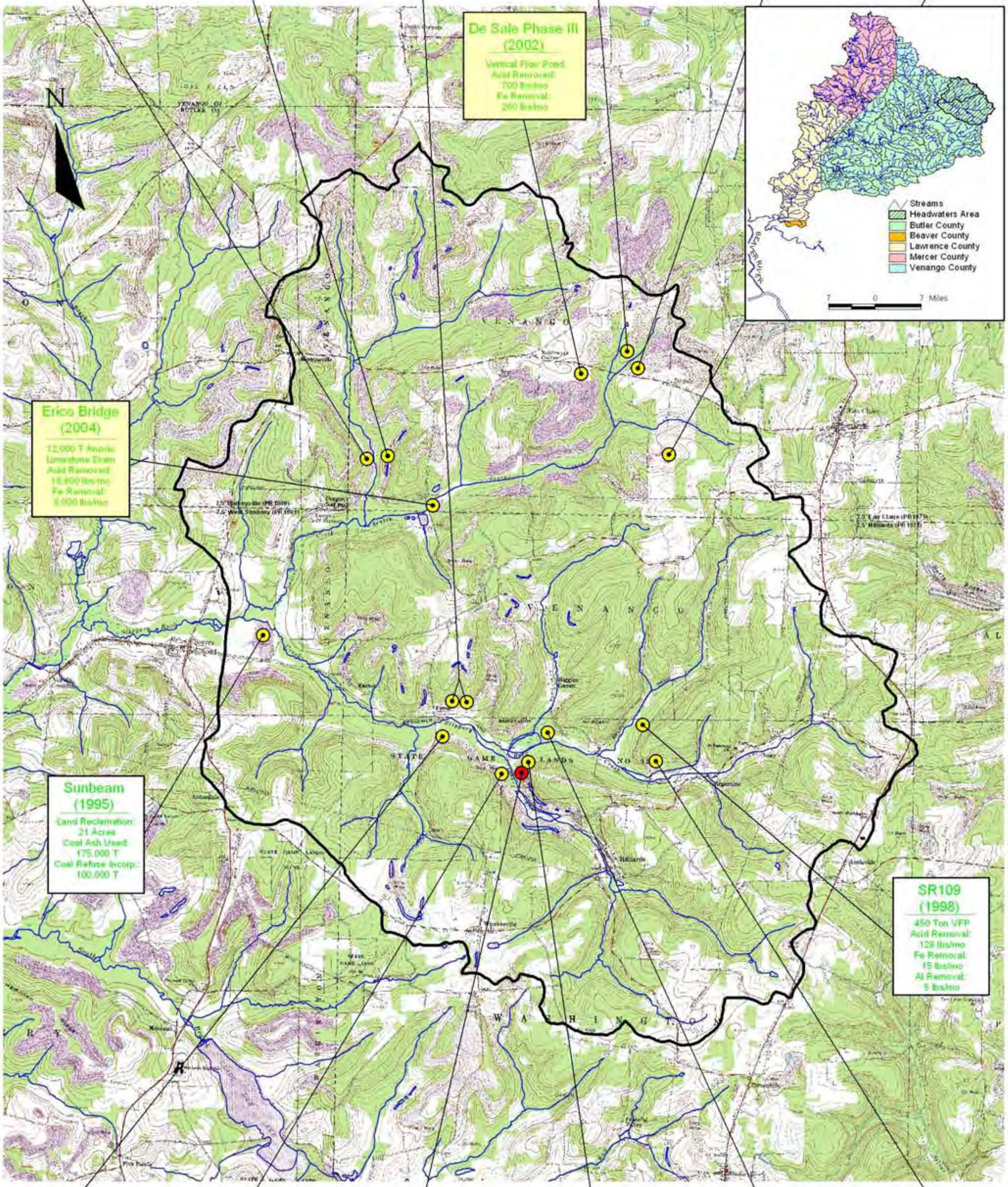
Brookville Pit (2002)
Land Reclamation: 20 Acres
Coal Ash Used: 200,000 Tons
Coal Refuse Incorporated: 94,000 T

Ferris Complex (1997)
Four Vertical Flow Systems
Acid Removed: 12,078 lbs/mo
Fe Removed: 437 lbs/mo
Al Removed: 372 lbs/mo

DeSale Phase II (2001)
4,400 Ton VFP
Acid Removed: 5,361 lbs/mo
Fe Removed: 249 lbs/mo
Al Removed: 218 lbs/mo

DeSale Phase I (2000)
3,000 Ton VFP
Acid Removed: 5,371 lbs/mo
Fe Removed: 1029 lbs/mo
Al Removed: 225 lbs/mo

Chernicky (1998)
Land Reclamation: 56 Acres
Coal Ash Utilization
Abandoned Open Pits Reclaimed



SR81(2002)
1,300 Ton ALD
Acid Removed: 173 lbs/mo
Fe Removed: 25 lbs/mo

SR96 (2002)
700 Ton ALD
Acid Removed: 292 lbs/mo
Fe Removed: 78 lbs/mo

SR89 (2004)
2,100 Ton VFP
Acid Removed: 7,127 lbs/mo
Fe Removed: 1,188 lbs/mo
Al Removed: 190 lbs/mo

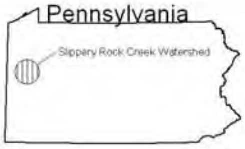
Big Bertha (1996)
900 Ton ALD
Acid Removed: 549 lbs/mo
Fe Removed: 740 lbs/mo

SR101A (1998)
900 Ton ALD
Acid Removed: 1,644 lbs/mo
Fe Removed: 800 lbs/mo

SR114 (1995)
1,450 Ton ALD
Acid Removed: 1,289 lbs/mo
Fe Removed: 2,588 lbs/mo

SYSTEMS UNDER CONSIDERATION FOR MN RECOVERY
COMPLETED PROJECT
PROJECT UNDER CONSTRUCTION
Headwaters Study Area
Stream

NOT TO SCALE



HFLB MONITORING and PERFORMANCE EVALUATION

Water monitoring of the influent and effluent for the HFLBs at the De Sale Phase 1, De Sale Phase 2, De Sale Phase 3, and Erico Bridge passive systems was conducted on 3/28/07, 4/26/07, and 5/23/07. The purpose of the monitoring was to assess the current functionality of the individual HFLB as well as to assist in developing an estimate of the quantity of manganese oxides accumulated within the HFLBs over time. The monitoring data was compiled together with historical data (See Table 1 below and water quality database in appendix.) to evaluate the systems as well as to develop the loading estimates presented in Table 2.

Based upon the data from the three monitoring events conducted in 2007, manganese concentrations were being reduced by 22%, 41%, 24%, and 6% at the De Sale Phase 1, De Sale Phase 2, De Sale Phase 3, and Erico Bridge HFLBs, respectively, which when compared with available the historic removal of 21%, 34%, 4%, and 76% indicates that all of the HFLBs were performing as well if not better in terms of manganese removal except for Erico Bridge, which was significantly less. Likewise, in terms of acid neutralization, all HFLBs are performing as well if not better with the exception of the Erico Bridge HFLB. A visual examination of the HFLBs indicated that the De Sale Phase 1, De Sale Phase 2 and Erico Bridge HFLBs were at least partially plugged as water levels were above the top of the stone at these three sites. Note, however, that the three monitoring events were conducted in the spring of 2007 during what is traditionally a high-flow period. This is quite obvious when comparing the flow rates provided in Table 1 where in all cases the average flow rate measured during this brief time period is at least twice as much as the average flow rate of all previous data. A comparison, therefore, of the 2007 data with the average data for that system may slightly skew the interpretation of the functionality of the systems especially for Erico Bridge.

The loading values in Table 2 represent an estimated range in the quantity of manganese contained within the HFLBs. The range reflects the number of sampling events, water quality, and treatment effectiveness. Based upon available data, as of 2007, between 150,000 pounds (75 tons) and 250,000 pounds (100 tons) of manganese (as the element) appears to be currently available for recovery within the four HFLBs located in the Slippery Rock Creek Watershed.

Table 1: Average Influent and Effluent Quality of Selected HFLBs

Parameter	Time Period	De Sale 1 HFLB (online: 05/10/2000)		De Sale 2 HFLB (online: 08/29/2000)		De Sale 3 HFLB (online: 12/24/2002)		Erico Bridge HFLB (online: 06/24/2003)	
		In	Out	In	Out	In	Out	In	Out
Flow	Pre-2007	42	42	83	83	17	17	500	500
	2007	103	103	298	298	41	41	1000	1000
pH (Field)	Pre-2007	7.1	7.2	6.9	7.1	6.8	6.8	6.9	7.2
	2007	6.0	6.4	4.7	6.1	5.6	6.4	6.8	7.1
Alkalinity	Pre-2007	100	96	55	81	45	62	75	113
	2007	12	26	2	18	7	43	105*	87*
Acidity	Pre-2007	9	-2	17	-5	70	53	-18	-62
	2007	16	-1	61	-0	135	48	-42	-56
Iron	Pre-2007	5.1	1.1	2.3	2.3	2.6	0.8	9.7	1.0
	2007	0.2	0.1	0.2	0.1	2.0	0.1	5.5	5.6
Manganese	Pre-2007	41.5	32.9	37.1	24.3	71.2	68.2	18.8	4.5
	2007	32.9	25.5	33.6	19.9	86.2	65.8	19.8	18.6
Aluminum	Pre-2007	0.3	0.4	0.3	0.3	1.4	0.3	0.2	0.1
	2007	0.6	0.3	3.3	1.2	2.0	0.4	0.3	0.3

*Number of samples (n) varies; Time Period Pre-2007 from date online to 12/2006; Average values; Flow in gallons per minute (gpm) measured at effluent of HFLB typically with bucket & stopwatch and assumed equal to influent flow rate; pH measured in field, in standard units, and not averaged from H-ion concentration; All concentrations laboratory measurements; Alkalinity and Acidity values in mg/L as $CaCO_3$; Iron, Manganese, and Aluminum as total metals in mg/L: * indicates probable spurious values*

Table 2: Estimated Manganese Accumulation within Selected HFLBs

Passive System	Low Estimate (pounds)	High Estimate (pounds)
De Sale 1	30,000	35,000
De Sale 2	60,000	80,000
De Sale 3	5,000	15,000
Erico Bridge	70,000	100,000
Total	**165,000**	**230,000**

Pounds of manganese retained within HFLB based on decrease in loading in effluent compared to influent

DE SALE PHASE 2 PASSIVE SYSTEM PERFORMANCE EVALUATION

Influent vs. Effluent Quality

As the De Sale Phase 2 passive system was selected for manganese recovery, a more thorough performance evaluation was conducted. The De Sale Phase 2 system has been successfully treating acidic, metal-laden, mine drainage with widely varying flow rates for nearly eight years. Table 3 depicts the general treatment and effectiveness of the system. While the maximum design flow was 200 gpm, actual measured flow rates have ranged from 10 to 445 gpm and at times have probably exceeded 500 gpm. As can be seen from Tables 1 and 3, the influent to the system can be characterized as low pH, acidic, metal-laden drainage while the effluent can be characterized as a circum-neutral, alkaline discharge with low concentrations of iron and aluminum and significantly reduced concentrations of manganese.

Table 3: De Sale Phase 2 Passive System Influent and Effluent Values (min/max)

Point	**Flow** (gpm)	**F. pH** (s.u.)	**F. Alk** (mg/L)	**L. Alk** (mg/L)	**Acidity** (mg/L)	**T. Fe** (mg/L)	**D. Fe** (mg/L)	**T. Mn** (mg/L)	**D. Mn** (mg/L)	**T. Al** (mg/L)	**D. Al** (mg/L)
Raw		2.9/4.5	0	0	92/451	7/82	8/37	18/84	11/77	2/15	5/13
Final Effluent	10/445	5.8/7.7	22/219	6/250	-73/35	0/15	0/6	0/51	3/46	0/3	0/1

Final effluent = HFLB effluent; sampling dates and number of events vary for each point and for individual parameters; field (F) or lab (L) measurement; total (T) or dissolved (D) metals

Based upon available data, an estimate of loading reduction reveals that after 7½ years ~60,000 to ~80,000 lbs. (~30 to ~40 tons) of manganese have been retained within the passive treatment system which would have otherwise entered Seaton Creek.

By 2003, the accumulation of manganese as well as other metals, sediment, vegetation, etc. resulted in the HFLB component having small pockets of standing water. During occasional excessive high flow periods, a portion of the influent water would flow across the top of the HFLB and over an emergency spillway instead of flowing through the stone, which reduced treatment effectiveness. Even though effectiveness was reduced, the final effluent continued to demonstrate substantial treatment.

Initial Attempts to Rehabilitate the De Sale 2 Horizontal Flow Limestone Bed

Prior to the rehabilitation and recovery effort in 2007, several previous attempts were made with varying success to rehabilitate the HFLB at De Sale Phase 2. In March 2004, the 10-inch perforated manifold installed along the width of the HFLB was backflushed at ≈15 psi using an air compressor. Backflushing was conducted to remove solids from the pipe and from within the aggregate in the vicinity of the pipe perforations. Backflushing did lower the water level in the HFLB and manganese-bearing “chips” were observed in the flush water, indicating that at least a portion of the reduced permeability was probably due to the precipitation of manganese material within and near the pipe. (Based on our current understanding, manganese oxides commonly form as pipe scale in PVC pipes.) The water level, however, was still higher than the design elevation, indicating reduced permeability within the bed. In April 2004, a small track loader was used to "stir" the upper portion (≈2-3 feet) of stone. In addition to vegetative growth, including what appeared to be possible algal(?) mats, manganese material was observed on the limestone aggregate and within the void spaces. The impact of the backflushing and stirring events was short lived. In October 2004, a trench was excavated along the influent and effluent ends of the HFLB. The entire length of the manifold collection pipe was exposed. In addition, the outlet piping was reconfigured to provide the ability to raise and to lower the head as well as drain the HFLB. During this work, the pond was drained and the vegetative material and manganese-bearing precipitates on the surface of the bed were allowed to dry, "breaking up" some of the accumulated material. This effort resulted in improved flow through the bed with the water level remaining below the surface of the stone for one year. After that period, the water level again began to rise and typically a small portion of the drainage was observed discharging through the emergency spillway during periods of high flow. A new approach was required and preferably one that incorporated the recovery and use of the manganese material.

BENCH-SCALE TESTING and RECOVERY PROCESS DEVELOPMENT

As there were no known previous attempts to conduct large-scale recovery of manganese-bearing material from a Horizontal Flow Limestone Bed, a considerable amount of research and testing was conducted under this grant. Research included searching for and evaluating various heavy machinery, screening/filtering materials and equipment, pumps, tanks, liners, etc. in order to develop an efficient and cost-effective method of recovery. During the concept stage, several potential recovery methods were considered and evaluated.

Initially, the plan was to develop a bench-scale method then progress to a pilot-scale test prior to attempting a full-scale recovery operation. One of the major questions at the onset was whether the recovery process should be wet or dry. This was of particular interest as the initial thought was to use a rotating screening device similar to a Bradford Breaker or portable Trommel Screen. At this time, there was uncertainty as to whether the manganese-bearing material would separate from the limestone when wet or if the material would require drying prior to processing. There was also the question as to the benefits of using a washer or water spray in the recovery process.

A very simple bench-scale test was developed in order to mimic a Bradford Breaker/Portable Trommel Screen-type device and to examine the effectiveness of recovering manganese under wet and dry conditions. On May 5, 2007, eighteen, 5-gallon, buckets of manganese-coated limestone was collected from the De Sale Phase 2 HFLB. The limestone was collected from 6 hand-dug pits. Three buckets of limestone were collected from each pit. The following describes the methodology used to conduct the bench-scale test:

Bench-Scale Testing Procedure

1. Numbered 5-gallon buckets 1-18.
2. Weighed and recorded each empty bucket prior to stone collection.
3. Hand-dug a total of six holes approximately the same size and depth across the same section of the HFLB. From each hole, 3 buckets of stone were collected at different depths.
4. Photographed stone and noted general observations as to manganese coverage on the stone.
5. Reweighed each bucket after stone collection and recorded value.
6. Repeated Steps 2-5 until all buckets were filled with manganese-coated limestone.
7. Selected three buckets from the same hole for "processing".
8. Hand-rolled one of the three buckets with the lid closed tightly back-and-forth for 1 minute to simulate a Bradford Breaker-type device.
9. Removed lid after 1 minute of rolling and emptied contents of bucket onto a tarp.
10. Photographed stone and described general observations as to change in manganese coverage.
11. Collected manganese material separated from the stone remaining in the bucket and on the tarp and then placed manganese material in a sample bag labeled with the bucket # (1-18), the roll # (1-3), and the date.
12. Replaced stone carefully into the bucket.
13. Repeated Steps 8-12 for the same bucket 2 additional times; rolled bucket for 2 minutes for the 2nd & 3rd rolls.
14. Weighed sample bags containing the manganese collected during Step 1.
15. Repeated Steps 8-14 for the remaining two buckets selected in Step 7.
16. Repeated Steps 7-15 after 1 day utilizing different buckets.
17. Repeated Steps 7-15 after 1 week utilizing different buckets.
18. Repeated Steps 7-15 after 2 weeks utilizing different buckets.
19. Repeated Steps 7-15 after 3 weeks utilizing different buckets.

Bench-Scale Testing Results and Discussion

Table 4 depicts selected data of interest associated with the Bench-Scale Recovery Test. The first set of buckets (1, 2, 3) was processed on 5/15/07 within about two hours of collection. The stone in Bucket 1 was collected near the surface and the manganese material appeared drier and was easier to recover and to collect. The manganese-coated stone in Buckets 2 and 3, however, was wet and, therefore, the material was harder to collect as the manganese material tended to smear and stick on the stone and the bucket. The weight of the collected manganese-bearing material was much higher in Bucket 3 because of the inclusion of many small rock fragments and the manganese was very wet. On 5/16/07 (1 day after collection), two buckets (4 and 5) were processed. Due to the difficulty in processing the stone, Bucket 6 was not processed and a decision was made on 5/18/07 to remove the lids of all the remaining buckets (7 through 18) to speed drying. On 5/22/07, buckets 7, 8, 9 were processed. On 5/29/07, buckets 10, 11, 12 were processed.

Various discussions were held about the effectiveness of the bench-scale tests as well as the positive and negative factors surrounding drying the material extensively. As the generation of manganese dust was a concern, one approach considered drying to break "the bond" between the stone and the manganese material and then rewetting for dust suppression. On 6/6/07 (after drying for 20 days) at ~0920, buckets 16, 17, 18 were filled to the top with water and the lids replaced. At ~1420 (5 hours later) the lids were removed and a 1/8" hole was drilled in the bottom of each bucket to drain the water. The buckets were allowed to drain and dry for ~2½ hours before processing the first bucket. Bucket 17 was chosen first, having drained more quickly than the other two buckets. The material was very wet and sticky. Processing was difficult and not as successful. A decision was made to allow buckets 16 and 18 time to further dry. Bucket 16 was then processed two days later on 6/8/07. Bucket 18 was processed 1 week later on 6/13/07. The amount of drying time for each bucket, therefore, varied. A direct benefit in terms of ease and/or efficiency of recovery was not realized; however, the amount of dust generated during processing definitely decreased as a result of the rewetting.

Table 4: Bench-Scale Manganese Recovery Data

(weight, in grams, of Mn-bearing material recovered in response to timed hand-rolling)

Bucket #	Process Date	Roll #			Total
		1	2	3	
1	5/15/2007	105.0	20.8	8.3	134.1
2	5/15/2007	150.6	26.2	10.0	186.8
3	5/15/2007	763.1	26.0	11.6	800.7
4	5/16/2007	171.2	50.2	18.1	239.5
5	5/16/2007	194.9	17.6	7.0	219.5
6	6/13/2007	381.4	NA	NA	381.4
7	5/22/2007	232.7	91.1	55.8	379.6
8	5/22/2007	208.0	86.7	61.0	355.7
9	5/22/2007	113.2	10.8	10.3	134.3
10	5/29/2007	304.3	59.3	32.2	395.8
11	5/29/2007	328.1	74.6	33.0	435.7
12	5/29/2007	572.3	103.2	53.3	728.8
13	6/06/2007	402.5	48.3	28.3	479.1
14	6/06/2007	355.5	47.9	31.6	435.0
15	6/06/2007	404.2	59.4	35.5	499.1
16	6/08/2007	311.9	94.3	31.5	437.7
17	6/06/2007	300.4	76.1		376.5
	6/08/2007			139.5	139.5
18	6/13/2007	493.2	80.5	29.1	602.8

Another question that arose during the bench-scale recovery process development stage was whether the manganese could be washed from the limestone with agitation. A separate limited, bench-scale, test was conducted which began on 6/13/07. The manganese material on the limestone in bucket 6, which was in a closed container and never processed, remained wet on the bottom of the bucket and very damp in the uppermost portion of the stone. Stone from bucket 6 was placed within a netted bag and then lowered into a large, water-filled, 18-gallon plastic tote. (See Photos.) Once in the water, the bag was repeatedly dunked and minimally agitated for about 1 minute in order to attempt washing the manganese from the stone. The washed stone was almost completely cleaned of the manganese material, which was now suspended in the water. Within an hour, the majority of the manganese was visually observed to have settled to the bottom of the tote. Once the manganese had settled for approximately 24 hours the water was siphoned from the tote. The remaining sludge was then allowed to air dry before being collected and weighed.

The following lists selected general conclusions from the bench-scale testing:

- The manganese material could be recovered utilizing a Bradford Breaker, Trumell Screen or similar piece of equipment.
- The manganese was easier to recover if the Horizontal Flow Limestone Bed could be drained and the material allowed to air dry prior to recovery efforts.
- The majority (60-80%) of the material was recovered during the 1st 1-minute roll as opposed to the 20-40%, which was recovered from the two, 2-minute rolls (rolls #2 and 3) combined, indicating that most of the material “fell off” the stone easily.
- If the material became too dry, dust could become an issue of concern.
- Other than for dust control, there appeared to be no observable benefit to drying, then rewetting, and then drying again prior to processing.
- The majority of the manganese appeared to be washed from the limestone within a water-filled container with relatively little effort. The manganese was observed to settle in the water-filled container very rapidly.

FULL-SCALE REHABILITATION and RESOURCE RECOVERY PROCESS

Implementation of Manganese Recovery Process

After completing a literature and Internet search and conducting the bench-scale studies, a proposed method to simultaneously restore the efficacy and functionality of the HFLB and recover the manganese material was developed. This was accomplished through the use and combination of several existing products and conceptual ideas into a unique process that, to our knowledge, had not been previously attempted. One aspect that makes this approach unique is the portability and quick set-up time of the recovery system even in remote locations. There is currently a patent pending (US 61/137,556) for the process. Early cost estimates indicate that the recovery process can be implemented at less than one-half (<½) the cost of removing and replacing the treatment media, with costs projected to decrease as the process is perfected.

The first implementation of this process was conducted in August and September of 2007 at the De Sale Phase 2 passive treatment system. The influent flow was bypassed and the HFLB was drained. During this seasonal low-flow period, the drainage was adequately treated by manipulating the flow through the other passive components. Two wash pits, excavated within the HFLB, were lined with impermeable material and filled with water from the treatment wetland using a small pump. A 21-ton excavator was adapted to use a rotating screen attachment developed for use in topsoil screening, called a Flip Screen (Flip Screen Australia Pty Ltd., New South Wales). After using the Flip Screen as a bucket to excavate the limestone aggregate, the attachment was then lowered into the wash pit and rotated. (See photos.) As the Flip Screen rotated within the water, the stones abraded against each other and the water washed the manganese from the stone. The material passing through the 3/8-inch screen settled within the wash pit while the limestone aggregate remained in the bucket. (Note that screens with different size openings are readily interchangeable.) The now clean and refurbished treatment medium was then returned to the HFLB. The slurry within the wash pit was generally pumped into flexible, intermediate, bulk containers **(FIBC)** supported by a fabricated wooden frame for settling and dewatering. The residual material remaining in the wash pit was allowed to dry and was then excavated (See photos.) and stockpiled on a pad for additional drying prior to placement in an FIBC.

Thirty-one of the thirty-two bulk containers, each containing an estimated ton of recovered material, were removed from the site. (As in-kind contributions, Quality Aggregates Inc. provided use of the scalehouse at the Boyers Quarry, Boyers, PA to weigh representative totes containing the recovered manganese material.) FIBC #13 (See Table 5.) was accidentally ripped while being loaded on the trailer. In addition, an estimated 25-50 tons of recovered material was left within the wash pits for future removal.

Table 5 provides information for each tote related to how the material was transferred to the totes, the source of the material, as well as miscellaneous notes. This information may be helpful when evaluating the material characterization data provided later in this report.

Table 5: Manganese Material Recovery "Notes on Totes"

FIBC/ Tote #	Material Source	Material Transfer Method to Tote & Miscellaneous Notes
1	Excavated	"dry" flipped into tote (8/21/07); minimal recovery - v. wet; 8/22/07 transferred to Tote 2
	Wash Pit 2	slurry; pumped w/o intake screen; fine & coarse
2	Excavated	"dry" flipped into tote; material transferred from Totes 1 & 3; v. moist/damp to v. wet
3	Excavated	"dry" flipped into tote (8/21/07); minimal recovery - v. wet; 8/22/07 transferred to Tote 2
	Wash Pit 2	slurry; pumped w/o intake screen; fine & coarse
4	Stockpile	"dry" flipped over tarp & hand-shoveled into tote;
5	Wash Pit 1	slurry; pumped w/intake screen; finer/top material
6	Wash Pit 1	slurry; pumped w/intake screen; finer/top material
7	Wash Pit 1	slurry; pumped w/intake screen; finer/top material
8	Wash Pit 2	slurry; pumped w/o intake screen; fine & coarse
9	Wash Pit 2	slurry; pumped w/o intake screen; fine & coarse
10	Wash Pit 2	slurry; pumped w/o intake screen; fine & coarse
11	Wash Pit 2	slurry; pumped w/o intake screen; fine & coarse
12	Wash Pit 2	slurry; pumped w/o intake screen; fine & coarse
13	Wash Pit 2	slurry; split from Tote 8; ripped during loading onto flatbed
14	Wash Pit 2	slurry; split from Tote 10
15	Wash Pit 2	slurry; split from Tote 11
16	Wash Pit 2	slurry; split from Tote 1
17	Wash Pit 2	slurry; split from Tote 3
18	Wash Pit 2	slurry; split from Tote 7
19	Wash Pit 2	residual; excavated & stockpiled on Tarp 2; transferred by bucket & hand-shovel
20	Wash Pit 2	residual; excavated & stockpiled on Tarp 2; transferred by bucket & hand-shovel
21	Wash Pit 2	residual; excavated & stockpiled on Tarp 2; transferred by bucket & hand-shovel
22	Wash Pit 2	residual; excavated & stockpiled on Tarp 2; transferred by bucket & hand-shovel
23	Wash Pit 2	residual; excavated & stockpiled on Tarp 2; transferred by bucket & hand-shovel
24	Wash Pit 2	residual; excavated & stockpiled on Tarp 1 & 2; transferred by bucket & hand-shovel
25	Wash Pit 2	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel
26	Wash Pit 2	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel
27	Wash Pit 2	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel
28	Wash Pit 1	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel
29	Wash Pit 1	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel
30	Wash Pit 1	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel
31	Wash Pit 1	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel
32	Wash Pit 1	residual; excavated & stockpiled on Tarp 1; transferred by bucket & hand-shovel

Notes: Tote 4 loaded from stockpile of manganese material developed by dry flipping 28 excavator bucket loads (~42 tons) of stone over a tarp during construction of Wash Pit 1; 9/04/07 pumped slurry from Wash Pit 2 to Wash Pit 1; dipped ~7 buckets from Wash Pit 2 to Wash Pit 1; 9/5/07 pumped to Totes 12, 10, 11, 1, 3 and Wash Pit 1 from Wash Pit 2

Preliminary Evaluation of Effectiveness of HFLB Rehabilitation

As the rehabilitation and recovery effort was completed in September 2007, only the preliminary short-term effectiveness of the process can be described. Water sampling of the HFLB influent and effluent was conducted 3, 24, 64, and 118 days after completing the recovery effort. Table 6 provides the post-rehabilitation results for selected parameters.

Table 6: Post-Rehabilitation Influent and Effluent Quality of De Sale 2 HFLB

	3 days (<1 wk.)		**24 days** (~1 mo.)		**64 days** (~2 mo.)		**118 days** (~4 mo.)	
Parameter	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Flow	10	10	40	40	83	83	250	250
pH (field)	5.08	6.49	6.42	6.93	6.86	6.76	5.58	6.53
ORP	316	279	169	158	153	141	245	176
DO	7.27	5.08	7.57	1.33	9.35	2.28	10.63	8.43
Temp.	22.5	18.7	20.0	18.1	10.8	8.8	3.9	2.9
Alkalinity (field)	16	58	18	87	36	71	7	25
Alkalinity (lab)	2.47	42.25	12.90	82.74	30.78	66.57	3.24	26.45
Hot Acidity	117.11	4.66	81.59	-73.04	54.90	-52.15	39.20	-12.81
T. Fe	0.25	0.19	0.16	0.05	0.56	0.07	0.44	0.10
D. Fe	0.23	0.13	0.10	0.02	0.48	0.06	0.34	0.02
T. Mn	64.83	30.78	55.12	9.84	47.44	8.77	20.41	8.59
D. Mn	63.83	30.14	54.89	9.78	46.38	8.67	19.82	7.77
T. Al	3.43	0.24	0.48	0.26	0.38	0.23	2.19	0.25
D. Al	3.25	0.09	0.13	0.08	0.30	0.15	0.93	0.18
SO4	1279.8	1297.1	1308.3	1322.0	1131.7	1123.9	538.6	519.5

Flow in gallons per minute; pH in standard units; ORP in mV; Dissolved Oxygen in mg/L; Alkalinity and Acidity in mg/L as $CaCO_3$; Total (T) and Dissolved (D) Metals in mg/L; Sulfates in mg/L;

As illustrated in the above table, the influent to the HFLB is consistently an alkaline, circumneutral, net-acidic, manganese-bearing (20 to 65 mg/L) drainage with low dissolved concentrations of iron and aluminum. On days 24, 64, and 118, the effluent is characterized as net-alkaline with dissolved manganese concentrations <10 mg/L. Post-rehabilitation monitoring indicates that, on average, the manganese concentration is decreased by about 32 mg/L (70%) compared with the average of 12 mg/L (35%) removed prior to rehabilitation. Further, a comparison of the loading reductions indicates that in the spring of 2007 prior to rehabilitation, the HFLB was removing about 30% of the manganese loading while post-rehabilitation monitoring indicates a 75% loading reduction.

Prior to rehabilitation, the water level in the HFLB was at or near the surface across the entire length of the bed. (See Figure 1.) The manganese removal rate was calculated as 0.008 pounds/day/ton of stone. The hydraulic gradient was significantly increased from the rehabilitation effort, which resulted in less limestone being utilized for treatment. (See Figure 1.) Based on the gradient and other factors, a rough calculation indicates that only about 2/3 of the treatment media is currently being used. The manganese removal rate is currently 0.012 pounds/day/ton of stone effectively twice that pre-rehabilitation. Review of pre- and post-rehabilitation conditions indicates that the efficacy of the HFLB has improved. Additional monitoring and evaluation is recommended to further document and verify the long-term improvement.

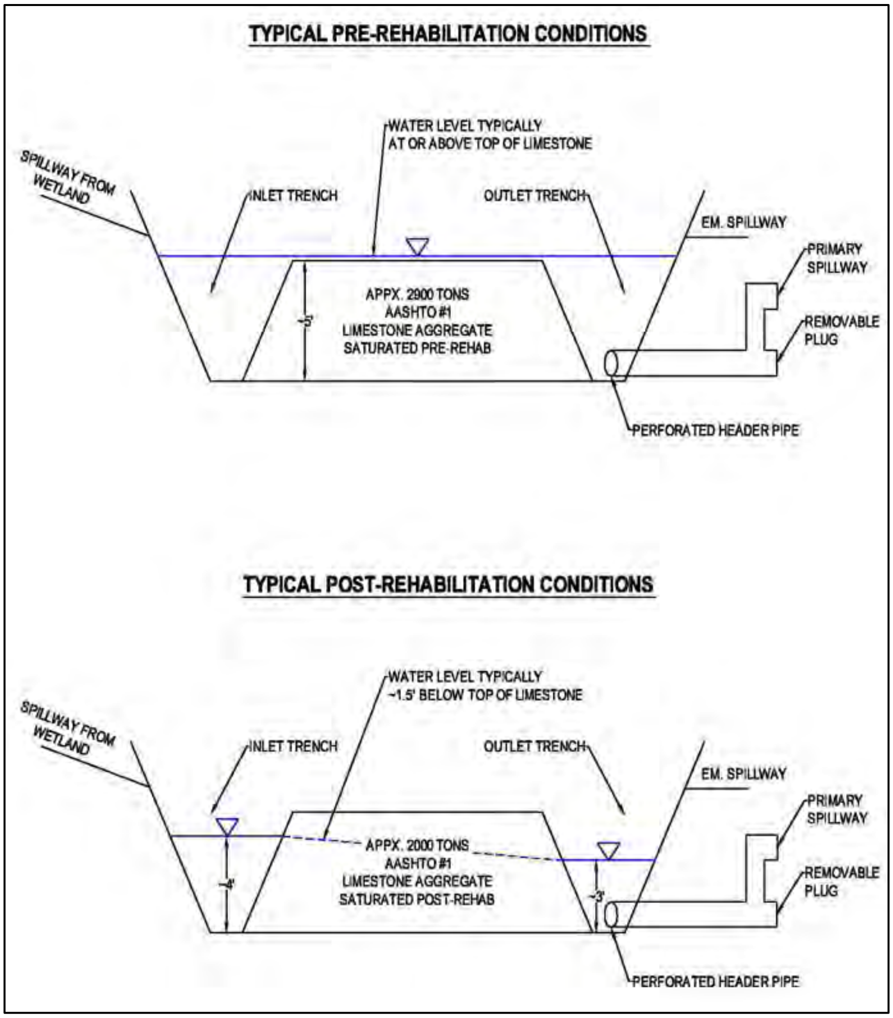


Figure 1: Comparison of Pre- and Post- Rehabilitation HFLB Conditions

RECOVERED MATERIAL ANALYSIS and CHARACTERIZATION

Particle-Size Distribution (Sieve) Analysis (Size Consist)

Samples from 4 of the 32 totes representing both the pumped slurry and the excavated residual material were collected for particle-size distribution (sieve) analysis. (See Table 7 and Attachments 1 and 2.) Totes 6 and 15 were sampled to characterize the slurry transferred from Wash Pit 1 and 2, respectively, using a 3-inch trash pump with (Tote 6) and without (Tote 15) a screen attached to the intake hose. Totes 22 and 32 were sampled to characterize the residual material transferred from Wash Pit 2 and 1, respectively, using an excavator bucket and hand shovel. The top-size of all material was assumed to be 3/8": the size opening of the screen used on the excavator attachment. The measured (mass) weight, % retained, and % cumulative for each size fraction are shown on Attachments 1 & 2. A summary table is provided below of the percentage by weight for each size fraction and for each tote sample.

Table 7: Particle-Size Distribution for Samples from Totes 6, 15, 22, 32

Size Fraction	**% by weight** (individual size fractions)			
	Tote 6	**Tote 15**	**Tote 22**	**Tote 32**
	Slurry; w/screen	Slurry; w/o screen	Residual	Residual
$^3/_8$"x¼"	0.00	0.23	14.48	19.16
¼"x4M	0.01	0.22	10.37	7.57
4Mx8M	0.07	0.65	19.73	12.01
8Mx10M	0.08	0.78	6.73	4.36
10Mx16M	0.12	1.61	5.89	6.48
16Mx20M	1.45	2.79	5.44	6.07
20Mx40M	9.29	18.24	11.15	11.97
40Mx60M	8.21	11.41	6.27	7.98
60Mx140M	13.42	12.47	7.15	6.02
140Mx200M	9.57	6.35	2.56	3.17
200Mx325M	12.20	10.98	2.32	4.17
325Mx0	45.58	34.27	7.91	11.04
Total	100.00	100.0	100.00	100.00

Tote 6 (Bucket B) slurry from Wash Pit 1 pumped to Tote 6 using screened intake hose; Tote 15 (Bucket B) slurry from Wash Pit 2 pumped to Tote 15 unscreened intake hose; Tote 22 (Bucket B) residual material transferred from Wash Pit 2 by excavator bucket and hand shovel. Tote 32 (Bucket B) residual material transferred from Wash Pit 1 by excavator bucket and hand shovel.

The sieve analyses identify that there was <1% of the slurry material in both Totes 6 and 15 in the individual size fractions above +10M, indicating a similar recovery when using either a screened or unscreened intake hose. The analyses also show that the smallest size fractions (-40M) for the slurry comprise a greater proportion (by weight) compared to the residual.

With settling and by excavating instead of pumping, the residual material (Totes 22 & 32) recovered from the wash pits with an excavator bucket and by hand-shoveling contained in both cases significant quantities (by weight) of larger-sized material ~40% to 45% above +4M on a cumulative basis compared to the slurry. The $^3/_8$"x¼" split alone contained ~15 to ~20% of the material.

Visual Examination

A visual examination of the size fractions was then conducted to determine if the larger-sized material was represented by limestone fragments or other materials that may be responsible for diluting the concentration of the manganese oxides. Each size fraction from the sieve analysis for samples collected from Totes 6, 15, 22 and 32 was

Attachment 1: Compiled Recovered Manganese & Iron Crystalline Phases & Major Oxides

pumped material w/ or w/o intake screen = **as-recovered slurry**	dug material = **as-recovered residual**

Sample ID	Size Fraction	Description	Crystalline Phases (XRD)	Lab	Sieve Analysis			Major Oxides (as percent)																					
					G&C	G&C	G&C	SiO2	Al2O3	Fe2O3	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	Cr2O3	SO3	Cl	V2O5	SrO	CoO	NiO	ZnO	Y2O3	BaO	LOI	Total
					g	%	%Cum	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
BULK/MISC.																													
5A1	bulk	WP1; pumped; intake screen; Tote 5	quartz; calcite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				22.20	13.20	5.84	22.50	0.87	10.10	0.14	1.11	0.30	0.35		1.21	<0.01		0.03	0.31	0.23	0.27	0.04	0.09	21.20	99.99
14A1	bulk	WP2; pumped; no intake screen; Tote10 split	quartz; calcite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				24.80	11.90	3.41	23.10	1.04	12.00	0.19	1.09	0.32	0.20		0.63	0.02		0.03	0.20	0.22	0.24	0.03	0.07	20.60	100.09
25A1	bulk	WP2; dug; placed on Tarp1; Tote 25	quartz; calcite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				18.60	8.41	2.33	26.60	0.96	10.40	0.19	0.72	0.23	0.14		0.61	0.02	<0.01	0.03	0.23	0.23	0.26	0.03	0.07	30.00	100.06
28A1	bulk	WP1, dug; placed on Trap1; Tote 28	quartz; calcite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				16.20	9.55	3.95	21.30	0.78	13.70	0.16	0.78	0.21	0.26		0.83	<0.01		0.04	0.27	0.18	0.21	0.03	0.08	31.50	100.03
DS2-1	bulk	handpicked from De Sale Phase 2 HFLB prior to full-scale recovery effort		ACT				4.56	1.43	15.45	49.90	0.70	7.27	0.15	0.11	0.057	0.02											20.29	99.94
Erico-1	bulk	handpicked from Erico Bridge HFLB pipe		ACT				3.48	1.57	0.79	64.70	0.74	6.34	0.18	0.28	0.056	0.02											21.88	100.04
TOTE 6	WP1; pumped; intake screen																												
6A1	bulk	WP1; pumped; intake screen; Tote 6	calcite magnesian; qtz; muscovite; staurolite(?); unidentified	ACT				21.31	10.82	6.19	24.97	0.78	10.00	0.11	1.02	0.326	0.36											23.13	99.02
6C1	bulk	WP1; pumped; intake screen; Tote 6	quartz; calcite; muscovite; birnessite; amorphous (todorokie? or buserite?)	RJL				22.70	13.50	6.19	20.50	0.84	10.60	0.16	1.18	0.33	0.38		1.11	0.02		0.03	0.29	0.21	0.27	0.04	0.08	21.60	100.03
6B	+1/4"			G&C	0.0	0.00	0.00																						
6B	1/4"x4M	LS?; dk-brn (10/25/07 viewed in bag)		G&C	1.2	0.01	0.01																						
6B	4Mx8M	LS? (65%) w/min.Mn; dk-brn; veg(35%); lt-brn, w/min. Mn (10/25/07 viewed in bag)		G&C	7.2	0.07	0.08																						
6B	8Mx10M	LS? (60%) rare bony?(blk); min. Mn; md- to dk-brn; veg (40%); lt-brn (10/25/07 viewed in bag)		G&C	8.0	0.08	0.16																						
6B	10Mx16M	LS? (50%); rare bony?(blk); min. Mn; md- to dk-brn; veg (50%); lt-brn (10/25/07 viewed in bag)		G&C	12.2	0.12	0.28																						
6B1	16Mx20M	LS? (95%); min. Mn; md- to dk-brn; veg (5%); lt-brn (10/25/07 viewed in bag)		G&C + ACT	147.7	1.45	1.73	20.30	10.82	5.99	28.18	0.77	9.44	0.12	1.10	0.320	0.37											23.50	100.90
6B2	20Mx40M	LS? (99%); min. Mn; md- to dk-brn; veg (1%); lt-brn (10/25/07 viewed in bag)		G&C + ACT	943.8	9.29	11.02	20.05	10.74	5.95	27.82	0.76	9.17	0.10	1.11	0.318	0.37											23.43	99.81
6B3	40Mx60M	LS? (99%); some Mn; dk-brn; veg (<1%); lt-brn (10/25/07 viewed in bag)		G&C + ACT	834.0	8.21	19.23	19.90	10.77	5.99	27.69	0.76	8.88	0.10	1.01	0.319	0.37											23.52	99.30
6B4	60Mx140M	LS? ; sig. Mn?; v. dk-brn; veg (<1%); lt-brn (+150 mesh on bag) (10/25/07 viewed in bag)		G&C + ACT	1363.4	13.42	32.65	17.48	10.01	5.59	34.08	0.78	7.63	0.07	1.03	0.273	0.35											23.37	100.70
6B5	140Mx200M	Mn? (99%); v. dk-brn to blk (10/25/07 viewed in bag)		G&C + ACT	972.9	9.57	42.22	19.78	10.47	6.00	28.92	0.78	7.88	0.09	1.00	0.299	0.35											23.26	98.83
6B6	200Mx325M	Mn? (99%); v. dk-brn to blk (10/25/07 viewed in bag)		G&C + ACT	1239.3	12.20	54.42	19.48	10.16	5.73	30.68	0.75	7.78	0.08	0.98	0.286	0.34											22.72	98.99
6B7	325Mx0	Mn? (99%); v. dk-brn to blk (10/25/07 viewed in bag)		G&C + ACT	4631.3	45.58	100.00	23.16	10.81	6.32	19.48	0.75	12.43	0.12	1.13	0.347	0.36											23.62	98.54
Total					10161.0	100.00																							
TOTE 15	WP2; pumped; no intake screen; Tote11 split																												
15A1	bulk	WP2; pumped; no screen; Tote11 split	calcite magnesian; quartz; muscovite; staurolite(?); unidentified	ACT				24.69	8.71	3.49	25.73	0.86	12.90	0.14	0.94	0.360	0.19											20.94	98.96
15A1	bulk	WP2; pumped; no screen; Tote11 split	quartz; calcite;muscovite; birnesite; johannsenite	ACT																									
15C1	bulk	WP2; pumped; no screen; Tote11 split; material very wet from precipitation - uncovered	quartz; calcite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				24.40	12.00	3.52	22.90	1.02	12.20	0.18	1.09	0.32	0.22		0.52	0.02		0.03	0.20	0.22	0.26	0.03	0.07	20.80	100.00
15B	+1/4"	LS; md-gy; "dirty" Mn fines on stone (10/25/07 viewed in bag)		G&C	24.3	0.23	0.23																						
15B	1/4"x4M	LS; md-gy; "dirty" Mn fines on stone?; 5% veg; md-brn (10/25/07 viewed in bag)		G&C	22.7	0.22	0.45																						
15B	4Mx8M	LS; dk-brn; "dirty" Mn fines on stone?; 5% veg; md-brn (10/25/07 viewed in bag)		G&C	68.4	0.65	1.10																						
15B	8Mx10M	LS and/or Mn (80%); 20% LS w/sig Mn; dk-brn; veg (<<1%); lt-brn (10/25/07 viewed in bag)		G&C	82.8	0.78	1.88																						
15B	10Mx16M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)		G&C	169.3	1.61	3.49																						
15B	16Mx20M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)		G&C	293.7	2.79	6.28																						
15B	20Mx40M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)		G&C	1919.4	18.24	24.52																						
15B	40Mx60M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)		G&C	1200.6	11.41	35.93																						
15B	60Mx140M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)		G&C	1312.5	12.47	48.40																						
15B	140Mx200M	Mn (95%); v. drk-gy to blk; 1% unk. material; lt-brn (10/25/07 viewed in bag)		G&C	668.3	6.35	54.75																						
15B	200Mx325M	Mn (95%); v. drk-gy to blk; 1% unk. material; lt-brn (10/25/07 viewed in bag)		G&C	1155.6	10.98	65.73																						
15B	325Mx0	Mn (95%); v. dk-brn to blk (some chunks from drying) (10/25/07 viewed in bag)		G&C	3606.9	34.27	100.00																						
Total					10524.5	100.0																							
TOTE 22	WP2; dug; placed on Tarp2; (pumped out WP2 prior to excavating & placement on Tarp2)																												
22A1	bulk	WP2; dug; placed on Tarp2 (pumped out WP2 prior to excavating & placement on Tarp2); Tote 22	quartz, calcite magnesian; muscovite; kaolinite	ACT				42.31	7.07	3.26	18.10	0.71	11.13	0.15	1.18	0.536	0.11											16.34	100.90
22C1	bulk	WP2; dug; placed on Tarp2 (pumped out WP2 prior to excavating & placement on Tarp2); Tote 22	quartz; calcite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				24.70	9.80	3.08	14.80	0.84	15.40	0.22	1.00	0.38			0.43	0.02	<0.01	0.04	0.13	0.12	0.15	<0.01	0.07	28.70	99.88
22B1	+1/4"	LS; md-gy & md-brn; Mn fines on stone (10/25/07 viewed in bag)		G&C + ACT	1977.4	14.48	14.48	3.10	0.78	0.92	0.12	0.49	53.20	0.02	0.13	0.030	0.05											41.44	100.30
22B2	1/4"x4M	LS; predominantly clean, md-gy; some Mn fines on stone (10/25/07 viewed in bag)		G&C + ACT	1415.4	10.37	24.85	12.07	3.33	2.83	11.61	0.61	35.92	0.04	0.50	0.161	0.11											31.21	98.40
22B3	4Mx8M	LS; predominantly clean, md-gy; some Mn fines on stone (10/25/07 viewed in bag)		G&C + ACT	2694.8	19.73	44.58	7.97	1.91	1.55	0.24	0.60	47.79	0.05	0.19	0.093	0.08											39.04	99.51
22B4	8Mx10M	LS (98%);Mn on 50+% of stone; md- to dk-gy (10/25/07 viewed in bag)		G&C + ACT	918.6	6.73	51.31	11.79	3.09	2.88	5.27	0.56	42.26	0.04	0.45	1.158	0.11											34.06	100.70
22B5	10Mx16M	LS (50%) ang.; 50% Mn coated rounded globs; dk-brn; veg (<1%); lt-brn (10/29/07 viewed in hand)		G&C + ACT	804.4	5.89	57.20	10.39	2.11	1.83	0.37	0.47	46.51	0.02	0.21	0.105	0.07											37.03	99.14
22B6	16Mx20M	LS (40%) ang.; 40% Mn coated rd globs; dk-brn; veg (<1%); lt-brn; 10% qtz (10/29/07 viewed in hand)		G&C + ACT	743.0	5.44	62.64	10.49	2.50	2.38	1.91	0.52	44.70	0.03	0.23	0.132	0.10											35.85	98.85
22B7	20Mx40M	LSand/orMn(80%); 20%LSsig Mn; dk-brn; 20%LSminMn; lt-gy; veg (<<1%); lt-brn (10/25/07 in bag)		G&C + ACT	1522.2	11.15	73.79	14.84	4.01	3.12	16.76	0.74	31.21	0.09	0.32	0.167	0.08											26.97	98.31
22B8	40Mx60M	Mn(80%); 20%LSsigMn; dk-brn; 5%LSminMn; lt-gy; veg(<<1%);lt-brn;qtz xls; lt-brn (11/1/07 in hand)		G&C + ACT	856.0	6.27	80.06	22.54	4.34	3.25	21.32	0.72	23.74	0.07	0.54	0.208	0.16											23.61	100.50
22B9	60Mx140M	Mn(80%); 20%LSsig Mn; dk-brn; 5%LSminMn; lt-gy; veg(<<1%); lt-brn; qtz xls; lt-brn (11/1/07 in hand)		G&C + ACT	976.5	7.15	87.21	48.18	5.27	3.10	11.29	0.52	13.70	0.04	0.73	0.379	0.10											16.31	99.62
22B10	140Mx200M	Mn(50%); 20% LSsigMn; dk-brn; 5%LSminMnlt-gy; veg(<<1%); lt-brn; 30%qtz xls; tan (11/1/07 in		G&C + ACT	349.3	2.56	89.77	47.41	6.29	3.06	14.27	0.58	11.14	0.07	0.82	0.537	0.10											14.79	99.07
22B11	200Mx325M	Mn(50%); 20%LSsigMn; dk-brn; 5%LSminMn; lt-gy; veg (<<1%); lt-brn; 30%qtz xls; tan (11/1/07 in		G&C + ACT	316.8	2.32	92.09	40.48	7.21	3.19	22.13	0.72	9.94	0.14	0.97	0.566	0.12											15.51	101.00
22B12	325Mx0	Mn? (95%); v. dk-brn to blk (chunky from drying) (11/1/07 in hand)		G&C + ACT	1080.0	7.91	100.00	32.07	10.58	4.15	18.29	0.88	11.58	0.25	1.58	0.576	0.17											18.96	99.08
Total					13654.4	100.00																							
TOTE 32	WP1; dug; placed on Tarp1 (portion of WP1 pumped out prior to excavation & placement on Tarp1)																												
32A1	bulk	WP1; dug; placed on Tarp1 (portion of WP1 pumped out prior to excavation & placement on Tarp1)	quartz, calcite magnesian; muscovite; kaolinite, unidentified	ACT				21.11	8.84	5.15	29.33	0.81	11.18	0.10	0.97	0.307	0.29											21.85	99.93
32C1	bulk	WP1; dug; placed on Tarp1	quartz; calcite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				18.50	10.70	4.15	21.50	0.83	9.50	0.16	0.86	0.23	0.29		0.69	<0.01		0.03	0.28	0.19	0.23	0.03	0.07	31.80	100.04
32B	+1/4"	LS; "dirty", md-gy & md-brn; Mn fines on stone; min. veg. (10/25/07 viewed in bag)		G&C	2050.7	19.16	19.16																						
32B	1/4"x4M	LS; "dirty", md-gy & md-brn; Mn fines on stone; min. veg. (10/25/07 viewed in bag)		G&C	810.3	7.57	26.73																						
32B	4Mx8M	LS? (98%) some Mn on stone; dk-brn; veg (<1); lt-brn (10/25/07 viewed in bag)		G&C	1286.0	12.01	38.74																						
32B	8Mx10M	LS? (98%);Mn on 50+% of stone; "dirty" md-gy to dk-brn; min. veg. (10/25/07 viewed in bag)		G&C	466.6	4.36	43.10																						
32B	10Mx16M	LS? (98%); 88% Mn coated; dk-brn; 10%minMn; lt-gy; veg(<1%); lt-brn (10/25/07 viewed in bag)		G&C	694.2	6.48	49.58																						
32B	16Mx20M	LS? (98%); 88% Mn coated; dk-brn; 10%minMn; lt-gy; veg (<1%); lt-brn (10/25/07 viewed in bag)		G&C	650.3	6.07	55.65																						
32B	20Mx40M	Mn (70%); 20%LS w/sig Mn; dk-brn; 10%LS w/min. Mn; lt-gy; veg (<1%); lt-brn (10/25/07 viewed in		G&C	1281.1	11.97	67.62																						
32B	40Mx60M	Mn (80%); 20%LS sig Mn; dk-brn; 5%LS w/min. Mn; lt-gy; veg (<<1%); lt-brn (10/25/07 viewed in bag)		G&C	853.9	7.98	75.60																						
32B	60Mx140M	Mn (80%); 20%LS sig Mn; dk-brn; 5%LS w/min. Mn; lt-gy; veg (<<1%); lt-brn (10/25/07 viewed in bag)		G&C	645.0	6.02	81.62																						
32B	140Mx200M	Mn? (95%); v. dk-brn to blk; 5% unk. material lt-brn (10/25/07 viewed in bag)		G&C	339.0	3.17	84.79																						
32B	200Mx325M	Mn? (95%); v. dk-brn to blk; <5% unk. material lt-brn (10/25/07 viewed in bag)		G&C	446.8	4.17	88.96																						
32B	325Mx0	Mn? (99%); v. dk-brn to blk (chunky from drying) (10/25/07 viewed in bag)		G&C	1182.0	11.04	100.00																						
Total					10705.9	100.00																							
Processed	Samples of Mn material following some level of post-recovery processing																												
MN1	60M x 0	Tote 15 Bucket A & Tote 32 Bucket A, dried, screened, crushed, & seived by Tom Grote, BMI	quartz; calcite;muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				23.30	12.50	4.29	24.00	1.04	11.20	0.19	1.11	0.30	0.25		0.90	<0.01	<0.01	0.03	0.26	0.23	0.28	0.04	<0.01	20.00	99.92
MN2	60M x 0	Tote 15 Bucket A & Tote 32 Bucket A, dried, screened, crushed, & seived by Tom Grote, BMI	quartz; calcite;muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				23.70	12.10	4.22	23.70	0.98	11.30	0.20	1.10	0.310	0.26		0.89	0.09	<0.01	0.03	0.26	0.23	0.28	0.04	<0.01	20.30	99.99
Commercial																													
COM1	60/90mesh	purchased from Standard Ceramic Supply Company Pgh,PA	pyro; crypt; qtz; unk; RJL - pyro; qtz; crypt; birn; amorphous (tod? or bus?)	ACT				3.97	2.44	4.08	44.10	0.26	0.12	0.18	0.82	0.134	0.18											11.32	67.61
COM1 (rev.)	60/90mesh	purchased from Standard Ceramic Supply Company Pgh,PA	pyro; crypt; qtz; unk; RJL - pyro; qtz; crypt; birn; amorphous (tod? or bus?)	ACT				4.32	2.16	4.36	72.36	0.01	0.20	0.28	0.68	0.160	0.20	0.04										11.24	95.88
COM1A	60/90mesh	purchased from Standard Ceramic Supply Company Pgh,PA	pyrolusite; qtz; cryptomelane; birnessite; amorphous (tod? or bus?)	RJL				4.77	2.83	4.79	72.50	0.21	0.08	0.16	0.81	0.13	0.14		<0.01	<0.01	0.08	0.08	0.03	<0.01	0.03	<0.01	1.29	12.00	99.93
COM2	200mesh	purchased from Standard Ceramic Supply Company Pgh,PA	nsutite; pennantite; crypt; lithophorite; unidentified	ACT				2.18	4.51	4.47	41.85	0.26	0.22	0.07	0.92	0.246	0.24											12.60	67.56
COM2 (rev.)	200mesh	purchased from Standard Ceramic Supply Company Pgh,PA	nsutite; pennantite; crypt; lithophorite; unidentified	ACT				2.12	4.16	4.92	70.00	<.0.01	0.28	0.28	1.72	1.240	0.24	<0.01										12.69	95.54
COM3	granular	purchased from Ceramic Supply Lodi, NJ		ACT				3.96	2.40	4.01	42.79	0.26	0.10	0.21	0.79	0.124	0.13											11.28	66.04
COM3 (rev.)	granular	purchased from Ceramic Supply Lodi, NJ		ACT				4.12	2.04	4.48	72.80	<.0.01	0.20	0.32	0.64	0.160	0.20	<0.01										11.26	96.06
COM4	powder	purchased from Ceramic Supply Lodi, NJ		ACT				2.12	4.39	4.31	41.32	0.26	0.24	0.10	0.86	0.220	0.19											12.69	66.71
COM4 (rev.)	powder	purchased from Ceramic Supply Lodi, NJ		ACT				2.08	4.04	4.65	70.66	0.06	0.24	0.20	0.55	0.220	1.24	<0.01										12.63	95.60
Iron																													
DS2FE1	bulk	DS2; top of VFPW	goethite; quartz	ACT				8.10	3.12	63.63	0.41	0.16	0.11	0.04	0.28	0.134	0.14											23.59	99.71
DS2FE2	60Mx0	DS2; top of VFPW; dried, crushed, sieved by TG	quartz; goethite; muscovite; birnessite; amorphous (todorokite? or buserite?)	RJL				13.20	4.98	54.80	0.06	0.21	0.04	0.10	0.67	0.20	0.24		3.56	0.02		<0.01	<0.01	<0.01	0.01	<0.01	<0.01	21.9	99.99
DS1FE1	bulk	DS1; forebay	amorphous	RJL				0.46	0.25	54.50	0.03	0.12	0.09	0.12	0.03	<0.01	0.10		10.30	0.02		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	33.9	99.92
Com5A	bulk?	Red Iron Oxide (Standard Ceramic Supply Co., Pgh, PA)	hematite; quartz; chlorite; muscovite; birnessite	RJL				13.30	4.64	76.30	0.50	1.64	0.70	<0.01	0.23	0.17	0.20		0.02	0.02		<0.01	0.15	<0.01	<0.01	<0.01	<0.01	2.1	99.97
Com6A	bulk?	Yellow Iron Oxide (Standard Ceramic Supply Co., Pgh, PA)	goethite	RJL				0.04	0.04	87.30	0.04	<0.01	0.03	0.14	<0.01	0.03	<0.01		0.55	0.03		<0.01	0.15	<0.01	0.02	<0.01	<0.01	11.6	99.97

Co., Date, Rept.#, Analyses: **ACT**: A07-1476 bulk chemical composition (oxides) & elements (2 samples) - 5/23/07; A07-5811 bulk chemical composition (oxides) & elements (30 samples)-
2/7/08 (i)rev2 Rev 2; 2/22/08 (i); 3/28/08 (i) rev1 REV, 1; crystalline phases (XRD) (7 samples) - 1/10/08, 3/10/08; **G&C**: particle-size distribution - 10/11/07; **RJL**: bulk chemical composition (oxides) - 4/1/08; crystalline phases (XRD) - 4/1/08

bulk - refers to a sample which is "as is" and is not a sieve fraction nor has been further processed; rev. - data revised by ACT Labs following data analysis

Attachment 2: Compiled Recovered Manganese & Iron Elemental Analyses

pumped material w/ or w/o intake screen = **as-recovered slurry**	dug material = **as-recovered residual**

Sample ID	Size Fraction	Description	Lab	Sieve Analysis G&C g	G&C %	G&C %Cum	Au ppb INAA	Ag ppm ULT INAA/TD-ICP	As ppm INAA	Ba ppm ULT INAA/FUSICP	Be ppm FUS-ICP	Bi ppm TD-ICP	Br ppm INAA	Cd ppm TD-ICP	Co ppm INAA	Cr ppm INAA	Cs ppm INAA	Cu ppm TD-ICP	Hf ppm INAA	Hg ppm INAA	Ir ppb INAA	Mo ppm TD-ICP	Ni ppm TD-ICP
BULK/MISC.																							
5A1	bulk	WP1; pumped; intake screen; Tote 5	RJL						15.4	498				3.3	2510	11		37.7		0.0606			1540
14A1	bulk	WP2; pumped; no intake screen; Tote10 split	RJL						11.7	481				2.8	1890	12.9		27.4		0.057			1600
25A1	bulk	WP2; dug; placed on Tarp1; Tote 25	RJL						14.2	457				2.9	2110	24.7		27.5		0.0471			1710
28A1	bulk	WP1, dug; placed on Trap1; Tote 28	RJL						15.2	538				2.4	2310	9.35		26.3		0.0507			1320
DS2-1	bulk	handpicked from De Sale Phase 2 HFLB prior to full-scale recovery effort	ACT				<1	<0.5	5	257	<1	3	2.2	<0.5	1130	7	<0.2	4	0.4	<1	<1	8	1000
Erico-1	bulk	handpicked from Erico Bridge HFLB pipe	ACT				<1	<0.5	4	194	1	3	2.6	1.8	1160	<0.5	1.5	4	0.9	<1	<1	14	1190
TOTE 6	WP1; pumped; intake screen																						
6A1	bulk	WP1; pumped; intake screen; Tote 6	ACT				< 5	< 0.5	25	584	12	< 2	6	< 0.5	1840	45	3.8	< 1	1.9	< 1	< 5	< 2	< 1
6C1	bulk	WP1; pumped; intake screen; Tote 6	RJL						17.4	416				3.4	2220	11.4		42.2		0.101			1450
6B	+1/4"		G&C	0.0	0.00	0.00																	
6B	1/4"x4M	LS?; dk-brn (10/25/07 viewed in bag)	G&C	1.2	0.01	0.01																	
6B	4Mx8M	LS? (65%) w/min.Mn; dk-brn; veg(35%); lt-brn, w/min. Mn (10/25/07 viewed in bag)	G&C	7.2	0.07	0.08																	
6B	8Mx10M	LS? (60%) rare bony?(blk); min. Mn; md- to dk-brn; veg (40%); lt-brn (10/25/07 viewed in bag)	G&C	8.0	0.08	0.16																	
6B	10Mx16M	LS? (50%); rare bony?(blk); min. Mn; md- to dk-brn; veg (50%); lt-brn (10/25/07 viewed in bag)	G&C	12.2	0.12	0.28																	
6B1	16Mx20M	LS? (95%); min. Mn; md- to dk-brn; veg (5%); lt-brn (10/25/07 viewed in bag)	G&C + ACT	147.7	1.45	1.73	5	4.4	24	630	12	11	5	2.1	2140	49	4.2	41	<0.5	< 1	< 5	4	1430
6B2	20Mx40M	LS? (99%); min. Mn; md- to dk-brn; veg (1%); lt-brn (10/25/07 viewed in bag)	G&C + ACT	943.8	9.29	11.02	< 5	4.6	26	612	12	9	7	1.9	2130	41	4.2	43	1.8	< 1	< 5	4	1440
6B3	40Mx60M	LS? (99%); some Mn; dk-brn; veg (<1%); lt-brn (10/25/07 viewed in bag)	G&C + ACT	834.0	8.21	19.23	< 5	4.1	25	618	12	10	5	2.0	2090	42	3.9	41	2.1	< 1	< 5	4	1410
6B4	60Mx140M	LS? ; sig. Mn?; v. dk-brn; veg (<1%); lt-brn (+150 mesh on bag) (10/25/07 viewed in bag)	G&C + ACT	1363.4	13.42	32.65	6	7.0	27	686	12	14	6	1.9	2680	51	4.5	44	1.7	< 1	< 5	4	1700
6B5	140Mx200M	Mn? (99%); v. dk-brn to blk (10/25/07 viewed in bag)	G&C + ACT	972.9	9.57	42.22	<5	5.8	24	700	12	12	<1	2.2	2690	38	<0.5	57	1.7	<1	<5	5	1610
6B6	200Mx325M	Mn? (99%); v. dk-brn to blk (10/25/07 viewed in bag)	G&C + ACT	1239.3	12.20	54.42	< 5	5.0	22	629	12	11	6	1.8	2390	40	2.9	69	2.2	< 1	< 5	4	1490
6B7	325Mx0	Mn? (99%); v. dk-brn to blk (10/25/07 viewed in bag)	G&C + ACT	4631.3	45.58	100.00	< 5	2.5	27	500	11	6	6	1.7	1470	46	4.2	82	2.5	< 1	< 5	3	1180
Total				10161.0	100.00																		
TOTE 15	WP2; pumped; no intake screen; Tote11 split																						
15A1	bulk	WP2; pumped; no screen; Tote11 split	ACT				< 5	< 0.5	22	615	9	< 2	< 1	< 0.5	1270	71	3.2	< 1	3.3	< 1	< 5	< 2	< 1
15A1	bulk	WP2; pumped; no screen; Tote11 split	ACT																				
15C1	bulk	WP2; pumped; no screen; Tote11 split; material very wet from precipitation - uncovered	RJL						13.4	434				2.8	1800	16		28.1		0.060			1630
15B	+1/4"	LS; md-gy; "dirty" Mn fines on stone (10/25/07 viewed in bag)	G&C	24.3	0.23	0.23																	
15B	1/4"x4M	LS; md-gy; "dirty" Mn fines on stone?; 5% veg; md-brn (10/25/07 viewed in bag)	G&C	22.7	0.22	0.45																	
15B	4Mx8M	LS; dk-brn; "dirty" Mn fines on stone?; 5% veg; md-brn (10/25/07 viewed in bag)	G&C	68.4	0.65	1.10																	
15B	8Mx10M	LS and/or Mn (80%); 20% LS w/sig Mn; dk-brn; veg (<<1%); lt-brn (10/25/07 viewed in bag)	G&C	82.8	0.78	1.88																	
15B	10Mx16M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)	G&C	169.3	1.61	3.49																	
15B	16Mx20M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)	G&C	293.7	2.79	6.28																	
15B	20Mx40M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)	G&C	1919.4	18.24	24.52																	
15B	40Mx60M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)	G&C	1200.6	11.41	35.93																	
15B	60Mx140M	LS and/or Mn (80%); 20% LS sig Mn; dk-brn; 5% unk.; lt-brn (10/25/07 viewed in bag)	G&C	1312.5	12.47	48.40																	
15B	140Mx200M	Mn (95%); v. drk-gy to blk; 1% unk. material; lt-brn (10/25/07 viewed in bag)	G&C	668.3	6.35	54.75																	
15B	200Mx325M	Mn (95%); v. drk-gy to blk; 1% unk. material; lt-brn (10/25/07 viewed in bag)	G&C	1155.6	10.98	65.73																	
15B	325Mx0	Mn (95%); v. dk-brn to blk (some chunks from drying) (10/25/07 viewed in bag)	G&C	3606.9	34.27	100.00																	
Total				10524.5	100.0																		
TOTE 22	WP2; dug; placed on Tarp2; (pumped out WP2 prior to excavating & placement on Tarp2)																						
22A1	bulk	WP2; dug; placed on Tarp2 (pumped out WP2 prior to excavating & placement on Tarp2); Tote 22	ACT				< 5	< 0.5	19	974	5	< 2	< 1	< 0.5	911	66	< 0.5	< 1	6.5	< 1	< 5	< 2	< 1
22C1	bulk	WP2; dug; placed on Tarp2 (pumped out WP2 prior to excavating & placement on Tarp2); Tote 22	RJL						10.4	321				1.6	979	7.56		17.4		0.0521			858
22B1	+1/4"	LS; md-gy & md-brn; Mn fines on stone (10/25/07 viewed in bag)	G&C + ACT	1977.4	14.48	14.48	< 5	< 0.5	10	41	< 1	< 2	< 1	< 0.5	4	7	< 0.5	4	< 0.5	< 1	< 5	< 2	8
22B2	1/4"x4M	LS; predominantly clean, md-gy; some Mn fines on stone (10/25/07 viewed in bag)	G&C + ACT	1415.4	10.37	24.85	< 5	1.3	16	368	3	4	< 1	1.1	741	59	1.1	15	1.7	< 1	< 5	2	474
22B3	4Mx8M	LS; predominantly clean, md-gy; some Mn fines on stone (10/25/07 viewed in bag)	G&C + ACT	2694.8	19.73	44.58	< 5	< 0.5	12	606	< 1	< 2	< 1	< 0.5	9	47	0.7	7	0.9	< 1	< 5	2	16
22B4	8Mx10M	LS (98%);Mn on 50+% of stone; md- to dk-gy (10/25/07 viewed in bag)	G&C + ACT	918.6	6.73	51.31	< 5	< 0.5	14	232		< 2	< 1	0.5	349	44	< 0.5	11	1.3	< 1	< 5	2	223
22B5	10Mx16M	LS (50%) ang.; 50% Mn coated rounded globs; dk-brn; veg (<1%); lt-brn (10/29/07 viewed in hand)	G&C + ACT	804.4	5.89	57.20	< 5	< 0.5	11	206	< 1	< 2	< 1	< 0.5	26	19	0.7	8	1.0	< 1	< 5	2	27
22B6	16Mx20M	LS (40%) ang.; 40% Mn coated rd globs; dk-brn; veg (<1%); lt-brn; 10% qtz (10/29/07 viewed in hand)	G&C + ACT	743.0	5.44	62.64	< 5	< 0.5	13	182	1	< 2	1	< 0.5	139	41	1.2	9	1.3	< 1	< 5	2	91
22B7	20Mx40M	LSand/orMn(80%); 20%LSsig Mn; dk-brn; 20%LSminMn; lt-gy; veg (<<1%); lt-brn (10/25/07 in bag)	G&C + ACT	1522.2	11.15	73.79				504	3	11		2.0				21				3	897
22B8	40Mx60M	Mn(80%); 20%LSsigMn; dk-brn; 5%LSminMn; lt-gy; veg(<<1%);lt-brn;qtz xls; lt-brn (11/1/07 in hand)	G&C + ACT	856.0	6.27	80.06				679	4	12		2.2				22				4	1060
22B9	60Mx140M	Mn(80%); 20%LSsig Mn; dk-brn; 5%LSminMn; lt-gy; veg(<<1%); lt-brn; qtz xls; lt-brn (11/1/07 in hand)	G&C + ACT	976.5	7.15	87.21	< 5	1.5	25	877	3	4	2	1.2	885	73	1.6	20	2.7	< 1	< 5	3	706
22B10	140Mx200M	Mn(50%); 20% LSsigMn; dk-brn; 5%LSminMnlt-gy; veg(<<1%); lt-brn; 30%qtz xls; tan (11/1/07 in	G&C + ACT	349.3	2.56	89.77	< 5	2.2	24	949	4	5	2	1.4	813	87	0.9	28	5.6	< 1	< 5	3	861
22B11	200Mx325M	Mn(50%); 20%LSsigMn; dk-brn; 5%LSminMn; lt-gy; veg (<<1%); lt-brn; 30%qtz xls; tan (11/1/07 in	G&C + ACT	316.8	2.32	92.09	< 5	3.3	21	1030	5	4	2	1.9	1070	84	2.7	54	13.6	< 1	< 5	3	1050
22B12	325Mx0	Mn? (95%); v. dk-brn to blk (chunky from drying) (11/1/07 in hand)	G&C + ACT	1080.0	7.91	100.00	6	3.1	21	679	7	5	6	1.5	903	64	4.4	48	6.0	< 1	< 5	4	1070
Total				13654.4	100.00																		
TOTE 32	WP1; dug; placed on Tarp1 (portion of WP1 pumped out prior to excavation & placement on Tarp1)																						
32A1	bulk	WP1; dug; placed on Tarp1 (portion of WP1 pumped out prior to excavation & placement on Tarp1)	ACT				< 5	4.8	27	996	10	12	< 1	1.8	2100	58	3.7	32	2.3	< 1	< 5	4	1410
32C1	bulk	WP1; dug; placed on Tarp1	RJL						16.6	487				2.5	2300	31.8		27.2		0.0432			1280
32B	+1/4"	LS; "dirty", md-gy & md-brn; Mn fines on stone; min. veg. (10/25/07 viewed in bag)	G&C	2050.7	19.16	19.16																	
32B	1/4"x4M	LS; "dirty", md-gy & md-brn; Mn fines on stone; min. veg. (10/25/07 viewed in bag)	G&C	810.3	7.57	26.73																	
32B	4Mx8M	LS? (98%) some Mn on stone; dk-brn; veg (<1); lt-brn (10/25/07 viewed in bag)	G&C	1286.0	12.01	38.74																	
32B	8Mx10M	LS? (98%);Mn on 50+% of stone; "dirty" md-gy to dk-brn; min. veg. (10/25/07 viewed in bag)	G&C	466.6	4.36	43.10																	
32B	10Mx16M	LS? (98%); 88% Mn coated; dk-brn; 10%minMn; lt-gy; veg(<1%); lt-brn (10/25/07 viewed in bag)	G&C	694.2	6.48	49.58																	
32B	16Mx20M	LS? (98%); 88% Mn coated; dk-brn; 10%minMn; lt-gy; veg (<1%); lt-brn (10/25/07 viewed in bag)	G&C	650.3	6.07	55.65																	
32B	20Mx40M	Mn (70%); 20%LS w/sig Mn; dk-brn; 10%LS w/min. Mn; lt-gy; veg (<1%); lt-brn (10/25/07 viewed in	G&C	1281.1	11.97	67.62																	
32B	40Mx60M	Mn (80%); 20%LS sig Mn; dk-brn; 5%LS w/min. Mn; lt-gy; veg (<<1%); lt-brn (10/25/07 viewed in bag)	G&C	853.9	7.98	75.60																	
32B	60Mx140M	Mn (80%); 20%LS sig Mn; dk-brn; 5%LS w/min. Mn; lt-gy; veg (<<1%); lt-brn (10/25/07 viewed in bag)	G&C	645.0	6.02	81.62																	
32B	140Mx200M	Mn? (95%); v. dk-brn to blk; 5% unk. material lt-brn (10/25/07 viewed in bag)	G&C	339.0	3.17	84.79																	
32B	200Mx325M	Mn? (95%); v. dk-brn to blk; <5% unk. material lt-brn (10/25/07 viewed in bag)	G&C	446.8	4.17	88.96																	
32B	325Mx0	Mn? (99%); v. dk-brn to blk (chunky from drying) (10/25/07 viewed in bag)	G&C	1182.0	11.04	100.00																	
Total				10705.9	100.00																		
Processed	Samples of Mn material following some level of post-recovery processing																						
MN1	60M x 0	Tote 15 Bucket A & Tote 32 Bucket A, dried, screened, crushed, & seived by Tom Grote, BMI	RJL						14.1	509				3.0	2160	18		31.6		0.0793			1630
MN2	60M x 0	Tote 15 Bucket A & Tote 32 Bucket A, dried, screened, crushed, & seived by Tom Grote, BMI	RJL						15.5	498				2.8	2010	17.8		30.4					1540
Commercial																							
COM1	60/90mesh	purchased from Standard Ceramic Supply Company Pgh,PA	ACT				< 5	20.3	56	7450	5	42	< 1	2.4	131	80	1.1	63	1.2	< 1	< 5	38	167
COM1 (rev.)	60/90mesh	purchased from Standard Ceramic Supply Company Pgh,PA	ACT				< 5	20.3	56	7450	5	42	< 1	2.4	131	80	1.1	63	1.2	< 1	< 5	38	167
COM1A	60/90mesh	purchased from Standard Ceramic Supply Company Pgh,PA	RJL						38.6	8240				1.1	107	11.8		65.2		0.0343			81.6
COM2	200mesh	purchased from Standard Ceramic Supply Company Pgh,PA	ACT				7	20.5	70	1170	3	40	< 1	5.2	244	28	4.4	594	0.9	< 1	< 5	98	708
COM2 (rev.)	200mesh	purchased from Standard Ceramic Supply Company Pgh,PA	ACT				7	20.5	70	1170	3	40	< 1	5.2	244	28	4.4	594	0.9	< 1	< 5	98	708
COM3	granular	purchased from Ceramic Supply Lodi, NJ	ACT				< 5	16.0	58	7750	4	44	< 1	2.1	131	83	1.3	64	1.3	< 1	< 5	38	173
COM3 (rev.)	granular	purchased from Ceramic Supply Lodi, NJ	ACT				< 5	16.0	58	7750	4	44	< 1	2.1	131	83	1.3	64	1.3	< 1	< 5	38	173
COM4	powder	purchased from Ceramic Supply Lodi, NJ	ACT				< 5	19.9	70	1240	3	1	< 1	5.1	237	24	4.5	571	0.9	< 1	< 5	97	708
COM4 (rev.)	powder	purchased from Ceramic Supply Lodi, NJ	ACT				< 5	20.2	70	1240	3	1	< 1	5.1	237	24	4.5	579	0.9	< 1	< 5	98	703
Iron																							
DS2FE1	bulk	DS2; top of VFPW	ACT				< 5	< 0.5	8	96	< 1	< 2	5	1.5	11	23	< 0.5	31	0.9	< 1	< 5	< 2	12
DS2FE2	60Mx0	DS2; top of VFPW; dried, crushed, sieved by TG	RJL						8.17	29				8.3	10.9	6.35		35.4		0.068			6.06
DS1FE1	bulk	DS1; forebay	RJL						8.27	<1.93				9.7	9.22	2.46		<2.89		<0.0314			4.13
Com5A	bulk?	Red Iron Oxide (Standard Ceramic Supply Co., Pgh. PA)	RJL						36.8	31.4				9.2	14	89.7		16.5		0.0442			17.2
Com6A	bulk?	Yellow Iron Oxide (Standard Ceramic Supply Co., Pgh. PA)	RJL						<4.95	<1.98				12.4	55.2	3.36		<2.97		<0.0333			55.1

Sample ID	Size Fraction	Pb ppm TD-ICP	Rb ppm INAA	S % TD-ICP	Sb ppm INAA	Sc ppm INAA	Se ppm INAA	Sr ppm FUS-ICP	Ta ppm INAA	Th ppm INAA	U ppm INAA	V ppm FUS-ICP	W ppm INAA	Y ppm FUS-ICP	Zn ppm TD-ICP	Zr ppm FUS-ICP	La ppm INAA	Ce ppm INAA	Nd ppm INAA	Sm ppm INAA	Eu ppm INAA	Tb ppm INAA	Yb ppm INAA	Lu ppm INAA
5A1	bulk	22.9						182						267	2200									
14A1	bulk	22.7						198						227	2100									
25A1	bulk	22.7						236						228	2220									
28A1	bulk	18.5						287						187	1780									
DS2-1	bulk		<10	0.083	0.2	1.0	<0.5	295	1.4	<0.1	4.4	<5	<1	21	252	<2	10.5	12	12	3.1	0.9	0.5	0.9	0.10
Erico-1	bulk		<10	0.030	0.4	0.8	<0.5	128	<0.3	0.8	3.0	<5	<1	61	840	<2	21.1	35	22	5.5	1.6	0.8	1.8	0.23
6A1	bulk	< 5	< 20	< 0.001	0.8	6.5	< 3	272	< 1	6.4	7.2	47	< 3	293	1	32	91.9	182	122	26.0	9.0	6.0	11.7	1.64
6C1	bulk	23.2						186						274	2080									
6B1	16Mx20M	36	80	0.541	0.9	6.6	< 3	276	< 1	6.6	9.7	40	< 3	295	1780	21	98.6	201	127	27.3	9.2	6.2	12.3	1.73
6B2	20Mx40M	35	< 20	0.533	0.9	6.4	5	269	< 1	5.8	8.4	38	< 3	292	1800	20	98.0	201	135	27.6	9.2	6.7	12.3	1.69
6B3	40Mx60M	30	< 20	0.532	1.3	6.5	< 3	266	< 1	5.3	10.4	39	< 3	293	1770	25	95.8	195	128	27.0	9.1	6.4	12.3	1.64
6B4	60Mx140M	33	< 20	0.600	1.3	6.1	< 3	258	< 1	5.2	8.6	32	< 3	307	2110	< 2	104.0	210	138	28.6	9.7	6.5	12.6	1.71
6B5	140Mx200M	30	70	0.586	1.3	6.4	<3	262	<1	5.5	9.0	35	<3	318	2000	12	109.0	226	134	30.4	10.3	7.1	13.3	1.75
6B6	200Mx325M	29	< 20	0.539	1.2	6.4	< 3	236	< 1	6.0	8.9	37	< 3	293	1870	15	103.0	216	128	29.0	9.7	6.5	13.0	1.76
6B7	325Mx0	29	70	0.551	1.2	7.0	< 3	282	< 1	7.0	8.9	48	< 3	271	1480	59	89.6	179	122	25.5	8.8	6.0	12.3	1.61
15A1	bulk	< 5	60	< 0.001	0.8	5.9	< 3	247	< 1	6.0	8.1	34	< 3	238	< 1	87	84.7	163	102	22.2	7.7	5.5	10.1	1.41
15C1	bulk	22.7						196						246	2170									
22A1	bulk	< 5	< 20	< 0.001	0.8	5.8	< 3	251	< 1	7.9	7.2	35	< 3	151	< 1	175	60.4	112	64	12.9	4.5	2.6	6.0	0.85
22C1	bulk	13.4						300						100	1000									
22B1	+1/4"	< 5	< 20	0.219	< 0.2	1.0	< 3	679	< 1	0.6	4.0	11	< 3	5	11	8	4.2	6	< 5	0.6	0.2	< 0.5	0.3	< 0.05
22B2	1/4"x4M	15	< 20	0.354	0.5	3.1	< 3	521	< 1	2.7	6.3	21	< 3	73	500	30	32.8	66	35	7.4	2.8	1.6	3.6	< 0.05
22B3	4Mx8M	8	< 20	0.387	0.4	1.5	< 3	833	< 1	1.3	4.4	18	< 3	8	29	43	6.6	12	6	1.0	0.4	< 0.5	0.6	< 0.05
22B4	8Mx10M	9	< 20	0.337	0.4	2.9	< 3	604	< 1	2.5	6.4	23	< 3	40	253	50	20.1	41	21	4.2	1.5	0.9	2.0	< 0.05
22B5	10Mx16M	7	< 20	0.313	0.4	2.2	< 3	602	< 1	1.9	5.4	20	< 3	10	36	35	8.4	15	8	1.4	0.4	< 0.5	0.8	< 0.05
22B6	16Mx20M	6	20	0.355	0.4	2.6	< 3	587	< 1	2.6	5.5	20	< 3	21	109	45	12.7	25	12	2.4	0.9	< 0.5	1.2	< 0.05
22B7	20Mx40M	29		0.399				495				12		127	995	<2								
22B8	40Mx60M	27		0.416				405				21		136	1160	14								
22B9	60Mx140M	19	30	0.489	0.8	4.3	< 3	245	< 1	4.7	5.5	32	< 3	85	799	123	47.0	87	50	9.8	3.5	2.3	5.1	0.47
22B10	140Mx200M	16	< 20	0.442	0.8	5.3	< 3	220	1	5.8	5.5	34	< 3	109	969	239	52.0	94	56	10.5	3.6	2.5	5.6	0.57
22B11	200Mx325M	27	40	0.486	0.8	6.0	< 3	221	< 1	8.5	7.9	40	< 3	160	1190	685	71.2	132	79	14.8	5.0	2.8	8.6	1.00
22B12	325Mx0	30	40	0.340	1.0	8.1	< 3	271	< 1	9.2	8.0	54	3	170	1210	231	70.2	134	72	15.4	5.3	3.5	8.6	1.06
32A1	bulk	33	< 20	0.720	1.2	5.4	< 3	286	< 1	6.2	8.4	28	< 3	261	1730	51	88.5	184	102	23.2	8.3	5.4	10.1	1.39
32C1	bulk	19						271						180	1750									
MN1	60M x 0	23.8						196						246	2210									
MN2	60M x 0	22.8						195						232	2100									
COM1	60/90mesh	95	< 20	0.004	3.3	5.5	< 3	640	< 1	3.5	2.8	362	11	47	143	< 2	57.3	110	68	12.6	4.5	2.1	5.2	0.57
COM1 (rev.)	60/90mesh	95	< 20	0.004	3.3	5.5	< 3	640	< 1	3.5	2.8	362	11	47	143	< 2	57.3	110	68	12.6	4.5	2.1	5.2	0.57
COM1A	60/90mesh	80						632						38.9	127									
COM2	200mesh	211	40	0.011	2.5	14.2	< 3	194	< 1	4.4	3.6	206	5	40	680	< 2	28.5	48	24	4.5	1.6	0.8	3.6	0.45
COM2 (rev.)	200mesh	211	40	0.011	2.5	14.2	< 3	194	< 1	4.4	3.6	206	5	40	680	< 2	28.5	48	24	4.5	1.6	0.8	3.6	0.45
COM3	granular	93	30	0.004	3.4	5.7	< 3	642	< 1	3.5	3.8	274	12	47	144	< 2	58.5	113	68	13.1	4.7	2.0	5.2	0.61
COM3 (rev.)	granular	93	30	0.004	3.4	5.7	< 3	642	< 1	3.5	3.8	274	12	47	144	< 2	58.5	113	68	13.1	4.7	2.0	5.2	0.61
COM4	powder	221	40	0.011	2.3	13.7	< 3	207	< 1	4.1	3.6	152	4	43	685	< 2	28.0	49	22	4.5	1.6	0.8	3.4	0.44
COM4 (rev.)	powder	220	40	0.010	2.3	13.7	< 3	207	< 1	4.1	3.6	152	4	43	691	< 2	28.0	49	22	4.5	1.6	0.8	3.4	0.44
DS2FE1	bulk	40	40	1.450	0.6	5.2	< 3	37	< 1	3.3	1.4	24	< 3	6	108	30	8.6	17	7	1.3	0.4	< 0.5	0.8	0.10
DS2FE2	60Mx0	9.23						4.79						4.55	107									
DS1FE1	bulk	<4.82						<2.89						5.12	20.3									
Com5A	bulk?	7.99						25.7						11.6	33.2									
Com6A	bulk?	<4.95						<2.97						<2.97	144									

Co., Date, Rept.#, Analyses: **ACT**: A07-1476 bulk chemical composition (oxides) & elements (2 samples) - 5/23/07; A07-5811 bulk chemical composition (oxides) & elements (30 samples)-

bulk - refers to a sample which is "as is" and is not a sieve fraction nor has been further processed;rev. - data revised by ACT Labs following data analysis

examined using a hand-lens. Limestone and quartz were identified in practically every size fraction. (See Table 8 & Attachment 1.) The material fizzed aggressively with 10% HCl indicating the presence of limestone as well as with 3% hydrogen peroxide indicating the presence of manganese oxides. The visual examination, therefore, indicated that the recovered manganese was diluted by limestone and quartz. (Plant debris was also observed.) Note in the fractions below a top-size of 140M (or -140M) in the totes containing the slurry (Totes 6 and 15), the predominant constituent visually appeared to be the manganese-bearing material; however, the bulk chemical analysis described later did not substantiate the observation. (See Attachments 1 & 2.)

Mineralogy

In 2005, under a grant through the Southern Allegheny Conservancy, grab samples of manganese-bearing material were collected by hand directly from several different HFLBs. X-ray diffraction conducted on the samples revealed that the manganese-bearing material, the major constituent, was comprised of a mixture of birnessite, todorokite, and takanelite. Minor constituents were quartz, muscovite, and calcite. (For general chemical formulas of minerals, see Table 9.)

In order to identify any crystalline phases present in the material recovered during the full-scale field effort using the Flip Screen, un-sieved (bulk material) samples were submitted for X-Ray Diffraction. Material from Totes 6, 15, 22, 32 from which size fractions were visually described were included, as well as samples of manganese oxide, commercially-available to the ceramic industry, and recovered material that was air-dried, crushed, and sieved. The results are provided in Attachment 1 with laboratory sheets included in the appendix. Table 8 summarizes the results provided by RJ Lee, Monroeville, PA. The constituents are listed for the recovered material based on reported prevalence in the sample; however, please note that the bulk analysis, described later, which identifies the relative occurrence in percent by weight, indicates a much greater quantity of manganese-bearing material.

Table 8: Mineralogy of Recovered & Commercial Mn-Bearing Materials

Sample	Type	Pyrolusite	Quartz	Cryptomelane	Calcite	Muscovite	Birnessite	Amorphous
5A1	Slurry		X		X	X	X	X
6C1	Slurry		X		X	X	X	X
14A1	Slurry		X		X	X	X	X
15C1	Slurry		X		X	X	X	X
22C1	Residual		X		X	X	X	X
25A1	Residual		X		X	X	X	X
28A1	Residual		X		X	X	X	X
32C1	Residual		X		X	X	X	X
MN1	Minor prep.		X		X	X	X	X
MN2	Minor prep.		X		X	X	X	X
DS2(2005)	Handpicked		X		X	X	X	
COM1A	Commercial	X	X	X			X	X

Sample includes Tote #, i.e., sample 6C1 from Tote 6; MN1 & MN2 - minor in-house processing including air-dried, crushed, and sieved (60Mx0); DS2(2005) collected by hand from De Sale 2 HFLB (BioMost, 2005) with birnessite identified as major constituent; COM1A - commercially-available manganese oxide (60Mx90M?); Amorphous (todorokite or buserite) reported by lab as inconclusive due to poor crystallinity

Table 9: Description of Minerals in Recovered & Commercial Mn-Bearing Materials

Name	General Chemical Formula	Crystal System
Quartz	SiO_2	Trigonal
Calcite	$CaCO_3$	Trigonal
Muscovite	$KAl_2(AlSi_30_{10})(OH)_2$	Monoclinic
Birnessite	$(Na,Ca)Mn_7O_{14}$•$3H_2O$	Hexagonal
Todorokite	$(K,Na,Ba)(Mn,Al)_6O_{12}$•$3H_2O$	Monoclinic
Buserite	$Na_4Mn_{14}O_{27}$•$21H_2O$	Monoclinic/triclinic
Takanelite*	$(Mn^{+2},Ca)Mn_4^{+4}O_9$•H_2O	Hexagonal
Pyrolusite	MnO_2	Tetragonal
Cryptomelane	$K(Mn^{+4},Mn^{+2})_8O_{16}$	Monoclinic

**Takanelite reported in 2005 samples*

Quartz: Note that all samples contain quartz, including the “in-house dried-and-sieved” recovered material and the commercially-available manganese oxide sold as a colorant for ceramic glazes. (As previously mentioned, quartz was also observed by hand lens in the recovered samples.) At this time, the quartz is thought to be associated with the aggregate or as “washed-in” from disturbing the in-place soil and rock during construction.

Calcite: Although not present in the commercial sample, calcite is present in all of the recovered material samples. The calcite is attributed to fragments of limestone aggregate created during excavating and “tumbling” (abrading) in the Flip Screen. (AASHTO #1 with a size range of 4”x¾” was used as the treatment medium in the HFLB.) The calcite was identified visually by the reaction with dilute hydrochloric acid.

Muscovite: All samples of the recovered material contained muscovite. Like quartz, at this time, the muscovite is thought to be associated with the aggregate or “washed-in” during construction.

Birnessite, buserite, todorokite, takanelite: The primary manganese-bearing mineral identified in all the recovered material is birnessite. Birnessite and the related hydrated form, buserite, (reported by the lab as potentially in the amorphous fraction) are the most common layered manganese oxides in natural environments. [As mentioned earlier in the report, in a recent (ca. 6/2008) communication of initial findings by Dr. Cara Santelli, Harvard University, fungi were observed to play an important role in manganese precipitation in the De Sale Phase 2 HFLB.] Todorokite is also reported by the laboratory to be a potential constituent of the amorphous (due to the weak peaks on the x-ray pattern) constituents. Like birnessite, todorokite is common in soil and was identified with birnessite in samples collected in 2005. Takanelite, classified within the Birnessite Group, was reported only for the samples collected in 2005. The presence of manganese oxides was identified visually by the reaction with hydrogen peroxide.

Pyrolusite, cryptomelane: Pyrolusite and cryptomelane were only identified in the commercially-available manganese oxide material. Although both are present in the USA, pyrolusite, an ore of manganese, is imported. [The dendritic manganese oxide observed on sedimentary rocks, formerly thought to be pyrolusite, appears to be other forms of manganese oxides. See mindat.org - pyrolusite.] Cryptomelane is commonly associated with pyrolusite.

Bulk Chemical Composition
Under the previously mentioned 2005 grant through the Southern Allegheny Conservancy (BioMost, 2005), bulk chemical analysis of hand-collected manganese-bearing material from several different HFLBs indicated the samples contained >40% manganese, as oxides, on an as-received basis, with a loss-on-ignition of ~20%.

Bulk chemical (whole rock) analyses were performed on samples of recovered material and commercially-available manganese oxide. Table 10 summarizes the major oxides where >1% by weight. Samples of as-recovered bulk material; of dried, crushed, and sieved in-house material; and of commercial manganese oxide were analyzed by RJ Lee, Monroeville, PA. Samples collected by hand were analyzed by Act Labs. Attachment 1 lists all parameters and analyses reported.

Table 10: Major Oxides of Recovered & Commercial Mn-Bearing Materials
Recovered Material: bulk, in-house processed, & handpicked; Commercial Material: sized

Sample	Type	SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	LOI
5A1	Slurry	22	13	6	23	10	21
6C1	Slurry	23	14	6	21	11	22
14A1	Slurry	25	12	3	23	12	21
15C1	Slurry	24	12	4	23	12	21
22C1	Residual	25	10	3	15	15	29
25A1	Residual	19	8	2	27	10	30
28A1	Residual	16	10	4	21	14	32
32C1	Residual	19	11	4	22	10	32
MN1	Minor prep.	23	13	4	24	11	20
MN2	Minor prep.	23	12	4	24	11	20
DS2-1	Handpicked	5	1	15	50	7	20
Erico-1	Handpicked	3	2	1	65	6	22
COM1A	Commercial	5	3	5	73	<1	12

% by weight; values rounded; sample includes Tote #, i.e., sample 6C1 from Tote 6; MN1 & MN2 - minor in-house processing on a mixture of recovered slurry (Tote 15) and residual (Tote 32) material including air-dried, crushed, and screened (60Mx0). DS2-1 & Erico-1 - collected by hand from HFLB outlet pipe from De Sale Phase 2 and Erico, respectively, during this project; COM1A - commercially-available manganese oxide (60Mx90M?)

The above table indicates that all samples of the material recovered using the Flip Screen were similar in chemical composition not only for the bulk material (both slurry & residual) but also for the in-house processed (-60M) material that was a mixture of slurry and residual material. In general, the constituents, reported as weight percent oxides, can be very generally characterized as ~25% SiO_2, ~10% Al_2O_3, ~5% Fe_2O_3, ~25% MnO, and ~10% CaO with a loss-on-ignition of ~25%.
The composition, however, among the residual samples is not as consistent as among the slurry samples. In addition, when compared to the slurry samples, the loss-on-

ignition is notably higher for the residual material which may be, at least in part, attributed to organic matter. Note, however, that plant debris was observed during visual examination in both the slurry and residual material. The LOI for the handpicked and for the in-house processed material is essentially the same at ~20%, which may represent water of hydration, water of saturation, etc. associated with the manganese oxides. (Example: buserite - $Na_4Mn_{14}O_{27} \cdot 21H_2O$)

Comparison of the handpicked samples with the material separated by the Flip Screen indicates that much of the silicon, aluminum, and calcium do not appear to be inherent in the manganese-bearing material. This supports the presence of quartz and limestone noted during the visual examination of the recovered material. The total/dissolved aluminum present at times in the HFLB influent (See Table 6 and attached water quality data.) indicates a probable source of the aluminum as well as the ubiquitous muscovite identified by XRD. (Note that muscovite would also contribute to the silicon content.)

As the manganese-bearing material from the full-scale recovery operation appears to be significantly diluted by limestone fragments, etc., the manganese content, by weight, is substantially higher (>2x) in the handpicked samples than in samples from the recovered material. (Erico-1: MnO within 8%, by weight, of commercial manganese.)

Bulk chemical analyses of the individual size fractions were needed to further characterize the recovered material and to identify substantial differences in chemical composition associated with the slurry (represented by Tote 6) vs. residual (represented by Tote 22) material. (See Attachment 1 for complete analyses.)

<u>Table 11: Major Oxides in Size Fractions of Recovered Mn-Bearing Material</u>

Bulk Chemical Analyses by ACT Labs.

Size Fraction	SiO_2		Al_2O_3		Fe_2O_3		MnO		CaO		LOI	
	#6	#22	#6	#22	#6	#22	#6	#22	#6	#22	#6	#22
3/8”x¼”		3		1		1		<1		53		41
¼”x4M		12		3		3		12		36		31
4Mx8M		8		2		2		<1		48		39
8Mx10M		12		3		3		5		42		34
10Mx16M		10		2		2		<1		47		37
16Mx20M	20	11	11	3	6	2	28	2	9	45	24	36
20Mx40M	20	15	11	4	6	3	28	16	9	31	23	27
40Mx60M	20	23	11	4	6	3	28	21	9	23	24	24
60Mx140M	17	48	10	5	6	3	34	11	8	14	23	16
140Mx200M	20	47	10	6	6	3	29	14	8	11	23	15
200Mx325M	19	41	10	7	6	3	31	22	8	10	23	16
325Mx0	23	32	11	11	6	4	19	18	12	12	24	19
Bulk (3/8”x0)	21	42	11	7	6	3	25	18	10	11	23	16

% by weight; values rounded; Tote #6 slurry with screened intake hose; Tote #22 - residual from Wash Pit 2

Tote 6: The percent by weight as oxides of silicon, aluminum, iron, calcium, and also LOI in all size fractions for the material collected using a pump with screened intake is remarkably consistent. The visual appearance of the +60M size fractions suggested, however, that more limestone fragments were present than indicated in the analysis. The manganese is depicted as being the most variable, ranging from 19% to 34%. Even though the -325M appeared to contain the greatest amount of manganese-bearing material based on the visual inspection, this fraction had the least amount by weight of manganese as oxides. Bulk chemical analyses were not performed on size fractions containing material larger than +16M, as little or no material was present.

Tote 22: In the residual material, the larger size fractions of +20M appear to be essentially comprised of limestone fragments, with minor manganese-bearing material "clinging" to the limestone as observed by hand lens. The weight percent as manganese oxide in the residual is less in every size fraction compared to the slurry. In the -325M, however, the manganese content is similar to that of the slurry.

Even though manganese may be concentrated in a particular size fraction (i.e., 34% in Tote 6 sample at 60Mx140M), the weight of each size fraction compared to the whole (bulk material) assists in identifying a target size range for future recovery efforts.

Table 12: "Weighted Average" of Major Oxides in Size Fractions of Recovered Material

Bulk Chemical Analyses by ACT Labs.

Size Fraction	SiO_2		Al_2O_3		Fe_2O_3		MnO		CaO		LOI		Total	
	#6	#22	#6	#22	#6	#22	#6	#22	#6	#22	#6	#22	#6	#22
$^3/_8$"x¼"		<1		<1		<1		<1		8		6		15
¼"x4M		1		<1		<1		1		3		3		10
4Mx8M		2		<1		<1		<1		9		8		20
8Mx10M		1		<1		<1		<1		3		2		7
10Mx16M		1		<1		<1		<1		3		2		6
16Mx20M	<1	1	<1	<1	<1	<1	<1	<1	<1	2	<1	2	1	5
20Mx40M	2	2	1	1	1	<1	3	2	1	3	2	0	9	8
40Mx60M	2	1	1	<1	1	<1	2	1	1	2	2	2	8	6
60Mx140M	2	3	1	<1	1	<1	5	1	1	1	3	1	14	7
140Mx200M	2	1	1	<1	1	<1	3	<1	1	<1	2	<1	10	3
200Mx325M	2	1	1	<1	1	<1	4	1	1	<1	3	<1	12	2
325Mx0	11	3	5	1	3	<1	9	2	6	1	11	2	45	8
Cumulative	21	17	11	4	6	2	25	8	10	36	23	28	96	97
Bulk ($^3/_8$"x0)	21	42	11	7	6	3	25	18	10	11	23	16	96	97

Reported as % by weight; values rounded; Tote #6 - slurry with screened intake hose; Tote #22 - residual from Wash Pit 2; weighted average = weight % of material in size fraction x weight % of major oxide in size fraction; total values effected by rounding and minor oxides not included in table

Tote 6: As only ~1% by weight of the recovered slurry material had a size range of 16Mx20M, there is only a minor contribution by this size fraction to the composition of the whole. For size fractions within the range of 20Mx325M, even though the percent by weight of the individual splits varies between 8% and 13% (Δ5%) (See Table 7.), the percent by weight of silicon, aluminum, iron, and calcium as oxides essentially does not change. The manganese content varies slightly from 2% to 5% (Δ3%) in the 20Mx325M range with the LOI varying from 8% to 12% (Δ4%). As illustrated by the particle-size distribution (See Table 7.), >45% of the bulk slurry material is comprised of -325M, which contributes to higher "weighted averages". Note that of the 25% by weight as manganese oxides in the slurry material, more than half (~52%) lies within the clay/silt size fractions (-200M) and ~99% has a top-size of 20M. (In other words, material within the size range of 20Mx0 contains ~99% of the manganese oxides by weight.) Note also that comparison of the bulk sample ($^3/_8$"x0) with the cumulative total of the size fractions further demonstrates consistency of chemical composition in the slurry material.

Tote 22: For all size fractions, even though the weight among the individual splits varies [from 2% to 20% (Δ18%) as shown in Table 7], the "weighted averages" of silicon, aluminum, iron, and manganese as oxides are remarkably consistent. The calcium content is observed to decrease as the size decreases both in the "weighted average" and in the individual splits (Table 11 & 12). In the larger size fractions with lower manganese content, limestone is probably the major contributor of calcium while in the smaller size fractions with lower calcium but higher manganese content, manganese precipitate [example: birnessite - $(Na,Ca)Mn_7O_{14}\bullet 3H_2O$] may be the major contributor. LOI is also higher for the residual material above +8M. (Loss-on-ignition typically represents water, organic matter, and volatiles such as CO_2.) On a cumulative basis, even though ~45% of the weight of the total residual material lies within the size range of $^3/_8$"x8M (Table 7), manganese, as oxides, comprises only ~15% ("unrounded" computed values). Even though the manganese increases to between 11% and 22% for the individual size fractions at -20M (Table 11), the "weighted average" contribution to the whole remains low. Further note that the bulk sample indicates that the residual material as a whole contains 18%, by weight, manganese as oxides while the cumulative total from the size fractions is much less, demonstrating the heterogeneity of the residual material and difficulty in collecting representative samples. This substantial variation in chemical composition between the sample split into 12 size fractions with that of the bulk (un-split) sample is further depicted by the even larger difference (~25%) observed in the silicon and calcium values (as oxides). Note that minor, in-house, processing (material sieved to 60Mx0) of a mixture containing both slurry (Tote 6) and residual (Tote 15) material produced a product consistent with the slurry material where the manganese oxides are 24%. (See Mn1 & Mn2 Table 10.)

Elemental Analysis

In order to further characterize the recovered material, 40 parameters were measured to determine concentrations of trace elements using ICP and Instrumental Neutron Activation Analysis (INAA). The ranges in content of the elements in the bulk samples (including handpicked) of the recovered material are compared with the sized, commercially-available, manganese material in Table 13. The results are reported for each parameter and each sample, including size fractions, in Attachment 2.

Table 13: Elemental Analyses of Recovered & Commercial Mn-Bearing Materials

Range: min-max

Element	Unit	Mn-Bearing Material				General Comments
		Recovered		Commercial		
		min	max	min	max	
Au	ppb	nd	nd	nd	7	commercial higher content
Ag	ppm	nd	5	16	21	commercial higher content
As	ppm	4	27	39	70	handpicked lowest; commercial higher content
Ba	ppm	194	996	1170	8240	commercial higher content
Be	ppm	nd	12	3	5	commercial & recovered - minor constituent
Bi	ppm	nd	12	1	44	commercial higher content
Br	ppm	nd	6	nd	nd	commercial - absent; recovered - minor
Cd	ppm	nd	3	1	5	commercial & recovered - minor constituent
Co	ppm	911	2510	107	244	recovered - higher; coarser splits - lower
Cr	ppm	nd	66	12	83	commercial & recovered - variable
Cs	ppm	nd	4	1	5	commercial & recovered - minor constituent
Cu	ppm	nd	42	63	594	commercial higher content
Hf	ppm	<1	7	1	1	recovered - variable
Hg	ppm	0.04	nd(<1)	0.03	nd(<1)	commercial & recovered - absent to minimal
Ir	ppb	nd	nd	nd	nd	commercial & recovered - absent
Mo	ppm	nd	14	38	98	commercial higher content
Ni	ppm	nd	1710	82	708	commercial & recovered - variable
Pb	ppm	nd	33	80	221	commercial higher content
Rb	ppm	nd	60	nd	40	commercial & recovered - variable
S	%	nd	0.6	<0.0	<0.0	commercial & recovered - minimal
Sb	ppm	<1	1	2	3	commercial & recovered - minor constituent
Sc	ppm	1	7	6	14	commercial & recovered - minor constituent
Se	ppm	nd	nd	nd	nd	commercial & recovered - absent to minimal
Sr	ppm	128	300	194	642	commercial & recovered - variable
Ta	ppm	nd	1	nd	nd	commercial & recovered - absent to minimal
Th	ppm	nd	8	3	4	commercial & recovered - minor constituent
U	ppm	3	8	3	4	commercial & recovered - minor constituent
V	ppm	nd	47	152	362	commercial higher content
W	ppm	nd	nd	4	12	commercial - minor; recovered - absent
Y	ppm	21	293	39	47	recovered - variable
Zn	ppm	nd	2220	127	691	commercial & recovered - variable
Zr	ppm	nd	175	nd	nd	commercial - absent; recovered - variable
La	ppm	11	92	28	59	commercial & recovered - variable
Ce	ppm	12	184	48	113	commercial & recovered - variable
Nd	ppm	12	122	22	68	commercial & recovered - variable
Sm	ppm	3	26	5	13	commercial & recovered - variable
Eu	ppm	<1	9	2	5	commercial & recovered - minor constituent
Tb	ppm	1	6	1	2	commercial & recovered - minor constituent
Yb	ppm	1	12	3	5	commercial & recovered - minor constituent
Lu	ppm	<1	2	<1	1	commercial & recovered - minor constituent

nd- below detection limit; Hg - ACT Lab reported as <1 ppm; RJ Lee reported to 1/10,000th ppm; (See Attachment 2 for individual sample analyses and analyses of size fractions.)

Minimum values for many elements were below detection limits for both the commercial and recovered manganese material. In comparison with the recovered material, the commercially-available material appeared to have a noticeably higher concentration of the following elements: silver (Ag), arsenic (As), barium (Ba), bismuth (Bi), chromium (Cr), copper (Cu), molybdenum (Mo), lead (Pb), strontium (Sr), and vanadium (V). Cobalt (Co), nickel (Ni), yttrium (Y), and zinc (Zn), while present in all commercial material samples, were significantly higher in the recovered material. Zirconium (Zr), at times observed in the recovered material, was not detected in the commercial material.

Ceramic Glaze Testing

The US Food and Drug Administration (US FDA) has provided action levels/guidelines for leaching of cadmium and lead from pottery (ceramics). (See references: US FDA, 08/2000; US FDA, 9/26/07.) For testing to determine action levels, the US FDA cites ASTM C738-94(2006) *Standard Test Method for Lead and Cadmium Extracted from Glazed Ceramic Surfaces*. [See references: US FDA, updated 2005-11-29 (cadmium); US FDA, updated 2005-11-29 (lead).] ASTM C738 Paragraph 1.1 states "This test method covers the precise determination of lead and cadmium extracted by acetic acid for glazed ceramic surfaces. The procedure of extraction may be expected to accelerate the release of lead from the glaze and to serve, therefore, as a severe test that is unlikely to be matched under the actual conditions of usage of such ceramic ware. This test method is specific for lead and cadmium."

Small ceramic bowls with recovered manganese in the glaze were submitted to Ferro Color and Glass Performance Materials Analytical Services Laboratory (Washington, PA) to test for food safety. According to the US FDA Sec. 545.400 for cadmium, the guideline for small ceramic hollowware [depth of >25 mm (~1+") with a capacity of <1.1 liters] the guideline/action level is 0.5 ppm or µg/mL for any one of the 6 units tested. According to the US FDA Sec. 545.450 for lead, the guideline for small ceramic hollowware the guideline/action level is 2 ppm or µg/mL for any one of the 6 units tested. Table 14 indicates that all items tested were in compliance. (See lab sheets in Appendix.) Additional testing will be conducted in the future.

Table 14: Laboratory Test Data on Glazed Ceramic Surfaces using ASTM-C738

Date	Ceramic Bowl #	Acetic Acid (ml)	Pb (ppm)	Cd (ppm)
15-May-07	1	200	<0.2	<0.02
	2	165	<0.2	<0.02
	3	165	0.2	<0.02
	4	200	<0.2	<0.02
	5	200	0.3	<0.02
	6	N/A[1]	N/A	N/A
	Average[2]		0.22	<0.02
	Standard Deviation		0.04	N/A
	Average + 2xStandard Deviation		0.30	<0.02
05-Mar-08	1	117	<0.2	<0.02
	2	134	<0.2	<0.02
	3	140	<0.2	<0.02
	4	110	<0.2	<0.02
	5	112	<0.2	<0.02
	6	131	<0.2	<0.02
	Average		<0.2	<0.02
	Standard Deviation		N/A	N/A
	Average + 2xStandard Deviation		<0.2	<0.02

[1]bowl received broken; [2]method requires 6 samples; Detection Limits: Pb - 0.2 ppm; Cd - 0.02 ppm

POST-RECOVERY PROCESSING

An ideal situation would be to find a manufacturer to utilize the material on an as-recovered basis without additional processing. While possible, the likelihood appears to be small based on limited review of probable commercial uses. Stream Restoration Inc. and BioMost, Inc., therefore, began to explore the possibility of processing the material. Initially, the material was processed by hand on a small scale. The process involved distributing the material on a tarp within an enclosure and using portable small heaters, dehumidifiers and fans to promote drying. The dried material was then hand-sized to -60M utilizing a Talisman Rotary Sieve.

While effective in producing an acceptable quality product, this process was economically inefficient and time consuming. Nonetheless, the purchase of equipment to process the material more efficiently and on a larger scale appeared to be uneconomical until the demand for substantial and continued production was identified. A toll processing facility, with beneficiation completed on a fee basis, was then considered. The advantages of using a toll processor include:

- the postponement/elimination of the need for capital investment
- the utilization of the processing professionals expertise
- the wide selection of available equipment
- the ability to change production quantities and specifications to meet potentially changing market requirements

Several toll processing facilities were contacted to determine projected costs and available services. Custom Processing Services, East Greenville, PA was selected based on expertise, cost, willingness to help, and general interest in the project.

Six totes (Totes 8, 9, 11, 12, 14, 17) of as-recovered manganese-bearing slurry material (pumped without an intake screen from Wash Pit 2) were transported to the facility by BioMost, Inc. on 24-Jun-08 where the material was weighed and dried, reweighed and screened, packaged in supersacks and reweighed by Custom Processing Services.

The six totes were reported to contain a total of ~7300 lbs. (~3.65 tons) of unprocessed (as-delivered) material. Assuming that the totes were of approximately equal weight, on average, the weight per tote would be ~0.6 tons which is less than the estimated ~1½ tons at the time of recovery ~9 months prior in Sept. 2007. (Weight at the time of recovery was based on scalehouse readings at the Quality Aggregates, Inc., Boyers Quarry, Boyers, PA for selected totes.) The reason for the decrease in weight may reflect additional dewatering during storage in the permeable totes.

At the processing plant the moisture was determined to be ~26% on the as-delivered material. Using an Amjet JOD 6 jet dryer maintained at ~250° F, the moisture was decreased to ~2%. Moisture content was measured using a Mettler ACQ-11 moisture analyzer. Following processing, the material was reweighed at 3950 lbs. (1.98 tons) indicating that 3361 lbs. (1.68 tons) or ~46% by weight was lost as moisture. Sample analyses and evaluation of the drying process will aid in understanding material loss.

Using an 80-mesh production screen, the dried material was then sized, yielding ~1,764 lbs. or 45% of +80 mesh and ~2,156 lbs. or 55% of -80 mesh. The processor visually examined the material and indicated that the +80 mesh appeared to contain "gravel, sticks, and material". The processor then performed a sieve analysis of the -80 mesh dried material (See Table 15.), which indicated that nearly 80% was 325Mx0 and over 90%, on a cumulative basis, was 200Mx0. This is a higher percentage than reported for the sieve analyses performed by the laboratory for bulk samples of slurry material, where ~45% was 325Mx0 and ~60% was 200Mx0 on a cumulative basis. (See Table 7 and Attachments 1 & 2.)

Table 15: Sieve Analysis of Material Passing an 80-Mesh Production Screen

Mesh Size	% Retained
10	0.5
20	0.8
50	2.2
100	4.7
200	6.7
325	5.2
Pan (-325)	79.9
Total	**100.0**

Custom Processing Services, East Greenville, PA

Note that even though the size of the production screen was nominally 80 mesh, material with a top-size greater than 80 mesh was present. An explanation includes the possible presence of elongated particles that could pass through the screen vertically and/or "wear", etc. of the production screen. Samples are to be submitted to a laboratory for further analysis to determine crystalline phases, bulk chemical analysis, and elemental analysis. The evaluation of the commercial processing relating to cost and increased demand for the recovered manganese material is in process.

MANGANESE OVERVIEW

General Information

Manganese is derived from the Latin *magnese* meaning magnet, presumed in reference to the magnetic properties of the manganese ore, pyrolusite. Manganese was identified as an element in 1774 by the Swedish chemist Carl Whilhelm Scheele while working with pyrolusite and was isolated by an associate, Johan Gottlieb Gahn, the same year. Manganese (Mn), a transition metal in Group VIIB of the periodic table, is located between chromium and iron and is the 10th most abundant element in the Earth's crust. Manganese is present in more than 300 minerals. From a geochemical perspective manganese tends to behave like magnesium (Mg), iron (Fe), nickel (Ni), and cobalt (Co) and tends to partition into minerals that form in the early stages of magmatic crystallization. Manganese is rapidly depleted from rock by interactions with surface and subsurface water and is highly mobile as Mn^{+2} in acidic waters. Manganese oxides are common in soils. Manganese is essential to many plants and animals, including humans.

Manganese can occur in numerous oxidation states including: +7, +6, +4, +3, +2, 0, -1. Mn^{+2} is common in silicate and carbonate minerals. Manganese ore (material of economic value) typically contain Mn^{+4}, and include pyrolusite, psilomelane $[Ba(Mn^{+2})(Mn^{+4})_8O_{16}(OH)_4]$, cryptomelane, birnessite, and todorokite. (See Table 9 for chemical formulae.) Manganese-bearing minerals are known to form as chemical precipitates when a solution containing Mn^{+2} is oxidized. Dissolved manganous (Mn^{+2}), commonly found in coal mine drainage, when precipitated in response to passive treatment using bicarbonate alkalinity, is reported to primarily contain manganic (Mn^{+4} or to a lesser extent Mn^{+3}). Near the earth's surface, manganese is oxidized to produce more than 30 known oxide/hydroxide minerals, which form the major manganese reserves.

As a metal, manganese has the fourth highest demand in terms of tonnage, ranked only behind iron, aluminum, and copper. About 20 million tons of ore are mined annually worldwide with the majority (98%) produced in 10 countries. Listed in Table 16 are the producing countries, manganese content of the ore, and 2006 production information. Ores are typically classified into three categories based upon the percentage of manganese. Iron- and manganese-bearing ores containing 5-10% Mn are called manganiferrous iron ores and those containing 10-35% Mn are ferruginous manganese ores. Deposits with more than 35% Mn are called manganese ores. Based upon Table

16, the manganese content in ores, commercially mined worldwide, range from as low as 10% to more than 50% by weight. Major production is from sources with 15% to more than 50% Mn.

Based on information reviewed to date, there are no known commercially viable manganese ore bodies within the United States. The United States is, therefore, 100% dependent on foreign sources. There is one operation, however, in South Carolina that mines a manganiferrous (also spelled "manganiferous") deposit having a natural manganese content of less than 5% that is used as a colorant in bricks. Research has been conducted to examine the possibility of mining manganese nodules from the ocean floor. These manganese nodules, which have been estimated to cover 10-30% of the Pacific Ocean floor, are predominantly composed of birnessite (also spelled "birnesite"), todorokite, and vernadite $[(Mn^{+4},Fe^{+3},Ca,Na)(O,OH)_2 \bullet nH_2O]$. While a potential future manganese resource, at current market conditions, the nodules are not considered economically mineable.

Table 16: 2006 Manganese World Production

Country	Percent Mn	2006 Production (Thousands of Metric Tons)	
		Gross	Mn
Australia	37-53	4,556	2,192
Brazil	37-51	3,128	1,370
China	20-30	8,000	1,600
Gabon	45-53	3,000	1,350
Ghana	32-34	1,700	600
India	10-54	2003	811
Kazakhstan, crude ore	20-30	2250	550
Mexico	36-37	370	133
South Africa	30-48[+]	5,213	2,300
Ukraine	30-35	2,400	820
Other	NA	750	213
Total		**33,400**	**11,900**

Form of manganese unknown; Source: USGS

Uses of Manganese

Historical Uses

Manganese has been utilized for thousands of years and is one of the most important metals today. The first documented use can be traced back about 17,000 years to the Stone Age during the upper Paleolithic Age where manganese dioxide was used as a pigment in cave paintings. In Ancient Greece, the presence of manganese in the iron ore used by the Spartans is a likely explanation as to why their weapons were superior to those of their enemies. Both the Egyptians and the Romans used manganese ore either to decolorize or create pink, purple, and black tints to glass. In 1839, manganese was used as an additive in the manufacture of crucible steel. Since 1856, ferromanganese has been used in the Bessemer steel process.

Current Consumption

Today, about 90% of the manganese consumed is by the iron, steel, and alloy industry. The remainder of the manganese is used in a variety of industrial, chemical, agricultural, and pharmaceutical applications. Table 17 depicts the major end uses of manganese in the United States in 2003.

Table 17: Major End Uses of Manganese in the United States for 2003

End Use	% of Consumption
Steel	81
Cast Iron	2
Nonferrous Alloys	4
Batteries	8
Chemicals	5

Source: USGS, 2003

Different end-uses have different requirements in terms of quantity and quality of the manganese ore. This has given rise to the classification of manganese ore into metallurgical, chemical, and battery grades. Metallurgical-grade manganese has between 38-55% Mn. Chemical- and battery-grade ores are typically categorized by their MnO_2 content, which ranges from 70-85% and 44-54%, respectively.

The following is a general description of manganese consumption as included in the end-use categories listed above:

End Use: Steel and Cast Iron

Manganese is essential to iron and steel production and is used for desulfurizing, deoxidizing, and as a conditioning agent during the smelting of iron ore. As an alloy in steel, manganese increases toughness, strength, and hardness. Hardened steel is important in the manufacture of construction materials like I-beams, machinery, and transportation, where the manganese consumption is 24%, 14%, and 13%, respectively. Steel typically contains less than 1% manganese (~15½ lbs/ton); however, Hadfield steel (a.k.a., manganese steel) contains 12-14% (240 to 280 lbs/ton). Hadfield steel is used in very rugged applications such as for armor plating, safes, crushers, and cutting and grinding machinery.

No satisfactory substitute for manganese in steel has been identified. Steelmaking, including ironmaking, accounts for the majority (85-90%) of the total world manganese demand. Manganese ferroalloys, consisting of various grades of ferromanganese and siliconmanganese (also spelled "silicomanganese"), are used to provide the majority of this key ingredient to steelmaking. The increasing use of electric-arc furnaces in steelmaking has resulted in a gradual shift from high-carbon ferromanganese to siliconmanganese.

End Use: Nonferrous Alloys

Manganese is also a key component of certain widely-used nonferrous alloys. Aluminum alloys such as used in door frames, bicycle parts, kitchenware, roofing, car radiators, and beverage cans (100 billion cans/year) use manganese to increase strength. Certain alloys of copper with manganese (12%) and nickel exhibit an electrical resistance, which is almost temperature independent and essential for precision resistors. A titanium-base alloy, containing 8% manganese, was used for the Gemini re-entry control module in the 1960's. Manganese is also used in zinc and magnesium alloys (commonly at contents of 0.1 to 0.2%) and can be added to gold, silver, bismuth etc. for specialized applications in the electronic industry.

End Use: Batteries

Based on 2003 USGS data for the United States, the second most important market for manganese (~8%) in dioxide form is in portable dry cell batteries, with demand worldwide exceeding 20 billion units per year. In 1868, Leclanché developed the dry cell battery in which manganese dioxide reacts with the hydrogen generated to form water; thus, preventing a gas film that would inhibit electrical generation. Other types of batteries include the alkaline MnO_2 zinc cell, placed on the market in the 1950's, and the magnesium chloride-manganese dioxide cell developed for military applications.

Naturally-occurring manganese dioxides (NMD) can be used in standard cells with higher grade manganese dioxide, required in high performance cells, produced synthetically. The products are named after the processes used with electrochemical manganese dioxide (EMD) produced through electrolysis and chemical manganese dioxide (CMD) produced by a purely chemical process. Combined demand of both synthetic types is ~200,000 tons/year and is growing rapidly. The market for natural manganese dioxide is ~180,000 to 200,000 tons/year with very few ores having the properties required for manufacturing dry cells. Major countries producing natural MnO_2 are Gabon, Ghana, Brazil, China, Mexico, and India. These "natural grade battery ores" are crushed into fine powder before being used directly in the cathode mixture.

End Use: Chemicals

While chemicals only comprise about 5% of the end-use market in the United States, in some ways this market is one of the most important as the chemical industry uses manganese as a catalyst for a number of reactions and in the creation of numerous chemicals for a variety of applications.

Water Treatment: Manganese is used to make powerful oxidizers. Originally discovered in 1659, potassium permanganate ($K^{+1}Mn^{+7}O_4$), for instance, is a strong oxidizing agent that can be used to meet strict drinking water standards. With the ability to add oxygen, remove hydrogen, or remove electrons from an element or compound, this chemical is used to oxidize iron, manganese, hydrogen sulfide, and arsenic, to improve taste and odor, and as a pre-oxidant for the control of disinfection by-products. Sodium permanganate ($Na^{+1}Mn^{+7}O_4$), is also used in the treatment of drinking water as a pre-oxidant for iron and manganese, trihalomethane precursors, and organic compounds that cause taste and odor problems.

Manganese greensand is another manufactured product that utilizes potassium permanganate, manganese sulfate, and glauconite greensand to formulate a very effective filter media. Manganese greensand is capable of removing soluble iron, manganese, hydrogen sulfide, arsenic, and radium from water supplies through oxidation and filtration. Similar types of filter media using manganese-based products have also been developed.

Pigments and Colorants: Manganese oxides are used in pigments and colorants for a variety of applications. Manganese oxides are used either alone or in combination with other materials in ceramic glazes, frits, dyes, stains, and paints. These colorants can be used in ceramics ranging from dinnerware to floor tile to pottery. Manganese oxides are also used for coloring concrete and bricks. If manganese dioxide is added at ~1 to 4%, the brick will have a gray or brown color, depending on the composition (particularly iron content) of the clay. Higher concentrations of manganese can provide a metallic blue. Manganese is also used for coloring or decoloring of glass, as noted previously, and in the form of manganese acetate for textile dyeing, paints, and varnishes.

Pharmaceuticals: Manganese is used in the production of pharmaceuticals. For instance, potassium permanganate, previously noted for use in water treatment, is also used in pharmaceutical applications to oxidize functional groups, such as aromatic side chains to carboxylic acids, organic sulfides to sulfones, and to produce antibiotics and tranquilizers. Manganese is also used in vitamins, being an essential element for both humans and animals with recommended daily dietary intake levels established by US regulatory authorities. Manganese has been found to promote normal growth and development by aiding in energy generation by enzymes, metabolization of carbohydrates, formation of connective tissue, promotion of blood clotting by Vitamin K, and the anti-oxidation process. Possible positive side effects include reducing asthmatic symptoms, enhancing fertility, and possibly promoting glucose transportation. According to the references reviewed, humans have generally well-developed control mechanisms that regulate manganese to the desired range. Medical research into conditions arising from an excess or deficit of body manganese (with an estimate of 12 to 20 mg manganese within the body of a normal 150-lb man) is currently being conducted.

Agricultural: Manganese is used for a variety of agricultural purposes, including certain pesticides and fertilizers. Manganese accelerates germination and maturity and is essential for the synthesis of chlorophyll. Iron and manganese, both constituents of chlorophyll, are rarely lacking in the soil, but may be in a form unavailable to plants. Both are more readily available in soils with a pH less than 6.0 and are bound in insoluble forms in calcareous (high lime) soils. Manganese deficiency is common when the pH is 6.2 or higher, particularly on sandy coastal plain soils. This deficiency has adverse effects on yields of small grains and/or soybeans. Other factors contributing to the unavailability of iron and manganese include over irrigation, poor drainage, poor soil aeration, and the application of excessive amounts of lime or phosphate to certain soil types. Crops susceptible to manganese deficiency include maize, cotton, wheat, barley, brassicas, sugar beets, peas, beans, potatoes, citrus, and bush fruits. In addition to manganese sulfate, chelated forms (complex organic molecules which resist being bound in the soil) can be used to correct deficiency symptoms. Manganese oxide, even though only slightly water soluble, when finely ground, is also a satisfactory source, with application rates varying from 1 to 25 lbs/acre. Garden centers and other outlets commonly carry these soil amendments.

Manganese is also widely used in dry feeds for cattle, pigs, and poultry. As with humans, manganese is an essential trace element. Deficiency in livestock impairs reproductive performance, results in skeletal deformities and contracted (shortened) tendons in newborns and reduced birth weight. Deficiency in chicks and poults results in perosis or slipped tendon. In laying and breeding birds, deficiency results in lowered egg production and hatchability and reduced eggshell strength. Recommended doses have been developed for livestock.

Another agricultural application of manganese is “Maneb” (manganese-ethylene bisdithiocarbamate), an organo-chemical compound sold in the form of a yellow powder, is marketed under various trade names as a fungicide and is often used for controlling crop and cereal diseases, downy mildew in vines, scab in fruit trees, as well as banana and peanut diseases. An estimated 200,000 tons of Maneb has been used worldwide. (Note: Available information does not indicate annual demand.)

Selected Additional Uses: The chemical and manufacturing industries use manganese of various purities and forms. A limited listing is provided below.

- *Gas Purification* - catalyst to effectively destroy carbon monoxide in respirators, escape masks, and in cryogenic gas purification;
- *Sealant Curing* - curing (or hardening) agent for polysulfide rubber sealants used in the construction and aerospace industries;
- *Welding* - electrode coating or alloyed core for specialized welding operations;
- *Metal Finishing* - phosphating products (from manganese carbonate or manganese oxide) to apply surface films to protect steel, improve wear resistance, and increase lubrication efficiency;

- *Gasoline Additiv*e - octane booster or anti-knock agent to replace lead in the form of the organic manganese compound (methylcyclo-pentadienyl manganese tricarbonyl or MMT), currently in developmental stage;

- *Artificial Flavorings* - catalyst in production of artificial vanilla and other flavors;

- *Metal Processing* - oxidizing agent in treating uranium ore to produce oxide-concentrate known as "yellow cake"; production of manganese ferrite (from ores, oxides, carbonates) for use in computers and television circuit boards; electrolytic zinc process with MnO_2 oxidizing iron in leach solution; $MnSO_4$ added to electrolyte to form coating on cathode to facilitate stripping of zinc;

- *Various Processes* - chemical agent in manufacture of paints and paint desiccatives, amber glass, photographic chemicals, aromatic chemicals, wood preservatives, matches, leather, etc.

MARKETING

Major Markets

One of the objectives of the Manganese Resource Recovery project was to investigate potential markets in order to find an economical use for the recovered material. As previously identified, the major markets for manganese oxides are steel, iron, non-ferrous alloys, batteries, and chemicals. In general, these major markets do not use the manganese ore in a raw unprocessed state. Before the manganese is used, the ore material is refined in order to increase the percentage of manganese and/or to change various chemical properties of the material. For certain industries, such as steel, there appear to only be a few facilities in the world that process the manganese ore to a useable product. One of those facilities is located in Marietta, Ohio just west of Pennsylvania. Conversations with personnel from this facility indicated that for the recovered manganese to be considered, a minimum of 10,000 tons/year would need to be produced.

Smaller Markets Targeted for Commercial Use of Recovered Manganese Material

As meeting current annual demand for the above mentioned major markets from recovery efforts at passive, coal mine drainage, treatment systems does not appear economically or physically feasible at this time, the decision was made to focus on smaller markets. These markets include manufacturers/suppliers of pigments/colorants, agricultural soil amendments, animal feed supplements, and water treatment media. To determine the preliminary marketability and desirable material specifications (quantity and quality), the following criteria were used in order to compile an initial contact list of potential commercial users in the most time- and cost-effective manner:

- Manufactures ceramics, brick, concrete, paint, cosmetic, soil amendment, or water treatment products
- Uses similar materials (i.e., manganese oxides)
- Produces environmentally-friendly products

- Produces “Green” building products
- Is an environmentally-conscious company
- Is located within Pennsylvania (desirable)

Attachment 3 contains a list of ~85 potential manufacturers/suppliers. The column labeled, “Comments”, includes a brief description of the initial company response relating to use of the recovered manganese material as well as other company information. As can be seen, there have been numerous positive responses and not all companies have been contacted to date. Laguna Clay Company (City of Industry, CA) and Trinity Ceramic Supply (Dallas, TX) have completed initial testing of the material and have both expressed an interest in developing new product lines with the recovered material. Additional testing and evaluation of the material and market analysis are needed, however. (See following discussions.)

Pigment/Colorant
Initial efforts have focused on the use of recovered material as a pigment or colorant.

Hand-Made Ceramics: Manganese oxides are commonly used as pigments within the ceramic industry, including in the glazes of hand-made pottery. (See section, Ceramic Glaze Testing, for food safety information.) Interested in supporting both local watershed restoration efforts and the local economy, Stream Restoration Inc. and BioMost, Inc. began investigating the use of recovered manganese oxides from systems passively treating coal mine drainage in 2004 when ceramic artist Pam Esch used the manganese oxide material that was recovered by hand from a Horizontal Flow Limestone Bed in the Slippery Rock Creek Watershed. Pam Esch initially developed glaze “recipes” and tested the glazes on ceramic shards. Impressed with the results, small items to display the glaze were developed. This early work generated interest and support from government agencies and those involved in minesite reclamation, which encouraged Stream Restoration Inc. and BioMost, Inc. to further pursue this use.

In 2007, following a conversation with a BioMost, Inc. employee, Bob McCafferty, owner of the North Country Brewing Company (Slippery Rock, PA) contacted The Pottery Dome (Grove City, PA) and commissioned ceramic artist Robert Isenberg to use the recovered manganese material in the glaze of 300 hand-made beer mugs for the “Mug Club”. Stream Restoration Inc. provided the hand-collected manganese material to The Pottery Dome free of charge. BioMost, Inc. and Stream Restoration Inc. attended the opening of the “Mug Club” sales event and had the opportunity to discuss AMD, passive treatment systems, and the recovery of the manganese material with the patrons. An informational handout explaining that the mug contained manganese recovered from a passive system used to restore the Slippery Rock Creek Watershed was distributed with each mug sold. The mugs were very popular and quickly “sold out” and the North Country Brewing Company voluntarily donated $525 representing 5% of the sales to the Slippery Rock Watershed Coalition. The donation was, in turn, placed into a trust fund for future Operation and Maintenance activities relating to passive systems.

Attachment 3: Potential Commercial Users

Manufacturer	Product/Use	Address	City	State	Zip Code	Phone #	Website	Comments
Prince Agri Products, Inc	Agriculture - Animal Feed	P. O. Box 1009, P. O. Box 1009	Quincy	IL	62306	800-677-4623	www.princeagri.com	Have their own lab
Miller Chemical & Fertilizer Corp.	Agriculture - Fertilizers & soil amendments	Box 333, 120 Radio Road	Hanover	PA	17331	717-632-8921	www.millerchemical.com	Non-hazardous agricultural products - some approved organic
General Shale Brick, Inc.	Bricks	3211 North Roan St.	Johnson City	TN	37601	423-282-4661	www.generalshale.com	Plant in Darlington, PA, but it may be closed down
Green Leaf Brick	Bricks	8615 Golf Ridge Drive	Charlotte	NC	28277	704.307.0930	www.greenleafbrick.com	makes brick from recylced materials; LEED; uses mineral byproducts and accessory mine minerals
Redland Brick	Bricks	230 Rich Hill Rd.	Cheswick	PA	15024	412-828-8046	www.redlandbrick.com	Very interested. Uses both iron & manganese Made test pucks.
Glen-Gery Corp	Bricks	P O Box 7001, 1166 Spring Street	Wyomissing	PA	19601	610-374-4011	www.glengerybrick.com	Corporate office
Glen-Gery Corp	Bricks	PO Box 2903, 1090 E. Boundary Ave	York	PA	17403	717-848-2589	www.glengerybrick.com	York Manufacturing plant
Glen-Gery Corp	Bricks	PO Box 338, State Route #970	Bigler	PA	16825	814-857-7688	www.glengerybrick.com	Bigler Manufacturing plant
Glen-Gery Corp	Bricks	P O Box 68, Route 28	Summerville	PA	15864	814 856-2171	www.glengerybrick.com	Hanley Manufacturing plant
Glen-Gery Corp	Bricks	423 S. Pottsville Pike	Shoemakerrsville	PA	19555	610-562-8313	www.glengerybrick.com	Mid-Atlantic Manufacturing plant
Worldwide Refractories Inc	Bricks - Refractory bricks	6th and Center Sts	Tarentum	PA	15084	724-224-8800	www.wri-web.com	might not use, but worth trying
Watsontown Brick	Bricks and Pavers	PO Box 68, Route 405	Watsontown	PA	17777	800-538-2040	www.watsontownbrick.com	Not sure if they use colorants. Only mention of shales and sand
Whitacre Greer	Bricks and Pavers	1400 S. Mahoning Ave	Alliance	OH	44601	330-823-1610	www.wgpaver.com	Permeable pavers use recycled content; LEED points
Laguna Clay Company	Ceramic Supplies	14400 Lomitas Avenue	City of Industry	CA	91746	800-4-LAGUNA	www.lagunaclay.com	manufacturing facility in Ohio
Continental Clay Company	Ceramic Supply Store	1101 Stinson Blvd. NE	Minneapolis	MN	55413	800-432-CLAY	www.continentalclay.com	manufacturers own glazes as well as carries raw materials
Funkē Fired Arts	Ceramic Supply Store & Studio	3130 Wasson Road	Cincinnati	OH	45209	513-GET-CLAY	www.funkefiredarts.com	very interested. Potentially 1100 lbs each of Fe &Mn
American Olean Tile Co	Ceramic Tile	1000 Cannon Avenue, Box 271	Lansdale	PA	19446	215-885-1111	www.aotile.com	owned by Dal-Tile which is owned by Mohawk Industries
Daltile	Ceramic Tile	211 North Fourth St.	Gettysburg	PA	17325	717-334-1181	www.daltile.com	Gettysburg might be only unglazed but other manufacturing locations exist
Terra Green Ceramics, Inc	Ceramic Tile	1650 Progress Drive	Richmond	IN	47374	765-935-4760	www.terragreenceramics.com	ceramic tile from recycled materials; Probably not interested because consistency is very important also short firing time therefore non-calcined materials tend to be problematic but willing to evaluate.
US Ceramic Tile Company	Ceramic Tile	11190 NW 25th Street, Suite 100	Miami	FL	33172	800-321.0684	www.usctco.com	supposedly manufactured in Ohio, but not sure; green line
Armstrong World Industries	Ceramic Tile ; Linoleium; flooring	2500 Columbia Avenue	Lancaster	PA	17603	717-397-0611	www.armstrong.com	Corporate office; manufacturing throughout US
Armstrong World Industries	Ceramic Tile ; Linoleium; flooring	1018 11th St	Beaver Falls	PA	15010	724-843-5700	www.armstrong.com	local office
Bryan China Company	Ceramics - mass produced	657 Northgate Circle	New Castle	PA	16105	800-966-3098	www.bryanchina.com	local high output ceramic and porcelain ware manufacturing facility; may be able to produce products?
Hall China	Ceramics - mass produced	P.O. Box 989. 1 Anna Ave	East Liverpool	OH	43920	800-445-HALL	www.hallchina.com	mass production pottery
Homer Laughlin China Company	Ceramics - mass produced	672 Fiesta Drive	Newell	WV	26050	800-452-4462	www.hlchina.com	mass production pottery
Trenwyth Industries	Concrete - Architechtural	One Connelly Road, P.O. Box 438	Emigsville	PA	17318	717-767-6868	www.trenwyth.com/	recycled materials, Green building products, LEED
Pittsburgh Flexicore Co. Inc.	Concrete - beams, columns, walls	1877 Rt. 2023	Monongahela	PA	15063	412-462-7117	www.pittsburghflexicore.com	not interested in experimenting
Doren, Inc.	Concrete - Block	Rt.18	Wampum	PA	16157	724-535-4397	NA	not interested in experimenting
Montgomery Block Works	Concrete - Block	4275 William Flynn Hwy	Harrisville	PA	16038	724-735-2931	NA	cement block manufacturer close to SRWC sites
Semper Concrete Products	Concrete - Block	858 New Castle Road	Butler	PA	16001	724-865-2592	NA	not interested in experimenting
Shiderly Concrete Products & Pipes	Concrete - Block	5979 East State Street	Hermitage	PA	16148	724-981-0740	NA	not interested in experimenting
York Building Products Company	Concrete - Block & building matierals	950 Smile Way	York	PA	17404	717-848-2831	www.yorkbuilding.com	various manufacturing locations; various products with potential LEED; colored mortar is one product
Beavertown Block Company	Concrete - Block, Pavers etc	3612 Paxtonville Road	Middleburg	Pa	17842	570-837-1744	www.beavertownblock.com	Manufacturing plant; The Verde line is a LEED certified product using post-industrial materials

Manufacturer	Product/Use	Address	City	State	Zip Code	Phone #	Website	Comments
Beavertown Block Company	Concrete - Block, Pavers etc	121 N. Harrison Road	Pleasant Gap	PA	16823	814-359-2771	www.beavertownblock.com	Manufacturing plant; The Verde line is a LEED certified product using post-industrial materials
Beavertown Block Company	Concrete - Block, Pavers etc	Back Street	McKee	PA	16637	814-695-4448	www.beavertownblock.com	Manufacturing plant; The Verde line is a LEED certified product using post-industrial materials
R.I. Lampus Co	Concrete - Block, Pavers, etc	816 R.I. Lampus Avenue	Springdale	PA	15144	412-362-3800	www.lampus.com	Eco-Tek permeable paver provides LEED points and already uses Enviroxide pigment
Outlaw Studios	Concrete - Countertops, floors, etc	2420 Penn Avenue	Pittsburgh	PA	15222	412-471-1085	www.outlawstudios.com	unique concrete pieces; very interested; creating test pieces;
Ardex Inc	Concrete - Engineered Cement	400 Ardex Park Drive	Aliquippa	PA	15001	724-203-5000	www.ardex.com	might not use colorants
Baker's Home and Garden Center	Concrete - Lawn ornaments	570 Berlin Plank Road	Somerset	PA	15501	814-445-7028	NA	interested; plans to experiment
White's Concrete Products	Concrete - Lawn ornaments	225 Rt. 580	Clymer	PA	15728	724-254-2396	NA	interested; plans to experiment
Dayton Superior Corp.	Concrete - Matirals,Ready mix, Paving	55 North Pine Street	Tremont	PA	17981	570-695-3163	www.daytonsuperior.com	sells green/LEED products
Brentano Concrete Connection, Inc.	Concrete - ornamental stone and statues	520 Rodi Road	Pittsburgh	PA	15325	412-731-8485	NA	not interested in experimenting
Deitos Ornamental Concrete, Inc.	Concrete - Ornamental stone and statues	440 Johnson Street	Freeland	PA	18224	570-636-1887	NA	not interested in experimenting
Keystone Lintels, Inc.	Concrete - Products	2275 Old Bethlehem Pike	Quakertown	PA	18951	215-257-6855	NA	not interested in experimenting
Patio Concrete Products, Inc.	Concrete - Products	2339 Edgely Road	Levittown	PA	19057	215-946-6739	www.patioconcrete.com	mostly makes testing blocks, but does do other products
Smith Concrete Products	Concrete - Ready mix, Paving	1050 Old Rt. 119	Homer City	PA		724-349-5858	NA	not interested in experimenting
GCL, Inc.	Concrete - Retaining walls	2559 Brandt School Road	Wexford	PA	15090	412-367-7161	www.cambergroup.com	not interested in experimenting
Stone Vessel Sink	Concrete - Sinks & Counter tops	1166 S. Skylane Road	Durango	CO	81303	970-385-4044	www.greenpeople.org	sinks created from recycled glass and concrete, ceramics
Clayton Block Company Inc	Concrete -Block, Pavers, etc	PO Box 3015	Lakewood	NJ	08701	888-452-9348	www.claytonco.com	recycled materials; LEED points
Dectile	Concrete Roof Tile	195 Kriess Road	Butler	PA	16001	724-789-7125	www.dectile.com	uses iron oxide
Aubrey Organics	Cosmetics	4419 N. Manhattan Avenue	Tampa	FL	33614	800-282-7394	www.aubrey-organics.com	organic/natural cosmetics; uses iron oxides
Dr.Hauschka Skin Care, Inc.	Cosmetics	20 Industrial Drive East	South Deerfield	MA	01373	800-247-9907	www.drhauschka.com	eco-conscious; uses manganese violet? And iron oxides
EccoBella	Cosmetics	50 Church Street, Suite 108	Montclair	NJ	07042	877-696-2220	www.eccobella.com	organic/natural cosmetics - uses iron oxides
Perfect Organics	Cosmetics	PO Box 306	Merrifield	VA	22116	800-653-1078	www.perfectorganics.com	organic/natural cosmetics - uses iron oxides
Suki Inc	Cosmetics	99 industrial drive	North Hampton	MA	01060	888-858-suki	www.sukicolor.com	environmentally concious organic/natural cosmetics - uses iron oxides
SunCoat	Cosmetics	386 Laird Road, Unit #3 Hanlon Business Park	GUELPH, Ontario, Canada		N1G 3X7	519-820-5468	www.suncoatproducts.com	environmentally concious organic/natural cosmetics - uses iron oxides
Vitrium Tile	Glass Tile	6920 Tollgate Road	Point Pleaseant	PA	18950	215-297-9363	www.vitriumtiles.com	No mention of recycled content or green lines
Old Carolina Brick Company	Handmade bricks	475 Majolica Road	Salisbury,	NC	28147	704-636-8850	www.handmadebrick.com	hand-made brick; may accept variation; supposedly uses 20 tons of mn
Old Virginia Brick	Handmade bricks and pavers	2500 W. Main Street	Salem	VA	24153	540-389-2357	www.oldvirginiabrick.com	hand-made brick; may accept variation;
Seneca Tiles, Inc.	Hand-made Tile	7100 South County Road 23	Attica	OH	44807	800-426-4335	www.senecatiles.com	largest producer of authentically handmade tiles in the US and a recognized leader in manufacturing rustic, glazed tiles and unglazed paver tiles.
Trikeenan Tileworks, Inc	Hand-made Tile	P.O. Box 22	Keene	NH	03431	603-355-2961	www.trikeenan.com	Social responsiblility, green products, recycled content
Forbo Flooring North America	Marmoleum, Linoleum	8 Maplewood Drive • P.O. Box 667	Hazleton	PA	18202	800-842-7839	www.themarmoleumstore.com	environmentally friendly flooring products (marmoleum & linoleum); LEED points; might not be manufactured in US
Prince Minerals	Mineral Supplier	14 East 44th Street, 5th Floor	New York	NY	10017	646-747-4222	www.princeminerals.com	supplies manganese and iron oxides to a variety of industries including bricks, ceramic, agricultural, animal feeds, water treatment, etc;
Silacote	Paint	NA	Grass Valley	CA	NA	800-249-1881	www.silacote.com	for concrete, cement, wall board; uses minerals for colorant

Manufacturer	Product/Use	Address	City	State	Zip Code	Phone #	Website	Comments
Yolo Colorhouse	Paint	116 SE Yamhill Street	Portland	OR	97214	877-493-8275	www.yolocolorhouse.com	Green Seal certified, environmentally responsible paints
The Old Fashioned Milk Paint Co.	Paint - Milk Paint	436 Main Street	Groton	MA	1450	978-448-6336	www.milkpaint.com	environmentally friendly, organic paints; use minerals for color including iron oxide
The Real Milk Paint Company	Paint - Milk Paint	11 West Pumping Station Road	Quakertown	PA	18951	215-538-3886	www.realmilkpaint.com	environmentally friendly paint
BioShield Paint Company	Paint - Natural Paint	3005 S. St.Francis Suite 2A	Santa Fe	NM	87505	505-438-3448	www.bioshieldpaint.com	environmental natural paints; uses natural pigments
Sinan Company	Paint - Natural Paint	P.O. Box 857	Davis	CA	95617	530-753-3104	www.sinanco.com	natural green building materials
Eco Safety Products	Paint & Coatings	1522 E. Victory Street, Suite 2	Phoenix	AZ	85040	877-366-7547	www.ecoprocote.com	environmentally friendly/safe paint and coatings; ecoprocote product line; might not use mineral oxides
Ceramic Coloring and Chemical Mfg Co.	Pigments - Ceramics	13th St & 11th Ave	New Brighton	PA	15066	724-846-4000	NA	Manufactures pigments/colorants including inorganic oxides
Ferro Corporation	Pigments - Ceramics	1000 Lakeside Avenue	Cleveland	OH	44114	216-641-8580	www.ferro.com	corporate office; pigments and glazes for ceramics, paints, coatings industry;
Ferro Corporation	Pigments - Ceramics	251 West Wylie Avenue P.O. Box 519	Washington	PA	15301	724-223-5900	www.ferro.com	pigments and glazes for ceramics, paints, coatings industry;
Davis Colors	Pigments - Concrete	7101 Muirkirk Road	Beltsville	MD	20705	800-638-4444	www.daviscolors.com	some eco-friendly concrete pigmenst
Mason Color Works	Pigments -Ceramic stains	PO Box 76	East Liverpool	OH	43920	330-385-4400	www.masoncolor.com	manufacturers pigments
Crossville, Inc	Porcelain tile	P.O. Box 1168	Crossville	TN	38557	931-484-2110	www.crossvilleinc.com	Ecocycle line uses recycled matierals
W.C Bunting	Pottery- mass produced	1425 Globe St	East Liverpool	OH	43920	330-385-2050	www.wcbunting.com	mass production pottery with decals
Trinity Ceramic Supply	Raw Materials - Bricks & Ceramics	9016 Diplomacy Row	Dallas	TX	75247	214-631-0540	www.trinityceramic.com	very interested; samples of material were sent for evaluation; uses iron & manganese
Sandhill Industry Inc	Recycled Glass Tile	6898 S. Supply Way, Suite 100	Boise	ID	83716	208-345-6508	www.sandhillind.com	uses 100% recycled glass to make tiles; not sure about source of pigments to glass
IceStone, LLC	Recylced glass/concrete durble surfaces	63 Flushing Ave Unit 283, Building 12	Brooklyn	NY	11205	718.624.4900	www.icestone.biz	very environmentally conscious, LEED and Cradle to Cradle certification
Fireclay Tile Inc.	Tile	495 West Julian Street	San Jose	CA	95110	408-275-1182	www.fireclaytile.com	handmade; debris product line uses recycled materials; USGBC Member; very interested in Iron oxide- wants ~2 lbs; not interested in MnO
Quarry Tile	Tile	6328 E. Utah Ave	Spokane	WA	99212	509-536-2812	www.quarrytile.co	LEED certified and recycled ceramic tile
Mohawk Flooring	Tile; Linoleum	160 South Industrial Blvd	Calhoun	GA	30701	800-266-4295	www.mohawk-flooring.com	recycles, green products, environmentally conscious
ATEC Systems	Water Treatment	1329 Broadway, Suite 206	Longview	WA	98632	360-414-9223	www.pyrolox.com	pyrolox uses manganese dioxide to treat for H2S, Fe, Mn, and other metals; 8X20 & 20X40 mesh size; owned by Prince Minerals

With the excitement generated by the mugs and a strong interest from Robert Isenberg and Lois Hamilton (Owner of The Potter Dome), Stream Restoration Inc. developed an ongoing and mutually-beneficial relationship, which resulted in the development of a variety of named glaze patterns utilizing recovered manganese and iron oxides (precipitated at low pH). The glaze patterns were named after streams within the Slippery Rock Creek Watershed including Blacks Creek, Seaton Creek, Wolf Creek, Muddy Creek, Murrin Run, Jamison Run, and Slippery Rock Creek. These different glaze patterns can be applied to a wide variety of ceramic products. Table 18 provides a listing of ceramic products created to date as well as some potential future products.

Table 18: Current and Potential Future Ceramic Products

Current Ceramic Products Available		Potential Future Ceramic Products	
Beer Mugs	Serving Bowls	Ash Trays	Lamps
Canister Sets	Snack Trays	Book Ends	Magnets
Casserole Dishes	Soup/Salad Bowls	Candle Holders	Ornaments
Coffee Mugs	Tea Pots	Clocks	Salt/pepper Shakers
Cups	Tea Cups	Coasters	Soap Dishes
Dessert Plates	Vases	Cookie Jars	Soap/Lotion Dispensers
Dinner Plates	Water Pitchers	Flower Pots	Toothbrush Holders
Sauce Cups	Wine Goblets	Jewelry	Wall Hangings

In order to assist in marketing the recovered manganese and iron oxides as well as the ceramic products created utilizing these materials, Stream Restoration Inc. created a new division called Clean Creek Products. An e-commerce website was developed (www.cleancreek.org) with an online catalog for ordering which also included information about AMD, passive treatment systems, and resource recovery. In addition, a variety of marketing sheets/brochures were developed for both consumers of products and users of the raw material. Copies of these handouts and selected print-offs from the website are included in the Appendix entitled Marketing Materials. These marketing materials are planned to be updated and new marketing materials created as needed.

In addition to the website, the ceramic products are also being carried by a high-end, specialty shop, Kitchen Kaboodle (State College, PA) and have been displayed and marketed at various public events in 2008 (See timeline for dates.) such as:

- Boscov's Department Store Green Day (Butler, PA)
- Monroeville Expo Home and Garden Show (Monroeville, PA)
- PA Abandoned Mine Reclamation Conference (State College, PA)
- PA Assoc. of Environmental Professionals Annual Meeting (Grantsville, PA)
- American Society of Mining & Reclamation Annual Meeting (Richmond, VA)
- Harrisville Community Day (Harrisville, PA)
- National Council on Education for the Ceramic Arts Annual Conference (Pittsburgh, PA)

One of the most exciting events both for marketing and education/outreach was the 2008 National Council on Education for the Ceramic Arts (NCECA) Annual Conference, held in Pittsburgh, PA at the David L. Lawrence Convention Center. Clean Creek Products had a booth with poster display, informational handouts, examples of pottery, and sample packets of recovered manganese and iron oxides, which had been dried and sieved to a –60 mesh. The response from the attendees of the conference was overwhelmingly positive and generated much enthusiasm for not only the recovered material but also the watershed restoration projects as well. In fact, based upon the reactions of the attendees, Clean Creek Products may have been "the most talked about" exhibit at the conference of ~2000 people. As the news was spread by "word of mouth", many people at the conference sought out the display. During the course of the event, Clean Creek Products distributed roughly 500 packets each of the low-pH iron and manganese material to ceramic artists as well as large ceramic supply stores including Laguna Clay Company, Standard Ceramic Supply Company, and Trinity Ceramic Supply. These ceramic supply companies have all expressed an interest in the recovered materials, which would be marketed as a "green" glaze ingredient and/or used to create lines of commercial pre-mixed "green" glazes. In addition, many of the artists have expressed an interest in developing a relationship with Clean Creek Products to create and market ceramic items made with the recovered materials. Clean Creek Products will continue to work with the individual artists and ceramic supply companies to develop a "green", "Made in America", market for these materials.

Tile: In addition to ceramic pottery, the recovered material has potential use in ceramic tile. With a growing demand for "green" products and building materials, the recovered manganese and iron is projected to provide additional LEED certification points. Robert Isenberg created several hand-made ceramic tile pieces to use as marketing examples. Several tile manufacturers who focus on using recycled materials within their tile will be contacted including Terra Green (Richmond, IN) and Fireclay Tile Inc. (San Jose, CA).

Linoleum and Marmoleum: A potential flooring material with "green" market potential is true linoleum. While called "linoleum", some floor products are actually made with polyvinyl chloride. True linoleum is made with solidified linseed oil usually in combination with wood flour or cork dust. These natural materials have resulted in linoleum making a "comeback" within the flooring market as a "green" product. Likewise, marmoleum, made of linseed oil, rosins, and wood flour with a natural jute backing, is considered a "green" product as well. In the future, companies such as Armstrong Worldwide Industries, Mohawk Flooring, Forbo Flooring that manufacturer linoleum and/or marmoleum will be contacted.

Bricks: Manganese is sometimes used as a pigment in the making of bricks. With a growing interest in "green" buildings, the use of brick can contribute LEED certification points because of the non-toxic nature and natural materials. The use of a "green" colorant is expected to add points toward LEED certification and may be a preferred feature for certain segments of the population.

The Redland Brick Company (Cheswick, PA) was contacted to determine interest in the recovered manganese and iron material. The plant manager was very interested in potentially using the materials and offered to conduct some initial testing. Several test brick pucks, which are approximately the same shape and size of a hockey puck, were created using both the recovered manganese and iron material. (See photos in Appendix.) The manganese material was used to create three pucks using 1%, 2%, and 3% of the manganese oxide material by weight. The color of the pucks was then compared to their standard brick made with 0.6% of commercially available manganese oxide pigment purchased from Prince Minerals. (See photos in Appendix.) While the manufacturer seemed to be satisfied with the outcome, ~10 times the amount of the unprocessed recovered manganese is needed compared to the commercially-available manganese oxide. As the manufacturer indicated that the price of the commercially-available material is continually increasing, the changing economics will need to be monitored and evaluated to determine the viability of using the recovered product. In addition, a cost analysis that includes material processing to increase the percentage of manganese oxide may prove to be warranted. Recovered (low-pH) iron oxide was also used to create three pucks using 1%, 5%, and 10% of the material by weight. The color of the pucks was then compared to their standard brick made with 3% of commercially-available iron oxide pigment purchased from Prince Minerals. The manufacturer was very pleased with the recovered iron, which used about the same quantity of material to get the same effect. Again, economics will play a role. Stream Restoration Inc. will continue to work with Redland Brick as well as seek out other brick companies who may be interested in using the recovered materials.

Concrete: Manganese oxides are also used as colorants in concrete. Concrete is a rather versatile substance and can be used to make a variety of products from simple concrete blocks and pavers to very expensive ornate countertops. Several concrete product manufacturers were contacted to determine interest in utilizing the manganese material within various products including block, pavers, lawn ornaments, etc. Most manufacturers reported purchasing concrete colorants from suppliers such as Davis Colors and Bailey Ceramic Supply and were not interested in evaluating the recovered material for use. These manufacturers suggested working directly with the colorant supply companies. Samples of the recovered (low-pH) iron and manganese oxides were given to Baker's Home and Garden Center, White's Concrete Products, and Outlaw Studios free of charge for evaluation. Outlaw Studios (Pittsburgh, PA), manufacturer of a variety of attractive concrete products including sinks, countertops, benches, floors, etc. was particularly interested. At the time of writing of this report, there were no results available from these three companies. Stream Restoration Inc. will continue to work with these companies relating to market development for the recovered materials.

BioMost, Inc. conducted two, in-house, experiments/demonstrations utilizing the recovered manganese to color concrete. The first experiment consisted of comparing a commercial concrete colorant called Sakrete Charcoal with the unprocessed “residual” and “slurry” recovered manganese material. As discussed earlier, the residual material was excavated from the wash pits using an excavator and shovels while the slurry material was pumped directly from the wash pits into the totes for dewatering. The comparison tests were performed by mixing small, individual, batches of concrete within a bowl and then pouring the mixture into 8-oz. Styrofoam cups to set. The colorant to concrete ratios, weights of the colorant and concrete, and the amount of water for each sample are provided in Table 19. According to the Sakrete directions, the typical recommendation is 1 lb. of colorant to 80 lbs. of concrete or 1:80. Based upon this initial test, while the material can be used as a colorant, the color produced is not the same. (See photos in Appendix.) Increasing the quantity of manganese material within the mixture has not been tested to determine the feasibility of developing equal coloration to that of the commercial material. An economic evaluation to determine the desirability of colors developed from the unprocessed material and/or processing and retesting the material are proposed.

Table 19: Ratios, Weights, and Volumes Used In Batch Concrete Experiment

Colorant to Concrete Ratio	**Colorant Weight** (grams)	**Concrete Weight** (grams)	**Water Volume** (oz)
1:120	0.83	100	0.238
1:100	1.00	100	0.238
1:80	1.25	100	0.238
1:60	1.67	100	0.238
1:40	2.50	100	0.238
1:20	5.00	100	0.238
1:10	10.00	100	0.238

A second experiment/demonstration was conducted by BioMost, Inc. during installation of four lamp posts at the home of Tim Danehy. A 3.5-foot length of 8-inch form tubing was used to make the foundation for each post, which required a total of two, 80-pound, bags of Quickrete concrete. For each of the four posts, the first bag of concrete had no colorant added as this portion would not be visible. For the first three posts, the unprocessed manganese material (slurry from Tote 25) was added to the concrete mixture at a ratio of 8 lbs. of material to 80 lbs of concrete or 1:10. For the fourth post, a mixture of 16 lbs. of recovered manganese material was added to 80 lbs. of concrete or a ratio of 1:5. (See photos in Appendix.) Even though this is a positive indication of a potential commercial use of the recovered manganese, additional testing and potentially processing are needed.

Paint: Manganese and iron oxides are also used in paint. Most paint companies have very strict specifications for pigment usage. There are, however, several natural paint companies such as The Real Milk Paint Company (Quakertown, PA) and Nature's Paint Store (Fort Lauderdale, FL) which may consider using the material. These companies will be contacted in the future to determine specifications. Additional experimentation to develop samples for marketing purposes is being considered.

Cosmetics: There is a growing demand within the cosmetic industry for more natural and environmentally-friendly products. Several companies such as Sun Coat, Suki, Inc., and Aubrey Organics, utilize minerals to provide the color to cosmetics. Minerals most commonly used are iron oxides. Even though a compound called manganese violet was used in at least one of the products, the source and mineral constituent(s) have not been determined to date from the company. Extensive processing and testing of the recovered material would be necessary to pursue this market.

Agriculture

Manganese, an essential nutrient to plants and animals, is vital to a number of biological processes. Because of the complex biogeochemical processes involved in passive treatment the manganese-bearing material contains other elements in relatively small concentrations that are important micronutrients. (See earlier discussions relating to chemical characterization of recovered material.) In addition, the material contains significant quantity of limestone fragments which may be enable commercial usage as either a soil amendment or animal feed supplement. A product called "Glime Plus trace elements" is currently made in Australia as an agricultural crushed limestone material with added chelated trace elements including 480 mg/kg of manganese. A number of other soil amendments and animal feed supplements are currently available that contain minerals and micronutrients including manganese. The concentrations of several of the elements such as cobalt, nickel, and zinc within the recovered manganese material may need to be decreased through improvement of the recovery process and/or through commercial processing in order for the material to be suitable for this use. While significant development and testing would be required, this use does have potential and will most likely be further investigated.

Water Treatment

Another potential use of the manganese material is for water treatment. Manganese oxides, to catalyze reactions and to oxidize pollutants and for adsorption qualities are used in filter treatment media to remove iron, manganese, and a variety of heavy metals. Dr. Art Rose, geologist (Professor Emeritus Penn State Univ.) conducted tests to determine if the recovered manganese material would be useful in decreasing arsenic concentrations at a coal ash disposal site. The recovered manganese was added to the coal ash at 1% and then a Synthetic Precipitation Leaching Procedure (SPLP) test was conducted. While arsenic concentrations were reduced, the decrease was not sufficient to meet the goals of the experiment. As the facility produces ~250,000 tons of ash per year, with an addition rate of 1% by weight, 2500 tons of manganese annually would be required, which thought to be excessive. Additional scientific research is needed to determine the feasibility of use in water treatment.

MARKETING MATERIALS

A variety of marketing materials related to the recovered manganese were developed. A double-sided flyer for the general public was created not only to identify the connection of “abandoned mine drainage→ passive treatment→ resource recovery→ pottery” but also to explain the mission of Clean Creek Products to support “potters→ American-made products→ continued-and-sustainable watershed restoration”. The goal of sustainable watershed restoration was further illustrated by the commitment to donate a portion of all sales, whether of the raw/processed material or of finished pottery pieces, to support Operation and Maintenance of the passive treatment systems that improve the water quality of streams and restore aquatic habitat. An additional flyer was developed specifically for ceramic artists to further explain the partnership approach by Clean Creek Products to work with artists to create sellable products to support restoration efforts. A one-page fact sheet was created for both the recovered manganese oxide as well as the (low-pH) iron oxide material including source of the material, potential uses, chemical composition, particle-size distribution, and health & safety information. As previously mentioned, www.cleancreek.org, an e-commerce website was also developed to allow purchase of the pottery directly over the internet. In the future, other products are planned to be available for purchase through the website including the manganese and iron oxides. Copies of these marketing materials including print-outs from the website have been included in the Appendix.

EDUCATION & OUTREACH

Education and outreach have always been important to Stream Restoration Inc. and is, therefore, included in every project whenever appropriate. Selected events which included both marketing and education/outreach opportunities are listed in the previous subsection “Early and Continuing Use as Pigment/Colorant in Hand-Made Ceramics”.

Numerous articles (>20) providing state-wide, national, regional, and local coverage have also been published, providing both education/outreach and positive marketing opportunities. Except for the Slippery Rock Watershed Coalition monthly newsletter, *The Catalyst,* all articles were written by journalists through interviews with project participants or were written by invitation from the publisher or staff. Articles have appeared in the following publications: (See articles in Appendix for title, date, author, etc.)

- **National, Regional, Local Magazines/Periodicals:**
    - Sierra (national - Sierra Club)
    - Pittsburgh Quarterly (regional)
    - The Point North (local)
    - The Rock (regional)
    - Technology News and Trends (national - US EPA)
    - Reclamation Matters (national)

- **Local Newspapers:**
    - “The Eagle” (Slippery Rock, PA)
    - “The Butler Eagle” (Butler, PA)
    - “The Herald” (Grove City, PA)

- **Online Newsletters:**
    - *PA Environment Digest* (Crisci Associates)
    - *Envirobytes* (US EPA)
    - *Abandoned Mine Posts* (WPCAMR)
    - *Clay Art* (Potters.org)

- **Watershed Newsletter:**
    - *The Catalyst* (Slippery Rock Watershed Coalition)

A peer-reviewed professional paper was also written and presented at the 2008 conference of the American Society of Mining and Reclamation, which is included in the Appendix. This paper was well-received which precipitated, along with the exhibit displaying the pottery (See photos.), the article in the bi-annual official magazine of the organization. (See New Items in Appendix.)

Denholm, Clifford, Timothy Danehy, Shaun Busler, Robert Dolence, Margaret Dunn, 2008, Sustainable Passive Treatment of Mine Drainage: Demonstration of Manganese Resource Recovery (A Preliminary Case Study): *in proceedings* of the 2008 National Meeting of American Society of Mining & Reclamation, p. 285-297.

Through encouragement by project participants and supporters of the recovery effort, additional venues are being considered for marketing and education/outreach opportunities. These potential venues have been compiled in Table 20.

Table 20: Potential Future Venues for Articles and/or Advertisements

Potential Sources of Advertising	Type of Venue	Website
"On Q" WQED	TV-Local Program	www.wqed.org/tv/onq/
Abandoned Mine Posts	Website	amp.wpcamr.org
Allegheny Front	Radio-Env. Program	www.alleghenyfront.org
Audubon Magazine	Magazine	audubonmagazine.org
BTC Elements	Website- Retail	btcelements.com
Building Green	Website	www.buildinggreen.com
Ceramic Arts Daily	Website	www.ceramicartsdaily.org
Ceramic Arts Monthly	Magazine	www.ceramicartsdaily.org
Ceramic Industry	Website	www.ceramicindustry.com
Ceramics Today	Website	www.ceramicstoday.com
Clay Art	Website	http://www.potters.org/
Clay Times	Magazine	www.claytimes.com
Fired Arts and Crafts	Magazine	http://www.firedartsandcrafts.com
Good to be Green	Website	www.goodtobegreen.com
Green Building Pages	Website	www.greenbuildingpages.com
Green Building Supply	Website	www.greenbuildingsupply.com
Green For Good	Website	www.greenforgood.com
Green Home	Website-Retail	www.greenhome.com
Green Home Living	Magazine	www.greenhome.com/info/magazine
Industrial Ceramics and Pottery Directory	Website	www.ceramics-directory.com
Kiwi Magazine	Magazine	www.kiwimagonline.com
Low Impact Living	Website	www.lowimpactliving.com
Mother Earth News	Magazine	www.motherearthnews.com
National Council on Education for Ceramic Arts	Website	www.nceca.net
National Geographic	Magazine	www.nationalgeographic.com
Pennsylvania Environmental Digest	Website	www.paenvironmentdigest.com
Plug Green	Website	www.pluggreen.com
Pottery Making Illustrated	Magazine	www.ceramicartsdaily.org
Reclamation Matters	Magazine	ces.ca.uky.edu/asmr
Sierra Magazine	Magazine	www.sierraclub.org
Subaru Drive Magazine	Magazine	www.drive.subaru.com
The American Ceramic Society	Website	www.ceramics.org
The American Ceramic Society Bulletin	Magazine	www.ceramics.org
The Green Guide	Website	www.thegreenguide.com
The Journal of the American Art Pottery Assoc.	Magazine	www.aapa.info
The Journal of the American Ceramic Society	Magazine	www.ceramics.org

FUTURE MANGANESE “RESERVES”

One “often-asked” question from potential users of the recovered manganese material is, “How much do you have?” In Table 2, a combined total estimate of ~165,000 to ~230,000 lbs. or ~80 to ~115 tons of manganese as the element based on decreases in loading (influent vs. effluent) are available within four Horizontal Flow Limestone Beds (HFLBs) in the Slippery Rock Creek Watershed. Another HFLB is in the process of being installed and at least one other passive system with an HFLB has been proposed. In addition, Stream Restoration Inc. and/or BioMost, Inc. have been involved in the design and installation of at least five other HFLBs in western Pennsylvania. An annual rotation where the recovery process rehabilitates one HFLB annually is projected to conservatively generate ~25 to ~50 tons of manganese oxide material every year. Needless to say, with the installation of additional HFLBs, the quantity of available manganese-bearing material for recovery increases.

CONCLUSIONS & RECOMMENDATIONS

A method that successfully and economically restores the treatment performance of Horizontal Flow Limestone Beds, reuses the treatment medium, and recovers manganese material as a new “natural” resource has been demonstrated. Early market development efforts indicate that the recovered manganese-bearing material has commercial value, particularly associated with “recycling as a green product”. The early use of the recovered material in hand-made pottery glazes has also helped to financially support local potters, local businesses, and local watershed groups, while at the same time providing education and outreach opportunities, which have resulted in an increased awareness and interest in watershed restoration. In other words, the manganese resource recovery effort was and continues to be instrumental in the

- ***sustainability* of the treatment performance of passive systems** to maintain stream improvement which increases property, recreational, wildlife, and industrial/commercial values;

- ***sustainability* of the watershed stewardship concept** by providing education and outreach with an opportunity for the general public to directly contribute (purchase of pottery, etc.) to the restoration effort; and

- ***sustainability* of local businesses** (increased patronage and sales at the brew pub; financial support of local potters, etc.) which supports the economic viability of the community.

While this is currently a “win-win-win” effort locally, the “reuse” of manganese-bearing material is still in the early stages of development. While much has been accomplished through this project, there is still much to be gained. The following recommendations seek to further the resource recovery effort and to sustain and improve the passive treatment of abandoned mine drainage:

- refinement of the recovery process to decrease extraneous material (limestone fragments) and increase the percentage of manganese oxides and/or to develop a processing procedure (in the field or at a commercial facility) to beneficiate the manganese oxide;

- continued expansion and evaluation of the use of the recovered manganese material in ceramic glazes;

- further evaluation of other potential uses of the recovered manganese material including bricks, concrete, tile, cosmetics, agricultural and water treatment applications;

- completion of a detailed cost-benefit analysis of the recovery effort;

- development of an aggressive marketing campaign;

- continuation of monitoring to document and evaluate the long-term impact on HFLB rehabilitation, especially in terms of water quality and treatment media permeability/hydraulic conductivity.

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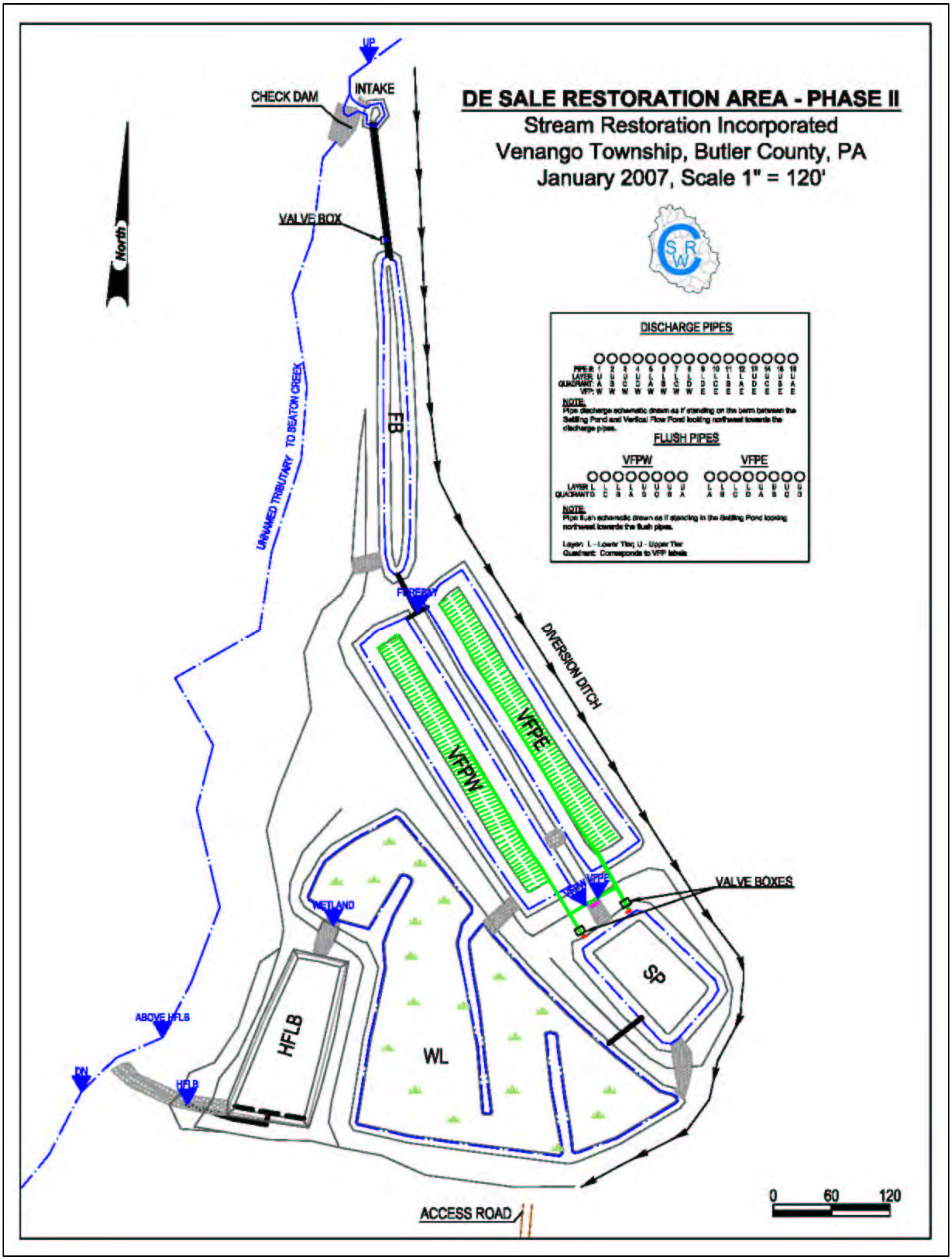
De Sale Restoration Area Phase 1 and Phase 2: Aerial view of the uppermost headwaters of Seaton Creek with the De Sale Phase 1 (online 2000) passive treatment system (foreground-right) and the De Sale Phase 2 (online 2000) passive treatment system (background-left). Photo taken by Dave Hess 05/17/01.



De Sale Restoration Area Phase 2 Site Schematic.

De Sale Restoration Phase 2 Horizontal Flow Bed: 2,900 tons of AASHTO #1 limestone (>90%$CaCO_3$) shortly after construction (top). After about three years, reduced hydraulic conductivity caused water to flow across the top of the limestone treatment media (bottom) during seasonally high-flow periods.

Bench-Scale Tests: Three 5-gallon buckets of manganese-coated limestone were collected from each of six hand-dug test pits (18 buckets total) (Top Right) midway in the HFLB at the De Sale Phase 2 Passive System (Top Left). Each bucket was rolled (Center Left) for 1 minute then the contents were dumped onto a tarp (Bottom Left). Mn material remaining in the bucket (Center Right) and on the tarp was collected and placed within a sample bag. The process was then repeated twice, 2 minutes rolling each. When the treatment media was not allowed to dry, the Mn material was not readily removed from the aggregate and was more difficult to collect. When wet, the Mn material required scraping from the bucket and the tarp (Bottom Right).

Bench-Scale Tests: Bench-scale processing after media drying was much easier and more effective (Top), although significant dust was generated. The washing process, which consisted of placing the Mn-coated limestone in a mesh bag (Center Left) and then vigorously dunking the bag in a water-filled tote (Center Right), produced relatively clean stone (Bottom Left). Once washing was completed, the Mn material was allowed to settle, the water was siphoned off, and the remaining sludge was allowed to dry before collection (Bottom Right).

Recovery Effort: The first attempt at simultaneously rehabilitating a Horizontal Flow Limestone Bed (HFLB) and recovering manganese was conducted at the De Sale Phase 2 site (Top Left). A grid was marked on the surface of the HFLB (Top Right) for ease in assigning observations made during the recovery attempt. A wash pit was excavated (Center Left) and lined (Center Right) for increased ease and efficiency of the recovery effort. An excavator attachment, FlipScreen (Bottom Left), used for topsoil screening, was rented, at reduced rates, from Giberson Enterprises (Bottom Right) who were extremely helpful in setting up and demonstrating attachment operation.

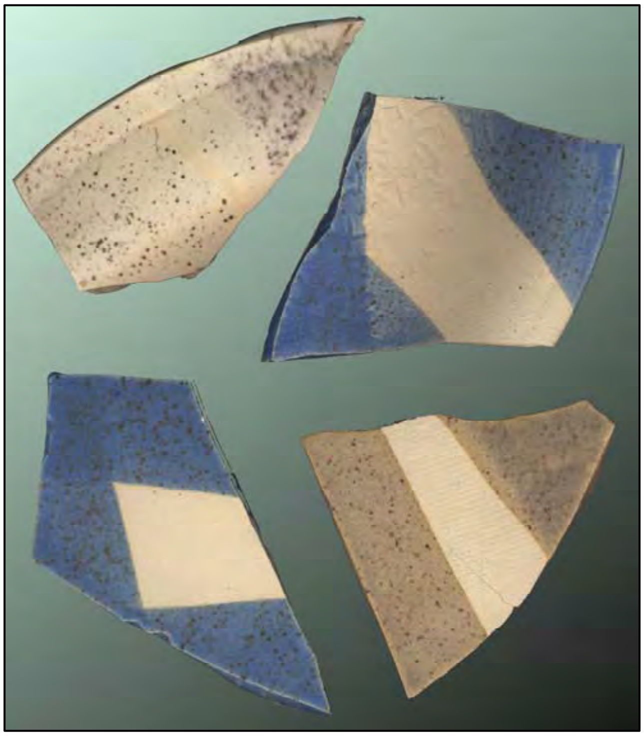
Recovery Effort: Experiments were conducted with the FlipScreen prior to full-scale recovery to finalize the methodology to be utilized, including determining the value of using a wash pit (Top Left). As the use of the wash pit was determined to be advantageous, additional experiments were conducted to determine the most effective time and speed of rotation in using the FlipScreen. As depicted by the photos, a significant difference was not observed between a 5-minute (Center Left) and 1-minute (Bottom Left) period of rotation. A difference was noted at 30 seconds (Bottom Right) and during a slow rotation (Center Right), however.

Recovery Effort: Once the process was finalized, full-scale recovery began (Top Left). As the Flip-Screen rotates within the wash pit, Mn-bearing material and small rock fragments (minus 3/8") passed through the screen (Top Right) while the larger-sized aggregate was retained. Mn-bearing material was observed to be not only throughout the bed but also extending the entire thickness (Center Left and Right). The process was observed to be extremely effective at cleaning the stone as can be seen by the contrasting blackish color of unprocessed with the light-gray of the processed stone (Bottom Left) and just cleaned stone (Bottom Right).

Recovery Effort: As recovery efforts progressed (Top Left), a second wash pit was installed (Top Right). When a wash pit filled with accumulated material, the sludge, as feasible, was pumped as a slurry from the wash pit (Center Left) to flexible, intermediate, bulk containers (FIBCs) (Center Right and Bottom Left) for dewatering, storage and offsite shipping. Manual labor was also used in order to pump as much sludge as possible from the wash pit (Bottom Right).

Recovery Effort: Material remaining (residual) in the wash pit (Top Left) was then excavated (Top Right) and either placed on tarps for further drying (Center Left) or directly into FIBCs. As removal neared the bottom of the wash pit, residual material was loaded by hand into the excavator bucket to prevent ripping the wash pit liner. FIBCs were lifted from the wooden support frames (Bottom Left) and loaded onto a flatbed trailer (Bottom Right) for off-site storage. 31 FIBCs (~30 tons) were removed from the site. (Selected loads weighed at Quality Aggregates Inc., Boyers, PA scalehouse)

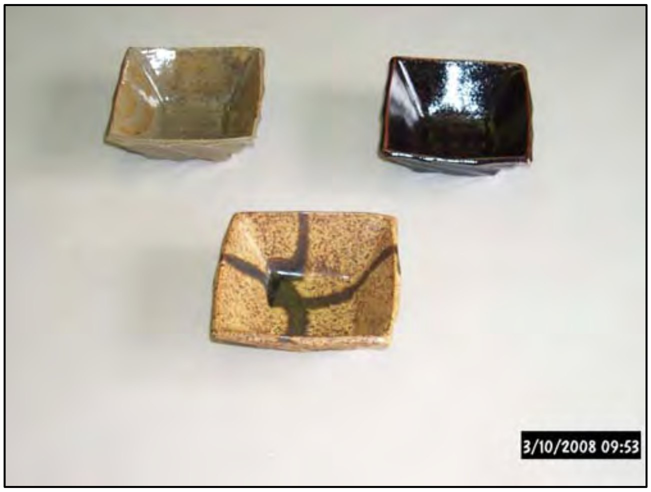
Material Sampling and Analysis: Samples of the recovered material were collected from selected totes (Top Left) for a variety of laboratory analyses. Representative samples included both residual (Top Right) and pumped material (Center Left). A sieve analysis (Center Right) to determine particle-size distribution was conducted on samples from four totes representing both residual (excavated from wash pit) and slurry (pumped from wash pit) materials. Each size fraction was visually examined (Bottom Left) by hand lens and tested with both 10% HCl and 3% H_2O_2. Select size fractions as well as bulk/unsieved samples were weighed and sent for laboratory analysis including identification of mineral phases, bulk chemical (whole rock) analysis, and elemental analysis.



Ceramic Use of Recovered Material: Utilizing recovered manganese oxide began with Stream Restoration Inc. board member and ceramic artist Pam Esch (Top Right) who noticed some hand-collected manganese material in a container in the office. She used the material to test glaze recipes on pottery shards (Top Left). Based on the test shards, small bowls and cups were created with various glaze recipes, which led to a commission piece of art. Glazes were also tested and found to be safe for food use.

Ceramic Use of Recovered Material: Bob McCafferty (Top Left), North Country Brewing, Slippery Rock, PA, hired Robert Isenberg (Top Right), Pottery Dome, Grove City, PA, to create 300 beer mugs. McCafferty donated $550 from the sales to the Slippery Rock Watershed Coalition, inspiring SRI to start Clean Creek Products and to partner with Isenberg to create glaze patterns utilizing recovered Mn & low-pH iron named after streams in the watershed including Bear Creek and Blacks Creek (Center Left), Wolf Creek and Muddy Creek (Center Right), Slippery Rock Creek and Seaton Creek (Bottom Left) and Murrin Run (Bottom Right).

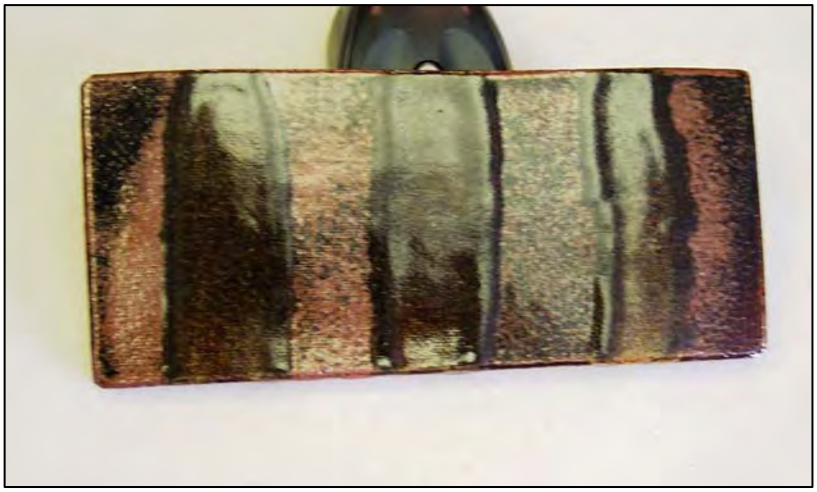
Ceramic Use of Recovered Material: A variety of functional ceramic pieces utilizing glazes made with recovered manganese and low-pH iron oxides have been created by Robert Isenberg and are now available through www.cleancreek.org including canister sets (Top Left), pitcher and cup set (Top Right), round "cereal/soup" bowls (Center Left), goblets (Center Right), and small sauce cups (Bottom). These pieces can be ordered in the 6 glaze patterns that were named after streams within the Slippery Rock Creek Watershed.

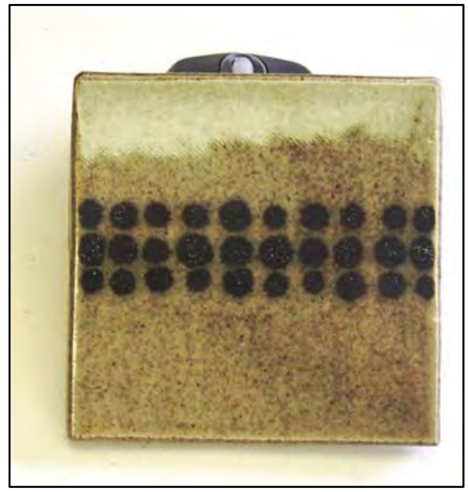


Ceramic Use of Recovered Material: Other food related/serving ceramic wares available in the 6 glazes include square "snack" bowls (Top Left), place settings which include a salad plate, dinner plate, soup bowl, and mug (Top Right), tea sets (Center Left), casserole dish (Center Right), chip and dip platter (Bottom Left) and serving tray (Bottom Right).

Ceramic Use of Recovered Material: Also available are more decorative-type pieces including large bowls (Top Left), medium vases (Top Right), art pieces (Center Left), flower pots (Center Right), candlestick holders (Bottom Left) and flower vases (Bottom Right).

Ceramic Use of Recovered Material: Clean Creek Products also wishes to be able to offer smaller and less expensive ceramic items such as jewelry and magnets for purchase as mementos that would also provide funding to watershed groups to assist in the maintenance of passive treatment systems. Above are some crude mock-up test pieces provided by various ceramic artists as examples.





Recovered Mn and low-pH Iron for "Green" Ceramic Tiles: As there is a growing demand for "Green" building materials, it was only natural to pursue creating ceramic tiles made utilizing glazes containing the recovered manganese and low-pH iron. Bob Isenberg made these test/marketing pieces as examples when talking to tile manufacturers

Recovered Mn and low-pH Iron for "Green" Bricks: Continuing with the search to find a use in the "Green" building materials market, Stream Restoration Inc. contacted Redland Brick located in Cheswick, PA, who are evaluating the material for use in their product line. Redland Brick created test pucks utilizing recovered the manganese and low-pH iron material. In the top photo, the first three pucks were made with 1%, 2%, and 3% recovered manganese oxide while the fourth puck was made with 0.6% manganese oxide obtained from a commercial producer. In the bottom photo, the first three pucks were made with 1%, 5%, and 10% recovered iron oxide while the fourth puck was made with 3% iron oxide obtained from a commercial producer.

Recovered Mn and low-pH Iron for "Green" Concrete: BioMost, Inc. conducted two experiments/demonstrations utilizing the recovered manganese in concrete. The first compared the commercially available colorant Sakrete with the recovered manganese (Top and Center Photos) at various ratios of colorant to concrete. In all cases, the commercial created a darker color. The second demonstration, utilized the recovered manganese in the construction of lamp posts at the home of Tim Danehy (Bottom Photos).

Marketing and Outreach Activities: Pottery glazed with recovered materials provides opportunities not only to raise funds for O&M but also to engage and excite the public about AMD, passive treatment, resource recovery, and watershed restoration. Penn State and Harvard (Top) professors and graduate students have conducted testing at De Sale Phase 2 as well as other SRWC passive systems to study biogeochemical processes involved in Mn removal. Westminster College students (Center Left) have toured and sampled the site as well. SRI participates in the annual Harrisville Community Day (Center Right). An open house at the Pottery Dome provided an opportunity to meet and talk to new people (Bottom Left) as did The Home & Garden Show (Bottom Right) and “Green Day” events at Boscov’s Department Store.

Marketing and Outreach Activities: The first commercial store to carry Clean Creek Pottery products was Kitchen Kaboodle, State College, PA, owned and operated by Katie Dawes and Cathy Stapelfeld. Tom Grote (SRI) and Bob Isenberg (Pottery Dome) (Top Right) were invited by Kitchen Kaboodle to participate in several store events as well as the annual Central Pennsylvania Festival of the Arts. Participation in these events provided the opportunity to not only market pottery made with glazes that utilized the recovered metals but also to engage the public about mine drainage, passive treatment, and watershed restoration.

Marketing and Outreach Activities: An exciting and encouraging experience occurred at the National Council on Education for the Ceramic Arts (NCECA) conference which was held in 2008 in Pittsburgh, PA. Stream Restoration Inc. had an amazing opportunity to talk to literally hundreds of ceramic artists as well as a number of ceramic supply businesses. The excitement and interest in the project was very rewarding and energizing.

Marketing and Outreach Activities: Just one example of a positive outcome from the NCECA conference was working with ceramic artist Paul Gruner who utilized the free samples of recovered low-pH iron and manganese to make several pieces including a bowl (Top Left), a jewelry box (Top Right), a vase (Bottom Left) and composting crocks (Bottom Center and Bottom Right).

Abandoned Mine Drainage

Resource Recovery

& Pottery ??

WHAT'S THE CONNECTION?

TURN AND LEARN

Brief History of Abandoned Mine Drainage

In Pennsylvania, coal has been mined for over 200 years. The first known commercial mine was opened in 1761 on Coal Hill, which is now Mt. Washington in Pittsburgh. While coal has fueled our economy, heated our homes, and provided countless kilowatt-hours of electricity, historical mining activities have left a legacy of scarred landscapes and polluted streams. Forty-five of Pennsylvania's sixty-seven counties have abandoned mine lands. An estimated 4,000 miles of streams (more than any other State) have been degraded by abandoned mine drainage (AMD), greater than the distance from Pennsylvania to Alaska. In many instances, metal precipitates have coated the bottom of streams destroying the habit of the macro invertebrates ("stream bugs") that are so extremely important in the aquatic food chain. Only the most tolerant of species are able to survive with some streams being designated as "dead".

Resource Recovery

Within the last 15 years, government agencies, watershed groups, nonprofits, academic institutions, and private industry have developed and implemented environmentally friendly systems to treat these abandoned mine discharges in a cost-effective manner. Combining remining, land reclamation, and the installation of passive treatment systems have resulted in restoring barren land to productive farmland and in turning streams that had been lifeless for decades to healthy aquatic habitats capable of supporting reproducing fish populations.

Many of these passive systems remove literally tons of metals before the drainage from the abandoned mine site enters our streams. The accumulation of these metal solids has the potential of being an asset. The question becomes, "What can we do with the metal precipitates?"

The Pottery Connection

One approach is to develop markets for these "by-products" of passive systems. Stream Restoration Inc. (SRI) is recovering iron minerals, which are naturally precipitated from acid mine drainage, and manganese minerals, which precipitate on limestone, for use in ceramic glazes. The locally-made pottery on the front page have glazes using these recovered minerals as a colorant. Your purchase of this "green technology" glazed pottery will contribute to SRI's continued efforts to treat AMD and keep our streams and rivers clean. Thank you very much.

Contact Information

Clean Creek Products

A division of Stream Restoration Inc. [non-profit 501(c)(3)]

434 Spring Street Ext.

Mars, PA 16046

www.cleancreek.org

Email - ccp@cleancreek.org

Recycling
Abandoned Mine Drainage

Clean Creek Products

A Division of Stream Restoration Incorporated (Non-Profit)
434 Spring Street Ext., Mars, PA 16046
Ph: (724) 776-0161 Fx: (724) 776-0166 ccp@cleancreek.org
www.cleancreek.org

Thank You for Your Interest!

Clean Creek Products (CCP) mission is to develop uses of materials recovered during treatment of abandoned coal mine drainage using environmentally-friendly methods. Recycling and reusing these materials will help to financially support watershed improvement efforts and **spread the word about the tremendous progress being made by many local and grass-roots organizations working to restore our streams and rivers.**

CCP focuses on developing partnerships with potters in order to provide environmentally-conscious consumers like you with hand-made original **"pottery that makes a difference".**

This approach helps us insure that watershed groups receive the much needed funds to maintain and expand their treatment efforts and that we continually **"get the word out"** about the importance of supporting these efforts. Since **"dollar one"** a portion of all proceeds have been **donated to support watershed groups**.

Your comments are valued!!! Please do not hesitate to email us with suggestions at **ccp@cleancreek.org.**

Order online at www.cleancreek.org !

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Abandoned Mine Drainage

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Order online at www.cleancreek.org!

Within the last 15 years, government agencies, watershed groups, nonprofits, academic institutions, and private industry have developed and implemented environmentally-friendly systems to treat abandoned coal mine discharges in a cost effective manner. Combining remining, land reclamation, and the installation of passive treatment systems has resulted in restoring land to desirable uses and in turning streams that had been lifeless for decades into healthy aquatic habitats capable of supporting fish.

Literally tons of metals are removed by treatment systems before the drainage from the abandoned mine enters our streams. The accumulation of these metal oxides has the potential of being an asset with recent technological advancements allowing cost-effective recovery. Clean Creek Products is working to establish viable uses for the recovered materials in order to support continued stream improvement efforts.

www.cleancreek.org

For more information please contact:
Tom Grote, Project Facilitator
Clean Creek Products, c/o Stream Restoration Inc.
434 Spring Street Ext., Mars, PA 16046
Ph: 724-776-0161 Fax: 724-776-0166
ccp@cleancreek.org

Within the last 15 years, government agencies, watershed groups, nonprofits, academic institutions, and private industry have developed and implemented environmentally-friendly systems to treat abandoned coal mine discharges in a cost effective manner. Combining remining, land reclamation, and the installation of passive treatment systems has resulted in restoring land to desirable uses and in turning streams that had been lifeless for decades into healthy aquatic habitats capable of supporting fish.

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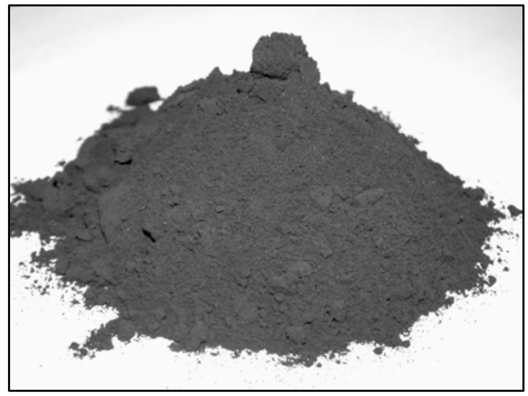
Recycling Abandoned Mine Drainage

Mn Fe

Manganese Oxide



Who we are: **Clean Creek Products (CCP)**, a division of Stream Restoration Incorporated (a nonprofit organization), has been formed to market the metal oxides recovered during the maintenance of environmentally-friendly systems that treat abandoned coal mine drainage for the purpose of restoring polluted streams. CCP is promoting these recycled metal oxides as raw materials to industries as a “Green Product” made in the USA. A portion of all proceeds received through the purchase of CCP products is donated to small watershed groups for stream rehabilitation activities.

Description & Source: Our manganese oxide has been recovered from the De Sale Phase II abandoned mine drainage passive treatment system located in the Slippery Rock Creek Watershed in western Pennsylvania. Abandoned Mine Drainage (AMD) is water that has become polluted due to old mining activities. Passive treatment is an environmentally-friendly technology that utilizes natural materials such as limestone, compost, and plants in a series of ponds, beds, channels, and wetlands to encourage and/or enhance naturally-occurring processes that improve water quality. The manganese oxide is removed in the final treatment component called a Horizontal Flow Limestone Bed (HFLB). The manganese oxide coats the limestone as a result of complex biogeochemical processes. The manganese oxide is then recovered from the HFLB utilizing an innovative process (patent pending).

Uses: Manganese oxide has a variety of uses including as a colorant in ceramic glazes by potters and in concrete pavers by the building materials industry. [Use of the CCP materials may add points in the U. S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) or other “green” certifications.] Manganese oxide is also used in the manufacture of batteries, steel, and chemicals to name just a few.

Chemical Composition: The following table provides a simple, generalized, comparison of essentially unprocessed manganese oxide recovered by Clean Creek Products and commercial manganese oxides that have been mined/processed and available for purchase from ceramic supply companies. Additional information is available upon request.

	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
CCP	27.4	8.9	4.5	24.5	0.8	11.3	0.1	1.0	0.4	0.2	20.6	99.7
Commercial	3.5	3.0	4.6	71.7	0.1	0.2	0.2	0.9	0.4	0.4	12.0	97.0

Values reported as %; major oxides determined by ICP; CCP material analyses averaged from 4 grab samples of bulk material; commercial material analyses averaged from 4 samples: 60 mesh x 90 mesh, -200 mesh, and material identified as powder and granular. Additional analyses may identify variations in composition.

Particle-Size Distribution: The material is available in both a relatively raw unprocessed form (wide size range) or in a specified size fraction (prepared by crushing and/or screening).

Health & Safety: Passes ASTM-C738 laboratory test for glazed ceramic surfaces. Many natural materials are potentially hazardous substances if handled inappropriately. Take proper precautions when utilizing the material. Use of a NIOSH approved respirator is recommended whenever handling the material. More information can be obtained upon request.

Clean Creek Products

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www.cleancreek.org

Recycling Abandoned Mine Drainage

Mn Fe

Iron Oxide

Who we are: **Clean Creek Products (CCP)**, a division of Stream Restoration Incorporated (a nonprofit organization), has been formed to market the metal oxides recovered during the maintenance of environmentally-friendly systems that treat abandoned coal mine drainage for the purpose of restoring polluted streams. CCP is promoting these recycled metal oxides as raw materials to industries as a "Green Product" made in the USA. A portion of all proceeds received through the purchase of CCP products is donated to small watershed groups for stream rehabilitation activities.

Description & Source: Our iron oxide has been recovered from the De Sale Phase II abandoned mine drainage passive treatment system located in the Slippery Rock Creek Watershed in western Pennsylvania. Abandoned Mine Drainage (AMD) is water that has become polluted due to old abandoned mining activities. Passive treatment is an environmentally-friendly technology that utilizes natural materials such as limestone, compost, and plants in a series of ponds, beds, channels, and wetlands to encourage and/or enhance naturally-occurring processes that result in clean water and help to restore the polluted streams. The iron oxide accumulated on top of the treatment media in a passive component known as a Vertical Flow Pond as a result of complex biogeochemical processes in acidic conditions. The iron oxide was then recovered.

Uses: Iron oxide has a variety of uses including for pigments/colorants in ceramic glazes and in building materials as well as for cosmetics. [Use of the CCP materials may add points in the U. S. Green Building Council's Leadership in Energy and Environmental Design (LEED) or other "green" certifications.]

Chemical Composition: The following table provides a simple, generalized, comparison of essentially unprocessed iron oxide recovered by Clean Creek Products. Additional information is available upon request.

	SiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	LOI	Total
CCP	8.1	3.1	63.6	0.4	0.2	0.1	0.0	0.3	0.1	0.1	23.6	99.6

Values reported as %; major oxides determined by ICP; CCP material analysis - grab sample of bulk material; Additional analyses may identify variations in composition.

Particle-Size Distribution: The material is available in both a relatively raw unprocessed form (wide size range) or in a specified size fraction (prepared by crushing and/or screening).

Health & Safety: Passes ASTM-C738 laboratory test for glazed ceramic surfaces. Many natural materials are potentially hazardous substances if handled inappropriately. Take proper precautions when utilizing the material. Use of a NIOSH approved respirator is recommended whenever handling the material as breathing of the dust is to be avoided. More information can be obtained upon request.

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Support Local Watershed Groups With Your CCP Purchase!

Clean Creek Products (CCP), a division of Stream Restoration Incorporated (nonprofit), has been formed to market the metals recovered in treating abandoned coal mine drainage. CCP is promoting these metals as raw materials to many industries. Your purchase of CCP will help us help local watershed groups keep our streams clean. A portion of all proceeds will be donated to their efforts. Thank you very much for your support!

"Green Technology" restoring the environment. Your purchase helps keep streams clean!
(A portion of all proceeds donated to stream clean up efforts.)

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About AMD & Clean Creek Products

Brief History of Abandoned Mine Drainage

In Pennsylvania, coal has been mined for over 200 years. The first known commercial mine was opened in 1761 on Coal Hill, which is now known as Mt. Washington in Pittsburgh. While coal has fueled our economy, heated our homes, and provided countless kilowatt-hours of electricity, historical mining activities have left a legacy of scarred landscapes and polluted streams. An estimated 4,000 miles of streams (more than any other State) have been degraded by abandoned mine drainage (AMD). In many instances, metal precipitates have coated the bottom of streams destroying the habit of the macroinvertebrates ("stream bugs") that are so extremely important in the aquatic food chain. Only the most tolerant of species are able to survive with some streams being designated as "dead".

Resource Recovery

Within the last 15 years, government agencies, watershed groups, nonprofits, academic institutions, and private industry have developed and implemented environmentally friendly systems to treat these abandoned mine discharges in a cost effective manner. The installation of passive treatment systems has resulted in turning streams that had been lifeless for decades to healthy aquatic habitats capable of supporting a great diversity of reproducing fish populations. Many of these passive systems remove literally tons of metals before the drainage from the abandoned mine site enters our streams. The accumulation of these metal solids has the potential of being an asset. The question is, "What can we do with the metal precipitates?"

Clean Creek Products

Clean Creek Products (CCP) recovers iron that precipitates from acid mine drainage and manganese which precipitates on limestone. Our approach is to develop markets for these "by-products" of passive systems. The recovery of these metals has focused us on using them as pigments. Please check our Products for Sale page for more details.

Clean Creek Pottery

Our locally-made hand thrown pottery has glazes using these recovered minerals as a colorant. Your purchase of this “green technology” glazed pottery will contribute to CCP’s continued efforts to treat AMD and keep our streams and rivers clean. Thank you very much.

Clean Creek Products

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  - Tableware
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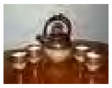
Pottery



Clean Creek Products (CCP) recovers iron that precipitates from acid mine drainage and manganese which precipitates on limestone. Our locally-made hand thrown pottery has glazes using these recovered minerals as a colorant. Your purchase of this “green technology” glazed pottery will contribute to CCP’s continued efforts to treat AMD and keep our streams and rivers clean.

Our pottery is hand thrown and is unique in size and shape. Therefore the pieces you buy will not be exactly like the photos. All dimensions and capacities are approximate.


Coffee Mugs


Large Mugs


Serving Dishes


Tableware


Vases & Containers

"Green Technology" restoring the environment. Your purchase helps keep streams clean!
(A portion of all proceeds donated to stream clean up efforts.)

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Information

Products:

	Product Name+	Price	Buy Now
	Coffee Mug - Bear Creek Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Coffee Mug - Blacks Creek Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Coffee Mug - Hell Run Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Coffee Mug - Jamison Run Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Coffee Mug - Muddy Creek Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Coffee Mug - Seaton Creek Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Coffee Mug - Slippery Rock Creek Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Coffee Mug - Wolf Creek Glaze Size: Diameter 3", Height 4.25", 12 oz.	$25.00	Buy Now!
	Stoneware Coffee Cup - Murrin Run Glaze Size: 3.35" Diameter, 4" Tall, Capacity 10 oz.	$25.00	Buy Now!

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  - Tableware
  - Vases & Containers

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Products:

	Product Name+	Price	Buy Now
	Large Beverage Mug - Blacks Creek Glaze Size: 3" Diameter x 6" Tall, Capacity - 20 Fl. Oz.	$30.00	Buy Now!
	Large Beverage Mug - Brush Run Glaze Size: 3" Diameter x 6" Tall, Capacity 20 Fl. Oz.	$30.00	Buy Now!
	Large Beverage Mug - Muddy Creek Glaze Size: 3" Diameter x 6" Tall, Capacity 20 Fl. Oz.	$30.00	Buy Now!
	Large Beverage Mug - Seaton Creek Glaze Size: 3" Diameter x 6" Tall, Capacity 20 Fl. Oz.	$30.00	Buy Now!
	Large Beverage Mug - Slippery Rock Creek Glaze Size: 3" Diameter x 6" Tall, Capacity 20 Fl. Oz.	$30.00	Buy Now!

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(A portion of all proceeds donated to stream clean up efforts.)

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Products:

	Product Name+	Price	Buy Now
	Casserole Dish - Blacks Creek Glaze Medium Size - 9" Diameter x 5" tall Capacity - 3 Quarts	$105.00	Buy Now!
	Casserole Dish - Findlay Run Glaze Medium Size - 9" Diameter x 5" tall Capacity - 3 Quarts	$105.00	Buy Now!
	Chip/Veggie & Dip Tray - Seaton Creek Glaze Diameter: 12" , Height: 2"	$90.00	Buy Now!
	Medium Bowl - Blacks Creek Diameter: 12", Depth: 6"	$105.00	Buy Now!
	Medium Bowl - Muddy Creek Diameter: 12", Depth 6"	$105.00	Buy Now!
	Pitcher & Cups - Wolf Creek Glaze Pitcher Size: 4.5" Diameter, 6.5" Tall, 48 oz., Cup Size: 3.5" Diameter, 3.75" Tall, 8 oz.	$130.00	Buy Now!
	Tea Pot & Matching Cups - Blacks Creek Glaze Tea Pot Size: Diameter 8", Height 10", 32 oz., Cup Size: Diameter 3.5", Height 3.5", 8 oz.	$145.00	Buy Now!
	Tea Pot & Matching Cups - Seaton Creek Glaze Tea Pot Size: Diameter 8", Height 10", 32 oz., Cup Size: Diameter 3.5", Height 3.5", 8 oz.	$145.00	Buy Now!
	Tea Pot & Matching Cups - Swamp Run Glaze Tea Pot Size: Diameter 8", Height 10", 32 oz., Cup Size: Diameter 3.5", Height 3.5", 8 oz.	$145.00	Buy Now!
	Tea Pot - Taylor Run Glaze Tea Pot Size: Diameter 8", Height 10", 32 oz.	$90.00	Buy Now!

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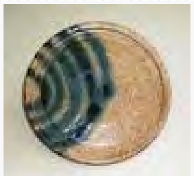
Products:

	Product Name+	Price	Buy Now
	Dessert Plate - Muddy Creek Glaze Matches the Muddy Creek Dinner Place Setting, Stoneware Plate - 7" Diameter	$20.00	Buy Now!
	Dessert Plate - Slippery Rock Creek Glaze Matches the Slippery Rock Creek Dinner Place Setting, Stoneware Plate - 7" Diameter	$20.00	Buy Now!
	Dinner Place Setting - Muddy Creek Glaze Sizes: 10" Dinner Plate, 7" Dessert Plate, 12 oz. Coffee mug, Soup/Cereal Bowl-6" diameter x 3" deep	$75.00	Buy Now!
	Dinner Place Setting - Slippery Rock Creek Glaze Sizes: 10" Dinner Plate, 7" Dessert Plate, 12 oz. Coffee mug, Soup/Cereal Bowl-6" diameter x 3" deep	$75.00	Buy Now!
	Dinner Plates - Muddy Creek Glaze Matches the Muddy Creek Dinner Place Setting, 10" Stoneware Dinner Plate	$25.00	Buy Now!
	Dinner Plates - Slippery Rock Creek Glaze 10" Stoneware Dinner Plate	$25.00	Buy Now!
	Round Bowl - Collage of Glazes Size: 6" diameter x 3" deep	$20.00	Buy Now!
	Salad/Soup Bowl - Muddy Creek Glaze Matches Muddy Creek Dinner Place Setting, Size: 6" Diameter x 3" Deep, Capacity 16 oz.	$20.00	Buy Now!
	Salad/Soup Bowl - Slippery Rock Creek Glaze Matches Slippery Rock Creek Dinner Place Setting, Size: 6" Diameter x 3" Deep, Capacity 16 oz.	$20.00	Buy Now!
	Small Sauce/Dip Cups - Big Run Glaze Size: 2" to 3" wide x 2" tall Capacity: 4 oz.	$10.00	Buy Now!

Displaying **1** to **10** (of **22** products)

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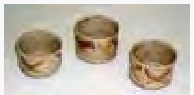
Products:

	Product Name+	Price	Buy Now
	Small Sauce/Dip Cups - Blacks Creek Glaze Size: 2" to 3" wide x 2" tall Capacity: 4 oz.	$10.00	Buy Now!
	Small Sauce/Dip Cups - Glade Run Glaze Size: 2" to 3" wide x 2" tall Capacity: 4 oz.	$10.00	Buy Now!
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	Square Snack Bowl - Muddy Creek Glaze Size: 5" x 5" x 2"	$20.00	Buy Now!
	Stoneware Coffee Cup - Muddy Creek Glaze Matches Muddy Creek Dinnerware, Size: 3.35" Diameter, 4" Tall, Capacity 10 oz.	$25.00	Buy Now!
	Stoneware Coffee Cup - Slippery Rock Creek Glaze Matches Slippery Rock Creek Dinnerware, Size: 3.35" Diameter, 4" Tall, Capacity 10 oz.	$25.00	Buy Now!
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SUSTAINABLE PASSIVE TREATMENT OF MINE DRAINAGE: DEMONSTRATION OF MANGANESE RESOURCE RECOVERY

(A Preliminary Case Study)[1]

Clifford Denholm[2], Timothy Danehy, Shaun Busler, Robert Dolence, Margaret Dunn

Abstract: Passive treatment system components containing limestone are an effective means to decrease Mn concentrations in coal mine drainage. As precipitates, sediment, vegetation, and other materials accumulate in the void spaces, permeability decreases and treatment effectiveness is reduced. Recently, the ability to recover manganese-bearing material for potential economic use while restoring treatment efficiency has been demonstrated at the De Sale Phase 2 passive treatment system, installed at an abandoned surface coal mine in western Pennsylvania. Efforts to date include pre- and post-recovery water monitoring; development of a unique "full-scale" recovery technique; preliminary physical, chemical, and mineralogical analysis; and identification of a potentially economically-viable use of the recovered material. The horizontal flow limestone bed was monitored 3, 24, 64, and 118 days after Mn recovery. Comparing the influent with the effluent indicated decreases in dissolved Mn concentrations from 64 to 30 mg/L, 55 to 10 mg/L, 46 to 9 mg/L, and 20 to 8 mg/L, respectively, essentially doubling treatment effectiveness. Over 40 cubic yards (30 cubic meters) of manganese-bearing material were recovered. Currently, the Mn material is being used by local ceramic artists as a glaze colorant and is being evaluated by other industries including brick manufacturing.

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[1] Paper was presented at the 2008 National Meeting of the American Society of Mining and Reclamation, Richmond, VA, ***New Opportunities to Apply Our Science*** June 14-19, 2008. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

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Introduction

Mine drainage from abandoned sites is an international issue. In Pennsylvania, abandoned mine drainage is the largest non-point source of stream impairment. According to the 2006 Pennsylvania Integrated Water Quality Monitoring and Assessment Report, over 4,600 miles (7,400 km) of streams have been degraded. In many cases, entire watersheds have been completely decimated.

Passive systems typically use no electricity, require limited maintenance, and use environmentally friendly materials, such as limestone aggregate and spent mushroom compost in a series of constructed ponds, beds, ditches, and wetlands. As with any type of system, the goal is to provide economical, long-term, effective treatment. Passive components are selected based upon the often variable quality and flow rate of the mine drainage, preferred chemical and/or biological processes, and available construction space.

One of the many effective components available to designers of passive treatment systems is the Horizontal Flow Limestone Bed (HFLB). An HFLB is an open, unburied, bed of limestone aggregate, which is commonly installed as the final component in a passive treatment system. The HFLB serves two major purposes. First, the HFLB provides an alkalinity "boost" to the final effluent, which adds buffering capacity to the stream, which in many cases is much needed in order to lessen the impact of other acidic sources downstream. Second, the HFLB is effective in removing dissolved Mn.

Historically, removal of dissolved Mn from mine drainage has been problematic and thought to require chemical treatment in order to raise the pH above ≈ 9. With the development of passive technology, dissolved Mn has been observed to form solids at a much lower pH (6 to 7). The exact mechanism is not completely understood at this time, but biogeochemical factors such as low dissolved ferrous iron concentrations, high dissolved oxygen concentrations, available surface area, sufficient alkalinity, presence of certain microorganisms, and autocatalytic processes appear to play a significant role (Rose, 2003). The availability of certain nutrients, dissolved organic carbon, and other factors may also be important, depending upon the role and type of the microorganisms in the removal process (Dr. William Burgos, personal communication, 11/2007).

The HFLB, as well as many other effective passive components, accumulates metal precipitates, sediment, vegetative debris, etc. Over time, the accumulation of these materials can result in decreased treatment efficiency as the treatment media becomes plugged and permeability decreases.

Manual removal of the surface debris has been conducted and various methods have been used to restore the permeability of the treatment media, including flushing, backflushing, stirring, etc. While these methods can be effective for some passive components, for others the impact to the overall functionality and effectiveness has been minimal or short-lived. In some cases, the treatment media was actually removed/discarded and subsequently replaced even though the media still possessed significant treatment capabilities. Decreased functional life expectancy of the component increases long-term operation and maintenance costs and in some cases can lead to the perception that passive treatment is too costly, ineffective, and/or unreliable.

The authors have developed a method for the rehabilitation of treatment media that not only restores the efficacy and functionality of the component, but also facilitates the reuse of viable treatment media and the recovery and use of the accumulated material as a resource. Another aspect that makes this approach unique is that the recovery system is readily portable (even to remote locations) with a quick set-up time. While the following is a case study of the first attempt at rehabilitation of an HFLB and the simultaneous recovery of Mn, this process could potentially be used for other passive components and metals as well.

Project Location

The first full-scale attempt by the authors to rehabilitate an HFLB and simultaneously recover Mn was conducted at the De Sale Restoration Area Phase II Passive Treatment System located in western Pennsylvania about 50 miles (80 km) north of Pittsburgh in Venango Township, Butler County. More specifically, the site is about 2 miles (3 km) west of the town of Eau Claire along State Route 58 at latitude 41° 08’ 40” and longitude 79° 49’ 55” (BioMost, 2002). (See Fig. 1 or go to www.datashed.org.)

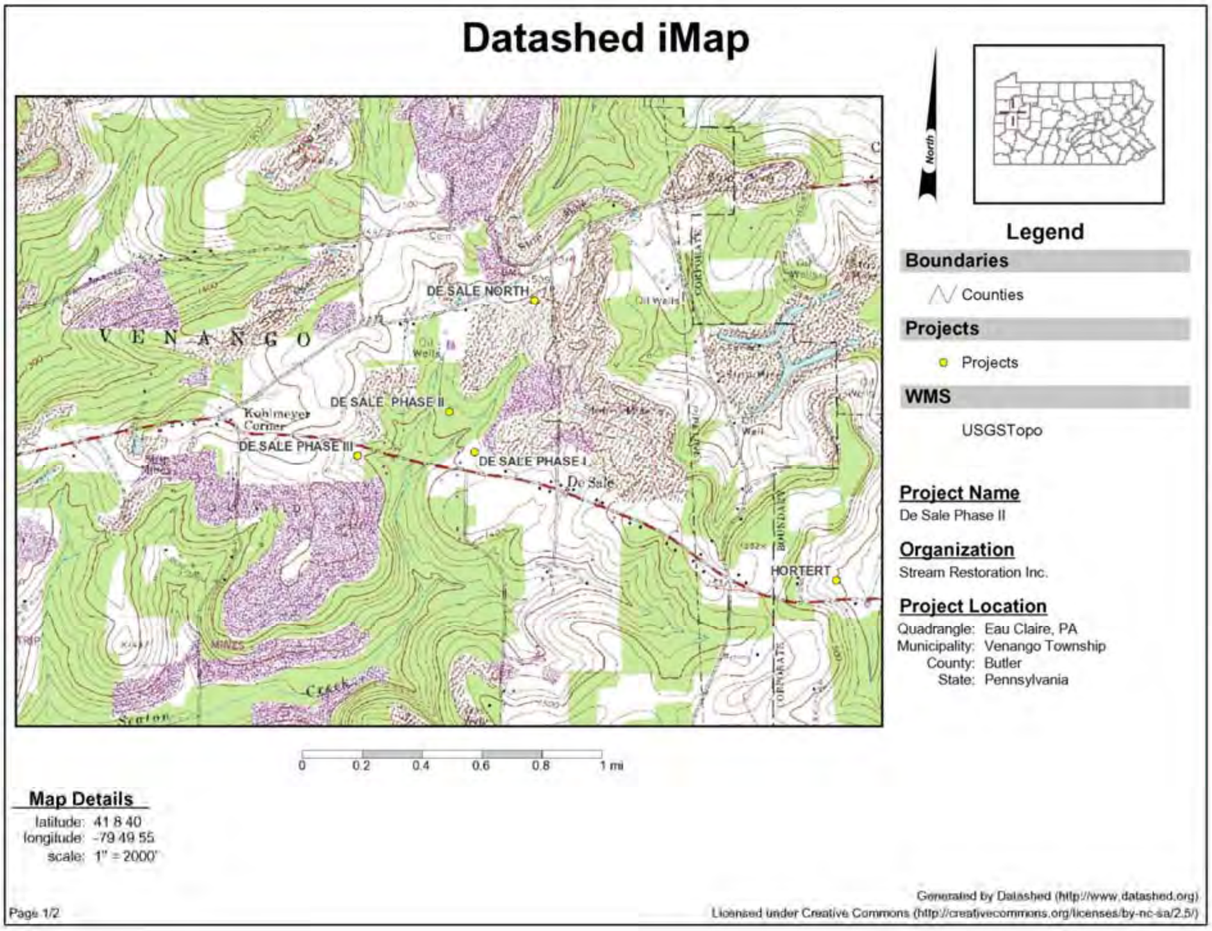

Figure 1. De Sale Phase 2 Location Map generated by www.datashed.org

Site History

Coal extraction activities conducted prior to the implementation of the federal Surface Mining Control and Reclamation Act of 1977, severely impacted Seaton Creek, one of two major tributaries within the headwaters of the Slippery Rock Creek Watershed (Ohio River Basin). The essentially "dead" Seaton Creek was identified as the most heavily impacted tributary in the watershed (PA DEP, 1998). In 2000, through the generosity of a landowner, a public-private partnership effort involving a watershed group, nonprofits, mining companies, environmental consulting firms, and government agencies, was formed to address the problem. In August 2000, the De Sale Phase II passive system was constructed to treat a headwaters tributary to Seaton Creek. The primary source of flow to the unnamed tributary was toe-of-spoil drainage and runoff from an abandoned surface mine (ca. 1960) on the Middle Kittanning coalbed (Kittanning Fm.; Allegheny Gp.) (BioMost, 2002).

Passive Treatment System Description

The passive system consists of seven components (See Fig. 2). A stream intake, installed upon approval by the US Army Corps of Engineers, captures the flow, except during excessive storm events, of the small-unnamed tributary. From the intake, the flow is directed through a long narrow forebay with the effluent split between two Vertical Flow Ponds, each containing about 2200 tons (1996 metric tons) of limestone (90% $CaCO_3$) aggregate (AASHTO #1: 4" x ¾") overlain by about ½ foot (15 cm) of spent mushroom compost. The effluent of the two Vertical Flow Ponds is then conveyed by adjustable risers to a settling pond before entering a 1½-acre (0.6 hectare) aerobic wetland. From the wetland, the effluent is conveyed to an HFLB, containing 2900 tons (2631 metric tons) of limestone with the same size consist and quality as used in the VFPs, prior to being returned to the unnamed tributary (BioMost, 2002).

Passive System Performance

The De Sale Phase II passive system has been successfully treating acidic, metal-laden, mine drainage with widely varying flow rates for nearly eight years. Table 1 depicts the general treatment and effectiveness of the system (Maximum design flow: 200 gpm (757 lpm). The actual measured flow rates have ranged from 10 to 445 gpm (38 to 1685 lpm).

Table 1. De Sale Phase II Passive System Influent and Effluent Values (range)

Point	**Flow** (gpm)	**F. pH** (s.u.)	**F. Alk** (mg/L)	**L. Alk** (mg/L)	**Acidity** (mg/L)	**T. Fe** (mg/L)	**D. Fe** (mg/L)	**T. Mn** (mg/L)	**D. Mn** (mg/L)	**T. Al** (mg/L)	**D. Al** (mg/L)
Raw		2.9-4.5		0	92-451	7-82	8-37	18-84	11-77	2-15	5-13
Effluent	10-445	5.8-7.7	22-219	6-250	-73-35	0-15	0-6	0-51	3-46	0-3	0-1

Number of sampling events and sampling dates vary for each point and for individual parameters; field (F) or lab (L) measurement; total (T) or dissolved (D) metals

Based upon available data, an estimate of loading reduction reveals that over the past seven and a half years approximately 60,000 to 80,000 lbs (22,000 to 30,000 kg) of Mn have been retained within the passive treatment system that would have otherwise entered Seaton Creek.

By 2003, the accumulation of Mn as well as other metals, sediment, vegetation, etc. resulted in the HFLB component having small pockets of standing water. During high flow periods, a portion of the influent water would flow across the top of the HFLB and over an emergency spillway instead of flowing through the stone, which reduced treatment effectiveness.

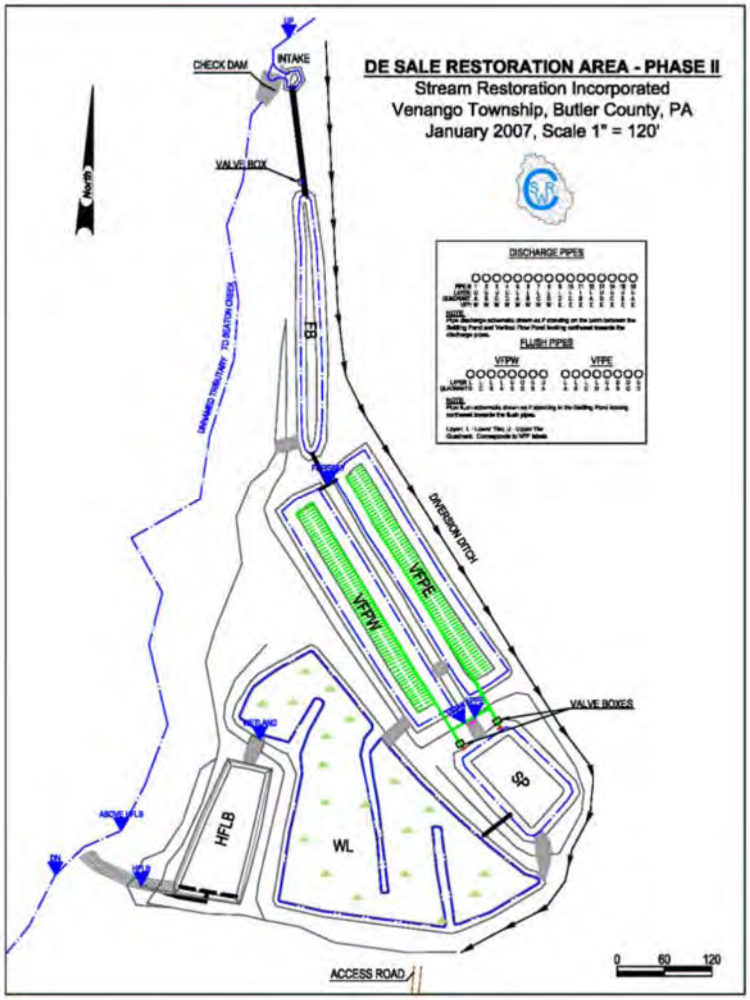

Figure 2. De Sale Phase 2 Site Schematic available at www.datashed.org

Initial Attempts to Rehabilitate the Horizontal Flow Limestone Bed

Prior to the effort in 2007, several previous attempts were made with varying success to rehabilitate the HFLB at De Sale Phase 2. In March 2004, the 10-inch (25.4 cm), perforated manifold installed along the width of the HFLB was backflushed at ~15 psi (103 kPa) using an air compressor. Backflushing was conducted to remove solids from the pipe and in the aggregate in the vicinity of the perforations. Manganese "chips" were observed in the flush water, indicating that at least a portion of the plugging was probably due to the precipitation of Mn within and near the pipe. Backflushing did lower the water level in the HFLB; however, the water level was still higher than the design elevation, indicating plugging within the bed. In April 2004, a small track loader was used to "stir" the upper portion (~2-3 feet) (0.6–0.9 m) of stone. In addition to vegetative growth, including what appeared to be algal (?) mats, Mn material was observed on the limestone aggregate and in the void spaces (See Fig. 3). The impact of the backflushing and stirring events was short lived. In October 2004, a trench was excavated at the beginning and the end of the HFLB, exposing the manifold collection pipe. In addition, the outlet piping was reconfigured to provide the ability to raise and lower the head as well as drain the HFLB. During this work, the pond was drained and the vegetative material and manganese-bearing precipitates on the surface of the bed were allowed to dry, "breaking up" some of the accumulated material. This effort resulted in improved flow through the bed with the water level remaining below the surface of the stone for one year. After that period, the water level again began to rise and typically a small portion was observed discharging through the emergency spillway. A new approach was required.

Figure 3. Manganese material filled void spaces and coated limestone aggregate prior to recovery

Rehabilitation and Resource Recovery Process

Shortly after the initial backflushing event during the period of 2004-2005, the authors were also examining the possibility of removing and recovering the Mn precipitates. During this investigation, samples of Mn solids were collected and analyzed indicating that the MnO could be considered an "ore" of Mn, containing about 50% Mn on an "as-received" basis and about 20% Loss On Ignition (LOI), which typically accounts for water, volatiles, and organic matter. Initial research indicated the Mn was suitable for use in ceramic glazes as well as other uses. A grant was received in 2006 through the Pennsylvania Department of Environmental Protection

Bureau of Abandoned Mine Reclamation (PA DEP BAMR) to further investigate and develop a method to economically recover and use the Mn material as a resource.

Through a literature and Internet search and bench-scale studies, a proposed method to simultaneously restore the efficacy and functionality of the HFLB and to recover the material was developed. This was accomplished through the use and combination of several existing products or conceptual ideas into a unique process that, to our knowledge, had not been previously attempted. One aspect that makes this system unique is the portability and quick set-up time of the recovery system (even in remote locations).

The first implementation of this process was conducted in August and September of 2007 at the De Sale Phase 2 passive treatment system. The influent flow was bypassed and the HFLB was drained. (During this seasonal low-flow period, the drainage was adequately treated by manipulating the flow through the other passive components.) Two wash pits were excavated within the HFLB, lined with impermeable material, and filled with water from the treatment wetland using a small pump. Using an excavator with a rotating screen attachment called a Flip Screen (Flip Screen Australia Pty Ltd., New South Wales), the bucket was filled with the limestone aggregate and the Mn-bearing material was removed by rotating the Flip Screen within the wash pit (See Fig. 4 and 5). Material passing the 3/8-inch (0.95 cm) screen settled within the wash pit while the limestone aggregate remained in the bucket. (Note that screens with different size openings are readily interchangeable.) The now clean and refurbished treatment media was then returned to the HFLB. The slurry was generally pumped into flexible intermediate bulk containers (FIBC) held in place with a frame structure for settling and dewatering. In some cases, the water in the wash pit was allowed to evaporate and was then excavated (See Fig. 6) and stockpiled on a pad for additional drying prior to placement in an FIBC. Thirty-two bulk containers, each containing approximately one ton of recovered material, were removed from the site. In addition, an estimated 25-50 tons (23-45 metric tons) of recovered material was left within the wash pits for future removal.

Preliminary Evaluation of Effectiveness of HFLB Rehabilitation

As the rehabilitation and recovery effort was completed in September 2007, only the preliminary short-term effectiveness of the process can be described. Water sampling of the HFLB influent and effluent was conducted 3, 24, 64, and 118 days after completing the recovery effort. Table 2 provides the post-rehabilitation results for selected parameters.

Figure 4. Excavator with FlipScreen attachment "washing" Mn covered limestone

Figure 5. Close up of FlipScreen during manganese recovery operation

Note that the influent to the HFLB is consistently an alkaline, circumneutral, net-acidic, Mn-bearing (20 to 65 mg/L) drainage with low dissolved concentrations of Fe and Al. On days 24, 64, and 118, the effluent is characterized as net alkaline with dissolved Mn concentrations <10 mg/L. Post-rehabilitation monitoring indicates that, on average, the Mn concentration is decreased by about 32 mg/L (70%) compared with the average of 12 mg/L (35%) removed prior to rehabilitation. Further, a comparison of the loading reductions indicates that in the spring of 2007 prior to rehabilitation, the HFLB was removing about 30% of the Mn loading while post-rehabilitation monitoring indicates a 75% loading reduction.

Figure 6. View of recovered manganese material excavated from wash pit

Prior to rehabilitation, the water level in the HFLB was at or near the surface across the entire length of the bed (See Fig. 7). The Mn removal rate was calculated as 0.008 pounds/day/ton of stone. The hydraulic gradient was significantly increased from the rehabilitation effort, which resulted in less limestone being utilized for treatment (See Fig. 7). Based on the gradient and other factors, a rough calculation indicates that only about 2/3 of the treatment media is currently being used. The Mn removal rate is currently 0.012 pounds/day/ton of stone. Review of pre- and post-rehabilitation conditions indicates that the efficacy of the HFLB has improved. Additional monitoring and evaluation is recommended to further document and verify the long-term improvement.

Recovered Material Analysis and Characterization

Samples from 4 of the 32 totes were collected for laboratory testing, including particle-size distribution, bulk chemical analysis, and x-ray diffraction. Not all of the results from these analyses were available at the time of writing this paper. Grab samples of the material directly from the HFLB were collected by hand in 2005. Laboratory analyses indicated that the material was about 50% Mn on an as-received basis with a loss-on-ignition of about 20%. X-ray diffraction conducted on the samples revealed that the Mn material was a mixture of todorokite and birnessite. Preliminary X-Ray Fluorescence (XRF) results of the material recovered in 2007 report major oxides about 25% MnO, 25% SiO_2, 10% Al_2O_3, 10% CaO, and 25% Loss-on-Ignition. Limestone and quartz were identified by visual examination using a hand-lens. The material fizzed aggressively with 10% HCl indicating the presence of limestone as well as with H_2O_2 indicating the presence of Mn oxides. The preliminary analyses suggest that the recovered

Mn has become diluted primarily with limestone and quartz by the recovery process. Future efforts will include attempts to improve the recovery process to minimize dilution of the Mn material and to examine beneficiation processes to remove impurities.

Table 2. Post-Rehabilitation Influent and Effluent Water Quality of De Sale 2 HFLB

	3 days		**24 days**		**64 days**		**118 days**	
Parameter	**In**	**Out**	**In**	**Out**	**In**	**Out**	**In**	**Out**
Flow	10	10	40	40	83	83	250	250
pH (field)	5.08	6.49	6.42	6.93	6.86	6.76	5.58	6.53
ORP	316	279	169	158	153	141	245	176
DO	7.27	5.08	7.57	1.33	9.35	2.28	10.63	8.43
Temp.	22.5	18.7	20.0	18.1	10.8	8.8	3.9	2.9
Alkalinity (field)	16	58	18	87	36	71	7	25
Alkalinity (lab)	2.47	42.25	12.90	82.74	30.78	66.57	3.24	26.45
Hot Acidity	117.11	4.66	81.59	-73.04	54.90	-52.15	39.20	-12.81
T. Fe	0.25	0.19	0.16	0.05	0.56	0.07	0.44	0.10
D. Fe	0.23	0.13	0.10	0.02	0.48	0.06	0.34	0.02
T. Mn	64.83	30.78	55.12	9.84	47.44	8.77	20.41	8.59
D. Mn	63.83	30.14	54.89	9.78	46.38	8.67	19.82	7.77
T. Al	3.43	0.24	0.48	0.26	0.38	0.23	2.19	0.25
D. Al	3.25	0.09	0.13	0.08	0.30	0.15	0.93	0.18
SO4	1279.8	1297.1	1308.3	1322.0	1131.7	1123.9	538.6	519.5

Flow in gallons per minute; pH in standard units; ORP in mV; Dissolved Oxygen in mg/L; Alkalinity and Acidity in mg/L as $CaCO_3$; Total (T) and Dissolved (D) Metals in mg/L; Sulfates in mg/L;

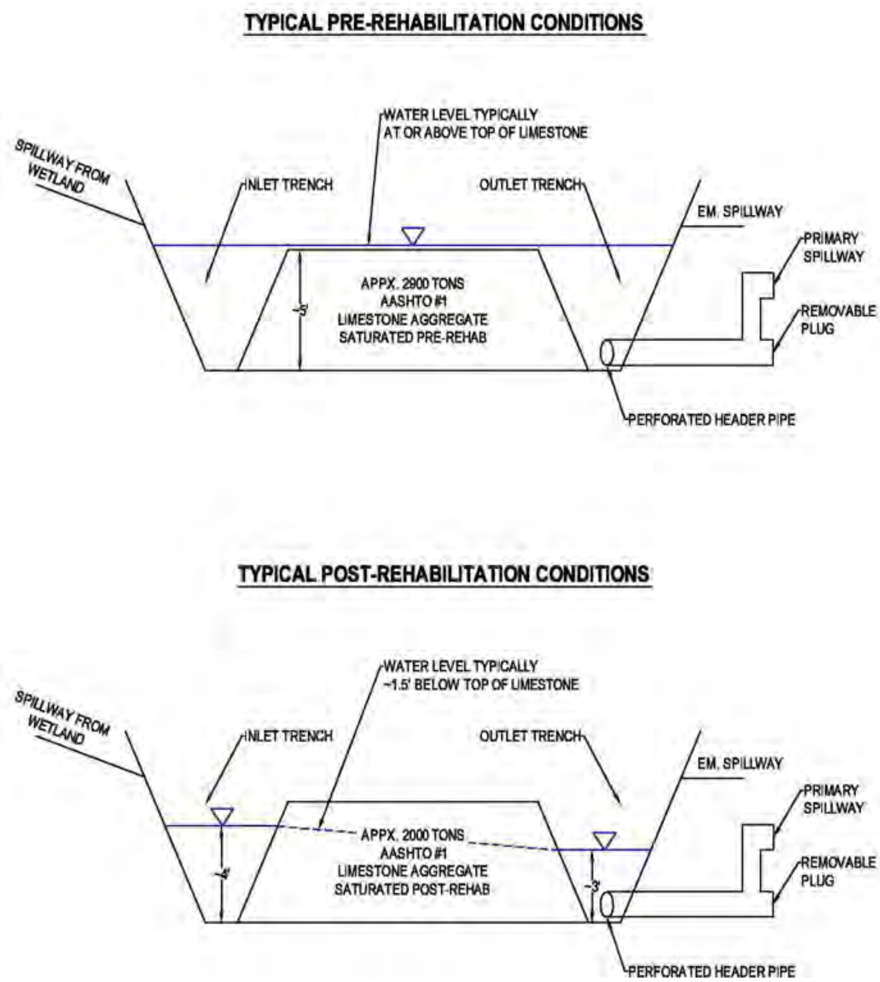

Figure 7. Typical Pre- and Post-Rehabilitation Conditions of the HFLB

Potential Uses

While Mn is used in a variety of products and processes including steel, batteries, chemicals, fertilizers, animal feeds, etc., current markets targeted include the use as colorants in bricks and cement and in ceramic glazes (BioMost, 2005). The recovered material is currently being utilized in ceramic glazes (See Fig. 8) and demand is growing. Over 300 hand-thrown pieces by local artisans have been sold or are on order. The colorant is also being sold by non-profits as a "green product" to the ceramics industry.

Conclusions and Recommendations

A method that effectively restored the efficacy of the De Sale Phase 2 Horizontal Flow Limestone Bed, reused the treatment media, and recovered Mn material for "recycling" has been demonstrated. Further investigations and marketing research, however, are needed to determine the commercial value of the product. In addition, continued and expanded monitoring of the HFLB is necessary to evaluate long-term treatment improvement. Research is needed to either improve the recovery process or develop efficient economical beneficiation process.

Figure 8: Examples of pottery with glazes using recovered Mn and Fe oxides formed at low pH

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For Your Body, Mind & Spirit

The Point North

NOVEMBER 2008

Make This Holiday Season A Bit More "Green"

pages 18-19

Make This Holiday Season A Bit More "Green"

By Cliff Denholm

NOW THAT HALLOWEEN IS BEHIND US AND THE HOLIDAY SEASON IS QUICKLY approaching, many people are beginning to think about what gifts they are going to purchase for friends and family. Do you have a loved one or dear friend who has just about everything she could possibly need or use? Maybe you will be looking for a gift that is beautiful? Unique? Locally hand-made? Good for the environment? A gift that supports a great cause right here in our community?

…Perhaps you need an idea?

Well, I have a suggestion for you! What about a "Green" gift for your loved one? No, I don't mean money. I mean an eco-friendly gift. I am talking about a beautiful, yet functional piece of locally hand-made pottery, whose purchase will help support local watershed groups treat abandoned coal mine drainage, the number one source of pollution to Pennsylvania's rivers and streams. In fact, about 4,000 to 6,000 miles of streams throughout our state are so significantly polluted by mine drainage that many have been lifeless or have had little aquatic life for more than a century!

New line of coffee cups called "Murrin Run Glaze"

To address this issue, watershed groups across Pennsylvania have built environmentally-friendly, passive systems to treat the mine water before it enters the stream. The process isn't pretty but the "green," hand-made pottery produced from the residue is beautiful. Now for the unpleasant part: passive systems neutralize the acid as well as remove and retain the metals such as iron and manganese that are present in the mine water. Eventually these systems, which use limestone used in many driveways and compost like that used by gardeners, become full of metals, which then need to be removed so that the system can continue to clean more water. So then the question becomes, "Who would want metal sludge as a Christmas present?"

Clean Creek Products, a "division" of Stream Restoration Incorporated, a small non-profit organization, located in Mars, PA had a rather creative idea. Instead of using the commercially available metal oxides that are often mined and processed in some other part of the world, why not recover and recycle these metal oxides as "Made in the USA" pigments. These metal oxides which would have otherwise been a pollutant to Slippery Rock Creek are now being used to make a whole range of beautiful, functional pottery that is sure to please even the most discriminating gift recipient.


Bob Isenberg: Owner, The Pottery Dome

The pottery is primarily made by local ceramic artist, Bob Isenberg, from the Pottery Dome which is located near Grove City, PA. Bob has been experimenting with the recovered metals to make a variety of ceramic pieces including coffee mugs, beer steins, plates, bowls, vases, teapots, cups, and more. The lead-free glazes, which create the color of the pottery, are made using the recovered iron and/or manganese oxides from the treatment systems to create very interesting effects and beautiful earth tones. A portion of the proceeds from each piece of pottery sold goes back to help watershed groups who are trying to restore streams impacted by the old abandoned coal mines.

So the water gets treated. The streams get cleaner so that fish and aquatic life can live in them again. The metals from the polluted water get recycled into valuable products. People buy beautiful pottery for friends and loved ones. Artists make a living doing what they love and watershed groups get much needed financial assistance to help them clean up our streams. That is what I would call a Win-Win-Win-Win-Win situation! Buy your eco-friendly pottery before the rush starts.

For more information, visit Clean Creek Products' website at www.cleancreek.org

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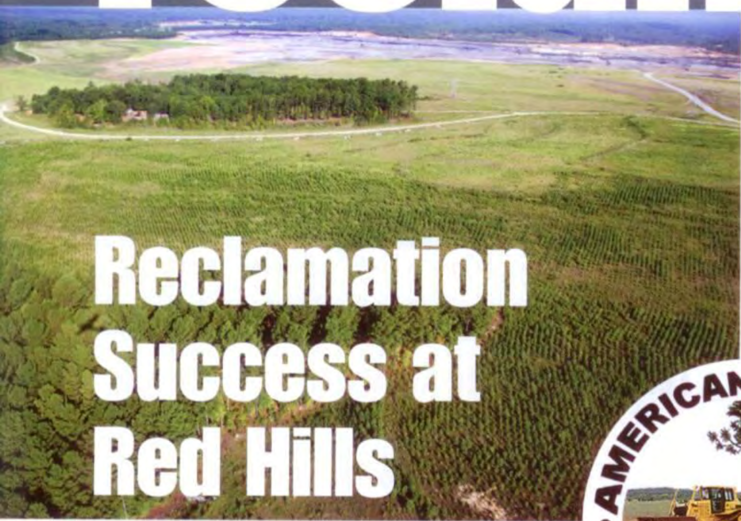
Issue 2 2008

reclamation matters



Reclamation Success at Red Hills

Mine Drainage Sludge: Helping the environment?

The 2008 Annual Meeting

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BY CLIFF DENHOLM, TIM DANEHY, TOM GROTE, SHAUN BUSLER, MARGARET DUNN,
CLEAN CREEK PRODUCTS, INC.

Mine Drainage Sludge:

Helping the environment?

Introduction

Within the recent past, government agencies, watershed groups, nonprofits, universities, and private industry have successfully developed and implemented passive technology to treat abandoned mine drainage. In some instances, these systems have restored lifeless streams to healthy aquatic habitats supporting reproducing fish populations after many decades of being essentially lifeless.

As thousands of tons of metal precipitates are being retained within numerous passive systems every year, this "sludge" has the potential to be either a liability or an asset. Since periodic "cleaning" of some components may be needed to maintain effective treatment, the question then becomes what to do with the metal-bearing precipitates that are removed?

One approach is to develop markets for these "byproducts" with the goals of: 1) helping to sustain watershed restoration efforts of nonprofits and volunteer organizations, 2) creating "green" products, and 3) rejuvenating the treatment medium while essentially eliminating disposal costs.

Resource Recovery Effort

With the ongoing support of the landowner and with funding received from the PA Department of Environmental Protection Bureau of Abandoned Mine Reclamation, the De Sale Phase II passive system in the Slippery Rock Creek Watershed, Venango Twp., Butler Co., Pa., was selected to test conceptual ideas for a portable process with quick set up time to recover manganese-bearing material.

The De Sale Phase II passive treatment system, with the design based on the 75th percentile of raw water monitoring data: 204 gpm, 3.2 lab pH, 233 mg/L acidity, 10 mg/L total iron, 50 mg/L total manganese, 8 mg/L total aluminum (Ref: PA DEP, Knox DMO, 1998), contains the following components: Stream Intake → Forebay → Vertical Flow Ponds (2 in parallel) → Settling Pond → Aerobic Wetland → Horizontal Flow Limestone Bed (HFLB).

As the final component in the system, the HFLB was installed primarily to provide an alkalinity "boost" prior to discharging to the receiving stream. Manganese removal was a secondary consideration at the time of design and installation in 2000. After seven years of continuous operation, however, the HFLB was estimated to contain 60,000 to 80,000 lbs. of manganese-bearing material. The general decrease in manganese concentration in the abandoned mine drainage is depicted in the following table:

Table 1. Raw and Selected Monitoring Data for De Sale Phase II

Mean
min/median/max

Point	Flow	Lab pH	Lab Alk	Acidity	T. Fe	T. Mn	T. Al
Raw (n= 55 to 58)	72 25/53/200	3.3 2.9/3.2/3.7		253 92/250/451	25 7/24/82	52 18/51/84	10 2/10/15
HFLB effluent (n=51 to 58)	95 10/73/445	6.8 5.8/6.8/7.5	75 0	-7 -73/0/35	2 0/<1/15	23 0/19/75	<1 0/<1/3

Lab alkalinity and acidity (mg $CaCO_3$/L); total metals (mg/L); prior to 2004 lab acidity reported as "0" for negative readings; sampling dates vary among individual sampling points.

Figure 1. Manganese material filled the void spaces and coated limestone aggregate prior to recovery.

The earlier components improve the abandoned mine drainage, based on limited sampling, so that the HFLB influent is characteristically net acid with circumneutral pH and essentially no iron or aluminum. Substantial manganese is not typically removed prior to entering the HFLB.

In August and September 2007, a full-scale recovery of manganese oxides with the simultaneous rehabilitation of limestone aggregate in the HFLB was initiated. The HFLB at this site contains 2,900 short tons of 4-inch x ¾-inch, >90% $CaCO_3$, limestone aggregate with a riprap-lined influent spillway and effluent piping with 10-inch, perforated PVC along the outlet end.

Before the recovery process began, the influent flow to the HFLB was bypassed and the component was drained. (During the seasonal low-flow period, the drainage was adequately treated by manipulating the flow through other system components.) Within the HFLB limestone aggregate, two wash pits were excavated, lined with an impermeable membrane, and filled with water pumped from the treatment wetland. Using an excavator with a rotating screen attachment called a FlipScreen (FlipScreen Australia Pty Ltd., New South Wales), the manganese-bearing material was separated from the aggregate by rotating the FlipScreen within the wash pit. Material passing the 3/8-inch (0.95-centimeter) screen settled within the wash pit. The "cleaned" limestone aggregate retained in the bucket was returned to the HFLB. The slurry from the wash pits was pumped into flexible bulk containers for settling and dewatering. In some cases, the wash pit was drained prior to excavating and stockpiling the manganese-bearing material on a pad for additional drying before placement in the containers. Thirty-two containers, each with approximately one ton of recovered material, were removed from the site. An estimated 25 to 50 tons of recovered material remains at the site for future removal.

Material Characterization

X-ray fluorescence provided the following bulk chemical (whole rock) analyses for the recovered material: about 25% MnO, 25% SiO_2, 10% Al_2O_3, 10% CaO, and 25% Loss-on-Ignition. Limestone and quartz were identified by visual examination using a hand-lens. The material fizzed aggressively with 10% HCl also indicating the presence of limestone, as well as with hydrogen peroxide, indicating the presence of manganese oxides. Future efforts will include improvements to the recovery process to try to minimize dilution and examination of beneficiation processes to remove impurities.

Figure 2. Excavator with FlipScreen attachment "washing" manganese covered limestone.

Figure 3. Close up of FlipScreen during manganese recovery operation.

Figure 4. View of recovered manganese material excavated from wash pit.

Figure 5: Examples of pottery with glazes using recovered manganese material and iron oxides formed at low pH.

Material Uses

Investigations into the use of the recovered manganese began in 2004 when ceramic artist, Pam Esch (MEC Clay Studios, Cleveland, Ohio) became intrigued with the possibilities of using the material for pottery glazes in place of the commercially available, imported, manganese oxides. Initially, small batches of different glaze recipes were tested on ceramic shards with small bowls and cups created as interest continued to grow.

The concept that this "Made in the USA" product could potentially help to fund watershed restoration activities was realized in 2007, when the North Country Brewing Company (Slippery Rock, Pa.) commissioned the nearby Pottery Dome (Grove City, Pa.) to use recovered material in the glaze of 300 ceramic beer mugs. Due to the quick sales, and in support of the restoration activities, the brewery donated a portion of the proceeds to the Slippery Rock Watershed Coalition, which was, in turn, placed into a trust fund to offset future maintenance costs.

Encouraged by the interest, the recovery and reuse effort now includes pottery glazes with iron-bearing materials precipitating at low pH, as well as the identification of other potential uses for the manganese material, such as colorants for bricks and concrete.

With positive interest by local newspapers and national publications, and with support from both the mining industry and watershed groups, what was once a liability is now potentially part of the solution.

To learn more about the pottery and other activities of the Slippery Rock Watershed Coalition, see the following Web sites: www.cleancreek.org and www.srwc.org ■

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TECHNOLOGY NEWS AND TRENDS

A newsletter about soil, sediment, and ground-water characterization and remediation technologies

Issue 37 July 2008

This issue of Technology News and Trends *highlights innovative approaches to remediate and reclaim former mining sites and larger areas impacted by abandoned mining sites. Environmental problems associated with mine-scarred lands include revegetation difficulties, waste piles or dumps contributing to metal-loading in surface water, and acid mine drainage (AMD) deteriorating regional surface and ground water quality.*

Contents

Passive Systems Treat AMD While Allowing Recovery of Metal Oxides

A public-private partnership is installing a series of passive treatment systems to treat AMD from abandoned surface and underground coal mines in western Pennsylvania. Since 1994, the Slippery Rock Watershed Coalition has constructed 16 systems annually treating over 750 million gallons of AMD. Each system typically employs a sequence of natural gradient-driven treatment steps involving settling ponds, vertical-flow ponds containing limestone and organic material such as compost, and constructed wetlands to treat surface water that is diverted from (and later returned to) mining-impacted streams. Under the state's *Growing Greener Program*, academic volunteers and the Pennsylvania Department of Environmental Protection (PA DEP) have noted significant improvements in water quality of receiving streams as well as a return of fish in about 11 miles of headwaters streams as a result of AMD treatment. Sale of metal oxides reclaimed from the treatment systems helps cover maintenance costs for existing systems and is anticipated to help install new systems addressing other abandoned discharges in the region.

PA DEP investigations in 1998 indicated that mine drainage into Seaton Creek, a major headwaters tributary, contributed 42% of the acid load and 49% and 41% of the iron and aluminum loadings, respectively, to Slippery Rock Creek. The findings focused cleanup efforts on Seaton Creek at a 40-year-old, 100-acre surface mine known as the De Sale Restoration Area. The target area for metal oxides recovery at this mine comprises an unnamed tributary with pH averaging 3.1 and acidity (the amount of base needed to neutralize a volume of water) of 100-450 mg/L. Metal concentrations in surface water range from 10 to 80 mg/L total iron, 20-80 mg/L total manganese, and 5-15 mg/L total aluminum. Stream flow ranges seasonally from 10 to 500 gpm.

Remedy construction included installation of a 16-ft-wide by 3-ft-high instream dam with 6-in and 8-in intake pipes allowing diversion of up to 700 gpm under the natural gradient into the treatment system. The entire stream (except during occasional storm events) is diverted into an 8,000-ft^2 forebay to settle solids and debris. Upon exiting the forebay, water passively flows to two flushable vertical-flow ponds operating in parallel to neutralize acidity, raise pH, and remove metals. Each 20,000-ft^2 pond contains 2,200 tons of limestone aggregate overlain by a 0.5-ft layer of spent mushroom compost. Iron oxides precipitate at low pH above the compost as water percolates down through the component.

Two tiers of perforated plastic pipe within the aggregate of each vertical-flow pond collect and transfer water to a 0.2-acre, 5-ft-deep settling pond. A riprap-lined spillway allows water to then pass to a 1.5-acre, free-

[continued on page 2]

CLU-IN Resources

CLU-IN provides an online "issue area" to help stakeholders clean up and reclaim ***Mining Sites*** (http://cluin.org/issues/). Resources include a link to EPA's Abandoned Mine Land webpage, which contains site-specific case studies, technical information on geochemistry, characterization, and remediation, and research reports on unique aspects such as metals loading and attenuation.

Figure 1. *Native plants in the De Sale Restoration Area wetlands include broad-leaved cattails, soft rush, and tussock sedge.*

[continued from page 1]
flowing, aerobic, constructed wetland to precipitate amorphous iron hydroxides at circumneutral pH (Figure 1). Upon exiting the wetlands, water enters a horizontal-flow limestone bed containing 2,900 tons of limestone aggregate that removes manganese and provides an alkalinity boost for additional buffering capacity downstream.Treated water finally discharges through a 10-in pipe into a rock-lined channel that returns flow to the watercourse at a location approximately 1,000 feet below the intake.

The treatment system was constructed over six weeks in June-July 2000. Limestone (90% $CaCO_3$) aggregate was obtained from a local quarry three miles distant at a material and delivery cost of $12/ton. Spent mushroom compost was obtained from an agricultural producer based 12 miles away, at a material and delivery cost of $10/yd^3.

The system currently neutralizes approximately 180 pounds of acid discharge each day. Daily reduction rates for metals average 20 pounds of iron, 8 pounds of aluminum, and 25 pounds of manganese. Monitoring of surface water re-entering the stream after treatment typically shows a pH of 6-7 with total iron and aluminum concentrations less than 2 mg/L and manganese concentrations at least 50% lower than intake levels. Sampling of treated surface water in Spring 2008 indicated pH 6.7, alkalinity 60 mg/L, acidity -33 mg/L, dissolved iron 0.1 mg/L, dissolved aluminum 0.1 mg/L, and dissolved manganese 14 mg/L. These results represent 100% neutralization of the acid discharge and 99%, 99%, and 70% reductions of iron, aluminum, and manganese concentrations, respectively.

Efforts to recover manganese oxide from the horizontal-flow limestone bed began last fall. Recovery equipment for dewatering, separation, and handling of manganese-bearing material included a 21-metric-ton excavator equipped with a "flip screen" attachment to screen materials, a gasoline-powered water pump, and 1-yd^3 bulk storage containers. About 30 tons of recovered material currently is stockpiled offsite, and an estimated 20 tons of material remain for future recovery. Additional drying and screening can be conducted before reuse, depending on user needs. Preliminary laboratory results indicate the unprocessed, recovered material consists of approximately 25% manganese oxide with the remainder constituting primarily quartz, limestone, and water.

A large-scale effort to recover the iron oxide precipitating at low pH is planned for later this summer. Recovery will employ a small excavator to remove an estimated 200 yd^3 of material collected in the existing vertical-flow ponds. In order to provide continuous treatment, the process directs all raw water to one pond while recovering iron oxide precipitate from the other and vice versa. Recovered iron oxide will be used as pigments for bricks, concrete, and ceramics. Commercially available material of similar quality currently is sold in the area for about $0.50 to $1 per pound.

The non-profit Stream Restoration, Inc. assists the Slippery Rock Watershed Coalition in coordinating treatment system installation and maintenance. The partnership relies on field assistance from Grove City College, Westminster College, and Slippery Rock University students, mining companies, local residents, and other youth or service organizations. Recovered manganese and iron oxides have been used by local artists as colorants in ceramic glazes, and future markets are anticipated to include manufacture of "green" products such as tile and paint.

Since 2005, the PA DEP has awarded over $4 million in innovative technology grants to develop cost-effective industrial applications helping to treat the state's estimated 23 billion gallons of AMD from active and abandoned coal mines. Other innovative strategies explored under the *Growing Greener* initiative include self-flushing limestone systems, steel slag as treatment media, and optimization and combination of passive treatment systems providing added value to site cleanup.

Contributed by Scott Roberts, Deputy Secretary of the Office of Mineral Resources, PA DEP (jayroberts@state.pa.us or 717-783-5338), Margaret Dunn, Slippery Rock Watershed Coalition, and Cliff Denholm, Stream Restoration, Inc. (sri@streamrestorationinc.org or 724-776-0161)

Ecological Approach Used to Remediate Former Mining Site

Cleanup of the inactive Burlington Mine site in Boulder County, CO, was initiated in 2003 as a voluntary cleanup overseen by the Colorado Department of Public Health and Environment (CDPHE) pursuant to the Colorado Voluntary Cleanup Redevelopment Act of 1994. An ecological approach was used to improve downstream water quality, reduce surface- and groundwater interaction with contaminated materials, and limit potential for subsidence. Activities included the filling and mounding of subsidence pits, realignment of intermittent tributaries, management of surface-water runoff, and revegetation of barren areas.

The 11-acre property was used by several companies from 1920 to 1973 to produce fluorspar (calcium fluoride), an active ingredient of fluorinated compounds commonly needed for water fluoridation and ceramic manufacturing. In the 30 years prior to cleanup, the site experienced significant and increasing subsidence. Site investigations in 1999 indicated acidic and metals contamination in waste rock onsite and in the adjacent surface-water drainage. Geotechnical investigations indicated a 12- to 15-foot layer of alluvium overlying bedrock at a depth of 25 feet below ground surface. Ground water is encountered at a depth of 8-10 feet.

Field preparation began with consolidation of 25,000 yd^3 of acid-generating waste rock and closure of three onsite adits and shafts. Activities then focused on addressing three subsidence pits that provided direct paths for flow of contaminated material from the subsurface mine workings to surface and ground water. Of particular concern was a 1/3-acre pit that intercepted intermittent drainage from Balarat Gulch in the Lefthand Canyon watershed. Approximately 17,000 yd^3 of uncontaminated or neutralized onsite soil was used to backfill the pits. Sufficient material was added to create a minimum 2% slope for discouraging infiltration and promoting runoff. In anticipation of the backfill settling, the area was over-mounded 4 feet.

Significant water interactions associated with Balarat Gulch were addressed by constructing a 500-ft diversion channel to realign drainage away from mine workings. The design used a step-pool configuration typical of high-gradient alpine streams, whereby system stability relies on closely spaced, low-profile drop structures (i.e., elevation reductions) to dissipate flow energy. Construction of the channel bed in this way helped to more closely imitate natural channel form and function, incorporate naturalizing elements, and create aquatic and riparian habitat.

Three-dimensional mining maps were used to identify the channel's optimal centerline location and inversions. The channel design accommodated sizing and configuration sufficient to contain the design discharge of 264 cfs, which is 120% of a 100-year storm event. In an upper reach of the diversion channel, where realignment required a sharp bend away from the historic surface-water path, a PVC liner was installed to fully confine water and reduce potential for piping failure behind a constructed 10-ft-wide, 2-ft-high boulder wall. Two lower reaches of the channel were left unlined to allow hillslope ground water to access the new channel rather than flowing beneath it and potentially accessing the mine workings below.

The Balarat Gulch diversion channel required excavation at a steep (2:1- 2.5:1 horizontal:vertical) 1/2-acre sideslope. To prevent erosion, the slope was stabilized with a native seed mix including mountain mahogany (*Cercocarpus montanus*) and bitterbrush (*Purshia tridentata*) shrubs suited for optimal establishment on bedrock face microniches. Following seeding, the slope surface was amended with Biosol® prior to installing a biodegradable woven-coconut coir erosion control fabric.

A primary alluvial water control structure extending to bedrock was installed at the top of the diversion channel to address subsurface flow. The engineered structure comprises a 75-ft-long, 25-ft-deep impermeable liner and curtain drain consisting of prefabricated drainage panels with perforated PVC pipe threaded through bottom sleeves. The impermeable lining intercepts alluvial water and forces it into the curtain drain system. Localized ground water and surface water not intercepted by the primary control system are captured in a secondary, downstream "scavenger" drain.

Revegetation focused on stabilizing the site, promoting evapotranspiration, and preventing precipitation and subsurface infiltration. Preparations required surface application of agricultural lime to neutralize acid generation potential of the waste rock. Approximately 15 tons of lime were applied per 1,000 tons of waste rock throughout the backfilled areas. These areas were covered with 12-18 inches of native subsoil and topdressed with "type A" commercial compost at a rate of 60 tons per acre. This created a physical barrier to precipitation reaching the waste rock and provided a suitable medium for plant growth. A seed mix of native grasses, wildflowers, and shrubs was broadcast seeded at a rate of 240 pure live seed (PLS) per square foot. Shrub and tree plantings included over 220 riparian species such as thinleaf

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Figure 2. *The ecological approach used to address AMD in the Balarat Gulch relies on revegetation with native plants to help stabilize banks of the diversion channel constructed four years ago.*

[continued from page 3]

alder (*Alnus incana*), 150 upland shrub species such as wax currant (*Ribes cereum*), and 20 ponderosa pine trees (*Pinus ponderosa*).

A mobile bed of soil and rock gradations in the natural channel was used to allow mobilization by low-intensity storms, as in a natural, dynamic system. Material mobility results in natural scour and deposition cycles capable of forming localized pools or overly wide water flow. The mobile bed is underlain by a resistive, grouted riprap layer providing vertical protection against channel lowering. To replicate native conditions, natural rock and boulders were given preference over concrete during construction of the bed and bank treatments. Creating small notches in the tops of the drop structures in an alternating alignment encouraged development of low-flow channels with increased sinuosity.

After 12 months of remedy operation, corrective measures were required to address unanticipated drainage along the hillslope of Balarat Gulch. Deep rills had developed under the erosion control fabric due to interception of several small drainages and a ground-water seep caused by remedial excavation; in some areas, the fabric was stretched to failure by underlying erosion. Woody material was installed where possible to reroute flows and serve as supplemental breaks to drainage flows, and a subsurface drain system was installed to collect and route seep water around the vulnerable hillslope to more stable, vegetated areas. Large rills were regraded to the extent possible and erosion control fabric was re-installed in problem areas.

Wildlife protection methods included installation of Bird Balls™ recommended by the U.S. Fish and Wildlife Service to prevent waterfowl from landing or residing in a pond receiving constant discharge from underlying mine tunnel. After three growing seasons, vegetative coverage is as low as 5% (in sections of the steep 2:1 hillslope), but as high as 85% in other areas (Figure 2). Complete revegetation is expected to require 10-20 years. CDPHE estimates a total cleanup project cost of $1.5 million, or about $140,000 per acre.

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Interagency Study Examines Impacts of Mine Spoil Types on Reforestation Efforts

The University of Kentucky, in cooperation with the U.S. Department of Interior (DOI) Office of Surface Mining, the Kentucky Department of Natural Resources, and the coal industry has initiated a research program to examine reforestation techniques on surface mined lands. Research plots were established on the Bent Mountain surface mine in Pike County, KY, for the purpose of evaluating the influence of three different loose-graded spoil types on tree performance, water quality, and hydrology.

Historically, reforestation was used to reclaim sites impacted by surface mining in the Eastern U.S. The passage of the Surface Mining Control and Reclamation Act of 1977 required that mined lands be returned to their approximate original contour (AOC). Spoil compaction involved in reconstructing sites to the AOC often hinders reforestation efforts, contributing to a decline in the amount, diversity, and productivity of forestland in coal-producing areas. Compacted soil and inappropriate geochemical characteristics often lead to high seedling mortality, slow plant

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growth, accelerated erosion, and deteriorated quality of receiving streams.

Previous research on mined lands has shown that loosely graded topsoil, weathered sandstone, and other non-toxic topsoil substitutes are suitable growing media for establishing native hardwood forests in Appalachia (Figure 3). Research is now helping to evaluate media other than topsoil and the influence of loose-grading techniques.

The Bent Mountain surface mine covers a total of more than 1,000 acres, including 150 acres of reforestation research areas. University of Kentucky researchers constructed one-acre test plots to evaluate three on-site spoil types: (1) predominately brown weathered sandstone (brown); (2) predominately gray un-weathered sandstone (gray); and (3) mixed weathered and un-weathered sandstones and shale material (mixed). Prior to placement of the spoil in each plot, a system of drain pipes and tipping buckets was installed on a stable mine surface to capture and measure infiltrated water that percolated through the spoil. Six to eight feet of the respective spoil material was end dumped from a truck on top of the drainage system in each plot. Four tree species (white oak, yellow poplar, red oak and green ash) were planted into the loose spoils at a rate of 800 per acre.

Physical and chemical characteristics of the spoils indicated that the brown spoil type exhibited a higher productivity potential than the gray and mixed spoil types due to a finer soil texture, higher cation exchange capacity, higher phosphorous concentration, and a pH more suitable for native hardwood trees. After three years, the gray spoil type had an overall higher mean tree seedling survival (88%) than the brown spoil (86%) and mixed spoil (81%), but no significant differences in survival were observed among spoil types. The brown sandstone plots however, showed significantly more growth in height and diameter than the gray and mixed plots. Mean tree volume index was 230, 80, and 40 cm^3 for the brown, mixed and gray, respectively.

Results showed that loose-graded spoil exhibited low discharge volumes to surface water, small peak discharges, and long durations of discharge. Storm flow characteristics and mean runoff curve numbers were similar to that of an unmined reference forested watershed. Surface water interception and storage is expected to increase as the forest matures, thereby further reducing discharge volumes and peak discharges. Electrical conductivity (EC), as an indicator of water quality and ionic strength, decreased by 75% in the gray and mixed spoil types, while concentrations in the brown remained steady. After three years, EC levels for all spoil types were below 500 uS/cm–a reported threshold level for mayflies *(Ephemeroptera)*, a pollution indicator species for headwater streams of the Central Appalachian Mountains.

Study results indicated that topsoil substitutes can be used effectively as growth media for native vegetation when combined with field techniques for loose grading and minimized surface compaction. Strategies relying on these techniques are being incorporated into a regional watershed restoration design that incorporates landscape modification, stream restoration/creation, and reforestation at a head-of-hollow fill in eastern Kentucky.

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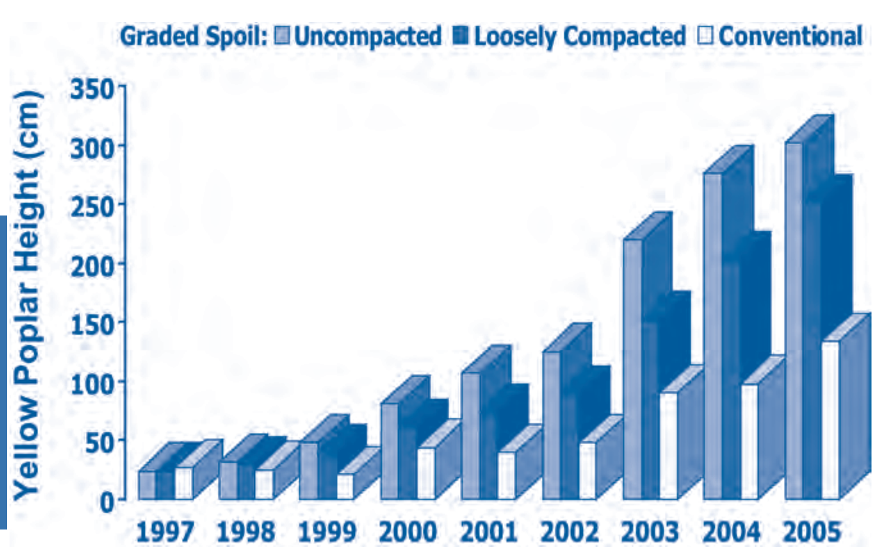

Figure 3. *University of Kentucky studies at the Starfire surface mine of eastern Kentucky in 1996 showed that yellow poplar (Liriodendron tulipifera) showed increased survivability when soil compaction was minimized through one or two bulldozer "strike-off" passes and reduced machinery traffic.*

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TECHNOLOGY NEWS AND TRENDS

Upcoming Conferences

The U.S. EPA and National Ground Water Association (NGWA) joint ***Remediation of Abandoned Mine Lands Conference*** will be held October 2-3, 2008, in Denver, CO. The agenda includes detailed discussion of characterization, source controls, treatment technologies, and reuse/reclamation strategies. More information and registration for this event is available from the NGWA at http://www.ngwa.org/development/conferences.aspx.

The U.S. EPA and federal partners such as the Agency for Toxic Substances and Disease Registry, National Institute of Health, and Department of Energy will sponsor the ***International Environmental Nanotechnology Conference: Applications and Implications*** on October 7-9, 2008, in Chicago, IL. Presentations will address nanotechnology applications for remediation of environmental contaminants, implications of releasing manufactured nanoparticles in the environment, and pollution control and nano-enabled sensing. Registration and a detailed agenda are available online at http://emsus.com/nanotechconf/index.htm.

The Groundwater Resources Association of California (GRAC) will convene its ***Emerging Contaminants 2008 Symposium*** on November 19-20, 2008, in San Jose, CA. Topics will include nanomaterials, pesticides/herbicides, pharmaceuticals, phthalates, and flame/fire retardants. For more information, visit GRAC online at http://www.grac.org/contaminants.asp.

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08/01/08 - Old Fashioned Groundbreaking for Quecreek Mine Rescue Visitors Center. See 8/4/08 Digest for Video Blog Feature

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Dissolved Metal From Mine Drainage Used to Make Pottery by Cranberry Company

Clean Creek Products Company of Cranbury Township, Pa is helping to recycle dissolved metals from acid mine drainage runoff by using this byproduct as pigments in pottery products.

The company manufactures and sells hand-thrown glazed pottery (the glaze using the manganese byproduct-based colorant) and also promotes the metal byproducts as raw materials to other industries.

The proceeds from these efforts are given to local watershed groups to keep streams and rivers clean from acid mine drainage in partnerships with the Slippery Rock Watershed Coalition in Butler County and the non-profit group Stream Restoration, Inc.

Other watershed cleanup projects in Pennsylvania also pioneered the recycling of dissolved metals in acid mine drainage like Iron Oxide Recovery, Inc. and the Sewickley Creek Watershed Association in Allegheny County.

Pictured in the photo are Clean Creek Products partners Betty McDevitt, Ray Nelson, Lois Hamilton, Margaret Dunn, Bob Isenberg, and Cliff Denholm.

To learn about these byproduct reuse efforts, go to the Clean Creek Products Company website.

Link: Iron Oxide Recovery, Inc. Wins Governor's Excellence Award

Passive Treatment Systems in Slippery Rock Yield Black Glaze

5/9/2008

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Envirobytes - An Environmental Newsletter

EnviroBytes, a Summary of Issues and Events for Week Ending May 2, 2008

GREENING OF THE PHILLIES

The Philadelphia Phillies major league baseball team has signed up with EPA's Green Power Partnership, becoming the third-largest purchaser of green power in the city. The Phillies purchased 20 million kilowatt-hours of renewable energy to cover ballpark energy use this year, equivalent to planting 100,000 trees. The ballpark will use only biodegradable cups and plates, turn frying oil into biodiesel and recycle stadium cans and bottles. Regional Administrator Donald S. Welsh remarked how the Phillies "have hit a grand slam for the environment" by investing in clean, renewable energy to offset their carbon footprint and act as an example to others. For information about the Green Power Partnership, go to http://www.epa.gov/greenpower/basic/index.htm

EPA CO-HOSTS THE 17TH ANNUAL INDUSTRIAL PRETREATMENT CONFERENCE

EPA Region 3 and the PA-DEP co-sponsored the April 23-24 Annual Industrial Pretreatment Conference in Myerstown, Pa., hosted by the Eastern Pennsylvania Water Pollution Control Operators Association of Reinholds, Pa. EPA presentations included types of samples used for pretreatment program monitoring, emerging contaminants (focusing on mercury), and the federal regulations code. Other presentations included pharmaceuticals and personal care products, laboratory audits, talking with regulators, and emergency response procedures. Well-trained sewage and wastewater pretreatment operators are important in keeping water supplies clean and safe to protect the health and well being of communities.

EPA ISSUES TRAINING MATERIAL TO IMPROVE WATERSHED ORGANIZATIONS' FINANCING STRATEGIES

EPA's Office of Wetlands, Oceans and Watersheds has released a set of online training materials designed to help nonprofit watershed organizations develop and implement sustainable funding plans to finance their watershed projects. The materials outline six key steps to funding plan development, introduce fundraising options, and provide success stories as examples to successful financing. Watershed organizations will be able to create their own financing plans, ensure their own sustainability, and protect the nation's water quality. The materials are available at http://www.epa.gov/watertrain/sustainablefinance/.

COMPANY DISCOVERS NEW USES FOR BYPRODUCTS OF ACID MINE DRAINAGE

EPA considers acid mine drainage and its dissolved metal runoff into water bodies a major pollution concern from abandoned mines, but now, the byproducts of acid mine drainage (removed through a passive treatment system) are being used to develop glaze pigments by the Clean Creek Products Co. of Cranbury Township, Pa. The company manufactures and sells hand-thrown glazed pottery (the glaze using the byproduct-based colorant) and also promotes the metal byproducts as raw materials to other industries. The proceeds from these efforts are given to local watershed groups to keep streams and rivers clean from acid mine drainage. To learn about these byproduct reuse efforts, go to http://www.cleancreek.org/catalog/conditions.php EXIT Disclaimer To learn about acid mine drainage pollution in Region 3, go to http://www.epa.gov/reg3wapd/nps/mining/mines.htm#acid

STAR GRANT WINNERS PRESENT FINDINGS ON CLIMATE CHANGE AND PARTICULATE MATTER

EPA Region 3 hosted scholars and researchers on climate change and air pollution from regional universities (including Johns Hopkins, Carnegie Mellon and the University of Delaware) who presented their findings from work funded through their EPA Science to Achieve Results (STAR) Grants awards. The workshop included presentations on climate change and particulate matter and how the research complements and supports agency initiatives. Topics discussed included measurement of the size and composition of atmospheric particulate matter, and linking global to regional models to assess future impacts on U.S. surface ozone concentrations. For more information on the STAR program, the solicitation process, and topics of concentration, go to http://es.epa.gov/ncer/grants/

INTERNATIONAL COMPOST AWARENESS WEEK RUNS FROM MAY 4 TO MAY 10

According to EPA, yard trimmings and food residuals together constitute 24 percent of the U.S. municipal solid waste stream. We can help reduce these statistics by composting to reduce a household's waste. Tea bags, coffee grounds, fruit and vegetable peels, pet hair, dryer lint, egg shells, leaves, and grass clippings – almost any readily available organic materials -- can be recycled and thrown into a compost pile. The compost pile can be used to nourish soil, reduce the need for chemical fertilizers, herbicides and pesticides, save money, and also reduce contamination of streams, and lakes. For more information, go to www.epa.gov/epaoswer/non-hw/composting/basic.htm.

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LOIS HAMILTON'S *dome* of *wonders*

Ceramist molds impact on art, clean streams movement

Pottery art usually conjures up images of small, quiet storefronts or schoolroom-glazing projects. Lois Hamilton's Pottery Dome is so much more. Hand-thrown ceramics and glass come in earth tones and wild colors of blue, orange and pink. Moreover, she operates the studio with an extraordinary commitment to the environment – playing a key role in the restoration of local streams that were damaged by past mining operations.

"Fish now thrive in miles of previously lifeless streams, and it wouldn't have been possible without Lois Hamilton," said Margaret Dunn, the geologist that co-founded the Slippery Rock Watershed Coalition. The group is reclaiming 40 miles of land, water and wildlife resources that were damaged by acid mine drainage in Butler, Mercer and Venango counties.

As part of the reclamation process, workers have been removing sediment called muck – runoff from abandoned mines – from streambeds. Hamilton was one of the first ceramists to see that concentrations of manganese and iron in the muck could be used in pottery.

"We're recycling the muck to make new glazes," said Hamilton, a long-time SRU supporter who sponsors four scholarships, two in honor of her late parents, father Rhesa Service Byers, '13, and Lily Ray Byers. "The muck is dried up and pulverized. About 5 to 8 percent goes into the glaze, in powdered form."

Hamilton donates a portion of sales from the Pottery Dome to the watershed coalition to support further cleanup. North Country Brewery in Slippery Rock also sells her clay mugs to finance restoration.

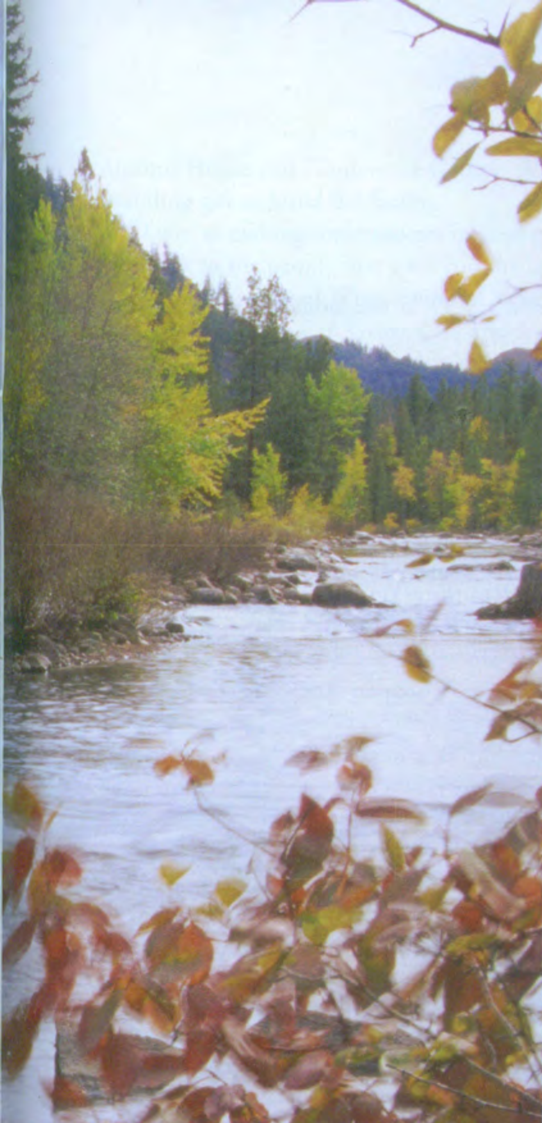
"We'd be burying this material or taking it to landfills if it wasn't for Lois Hamilton," Dunn said. "It's so exciting. All of the manganese in the U.S that is commercially available comes from overseas. Here we have a product that is coming out of the Slippery Rock Watershed. Because of Lois and other potters, we have had an inquiry from Texas about the possible purchase of 20 tons of manganese and iron. That's making a difference."

Hamilton, a former art teacher, said she involves herself with environmental stewardship because, "We're just using up the world's resources." The scarcity of some resources surprises her, even though she's always been conscious of conservation.

"When I started teaching back in 1958, I used to jokingly say, 'take care of these minerals. The world's going to run out of them,'" she said. "By the time I retired from teaching in 1994, we could no longer order about four items [used in ceramics]."

Hamilton taught drawing, painting, art history, art survey and art for education students, before she opened the Pottery Dome in 1994. She employs a full-time potter, Robert Isenberg, who received his art training at SRU.

The building, which includes a gallery and studio, captures the early greening concepts of 20th-century poet and architect R. Buckminster Fuller (1895-1983).



Fuller invented the geodesic dome as a cost-effective and aesthetic design.

Isenberg, Hamilton's full-time potter, kneads in many different sizes and throws functional pieces such as vases and plates and artistic items. He fires pieces with lead-free glazes and uses an emission-free oven.

"A pottery class at Slippery Rock University in 1991 introduced me to the medium of clay," he said. "The work at the Pottery Dome has been an incredibly unique and creatively enriching experience. It has shown me the discipline necessary to complete custom orders for functional work and maintain new works for the sales area."

Hamilton supports arts education as beneficial to all students. "There have been studies for the last 10 years showing that if you have art in public school in grades kindergarten through third grade, students do better in math in fifth, sixth and seventh grade," she said.

Lois Hamilton sponsors four scholarships at SRU and donated a horse, "Prince," for therapeutic riding at SRU's Storm Harbor Equestrian Center. Her scholarships include:

- **Lily Ray Byers Scholarship (named for her late mother)**
- **Rhesa Service Byers Scholarship (named for her late father)**
- **Lorancie Byers Scholarship (named for her late aunt)**
- **Charles Hamilton Memorial Art Scholarship (named for her late son)**

The Pottery Dome makes and sells hand-thrown stoneware pottery. Its inventory includes dinnerware, bowls, platters, pots and Raku as well decorative pieces, glass and sculptures.

Lois Hamilton opened the studio and gallery in 1994, in a distinctive geodesic dome. One side houses the gallery. Artist Robert Isenberg, who received his art training at SRU, creates pottery in the second half, using lead-free glazes and an emission-free oven.

More information: The Pottery Barn, 2347 Leesburg-Grove City Road, Mercer, Pa. 16137. 866.570.5001 or http://www.potterydome.com.

Healthy Alternatives For Your Body, Mind & Spirit

The Point North

APRIL 2008

Earth Day - April 22

Pages 18 - 19: Stream Restoration Inc.

Page 9: The Wonder of Parenting

Page 21: Baby Boomers and Seniors Sections

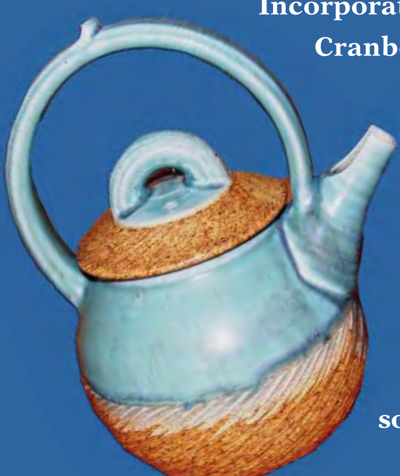
THINK ORGANIC!

POTTERY
Helping the Environment? *Are You Kidding!?*

By Cliff Denholm

WITH THE RETURN OF SPRING AND EARTH DAY COMING QUICKLY upon us, our thoughts often turn towards what WE can do to help the environment and make the world a better place. For some, this might mean planting a tree or picking up trash along a stream. But what if I said you could help the environment by simply buying a piece of pottery? "Are you kidding!?!" might be your response.

Well, that is exactly what one local nonprofit organization is doing. Stream Restoration Incorporated, based right here in Cranberry Township, has begun to sell locally produced, hand-thrown pottery using glazes made with recycled materials recovered during "cleaning" of water at old coal mines. A portion of the proceeds from every item sold is then used to continue the grassroots efforts of restoring streams impacted by abandoned mine drainage.



That's right—-Abandoned Mine Drainage or AMD for short. AMD is water that flows from old coal mines which were operational before environmental laws were passed. This water is often acidic containing high levels of metals such as iron, manganese, and aluminum that can pollute streams. Ever see an orange stream? That was probably mine drainage. AMD is a major source of pollution in Pennsylvania, where an estimated 6000 miles of streams have been degraded. Many streams are essentially lifeless.

So what does this have to do with pottery and helping the environment? Well, watershed and environmental groups such as the Slippery Rock Watershed Coalition, focusing on the problem in northern Butler and Mercer County, have built passive systems to treat the AMD before it flows into local streams. Passive systems are an environmentally-friendly way to treat AMD. The process uses safe, natural materials such as limestone and compost to purify the water without using electricity. The limestone neutralizes the acid similar to humans taking Tums® for stomach acid. The toxic metals are captured within the passive system. These passive systems have restored hundreds of miles of streams throughout Pennsylvania. A major tributary to Slippery Rock Creek, for instance, has fish living in it for the first time in about 100 years. And that is just one stream. There are many other success stories throughout the state.

"And what does that have to do with pottery?" you ask. Well, the metals from the mine water that are captured eventually need to be removed so the passive system can capture more metals. There are literally thousands of pounds of metals being retained every day. So what are you going to do with all those metals? Good question. Stream Restoration Incorporated is working with local potters who are interested in using these metals in pottery glazes and is seeking to develop other products as well.

Local ceramic artists such as Bob Isenberg of *The Pottery Dome* near Grove City commonly use commercially mined and processed manganese and iron oxides to produce various colors and effects in their pottery glazes. The iron and manganese recovered from the passive systems offers a "greener," more environmentally-friendly alternative colorant.

As interest has grown surrounding the pottery, Stream Restoration Incorporated has created a new "division" called Clean Creek Products to create a new line of pottery. By contributing a portion of the sales from each item to watershed groups who have worked so hard to restore their local streams, the passive systems will be able to be maintained. The clean streams will be available for fishing, swimming, boating, and just plain relaxation for generations to come.

Pottery is available for purchase on line at www.cleancreek.org

Page 8 of the March/April 2008 Issue of The Magazine of the Sierra Club

ONE SMALL STEP

Margaret Dunn Rochester, Pennsylvania
Cofounder of the Slippery Rock Watershed Coalition, age 59

Glazed With What Oozed

When life hands you lemons . . . well, you know. But when life hands you acidic mine drainage? Geologist Margaret Dunn has toiled most of her life to make something good from the nasty runoff.

With roots in West Virginia's coal country, Dunn has spent the past 30 years slogging through mud, working with volunteers and businesses to restore streams polluted by acidic runoff from coal mines abandoned a century ago.

Dunn's group, the Slippery Rock Watershed Coalition, focuses on a 40-square-mile area in western Pennsylvania. The work can be arduous, but in 1992 Dunn learned about a simple filtration method that requires no electricity and little maintenance. The team constructs a collection system at the source of the drainage; the runoff is diverted through several ponds containing mushroom compost and limestone to neutralize acidity and remove metals. So far, the group has installed 15 systems treating 750 million gallons of mine drainage a year, and fish now thrive in 11 miles of previously lifeless streams.

The coalition's work took an unexpected turn when Dunn discovered that two plentiful byproducts of the passive treatment process, manganese and iron oxide, could be used as a pottery glaze. The group contacted local potter Robert Isenberg, who warmed to the idea of creating mugs glazed with the recovered elements. "The iron ore creates a transparent yellow glaze," Isenberg said, "and the manganese gives off rich earth tones." A coalition volunteer who dropped in for a pint at the North Country Brewing Company came away with an order for 300 of the mugs; now the group sells the pottery to help finance additional restoration work.

"This is getting big," Dunn said. "We couldn't have done this without all these people. I just know about rocks and water."

—Bette McDevitt

PURIFY ME A RIVER Acid mine drainage affects over 6,000 miles of streams in Pennsylvania, leaving one of the worst legacies of abandoned coal mines in the country. Almost 300 passive treatment systems have been installed in the state.

ON THE WEB *To learn more about stream restoration and mine drainage, visit the Slippery Rock Watershed Coalition's Web site,* srwc.org, *or* datashed.org *and* streamrestorationinc.org.

free oxides

updated sat 29 mar 08

Anne Doyle on fri 28 mar 08

"Are You Kidding?"
those words just jumped out at us on the booth's background...
Above it were words to the effect that pottery was environmentally friendly...
Very apropos to discussions we've been having here and i imagine we will be seeing this subject more and more so these ppl were of great interest to us...

Its called Clean Creek Products and they have a mission of cleaning up the

dregs of a coal mine ... they are a non-profit and they are offering to supply potters freely with iron oxide (yellow ochre looks like) and manganese oxide that comes from their efforts. In exchange they would like
to purchase pottery to sell to raise money for their continued efforts...
they are scientists and really friendly ppl... we were well impressed with them... i plan to try their oxides next round...

their web-site is
http://www.cleancreek.org/catalog/conditions.php

anyone interested in using their recovered oxides to develop glazes should contact them... they were really approachable..

Anne Doyle,
in Saint-Sauveur QC

« Reclamation Obstacle? Pennsylvania's Prevailing Wage
The Burning Rock: How Coal Influenced Our Culture »

Resource Recovery With A Twist

By Andy McAllister, Watershed Coordinator

As watershed groups continue to grapple with funding for the operation and maintenance of their treatment systems, one group has developed an innovative way to use the by-products from their passive treatment systems to help them maintain their systems.

The Slippery Rock Watershed Coalition has been working to restore Slippery Rock Creek since 1994 and has installed 12 treatment systems throughout the 40 square mile watershed in western Pennsylvania–an impressive accomplishment. Even more impressive is the method by which they intend to help continue funding their reclamation efforts–by selling pottery.

Two of the by-products of the group's passive treatment systems, iron oxide and managanese, as it turns out, are useful in creating beautiful glazes for pottery. The group worked with Stream Restoration, Inc. to recover the iron and manganese by-products from the treatment systems, found a local potter who was willing to give these pigments a try and voila, a unique product, "Clean Creek Pottery" was born.

Teapot and cups from Clean Creek Pottery

Although only a young venture, Clean Creek Pottery has rapidly found increasing support within the Slippery Rock Watershed and beyond. When people purchase this "green technology" glazed pottery they contribute to SRWC and SRI's efforts to treat Abandoned Mine Drainage. You can read about Clean Creek Pottery in the March/April 2008 issue of the Sierra Club magazine which features an article about Margaret Dunn of Stream Restoration, Inc and her group's efforts to make lemonade from lemons.

To find out more about Clean Creek Pottery and restoration efforts in the Slippery Rock Watershed, visit:

Clean Creek Pottery

Stream Restoration, Inc

The Slippery Rock Watershed Coalition

Sierra Club Magazine's article "One Small Step: Glazed with What Oozed"

This entry was posted on Tuesday, February 26th, 2008 at 4:02 pm and is filed under General, Helpful Tools, Uncategorized. You can follow any responses to this entry through the RSS 2.0 feed. You can leave a response, or trackback from your own site.

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Please add' 8 and 10

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Potter finds gold in stream slime

By Carol Ann Gregg
Allied News Staff Writer

When you see the mugs on the shelves of North Country Brewery in Slippery Rock, it's hard to imagine that the beautiful colors on them came from mineral slime.

In a chance visit to the offices of Stream Restoration Inc. Pam Esch, local artist, asked if the black powder in a glass container was manganese.

Geologist Margaret Dunn was stunned that her longtime friend even knew what manganese was.

Not only did she know what it was, but she also paid money to have it for use in pottery glazes.

Esch asked if she could have some. With delight the scientists at SRI said she could have all she wanted.

That was the beginning of finding a practical use for the mineral deposits that collect in the limestone ponds that are used to filter water from abandoned mines.

This non-profit group has been working to restore the stream waters that have been tainted from abandoned mine drainage.

In Pennsylvania, coal has been mined for more than 200 years. The mining industry fueled the Industrial Revolution and most of the advancements that people enjoy today. But in its wake, the mines left scarred landscapes and polluted streams.

It is estimated that Pennsylvania has more than 4,000 miles of streams that have been degraded by abandoned mine drainage.

In many instances, minerals that precipitate out of the stream water coat the bottom of streams, destroying the habitat of the organisms that are food for the fish and other animals in the water.

Carol Ann Gregg/Allied News

Keith Kolarosky shows off a few of the Mug Club mugs at North Country Brewing in Slippery Rock.

SRI has been installing passive drainage systems to remove the minerals from the stream water.

The system allows the water to flow horizontally over limestone, and the minerals – manganese, iron, and aluminum – precipitate out and settle into the spaces between the limestone. Eventually, there is no room left in the limestone pond for the minerals.

SRI has done extensive work at the headwaters of Slippery Rock Creek, in the LeSalle area, just west of Eau Claire. They also have a restoration project along U.S. Route 62 at Fox Run between Jackson Center and Stoneboro.

"It is exciting to see a stream that has been dead to have fish appear there again," Dunn said. She related that the streams were running red and the shoreline vegetation was dead.

Within a year or two, green plants reappeared and fish were again swimming in the stream water.

The staff from SRI are excited about finding uses for the deposited minerals.

Bob Eisenberg, the potter at the Pottery Dome, Leesburg, has been experimenting with the iron and manganese in glazes for some of his work. The stream minerals provide colors different from the commercial minerals he purchases. He prefers the local minerals to the commercial ones.

Last year Eisenberg made 300 mugs for the North Country Brewery Mug Club. Each was unique and many used the new glazes.

Eisenberg and Tom Grote of SRI visited the Manchester Craftsman's Guild in Pittsburgh to encourage other artists to experiment with the minerals. The Craftsman's Guild members work in many media including fiber arts, woodworking and glass.

Eisenberg and Grote are also planning to investigate providing the manganese and iron materials to local commercial ceramic suppliers as an outlet for the products.

"I am astonished with how this has come together," Dunn said. People are excited to be a part of this project.

Jane Nugent with the Indoor/Outdoor Home Show, Monroeville, invited Dunn to share the project with the public at the show. She is taking some pottery pieces and literature to the show.

Dunn envisions developing a small pottery item with the glaze so the public can have a token of support for the restoration project and the further development of uses for the resulting mineral deposits.

The Herald 02/02/2008

Clean stream effort yields pottery glazes

They color mugs, plates

By KRIS MILLER
Eagle Staff Writer

GROVE CITY — When stream restoration is mentioned, people usually picture something unsightly being removed from creek beds so the water can run clear.

They don't think about colorful mugs, plates or teapots that can be created with the byproducts. That's unless you are a member of Stream Restoration, working to use these byproducts, like manganese and iron, to create beautiful works of pottery.

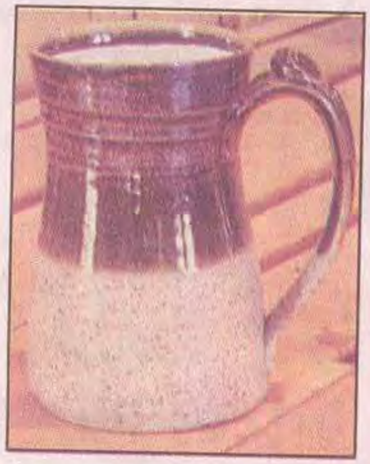
"The interest in the pottery keeps growing," said Margaret Dunn, a member of SRI. "We're right at the very, very beginning (of this effort), and from dollar one, we're going to put the money back into the operation and maintenance (of SRI)."

For more than 10 years now, Stream Restoration and the Slippery Rock Watershed Coalition have helped to restore streams ruined by drainage from abandoned coal mines, Dunn said.

These streams have no wildlife due to the level of acid and metals that eventually coat the bottoms of streams, Dunn said. After installing systems that use limestone or compost, metals can be removed from the streams.

"Fifteen systems have been installed that treat almost 1 billion gallons of abandoned mine drainage annually with fish habitat being restored in over 11 miles of streams that were essentially dead, in some cases, for more than a century," Dunn said.

These systems are mainly in the Slippery Rock, Boyers and Eau Claire areas of Butler County, Dunn said.



Glazes made from recycled manganese and iron taken from restored streams in northern Butler County are used to create colorful works of pottery.

"About three years ago, Pam Esch, a member of SRI who is a ceramic artist, remarked that the manganese compound used as a colorant in certain glazes looked very similar to what was accumulating in some of the restoration systems," Dunn said.

After testing, the material was determined to be safe for use and similar to the commercial colorant, she said. The material was used instead of imported manganese and found to be useful and more desirable to those involved.

Bob Isenberg, a potter who works at the Pottery Dome in Grove City, said the colors created by the byproduct materials are more interesting than commercial glazes he's used in the past. He agreed to make pottery for SRI and has received orders from other businesses since.

Isenberg makes four different glazes from the materials he receives, including one from manganese, two from iron and one that combines both of those byproducts. The natural, recycled "green materials," come in a rocky form, but can be ground up to create the glazes, he said.

JACK NEELY/BUTLER EAGLE

Bob Isenberg, a potter who works at the Pottery Dome in Grove City, dips a piece of his pottery in glaze made from manganese extracted from local streams during restoration.

"The color of the glaze depends on how much iron is in it," he said.

Glaze colors range from a light, glassy green color to a dark brown spotted tone.

"Before, we mixed glazes with store-bought chemicals, but I think these are more interesting," he said. "We had no idea. We thought they'd be really weak colors but they came out really nicely."

After seeing examples of the pottery glazes last spring, Bob McCafferty of North Country Brewing Co. placed an order for 300 mugs. A store called Kitchen Kaboodle in State College recently placed an order for a variety of items, including beer and coffee mugs, teapots, bowls and vases.

The work keeps Isenberg busy during the slower months of business at the Pottery Dome, like the winter months following Christmas, he said. Isenberg also has a standing order for SRI to create more pottery for them to sell at places like Jennings Environmental Education Center. He plans to travel to the Pittsburgh Ceramics Conference in March to show other potters what he's doing with the byproducts.

The glazes may eventually be used by brickmakers and other businesses who need the materials, Isenberg said.

For more information on the restoration efforts, visit www.streamrestorationinc.org.

The Butler Eagle 02/04/2008

The Eagle (Slippery Rock) 02/01/2008

PERFECT PIGMENT

JACK NEELEY/BUTLER EAGLE

Bob Isenberg dips a piece of his pottery in glaze made from manganese extracted from local streams. Isenberg, a potter at Pottery Dome in Grove City, makes pottery for Stream Restoration, which makes pottery glazes from material removed from creek beds.

Potters find stream residue quite colorful

By **KRIS MILLER**
Eagle Staff Writer

GROVE CITY — When stream restoration is mentioned, people usually picture something unsightly being removed from creek beds so the water can run clear.

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"The interest in the pottery keeps growing," said Margaret Dunn, member of SRI. "We're right at the very, very beginning (of this effort), and from dollar one, we're going to put the money back into the operation and maintenance (of SRI's stream restoration work)."

For more than 10 years now, Stream Restoration and the Slippery Rock Watershed Coalition have helped to

■ See **Pottery** on **Page 2**

SUBMITTED PHOTO

These candleholders were made using a material collected by Stream Restoration as a byproduct of its environmental work on creeks.

Pottery

■ **From Page 1**

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For more information on the restoration efforts, visit streamrestorationinc.org.

WHERE COMMERCE & CULTURE MEET

PITTSBURGH *Quarterly*

FALL 2007

River comes clean

Process produces glaze for local pub's beer mugs

written by **BETTE MCDEVITT**

KYLE DURRETT, A GEOLOGY MAJOR AT SLIPPERY ROCK University, likes to drop in to the North Country Brewery on Slippery Rock's Main Street. A cold brew after a day doing stream reclamation would seem about right.

Slippery Rock was once the heart of coal country, and Durrett works with the Slippery Rock Watershed Coalition to restore Slippery Rock Creek, damaged by acid mine drainage.

It was at the Brewery that he got the idea to put one and three together, one mineral and three sets of people to make a winning combination.

The mineral is manganese, one of the byproducts of the process used to clean the waters. The crumbly, black material is also useful as a pottery glaze, and pub owner Bob McCafferty needed beer mugs. McCafferty has a place in his heart for conservation, and when Durrett presented the idea of using mugs with the recovered manganese as a glaze, McCafferty was intrigued.

Durrett went over the river and through the woods to the Pottery Dome, on the Leesburg-Mercer Road, and presented the idea to potter Bob Isenberg. He liked it. McCafferty ordered 300 of Isenberg's mugs, each in a different color and shape, to be sold to pub customers, who would keep them on a shelf at the Brewery in the "Mug Club."

The Watershed Coalition receives 5 percent of the profits from mug sales to further its colossal work. Since 2000, a passive filter treatment system in a privately owned pasture in Butler County has neutralized 73,000 pounds of acidity and removed about 18,000 pounds of iron, aluminum and manganese from creek water a year. One of 15 sites operated by the coalition, the system uses no electricity and requires only minor maintenance.

Geologist Margaret Dunn, a coalition volunteer, explained the simple system. At the highest point of the site, murky, orange acid mine drainage had been flowing into a stream which ultimately joins Slippery Rock Creek. The Coalition diverted the stream into a series of pools. In the first two pools, water flows over a foot of mushroom compost and three feet of limestone. "This water is as acid as vinegar, and we give it something like a dose of Tums," Dunn said. The filters reduce the acid and remove the iron. The water then flows into another pool, where it becomes an unhealthy shade of turquoise, giving off gooey aluminum.

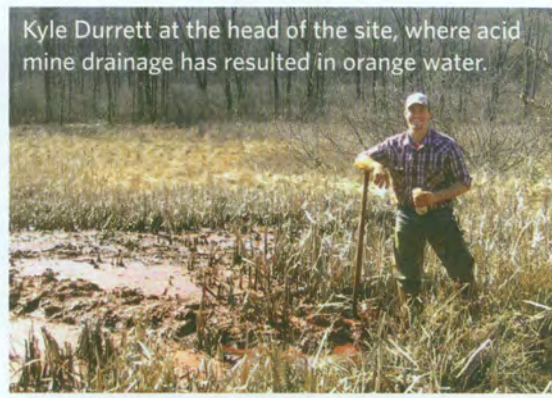
The water moves through pipes to another pond, a sort of wetland, where muskrats have made a home. Like canaries in a mine, if it weren't habitable, the muskrats wouldn't be there. Willow plants rooted along the edge stabilize the banks and further clean the water, which moves over a spillway, dropping out the manganese. Clean water then gushes out from a pipe and is diverted back into the stream.

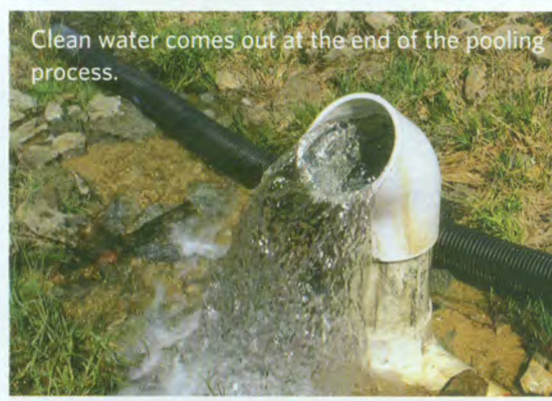
The group doesn't lay blame. "Because of the legacy of steel making and mining," Dunn said, "resources that were valuable in winning the war benefited all of us. Mine drainage impacts 4,000 miles of streams in Pennsylvania, one of the largest legacies in the country associated with abandoned mines." And mining companies have become allies, providing heavy equipment and funding.

It's been one of the most rewarding experiences of Dunn's life. With wide community support, they've cleaned 11 miles of the Slippery Rock Creek. "One day, an older man came walking across a field in my direction. You think, 'uh huh; he's heading for me with a complaint.' Instead he told me he wanted to thank me for all the work we do to clean the streams." We can all be grateful, since we all live downstream. PQ

Learn more at the coalition Web site: www.streamrestorationinc.org.

Bette McDevitt is a writer living in Deutschtown on Pittsburgh's North Side.


Kyle Durrett at the head of the site, where acid mine drainage has resulted in orange water.


Clean water comes out at the end of the pooling process.


The last to filter out of the water is manganese.

PA Environment Digest

An Update on Environmental Issues in Pennsylvania

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08/01/08 - Old Fashioned Groundbreaking for Quecreek Mine Rescue Visitors Center. See 8/4/08 Digest for Video Blog Feature

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Passive Treatment Systems in Slippery Rock Watershed Yield Black Glaze

Fifteen passive treatment system have been constructed in the Slippery Rock Creek Watershed to combat the effects of approximately 30 abandoned mine discharges that degrade the stream.

These passive treatment systems remove dissolved metals from the water using natural materials such as limestone and compost. The metals form solids that are collected in the system.

The sooty black mineral formed within the limestone beds of some passive treatment systems is called todorokite, which contains about 50 percent manganese. Particpants in the Slippery Rock Watershed Coalition are in the process of developing methods to recover this manganese ore.

Manganese, in the form of the materials collected from the mine drainage, is commonly used as a colorant in different glazes for pottery. When local potter Robert Isenberg of The Pottery Dome in Mercer, PA was approached by Slippery Rock Watershed Coalition participant Kyle Durrett with the concept of using some of the recovered manganese in his pottery glazes, he was immediately interested.

Isenberg feels that making good use of the recovered manganese is a worthwhile endeavor. The largest request for this new glaze has come from the North Country Brewing Company located in downtown Slippery Rock, PA to make mugs for its annual “Mug Club” event.

The North Country Brewing Company has a yearly “Mug Club” where patrons can purchase one of 300 handmade mugs that they can use as their own personal mug that resides at the brewery. Each mug holds slightly more than one pint and is unlike any other mug in size, shape and glaze.

North County Brewing supports many local grassroots organizations and is graciously donating 5 percent of the profits from sales of the new mugs to the Slippery Rock Watershed Coalition to benefit long-term maintenance on the passive treatment systems in the watershed. These highly anticipated new mugs will be available soon. They are sure to go fast so don’t wait until they are gone!

The Slippery Rock Watershed Coalition would like to thank North Country Brewing for the generous support and The Pottery Dome and

Robert Isenberg for helping to promote this truly green technology. *(reprinted from The Catalyst, April 2007)*

4/27/2007

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July 2008

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

<u>THIS MONTH'S MEETING:</u> Thursday 7/10/08 at 7 pm at Jennings Environmental Education Center, pizza and pop provided. 6/12/08 meeting attendance: C. Cooper, M. Dunn, D. Johnson, J. Winter

!!!!<u>Please note the August 2008 meeting will be canceled due to the PA AMR Conference</u>!!!!

<u>ARRI In the News…</u>

There's more!!!! For those of you interested in learning more about the partnering effort with the **U.S. Department of the Interior Office of Surface Mining, Jennings Environmental Education Center, Quality Aggregates Inc.,** and the rest of us to implement a scale model of a new approach to re-establish productive hardwood forests at mine sites, here are some additional news items. These articles describing the **"Appalachian Regional Reforestation Initiative" (ARRI)** have since been published and are helping spread the news about the ARRI project and its value to the education and research program at Jennings.

An image from the past: a giant American chestnut tree towers over those posing for the photo before the turn of the century.

The **Butler Eagle** newspaper printed an excellent article entitled "New Reforestation Technique is Tested at Jennings Center" on May 16. The weekly **PA Environment Digest** also published an article "Spotlight—Jennings EE Center Demonstrates New Approach to Hardwood Reforestation" on May 2, which is online at **<u>www.paenvironmentdigest.com/newsletter/</u>**. In addition to a news clip, "Reforestation Practice on Display", **Andy McAllister**, Watershed Coordinator at the **Western Pennsylvania Coalition for Abandoned Mine Drainage (WPCAMR)** has a wonderful video (even includes music!!!) on WPCAMR'S May 5th Video Diaries recording the event at Jennings. The news clip and video can be viewed at **<u>www.amp.wpcamr.org/archives/185</u>**. To our delight, there was even an article focusing on the educational opportunities in the **US Office of Surface Mining June ARRI newsletter** entitled "Pennsylvania Arbor Day Event Educates School Children" by **Dave Hamilton,** OSM**!!!**

Thanks much to everyone who contributed to these wonderful articles as word spreads locally and nationally about this brand-new, exciting method of hardwood reforestation! For those who are interested in ARRI, there is an up-coming conference entitled "Mined Land Reforestation" to be held in Logan, West Virginia, August 5-7 at the Chief Logan Lodge Hotel and Conference Center. Visit the ARRI web site to learn more: **<u>http://arri.osmre.gov/</u>**

Please make a note! <u>We have a new address!</u> We have relocated to Mars! No, your mail won't need to travel via rocketship to reach us! We literally outgrew our previous office (which we will miss) in Cranberry, PA and moved about 10 miles east — to Mars, PA. We have a spacious commercial-zoned-house with outbuildings on 3.5 acres (so now we have to mow!). All contact information stays the same, except for the new mailing address. Send correspondence for the Slippery Rock Watershed Coalition, SRI, and BioMost, Inc. to

434 Spring Street Ext.
Mars, PA 16046

PHOTO OF THE MONTH

Before last month's SRWC meeting, **Charlie Cooper** spent his time "keeping our highways clean"!!! Charlie says he has a "one-of-a-kind" technique and likes to perform this much appreciated volunteer effort by himself!!! Thank you, thank you for taking care of the I-79 roadside around mile marker 100!!!

PHOTO OF THE MONTH

New Intern Gets Down and Dirty

My name is Kelly Wacker and I am the new intern here at Stream Restoration Incorporated. I am a senior at the University of Pittsburgh and I am working towards a bachelor's degree in Environmental Studies. I am a native of the city of Pittsburgh and have lived there all of my life, although I do like to travel and have been fortunate enough to see some wonderful places in the world. At the age of 20 I traveled to the country of Tanzania in eastern sub-Saharan Africa to do environmental volunteer work, including planting trees on the majestic Mount Kilimanjaro. That experience forever changed my life and heavily influenced my decision to pursue a degree in Environmental Studies.

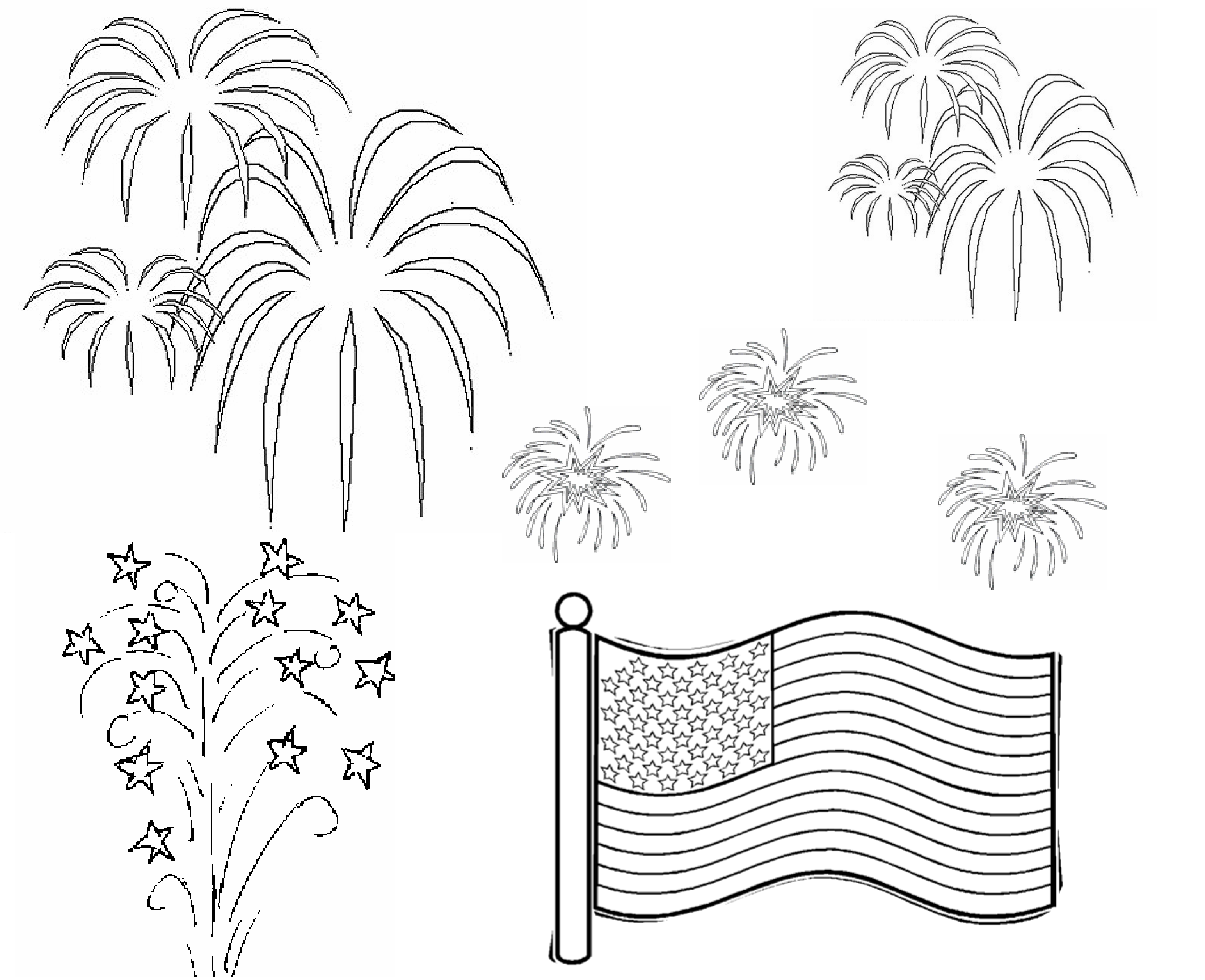
This summer while working with Stream Restoration Inc., I am very eager to soak up as much experience as I am able to. I am particularly interested in learning about the ins and outs of active and passive treatment systems for degraded waterways. I am also equally excited to get my hands dirty and help make an impact in improving the quality of some of our region's natural beauty as well as helping to ensure its longevity, and overall making the earth a little bit greener!

The KIDS Catalyst

SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY

The Science Behind Fireworks

It is believed that a cook in China accidentally created the first fireworks in the kitchen by lighting a mixture of three basic kitchen ingredients of the time - sulphur, charcoal and salt petre. The basic ingredients in fireworks in general have never really changed; they are still made of a source of fuel and an oxidizer. The purpose of the fuel is to provide heat, and the oxidizer provides more oxygen than the atmospheric air can supply, to speed up the burning process. To slow down the burning in order to give the audience a great visual effect, chemists use big grains of chemicals (the size of a small grain of sand) and they don't blend the ingredients of the "black powder" together very well. That makes it harder for the fuel and oxidizer to combine and burn, and produces a longer and brighter effect. The different colorant chemicals in fireworks each emit light at a specific wavelength, producing different colors: the element strontium produces red, copper produces blue, barium makes green, sodium makes yellow and orange. Colors can also be mixed; strontium (red) plus copper (blue) equals purple. Have a fun Independence Day and enjoy the fireworks you might see this 4th of July and throughout the summer! Color the fireworks page below and send it to us for a free gift certificate!



Name ________________________ Age _____ Address ______________________________________

Slippery Rock Watershed Coalition c/o Stream Restoration Incorporated
A PA Non-Profit Organization
434 Spring Street Ext.
Mars, PA 16046

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Thanks to The William & Frances Aloe Charitable Foundation, Environmentally Innovative Solutions, LLC, Dominion Peoples, Amerikohl Mining, Inc., Quality Aggregates Inc., Drs. Ron & Kathy Falk Family, BioMost, Inc., Allegheny Mineral Corporation and PA DEP for their support. For more information contact: Slippery Rock Watershed Coalition, c/o Stream Restoration Incorporated (PA non-profit), 434 Spring Street Ext., Mars, PA 16046 (724)776-0161, fax (724)776-0166, sri@streamrestorationinc.org, www.srwc.org. July distribution: 1355 copies

“The Point North Magazine” *Points* to the SRWC, Clean Creek Products

The April and June issues of “The Point North” magazine both featured articles connected to the SRWC and SRI. **Cliff Denholm**, of SRI and an SRWC participant, contributed the article **“Pottery: Helping the Environment? Are You Kidding!?”** This article was featured in the April issue and described the problem of AMD in PA and the efforts of the SRWC and SRI to clean the drainage using passive treatment systems. The pottery connection? Cliff explained how the thousands of pounds of metals removed from the water are being used in pottery glazes (other potential uses under consideration). The iron oxides (that precipitate under acidic conditions) and the manganese oxides (that precipitate under more alkaline conditions) are being used by ceramic artists to produce various colors and effects in their pottery glazes. As interest is growing, SRI created a new division, called “Clean Creek Products” and developed a website **www.cleancreek.org** in order to provide those interested an opportunity to purchase these unique items. **(A portion of all proceeds are donated to restoration efforts by watershed groups and volunteers!!!)**

For the June “Point North” publication, the article was entitled **“Making a Difference: A Fishy Epiphany”.** The article describes how the SRWC’s restoration efforts in the town of Erico, Butler County does indeed matter. Cliff mentions how in 1908 there were a reported 25 coal companies at work in Butler County, which employed 2000 men who produced 865,000 tons of coal a year. After closing the mines at Erico (named for the Erie Coal Mining Company), hundreds of gallons a minute of orange water left the mine and entered Seaton Creek—every minute of every hour of every day for **more than 70 years**! The resulting refuse pile and polluted stream were **cleaned up in 2 (!!!) years’** time by the partnership efforts of the landowners, community, a mining company, a private foundation, youth groups, and local, county, and state agencies. And, when Cliff was rewarded with the sight of a small school of fish swimming in Seaton Creek, which had been devoid of life for so long, he knew his work made, and continues to make, a difference! **Many thanks to “The Point North” magazine for caring!!!!!!! Check the current issue out at www.thepointnorth.com.**

Remember the Riverboat Cruise!

Registration will soon be up and running for the **7th Annual Ohio River Watershed Celebration**! As this fun, exciting, educational, (and free!!) event continues to grow in popularity, we will have two boats this year with one dedicated to youth education. So mark your calendars and be sure to register for the **Thursday, September 25th** event. You may contact us by phone at 724-776-0150 or register online at **www.streamrestorationinc.org/rsvp.**

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

<u>THIS MONTH'S MEETING:</u> Thursday 4/10/08 at 7 pm at Jennings Environmental Education Center, pizza and pop provided. 3/13/08 meeting attendance: C. Cooper, C. Denholm, K. Durrett, T. Grote, D. Johnson, V. Kefeli, J. McDowell, S. Smith

Margaret's Making News!

Margaret Dunn of Stream Restoration Inc. and a participant in the SRWC was honored on 1/26/08 in the **Pittsburgh Tribune-Review**. Below is a reprint of the "Newsmaker" column. **Thank you Bobby Kerlik!!!!**

NEWSMAKER

Margaret H. Dunn

Age: 59
Family: Husband, Mike
Residence: New Sewickley, Beaver County
Education: Master's degree in geology, Virginia Tech; bachelor's degree in geology, Florida State University
Occupation: Dunn is the founder and president of Cranberry-based Stream Restoration Inc., a nonprofit dedicated to working to restore watersheds. She also works for BioMost Inc., a Cranberry-based company dedicated to treating drainage problems at abandoned mines.
Noteworthy: Dunn recently was awarded the Conservation Educator of the Year Award by the Butler County Conservation District for her work and approach to education.
Quote: "It's the most meaningful and rewarding time of my life. It's not just a job. I feel like I'm doing something. In Pennsylvania, 4,000 miles of streams are impacted by abandoned mines, and it's very devastating in some areas."

— Bobby Kerlik

Creativity Abounds at the NCECA Conference

Stream Restoration Inc. branched out into the world of ceramics at the **42nd Annual National Council on Education for the Ceramic Arts** held at the David L. Lawrence Convention Center in Pittsburgh. Over 4000 attended this exciting and interesting conference. The positive response to **Clean Creek Products** *(See article on page 2.)*, a division of Stream Restoration Inc., was overwhelming!!!! We can't thank **Jane Nugent, "Garden Talk", WPTT 1360 AM** enough for taking time to be with us in support of the watershed clean up efforts!!! As many potters are avid gardeners, Jane was able to provide tips to many international visitors!!!! *(See Photo of the Month on page 2.)* **Tom Grote, Tim Danehy, Shaun Busler, Cliff Denholm, and Margaret Dunn** were on hand to showcase the manganese and iron oxides recovered from acidic mine drainage during passive treatment. CCP is acquainting various industries to these "green" materials.

And of course, the exhibit wouldn't have been possible without the FABULOUS POTTERY, with glazes containing the recovered material, by **Bob Isenberg (Pottery Dome, Mercer, PA); Pam Esch, Sarah Clague, and Carl Morrison (MEC-Clay Studios, Cleveland, OH); and Paul Jay (Little Creek Fine Arts, Harmony, PA)!!**

With **Lois Hamilton,** owner of the Pottery Dome, and **Pam Esch**, answering in-depth questions about glazes and pottery, about a thousand (!!!!) or more people expressed interest in using the materials and encouragement in continuing recovery efforts and the environmentally-friendly treatment of abandoned mine drainage!!!! The supply of the 900 sample packets was depleted before noon on Friday!!!!!!

The NCECA conference, which ran from March 19-22 with the theme "Confluence: Innovation, Community, Environment", was attended by student and professional potters from all over the world! There were many interesting presentations and demonstrations. Exhibitors included companies selling ceramic supplies, pottery tools, and glazes; art departments from colleges and universities; ceramic and art-related magazines; and much more.

Standard Ceramic Supply Company hosted a post-convention reception at their headquarters in Carnegie, PA. All buildings were open for art exhibits and Tom, Pam, Margaret, Tim, Shaun, and Cliff were thankful for the invitation and enjoyed the tour of the facilities (as well as the delicious food and beverages after a long day at the conference!)

The purpose of NCECA is to promote and improve the ceramic arts through education, research, and creative practice. NCECA members include artists, educators, students, patrons, retailers, and manufacturers. Visit their web site **<u>www.nceca.net</u>** to learn more! The NCECA conference was a great experience, and the representatives of Clean Creek Products were thrilled to meet so many people in the ceramic field and to learn about the variety in the world of ceramic arts!

PHOTO OF THE MONTH

Helping at the CCP display at the NCECA conference (left to right): Pam Esch (MEC-Clay Studios), Jane Nugent (WPTT radio personality), Margaret Dunn (SRI), Tom Grote (SRI), Bob Isenberg (Pottery Dome), and Betty McDevitt (Pottery Dome).

PHOTO OF THE MONTH

Introducing Clean Creek Products

Since 1995, participants of the Slippery Rock Watershed Coalition and Stream Restoration Inc. (SRI) have installed 15 passive treatment systems which treat over 750 million gallons of abandoned mine drainage every year! Slippery Rock Creek is free of 190 tons/year of acidity, 8 tons/year of aluminum, and 150 tons/year of iron. Until recently, there was no definitive answer to the question of what to do with the large amounts of byproducts retained in the treatment systems.

SRI found a use by accident... **Pam Esch**, a potter and lifelong friend of Margaret Dunn, saw a pile of “black dirt” in a pipe cap in the office of SRI that was cleaned from one of the effluent pipes of a Horizontal Flow Limestone Bed. She surprised everyone in the office when she recognized that this “black dirt” was manganese. As a potter she purchased manganese from commercial suppliers for use in her glazes. She took a portion of the manganese back to her studio and tried using it. She loved it!!! She has since used manganese and iron oxide from passive treatment systems in the Slippery Rock Creek watershed on many pieces of pottery.

SRI is excited to announce the formation of **Clean Creek Products (CCP)**, a division of SRI focused on marketing the metals recovered in treating abandoned mine drainage (AMD). CCP is promoting these metals as raw “green” materials to many industries.

A new e-commerce website, **www.cleancreek.org**, is now available to purchase pottery online. There are beautiful vases and containers, tableware, mugs, serving dishes, and more available for purchase right now. Each piece is locally made and hand thrown using the recycled material as a colorant. A variety of styles and glaze patterns will continue to be added to the website as they are created.

We are very excited about the potential of CCP to creatively and effectively use literally tons of iron oxide and manganese oxide leftover from treating AMD! Thank you to everyone who helped see CCP through from conception to fruition!

Your purchase will help the environment!! CCP donates a portion of all proceeds to help local watershed groups keep their streams clean!!!!! Please see the unique pottery available on the CCP website **www.cleancreek.org.** Consider making a purchase and doing your part to support “green technology!”

The KIDS Catalyst

SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY

The 3 R's: Reduce, Reuse, Recycle!

Do you know your 3 R's? *Reduce, reuse, recycle*! These 3 words give us all 3 important things we can do to help keep our environment clean. Recycle means to process old, used items in order that the material can be used to make new products. Examples of things that are often recycled are glass, plastic, newspapers, aluminum cans, used motor oil, and batteries. Reduce refers to lessening the amount of items or resources that are consumed, using only the amount that is needed, and looking for alternatives that will lessen our use. An example is using less water by taking a shorter shower. And reuse means extending the 'life' or repurposing an item rather than discarding or throwing it away. Examples include putting kitchen waste like eggshells and banana peels in a compost bin, and using plastic lids from coffee cans as coasters or for under plants to protect tabletops. Now that you have learned your 3 R's, it's time to find the R's hidden in the picture below! There are 3 letter R's hidden in the picture. Circle the R's and color the picture. If you send us your completed paper, we will mail you a free gift certificate! Don't forget to try doing the 3 R's around your house!

Name ________________________________ Age ________

Address ____

Slippery Rock Watershed Coalition c/o Stream Restoration Incorporated
A PA Non-Profit Organization
3016 Unionville Road
Cranberry Twp., PA 16066

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WINTER AVIAN PROGRAMS OFFERED AT JENNINGS

Jennings Environmental Education Center provided two public programs this winter dedicated to the lives of our avian fauna and the roles they play in our local environment. On Saturday, February 16, a program was presented on the national **Great Backyard Bird Count**. This activity is a citizen scientist project, sponsored by the **Cornell Lab of Ornithology** and the **National Audubon Society**, which recruits the public to dedicate one weekend of counting the birds they observe at their feeders. This information is entered on Cornell's web site, where it will be used to monitor the winter locations of the birds of North America. The Jennings event featured natural history information, identification and feeding tips, as well as instructions on how to correctly gather and enter the information into the online database. There were 20 participants in attendance, and **Kathy Setzer** of the **Birdwatcher's Store** along with members of the **Bartramian Audubon Society** provided resources for further involvement in the hobby.

Jennings' annual bluebird program was quite a "**Fledging Experience**", bringing out a crowd of *150 people*! **Harry Schmeider**, "the Ambassador for the Bluebirds", shared his passion for the feathered creatures at Jennings on Sunday, February 24. As a citizen scientist Harry maintains several bluebird trails and keeps specific data and pictures of each box. He uses this information to teach others the importance of bluebirds and the struggles the birds must overcome. He shared habitat and food preferences, bird box placement tips and information regarding the species that are a threat to the bluebirds' numbers. Each visitor had a chance to join the Bluebird Society of Pennsylvania and received a bluebird box while supplies lasted. As a result the society gladly accepted close to 30 new members!

Contributed by:

The eastern bluebird is pictured at left and right. These birds are an important predator on destructive insects such as grasshoppers, caterpillars, crickets, katydids, and beetles. Their diet also consists of various berries, spiders, sow bugs, earthworms, and snails.

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

THIS MONTH'S MEETING: Thursday 3/13/08 at 7 pm at Jennings Environmental Education Center, pizza and pop provided. 2/14/08 meeting attendance: E. Best, S. Busler, C. Cooper, C. Denholm, M. Dunn, T. Grote, D. Johnson, G. Kefeli, V. Kefeli, C. Leininger, S. Mastalski, B. Rihn, J. Schwarz, K. Schwarz, S. Smith, W. Taylor, S. VanDerWal

SRU Students "Love" their MS3 Program!

On Valentine's Day, 3 students from the **MS3 program** at **Slippery Rock University** presented research findings on "The Sustainability and Regeneration of Ecological Systems in Western Pennsylvania, USA" at the monthly meeting of the SRWC. Students **Katie Schwarz**, **Beth Rihn**, and **Shari Mastalski** have been working under the supervision of MS3 instructor **Chris Leininger**, as a legacy of research and efforts continues. Chris (pictured at left) graduated from the MS3 program in the 1990s, is on the SRU faculty, and works as a home designer/builder, designing straw-bale houses. He has a firm grasp on the 150-year-old technique of building walls from hay, having already built several structures, one as part of his thesis for his master's degree in the MS3 Program.

The Masters of Science in Sustainable Systems (MS3) Program at Slippery Rock University was established in 1990 to prepare students to face the pressing environmental challenges of the future by focusing on sustainability. Students study and practice sustainability through the integration of agriculture, natural resource management and the built environment with particular emphasis on the design and management of productive systems that reflect the diversity and resilience of natural systems. The program embraces the human element in the landscape, searching for sustainable ways to satisfy food, energy, shelter and other material and non-material human needs. These academic courses include exercises in creative design and problem solving, laboratory and field experiences, and non-curricular opportunities for learning and practicing sustainability through the **Robert A. Macoskey Center**, the surrounding community, internships, and other campus-related projects.

Each student presenter built on the previous information shared by the others, representative of their method of sharing and teamwork in their research work. Beginning the February 14 presentation was Katie, who was also the first student involved in the project. She was followed by Beth, who was then followed by Shari, the newest student on the research team, having only been working on the project for a couple of weeks. The students' sustainability project centered around transplanting willow plants from **Jennings Environmental Education Center** (JEEC) to passive treatment system site DeSale Phase II, in Venango Twp. Katie began the work using 4-5 year old willow trees, which resembled shrubs. After cutting these willows down she was left with their stumps. These stumps were transplanted to the DeSale site to provide another location to harvest willow cuttings and create habitat and structure at the passive treatment system. Beth continued the work as she then took willow branches from the cuttings, rooted some of them, and planted several at JEEC. The students were interested in seeing where the roots came from. After cutting slices of the bark and pulling it up, it was revealed that the roots originated in the cambium region. The students were also excited with the remarkably good survival rate of 80% of the willows! The SRWC is grateful to the SRU students for sharing their research work and looks forward to more interesting studies in the MS3 Program.

Closing remarks were made by SRWC soil scientist **Dr. Valentin Kefeli** (pictured at right), who worked on an interesting aspect of this research project. Valentin believes the willow cuttings act as a chemical buffer against the chestnut blight. So far, nearly all of these chestnuts have survived. Also of note is that Valentin is doing his plantings on a fabricated soil made of a mixture of topsoil and pond fines (fine particles of clay and limestone resulting from the processing of limestone aggregate). Chestnut blight is a fungal disease accidentally introduced to North America around 1900, which has virtually eliminated the once widespread American chestnut tree. Research is ongoing across the country by many individuals and organizations to overcome this disease and re-introduce the American chestnut back into its native land. How exciting to have a chestnut blight research project going on in the Slippery Rock Watershed!

P H O T O   O F   T H E   M O N T H

Part of the partnership effort that has made Clean Creek Products possible include (Left to Right): Betty McDevitt, Ray Nelson, Lois Hamilton, Margaret Dunn, Bob Isenberg, and Cliff Denholm. Look for more information about Clean Creek Products in future issues.

P H O T O   O F   T H E   M O N T H

Boscov's Green Day

Boscov's Department Store invited the **Slippery Rock Watershed Coalition** to have a display at their January 19th **Green Day** event. **Margaret Dunn** and **Tom Grote** represented the SRWC with a poster display near the inner mall entrance of Boscov's at Clearview Mall on Route 8 in Butler. The event took place to highlight environmental efforts in the area. Many local organizations took part in the festivities, which included playing environmental-themed movies in the Boscov's auditorium. Margaret and Tom enjoyed the chance to share educational information on the SRWC's mission and accomplishments with the Saturday shoppers, including information on public/private partnerships and the use of passive treatment systems. They also used the opportunity to showcase the SRWC's **Clean Creek Pottery** endeavor. **Clean Creek Products** (CCP), a division of Stream Restoration Incorporated, has been formed to market the metals recovered in treating abandoned coal mine drainage. Business was good at the Green Day event, as Margaret and Tom sold several pieces of Clean Creek Pottery, including serving bowls, mugs, and other unique pieces. Clean Creek Pottery gets its unique coloring from the iron and manganese pigments taken from the recovered metal precipitates from the SRWC's passive treatment systems. A portion of all proceeds from CCP purchases will be donated to the efforts of the SRWC and other local watershed groups to help keep local streams clean. Look for more information about CCP in the next few months, as the SRWC is looking forward to attending the 42nd Annual Conference of the National Council on Education for the Ceramic Arts at the David L. Lawrence Convention Center in Pittsburgh, March 19-22.

Excellent Experience at the Expomart: Thanks to Jane Nugent!!!

Jane Nugent, host of **"Garden Talk" 1360-AM WPTT**, generously invited the SRWC to share a booth at the **2008 Indoor/Outdoor Home and Garden Show** held at the Monroeville Expomart on January 24-27. It was "master gardener" and "master reclamationist" teaming up, as Margaret Dunn was there representing the SRWC. Besides giving demonstrations on the latest gardening tips and "tried-and-true" approaches, Jane met many of her loyal listeners and addressed their specific home gardening issues. As always when working with Jane, this was a non-stop, "high energy" event. The opportunity to share in the excitement and to talk to people about watersheds and the tireless work of grassroots organizations was very much appreciated. (200 of the SRWC educational flyers were quickly depleted!!!!) Jane Nugent has been a regular participant and sponsor of the **Ohio River Watershed Celebration** and has encouraged the efforts of watershed groups throughout western Pennsylvania. "Garden Talk" can be heard live on **1360 AM, WPTT Radio Saturday afternoons from 1:30 pm to 3:00 pm.** The Home and Garden Show provided the perfect platform for the two talkative ladies, as Jane loves to talk gardening in the 21st century and Margaret loves to restore streams in the 21st century! **Thank you Jane for providing this wonderful opportunity!!!**

The KIDS Catalyst

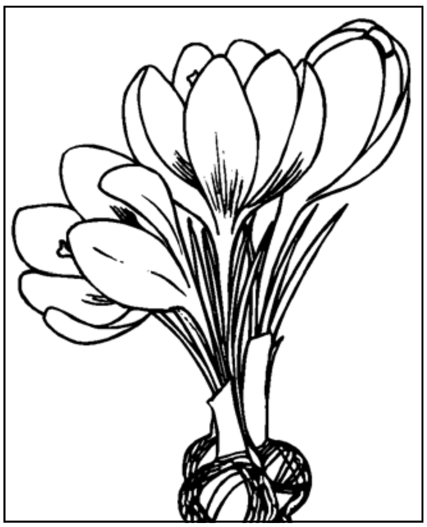
SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY

The Colors of Spring

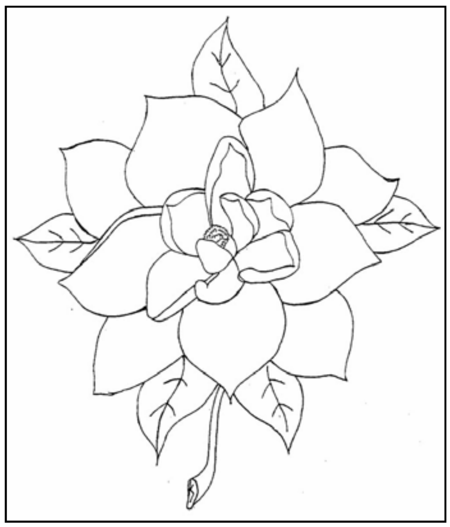
Spring is almost here! March 20 is the first day of spring, and soon the flowers will be blooming with beautiful colors and sweet scents! We have 6 flowers below for you to color— you may notice some of these growing in your yard, neighborhood, park, etc.! Use the numbered key of colors to color the flowers accurately. Some of these 6 flowers can typically be found in different colors, but we chose the more common colors to help you spot them in nature. Have fun coloring, and enjoy spring! If you mail us your completed picture, we will send you a free gift certificate!

1 = yellow 2 = purple 3 = white 4 = orange 5 = red

Crocus (2)



Magnolia (3)



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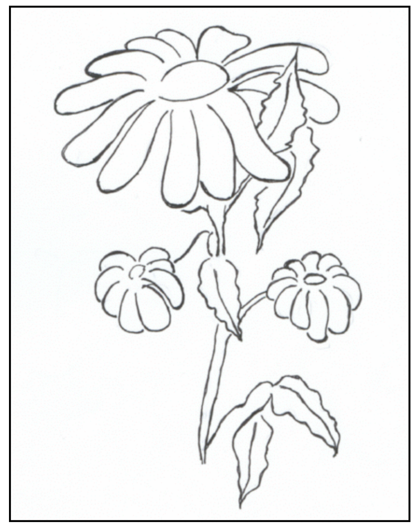

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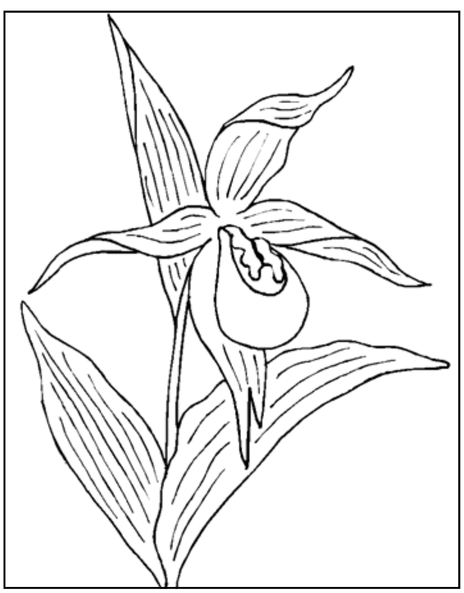
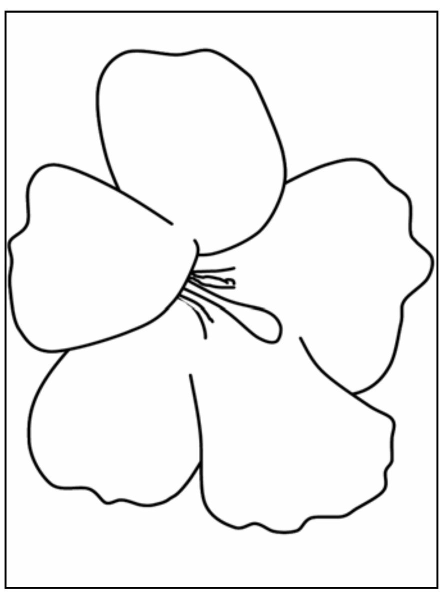
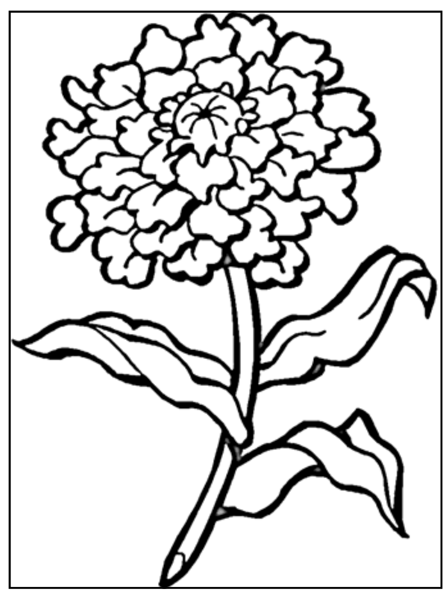


Hibiscus (5)



Marigold (4)



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3016 Unionville Road
Cranberry Twp., PA 16066

Thanks to The William & Frances Aloe Charitable Foundation, Environmentally Innovative Solutions, LLC, Dominion Peoples, Amerikohl Mining, Inc., Quality Aggregates Inc., Drs. Ron & Kathy Falk Family, BioMost, Inc., Allegheny Mineral Corporation and PA DEP for their support. For more information contact: Slippery Rock Watershed Coalition, c/o Stream Restoration Incorporated (PA non-profit), 3016 Unionville Road, Cranberry Twp., PA 16066, (724)776-0161, fax (724)776-0166, sri@streamrestorationinc.org, www.srwc.org. March. distribution: 1349

ARRI is Making a Difference: Trees for Appalachia's Future

Jennings Environmental Education Center, working in conjunction with the **Office of Surface Mining (OSM)**, **Quality Aggregates**, and the **Slippery Rock Watershed Coalition**, is pleased to announce an upcoming event demonstrating ARRI on **Friday, April 25**, to be held at JEEC. The **Appalachian Regional Reforestation Initiative (ARRI)** is a coalition of groups, including citizens, the coal industry, and government, dedicated to restoring forests on coal mined lands in the Eastern United States. ARRI was established in early 2004 as an initiative of the Office of Surface Mining. This initiative is important for several reasons, including (1) Economically: High quality timber can offer substantial revenue for landowners and job opportunities for local residents; (2) Environmentally: Trees minimize soil erosion, help conserve water resources, and provide wildlife habitat and diverse plant species; (3) Recreationally: Restored forests have value for hunting, hiking, mountain biking, camping, bird watching, backpacking, ATV riding, etc.

Dave Hamilton, program specialist from the **OSM Harrisburg** area office, will be on-hand at this educational April 25 event, and everyone is welcome to attend, including students. Chestnuts and other hardwoods will be planted on a small test plot at the JEEC passive treatment site and volunteers are encouraged to help plant and learn first-hand about these valuable, renewable resources! The American chestnut tree once dominated eastern forests, with 25% of the trees from Maine to Florida and west to the Ohio Valley being American chestnuts. The tree used to be known as the "Redwood of the East" – a strong, hardwood tree that provided an economic and ecological powerhouse throughout its natural range. One of the greatest ecological disasters in North America came about with the introduction of a fungus to New York from Asia in about 1900. By 1950, this pathogen had killed an estimated 3.5 billion American chestnut trees, nearly all of them in the United States.

The American Chestnut Foundation has been working for more than 25 years to develop a blight-resistant American chestnut to restore this great tree of the eastern woodlands. At breeding orchards in Virginia and at Penn State University, the foundation's scientists have taken Chinese chestnut trees, which are resistant to the blight, and bred them with their American cousins over several generations. The most recent generations of hybrids have nearly 95 percent of the American chestnut's genes, combined with the blight resistance of the Chinese chestnut. The project is producing seeds and seedlings to replant across the American landscape. An American chestnut, representing 25 years of crossbreeding science, was recently planted on the grounds of the U.S. Department of the Interior to mark in part the 30th anniversary of the signing of the Surface Mining Control and Reclamation Act (SMCRA) which has regulated mining of *29.5 billion tons* of coal!

We hope you will join us at JEEC on April 25 to share in this worthwhile event, learn more about interesting topics such as the American chestnut and passive treatment of acid mine drainage, and make a difference in the health of the Slippery Rock Watershed!

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

<u>THIS MONTH'S MEETING:</u> Thursday 2/14/08 at 7 pm at Jennings Environmental Education Center, pizza and pop provided. 1/10/08 meeting attendance: C. Cooper, C. Denholm, M. Dunn, V. Kefeli, W. Taylor

2007 Year in Review

Joining Efforts with Others to Make a Cleaner, Greener Tomorrow!

Education/Outreach Activities

- SRWC at Pittsburgh Expomart Indoor/Outdoor Home Show with Jane Nugent — 1/27-1/28
- Tour of Slippery Rock Creek Watershed passive treatment systems and reclamation projects for state DEP — 2/26
- 4th Annual Environmental Science Advisory Board Dinner and Meeting, Robert Morris University — 4/18
- SRWC Volunteer Work Day, SR114 and DeSale Phase II — 5/5
- American Water Works Association (NW Region) Presentation & Tour, Slippery Rock, PA—5/18
- Camp Lutherlyn passive treatment system maintenance — June
- SMRCA Title IV Abandoned Mine Lands Public Roundtable Meetings, Jennings Environmental Education Center — 6/5
- Harrisville Community Days, Harrisville Park — 7/4
- Institute for Learning in Retirement Workshop, Slippery Rock University — 9/17
- 6th Annual Ohio River Watershed Celebration — 9/20
- Technology Forum of the Spectroscopy Society of Pittsburgh November Meeting — 11/14
- GIS Day, Harrisburg, PA — 11/15
- Creation of SRWC Operation and Maintenance Manual
- Dr. Valentin Kefeli guest lectures at Humbolt University in Berlin, Germany
- 3rd printing of 2000 copies of "Accepting the Challenge"
- "Adopt-a-Highway" Program, clean-up effort for Interstate 79 mile markers 100-101

Recognition

- Butler County Conservation District 2007 Education Award, to Margaret Dunn, SRWC, SRI; Butler Farm-City Banquet, — 11/14

Conferences

- WV Mine Drainage Task Force Symposium, Morgantown, WV—4/10-4/11
- West Branch Susquehanna Restoration Symposium, Williamsport, PA—4/27-4/28
- 15th Annual PA GIS Conference, Camp Hill, PA — 5/16-5/17
- American Water Works Association, Northwest District, Spring Meeting, Slippery Rock University — 5/18
- 24th American Society of Mining and Reclamation National Meeting, Gillette, Wyoming — 6/2-6/6
- Northwest Regional Watershed Conference, Clarion University — 6/23
- PA Statewide Conference on Abandoned Mine Reclamation, State College — 7/20-7/21
- Conservation District Watershed Specialist Training/Meeting, State College — 10/16-10/18

Restoration Projects

- Slippery Rock Creek Watershed Assessment
- DeSale Phase II Operation & Maintenance
- Slippery Rock Creek Watershed Operation and Maintenance Plan
- Rivers Conservation Plan for Slippery Rock Creek Watershed initiated
- JEEC Vertical Flow System Maintenance

To learn more about the SRWC, why not join us at one of our monthly meetings? We meet every second Thursday of the month at 7 PM at Jennings Environmental Education Center in Slippery Rock, PA. Everyone is welcome to attend, and we'll even feed you free pizza and pop!

Slippery Rock University students in the MS3 program will be presenting their research findings at the February 14th SRWC meeting! Hope to see you there!

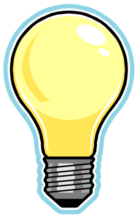
PHOTO OF THE MONTH

Jane Nugent, host of **"Garden Talk" WPTT 1360 AM** graciously shared her booth at the Indoor/Outdoor Home Show (Monroeville Expo-Mart) to highlight volunteer efforts by the orchid society, cactus society, and the SRWC. More next month...

PHOTO OF THE MONTH

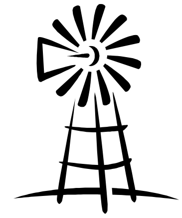
Young Catalyst Readers Show Off Their Talent

Check out the impressive artwork shown below, sent in to us by 2 of our younger Catalyst readers! Pictured at left is a cardinal resting on a tree branch, artwork created by **Madi Beining**; displayed at the right is an owl perching on a branch, a great picture made by **Sami Beining.** Thank you for sharing your talent with us! If there are other kids out there who enjoy drawing, we love to get your pictures and we encourage you to mail us your awesome creations! Who knows, maybe some day you'll see your picture here in the Catalyst, which is read by over 1,200 people in over a dozen different countries!!!



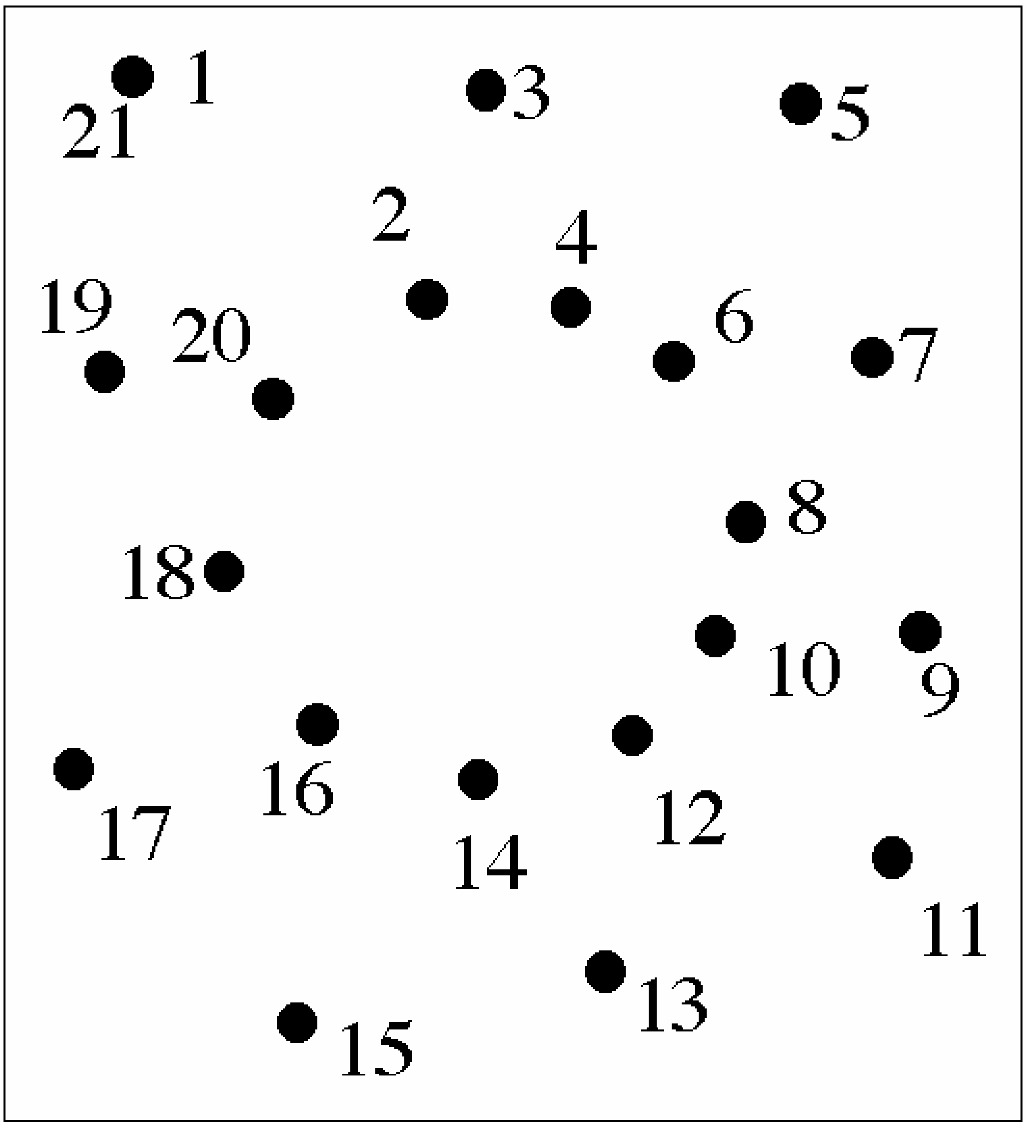
The KIDS Catalyst

SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY



Connect the Dots: All About Energy

We use energy to do work. Energy lights our cities, powers our vehicles, trains, planes, and rockets. Energy warms our houses, cooks our food, plays our music, gives us pictures on television. Energy powers machinery in factories and tractors on a farm. Energy is defined as "the ability to do work." When we eat, our bodies transform the energy stored in the food into energy to do work. When we run or walk, we "burn" food energy in our bodies. When we think or read or write, we are also doing work. Cars, planes, light bulbs, boats and machinery also transform energy into work. Work means moving something, lifting something, warming something, lighting something. All these are a few of the various types of work. There are many sources of energy, including: biomass energy (from plants), geothermal energy (earth's natural heat from deep below the ground), fossil fuels (coal, oil and natural gas), hydro-power (water), nuclear energy, solar, and wind. You can help conserve (save) energy by turning off lights when nobody is in the room and by not leaving things turned on when nobody is using them (tv, computer, stereo, etc.). To discover the earth's #1 source of energy, do the dot-to-dot number game below. You can color the picture, and if you send us your completed paper we will mail you a free gift certificate!



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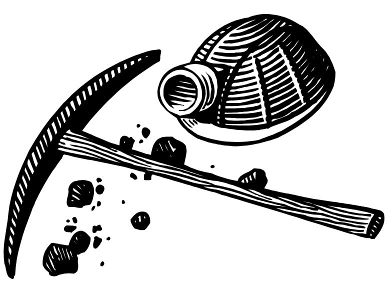
Jennings to Offer Unique Pennsylvania Coal Course for Area Teachers

Calling all middle and high school teachers! Jennings Environmental Education Center (2951 Prospect Road, Slippery Rock, PA) is offering a course on the past, present, and future of coal in Pennsylvania. Staff at JEEC will teach environment and ecology standards through the introduction of the topics of the history of coal mining and the issues, causes, and effects of abandoned mine drainage. Technologies currently used to treat AMD at the local, state, and national level will be included in the discussion. Teachers participating in this course will be given the knowledge to bring this topic into the classroom through handouts, activities, discussion, and field trips (which include the Tour Ed mine, an active limestone quarry, and reclamation sites).



The course is being held on 3 Saturdays, all 3 of which must be attended and completed to receive credit: **March 29, April 12, and May 17**. SRI and BioMost, Inc. are excited to be helping teach the session held on May 17!!! Each session runs from **8:00 AM until 4:00 PM**. A variety of books, materials, and a **stipend of $80** will be provided, and 1 CPE credit (30 Act 48 hours) will be awarded upon successful completion of all course activities, including in-class participation and out-of-class assignments. There is a *$130 registration fee* (and $80 stipend) which covers MIU4 administration costs, credit, and refreshments. Materials, admission fees, and stipends are provided by the **Department of Environmental Protection Environmental Education** grants program.

There will be outdoor activities, and participants must dress appropriately (no sandals). Break items will be provided but teachers will need to pack their own sack lunch (lunch is not provided) because there is nowhere close by to quickly buy a lunch. ***Enrollment is limited to 25, so register now!!!*** Contact the staff at JEEC at **(724) 794-6011** or email **Wil Taylor** at **wilbutaylo@state.pa.us.** If you are an educator, you won't want to miss this valuable workshop! There are over 280,000 acres of abandoned mine lands in PA, along with 3500 miles of stream impacted by AMD. Come learn about this important issue crucial to the health of our environment, and find out what you and your students can do to help fix the problem!

November 2007

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

<u>THIS MONTH'S MEETING:</u> Thursday 11/8/07 at 7 pm at Jennings Environmental Education Center, pizza and pop provided. 10/11/07 meeting attendance: S. Busler, C. Cooper, C. Denholm, M. Dunn, D. Johnson, V. Kefeli

<u>Presentations by Westminster College students at 11/8/07 SRWC meeting</u>!!! See article.

Manganese Recovery at De Sale Phase 2

Manganese material from the De Sale 2 passive system (installed in 2000) has recently been successfully recovered by Stream Restoration Incorporated and BioMost, Inc. The demonstration project combines Operation and Maintenance with metal recovery and is being funded by the **Pennsylvania Department of Environmental Protection's Bureau of Abandoned Mine Reclamation.**

The passive treatment component of interest is what BioMost, Inc. calls a Horizontal Flow Limestone Bed or HFLB for short. The HFLB, the final component of the passive system, is used to provide an alkalinity "boost" to the effluent prior to entering the headwaters of Seaton Creek as well as to remove manganese dissolved in the abandoned mine drainage. Over time, the manganese material has accumulated in the bed.

One of the potential issues identified in removing the manganese was that the material tended to cling to the stone. An excavator attachment called a FlipScreen, however, was utilized in conjunction with a wash pit to effectively clean the stone and contain the material. The manganese material was then able to be placed into large totes to dewater prior to hauling from the site.

Following processing, the stone looked almost brand new and was placed back into the HFLB. Look for future articles as we examine the quality of the manganese material as well as potential uses. One use, which we will continue to explore, is ceramic glazes for pottery. **<u>Special, special thanks to the Terwilliger family!!!</u>**

Accepting the Challenge Available

The Slippery Rock Watershed Coalition is pleased to announce that the 3rd printing of 2000 copies of the publication **<u>Accepting the Challenge</u>** has been completed. The popularity and interest in this primer on mine drainage and passive treatment systems has astounded the SRWC. We are thrilled that the book has been able to provide a valuable resource to so many people. The third printing has been made possible by an environmental education grant through the **Pennsylvania Department of Conservation and Natural Resources, Bureau of State Parks.**

PHOTO OF THE MONTH

<u>Playing in the Mud</u>
Shaun Busler, Tim Danehy, and Cliff Denholm pumping the manganese material cleaned from the limestone to a dewatering bag. (See article on page 1.)

PHOTO OF THE MONTH

Westminster College Students Monitor Passive Treatment Systems

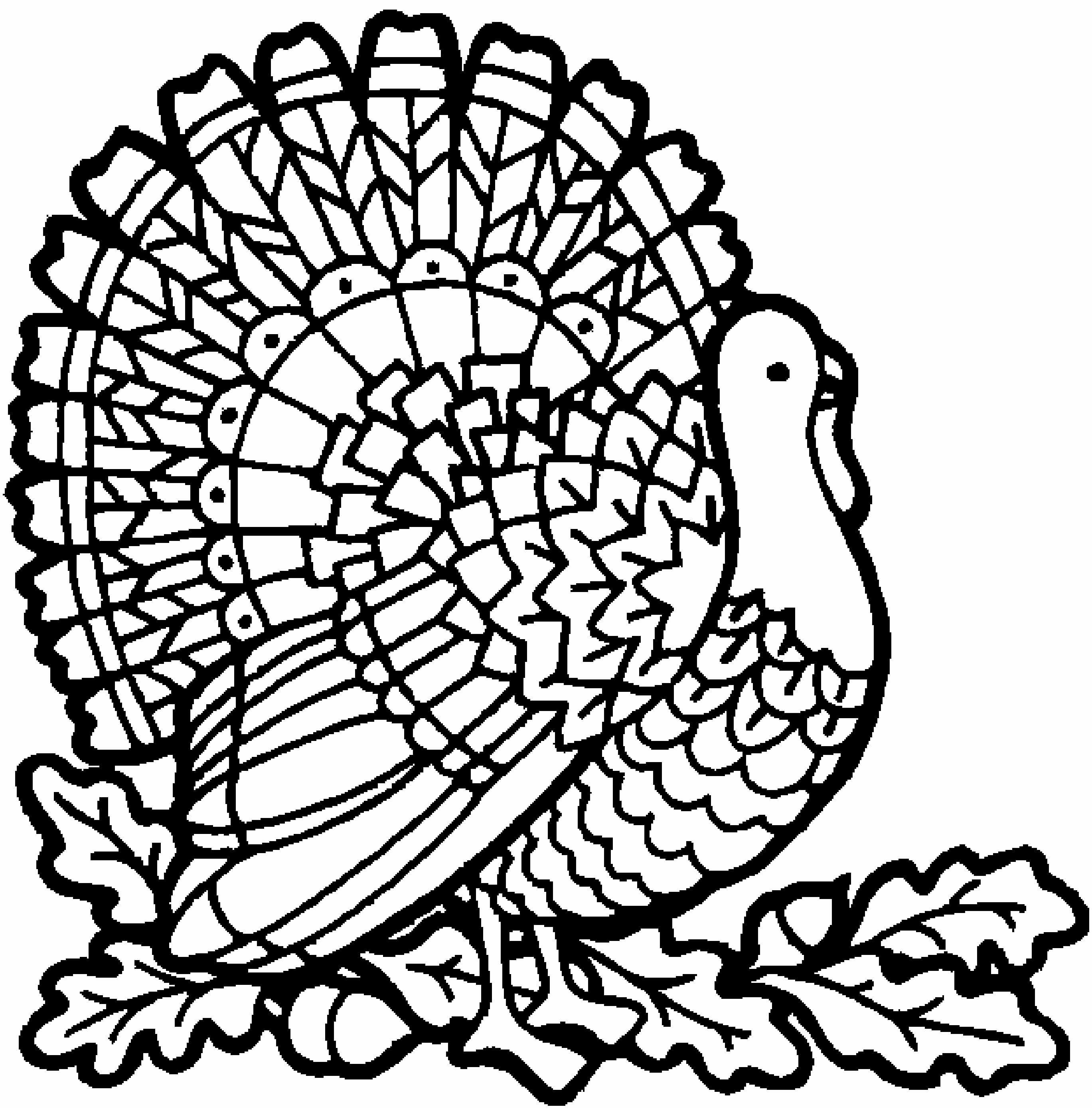
Westminster College students from **Dr. Helen Boylan's** Advanced Laboratory class have participated again this year in a collaborative effort with the Slippery Rock Watershed Coalition to monitor three passive treatment systems. The project provides the students with a practical hands-on experience to complement their classroom and laboratory instruction while gaining a better understanding of an important environmental issue such as abandoned mine drainage and environmentally-friendly methods of addressing the problem. The students worked in groups with **Wil Taylor** of the **Jennings Environmental Education Center** and **Cliff Denholm** of **Stream Restoration Incorporated** to conduct water quality monitoring of the De Sale Phase 1, De Sale Phase 2, and Erico Bridge Passive Treatment Systems. The students will be presenting the results of their study at the **November 8, 2007 Slippery Rock Watershed Coalition meeting at 7PM at the Jennings Environmental Education Center.** **<u>Please mark your calendars to support this worthwhile student contribution to our efforts!!!!</u>** As always, pizza and pop will be provided at the meeting.

The KIDS Catalyst

SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY

Totally Turkey!

Gobble, gobble, gobble! Here is your turkey trivia, in time for Thanksgiving! Did you know… only male turkeys (called toms) make the “gobble” sound? Females (hens) make a clicking sound. Mature turkeys have about 3,500 feathers. The heaviest turkey ever raised weighed 86 pounds! Benjamin Franklin thought the turkey was so American it should have been chosen as our national symbol rather than the eagle. We hope you have fun coloring the turkey below, and if you mail us your colored picture we’ll send you a free gift certificate! Happy Thanksgiving!



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SRWC goes Stir-Crazy at Jennings

In August of 2007, **Bob Beran** of **Beran Environmental** "stirred" the treatment media of the Vertical Flow Pond at the **Jennings Environmental Education Center** located in Butler County, PA. This was the second time in the 10 years of operation that the media was stirred due to a decrease in permeability, but not treatment. In fact, the VFP has consistently produced net alkaline water over the entire decade of operation. (General raw water quality characteristics: 3 pH, 280 mg/l acidity, 50 mg/l iron, 20 mg/l aluminum)

The treatment media consists of a mixture of compost and very small #9 limestone chips. The VFP was previously stirred in 2004.

In order to stir the media, the VFP was drained. The flow was diverted around the system and treated using an **Aquafix** system provided to the SRWC by the **US Department of Energy**. Prior to the stirring, a trench was dug lengthwise in order to examine the treatment media. Various distinguishable layers could be viewed including pockets (lenses) of limestone aggregate and decomposed compost material. Photos were taken and samples of the various layers were collected for analysis. Keep your eyes open for updates on the system in future issues of the Catalyst.

April 2007

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

<u>THIS MONTH'S MEETING:</u> Thursday 4/12/07 at 7 pm at Jennings Environmental Education Center, pizza and pop provided. 3/8/07 Meeting Attendance: J. Belgredan, S. Busler, C. Cooper, T. Danehy, C. Denholm, R. Donlan, M. Dunn, T. Grote, D. Johnson, V. Kefeli, B. Lubold, S. Smith, W. Taylor, S. VanDerWal

"Black Glaze" - Green Technology

Vessels to Sustain Watershed Restoration

Fifteen passive treatment systems have been constructed within the Slippery Rock Creek Watershed to combat the effects of approximately 30 abandoned mine discharges that degrade our streams. These passive treatment systems remove dissolved metals from the water using natural materials such as limestone and compost. The metals form solids that are collected in the passive treatment systems. The sooty black mineral formed within the limestone beds of some passive treatments systems in the Slippery Rock Creek Watershed is called todorokite, which contains about 50% manganese. Participants in the Slippery Rock Watershed Coalition are in the process of developing methods to recover this manganese ore.

Manganese, in the form of the material collected from the mine drainage, is commonly used as a colorant in different glazes for pottery. When local potter **Robert Isenberg of The Pottery Dome (Mercer, PA)** was approached by Slippery Rock Watershed Coalition participant **Kyle Durrett** with the concept of using some of the manganese in his pottery glazes, he was immediately interested. Robert Isenberg feels that making good use of the recovered manganese is a worthwhile endeavor. The largest request for this new glaze has come from the **North Country Brewing Company** located in downtown **Slippery Rock, PA**.

The **North Country Brewing Co.** has a yearly "Mug Club" where patrons can purchase one of **300 (!!!)** handmade mugs that they can use as their own personal mug that resides at the brewery. Each mug holds slightly more than one pint and is unlike any other mug in size, shape, and glaze. North Country Brewing supports many local grassroots organizations and is graciously **donating 5% (!!!!!) of the profits from sales of the new mugs to the Slippery Rock Watershed Coalition** to benefit long-term maintenance on the passive treatment systems in the watershed. These highly-anticipated new mugs will be available soon. They are sure to go fast so don't wait till they are gone!

The Slippery Rock Watershed Coalition would like to thank **North Country Brewing** for their generous support. To learn more about the **North Country Brewing Company**, check out their website at **www.northcountrybrewing.com** or stop in and enjoy a light snack or some "sturdy traditional food" at **141 South Main Street, Slippery Rock, PA**. The Coalition would also like to thank **The Pottery Dome** and **Robert Isenberg** for helping to promote this truly GREEN technology! To learn more about the award-winning art and the artist **Bob Isenberg**, visit **The Pottery Dome (www.potterydome.com) on the Leesburg–Grove City Road (State Route 208)** just 2 miles west of the Grove City Outlet Shops.

Above Left: Local businessman and North Country Brewing Co. host Bob McCafferty shows off a few of the new "Mug Club" mugs that incorporate manganese in the glaze recovered from passive treatment systems located in the Slippery Rock Creek Watershed. **Above Right:** Local artist and potter Robert Isenberg shows how he created 300 unique hand-thrown mugs at The Pottery Dome in Mercer, PA.

PHOTO OF THE MONTH

PHOTO OF THE MONTH

Shaun Busler, SRWC participant, is shown doing field work for the Blacks Creek assessment and implementation plan. Shaun checks rocks during a macroinvertebrate inventory (Left) and shows the location of an abandoned underground mine (Right), indicated by subsidence. *See article on back page.*

New Spring Research at Grove City College

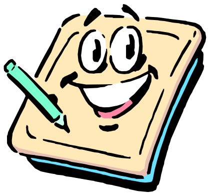
Richard Cattley, a junior at **Grove City College** who is majoring in Biology, will be assessing the water quality of Wolf Creek around the Grove City campus as part of an independent research program. Supervising Richard's work is **Dr. Fred Brenner**, a professor of Biology and participant of the **Slippery Rock Watershed Coalition**. Richard will be sampling for chemical parameters as well as biodiversity in order to determine the quality of the stream locally. The newly-collected data will then be compared to data from the late 1970s and early 1980s in order to compare how the stream is doing today in relation to the past. Some of the sampling locations will include above and below the water treatment plant located near the college. Other sampling points will be further upstream and north of I-80. We look forward to learning about Richard's findings and plan to share them in a future Catalyst issue!

PA Environmental Digest Showcases Westminster Students' Research Presentations

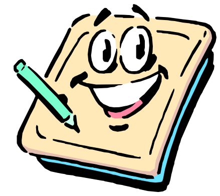
An article highlighting 19 Westminster College students' research of AMD treatment sites was featured in the PA Environment Digest on March 9, 2007! The chemistry and biochemistry students presented their research findings at a monthly meeting of the Slippery Rock Watershed Coalition. The article can be viewed via the PA Environment Digest at **www.paenvironmentdigest.com.** Thank you, PA Environment Digest for recognizing the importance of student involvement in the environmental research process and showing their hard work and accomplishments! (The PA Environment Digest is a weekly online update featuring written articles and short videos highlighting environmental issues in Pennsylvania.)

Women in Science at SRU and Kyle Durrett

"Women are valued and respected as educators and scientists at SRU." This comment from **Tamra Schiappa**, geology professor at **Slippery Rock University**, is backed up statistically by the fact that SRU employs high percentages of women faculty—twice the national average in some departments! **Kyle Durrett**, participant of the **SRWC**, can attest to it—he is a student at SRU who has studied under the tutelage of several female professors. In the Winter 2007 edition of **"The Rock"** magazine, Kyle is pictured working in a female educator's class in the article "Women Faculty Serve Critical Mentoring Role for Students."



The KIDS Catalyst

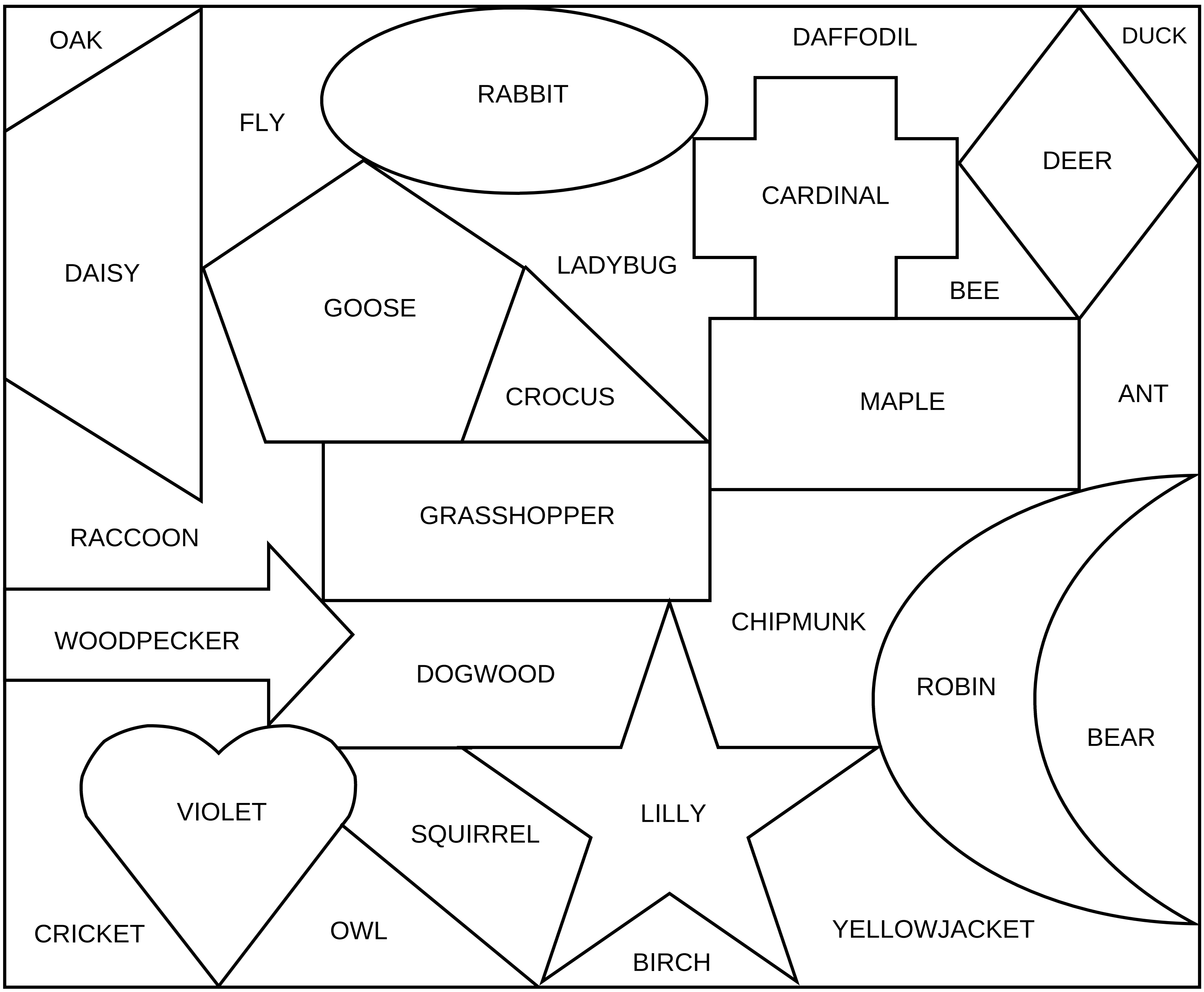


SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY

<u>Spring is “Shaping” Up</u>

Nature “springs” back to life this time of the year—it’s spring! Hibernating animals wake from their restful winter slumbers, migrating birds return from their warmer winter “vacation” spots, flowers bloom with beautiful colors and wonderful scents, insects creep, hop, and fly all around us, the trees are green again… Pennsylvania is blessed with an amazing variety of life in nature! The large square below contains many shapes each with the name of a bird, tree, mammal, flower, or insect we can usually see in the spring. You need to put each name into a category to color each shape according to the key below. You can even try to find all of these things in your backyard, neighborhood, park, etc.! If you mail us your completed paper, we will send you a free gift certificate!

Bird = yellow	Tree = green	Mammal = blue	Flower = purple	Insect = red



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Thanks to The William & Frances Aloe Charitable Foundation, Environmentally Innovative Solutions, LLC, Dominion Peoples, Amerikohl Mining, Inc., Quality Aggregates Inc., Drs. Ron & Kathy Falk Family, BioMost, Inc., Allegheny Mineral Corporation and PA DEP for their support. For more information contact: Slippery Rock Watershed Coalition, c/o Stream Restoration Incorporated (PA non-profit), 3016 Unionville Road, Cranberry Twp., PA 16066, (724)776-0161, fax (724)776-0166, sri@streamrestorationinc.org, www.srwc.org. April distribution: 1332

Restoring Blacks Creek

The SRWC is pleased and very excited to report that the assessment and implementation plan for the 9-sq. mi. Blacks Creek Watershed is nearing completion! This plan builds upon the more extensive **2006 Slippery Rock Creek Watershed Assessment and Restoration Plan** spear-headed by **Beran Environmental Services, Inc.** (Boyers, PA) with support from **Confluence Ecological, PA DEP Growing Greener Program, and the Butler County Commissioners**. In addition, abandoned mine restoration projects have been recently completed in the Blacks Creek Watershed by the **PA DEP Bureau of Abandoned Mine Reclamation and the Knox District Office; Aquascape; Quality Aggregates, Inc.; SRWC;** and others. A major tributary to Slippery Rock Creek, Blacks Creek is primarily in Butler County with a small portion extending into Venango County and is located just downstream of the 27-sq. mi. area, which has been the focus of the SRWC's restoration efforts for more than a decade.


Cliff Denholm takes a water sample from one of many water-filled pits

Shaun Busler and **Cliff Denholm** of Stream Restoration Inc. greatly appreciated the opportunity to inventory the abandoned mine discharges throughout the watershed and to develop a restoration plan. Many abandoned mine features were observed throughout the watershed: spoil piles, coal refuse piles, highwalls, subsidence, and water-filled surface mine pits. The impairment of Blacks Creek from AMD is evident and the main goal of this plan is to improve the stream quality and the aquatic ecosystem. The support of the **US EPA** and the **PA DEP Bureau of Watershed Management** in the efforts to restore Blacks Creek is greatly appreciated!

THE CATALYST

SLIPPERY ROCK WATERSHED COALITION MONTHLY ACTIVITIES UPDATE

THIS MONTH'S MEETING: Thursday 6/8/06 at 7 pm at Jennings Environmental Education Center, pizza and pop provided. 5/11/06 Meeting Attendance: C. Cooper, C. Denholm, M. Dunn, K. Durrett, D. Johnson, V. Kefeli, W. Taylor, S. VanDerWal, K. Williams

Student Summit a Success at Jennings!!!

On Thursday, April 27, 2006, Jennings Environmental Education Center held the **4th Annual Watershed Education Ohio Basin Student Summit.** The purpose of the summit is to highlight participants' achievement within the **Pennsylvania Bureau of State Parks Watershed Education** program and cultivate discovery and an environment conducive to the sharing of ideas, materials and enthusiasm intended for the lasting benefit of the Ohio Basin.

Approximately 60 students and teachers from the **Margaret B. Miller Middle School, St. Stephen's Academy, A.W. Beattie Career Center and the Quiet Creek Herb Farm & School of Country Living** were in attendance. Three interactive sessions and a resource based scavenger hunt were conducted throughout the day. Students also highlighted their efforts in watershed conservation and monitoring during presentations throughout the day. During the interactive sessions, **Mary Jo Shreffler** taught the basics of GPS. Students discovered how useful the technology is for recreational activities and for use in conjunction with watershed education program activities. At the T-shirt tye-dyeing station **Heidi Solley** and Jennings volunteer **Amber Sheppeck** revealed the effects of abandoned mine drainage (AMD) on Pennsylvania's streams. Students received a brief history of coal mining; discovered how AMD is formed and learned what methods are being used to treat AMD today. Iron oxide recovered from abandoned mine sites was used to dye the T-shirts.

April Claus of **Interactive Environmental Programs** engaged students with an array of reptiles and amphibians often sighted during monitoring activities. Students learned about the physical characteristics of each animal and also learned about their habitats. The final session students participated in was the resource based scavenger hunt made possible by participation from various agencies and organizations including the **PA Fish and Boat Commission, PA DCNR, Slippery Rock Watershed Coalition, Pennsylvania Game Commission, Western PA Conservancy, Mercer County Conservation District, PA DEP and the Beaver/Butler County Cooperative Extension;** thank you!! During the scavenger hunt students were able to explore the resource tables and learn even more about the Ohio Basin. A fun time was had by all!!!

PHOTO OF THE MONTH

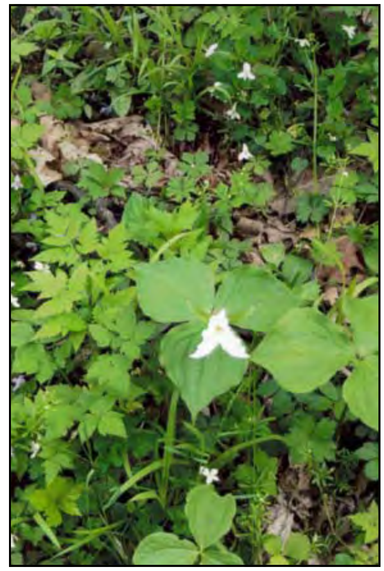


PHOTO OF THE MONTH

Heidi Solley guides a group at the annual Mother's Day wildflower walk at Jennings Environmental Education Center, Butler County, PA.

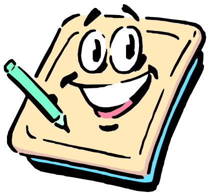
Manganese Recovery

The picture below (left) was taken shows the Environmentally Innovative Solutions display booth at the **2006 Society of Mining Engineering & American Society of Mine Reclamation Annual Conference** in St. Louis, Missouri near the end of March. The ceramic bowls on the display were created by a group of potters from Ohio and have been coated with glazes made out of manganese recovered from a passive treatment system in the Slippery Rock Watershed. This exciting use of metals recovered from acid mine drainage was unveiled at the conference and met with considerable excitement.

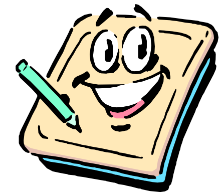
Manganese is the fourth-most used metal in terms of tonnage (ranked behind iron, aluminum, and copper) with 29 million tons mined annually worldwide. Its many applications which impact consumers' lives include objects made of steel, portable batteries, and aluminum beverage cans. Manganese plays a crucial role in improving the properties of the alloys and compounds involved in these uses. It even serves as an essential element for the human body, with recommended dietary intake levels established to maintain good health.

Over the last 15 years government agencies, watershed groups, nonprofits, universities, and private industry have developed and implemented passive treatment systems to inhibit the negative effects of acid mine drainage. These treatment systems have dramatically improved watersheds across the country, turning lifeless streams into healthy productive aquatic habitats.

In order to sustain the dramatic improvements in water quality using passive treatment systems, potential uses for the accumulating metal solids such as manganese need to be devised. **Stream Restoration Incorporated** and **BioMost Inc.** recognize this need and have been conducting research to recover the manganese metal and evaluate potential markets for this material. **The Southern Alleghenies Conservancy** and the **PA Department of Environmental Protection** have generously funded this project.



The KIDS Catalyst



SLIPPERY ROCK WATERSHED COALITION FUN ACTIVITY

Watershed Word Search

Wondering what is a **watershed**? A watershed is the word used to describe an area of land that drains water to a shared destination such as a river, or other body of water. The watershed drains down slope to its lowest point, moving through a network of drainage pathways. Generally, these pathways converge into streams and rivers, which become larger as the water moves on downstream, eventually reaching an estuary and the ocean. Watersheds can be large or small. Every stream, tributary, or river has an associated watershed, and small watersheds join to become larger watersheds. There are 5 major watersheds in Pennsylvania: the Delaware, the Great Lakes, the Ohio, the Potomac and the Susquehanna. Try to find the “watershed” words hidden in the Word Search below. Circle the words and if you mail us your completed paper, we will send you a free gift certificate!

WATERSHED	WATER	DRAINAGE	STREAM
CREEK	OCEAN	PRECIPITATION	DIVIDE
DOWNHILL	FRESHWATER	CYCLE	MOUNTAINS
TRIBUTARY	DELAWARE	GREAT LAKES	OHIO
POTOMAC	SUSQUEHANNA	BASIN	RESTORE

M	O	U	N	T	A	I	N	S	E	E	T	A	B	S	M	W	I	P	K	O	D	I	V	S	T
O	H	Z	V	Q	E	W	A	N	R	A	L	L	I	H	N	W	O	D	J	U	R	N	V	Q	M
C	R	E	G	N	U	O	H	Y	N	A	D	G	V	E	R	T	P	O	M	C	A	I	D	V	E
S	G	T	R	K	W	A	T	R	E	S	D	E	B	A	O	S	U	S	V	N	M	S	H	A	F
P	R	E	C	I	P	I	T	A	T	I	O	N	R	M	N	N	A	G	O	H	W	A	T	E	R
D	E	W	N	H	L	L	W	T	A	C	B	G	A	M	O	N	C	Q	A	Q	U	B	A	C	E
M	A	O	N	E	A	C	B	U	F	R	E	C	S	E	H	W	A	N	R	E	T	M	U	O	S
O	T	B	N	T	R	I	V	B	E	E	B	K	R	I	L	U	N	O	O	N	C	Z	X	A	H
A	L	S	F	Q	D	W	S	I	R	S	R	O	L	N	E	A	G	R	E	J	N	K	A	O	W
N	A	L	N	S	S	C	A	R	E	O	T	E	A	V	H	W	A	D	I	V	I	D	E	S	A
R	K	H	C	U	X	N	A	T	D	S	C	H	E	E	M	P	O	L	I	J	M	B	W	D	T
D	E	L	W	R	A	V	D	R	E	A	I	N	U	E	G	B	S	A	R	E	C	B	F	X	E
W	S	A	R	O	E	M	A	R	E	R	I	Q	O	C	B	A	M	U	T	C	R	T	A	I	R
T	R	V	B	C	A	K	A	N	G	R	S	A	R	O	R	E	N	E	B	O	Y	K	A	D	N
N	I	K	T	E	E	V	E	Q	V	U	I	H	B	K	E	C	H	I	S	U	S	C	Q	U	E
S	U	V	R	A	E	A	N	K	S	L	L	N	E	S	T	R	M	P	A	W	A	T	L	W	A
C	O	T	V	N	M	J	Y	X	W	Z	F	E	G	D	E	L	A	W	A	R	E	Q	U	E	V
A	S	G	B	C	U	K	B	A	Z	R	R	M	L	J	O	P	B	C	S	F	D	A	M	E	R
O	H	X	O	I	H	O	V	G	R	C	Q	U	E	H	M	E	N	N	S	S	A	S	H	A	U

Name ______________________________ Age __________

Address ____

Slippery Rock Watershed Coalition c/o Stream Restoration Incorporated
A PA Non-Profit Organization
3016 Unionville Road
Cranberry Twp., PA 16066

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Highlighting **O**ther **P**artnership **E**fforts (HOPE!)

Partnerships in the Bennett Branch Watershed

By Kim Lanich, Elk County Conservation District

On an exceptionally warm April day, members from the Bennett Branch Team, DEP representative **Secretary Kathleen McGinty**, and other elected officials met to discuss the environmental problems facing the Bennett Branch Watershed. Deep in the heart of elk country, Acid Mine Drainage (AMD) is a major problem affecting water quality to many tributaries flowing into the main stem of the Bennett Branch. AMD in Elk County is directly linked to over one hundred years of mining, and as you can see in the photo, mining is still part of the economic industry today.

Back row left to right: Tom Malesky-BAMR; Ken Stossel-P&N Coal Co; Jeff Ream-Gannett Fleming Inc; Steve Fisanick-BAMR; John Dzemyan-PA Game Commission; Jeff Gilmore-BBWA; Steve Garbarino-US Army Corp of Engineers; Kelly Burch-DEP; Don Wood-BBWA

Front row left to right: Kim Lanich-Elk Conservation District; Margaret Dunn-BioMost, Inc; Dan Surra- State Rep; Kathleen McGinty-Secretary DEP; Ken Rowe-President Bennett Branch Watershed Association; Eric Cavazza-BAMR; John Prushnok-P&N Coal Company; Michael DiMatteo-PA Game Commission; June Sorg-Elk County Commissioner; Howard Brush-Director of Governors Northwest Regional Office.

This photo represents the many partners that have joined the efforts of the Bennett Branch Watershed since its inception. In 1998 the Bennett Branch Watershed Association (BBWA) formed to begin the restoration work needed on the Bennett Branch to restore it to its pre-mining condition, and in 2004 the DEP completed an assessment of the work required to abate the impacts of the mine drainage on the Bennett Branch. After the assessment, the **Mineral Resources Management (MRM) Deputate** organized the "**Bennett Branch Team"** comprised of **Department of Environmental Protection** staff from the Cambria Office of the **Bureau of Abandoned Mine Reclamation (BAMR)**, the Moshannon and Knox offices of the **Bureau of District Mining Operations**, and members of the **BBWA**. Since then, many others have joined this team such as: the **Baltimore District of the US Army Corp of Engineers**, the **Elk County Conservation District**, the **PA Game Commission**, **Gannett Fleming**, **P & N Coal Company**, **Earthsavers**, and the newest partner **BioMost, Inc.** The Bennett Branch Watershed Association is fortunate to have such a diverse, highly qualified team remediate the many AMD issues plaguing the watershed.

KEY TO WATER SAMPLE POINTS

De Sale Phase 1 Passive Treatment System

- **Raw** *(influent to passive system)*
- **WL** *(influent to Horizontal Flow Limestone Bed from treatment wetland)*
- **HFLB** *(effluent from Horizontal Flow Limestone Bed; final system effluent)*

De Sale Phase 2 Passive Treatment System

- **Up** *(raw influent to passive system)*
- **Wetland** *(influent to Horizontal Flow Limestone Bed from treatment wetland)*
- **OUT/HFLB** *(effluent from Horizontal Flow Limestone Bed; final system effluent)*

De Sale Phase 3 Passive Treatment System

- **DEP Raw** *(influent to passive system)*
- **SP2** *(influent to Horizontal Flow Limestone Bed from settling pond)*
- **HFLB** *(effluent from Horizontal Flow Limestone Bed; final system effluent)*

Erico Bridge Passive Treatment System

- **ST 63E** *(raw influent to passive system)*
- **WL2@PP2** *(influent to Horizontal Flow Limestone Bed from treatment wetland)*
- **HFLB** *(effluent from Horizontal Flow Limestone Bed; final system effluent)*

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
RAW	8/12/1999		36		3.6	1842			0	381	78.5		66.5		17.3		1285	62
RAW	8/17/1999		36		3.5				0	286	77.2		62.0		14.8		1612	0
RAW	8/19/1999		36		3.4	1866			0	439	76.5		66.8		14.0		1478	8
RAW	8/20/1999				3.4				0	298	83.4		64.8		15.4		1449	10
RAW	9/2/1999		27	3.4	3.4	2221	25		0	372	84.0		72.3		15.9		1469	11
RAW	9/9/1999	Estimate	20		3.1				0	310	92.5		68.9		17.6		124	12
RAW	10/5/1999		29	3.2	3.2	2078	9		0	492	61.5		69.5		13.8		1665	35
RAW	10/13/1999	Estimate	24		3.2				0	408							1662	
RAW	11/12/1999	Estimate	26		3.1				0	556	83.5		69.0		21.0		1622	126
RAW	11/12/1999		28	3.1	3.1	2197	8		0	421	86.8		84.8		16.7		1746	42
RAW	11/18/1999	Bucket	24	4.8	3.1	2311	5		0	443	94.8		84.0		17.3		2358	41
RAW	12/8/1999		28	3.3	3.4	2156	4		0	338	47.5		72.5		22.0		2525	50
RAW	12/28/1999	Estimate	30		3.4				0	274	59.3		64.9		20.4		1288	12
RAW	1/13/2000		60	3.5	3.5	1691	4		0	306	48.1		57.0		13.7		1722	26
RAW	1/20/2000	Estimate	45		3.6				0	242	68.5		59.9		15.4		681	0
RAW	2/10/2000	Estimate	40		3.5				0	356	66.8		56.1		14.1		869	8
RAW	2/10/2000		11	3.8	3.5	1723	9		0	324	62.7		61.0		13.2		2170	31
RAW	3/1/2000		50	3.7	3.4	1610	11		0	224	29.9		43.1		10.1		1096	16
RAW	3/8/2000	Estimate	30		3.4				0	252								951
RAW	4/4/2000		28	4.2	4.0	1360	10		0	268	45.8		39.7		8.0		1199	23
RAW	4/25/2000	Estimate	50		4.0				3	238	58.4		41.0		6.9		851	0
RAW	5/4/2000		20	4.1	4.1	1474	12		0	229	64.9		41.3		7.9		1278	5
RAW	5/25/2000	Estimate	40		4.1				5	276	59.5		40.5		7.7		1044	0
RAW	6/15/2000	Estimate	50		4.2				7	286	61.1		41.3		7.5		1055	0
RAW	6/26/2000	Bucket	44	4.5	3.1	1641	11		0	251	70.8		9.3		8.2		1195	3
RAW	7/13/2000	Estimate	30		4.1				5	408	80.5		52.6		9.4		1150	4
RAW	7/20/2000		83	7.1	7.2	1850	20		140	0	1.5		36.3		0.4		1287	38
RAW	8/9/2000	Estimate	40		4.1				6	292	92.9		55.9		11.5		1858	2

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
RAW	9/20/2000			4.1			12			393	133.3		73.8		13.3		1375	
RAW	9/28/2000				4.2				8	318	125.0		69.6		13.0		1427	4
RAW	10/18/2000				4.1				7	388	132.0		71.2		13.3		1441	10
RAW	10/31/2000	Bucket	27	4.5	4.1	2205	12		0	419	138.0	137.3	79.5	77.5	12.8	12.5	2032	5
RAW	11/14/2000				4.0				4	488	142.0		75.3		14.0		1309	14
RAW	12/19/2000				4.0				3	440	128.0		63.8		13.0		1498	12
RAW	1/8/2001	Bucket	34	4.3	4.1	2032	11		0	395	112.8	110.0	73.0	68.5	57.8	51.0	1652	4
RAW	1/17/2001				3.9				0	388	121.0		63.1		11.0		1141	14
RAW	3/29/2001				4.1				5	246	78.6		48.5		8.2		750	2
RAW	4/5/2001	Measured	54		4.0				5	280	81.8		49.9		8.4		948	6
RAW	4/20/2001	Bucket	79	4.1	3.5	1496	10		0	254	69.6	65.8	42.9	40.3	7.4	7.0	1020	10
RAW	5/4/2001				3.7				0	184	71.7		45.7		7.8		1230	2
RAW	6/5/2001				3.3	1704			0	284	66.8	65.5	48.3	43.0	8.7	8.6	1063	10
RAW	6/19/2001				3.8				0	407							858	1
RAW	7/11/2001				3.9				0	423	104.0		64.4		10.8		1310	28
RAW	8/30/2001				3.7				0	435	118.0		67.7		11.9		1357	12
RAW	10/18/2001				3.8				0	669	148.0		78.5		14.6		1510	2
RAW	2/14/2002				4.2				9	388	95.9		56.8		9.8		720	4
RAW	3/13/2002				3.7				0	372	115.0		70.3		9.2		1048	18
RAW	4/30/2002				4.0				2	318	73.1		47.9		9.9		898	16
RAW	7/25/2002				3.7				0	267	83.5		55.3		11.9		1648	20
RAW	10/8/2002				3.9				0	578	127.0		74.3		15.6		1395	16
RAW	3/14/2003				4.6				12	247	66.8		46.3		9.5		964	6
RAW	6/17/2003				3.8				0	257							1037	14
RAW	9/16/2003				4.0				2	307	62.3		42.2		10.3		975	2
RAW	10/29/2003				3.9				0	319	80.1		50.3		12.0		1062	12
RAW	3/30/2004				4.2				7	190	44.0		35.0		10.2		796	2
RAW	6/4/2004				3.8				0	291							943	10

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
RAW	8/27/2004				4.0				0	218							842	10
RAW	11/4/2004				4.0				3	283	68.1		43.3		12.1		909	2
RAW	3/29/2005				4.2				8	223	46.4		35.9		9.7		976	2
RAW	6/9/2005				3.9				0	301							969	8
RAW	8/19/2005				4.0				2	382	105.0		61.9		13.7		1189	2
RAW	11/3/2005				4.0				4	434	106.0		53.7		12.7		1351	4
RAW	2/9/2006			4.4	4.4	1526	10		0	209	70.2	69.2	43.6	43.6	9.3	8.9	1232	8
RAW	3/8/2006			4.2	4.2	1596	10		0	262	81.0	79.9	46.6	45.3	8.0	7.8	1043	6
RAW	3/21/2006				4.4				9	222	55.1		36.8		8.0		888	4
RAW	6/21/2006				4.1				0	334							1045	4
RAW	9/7/2006				4.1				7	303	71.4		43.8		10.3		1123	2
RAW	11/2/2006				3.9				0	253	60.4		38.6		8.6		859	4
Min			11	3.1	3.1	1360	4		0	0	1.5	65.5	9.3	40.3	0.4	7.0	124	0
Max			83	7.1	7.2	2311	25		140	669	148.0	137.3	84.8	77.5	57.8	51.0	2525	951
Avg			37	4.1	3.8	1829	11		4	328	82.0	88.0	56.3	53.0	12.6	16.0	1247	28
Range			72	4.0	4.1	951	21		140	669	146.5	71.8	75.5	37.2	57.4	44.0	2401	951

Description: De Sale Phase 1 Passive Treatment System untreated influent.

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
WL	6/26/2000			7.9	7.5	1923	33		161	0	0.9		15.7		0.2		1489	10
WL	9/6/2000			7.3			15			0	0.3		52.5		0.0		1359	
WL	9/20/2000			7.4			16	110		0	0.3		50.1		0.0		1263	
WL	9/29/2000			7.3	7.0		13			0	18.0		14.8		1.3		18	
WL	10/10/2000			7.3	7.1			172		0	23.4		12.8		0.7		1432	
WL	10/23/2000			7.2			8				0.2		56.4				1446	
WL	10/23/2000			7.6			8				6.3		17.5		0.2		1618	
WL	10/31/2000	Assumed	27	7.0	7.2	2258	12	110	116	0	0.2	0.2	52.5	52.3	0.2	0.1	1942	9
WL	11/24/2000			7.1			2					0.5		47.1		0.0	1641	
WL	11/24/2000			7.1	7.0		2			0	5.5		46.6		0.2		1598	
WL	12/29/2000			6.6			1			0	3.5		72.5				1498	
WL	12/29/2000			6.9			0											
WL	1/8/2001			6.0	6.5	2186	0		103	34	3.3	0.3	67.5	62.0	0.2	0.2	1411	13
WL	1/26/2001			6.4	6.5		0			37	7.2		48.4		0.3		1044	
WL	3/20/2001			7.0			7											
WL	3/20/2001			7.2			12											
WL	4/20/2001			6.7	6.6	1575	9		58	8	1.6	0.1	41.2	40.7	0.1	0.0	1154	10
WL	6/5/2001				7.3	1576			61	30	0.3	0.2	33.1	32.8	0.1	0.1	1035	30
WL	3/28/2007	Bucket	150	5.4	5.5	1343	14	2	4	41	0.0	0.0	31.7	30.6	0.9	0.8	698	3
WL	4/26/2007	Bucket	100	6.3	6.2	1381	14	11	11	35	0.2	0.1	32.0	31.9	0.6	0.3	758	4
WL	5/23/2007	Bucket	60	6.3	6.3	1426	20	30	20	-27	0.2	0.2	35.0	34.6	0.3	0.3	564	2
Min			27	5.4	5.5	1343	0	2	4	-27	0.0	0.0	12.8	30.6	0.0	0.0	18	2
Max			150	7.9	7.5	2258	33	172	161	41	23.4	0.5	72.5	62.0	1.3	0.8	1942	30
Avg			84	6.9	6.7	1709	10	73	67	11	4.2	0.2	40.0	41.5	0.4	0.2	1220	10
Range			123	2.5	2.0	915	33	170	157	67	23.4	0.5	59.8	31.4	1.3	0.8	1924	28

Description: Wetland; De Sale Phase 1 Passive Treatment System; Effluent sampled at spillway before entering the Horizontal Flow Limestone Bed

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
HFLB	5/25/2000	Estimate	25		7.2				146	0	4.6		11.3		0.0		1413	0
HFLB	6/15/2000	Estimate	50		7.0				180	0	3.6		10.7		0.0		927	4
HFLB	6/26/2000	Bucket	39	7.6	7.3	1907	24		157	0	3.9		13.5		0.2		1557	15
HFLB	6/26/2000			7.6	7.4	1896			171	0	3.9		13.8		0.2		1609	15
HFLB	7/13/2000	Estimate	30		7.2				186	0	4.9		26.1		0.0		1038	12
HFLB	9/6/2000	Measured	23	7.2			19			0	0.4		45.5		0.0		1510	
HFLB	9/20/2000	Measured	25	7.1			16	110		0	0.8		42.6				1321	
HFLB	9/28/2000	Measured	24		6.7				118	0	0.2		42.8		0.3		1275	2
HFLB	10/18/2000	Estimate	30		7.0				110	0	0.7		46.0		0.3		1392	32
HFLB	10/23/2000			7.1			12				0.3		52.0				1415	
HFLB	10/31/2000	Bucket	25	7.3	7.3	2261	10	106	113	0	0.3	0.1	52.3	51.8	0.3	0.1	1568	10
HFLB	11/14/2000	Measured	20		7.0				110	0	0.4		50.5		0.3		1261	10
HFLB	12/19/2000	Estimate	40		6.9				110	0	0.6		47.5		0.3		1619	10
HFLB	12/29/2000	Measured	36	6.9			1				0.9		68.3		0.0		1489	
HFLB	1/8/2001	Bucket	32	6.8	6.9	2124	1		121	0	0.8	0.3	67.5	65.5	0.2	0.1	1381	5
HFLB	1/17/2001	Measured	32		6.7				120	0	0.7		53.9		0.3		1282	10
HFLB	3/20/2001		48	7.0			7											
HFLB	3/29/2001	Measured	90		6.5				90	0	0.5		21.5		0.3		1162	4
HFLB	4/5/2001	Measured	56		7.0				108	0	0.5		11.3		0.3		1073	8
HFLB	4/20/2001	Bucket	72	7.0	7.0	1661	10		98	0	0.4	0.2	8.4	8.3	0.0	0.0	1178	8
HFLB	5/4/2001	Measured	70		6.9				106	0	0.8		15.9		0.3		1045	8
HFLB	6/19/2001	Measured	30		6.9				106	0	0.7		34.2		0.3		1274	12
HFLB	7/11/2001	Measured	36		6.8				102	0	1.4		38.0		0.3		1181	6
HFLB	8/30/2001	Measured	15		6.7				96	0	1.7		45.1		0.3		1285	10
HFLB	10/18/2001	Measured	9		7.0				102	0	0.8		37.5		0.3		1700	16
HFLB	2/14/2002	Measured	48		6.6				68	0	0.8		34.4		0.3		948	2
HFLB	3/13/2002	Measured	60		6.5				78	0	0.7		25.1		0.3		1286	6
HFLB	4/30/2002	Measured	80		6.3				66	0	0.3		14.4		0.3		713	10

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
HFLB	7/25/2002	Measured	40		7.0				78	0	0.4		28.2		0.3		1610	4
HFLB	10/8/2002	Measured	24		7.2				68	0	0.6		43.7		0.3		1513	10
HFLB	3/14/2003	Measured	90		6.4				42	36	1.9		35.8		0.5		974	4
HFLB	6/17/2003	Measured	50		6.2				52	29	0.7		26.8		0.3		972	8
HFLB	9/16/2003	Estimate	50		6.8				65	0	1.1		24.1		0.3		910	2
HFLB	10/29/2003	Estimate	40		6.7				57	0	1.9		27.2		0.7		1034	4
HFLB	3/30/2004	Measured	80		5.0				11	51	0.7		33.0		4.5		850	6
HFLB	11/4/2004	Estimate	40		7.0				90	-16	0.3		9.4		0.3		834	2
HFLB	3/29/2005	Estimate	50		5.0				11	102	0.2		33.6		3.9		976	2
HFLB	6/9/2005	Estimate	40		7.1				121	-17							1108	6
HFLB	8/19/2005	Estimate	20		7.0				122	-46	1.5		30.6		0.3		1215	2
HFLB	11/3/2005	Estimate	25		6.9				81	-20	0.4		17.5		0.3		1307	4
HFLB	3/21/2006	Estimate	40		6.8				73	-47	0.2		10.1		0.3		931	4
HFLB	6/21/2006	Estimate	30		7.5				94	-80							953	6
HFLB	9/7/2006	Estimate	40		7.2				88	-69	0.2		2.8		0.3		991	2
HFLB	11/2/2006	Estimate	50		7.0				40	-12	0.5		0.1		0.6		943	4
HFLB	3/28/2007	Assumed	150	6.3	6.2	1368		17	18	17	0.0	0.0	25.7	24.8	0.5	0.3	856	4
HFLB	4/26/2007	Assumed	100	6.5	6.4	1392	13	27	21	7	0.2	0.1	30.6	26.5	0.2	0.1	706	3
HFLB	5/23/2007	Assumed	60	6.5	6.5	1447	20	55	38	-28	0.1	0.0	20.3	18.8	0.2	0.2	615	2
Min			9	6.3	5.0	1368	1	17	11	-80	0.0	0.0	0.1	8.3	0.0	0.0	615	0
Max			150	7.6	7.5	2261	24	110	186	102	4.9	0.3	68.3	65.5	4.5	0.3	1700	32
Avg			46	7.0	6.8	1757	12	63	91	-2	1.1	0.1	30.2	32.6	0.4	0.1	1178	7
Range			141	1.3	2.5	893	23	93	175	182	4.9	0.3	68.2	57.2	4.5	0.3	1085	32

Description: Horizontal Flow Limestone Bed; De Sale Phase 1 Passive Treatment System; Effluent sampled from discharge pipe at spillway; Also final effluent of entire system

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
UP	12/14/1999		25		3.4	2291			0	328	82.3		83.8		1.9		1789	7
UP	5/16/2000	Estimate	150		3.3				0	250	16.4		44.3		9.1		1473	
UP	7/13/2000				3.1				0	396	21.8		67.3		11.6		1141	
UP	8/9/2000				3.1				0	250	21.6		53.7		9.5		1387	4
UP	9/6/2000	Measured	40	2.9			19	0	0			37.0		76.9		12.9	1640	
UP	9/6/2000	Measured	40	2.9			19	0		288	35.8		73.1		13.3		1581	
UP	9/20/2000	Measured	40	3.2			14	0		306	32.9		73.6		11.8		1576	
UP	9/28/2000	Measured	60		3.2				0	296	32.7		67.1		11.9		1406	10
UP	9/29/2000	Measured	38	3.6	3.1		7	0		316	36.0		73.1		13.1		1550	
UP	9/29/2000	Measured	38	3.6			7	0				36.4		74.6		13.0	1575	
UP	10/10/2000	Measured	54	3.3	3.1			0		273	34.9		66.7		10.7		1436	
UP	10/18/2000	Estimate	50		3.2				0	306	30.7		66.9		11.1		1492	18
UP	10/23/2000	Measured	33	3.2	3.2		7	0		309	36.2		73.9		12.2		1597	
UP	10/30/2000	Bucket	37	4.4	3.2	2422	11		0	339	30.0	28.4	75.3	72.0	12.5	11.4	1434	10
UP	11/14/2000	Measured	40		3.3				0	314	32.9		68.6		11.9		1583	10
UP	11/24/2000	Measured	30	3.1	3.2		1	0		305	40.0		74.5		12.5		1619	
UP	12/19/2000				3.4				0	226	27.5		47.5		10.0		1664	
UP	12/29/2000			3.3			0	0										
UP	1/8/2001			4.5	3.3	1943	1		0	232	24.4	23.4	57.0	54.0	8.8	8.7	1249	3
UP	1/17/2001				3.4				0	192	24.4		40.7		6.9		928	12
UP	1/26/2001	Measured	40	2.8	3.2		0	0		236	33.7		59.4		9.8		1230	
UP	2/22/2001				3.4				0	190	26.1		41.4		8.0		785	16
UP	3/20/2001	Measured	79	3.6			5		0									
UP	3/24/2001	Bucket	93	4.4	3.7	980	5		0	111	10.7	8.3	22.9	11.4	5.2	4.9	793	4
UP	3/29/2001				3.6				0	166	20.2		39.4		7.7		767	4
UP	4/5/2001				3.4				0	224	22.8		45.6		9.1		1046	
UP	4/20/2001			3.6	3.5	1075	8		0	118	13.2	11.4	27.8	27.1	5.2	5.1	685	2
UP	5/4/2001				3.3				0	166	21.3		54.9		10.3		1096	8

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
UP	5/7/2001	Bucket	59	3.2			13		0	227	23.0		58.0		11.3		1284	
UP	6/6/2001	Bucket	75	4.0	3.2	2094	14		0	295	18.6	16.8	55.0	51.3	8.8	8.1	1348	4
UP	6/19/2001	Measured	65		3.1				0	308	25.2		64.2		11.0		1506	8
UP	6/20/2001	Bucket	58	3.1	3.0		17		0	331	26.2							
UP	7/11/2001	Measured	60		3.2				0	371	32.4		73.2		11.6		1270	10
UP	8/2/2001			4.5	2.9	2431	19		0	326	29.1	25.9	72.0	70.5	10.4	10.1	1607	6
UP	8/30/2001	Measured	60		3.0				0	354	34.8		68.7		11.6		1488	8
UP	9/21/2001	Bucket	29	3.1	3.1		14		0	337	35.6		75.9		12.4		1165	
UP	10/18/2001	Measured	38		3.1				0	451	38.7		67.7		12.0		1537	12
UP	11/29/2001	Bucket	75	4.5	3.2	1741	8		0	195	16.1	14.4	38.8	38.0	6.2	5.9	1272	14
UP	2/14/2002				3.6				0	258	29.0		45.6		8.8			22
UP	2/21/2002			3.4	3.4		5		0	150	16.6		32.6		5.6		730	
UP	3/13/2002	Measured	180		3.4				0	240	25.5		45.1		8.4			12
UP	3/14/2002	Bucket	85	4.5	3.3	2000	9		0	206	27.7	24.4	55.2	49.1	9.3	8.5	1153	11
UP	4/30/2002	Measured	100		3.4				0	230	20.4		43.2		10.0			12
UP	6/10/2002	Cross-section	60		3.2	1833				207	16.8	16.5	45.0	43.3	9.6	7.5	942	6
UP	7/25/2002	Measured	120		3.1				0	273	29.3		64.6		13.4		1533	14
UP	10/8/2002	Measured	40		3.1				0	442	35.3		71.1		15.1		1646	6
UP	3/14/2003	Measured	200		3.6				0	92	9.3		19.8		5.3		351	14
UP	6/17/2003	Measured	200		3.3				0	207	12.4		34.1		8.4		886	10
UP	9/16/2003				3.2				0	273	16.8		42.2		11.1		1078	0
UP	10/29/2003				3.2				0	220	18.4		41.8		10.0		983	8
UP	3/30/2004				3.4				0	136	12.2		30.9		10.1		724	0
UP	6/4/2004	Measured	150		3.1				0	292	18.9		45.4		12.5		1206	0
UP	8/27/2004				3.2				0	170	14.2		31.2		7.7		892	0
UP	11/4/2004				3.3				0	206	15.8		37.6		9.1		781	12
UP	3/29/2005				3.5				0	162	10.1		29.7		8.5		856	0
UP	6/9/2005				3.1				0	292	18.0		47.3		10.5		1007	14

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
UP	8/19/2005				3.0				0	314	24.7		55.6		10.8		1265	0
UP	11/3/2005				3.2				0	224	0.2		0.0		0.3		1125	0
UP	3/21/2006				3.4				0	152	13.5		31.0		8.6		751	6
UP	6/21/2006				3.0				0	318	17.4		44.4		10.2		1268	6
UP	9/7/2006				3.3				0	149	7.5		26.3		7.4		730	0
UP	11/2/2006				3.4				0	134	7.1		18.2		7.7		728	6
Min			25	2.8	2.9	980	0	0	0	92	0.2	8.3	0.0	11.4	0.3	4.9	351	0
Max			200	4.5	3.7	2431	19	0	0	451	82.3	37.0	83.8	76.9	15.1	13.0	1789	22
Avg			73	3.6	3.3	1881	9	0	0	253	24.2	22.1	51.0	51.6	9.6	8.7	1208	8
Range			175	1.7	0.8	1451	19	0	0	358	82.1	28.8	83.7	65.5	14.9	8.1	1438	22

Description: De Sale Phase 2 Passive Treatment System untreated influent (raw). Collected at the stream or the influent to the Forebay. Same as PA DEP POINT 23A

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
WETLAND	10/30/2000			7.9	7.9	2723	13	144	160	0	5.7	0.9	15.7	15.2	1.0	0.3	1897	26
WETLAND	1/8/2001			6.8	6.8	1729	0		59	27	6.2	4.6	46.3	42.8	0.4	0.2	1144	9
WETLAND	3/24/2001			6.5	7.1	1245	5	38	38	4	1.9	0.4	27.4	25.8	0.8	0.3	1020	11
WETLAND	4/20/2001			7.0	6.7	1154	9	34	34	14	2.9	0.1	25.9	24.9	0.4	0.0	874	16
WETLAND	5/7/2001			7.2	7.0		22				5.4		42.3		0.1		770	
WETLAND	6/6/2001			6.9	6.7	1739	18		51	15	1.2	0.2	29.7	27.4	0.2	0.0	1200	6
WETLAND	6/20/2001			6.8	6.8		24				0.1		39.6		0.0		1206	
WETLAND	8/2/2001			6.7	6.7	2051	23	54	68	44	1.8	1.7	53.5	52.5	0.2	0.1	1261	14
WETLAND	9/21/2001	Bucket	27	6.6	6.3		16		37	0	0.0	0.0	48.4	49.9	0.2	0.0	1054	
WETLAND	11/29/2001			6.5	6.9	1983	9		33	30	0.4	0.1	48.0	47.5	0.5	0.2	1703	4
WETLAND	2/21/2002			6.9	6.6		5				2.1		34.7		0.1		816	
WETLAND	3/14/2002			7.3	7.0	1413	15	79	36	0	0.5	0.1	40.2	37.1	0.1	0.0	980	6
WETLAND	6/10/2002				6.5	1292			31	32	1.5	0.4	30.9	29.6	0.2	0.2	719	10
WETLAND	3/28/2007	Estimate	300	4.9	4.8	1106	14	1	2	62	0.1	0.0	25.0	24.7	3.3	3.2	619	1
WETLAND	4/26/2007	Assumed	445	4.7	4.7	1230	17	4	1	30	0.2	0.2	27.0	19.2	4.3	3.8	679	5
WETLAND	5/23/2007	Assumed	150	4.7	4.8	1753	25	7	1	91	0.0	0.0	48.6	47.9	2.4	2.3	739	1
WETLAND	9/14/2007	Estimate	10	5.1	5.0	2112	23	16	2	117	0.3	0.2	64.8	63.8	3.4	3.3	1280	7
WETLAND	10/5/2007	Assumed	40	6.4	6.2	2351	20	18	13	82	0.2	0.1	55.1	54.9	0.5	0.1	1308	2
WETLAND	11/14/2007	Assumed	83	6.9	6.0	1911	11	36	31	55	0.6	0.5	47.4	46.4	0.4	0.3	1132	3
WETLAND	1/7/2008	Assumed	250	5.6	5.4	1111	4	7	3	39	0.4	0.3	20.4	19.8	2.2	0.9	539	5
Min			10	4.7	4.7	1106	0	1	1	0	0.0	0.0	15.7	15.2	0.0	0.0	539	1
Max			445	7.9	7.9	2723	25	144	160	117	6.2	4.6	64.8	63.8	4.3	3.8	1897	26
Avg			163	6.4	6.3	1681	14	37	35	38	1.6	0.6	38.5	37.0	1.0	0.9	1047	8
Range			435	3.2	3.3	1617	25	143	159	117	6.2	4.6	49.1	48.7	4.3	3.8	1358	25

Description: Wetland component of the De Sale Phase II passive treatment system; Effluent sampled at the spillway before entering the Horizontal Flow Limestone Bed.

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
OUT/HFLB	9/28/2000	Measured	60		7.2				250	0	9.7		9.4		0.8		1545	32
OUT/HFLB	9/29/2000	Measured	47	7.1			13			0	14.6		12.0		1.1			
OUT/HFLB	10/10/2000	Measured	49	7.4	7.3			219		0	10.9		9.9		0.4		1476	
OUT/HFLB	10/18/2000	Estimate	50		7.2				154	0	7.6		12.8		0.3		1556	36
OUT/HFLB	10/23/2000			7.2			12	110			3.2		14.9		0.1		1544	
OUT/HFLB	10/30/2000	Bucket	20	7.2	7.3	2575	13	141	157	0	4.9	3.3	15.8	15.6	0.9	0.2	1912	30
OUT/HFLB	11/14/2000	Measured	45		7.0				128	0	1.7		25.7		0.3		1266	18
OUT/HFLB	11/24/2000	Measured	30	7.1	7.0		4			0	1.4		38.0		0.1		1556	
OUT/HFLB	11/24/2000	Measured	30	7.1			4					0.3		38.9		0.0	1618	
OUT/HFLB	12/19/2000	Estimate	60		6.8				82	0	0.3		51.9		0.3		1677	6
OUT/HFLB	12/29/2000	Measured	50	7.0			1											
OUT/HFLB	1/8/2001			7.0	7.3	1758	1		95	0	0.2	0.1	44.0	41.0	0.2	0.1	1060	5
OUT/HFLB	1/17/2001	Measured	75		6.8				94	0	0.2		45.9		0.3		1130	36
OUT/HFLB	1/26/2001	Measured	42	6.8	7.1		1			0	0.0		47.0		0.0		1040	
OUT/HFLB	2/22/2001	Measured	95		6.9				60	0	0.4		17.6		0.3		504	
OUT/HFLB	3/20/2001	Measured	76	7.2			5											
OUT/HFLB	3/24/2001	Bucket	96	6.9	7.5	1267	5	60	64	0	0.3	0.0	21.7	20.6	0.1	0.1	1156	4
OUT/HFLB	3/29/2001	Measured	150		6.5				70	0	0.4		19.5		0.3		867	
OUT/HFLB	4/5/2001	Measured	85		7.1				76	0	0.4		14.8		0.3		611	
OUT/HFLB	4/20/2001	Bucket	100	7.2	7.2	1252	8	60	72	0	0.2	0.1	19.2	18.2	0.0	0.0	761	4
OUT/HFLB	5/4/2001	Measured	80		6.9				116	0	3.2		43.3		0.3		775	8
OUT/HFLB	5/7/2001	Bucket	51	7.7	6.8		19				1.8		75.0		0.3		843	
OUT/HFLB	6/6/2001	Bucket	60	7.2	7.3	1571	14		73	0	1.7	1.6	25.9	24.2	0.1	0.0	1004	10
OUT/HFLB	6/19/2001	Measured	70		6.7				82	0	10.8		35.8		0.3		1332	28
OUT/HFLB	6/20/2001	Bucket	48	7.2	6.7		23				11.3		36.7		0.0		1170	
OUT/HFLB	7/11/2001	Measured	60		6.6				72	0	5.5		49.5		0.3		1383	18
OUT/HFLB	8/2/2001			7.2	6.7	2022	21	72	73	35	9.1	5.8	47.3	46.3	0.0	0.0	1277	14
OUT/HFLB	8/30/2001	Measured	60		6.6				78	0	4.1		45.5		0.3		1491	14

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
OUT/HFLB	9/21/2001	Bucket	29	6.7	6.9		17		61	0	1.9		47.4		0.0		1055	
OUT/HFLB	10/18/2001	Measured	50		6.7				76	0	0.6		41.2		0.3		1420	10
OUT/HFLB	11/29/2001	Bucket	60	7.0	7.5	2045	9		86	0	0.2	0.1	17.0	16.4	0.2	0.1	1841	6
OUT/HFLB	2/14/2002	Measured	20		7.1				124	0	0.2		1.4		0.3		1042	8
OUT/HFLB	2/21/2002	Bucket	102	7.1	7.2		4				0.0		6.6		0.0		803	
OUT/HFLB	3/13/2002	Measured	180		6.7				108	0	0.2		0.0		0.3		861	2
OUT/HFLB	3/14/2002	Bucket	80	7.3	7.4	1550	5	103	109	0	0.2	0.1	2.6	2.6	0.1	0.0	839	6
OUT/HFLB	4/30/2002	Measured	80		6.5				98	0	0.2		2.0		0.3		982	6
OUT/HFLB	6/10/2002	Bucket	158		7.2	1380			67		0.2	0.1	12.5	11.7	0.2	0.2	676	4
OUT/HFLB	7/25/2002	Measured	120		7.1				58	0	0.2		51.3		0.3		1309	8
OUT/HFLB	10/8/2002	Measured	40		7.3				70	0	0.2		36.9		0.3		1334	8
OUT/HFLB	3/14/2003	Measured	200		6.6				35	0	0.2		13.1		0.3		414	0
OUT/HFLB	6/17/2003	Measured	200		6.4				58	0	0.2		7.6		0.3		735	6
OUT/HFLB	9/16/2003	Estimate	70		6.6				38	0	0.2		19.8		0.3		806	6
OUT/HFLB	10/29/2003	Measured	100		6.6				52	0	0.2		13.1		0.3		894	4
OUT/HFLB	3/30/2004	Measured	100		6.7				68	-44	0.2		9.3		0.3		635	6
OUT/HFLB	6/4/2004				7.1				65	7	0.2		21.2		0.3		866	8
OUT/HFLB	8/27/2004	Estimate	200		6.9				48	-13	0.2		15.2		0.3		623	0
OUT/HFLB	11/4/2004	Estimate	200		6.8				41	19	0.2		29.2		0.3		884	4
OUT/HFLB	3/29/2005	Estimate	200		6.5				42	-22	0.2		8.2		0.3		696	0
OUT/HFLB	6/9/2005	Measured	60		6.9				98	-72	0.2		5.7		0.3		1036	0
OUT/HFLB	8/19/2005	Estimate	60		7.0				106	-40	0.2		28.9		0.2		1255	0
OUT/HFLB	11/3/2005	Estimate	75		6.6				34	34	0.2		25.2		0.3		1119	0
OUT/HFLB	3/21/2006	Estimate	25		6.7				43	-18	0.2		12.2		0.9		611	6
OUT/HFLB	6/21/2006	Estimate	100		6.8				78	-59	0.4		6.7		0.3		964	12
OUT/HFLB	9/7/2006	Estimate	75		6.9				57	-40	0.2		2.0		0.3		677	0
OUT/HFLB	11/2/2006	Estimate	50		6.8				31	-12							543	0
OUT/HFLB	3/28/2007	Bucket	10	5.8	5.8	1061	15		6	31	0.0	0.0	19.6	19.1	2.5	0.8	616	5

De Sale I and II Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
OUT/HFLB	4/26/2007	Measured	445	6.1	6.2	1261	13	22	12	-4	0.2	0.1	20.9	19.0	0.9	0.4	653	5
OUT/HFLB	5/23/2007	Bucket	150	6.3	6.4	1724	22	45	36	-27	0.0	0.0	19.2	18.8	0.3	0.3	759	2
OUT/HFLB	9/14/2007	Estimate	10	6.5	6.8	2102	19	58	42	5	0.2	0.1	30.8	30.1	0.2	0.1	1297	3
OUT/HFLB	10/5/2007	Bucket	40	6.9	6.9	2370	18	87	83	-73	0.1	0.0	9.8	9.8	0.3	0.1	1322	2
OUT/HFLB	11/14/2007	Bucket	83	6.8	6.3	1900	9	71	67	-52	0.1	0.1	8.8	8.7	0.2	0.2	1124	3
OUT/HFLB	1/7/2008	Bucket	250	6.5	6.2	1110	3	25	26	-13	0.1	0.0	8.6	7.8	0.3	0.2	520	5
Min			10	5.8	5.8	1061	1	22	6	-73	0.0	0.0	0.0	2.6	0.0	0.0	414	0
Max			445	7.7	7.5	2575	23	219	250	35	14.6	5.8	75.0	46.3	2.5	0.8	1912	36
Avg			90	6.9	6.8	1684	11	83	75	-7	1.9	0.7	23.0	20.5	0.3	0.2	1047	8
Range			435	1.9	1.7	1514	22	197	244	108	14.6	5.8	75.0	43.7	2.5	0.8	1498	36

Description: Horizontal Flow Limestone Bed; De Sale Phase 2 Passive System; Effluent sampled from discharge pipe at spillway; Effluent of the entire passive treatment system.

De Sale Phase III Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	T. Fe (mg/L)	D. Fe (mg/L)	T. Mn (mg/L)	D. Mn (mg/L)	T. Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
DEP RAW	10/8/2002				3.0				0	842	128.0		143.0		28.7		2244	52
DEP RAW	3/14/2003				3.4				0	355	70.0		62.7		6.0		1173	24
DEP RAW	6/17/2003				3.0				0	552	95.4		108.0		25.8		1439	24
DEP RAW	9/11/2003				3.0				0	641	107.0		115.0		25.2		2229	20
DEP RAW	10/30/2003				3.2				0	672	111.0		101.0		20.2		1409	22
DEP RAW	3/30/2004				3.3				0	439	98.8		90.1		15.0		1390	
DEP RAW	6/4/2004				3.0				0	504	96.7		98.1		15.6		2069	10
DEP RAW	8/27/2004				3.1				0	464	106.0		101.0		14.7		2170	16
DEP RAW	11/4/2004				3.4				0	458	120.0		96.6		16.7		1370	4
DEP RAW	3/29/2005				3.4				0	539	111.0		93.2		13.5		1045	6
DEP RAW	6/9/2005				3.1				0	543	105.0		99.0		14.5		1747	26
DEP RAW	8/19/2005				2.9				0	580	96.1		105.0		18.0		2392	8
DEP RAW	11/3/2005				3.1				0	601	127.0		111.0		23.7		2848	6
DEP RAW	3/23/2006				3.4				0	458	73.3		67.8		12.0		1440	10
DEP RAW	6/21/2006				3.0				0	647	76.0		92.2		20.3		2202	10
DEP RAW	9/7/2006				3.1				0	511	97.4		93.9		21.3		1942	2
DEP RAW	11/2/2006				3.2				0	475	129.9		105.5		24.7		2100	6
Min					2.9				0	355	70.0		62.7		6.0		1045	2
Max					3.4				0	842	129.9		143.0		28.7		2848	52
Avg					3.2				0	546	102.9		99.0		18.6		1836	15
Range					0.5				0	487	59.9		80.3		22.7		1804	51

Description: De Sale Phase 3 Passive Treatment System raw AMD; PA DEP point; collection ditch influent to Forebay

De Sale Phase III Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	T. Fe (mg/L)	D. Fe (mg/L)	T. Mn (mg/L)	D. Mn (mg/L)	T. Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
SP2	12/12/2002	Not Flowing	0															
SP2	3/10/2003	Assumed	29	6.6	7.0	1463	1		59	-2	0.9	0.6	38.9	38.1	0.5	0.2	893	7
SP2	4/24/2003	Assumed	16	6.8	6.7	2611	9		53	98	6.3	0.5	76.3	71.1	0.2	0.1	3701	16
SP2	6/30/2003	Assumed	8	7.5	8.1	2475	25		38	52	2.2	0.1	68.6	54.6	0.2	0.1	1688	28
SP2	8/28/2003	Assumed	6	8.3	7.8	2225	29	90	80	22	1.1	0.1	73.7	73.1	0.2	0.1	1883	14
SP2	10/29/2003	Assumed	17	6.9	6.6	2542	10	32	37	101	0.5	0.1	96.1	95.7	0.4	0.2	1948	9
SP2	3/25/2004	Assumed	38	5.0	4.6	2340			1	150	5.0	2.5	73.4	72.8	6.8	5.8	1503	4
SP2	4/28/2004			6.0														
SP2	6/24/2004			6.6														
SP2	10/25/2004			5.4														
SP2	1/17/2007			5.0			6	4										
SP2	3/28/2007	Assumed	40	5.6	5.4	1940	13	8	4	120	0.4	0.1	69.8	67.4	1.8	1.2	1128	4
SP2	4/17/2007			4.9														
SP2	4/26/2007	Bucket	64	5.3	5.0	2200	14	11	3	132	2.3	1.6	88.3	83.1	3.4	2.6	1307	7
SP2	5/23/2007	Assumed	20	6.0	6.0	2749	18	19	16	152	3.4	2.5	100.7	100.2	0.9	0.8	1786	7
Min			0	4.9	4.6	1463	1	4	1	-2	0.4	0.1	38.9	38.1	0.2	0.1	893	4
Max			64	8.3	8.1	2749	29	90	80	152	6.3	2.5	100.7	100.2	6.8	5.8	3701	28
Avg			24	6.1	6.4	2283	14	27	32	92	2.4	0.9	76.2	72.9	1.6	1.2	1760	11
Range			64	3.4	3.5	1286	28	86	79	154	5.9	2.5	61.7	62.1	6.7	5.7	2808	24

Description: Settling Pond 2: Pre-existing treatment pond #3; Sampled at spillway; The effluent of this pond was previously sample point 10C which had been moved after the construction of the passive system to effluent of the HFLB

De Sale Phase III Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	T. Fe (mg/L)	D. Fe (mg/L)	T. Mn (mg/L)	D. Mn (mg/L)	T. Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
HFLB	10/8/2002		0															
HFLB	12/12/2002	Not Flowing	0	7.2				65										
HFLB	3/10/2003	Measured	30	6.9	7.1	1525	0	63	70	8	0.2	0.1	38.5	38.0	0.3	0.1	885	9
HFLB	3/14/2003	Measured	40		6.9				67	0	0.0		37.1		0.0		651	4
HFLB	4/24/2003	Measured	10	7.0	7.0	2555	12	70	66	81	1.1	0.1	73.9	72.9	0.1	0.0	1838	12
HFLB	6/17/2003	Measured	12		6.2				60	116	0.4		58.1		0.0		1204	14
HFLB	6/30/2003	Bucket	8	7.1	7.1	2518	20	67	64	42	2.6	2.1	69.3	65.5	0.1	0.1	1851	9
HFLB	8/28/2003	Bucket	5	7.2	7.4	2212	18	74	77	21	0.7	0.7	70.0	68.2	0.2	0.1	1783	10
HFLB	9/11/2003	Measured	10		7.0				82	0	0.0		34.5		0.0		929	4
HFLB	10/29/2003	Bucket	13	7.0	6.7	754	10		50	85	0.1	0.1	91.9	90.4	0.1	0.1	369	5
HFLB	10/30/2003	Measured	12		7.0				57	0	0.0		79.1		0.0		1236	20
HFLB	3/25/2004	Assumed	38	6.1	6.2	2413		35	34	85	0.2	0.1	65.6	65.0	0.9	0.5	1304	8
HFLB	3/30/2004	Measured	20		6.2				37	113	1.3		66.7		1.7		1171	6
HFLB	4/9/2004	Bucket	30	6.4														
HFLB	4/28/2004	Bucket	26	6.5														
HFLB	5/25/2004			6.8														
HFLB	6/4/2004	Measured	20		7.0				57	151	0.0		71.9		0.0		1725	10
HFLB	6/24/2004	Bucket	11	7.3														
HFLB	8/27/2004	Measured	10		7.0				78	-11	0.0		30.5		0.0		957	12
HFLB	9/10/2004			7.0														
HFLB	10/20/2004	Bucket	18	6.7														
HFLB	10/25/2004			6.6														
HFLB	11/4/2004	Measured	15		7.0				83	105	0.0		72.6		0.0		1370	0
HFLB	3/29/2005	Measured	20		6.5				60	76	0.0		45.3		0.0		1426	
HFLB	6/9/2005	Measured	12		7.0				82	123	0.0		75.6		0.0		1981	
HFLB	8/12/2005		0															
HFLB	8/19/2005	Estimated	0															
HFLB	11/3/2005	Measured	8		7.0				77	86	0.0		51.0		0.0		1686	
HFLB	3/23/2006	Measured	15		7.0				79	-7	0.0		20.8		0.0		1333	

De Sale Phase III Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	T. Fe (mg/L)	D. Fe (mg/L)	T. Mn (mg/L)	D. Mn (mg/L)	T. Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
HFLB	6/21/2006	Measured	8		6.8				97	28	0.0		43.5		0.0			
HFLB	9/7/2006	Measured	15		7.1				74	24	0.0		41.7		0.0		1379	0
HFLB	11/2/2006	Measured	20		7.1				65	-18	0.2		37.3		0.5		1276	2
HFLB	1/17/2007			6.2			5		51									
HFLB	3/28/2007		40	6.4	6.3	1947	12	34	39	-15	0.0	0.0	47.4	46.7	0.4	0.3	1189	1
HFLB	4/17/2007	Bucket	52	6.1				29										
HFLB	4/26/2007	Measured	64	6.3	6.4	2270	13	36	28	72	0.1	0.1	67.8	63.7	0.7	0.5	1307	4
HFLB	5/23/2007	Bucket	20	6.3	6.4	2740	17	58	49	87	0.0	0.0	82.2	79.6	0.2	0.2	1786	14
Min			0	6.1	6.2	754	0	29	28	-18	0.0	0.0	20.8	38.0	0.0	0.0	369	0
Max			64	7.3	7.4	2740	20	74	97	151	2.6	2.1	91.9	90.4	1.7	0.5	1981	20
Avg			18	6.7	6.8	2104	12	53	63	52	0.3	0.4	57.2	65.6	0.2	0.2	1332	8
Range			64	1.2	1.2	1986	20	45	69	169	2.6	2.0	71.1	52.4	1.7	0.5	1613	20

Description: Horizontal Flow Limestone Bed; at effluent pipe; passive treatment system final effluent; zero indicates below detection limit; samples collected by DEP, BMI, and others

Erico Bridge Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (Field) (mg/L)	Alk. (lab) (mg/L)	Acidity (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
ST 63E	10/12/1994				6.1				124	132	101.0	42.6	0.3	853	3
ST 63E	6/7/1995				5.9				84	154	78.1	30.7	0.3	939	18
ST 63E	6/28/1995		413		6.0				32	134	62.9	33.1	0.3	985	48
ST 63E	8/16/1995		108		5.7				22	194	62.9	41.0	0.3	1094	64
ST 63E	9/12/1995		40		6.0				26	152	51.1	40.7	0.3	1177	26
ST 63E	10/11/1995		40		3.4				0	128	8.2	34.3	0.9	901	8
ST 63E	11/15/1995		5		4.0				2	62	6.6	24.2	1.0	698	3
ST 63E	12/27/1995		78		6.1				30	142	30.0	36.8	0.3	1071	3
ST 63E	2/22/1996		331		5.8				24	148	70.2	41.4	0.3	1056	23
ST 63E	3/13/1996		524		5.8				26	188	65.6	35.3	0.3	1152	48
ST 63E	4/30/1996		466		4.3				5	17	5.9	5.6	0.3	319	11
ST 63E	5/9/1996		485		6.1				32	152	65.1	34.6	0.3	1156	31
ST 63E	6/18/1996		379		5.8				26	176	65.4	35.5	0.3	1171	46
ST 63E	7/9/1996		302		5.9				24	158	62.5	36.1	0.3	1168	36
ST 63E	8/15/1996		139		5.8				20	190	59.3	38.9	0.3	986	25
ST 63E	9/10/1996		106		5.7				22	192	57.6	41.1	0.3	1117	30
ST 63E	10/15/1996		158		5.9				22	172	58.7	39.6	0.3	1073	42
ST 63E	11/19/1996		395		5.8				26	184	63.2	37.2	0.3	999	62
ST 63E	1/23/1997		63		5.9				34	176	62.9	34.1	0.3	1043	8
ST 63E	2/27/1997		95		5.6				32	140	59.9	32.2	0.3	986	56
ST 63E	3/19/1997		51		6.1				30	110	48.6	23.9	0.3	849	16
ST 63E	5/20/1997		302		6.0				30	166	62.6	33.3	0.3	1014	44
ST 63E	8/6/1997		122		5.9				26	168	62.4	38.0	0.3	1033	24
ST 63E	10/9/1997		106		6.0				24	156	38.5	37.6	0.3	1022	6
ST 63E	1/7/1998		248		5.7				26	124	61.1	39.3	0.3	1013	26
ST 63E	5/14/1998	Measured	544		6.0				32	136	56.5	30.6	0.3	875	50
ST 63E	12/7/1999				3.8				0	74	2.1	23.6	0.3	848	2
ST 63E	3/30/2000	Measured	178		6.0				118	96	80.5	32.3	0.3	1017	20
ST 63E	1/15/2001	Weir	83	6.3			5	64							

Erico Bridge Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (Field) (mg/L)	Alk. (lab) (mg/L)	Acidity (mg/L)	Iron (mg/L)	Manganese (mg/L)	Aluminum (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
ST 63E	1/18/2001	Measured	66		6.4				44	114	40.3	36.5	0.3	922	4
ST 63E	2/2/2001	Weir	76												
ST 63E	5/8/2001	Measured	300		6.1				108	80	77.3	30.4	0.3	931	6
ST 63E	3/7/2002	Weir	106	6.3	6.0	1753	12		9	121	44.2	37.6	0.2	1124	17
ST 63E	10/8/2002				5.9				90	272	116.0	33.3	0.3	1339	6
Min			5	6.3	3.4	1753	5	64	0	17	2.1	5.6	0.2	319	2
Max			544	6.3	6.4	1753	12	64	124	272	116.0	42.6	1.0	1339	64
Avg			210	6.3	5.7	1753	9	64	36	144	55.8	34.1	0.3	998	25
Range			539	0.0	3.0	0	7	0	124	255	113.9	37.0	0.8	1020	63

Description: Abandoned mine discharge (raw); Largest of the discharges; Flows were measured at 90 degree V-Notch weir at the abandoned railroad grade. Currently collected in anoxic collection system 1 and conveyed into ALD1

Erico Bridge Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
WL2@PP2	7/23/2003	Assumed	270	6.8	6.7	1400	19	46	52	-22	7.1	3.5	20.2	19.7	0.1	0.0	1002	5
WL2@PP2	7/30/2003				6.6				61	0	9.2		17.6		0.3		645	18
WL2@PP2	9/16/2003				6.8				98	0	12.5		22.8		0.3		930	18
WL2@PP2	10/30/2003				6.9				100	0	18.5		24.8		0.3		743	34
WL2@PP2	10/30/2003	Assumed	400	7.1	6.6	1605	12	101	76	-23	16.8	11.8	27.5	27.2	0.2	0.0	1004	24
WL2@PP2	3/23/2004				6.8				102	-27	27.2		24.2		0.3		797	76
WL2@PP2	3/25/2004	Assumed	600	7.2	6.7	1487		100	76	-44	23.3	15.9	19.3	19.2	0.2	0.1	721	23
WL2@PP2	6/8/2004	Assumed	550	6.8	6.7	1553		89	86	-47	3.3	1.6	16.9	16.7	0.1	0.0	1114	3
WL2@PP2	6/16/2004				6.7				86	-12	3.3		21.7		0.3		780	20
WL2@PP2	7/20/2004	Assumed	400	6.8	6.6	1603	20	80	74	-31	2.7	0.3	15.7	14.9	0.0	0.0	1189	7
WL2@PP2	8/20/2004				6.6				64	-4	0.2		16.2		0.3		619	2
WL2@PP2	9/1/2004	Assumed	430	6.8	6.7	1430	22	40	44	-6	1.2	0.2	9.3	8.8	0.1	0.0	869	1
WL2@PP2	11/5/2004				6.3				53	-26	0.7		7.8		0.3		775	4
WL2@PP2	3/28/2007			7.0	6.7	1373	19	96	87	3	5.7	2.6	19.7	19.6	0.1	0.0	690	1
WL2@PP2	4/26/2007	Estimated	1000	6.7	7.0	2163	17	91	137	-75	7.8	3.3	20.2	19.9	0.1	0.1	1272	17
WL2@PP2	5/23/2007	Estimated	1000	6.8	6.8	1473	28	94	82	-42	2.9	0.3	25.8	24.9	0.7	0.3	584	6
Min			270	6.7	6.3	1373	12	40	44	-75	0.2	0.2	7.8	8.8	0.0	0.0	584	1
Max			1000	7.2	7.0	2163	28	101	137	3	27.2	15.9	27.5	27.2	0.7	0.3	1272	76
Avg			581	6.9	6.7	1565	20	82	80	-22	8.9	4.4	19.4	19.0	0.2	0.1	858	16
Range			730	0.5	0.7	790	16	61	93	78	27.1	15.7	19.7	18.4	0.6	0.2	687	75

Description: Wetland 2; Sampled at Plunge Pond 2; Receives influent from Settling Pond 3 (SP3), Settling Pond 4 (SP4) and several seeps (SEEP) and discharges to the Horizontal Flow Limestone Bed (HFLB)

For laboratory reported values that were noted as less than the minimum detection limit for that parameter, one half of the minimum detection limit was entered

Erico Bridge Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
HFLB	7/23/2003	Measured	270	7.4	7.4	1456	21	100	114	-106	0.1	0.1	0.1	0.1	0.1	0.0	969	2
HFLB	7/30/2003				7.3				115	0	0.2		0.1		0.3		595	2
HFLB	9/16/2003				7.1				149	0	0.2		0.2		0.3		919	4
HFLB	10/30/2003	Measured	400	7.2	7.0	1610	10	140	140	-111	0.1	0.1	0.9	0.8	0.0	0.0	1113	1
HFLB	10/30/2003				7.1				149	0	0.2		0.8		0.3		775	8
HFLB	3/23/2004				7.0				109	-55	9.3		16.2		0.3		855	26
HFLB	3/25/2004	Measured	600	7.2	7.0	1497		109	94	-73	8.1	5.5	13.1	13.1	0.2	0.0	721	8
HFLB	6/8/2004	Measured	550	7.2	7.0	1570	19	125	110	-92	0.2	0.1	4.7	3.8	0.1	0.0	910	4
HFLB	6/16/2004				6.9				114	-90	0.2		4.2		0.3		746	14
HFLB	7/20/2004	Measured	400	7.2	6.9	1580	20	109	107	-81	0.1	0.0	0.7	0.7	0.1	0.0	1054	1
HFLB	8/20/2004				7.1				93	-64	0.2		2.0		0.3		709	2
HFLB	9/1/2004	Measured	430	7.3	7.2	1433	20	83	75	-49	0.1	0.1	0.5	0.5	0.0	0.0	660	4
HFLB	9/8/2004	Measured	700	7.2														
HFLB	11/5/2004				6.6				81	-54	0.2		5.4		0.3		711	2
HFLB	3/23/2005				7.0				104	0	4.0		15.5		0.0		848	8
HFLB	3/23/2005				7.0				104	0	4.0		15.5		0.0		848	8
HFLB	6/15/2005				7.0				103	-15	0.0		8.1		0.0		915	0
HFLB	6/15/2005				7.0				103	-15	0.0		8.1		0.0		915	0
HFLB	8/11/2005				7.0				87	-50	0.0		5.4		0.0		943	12
HFLB	8/11/2005				7.0				87	-50	0.0		5.4		0.0		943	12
HFLB	10/28/2005				6.7				58	-37	0.0		1.1		0.0		801	12
HFLB	10/28/2005				6.7				58	-37	0.0		1.1		0.0		801	12
HFLB	3/10/2006				6.9				141	-33	1.7		6.0		0.0		758	0
HFLB	3/10/2006				6.9				141	-32	1.7		6.0		0.0		758	0
HFLB	6/28/2006				6.9				138	-123	0.0		2.5		0.0		763	26
HFLB	6/28/2006				6.9				138	-123	0.0		2.5		0.0		763	26
HFLB	8/30/2006				7.2				158	-144	0.0		1.2		0.0		786	0
HFLB	8/30/2006				7.2				158	-144	0.0		1.2		0.0		786	0

For laboratory reported values that were noted as less than the minimum detection limit for that parameter, one half of the minimum detection limit was entered

Erico Bridge Water Quality Database

Sample Point	Date	Method of Flow Meas.	Flow (gpm)	Field pH	Lab pH	Spec. cond. (umhos/cm)	Field Temp (C)	Alk. (F) (mg/L)	Alk. (L) (mg/L)	Acid. (mg/L)	Fe (mg/L)	D. Fe (mg/L)	Mn (mg/L)	D. Mn (mg/L)	Al (mg/L)	D. Al (mg/L)	Sulfate (mg/L)	Susp. Solids (mg/L)
HFLB	10/31/2006				7.5				130	-115	0.0		0.6		0.0		715	0
HFLB	10/31/2006				7.5				130	-115	0.0		0.6		0.0		715	0
HFLB	3/28/2007			7.0	6.9	1350	17	103	94	-69	5.3	2.6	17.9	17.4	0.0	0.0	716	9
HFLB	4/26/2007	Estimated	1000	7.0	6.9	1347	17	102	86	-58	8.5	3.8	18.3	18.1	0.1	0.1	706	9
HFLB	5/23/2007	Estimated	1000	7.2	7.0	1522	27	97	90	-54	1.2	0.0	19.6	19.5	0.2	0.1	584	3
Min			270	7.0	6.6	1347	10	83	58	-144	0.0	0.0	0.1	0.1	0.0	0.0	584	0
Max			1000	7.4	7.5	1610	27	140	158	0	9.3	5.5	19.6	19.5	0.3	0.1	1113	26
Avg			594	7.2	7.0	1485	19	108	111	-62	1.4	1.3	5.8	8.2	0.1	0.0	806	7
Range			730	0.4	0.9	263	17	57	101	144	9.3	5.5	19.5	19.4	0.3	0.1	528	26

Description: Horizontal Flow Limestone Bed; Sampled at effluent pipe; Receives flow from Wetland 2 via Plunge Pond 2; Discharges to Seaton Creek; One of two final effluent discharge points of the passive treatment complex

For laboratory reported values that were noted as less than the minimum detection limit for that parameter, one half of the minimum detection limit was entered

LABORATORY REPORT

Biomost, Inc.		Report Date:	April 1, 2008
3016 Unionville, Rd		Samples Received:	March 18, 2008
Cranberry Twp., PA 16066		RJ Lee Group Job No.:	PA180320080026
ATTENTION:	Mr. Cliff Denholm	Client Job No.:	N/A
Telephone:	(724) 776-0161	Purchase Order No.:	N/A

ANALYSIS: X-ray diffraction (XRD) for crystalline phases

A portion of each sample was ground, mixed with a CaF_2 internal standard and mounted into a standard XRD holder for analysis. The samples were run on a PANalytical X'Pert Pro diffractometer using copper radiation. The resulting diffraction patterns were then analyzed using the X'Pert HighScore program utilizing the ICDD database.

Client Sample No.: MN1
RJ Lee Group Sample No.: PA180320080026-001

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

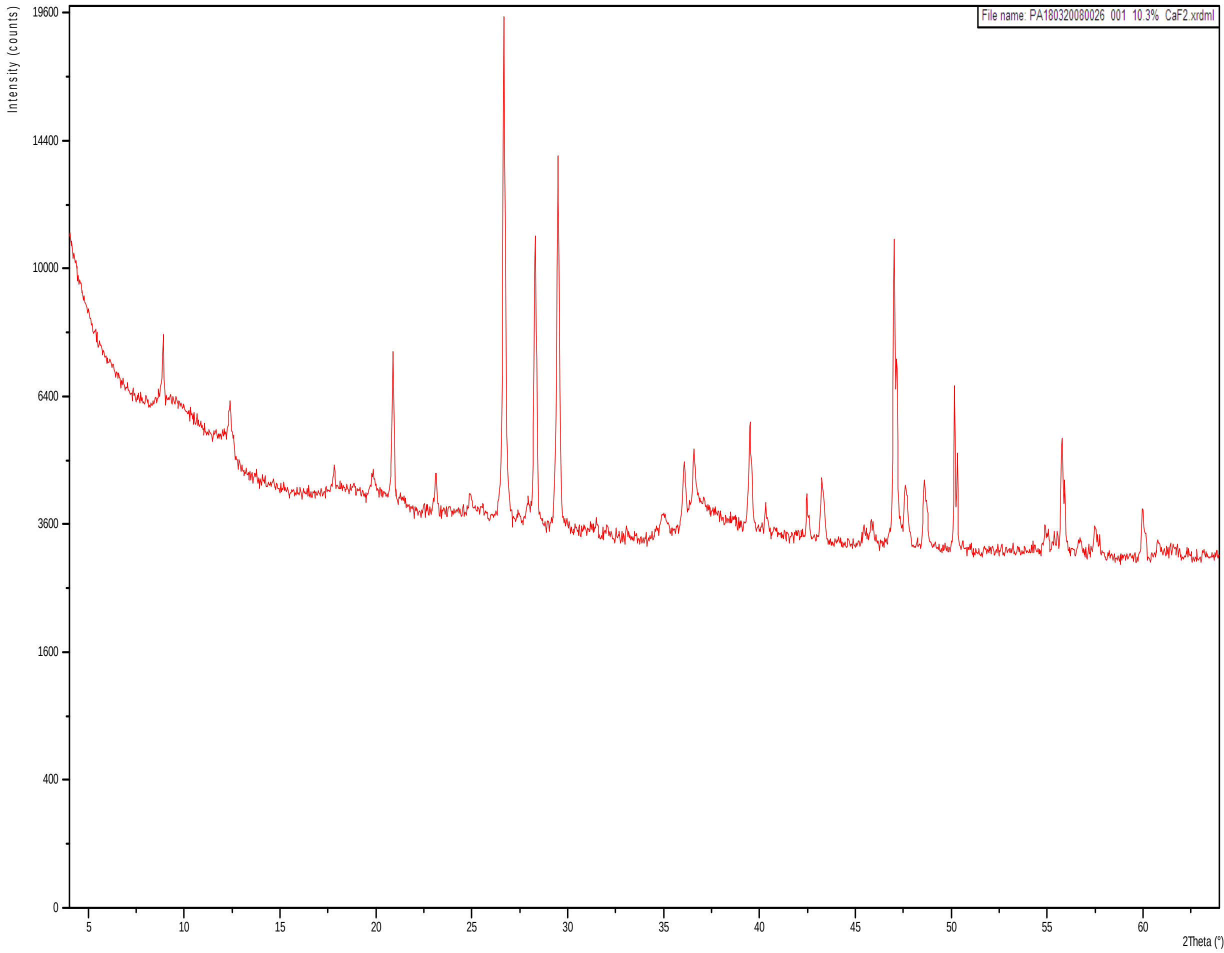

Figure 1 –X-ray diffraction pattern of the sample labeled "MN1", with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: MN2
RJ Lee Group Sample No.: PA180320080026-002

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

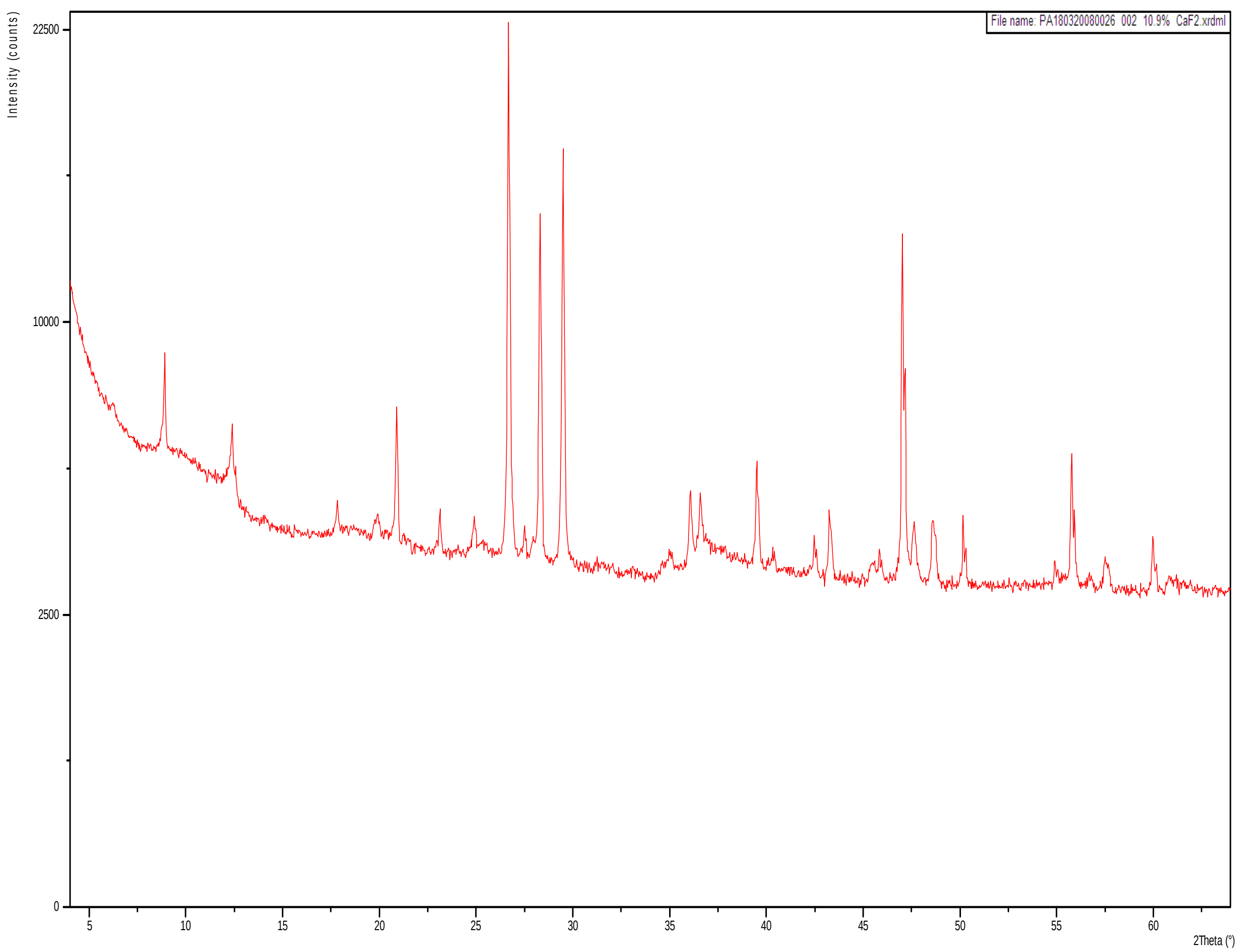

Figure 2 –X-ray diffraction pattern of the sample labeled "MN2", with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: COM1A
RJ Lee Group Sample No.: PA180320080026-003

Phase	Composition	Concentration
Pyrolusite	MnO_2	Major
Quartz	SiO_2	Minor
Cryptomelane	$(Na,K,Ba)(Mn^{4+},Mn^{2+})_3O_{16}$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Trace
Amorphous*	-	

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

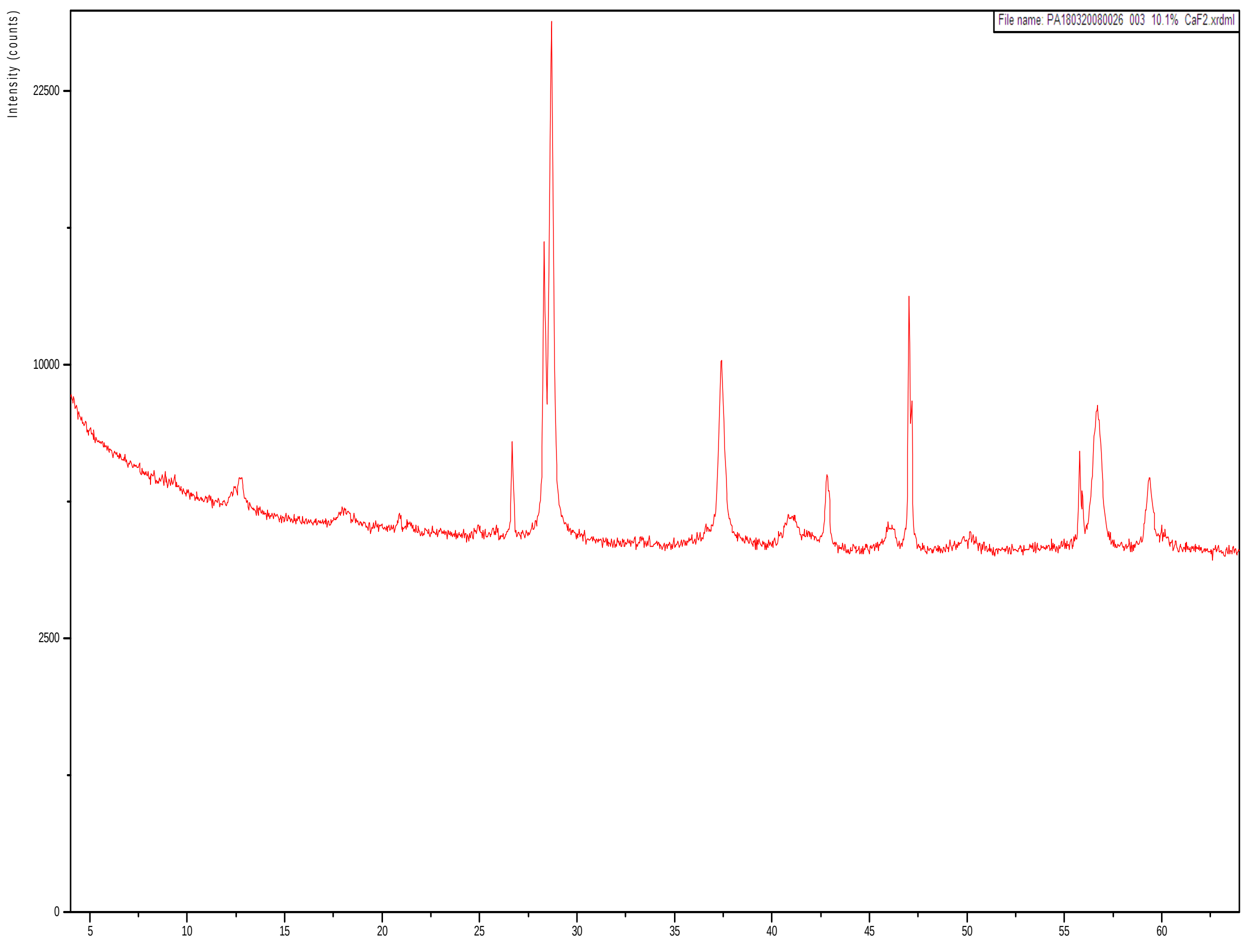

Figure 3 –X-ray diffraction pattern of the sample labeled "COM1A", with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 22C1
RJ Lee Group Sample No.: PA180320080026-004

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

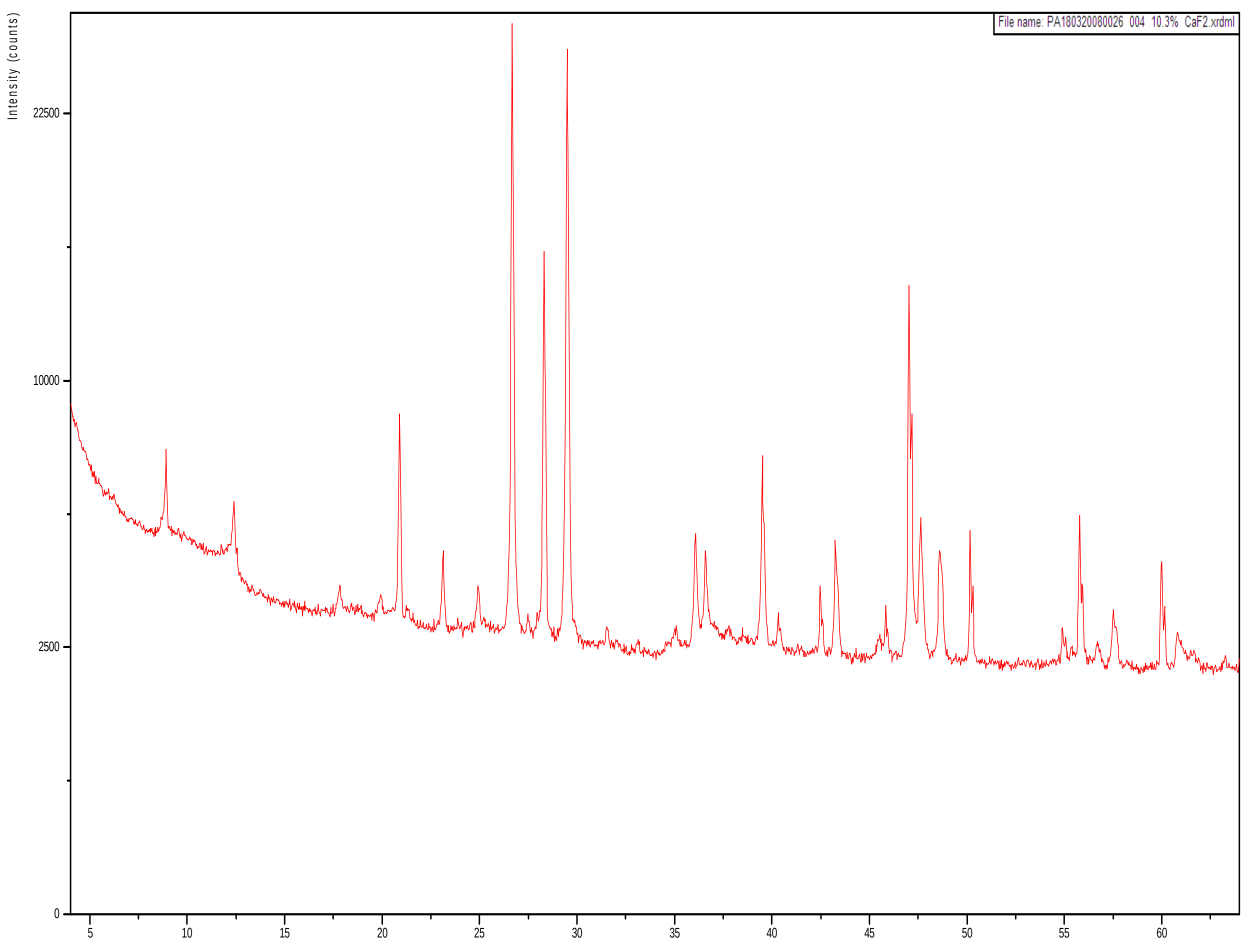

Figure 4 –X-ray diffraction pattern of the sample labeled "22C1", with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 25A1
RJ Lee Group Sample No.: PA180320080026-005

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

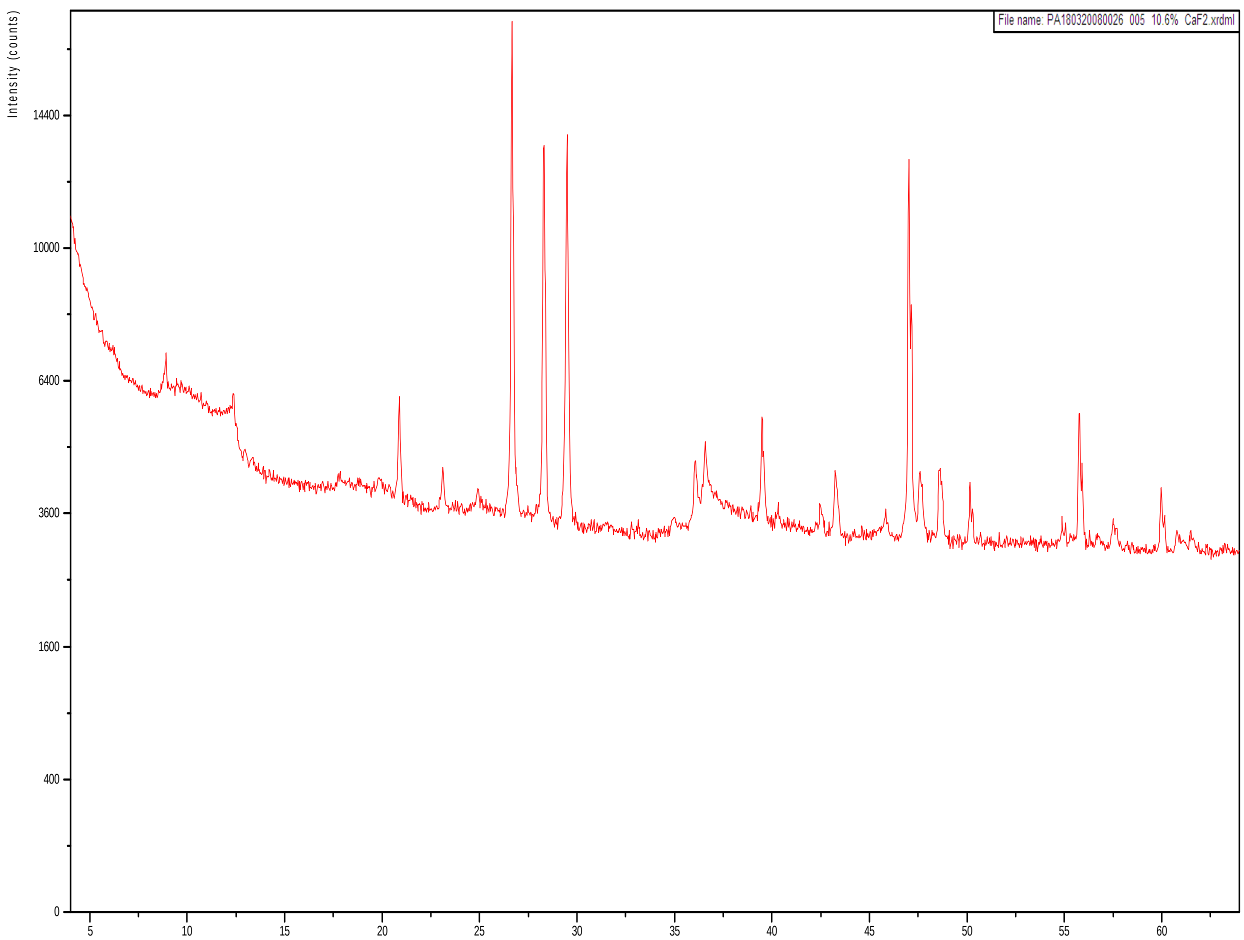

Figure 5 –X-ray diffraction pattern of the sample labeled “25A1”, with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 6C1
RJ Lee Group Sample No.: PA180320080026-006

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

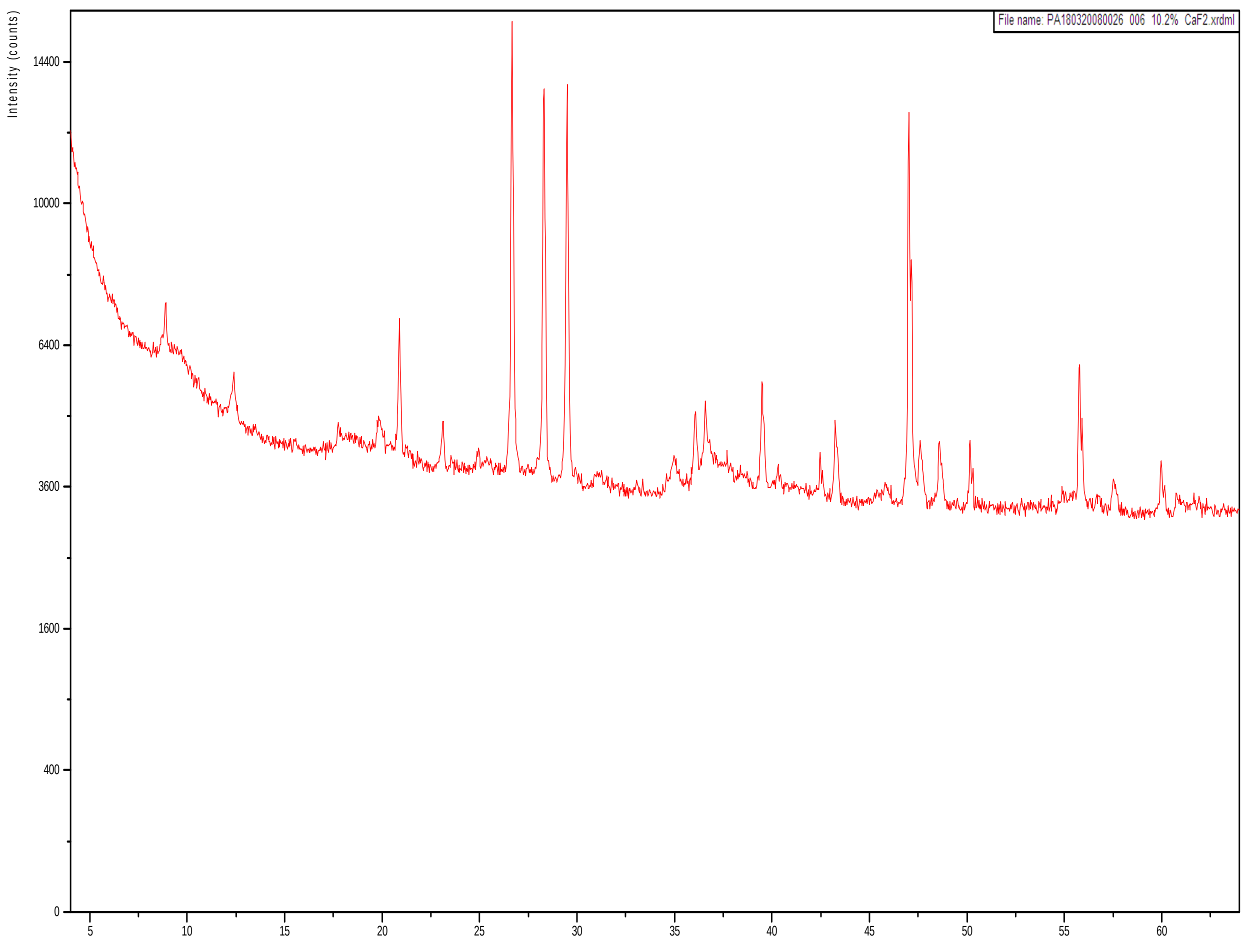

Figure 6 –X-ray diffraction pattern of the sample labeled “6C1”, with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 32C1
RJ Lee Group Sample No.: PA180320080026-007

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

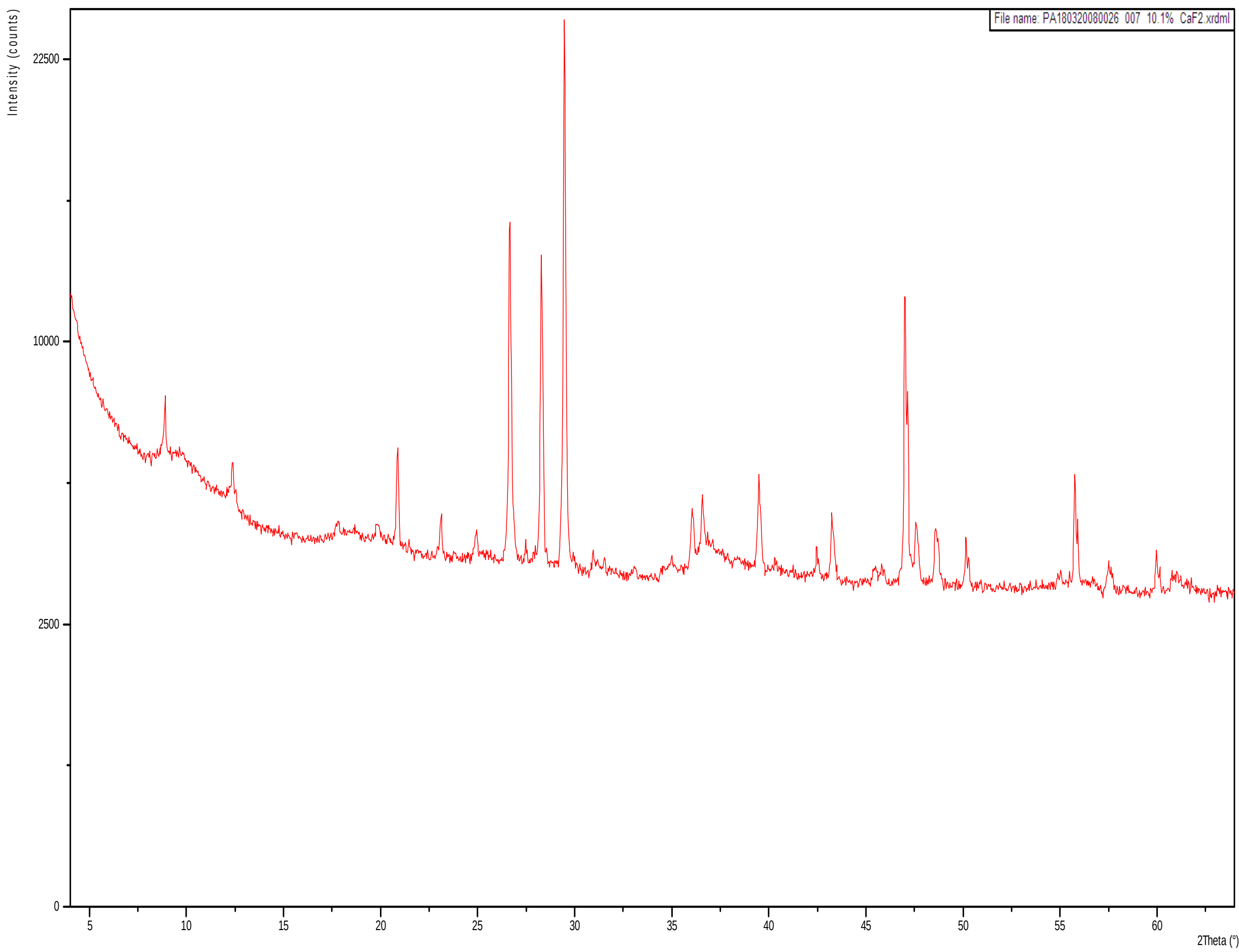

Figure 7 –X-ray diffraction pattern of the sample labeled “32C1”, with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 28A1
RJ Lee Group Sample No.: PA180320080026-008

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

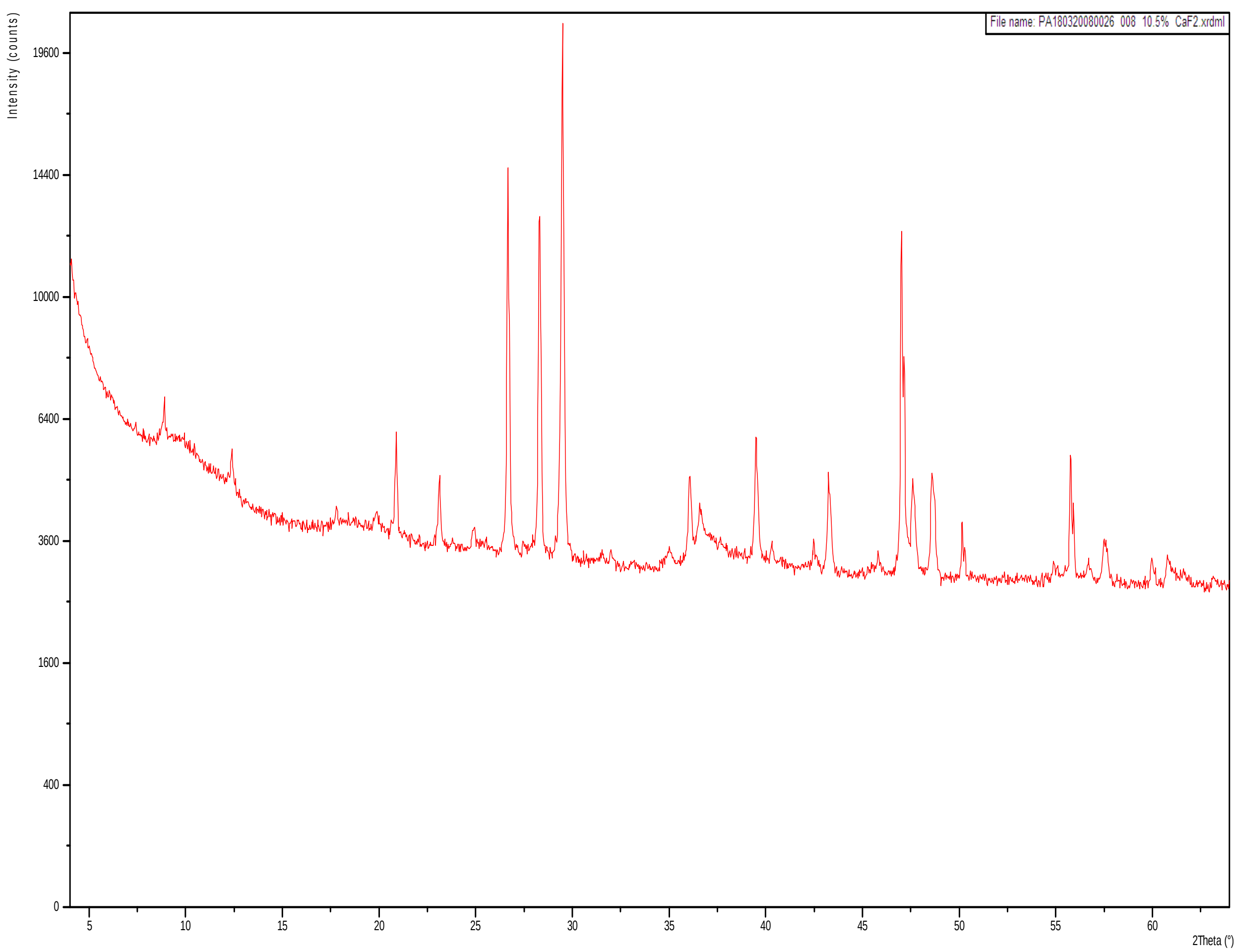

Figure 8 –X-ray diffraction pattern of the sample labeled "28A1", with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 5A1
RJ Lee Group Sample No.: PA180320080026-009

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

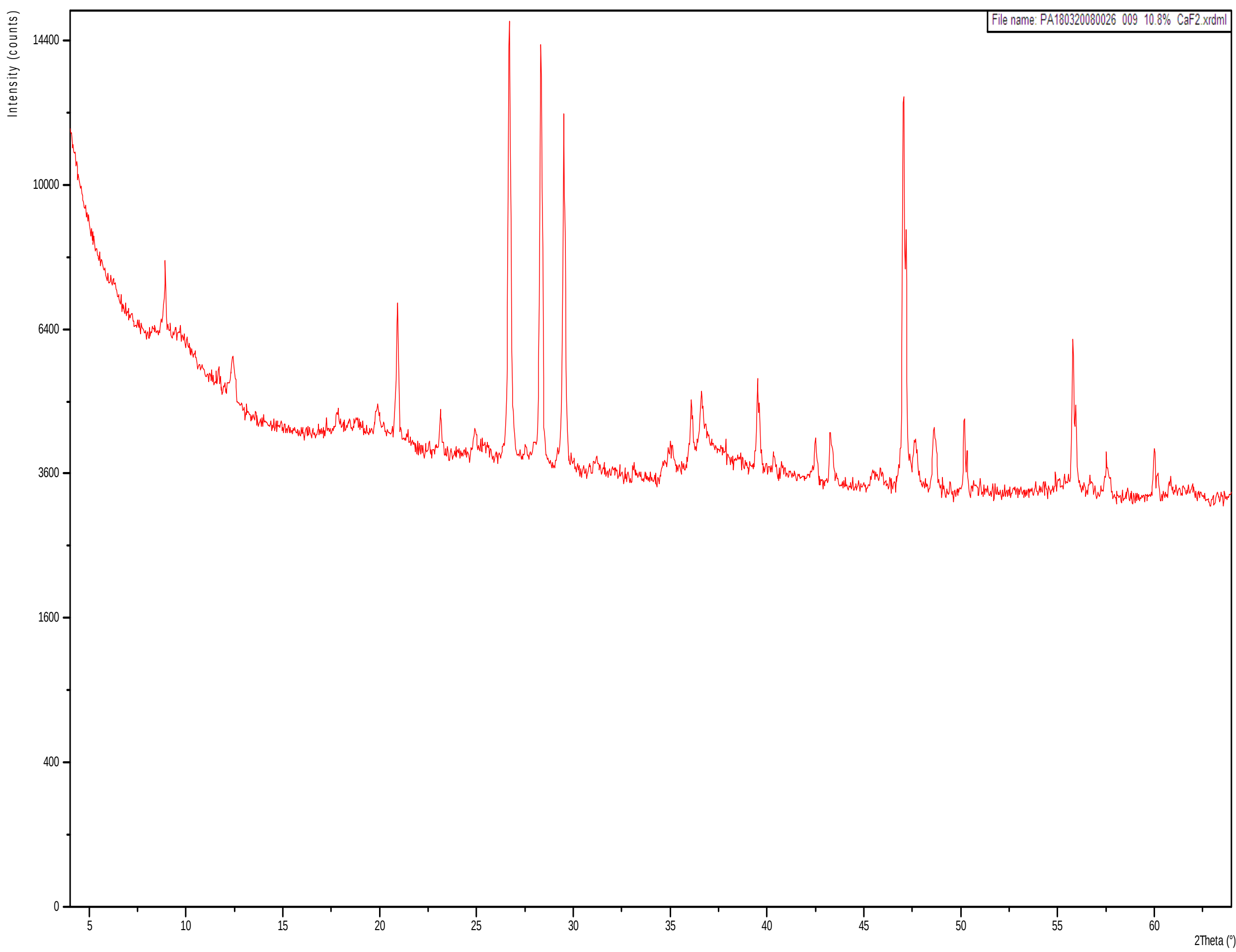

Figure 9 –X-ray diffraction pattern of the sample labeled “28A1”, with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 15C1
RJ Lee Group Sample No.: PA180320080026-010

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

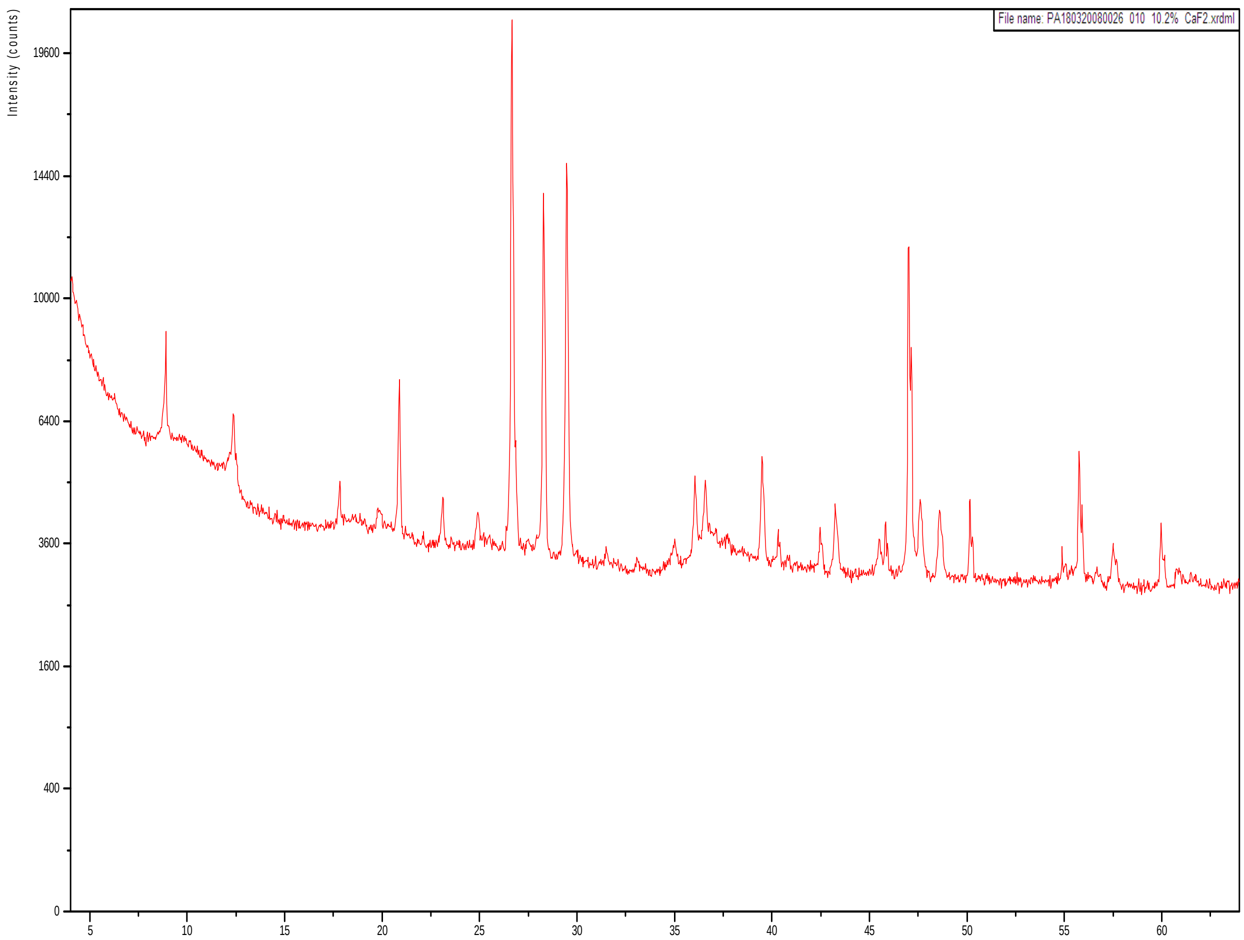

Figure 10 –X-ray diffraction pattern of the sample labeled “15C1”, with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: 14A1
RJ Lee Group Sample No.: PA180320080026-011

Phase	Composition	Concentration
Quartz	SiO_2	Major
Calcite	$CaCO_3$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Minor
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

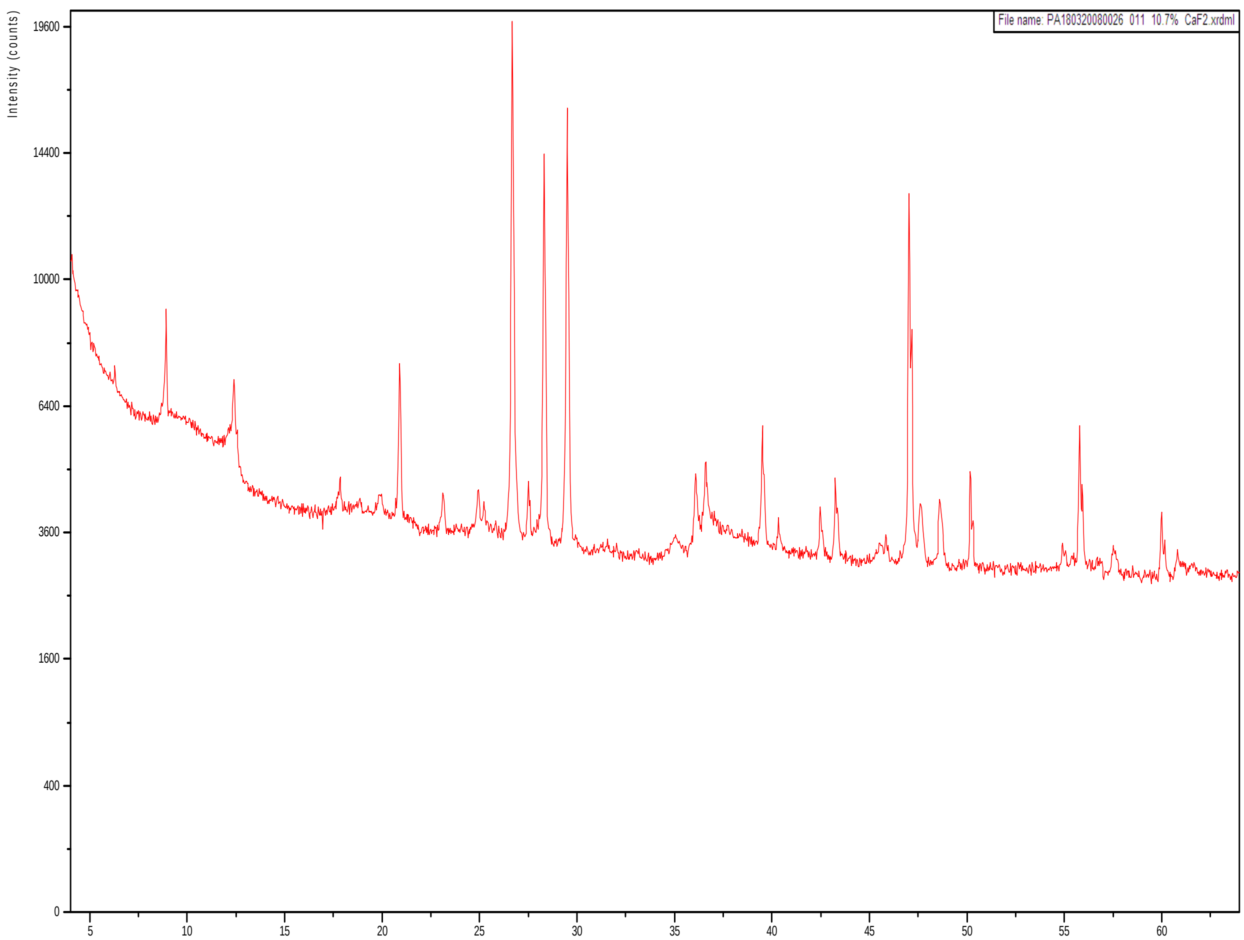

Figure 11 –X-ray diffraction pattern of the sample labeled “14A1”, with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: DS2FE2
RJ Lee Group Sample No.: PA180320080026-012

Phase	Composition	Concentration
Quartz	SiO_2	Major
Goethite	$FeO(OH)$	Major
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Trace
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Minor
Amorphous*	-	Trace

*This sample may contain a trace amount of todorokite or buserite. However, this result is inconclusive due to the poor crystallinity.

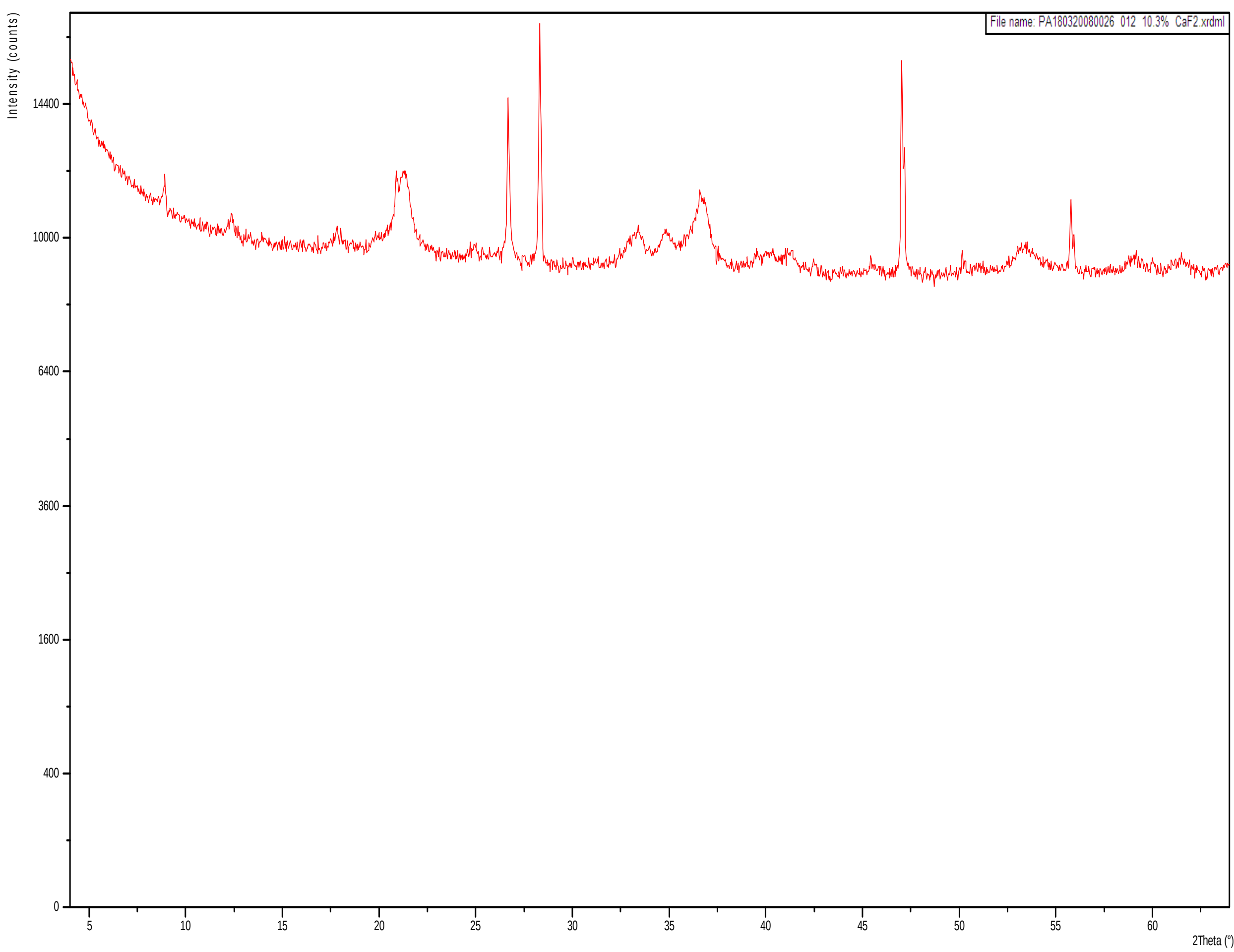

Figure 12 –X-ray diffraction pattern of the sample labeled "DS2FE2", with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: DS1FE1
RJ Lee Group Sample No.: PA180320080026-013

Phase	Composition	Concentration
Amorphous	*	Major

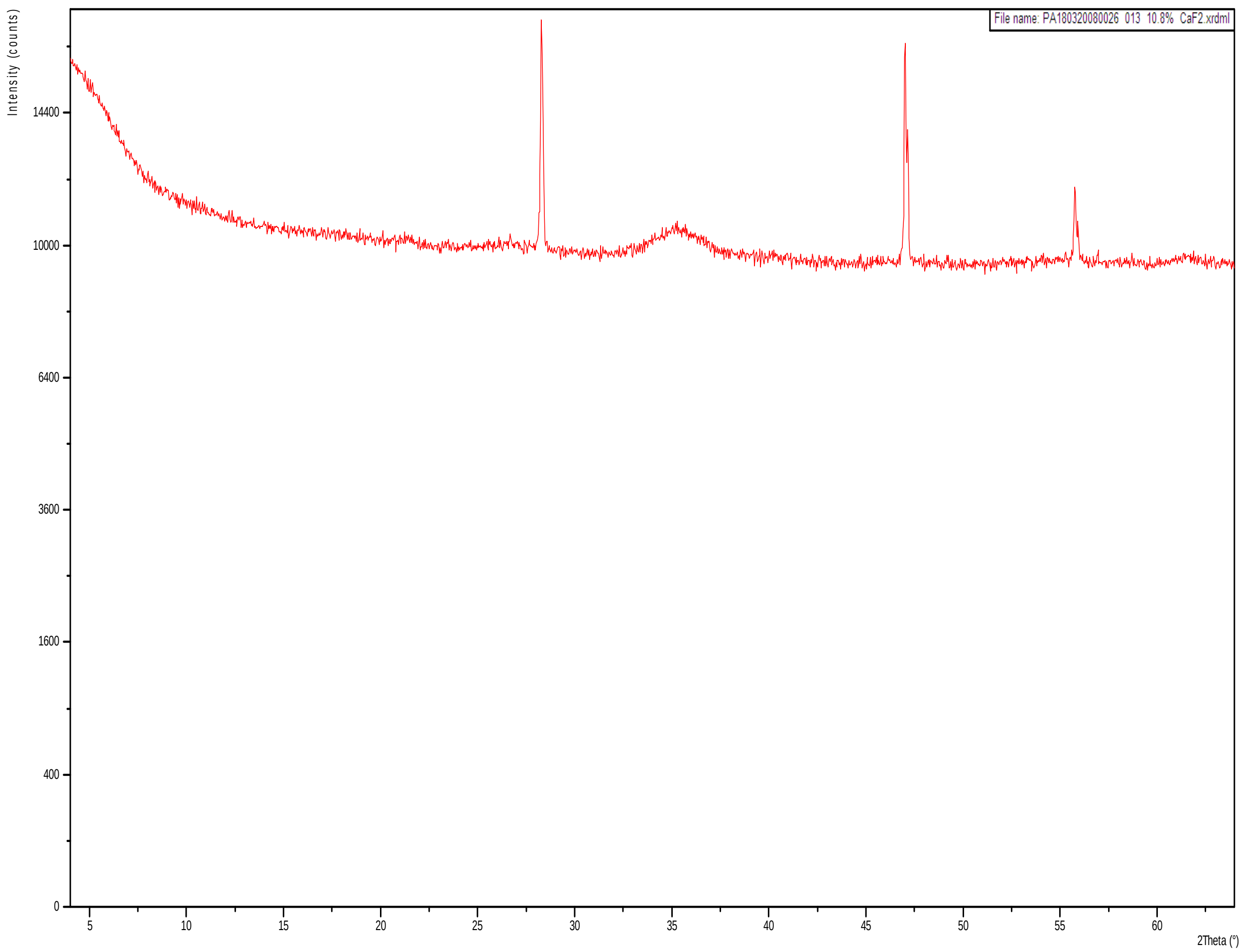

Figure 13 –X-ray diffraction pattern of the sample labeled "DS1FE1", with degrees 2θ along the x-axis and intensity (counts) along the y-axis. The peaks at 28.3°, 47.0°, and 55.8° are from the CaF_2 internal standard.

Client Sample No.: COM5A
RJ Lee Group Sample No.: PA180320080026-014

Phase	Composition	Concentration
Hematite	Fe_2O_3	Major
Quartz	SiO_2	Minor
Chlorite	$(Mg,Fe)_6(Si,Al)_4O_{10}(OH)_8$	Minor
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	Trace
Birnessite	$(Na, Ca, K)_x(Mn^{4+}, Mn^{3+})_2 \cdot 1.5H_2O$	Trace

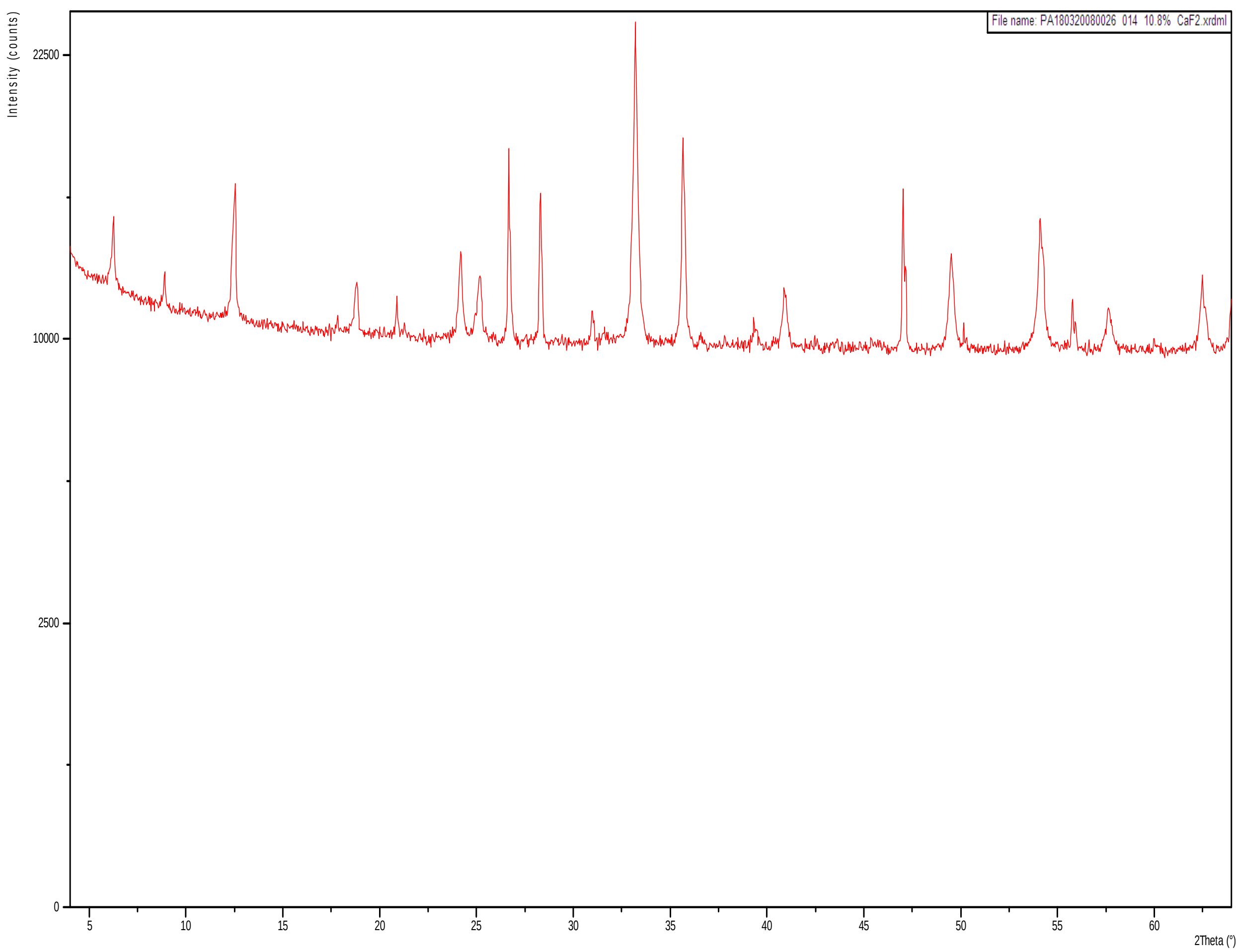

Figure 14 –X-ray diffraction pattern of the sample labeled “COM5A”, with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Client Sample No.: COM6A
RJ Lee Group Sample No.: PA180320080026-015

Phase	Composition	Concentration
Goethite	FeO(OH)	Major

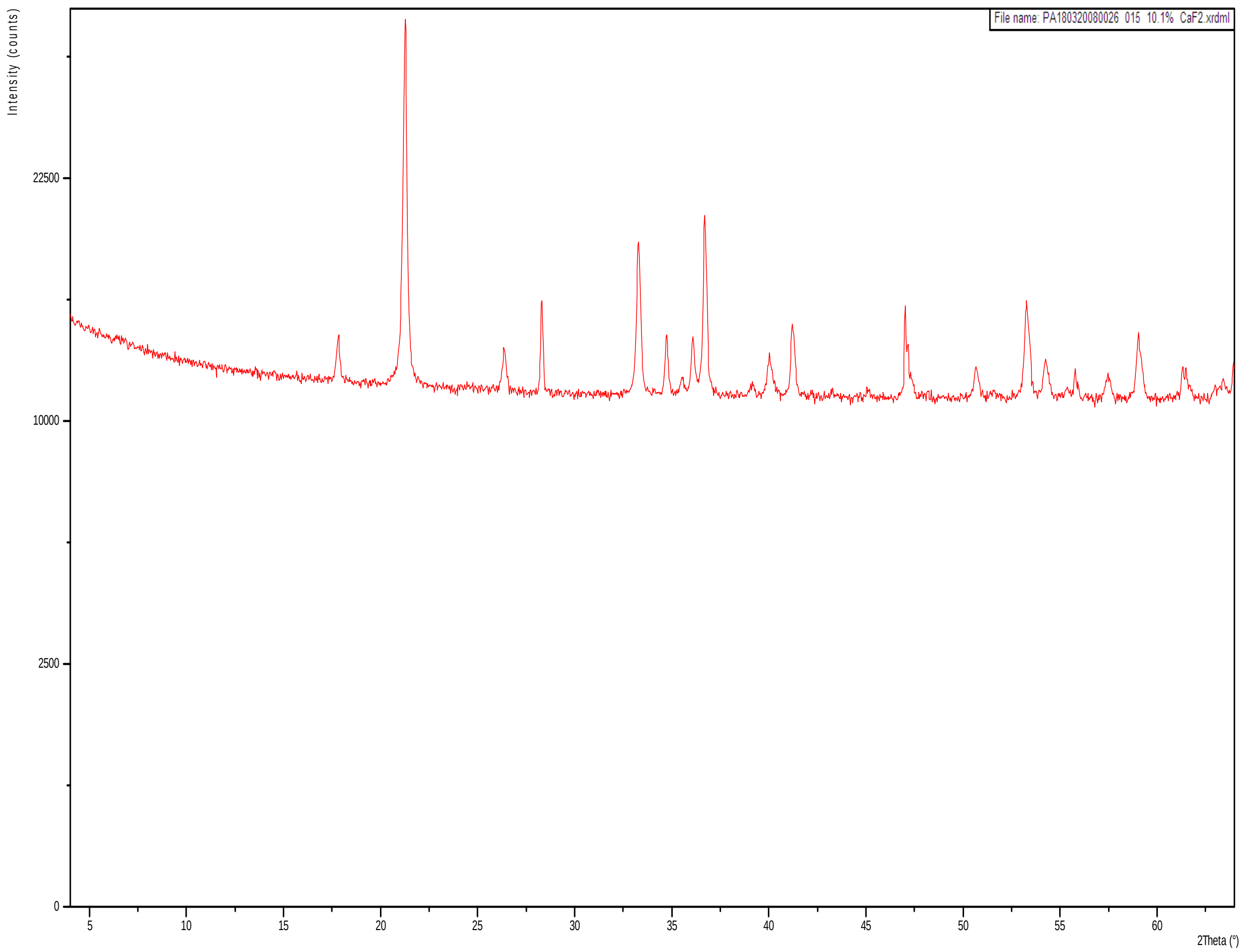

Figure 15 –X-ray diffraction pattern of the sample labeled "COM6A", with degrees 2θ along the x-axis and intensity (counts) along the y-axis.

Authorized Signature *Heather L Adamson* Date 4/1/2008
Heather L. Adamson
Scientist, X-ray Diffraction Group

These results are submitted pursuant to RJ Lee Group's current terms and conditions of sale, including the company's standard warranty and limitation of liability provisions. No responsibility is assumed for the manner in which the results are used or interpreted. Unless notified in writing to return the samples covered by this report, RJ Lee Group will store the samples for a period of thirty (30) or liability days before discarding. A shipping and handling fee will be assessed for the return of any samples. This laboratory operates in accord with ISO 17025 guidelines, and holds limited scopes of accreditation under AIHA lab ID 100364, NY ELAP Lab Code 101208-0, EPA Lab Code PA00162, CA ELAP Certificate 1970, PA DEP lab ID 02-00396, VA DCLS Lab

RJ Lee*Group*, Inc.
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Tel: (724) 325-1776 | Fax: (724) 733-1799

LABORATORY REPORT

Biomost, Inc.		Report Date:	April 1, 2008
3016 Unionville, Rd		Samples Received:	March 18, 2008
Cranberry Twp., PA 16066		RJ Lee Group Job No.:	PA180320080026
ATTENTION:	Mr. Cliff Denholm	Client Job No.:	N/A
Telephone:	(724) 776-0161	Purchase Order No.:	N/A

ANALYSIS: Bulk Chemical Composition
METHODS: X-Ray Fluorescence (XRF)

Client Sample No.:	**MN1**	**MN2**	**COM1A**	**22C1**	**25A1**
RJ Lee Group No.:	**PA180320080026-001**	**PA180320080026-002**	**PA180320080026-003**	**PA180320080026-004**	**PA180320080026-005**
Oxide	(Weight %)	(Weight %)	(Weight %)	(Weight %)	(Weight %)
Na_2O	0.19	0.20	0.16	0.22	0.19
MgO	1.04	0.98	0.21	0.84	0.96
Al_2O_3	12.5	12.1	2.83	9.80	8.41
SiO_2	23.3	23.7	4.77	24.7	18.6
P_2O_5	0.25	0.26	0.14	0.14	0.14
SO_3	0.90	0.89	< 0.01	0.43	0.61
Cl	< 0.01	0.09	< 0.01	0.02	0.02
K_2O	1.11	1.10	0.81	1.00	0.72
CaO	11.2	11.3	0.08	15.4	10.4
TiO_2	0.30	0.31	0.13	0.38	0.23
V_2O_5	< 0.01	< 0.01	0.08	< 0.01	< 0.01
MnO	24.0	23.7	72.5	14.8	26.6
Fe_2O_3	4.29	4.22	4.79	3.08	2.33
SrO	0.03	0.03	0.08	0.04	0.03
CoO	0.26	0.25	0.03	0.13	0.23
NiO	0.23	0.23	< 0.01	0.12	0.23
ZnO	0.28	0.27	0.03	0.15	0.26
Y_2O_3	0.04	0.04	< 0.01	< 0.01	0.03
BaO	< 0.01	< 0.01	1.29	0.07	0.07
LOI	20.0	20.3	12.0	28.7	30.0

Client Sample No.:	**6C1**	**32C1**	**28A1**	**5A1**	**15C1**
RJ Lee Group No.:	**PA180320080026-006**	**PA180320080026-007**	**PA180320080026-008**	**PA180320080026-009**	**PA180320080026-010**
Oxide	(Weight %)	(Weight %)	(Weight %)	(Weight %)	(Weight %)
Na_2O	0.16	0.16	0.16	0.14	0.18
MgO	0.84	0.83	0.78	0.87	1.02
Al_2O_3	13.5	10.7	9.55	13.2	12.0
SiO_2	22.7	18.5	16.2	22.2	24.4
P_2O_5	0.38	0.29	0.26	0.35	0.22
SO_3	1.11	0.69	0.83	1.21	0.52
Cl	0.02	< 0.01	< 0.01	< 0.01	0.02
K_2O	1.18	0.86	0.78	1.11	1.09
CaO	10.6	9.50	13.7	10.1	12.2
TiO_2	0.33	0.23	0.21	0.30	0.32
MnO	20.5	21.5	21.3	22.5	22.9
Fe_2O_3	6.19	4.15	3.95	5.84	3.52
SrO	0.03	0.03	0.04	0.03	0.03
CoO	0.29	0.28	0.27	0.31	0.20
NiO	0.21	0.19	0.18	0.23	0.22
ZnO	0.27	0.23	0.21	0.27	0.26
Y_2O_3	0.04	0.03	0.03	0.04	0.03
BaO	0.08	0.07	0.08	0.09	0.07
LOI	21.6	31.8	31.5	21.2	20.8

Client Sample No.:	**14A1**	**DS2FE2**	**DS1FE1**	**COM5A**	**COM6A**
RJ Lee Group No.:	**PA180320080026-011**	**PA180320080026-012**	**PA180320080026-013**	**PA180320080026-014**	**PA180320080026-015**
Oxide	(Weight %)	(Weight %)	(Weight %)	(Weight %)	(Weight %)
Na_2O	0.19	0.10	0.12	< 0.01	0.14
MgO	1.04	0.21	0.12	1.64	< 0.01
Al_2O_3	11.9	4.98	0.25	4.64	0.04
SiO_2	24.8	13.2	0.46	13.3	0.04
P_2O_5	0.20	0.24	0.10	0.20	< 0.01
SO_3	0.63	3.56	10.3	0.02	0.55
Cl	0.02	0.02	0.02	0.02	0.03
K_2O	1.09	0.67	0.03	0.23	< 0.01
CaO	12.0	0.04	0.09	0.70	0.03
TiO_2	0.32	0.20	< 0.01	0.17	0.03
MnO	23.1	0.06	0.03	0.50	0.04
Fe_2O_3	3.41	54.8	54.5	76.3	87.3
SrO	0.03	< 0.01	< 0.01	< 0.01	< 0.01
CoO	0.20	< 0.01	< 0.01	0.15	0.15
NiO	0.22	< 0.01	< 0.01	< 0.01	< 0.01
ZnO	0.24	0.01	< 0.01	< 0.01	0.02
Y_2O_3	0.03	< 0.01	< 0.01	< 0.01	< 0.01
BaO	0.07	< 0.01	< 0.01	< 0.01	< 0.01
LOI	20.6	21.9	33.9	2.10	11.6

Authorized Signature Heather L. Adamson Date 4/1/08

Heather L. Adamson
Scientist, X-ray Diffraction Group

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LABORATORY REPORT

BioMost, Inc.
3016 Unionville Road
Cranberry Twp., PA 16066

Attn: Mr. Cliff Denholm
Phone: 724-776-0161
Fax: 724-776-0166
Email: bmi@biomost.com

RJ Lee Group Job No.: PA180320080026
Samples Received: March 18, 2008
Report Date: April 9, 2008
Client Project: N/A
Purchase Order No.: N/A
Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
MN1	PA180320080026-001	N/A	Arsenic	0.00141	14.1	0.000492	4.92	04/08/2008	
MN1	PA180320080026-001	N/A	Barium	0.0509	509	0.000197	1.97	04/08/2008	
MN1	PA180320080026-001	N/A	Cadmium	0.000298	2.98	0.0000984	0.984	04/08/2008	
MN1	PA180320080026-001	N/A	Chromium	0.00180	18.0	0.000197	1.97	04/08/2008	
MN1	PA180320080026-001	N/A	Cobalt	0.216	2160	0.000197	1.97	04/08/2008	
MN1	PA180320080026-001	N/A	Copper	0.00316	31.6	0.000295	2.95	04/08/2008	
MN1	PA180320080026-001	N/A	Lead	0.00238	23.8	0.000492	4.92	04/08/2008	
MN1	PA180320080026-001	N/A	Nickel	0.163	1630	0.0000984	0.984	04/08/2008	
MN1	PA180320080026-001	N/A	Strontium	0.0196	196	0.000295	2.95	04/08/2008	
MN1	PA180320080026-001	N/A	Yttrium	0.0246	246	0.000295	2.95	04/08/2008	
MN1	PA180320080026-001	N/A	Zinc	0.221	2210	0.000492	4.92	04/08/2008	
MN1	PA180320080026-001	N/A	Mercury	0.00000793	0.0793	0.00000330	0.0330	04/03/2008	
MN2	PA180320080026-002	N/A	Arsenic	0.00155	15.5	0.000494	4.94	04/08/2008	
MN2	PA180320080026-002	N/A	Barium	0.0498	498	0.000198	1.98	04/08/2008	
MN2	PA180320080026-002	N/A	Cadmium	0.000283	2.83	0.0000988	0.988	04/08/2008	
MN2	PA180320080026-002	N/A	Chromium	0.00178	17.8	0.000198	1.98	04/08/2008	
MN2	PA180320080026-002	N/A	Cobalt	0.201	2010	0.000198	1.98	04/08/2008	
MN2	PA180320080026-002	N/A	Copper	0.00304	30.4	0.000296	2.96	04/08/2008	
MN2	PA180320080026-002	N/A	Lead	0.00228	22.8	0.000494	4.94	04/08/2008	
MN2	PA180320080026-002	N/A	Nickel	0.154	1540	0.0000988	0.988	04/08/2008	
MN2	PA180320080026-002	N/A	Strontium	0.0195	195	0.000296	2.96	04/08/2008	

Susan Kon

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RJ Lee Group Job No.: PA180320080026
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Report Date: April 9, 2008
Client Project: N/A
Purchase Order No.: N/A
Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
MN2	PA180320080026-002	N/A	Yttrium	0.0232	232	0.000296	2.96	04/08/2008	
MN2	PA180320080026-002	N/A	Zinc	0.210	2100	0.000494	4.94	04/08/2008	
MN2	PA180320080026-002	N/A	Mercury	0.00000841	0.0841	0.00000330	0.0330	04/03/2008	
COM1A	PA180320080026-003	N/A	Arsenic	0.00386	38.6	0.000370	3.70	04/08/2008	
COM1A	PA180320080026-003	N/A	Barium	0.824	8240	0.000148	1.48	04/08/2008	
COM1A	PA180320080026-003	N/A	Cadmium	0.000106	1.06	0.0000739	0.739	04/08/2008	
COM1A	PA180320080026-003	N/A	Chromium	0.00118	11.8	0.000148	1.48	04/08/2008	
COM1A	PA180320080026-003	N/A	Cobalt	0.0107	107	0.000148	1.48	04/08/2008	
COM1A	PA180320080026-003	N/A	Copper	0.00652	65.2	0.000222	2.22	04/08/2008	
COM1A	PA180320080026-003	N/A	Lead	0.00800	80.0	0.000370	3.70	04/08/2008	
COM1A	PA180320080026-003	N/A	Nickel	0.00816	81.6	0.0000739	0.739	04/08/2008	
COM1A	PA180320080026-003	N/A	Strontium	0.0632	632	0.000222	2.22	04/08/2008	
COM1A	PA180320080026-003	N/A	Yttrium	0.00389	38.9	0.000222	2.22	04/08/2008	
COM1A	PA180320080026-003	N/A	Zinc	0.0127	127	0.000370	3.70	04/08/2008	
COM1A	PA180320080026-003	N/A	Mercury	0.00000343	0.0343	0.00000316	0.0316	04/03/2008	
22C1	PA180320080026-004	N/A	Arsenic	0.00104	10.4	0.000433	4.33	04/08/2008	
22C1	PA180320080026-004	N/A	Barium	0.0321	321	0.000173	1.73	04/08/2008	
22C1	PA180320080026-004	N/A	Cadmium	0.000159	1.59	0.0000865	0.865	04/08/2008	
22C1	PA180320080026-004	N/A	Chromium	0.000756	7.56	0.000173	1.73	04/08/2008	
22C1	PA180320080026-004	N/A	Cobalt	0.0979	979	0.000173	1.73	04/08/2008	
22C1	PA180320080026-004	N/A	Copper	0.00174	17.4	0.000260	2.60	04/08/2008	

Susan Kon

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RJ Lee Group Job No.: PA180320080026
Samples Received: March 18, 2008
Report Date: April 9, 2008
Client Project: N/A
Purchase Order No.: N/A
Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
22C1	PA180320080026-004	N/A	Lead	0.00134	13.4	0.000433	4.33	04/08/2008	
22C1	PA180320080026-004	N/A	Nickel	0.0858	858	0.0000865	0.865	04/08/2008	
22C1	PA180320080026-004	N/A	Strontium	0.0300	300	0.000260	2.60	04/08/2008	
22C1	PA180320080026-004	N/A	Yttrium	0.0100	100	0.000260	2.60	04/08/2008	
22C1	PA180320080026-004	N/A	Zinc	0.100	1000	0.000433	4.33	04/08/2008	
22C1	PA180320080026-004	N/A	Mercury	0.00000521	0.0521	0.00000320	0.0320	04/03/2008	
25A1	PA180320080026-005	N/A	Arsenic	0.00142	14.2	0.000460	4.60	04/08/2008	
25A1	PA180320080026-005	N/A	Barium	0.0457	457	0.000184	1.84	04/08/2008	
25A1	PA180320080026-005	N/A	Cadmium	0.000290	2.90	0.0000919	0.919	04/08/2008	
25A1	PA180320080026-005	N/A	Chromium	0.00247	24.7	0.000184	1.84	04/08/2008	
25A1	PA180320080026-005	N/A	Cobalt	0.211	2110	0.000184	1.84	04/08/2008	
25A1	PA180320080026-005	N/A	Copper	0.00275	27.5	0.000276	2.76	04/08/2008	
25A1	PA180320080026-005	N/A	Lead	0.00227	22.7	0.000460	4.60	04/08/2008	
25A1	PA180320080026-005	N/A	Nickel	0.171	1710	0.0000919	0.919	04/08/2008	
25A1	PA180320080026-005	N/A	Strontium	0.0236	236	0.000276	2.76	04/08/2008	
25A1	PA180320080026-005	N/A	Yttrium	0.0228	228	0.000276	2.76	04/08/2008	
25A1	PA180320080026-005	N/A	Zinc	0.222	2220	0.000460	4.60	04/08/2008	
25A1	PA180320080026-005	N/A	Mercury	0.00000471	0.0471	0.00000321	0.0321	04/03/2008	
6C1	PA180320080026-006	N/A	Arsenic	0.00174	17.4	0.000466	4.66	04/08/2008	
6C1	PA180320080026-006	N/A	Barium	0.0416	416	0.000186	1.86	04/08/2008	
6C1	PA180320080026-006	N/A	Cadmium	0.000342	3.42	0.0000931	0.931	04/08/2008	

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LABORATORY REPORT

BioMost, Inc.
3016 Unionville Road
Cranberry Twp., PA 16066

RJ Lee Group Job No.: PA180320080026
Samples Received: March 18, 2008
Report Date: April 9, 2008
Client Project: N/A
Purchase Order No.: N/A
Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Attn: Mr. Cliff Denholm
Phone: 724-776-0161
Fax: 724-776-0166
Email: bmi@biomost.com

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
6C1	PA180320080026-006	N/A	Chromium	0.00114	11.4	0.000186	1.86	04/08/2008	
6C1	PA180320080026-006	N/A	Cobalt	0.222	2220	0.000186	1.86	04/08/2008	
6C1	PA180320080026-006	N/A	Copper	0.00422	42.2	0.000279	2.79	04/08/2008	
6C1	PA180320080026-006	N/A	Lead	0.00232	23.2	0.000466	4.66	04/08/2008	
6C1	PA180320080026-006	N/A	Nickel	0.145	1450	0.0000931	0.931	04/08/2008	
6C1	PA180320080026-006	N/A	Strontium	0.0186	186	0.000279	2.79	04/08/2008	
6C1	PA180320080026-006	N/A	Yttrium	0.0274	274	0.000279	2.79	04/08/2008	
6C1	PA180320080026-006	N/A	Zinc	0.208	2080	0.000466	4.66	04/08/2008	
6C1	PA180320080026-006	N/A	Mercury	0.0000101	0.101	0.00000332	0.0332	04/03/2008	
32C1	PA180320080026-007	N/A	Arsenic	0.00166	16.6	0.000483	4.83	04/08/2008	
32C1	PA180320080026-007	N/A	Barium	0.0487	487	0.000193	1.93	04/08/2008	
32C1	PA180320080026-007	N/A	Cadmium	0.000251	2.51	0.0000966	0.966	04/08/2008	
32C1	PA180320080026-007	N/A	Chromium	0.00318	31.8	0.000193	1.93	04/08/2008	
32C1	PA180320080026-007	N/A	Cobalt	0.230	2300	0.000193	1.93	04/08/2008	
32C1	PA180320080026-007	N/A	Copper	0.00272	27.2	0.000290	2.90	04/08/2008	
32C1	PA180320080026-007	N/A	Lead	0.00190	19.0	0.000483	4.83	04/08/2008	
32C1	PA180320080026-007	N/A	Nickel	0.128	1280	0.0000966	0.966	04/08/2008	
32C1	PA180320080026-007	N/A	Strontium	0.0271	271	0.000290	2.90	04/08/2008	
32C1	PA180320080026-007	N/A	Yttrium	0.0180	180	0.000290	2.90	04/08/2008	
32C1	PA180320080026-007	N/A	Zinc	0.175	1750	0.000483	4.83	04/08/2008	
32C1	PA180320080026-007	N/A	Mercury	0.00000432	0.0432	0.00000323	0.0323	04/03/2008	

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RJ Lee Group Job No.: PA180320080026
Samples Received: March 18, 2008
Report Date: April 9, 2008
Client Project: N/A
Purchase Order No.: N/A
Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
28A1	PA180320080026-008	N/A	Arsenic	0.00152	15.2	0.000470	4.70	04/08/2008	
28A1	PA180320080026-008	N/A	Barium	0.0538	538	0.000188	1.88	04/08/2008	
28A1	PA180320080026-008	N/A	Cadmium	0.000244	2.44	0.0000939	0.939	04/08/2008	
28A1	PA180320080026-008	N/A	Chromium	0.000935	9.35	0.000188	1.88	04/08/2008	
28A1	PA180320080026-008	N/A	Cobalt	0.231	2310	0.000188	1.88	04/08/2008	
28A1	PA180320080026-008	N/A	Copper	0.00263	26.3	0.000282	2.82	04/08/2008	
28A1	PA180320080026-008	N/A	Lead	0.00185	18.5	0.000470	4.70	04/08/2008	
28A1	PA180320080026-008	N/A	Nickel	0.132	1320	0.0000939	0.939	04/08/2008	
28A1	PA180320080026-008	N/A	Strontium	0.0287	287	0.000282	2.82	04/08/2008	
28A1	PA180320080026-008	N/A	Yttrium	0.0187	187	0.000282	2.82	04/08/2008	
28A1	PA180320080026-008	N/A	Zinc	0.178	1780	0.000470	4.70	04/08/2008	
28A1	PA180320080026-008	N/A	Mercury	0.00000507	0.0507	0.00000323	0.0323	04/03/2008	
5A1	PA180320080026-009	N/A	Arsenic	0.00154	15.4	0.000480	4.80	04/08/2008	
5A1	PA180320080026-009	N/A	Barium	0.0498	498	0.000192	1.92	04/08/2008	
5A1	PA180320080026-009	N/A	Cadmium	0.000328	3.28	0.0000959	0.959	04/08/2008	
5A1	PA180320080026-009	N/A	Chromium	0.00110	11.0	0.000192	1.92	04/08/2008	
5A1	PA180320080026-009	N/A	Cobalt	0.251	2510	0.000192	1.92	04/08/2008	
5A1	PA180320080026-009	N/A	Copper	0.00377	37.7	0.000288	2.88	04/08/2008	
5A1	PA180320080026-009	N/A	Lead	0.00229	22.9	0.000480	4.80	04/08/2008	
5A1	PA180320080026-009	N/A	Nickel	0.154	1540	0.0000959	0.959	04/08/2008	
5A1	PA180320080026-009	N/A	Strontium	0.0182	182	0.000288	2.88	04/08/2008	

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RJ Lee Group Job No.: PA180320080026
Samples Received: March 18, 2008
Report Date: April 9, 2008
Client Project: N/A
Purchase Order No.: N/A
Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
5A1	PA180320080026-009	N/A	Yttrium	0.0267	267	0.000288	2.88	04/08/2008	
5A1	PA180320080026-009	N/A	Zinc	0.220	2200	0.000480	4.80	04/08/2008	
5A1	PA180320080026-009	N/A	Mercury	0.00000606	0.0606	0.00000328	0.0328	04/03/2008	
15C1	PA180320080026-010	N/A	Arsenic	0.00134	13.4	0.000420	4.20	04/08/2008	
15C1	PA180320080026-010	N/A	Barium	0.0434	434	0.000168	1.68	04/08/2008	
15C1	PA180320080026-010	N/A	Cadmium	0.000280	2.80	0.0000840	0.840	04/08/2008	
15C1	PA180320080026-010	N/A	Chromium	0.00160	16.0	0.000168	1.68	04/08/2008	
15C1	PA180320080026-010	N/A	Cobalt	0.180	1800	0.000168	1.68	04/08/2008	
15C1	PA180320080026-010	N/A	Copper	0.00281	28.1	0.000252	2.52	04/08/2008	
15C1	PA180320080026-010	N/A	Lead	0.00227	22.7	0.000420	4.20	04/08/2008	
15C1	PA180320080026-010	N/A	Nickel	0.163	1630	0.0000840	0.840	04/08/2008	
15C1	PA180320080026-010	N/A	Strontium	0.0196	196	0.000252	2.52	04/08/2008	
15C1	PA180320080026-010	N/A	Yttrium	0.0246	246	0.000252	2.52	04/08/2008	
15C1	PA180320080026-010	N/A	Zinc	0.217	2170	0.000420	4.20	04/08/2008	
15C1	PA180320080026-010	N/A	Mercury	0.00000597	0.0597	0.00000281	0.0281	04/03/2008	
14A1	PA180320080026-011	N/A	Arsenic	0.00117	11.7	0.000488	4.88	04/08/2008	
14A1	PA180320080026-011	N/A	Barium	0.0481	481	0.000195	1.95	04/08/2008	
14A1	PA180320080026-011	N/A	Cadmium	0.000282	2.82	0.0000977	0.977	04/08/2008	
14A1	PA180320080026-011	N/A	Chromium	0.00129	12.9	0.000195	1.95	04/08/2008	
14A1	PA180320080026-011	N/A	Cobalt	0.189	1890	0.000195	1.95	04/08/2008	
14A1	PA180320080026-011	N/A	Copper	0.00274	27.4	0.000293	2.93	04/08/2008	

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RJ Lee Group Job No.: PA180320080026
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Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
14A1	PA180320080026-011	N/A	Lead	0.00227	22.7	0.000488	4.88	04/08/2008	
14A1	PA180320080026-011	N/A	Nickel	0.160	1600	0.0000977	0.977	04/08/2008	
14A1	PA180320080026-011	N/A	Strontium	0.0198	198	0.000293	2.93	04/08/2008	
14A1	PA180320080026-011	N/A	Yttrium	0.0227	227	0.000293	2.93	04/08/2008	
14A1	PA180320080026-011	N/A	Zinc	0.210	2100	0.000488	4.88	04/08/2008	
14A1	PA180320080026-011	N/A	Mercury	0.00000570	0.0570	0.00000321	0.0321	04/03/2008	
DS2FE2	PA180320080026-012	N/A	Arsenic	0.000817	8.17	0.000487	4.87	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Barium	0.00290	29.0	0.000195	1.95	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Cadmium	0.000831	8.31	0.0000975	0.975	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Chromium	0.000635	6.35	0.000195	1.95	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Cobalt	0.00109	10.9	0.000195	1.95	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Copper	0.00354	35.4	0.000292	2.92	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Lead	0.000923	9.23	0.000487	4.87	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Nickel	0.000606	6.06	0.0000975	0.975	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Strontium	0.000479	4.79	0.000292	2.92	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Yttrium	0.000455	4.55	0.000292	2.92	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Zinc	0.0107	107	0.000487	4.87	04/08/2008	
DS2FE2	PA180320080026-012	N/A	Mercury	0.00000677	0.0677	0.00000332	0.0332	04/03/2008	
DS1FE1	PA180320080026-013	N/A	Arsenic	0.000827	8.27	0.000482	4.82	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Barium	< 0.000193	< 1.93	0.000193	1.93	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Cadmium	0.000972	9.72	0.0000963	0.963	04/08/2008	

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RJ Lee Group Job No.: PA180320080026
Samples Received: March 18, 2008
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Client Project: N/A
Purchase Order No.: N/A
Matrix: Solid
Prep/Analysis: EPA 3050B / EPA 6010C (Solids)-PA
EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
DS1FE1	PA180320080026-013	N/A	Chromium	0.000246	2.46	0.000193	1.93	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Cobalt	0.000922	9.22	0.000193	1.93	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Copper	< 0.000289	< 2.89	0.000289	2.89	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Lead	< 0.000482	< 4.82	0.000482	4.82	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Nickel	0.000413	4.13	0.0000963	0.963	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Strontium	< 0.000289	< 2.89	0.000289	2.89	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Yttrium	0.000512	5.12	0.000289	2.89	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Zinc	0.00203	20.3	0.000482	4.82	04/08/2008	
DS1FE1	PA180320080026-013	N/A	Mercury	< 0.00000314	< 0.0314	0.00000314	0.0314	04/03/2008	
COM5A	PA180320080026-014	N/A	Arsenic	0.00368	36.8	0.000497	4.97	04/08/2008	
COM5A	PA180320080026-014	N/A	Barium	0.00314	31.4	0.000199	1.99	04/08/2008	
COM5A	PA180320080026-014	N/A	Cadmium	0.000917	9.17	0.0000993	0.993	04/08/2008	
COM5A	PA180320080026-014	N/A	Chromium	0.00897	89.7	0.000199	1.99	04/08/2008	
COM5A	PA180320080026-014	N/A	Cobalt	0.00140	14.0	0.000199	1.99	04/08/2008	
COM5A	PA180320080026-014	N/A	Copper	0.00165	16.5	0.000298	2.98	04/08/2008	
COM5A	PA180320080026-014	N/A	Lead	0.000799	7.99	0.000497	4.97	04/08/2008	
COM5A	PA180320080026-014	N/A	Nickel	0.00172	17.2	0.0000993	0.993	04/08/2008	
COM5A	PA180320080026-014	N/A	Strontium	0.00257	25.7	0.000298	2.98	04/08/2008	
COM5A	PA180320080026-014	N/A	Yttrium	0.00116	11.6	0.000298	2.98	04/08/2008	
COM5A	PA180320080026-014	N/A	Zinc	0.00332	33.2	0.000497	4.97	04/08/2008	
COM5A	PA180320080026-014	N/A	Mercury	0.00000442	0.0442	0.00000329	0.0329	04/03/2008	

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EPA 7471A / EPA 7471A (Solid)-PA

Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		
COM6A	PA180320080026-015	N/A	Arsenic	< 0.000495	< 4.95	0.000495	4.95	04/08/2008	
COM6A	PA180320080026-015	N/A	Barium	< 0.000198	< 1.98	0.000198	1.98	04/08/2008	
COM6A	PA180320080026-015	N/A	Cadmium	0.00124	12.4	0.0000991	0.991	04/08/2008	
COM6A	PA180320080026-015	N/A	Chromium	0.000336	3.36	0.000198	1.98	04/08/2008	
COM6A	PA180320080026-015	N/A	Cobalt	0.00552	55.2	0.000198	1.98	04/08/2008	
COM6A	PA180320080026-015	N/A	Copper	< 0.000297	< 2.97	0.000297	2.97	04/08/2008	
COM6A	PA180320080026-015	N/A	Lead	< 0.000495	< 4.95	0.000495	4.95	04/08/2008	
COM6A	PA180320080026-015	N/A	Nickel	0.00551	55.1	0.0000991	0.991	04/08/2008	
COM6A	PA180320080026-015	N/A	Strontium	< 0.000297	< 2.97	0.000297	2.97	04/08/2008	
COM6A	PA180320080026-015	N/A	Yttrium	< 0.000297	< 2.97	0.000297	2.97	04/08/2008	
COM6A	PA180320080026-015	N/A	Zinc	0.0144	144	0.000495	4.95	04/08/2008	
COM6A	PA180320080026-015	N/A	Mercury	< 0.00000333	< 0.0333	0.00000333	0.0333	04/03/2008	

Analyst Comments:

Report Qualifiers (Q):
H = Holding times for preparation or analysis exceeded
P = NELAC[a] analyte certification pending
N = Analyte not NELAC[a] certified
[a]NELAC-National Environmental Laboratory Accreditation Conference

E = Value above highest calibration standard but below LDR (Linear Dynamic Range)
J = Value below lowest calibration standard but above MDL (Method Detection Limit)
L = LCS (Laboratory Control Standard)/SRM (Standard Reference Material) recovery outside accepted recovery limits

B = Analyte detected in the associated Method Blank
S = Spike Recovery outside accepted recovery limits
R = RPD (relative percent difference) outside accepted recovery limits

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Client Sample ID	RJ Lee Group ID	Sampling Date	Analyte	Sample Concentration		Minimum Reporting Limit		Analysis Date	Q
				Weight Percent (%)	Parts per Million (PPM)	Weight Percent (%)	Parts per Million (PPM)		

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Quality Control data is available upon request.

Susan Kon

Susan Kon

Report: A07-1476
Report Date: 23/05/2007

Final Report
Activation Laboratories

Analyte Symbol	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total	Au	Ag	As	Ba	Be	Bi
Unit Symbol	%	%	%	%	%	%	%	%	%	%	%	%	ppb	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01	0.01	0.01	1	0.5	1	1	1	2
Analysis Method	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	INAA	MULT INAA / TD-ICP	INAA	FUS-ICP	FUS-ICP	TD-ICP
DS2-1	4.56	1.43	15.45	49.9	0.7	7.27	0.15	0.11	0.057	0.02	20.29	99.95	< 1	< 0.5	5	257	< 1	3
ERICO-1	3.48	1.57	0.79	64.7	0.74	6.34	0.18	0.28	0.056	0.02	21.88	100	< 1	< 0.5	4	194	1	3

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Analyte Symbol	Br	Cd	Co	Cr	Cs	Cu	Hf	Hg	Ir	Mo	Ni	Pb	Rb	S	Sb	Sc	Se	Sr	Ta	Th	U	V	W
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.5	0.5	0.1	0.5	0.2	1	0.2	1	1	2	1		10	0.001	0.1	0.01	0.5	2	0.3	0.1	0.1	5	1
Analysis Method	INAA	TD-ICP	INAA	INAA	INAA	TD-ICP	INAA	INAA	INAA	TD-ICP	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	FUS-ICP	INAA	INAA	INAA	FUS-ICP	INAA
DS2-1	2.2	< 0.5	1130	7	< 0.2	4	0.4	< 1	< 1	8	1000	--	< 10	0.083	0.2	0.98	< 0.5	295	1.4	< 0.1	4.4	< 5	< 1
ERICO-1	2.6	1.8	1160	< 0.5	1.5	4	0.9	< 1	< 1	14	1190	--	< 10	0.03	0.4	0.81	< 0.5	128	< 0.3	0.8	3	< 5	< 1

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Analyte Symbol	Y	Zn	Zr	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Mass
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	g
Detection Limit	1	1	2	0.05	1	1	0.01	0.05	0.1	0.05	0.01	
Analysis Method	FUS-ICP	MULT INAA / TD-ICP	FUS-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
DS2-1	21	252	< 2	10.5	12	12	3.05	0.86	0.5	0.88	0.1	1.055
ERICO-1	61	840	< 2	21.1	35	22	5.47	1.64	0.8	1.78	0.23	1.058

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Analyte Symbol	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total	Au	Ag	As	Ba	Be	Bi	Br
Unit Symbol	%	%	%	%	%	%	%	%	%	%	%	%	ppb	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.001	0.01	0.01	0.01	1	5	1	1	1	2	0.5
Analysis Method	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	INAA	INAA	INAA	FUS-ICP	FUS-ICP	TD-ICP	INAA
WMG-1 Meas													133	< 5	9				
WMG-1 Cert													110	3	7				
SDC-1 Meas																		< 2	
SDC-1 Cert																		3	
DNC-1 Meas																		< 2	
DNC-1 Cert																		0.02	
SCO-1 Meas																		< 2	
SCO-1 Cert																		0.4	
GXR-6 Meas																		< 2	
GXR-6 Cert																		0.3	
GXR-2 Meas																		< 2	
GXR-2 Cert																		0.7	
GXR-1 Meas																		1380	
GXR-1 Cert																		1380	
GXR-4 Meas																		16	
GXR-4 Cert																		19	
SY-3 Meas	60.13	11.52	6.27	0.325	2.6	8.27	3.99	4.24	0.14	0.57						437	20		
SY-3 Cert	59.62	11.76	6.49	0.32	2.67	8.25	4.12	4.23	0.15	0.54						450	20		
NIST 694 Meas	10.25	1.87	0.72	0.011	0.32	43.4	0.95	0.61	0.112	30.29									
NIST 694 Cert	11.2	1.8	0.79	0.012	0.33	43.6	0.86	0.51	0.11	30.2									
W-2a Meas	53.76	15.62	10.65	0.17	6.33	10.98	2.23	0.73	1.093	0.14						178	1		
W-2a Cert	52.44	15.35	10.74	0.163	6.37	10.87	2.14	0.63	1.06	0.13						182	1		
DNC-1 Meas	46.89	18.6	9.7	0.145	10.16	11.33	1.94	0.24	0.488	0.07						108	< 1		
DNC-1 Cert	47.04	18.3	9.93	0.149	10.05	11.27	1.87	0.23	0.48	0.09						114	1		
BIR-1 Meas	48.09	15.78	11.17	0.172	9.7	13.37	1.84	0.03	0.981	0.03						7	< 1		
BIR-1 Cert	47.77	15.35	11.26	0.171	9.68	13.24	1.75	0.03	0.96	0.05						7	0.6		
GBW 07113 Meas	72.71	12.62	3.08	0.138	0.14	0.58	2.46	5.46	0.272	0.05						498	4		
GBW 07113 Cert	72.78	12.96	3.21	0.14	0.16	0.59	2.57	5.43	0.3	0.05						506	4		
NIST 1633b Meas	49.36	28.71	10.86	0.017	0.78	2.16	0.32	2.44	1.297	0.59						725			
NIST 1633b Cert	49.24	28.43	11.13	0.02	0.8	2.11	0.27	2.35	1.32	0.53						709			
NIST 696 Meas	3.43	53.82	8.3	0.004	< 0.01	0.02		0.06	2.571	0.05									
NIST 696 Cert	3.79	54.5	8.7	0.004	0.01	0.02		0.009	2.64	0.05									
FK-N Meas	63.37	17.92	0.09	0.002	0.02	0.1	2.44	12.55	0.003	0.02						203	1		
FK-N Cert	65.02	18.61	0.09	0.005	0.01	0.11	2.58	12.81	0.02	0.02						200	1		

Final Report
Activation Laboratories

Analyte Symbol	Cd	Co	Cr	Cs	Cu	Hf	Hg	Ir	Mo	Ni	Rb	S	Sb	Sc	Se	Sr	Ta	Th	U	V	W	Y	Zn
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.5	0.1	0.5	0.2	1	0.2	1	1	2	1	10	0.001	0.1	0.01	0.5	2	0.3	0.1	0.1	5	1	1	1
Analysis Method	TD-ICP	INAA	INAA	INAA	TD-ICP	INAA	INAA	INAA	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	FUS-ICP	INAA	INAA	INAA	FUS-ICP	INAA	FUS-ICP	TD-ICP
WMG-1 Meas		203	782	< 0.2		1.2		45					1.6	25.5	15.9		< 0.3	1.4	< 0.1		< 1		
WMG-1 Cert		200	770	0.5		1.3		46					1.8	26	15		0.5	1.1	0.6		1		
SDC-1 Meas	< 0.5				32				< 2	34		0.065											104
SDC-1 Cert	0.08				30				0.3	38		0.065											103
DNC-1 Meas					99				3	251		0.068											64
DNC-1 Cert					96				0.7	247		0.039											66
SCO-1 Meas	< 0.5				29				3	27		0.067											105
SCO-1 Cert	0.1				29				1	27		0.063											103
GXR-6 Meas	< 0.5				68				4	24		0.021											125
GXR-6 Cert	1				66				2	27		0.016											118
GXR-2 Meas	4.5				81				2	20		0.033											550
GXR-2 Cert	4.1				76				2	21		0.031											530
GXR-1 Meas	3.2				1080				19	39		0.229											681
GXR-1 Cert	3.3				1110				18	41		0.257											760
GXR-4 Meas	< 0.5				6200				309	40		1.84											76
GXR-4 Cert	0.9				6520				310	42		1.77											73
SY-3 Meas																301				51		717	
SY-3 Cert																302				50		718	
NIST 694 Meas																				1669			
NIST 694 Cert																				1737			
W-2a Meas																198				281		21	
W-2a Cert																190				262		24	
DNC-1 Meas																143				159		17	
DNC-1 Cert																145				148		18	
BIR-1 Meas																108				343		15	
BIR-1 Cert																108				313		16	
GBW 07113 Meas																40				< 5		46	
GBW 07113 Cert																43				5		43	
NIST 1633b Meas																1044				308			
NIST 1633b Cert																1041				296			
NIST 696 Meas																				401			
NIST 696 Cert																				403			
FK-N Meas																37				< 5		3	
FK-N Cert																39				5		0.5	

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Analyte Symbol	Zn	Zr	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Mass
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	g
Detection Limit	50	2	0.05	1	1	0.01	0.05	0.1	0.05	0.01	
Analysis Method	INAA	FUS-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA
WMG-1 Meas	150		8.23	17	8	2.32	0.79	0.5	1.3	0.21	
WMG-1 Cert	110		8.2	16	9	2.3	0.82	0.3	1.3	0.21	
SDC-1 Meas											
SDC-1 Cert											
DNC-1 Meas											
DNC-1 Cert											
SCO-1 Meas											
SCO-1 Cert											
GXR-6 Meas											
GXR-6 Cert											
GXR-2 Meas											
GXR-2 Cert											
GXR-1 Meas											
GXR-1 Cert											
GXR-4 Meas											
GXR-4 Cert											
SY-3 Meas		343									
SY-3 Cert		320									
NIST 694 Meas											
NIST 694 Cert											
W-2a Meas		88									
W-2a Cert		94									
DNC-1 Meas		35									
DNC-1 Cert		41									
BIR-1 Meas		13									
BIR-1 Cert		16									
GBW 07113 Meas		403									
GBW 07113 Cert		403									
NIST 1633b Meas											
NIST 1633b Cert											
NIST 696 Meas		1034									
NIST 696 Cert		1037									
FK-N Meas		< 2									
FK-N Cert		10									

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Analyte Symbol	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total	Au	Ag	As	Ba	Be	Bi
Unit Symbol	%	%	%	%	%	%	%	%	%	%	%	%	ppb	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.01	0.01	5	0.5	2	3	1	2
Analysis Method	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	INAA	MULT INA	INAA	MULT INA	FUS-ICP	TD-ICP
6A1	21.31	10.82	6.19	24.97	0.78	10	0.11	1.02	0.326	0.36	23.13	99.02	< 5	< 0.5	25	584	12	< 2
15A1	24.69	8.71	3.49	25.73	0.86	12.9	0.14	0.94	0.36	0.19	20.94	98.96	< 5	< 0.5	22	615	9	< 2
22A1	42.31	7.07	3.26	18.1	0.71	11.13	0.15	1.18	0.536	0.11	16.34	100.9	< 5	< 0.5	19	974	5	< 2
32A1	21.11	8.84	5.15	29.33	0.81	11.18	0.1	0.97	0.307	0.29	21.85	99.93	< 5	4.8	27	996	10	12
6B1	20.3	10.82	5.99	28.18	0.77	9.44	0.12	1.1	0.32	0.37	23.5	100.9	5	4.4	24	630	12	11
6B2	20.05	10.74	5.95	27.82	0.76	9.17	0.1	1.11	0.318	0.37	23.43	99.81	< 5	4.6	26	612	12	9
6B3	19.9	10.77	5.99	27.69	0.76	8.88	0.1	1.01	0.319	0.37	23.52	99.3	< 5	4.1	25	618	12	10
6B4	17.48	10.01	5.59	34.08	0.78	7.63	0.07	1.03	0.273	0.35	23.37	100.7	6	7	27	686	12	14
6B5	19.78	10.47	6	28.92	0.78	7.88	0.09	1	0.299	0.35	23.26	98.83	< 5	5.8	24	700	12	12
6B6	19.48	10.16	5.73	30.68	0.75	7.78	0.08	0.98	0.286	0.34	22.72	98.99	< 5	5	22	629	12	11
6B7	23.16	10.81	6.32	19.48	0.75	12.43	0.12	1.13	0.347	0.36	23.62	98.54	< 5	2.5	27	500	11	6
22B1	3.1	0.78	0.92	0.12	0.49	53.2	0.02	0.13	0.03	0.05	41.44	100.3	< 5	< 0.5	10	41	< 1	< 2
22B2	12.07	3.33	2.83	11.61	0.61	35.92	0.04	0.5	0.161	0.11	31.21	98.4	< 5	1.3	16	368	3	4
22B3	7.97	1.91	1.55	0.24	0.6	47.79	0.05	0.19	0.093	0.08	39.04	99.51	< 5	< 0.5	12	606	< 1	< 2
22B4	11.72	3.03	2.82	5.2	0.55	41.63	0.03	0.48	0.155	0.11	34.06	99.79	< 5	< 0.5	14	223	2	< 2
22B5	10.39	2.11	1.83	0.37	0.47	46.51	0.02	0.21	0.105	0.07	37.03	99.14	< 5	< 0.5	11	206	< 1	< 2
22B6	10.49	2.5	2.38	1.91	0.52	44.7	0.03	0.23	0.132	0.1	35.85	98.85	< 5	< 0.5	13	182	1	< 2
22B7	14.84	4.01	3.12	16.76	0.74	31.21	0.09	0.32	0.167	0.08	26.97	98.31				504	3	11
22B8	22.54	4.34	3.25	21.32	0.72	23.74	0.07	0.54	0.208	0.16	23.61	100.5				679	4	12
22B9	48.18	5.27	3.1	11.29	0.52	13.7	0.04	0.73	0.379	0.1	16.31	99.62	< 5	1.5	25	877	3	4
22B10	47.41	6.29	3.06	14.27	0.58	11.14	0.07	0.82	0.537	0.1	14.79	99.07	< 5	2.2	24	949	4	5
22B11	40.48	7.21	3.19	22.13	0.72	9.94	0.14	0.97	0.566	0.12	15.51	101	< 5	3.3	21	1030	5	4
22B12	32.07	10.58	4.15	18.29	0.88	11.58	0.25	1.58	0.576	0.17	18.96	99.08	6	3.1	21	679	7	5
COM1	3.97	2.44	4.08	44.1	0.26	0.12	0.18	0.82	0.134	0.18	11.32	67.61	< 5	20.3	56	7450	5	42
COM2	2.18	4.51	4.47	41.85	0.26	0.22	0.07	0.92	0.246	0.24	12.6	67.56	7	20.5	70	1170	3	40
COM3	3.96	2.4	4.01	42.79	0.26	0.1	0.21	0.79	0.124	0.13	11.28	66.04	< 5	16	58	7750	4	44
COM4	2.12	4.39	4.31	41.32	0.26	0.24	0.1	0.86	0.22	0.19	12.69	66.71	< 5	20	70	1240	3	38
DS2FE1	8.1	3.12	63.63	0.41	0.16	0.11	0.04	0.28	0.134	0.14	23.59	99.71	< 5	< 0.5	8	96	< 1	< 2

Final Report
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Analyte Symbol	Br	Cd	Co	Cr	Cs	Cu	Hf	Hg	Ir	Mo	Ni	Pb	Rb	S	Sb	Sc	Se	Sr	Ta	Th	U	V	W
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	1	0.5	1	1	0.5	1	0.5	1	5	2	1	5	20	0.001	0.2	0.1	3	2	1	0.5	0.5	5	3
Analysis Method	INAA	TD-ICP	INAA	INAA	INAA	TD-ICP	INAA	INAA	INAA	TD-ICP	TD-ICP	TD-ICP	INAA	TD-ICP	INAA	INAA	INAA	FUS-ICP	INAA	INAA	INAA	FUS-ICP	INAA
6A1	6	< 0.5	1840	45	3.8	< 1	1.9	< 1	< 5	< 2	< 1	< 5	< 20	< 0.001	0.8	6.5	< 3	272	< 1	6.4	7.2	47	< 3
15A1	< 1	< 0.5	1270	71	3.2	< 1	3.3	< 1	< 5	< 2	< 1	< 5	60	< 0.001	0.8	5.9	< 3	247	< 1	6	8.1	34	< 3
22A1	< 1	< 0.5	911	66	< 0.5	< 1	6.5	< 1	< 5	< 2	< 1	< 5	< 20	< 0.001	0.8	5.8	< 3	251	< 1	7.9	7.2	35	< 3
32A1	< 1	1.8	2100	58	3.7	32	2.3	< 1	< 5	4	1410	33	< 20	0.72	1.2	5.4	< 3	286	< 1	6.2	8.4	28	< 3
6B1	5	2.1	2140	49	4.2	41	< 0.5	< 1	< 5	4	1430	36	80	0.541	0.9	6.6	< 3	276	< 1	6.6	9.7	40	< 3
6B2	7	1.9	2130	41	4.2	43	1.8	< 1	< 5	4	1440	35	< 20	0.533	0.9	6.4	5	269	< 1	5.8	8.4	38	< 3
6B3	5	2	2090	42	3.9	41	2.1	< 1	< 5	4	1410	30	< 20	0.532	1.3	6.5	< 3	266	< 1	5.3	10.4	39	< 3
6B4	6	1.9	2680	51	4.5	44	1.7	< 1	< 5	4	1700	33	< 20	0.6	1.3	6.1	< 3	258	< 1	5.2	8.6	32	< 3
6B5	< 1	2.2	2690	38	< 0.5	57	1.7	< 1	< 5	5	1610	30	70	0.586	1.3	6.4	< 3	262	< 1	5.5	9	35	< 3
6B6	6	1.8	2390	40	2.9	69	2.2	< 1	< 5	4	1490	29	< 20	0.539	1.2	6.4	< 3	236	< 1	6	8.9	37	< 3
6B7	6	1.7	1470	46	4.2	82	2.5	< 1	< 5	3	1180	29	70	0.551	1.2	7	< 3	282	< 1	7	8.9	48	< 3
22B1	< 1	< 0.5	4	7	< 0.5	4	< 0.5	< 1	< 5	< 2	8	< 5	< 20	0.219	< 0.2	1	< 3	679	< 1	0.6	4	11	< 3
22B2	< 1	1	741	59	1.1	15	1.7	< 1	< 5	2	474	14	< 20	0.374	0.5	3.1	< 3	521	< 1	2.7	6.3	21	< 3
22B3	< 1	< 0.5	9	47	0.7	7	0.9	< 1	< 5	2	16	8	< 20	0.387	0.4	1.5	< 3	833	< 1	1.3	4.4	18	< 3
22B4	< 1	0.5	349	44	< 0.5	11	1.3	< 1	< 5	2	223	9	< 20	0.337	0.4	2.9	< 3	588	< 1	2.5	6.4	23	< 3
22B5	< 1	< 0.5	26	19	0.7	8	1	< 1	< 5	2	27	7	< 20	0.313	0.4	2.2	< 3	602	< 1	1.9	5.4	20	< 3
22B6	1	< 0.5	139	41	1.2	9	1.3	< 1	< 5	2	91	6	20	0.355	0.4	2.6	< 3	587	< 1	2.6	5.5	20	< 3
22B7		2				21				3	897	29		0.399				495				12	
22B8		2.2				22				4	1060	27		0.416				405				21	
22B9	2	1.2	885	73	1.6	20	2.7	< 1	< 5	3	706	19	30	0.489	0.8	4.3	< 3	245	< 1	4.7	5.5	32	< 3
22B10	2	1.4	813	87	0.9	28	5.6	< 1	< 5	3	861	16	< 20	0.442	0.8	5.3	< 3	220	1	5.8	5.5	34	< 3
22B11	2	1.9	1070	84	2.7	54	13.6	< 1	< 5	3	1050	27	40	0.486	0.8	6	< 3	221	< 1	8.5	7.9	40	< 3
22B12	6	1.5	903	64	4.4	48	6	< 1	< 5	4	1070	30	40	0.34	1	8.1	< 3	271	< 1	9.2	8	54	3
COM1	< 1	2.4	131	80	1.1	63	1.2	< 1	< 5	38	167	95	< 20	0.004	3.3	5.5	< 3	640	< 1	3.5	2.8	362	11
COM2	< 1	5.2	244	28	4.4	594	0.9	< 1	< 5	98	708	211	40	0.011	2.5	14.2	< 3	194	< 1	4.4	3.6	206	5
COM3	< 1	2.1	131	83	1.3	64	1.3	< 1	< 5	38	173	93	30	0.004	3.4	5.7	< 3	642	< 1	3.5	3.8	274	12
COM4	< 1	5.1	237	24	4.5	575	0.9	< 1	< 5	98	706	221	40	0.01	2.3	13.7	< 3	207	< 1	4.1	3.6	152	4
DS2FE1	5	1.5	11	23	< 0.5	31	0.9	< 1	< 5	< 2	12	40	40	1.45	0.6	5.2	< 3	37	< 1	3.3	1.4	24	< 3

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Analyte Symbol	Y	Zn	Zr	La	Ce	Nd	Sm	Eu	Tb	Yb	Lu	Mass	SiO_2	Al_2O_3	Fe_2O_3(T)	MnO	MgO	CaO	Na_2O	K_2O
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	g	%	%	%	%	%	%	%	%
Detection Limit	1	1	2	0.2	3	5	0.1	0.1	0.5	0.1	0.05		0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01
Analysis Method	FUS-ICP	TD-ICP	FUS-ICP	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	INAA	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF
6A1	293	1	32	91.9	182	122	26	9	6	11.7	1.64	0.9								
15A1	238	< 1	87	84.7	163	102	22.2	7.7	5.5	10.1	1.41	1.038								
22A1	151	< 1	175	60.4	112	64	12.9	4.5	2.6	6	0.85	1.368								
32A1	261	1730	51	88.5	184	102	23.2	8.3	5.4	10.1	1.39	0.841								
6B1	295	1780	21	98.6	201	127	27.3	9.2	6.2	12.3	1.73	0.808								
6B2	292	1800	20	98	201	135	27.6	9.2	6.7	12.3	1.69	0.828								
6B3	293	1770	25	95.8	195	128	27	9.1	6.4	12.3	1.64	0.8								
6B4	307	2110	< 2	104	210	138	28.6	9.7	6.5	12.6	1.71	0.684								
6B5	318	2000	12	109	226	134	30.4	10.3	7.1	13.3	1.75	0.678								
6B6	293	1870	15	103	216	128	29	9.7	6.5	13	1.76	0.761								
6B7	271	1480	59	89.6	179	122	25.5	8.8	6	12.3	1.61	0.806								
22B1	5	11	8	4.2	6	< 5	0.6	0.2	< 0.5	0.3	< 0.05	1.458								
22B2	73	519	30	32.8	66	35	7.4	2.8	1.6	3.6	< 0.05	1.362								
22B3	8	29	43	6.6	12	6	1	0.4	< 0.5	0.6	< 0.05	1.737								
22B4	40	253	54	20.1	41	21	4.2	1.5	0.9	2	< 0.05	1.505								
22B5	10	36	35	8.4	15	8	1.4	0.4	< 0.5	0.8	< 0.05	1.593								
22B6	21	109	45	12.7	25	12	2.4	0.9	< 0.5	1.2	< 0.05	1.483								
22B7	127	995	< 2																	
22B8	136	1160	14																	
22B9	85	799	123	47	87	50	9.8	3.5	2.3	5.1	0.47	1.484								
22B10	109	969	239	52	94	56	10.5	3.6	2.5	5.6	0.57	1.491								
22B11	160	1190	685	71.2	132	79	14.8	5	2.8	8.6	1	1.261								
22B12	170	1210	231	70.2	134	72	15.4	5.3	3.5	8.6	1.06	1.053								
COM1	47	143	< 2	57.3	110	68	12.6	4.5	2.1	5.2	0.57	2.483	4.32	2.16	4.36	72.36	< 0.01	0.2	0.28	0.68
COM2	40	680	< 2	28.5	48	24	4.5	1.6	0.8	3.6	0.45	2.036	2.12	4.16	4.92	70	< 0.01	0.28	0.28	0.72
COM3	47	144	< 2	58.5	113	68	13.1	4.7	2	5.2	0.61	2.013	4.12	2.04	4.48	72.8	< 0.01	0.2	0.32	0.64
COM4	43	688	< 2	28	49	22	4.5	1.6	0.8	3.4	0.44	2.15	2.08	4.04	4.65	70.66	0.06	0.24	0.2	0.55
DS2FE1	6	108	30	8.6	17	7	1.3	0.4	< 0.5	0.8	0.1	0.935								

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Analyte Symbol	TiO2	P2O5	Cr2O3	LOI	Total
Unit Symbol	%	%	%	%	%
Detection Limit	0.01	0.01	0.01	0.01	0.01
Analysis Method	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF
6A1					
15A1					
22A1					
32A1					
6B1					
6B2					
6B3					
6B4					
6B5					
6B6					
6B7					
22B1					
22B2					
22B3					
22B4					
22B5					
22B6					
22B7					
22B8					
22B9					
22B10					
22B11					
22B12					
COM1	0.16	0.2	0.04	11.24	95.88
COM2	0.24	0.24	< 0.01	12.69	95.54
COM3	0.16	0.2	< 0.01	11.26	96.06
COM4	0.22	0.24	< 0.01	12.63	95.6
DS2FE1					

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Analyte Symbol	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total	Au	Ag	As	Ba	Ba	Be
Unit Symbol	%	%	%	%	%	%	%	%	%	%	%	%	ppb	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.01	0.01	5	0.5	2	2	50	1
Analysis Method	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	INAA	TD-ICP	INAA	FUS-ICP	INAA	FUS-ICP
GXR-1 Meas														31.5				
GXR-1 Cert														31				
GXR-1 Meas														29.4				
GXR-1 Cert														31				
NIST 694 Meas	11.01	1.99	0.72	0.01	0.33	43.47	0.87	0.54	0.12	30.14								
NIST 694 Cert	11.2	1.8	0.79	0.0116	0.33	43.6	0.86	0.51	0.11	30.2								
DNC-1 Meas	47.7	18.95	9.88	0.15	10.33	11.45	1.97	0.15	0.499	0.08				< 0.5		110		< 1
DNC-1 Cert	47	18.3	9.93	0.149	10.1	11.3	1.87	0.234	0.48	0.09				0.027		114		1
DNC-1 Meas														< 0.5				
DNC-1 Cert														0.027				
BIR-1 Meas	48.19	15.93	11.26	0.18	9.75	13.37	1.87	< 0.01	0.987	0.03						10		1
BIR-1 Cert	47.8	15.4	11.3	0.171	9.68	13.2	1.75	0.03	0.96	0.05						7		0.58
STM-1 (Depleted) Meas																		
STM-1 (Depleted) Cert																		
GXR-4 Meas														3.2				
GXR-4 Cert														4				
GXR-4 Meas														3.2				
GXR-4 Cert														4				
GXR-2 Meas														17.3				
GXR-2 Cert														17				
GXR-2 Meas														19.3				
GXR-2 Cert														17				
SDC-1 Meas														< 0.5				
SDC-1 Cert														0.041				
SDC-1 Meas														< 0.5				
SDC-1 Cert														0.041				
SCO-1 Meas														< 0.5				
SCO-1 Cert														0.134				
SCO-1 Meas														< 0.5				
SCO-1 Cert														0.134				
GXR-6 Meas														< 0.5				
GXR-6 Cert														1.3				
GXR-6 Meas														0.5				
GXR-6 Cert														1.3				
FK-N Meas	62.27	17.93	0.13	< 0.01	< 0.01	0.1	2.39	12.19	0.007	0.02						201		1
FK-N Cert	65	18.6	0.09	0.005	0.01	0.11	2.58	12.8	0.02	0.024						200		1
NIST 1633b Meas	48.9	28.79	10.95	0.02	0.78	2.15	0.25	2.32	1.318	0.58						721		
NIST 1633b Cert	49.2	28.4	11.1	0.02	0.8	2.11	0.27	2.35	1.32	0.53						709		
SY-3 Meas	59.99	11.99	6.06	0.32	2.6	7.89	4.29	4.31	0.135	0.45						456		22
SY-3 Cert	59.6	11.8	6.49	0.32	2.67	8.25	4.12	4.23	0.15	0.54						450		20
BE-N Meas																		
BE-N Cert																		
SGR-1 Meas																		
SGR-1 Cert																		
NOD-A-1 Meas																		
NOD-A-1 Cert																		
NOD-P-1 Meas																		
NOD-P-1 Cert																		

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Analyte Symbol	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total	Au	Ag	As	Ba	Ba	Be
Unit Symbol	%	%	%	%	%	%	%	%	%	%	%	%	ppb	ppm	ppm	ppm	ppm	ppm
Detection Limit	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.01	0.01	5	0.5	2	2	50	1
Analysis Method	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	INAA	TD-ICP	INAA	FUS-ICP	INAA	FUS-ICP
GXR-1 Meas														31.5				
W-2a Meas	51.9	15.28	10.47	0.17	6.27	10.75	2.22	0.54	1.075	0.15						172		2
W-2a Cert	52.4	15.4	10.7	0.163	6.37	10.9	2.14	0.626	1.06	0.13						182		1.3
OREAS 13P Meas																		
OREAS 13P Cert																		
OREAS 13P Meas																		
OREAS 13P Cert																		
NIST 696 Meas	3.54	51.96	7.99	< 0.01	0.01	0.03		< 0.01	2.521	0.05								
NIST 696 Cert	3.79	54.5	8.7	0.004	0.012	0.018		0.009	2.64	0.05								
DMMAS-104 Meas													257		1590		810	
DMMAS-104 Cert													229		1570		850	
DMMAS-104 Meas													200		1580		820	
DMMAS-104 Cert													229		1570		850	
JSD-3 Meas	70.5	9.17	3.84	0.13	1.05	0.51	0.35	1.68	0.378	0.09								
JSD-3 Cert	76	9.908	4.368	0.148	1.17	0.56	0.411	1.971	0.403	0.0817								
ZW-C Meas																		
ZW-C Cert																		
22B2 Orig														1.3				
22B2 Dup														1.3				
22B4 Orig	11.79	3.09	2.88	5.27	0.56	42.26	0.04	0.45	0.158	0.11	34.06	100.7				232		2
22B4 Dup	11.65	2.96	2.76	5.14	0.54	40.99	0.02	0.5	0.152	0.11	34.06	98.89				215		2
COM4 Orig														19.9				
COM4 Dup														20.2				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank														< 0.5				
Method Blank Method Blank																		

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Analyte Symbol	Bi	Cd	Co	Cr	Cu	Mo	Ni	Pb	S	Sb	Sc	Sr	Th	U	V	W	Y	Zn	Zr	La	Ce
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	2	0.5	1	1	1	2	1	5	0.001	0.2	0.1	2	0.5	0.5	5	3	1	1	2	0.2	3
Analysis Method	TD-ICP	TD-ICP	INAA	INAA	TD-ICP	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA	INAA	FUS-ICP	INAA	INAA	FUS-ICP	INAA	FUS-ICP	TD-ICP	FUS-ICP	INAA	INAA
GXR-1 Meas	1760	3.8			1160	15	44	766	0.241									780			
GXR-1 Cert	1380	3.3			1110	18	41	730	0.257									760			
GXR-1 Meas	1390	3.3			1300	16	38	701	0.271									713			
GXR-1 Cert	1380	3.3			1110	18	41	730	0.257									760			
NIST 694 Meas															1643						
NIST 694 Cert															1740						
DNC-1 Meas	< 2				88	< 2	243	5	0.05			145			182		18	55	37		
DNC-1 Cert	0.02				96	0.7	247	6.3	0.039			145			148		18	66	41		
DNC-1 Meas	< 2				116	< 2	252	5	0.063									55			
DNC-1 Cert	0.02				96	0.7	247	6.3	0.039									66			
BIR-1 Meas												109			333		17		13		
BIR-1 Cert												108			313		16		16		
STM-1 (Depleted) Meas																					
STM-1 (Depleted) Cert																					
GXR-4 Meas	15	0.7			6470	314	42	47	1.82									75			
GXR-4 Cert	19	0.86			6520	310	42	52	1.77									73			
GXR-4 Meas	10	0.6			6330	313	40	43	1.75									70			
GXR-4 Cert	19	0.86			6520	310	42	52	1.77									73			
GXR-2 Meas	< 2	3.3			72	< 2	20	662	0.015									506			
GXR-2 Cert	0.69	4.1			76	2.1	21	690	0.0313									530			
GXR-2 Meas	< 2	3.9			105	2	20	720	0.033									553			
GXR-2 Cert	0.69	4.1			76	2.1	21	690	0.0313									530			
SDC-1 Meas	< 2	< 0.5			24	< 2	32	17	0.052									93			
SDC-1 Cert	2.6	0.08			30	0.25	38	25	0.065									103			
SDC-1 Meas	< 2	< 0.5			30	< 2	36	23	0.069									101			
SDC-1 Cert	2.6	0.08			30	0.25	38	25	0.065									103			
SCO-1 Meas	< 2	< 0.5			26	< 2	30	29										101			
SCO-1 Cert	0.37	0.14			28.7	1.37	27	31										103			
SCO-1 Meas	< 2	< 0.5			32	< 2	25	25										94			
SCO-1 Cert	0.37	0.14			28.7	1.37	27	31										103			
GXR-6 Meas	< 2	1.3			64	< 2	27	94	0.012									131			
GXR-6 Cert	0.29	1			66	2.4	27	101	0.016									118			
GXR-6 Meas	< 2	1.3			99	3	30	101	0.015									145			
GXR-6 Cert	0.29	1			66	2.4	27	101	0.016									118			
FK-N Meas												37			28		< 1		< 2		
FK-N Cert												39			5		0.5		13		
NIST 1633b Meas												1050			296						
NIST 1633b Cert												1040			296						
SY-3 Meas												272			81		131		302		
SY-3 Cert												302			50		718		320		
BE-N Meas																					
BE-N Cert																					
SGR-1 Meas																					
SGR-1 Cert																					
NOD-A-1 Meas																					
NOD-A-1 Cert																					
NOD-P-1 Meas																					
NOD-P-1 Cert																					

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Analyte Symbol	Bi	Cd	Co	Cr	Cu	Mo	Ni	Pb	S	Sb	Sc	Sr	Th	U	V	W	Y	Zn	Zr	La	Ce
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Detection Limit	2	0.5	1	1	1	2	1	5	0.001	0.2	0.1	2	0.5	0.5	5	3	1	1	2	0.2	3
Analysis Method	TD-ICP	TD-ICP	INAA	INAA	TD-ICP	TD-ICP	TD-ICP	TD-ICP	TD-ICP	INAA	INAA	FUS-ICP	INAA	INAA	FUS-ICP	INAA	FUS-ICP	TD-ICP	FUS-ICP	INAA	INAA
GXR-1 Meas	1760	3.8			1160	15	44	766	0.241									780			
W-2a Meas												192			276		21		95		
W-2a Cert												190			262		24		94		
OREAS 13P Meas					2510		2230														
OREAS 13P Cert					2500		2260														
OREAS 13P Meas					3000		2110														
OREAS 13P Cert					2500		2260														
NIST 696 Meas															392				1046		
NIST 696 Cert															403				1040		
DMMAS-104 Meas			48	99						6.5	14.9		8.2	70.3		8				37	61
DMMAS-104 Cert			48.8	95.1						6.2	14.1		8.3	71.9		6				36.6	62.9
DMMAS-104 Meas			47	94						6.8	14.2		8.1	70.5		8				37.5	60
DMMAS-104 Cert			48.8	95.1						6.2	14.1		8.3	71.9		6				36.6	62.9
JSD-3 Meas																					
JSD-3 Cert																					
ZW-C Meas																					
ZW-C Cert																					
22B2 Orig	4	1.1			15	2	456	15	0.354									500			
22B2 Dup	4	0.8			15	2	492	13	0.394									538			
22B4 Orig												604			23		40		50		
22B4 Dup												572			22		40		58		
COM4 Orig	37	5.1			571	97	708	221	0.011									685			
COM4 Dup	40	5.1			579	98	703	220	0.01									691			
Method Blank Method Blank	< 2	< 0.5			2	< 2	< 1	< 5	< 0.001									< 1			
Method Blank Method Blank	< 2	< 0.5			1	< 2	< 1	< 5	< 0.001									< 1			
Method Blank Method Blank	< 2	< 0.5			< 1	< 2	< 1	< 5	< 0.001									< 1			
Method Blank Method Blank	< 2	< 0.5			2	< 2	< 1	< 5	< 0.001									< 1			
Method Blank Method Blank	< 2	< 0.5			1	< 2	< 1	< 5	< 0.001									5			
Method Blank Method Blank	< 2	< 0.5			< 1	< 2	< 1	< 5	< 0.001									< 1			
Method Blank Method Blank	< 2	< 0.5			< 1	< 2	< 1	< 5	< 0.001									< 1			
Method Blank Method Blank	< 2	< 0.5			< 1	< 2	< 1	< 5	< 0.001									< 1			
Method Blank Method Blank																					

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Activation Laboratories

Analyte Symbol	Nd	Sm	Eu	Yb	Lu	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	Cr2O3
Unit Symbol	ppm	ppm	ppm	ppm	ppm	%	%	%	%	%	%	%	%	%	%	%
Detection Limit	5	0.1	0.1	0.1	0.05	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Analysis Method	INAA	INAA	INAA	INAA	INAA	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF
GXR-1 Meas																
GXR-1 Cert																
GXR-1 Meas																
GXR-1 Cert																
NIST 694 Meas																
NIST 694 Cert																
DNC-1 Meas						45.97	18.37	9.86	0.15	10.03	11.1	1.86	0.23	0.49	0.07	
DNC-1 Cert						47	18.3	9.93	0.149	10.1	11.3	1.87	0.234	0.48	0.09	
DNC-1 Meas																
DNC-1 Cert																
BIR-1 Meas																
BIR-1 Cert																
STM-1 (Depleted) Meas						59.57	18.46	5.4	0.231	0.06	1.16	8.72	4.34	0.14	0.16	
STM-1 (Depleted) Cert						59.6	18.4	5.22	0.22	0.1	1.09	8.94	4.28	0.135	0.16	
GXR-4 Meas																
GXR-4 Cert																
GXR-4 Meas																
GXR-4 Cert																
GXR-2 Meas																
GXR-2 Cert																
GXR-2 Meas																
GXR-2 Cert																
SDC-1 Meas																
SDC-1 Cert																
SDC-1 Meas																
SDC-1 Cert																
SCO-1 Meas																
SCO-1 Cert																
SCO-1 Meas																
SCO-1 Cert																
GXR-6 Meas																
GXR-6 Cert																
GXR-6 Meas																
GXR-6 Cert																
FK-N Meas																
FK-N Cert																
NIST 1633b Meas																
NIST 1633b Cert																
SY-3 Meas																
SY-3 Cert																
BE-N Meas						38.13	9.95		0.199	13.17	13.86	3.14	1.35	2.69	1.08	0.06
BE-N Cert						38.2	10.1		0.2	13.1	13.9	3.18	1.39	2.61	1.05	0.05
SGR-1 Meas						28.68	6.68		0.035	4.55	8.45	3.06	1.6	0.25	0.28	
SGR-1 Cert						28.2	6.52		0.034	4.44	8.38	2.99	1.66	0.26	0.33	
NOD-A-1 Meas						3.95	3.86		23.98	4.91	16.23	0.37	0.13	0.5	1.28	
NOD-A-1 Cert						3.81	3.87		23.9	4.76	15.4	1.04	0.6	0.53	1.37	
NOD-P-1 Meas						14.76	4.69		37.47	3.36	3.14	2.08	1.16	0.48	0.48	
NOD-P-1 Cert						13.9	4.82		37.6	3.3	3.06	2.21	1.21	0.5	0.46	

Final Report
Activation Laboratories

Analyte Symbol	Nd	Sm	Eu	Yb	Lu	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	Cr2O3
Unit Symbol	ppm	ppm	ppm	ppm	ppm	%	%	%	%	%	%	%	%	%	%	%
Detection Limit	5	0.1	0.1	0.1	0.05	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Analysis Method	INAA	INAA	INAA	INAA	INAA	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF	FUS-XRF
GXR-1 Meas																
W-2a Meas						52.21	15.25	11.06	0.171	6.42	10.95	2.19	0.63	1.09	0.12	
W-2a Cert						52.4	15.4	10.7	0.163	6.37	10.9	2.14	0.626	1.06	0.13	
OREAS 13P Meas																
OREAS 13P Cert																
OREAS 13P Meas																
OREAS 13P Cert																
NIST 696 Meas																
NIST 696 Cert																
DMMAS-104 Meas	18	4.7	1.6	3.2	0.45											
DMMAS-104 Cert	18.8	4.3	1.2	3	0.4											
DMMAS-104 Meas	18	4.8	1.6	3.5	0.43											
DMMAS-104 Cert	18.8	4.3	1.2	3	0.4											
JSD-3 Meas																
JSD-3 Cert																
ZW-C Meas						54.21	18.57	9.33	0.94	0.19	0.43	0.74	7.74	0.06	0.03	
ZW-C Cert						54	18.45	9.46	0.97	0.16	0.37	0.33	7.72	0.05	0.025	
22B2 Orig																
22B2 Dup																
22B4 Orig																
22B4 Dup																
COM4 Orig																
COM4 Dup																
Method Blank Method Blank																
Method Blank Method Blank																
Method Blank Method Blank																
Method Blank Method Blank																
Method Blank Method Blank																
Method Blank Method Blank																
Method Blank Method Blank																
Method Blank Method Blank																
Method Blank Method Blank						< 0.01	< 0.01	< 0.01	< 0.001	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

X-ray Diffraction Analysis of Seven Samples

W.O. # A07-5811
Invoice # A07-5811
No. of pages: 4

Client: Biomost, Inc
3016 Unionville Road
Cranberry Township
PA 16066, USA

Contact person: Cliff Denholm

Tel: 724 776 0161
Fax: 724-776-0166
Email bmi@biomost.com

Date Received: November 9, 2007

Date Reported: January 10, 2008

EXPERIMENTAL

Seven samples were submitted for mineral identification. The samples were identified as follows:

Client sample ID	ActLabs sample ID
6A1	A07-5811-1
15A1	A07-5811-2
22A1	A07-5811-3
32A1	A07-5811-4
COM1	A07-5811-24
COM2	A07-5811-25
DS2FE1	A07-5811-28

The samples were ground in a ceramic mortar prior to X-ray analysis.

X-ray diffraction was performed on a pressed portion of the samples using Phillips PW 1050 diffractometer equipped with Cu X-ray source and operated at 40kV and 30 mA.

Measured data was processed using X-ray diffraction processing software GBC Traces Version 6 and ICDD PDF-4/Minerals X-ray powder diffraction dtatabase.

RESULTS

The minerals identified in the sample are listed in the Table I below; the spectra (32 pages) are enclosed. Identification of the clay minerals (Muscovite, Kaolinite) is tentative. Dedicated clay speciation analysis is required to identify clay minerals with precision.

Table I. Mineral identification in the samples.

Client sample ID **ActLabs Sample ID**	**Identified Minerals**	**Comments**
6A1 A07-5811-1	Calcite Magnesian $Mg_{0.064}Ca_{0.936}CO_3$ Quartz, SiO_2 Muscovite, $H_4K_2(Al,Fe)_6Si_6O_{24}$ Staurolite, $(Fe,Mg)_4Al_{18}H_2Si_8O_{48}$ Unidentified mineral(s)	 Possibly present Traces
15A1 A07-5811-2	Calcite Magnesian $Mg_{0.064}Ca_{0.936}CO_3$ Quartz, SiO_2 Muscovite, $H_4K_2(Al,Fe)_6Si_6O_{24}$ Staurolite, $(Fe,Mg)_4Al_{18}H_2Si_8O_{48}$ Unidentified mineral(s)	 Possibly present Traces
22A1 A07-5811-3	Quartz, SiO_2 Calcite Magnesian $Mg_{0.064}Ca_{0.936}CO_3$ Muscovite, $H_4K_2(Al,Fe)_6Si_6O_{24}$ Kaolinite, $Al_2Si_2O_5(OH)_4$	
32A1 A07-5811-4	Quartz, SiO_2 Calcite Magnesian $Mg_{0.064}Ca_{0.936}CO_3$ Muscovite, $H_4K_2(Al,Fe)_6Si_6O_{24}$ Kaolinite, $Al_2Si_2O_5(OH)_4$ Unidentified mineral(s)	 Traces

COM1 A07-5811-24	Pyrolusite, MnO_2 Cryptomelane, KMn_8O_{16} Quartz, SiO2 Unidentified mineral(s)	
COM2 A07-5811-25	Nsutite, $Mn(O,OH)_2$ Pennantite, $(Mn_5Al)(Si_3Al)O_{10}(OH)_8$ Cryptomelane, KMn_8O_{16} Lithophorite, $(Al,Li)Mn_4O_2(OH)_2$ Unidentified mineral(s)	Possibly present Traces
DS2FE1 A07-5811-28	Goethite, $Fe_{+3}O(OH)$ Quartz, SiO_2	

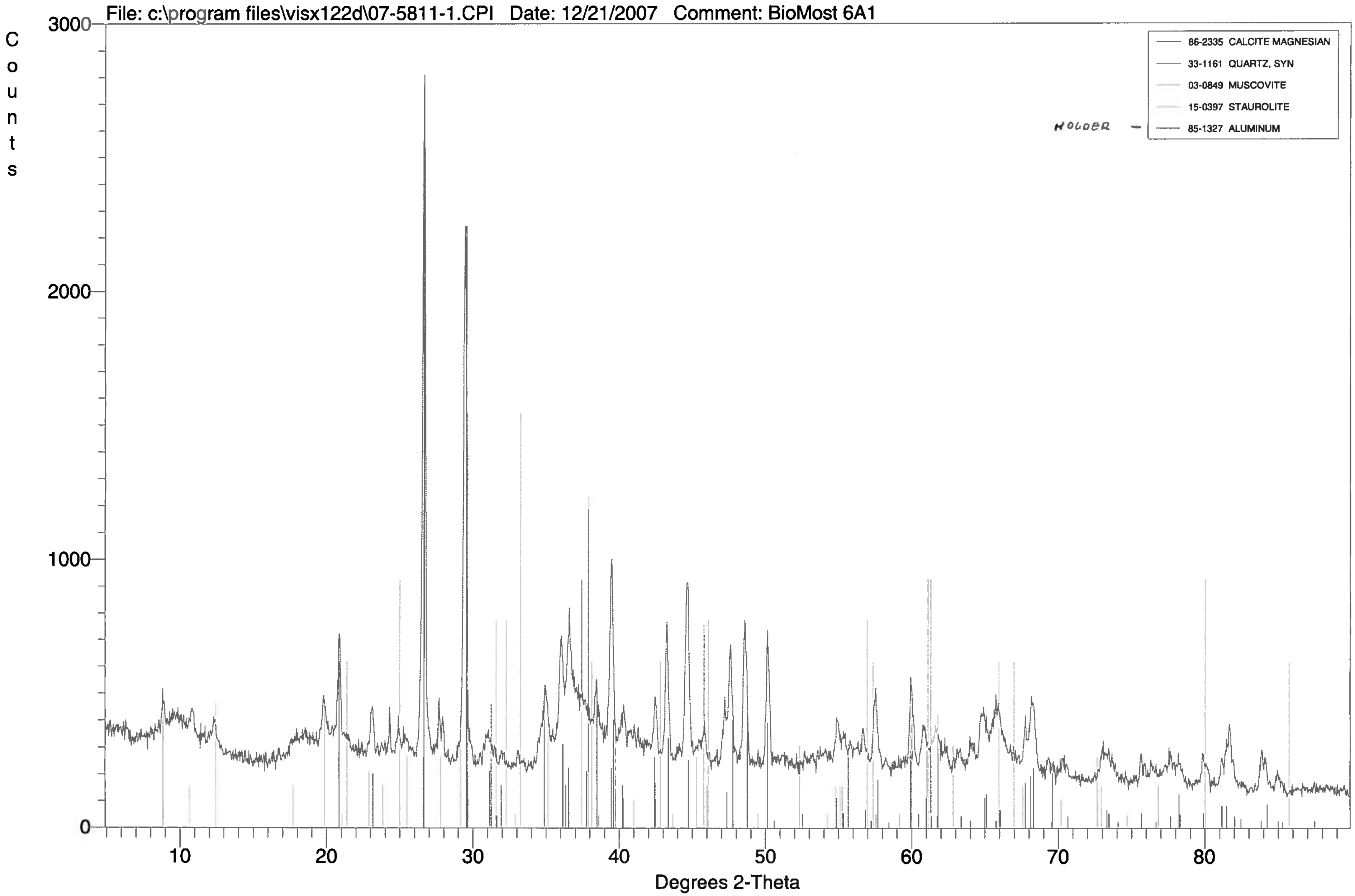
Reported by:

Karen Gabrielyan, Ph.D.
Scientist
Activation Laboratories

Approved by:

Stephen Jenkins, Ph.D.
Pharmaceutical Lab Manager
Activation Laboratories

Activation Laboratories Ltd



KG 01/09/08.

Activation Laboratories Ltd

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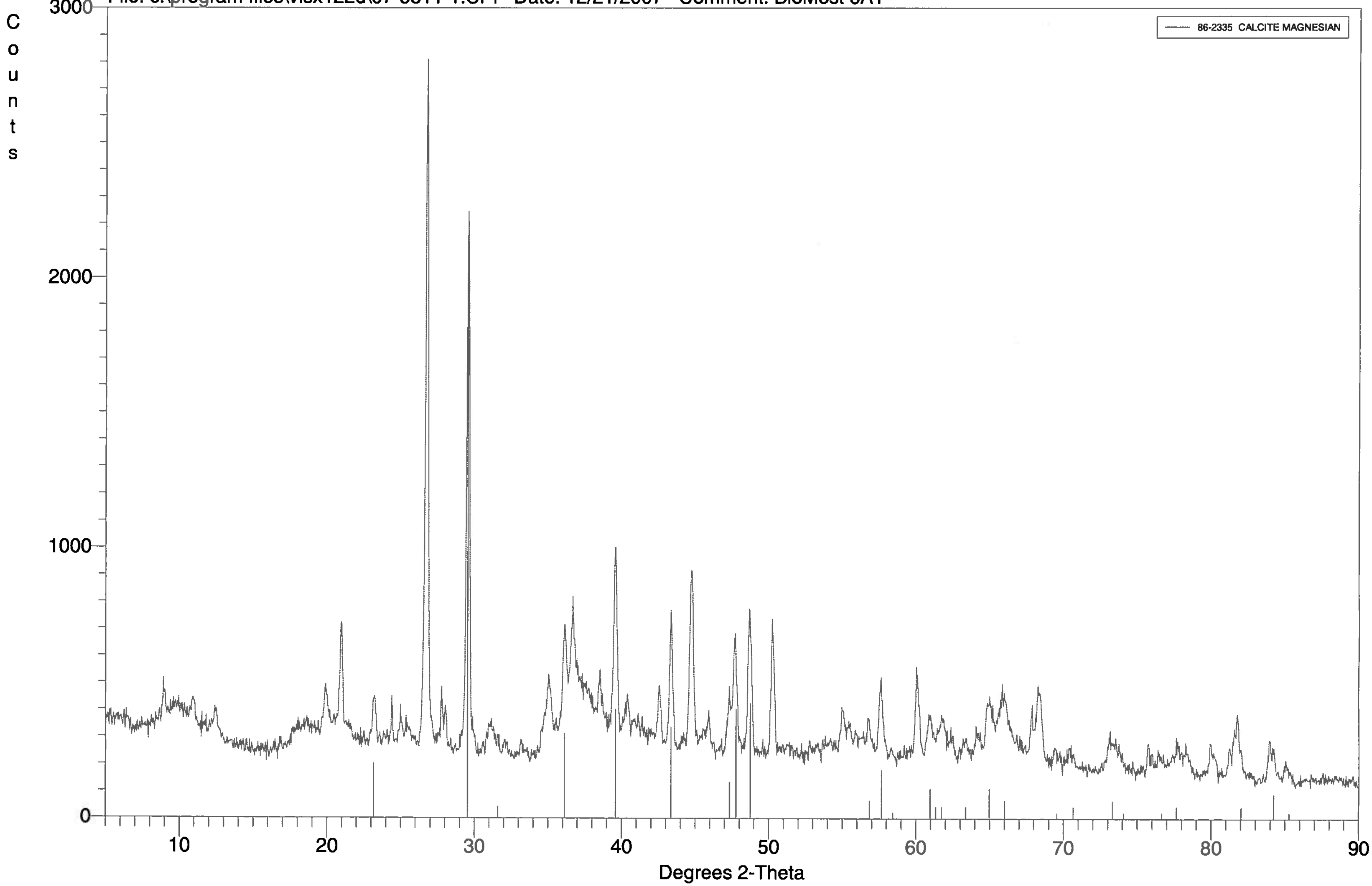

KG   01/09/08

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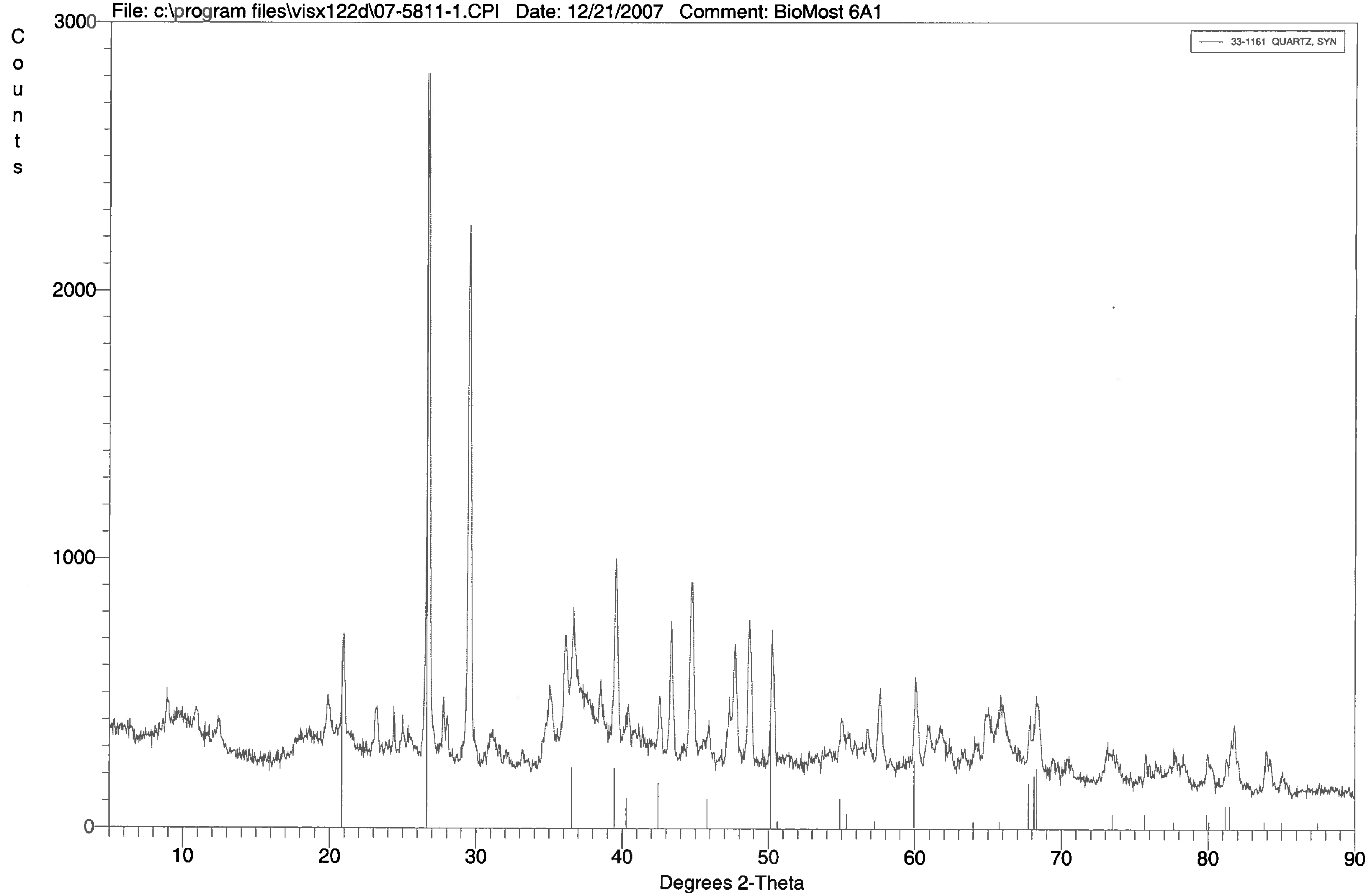
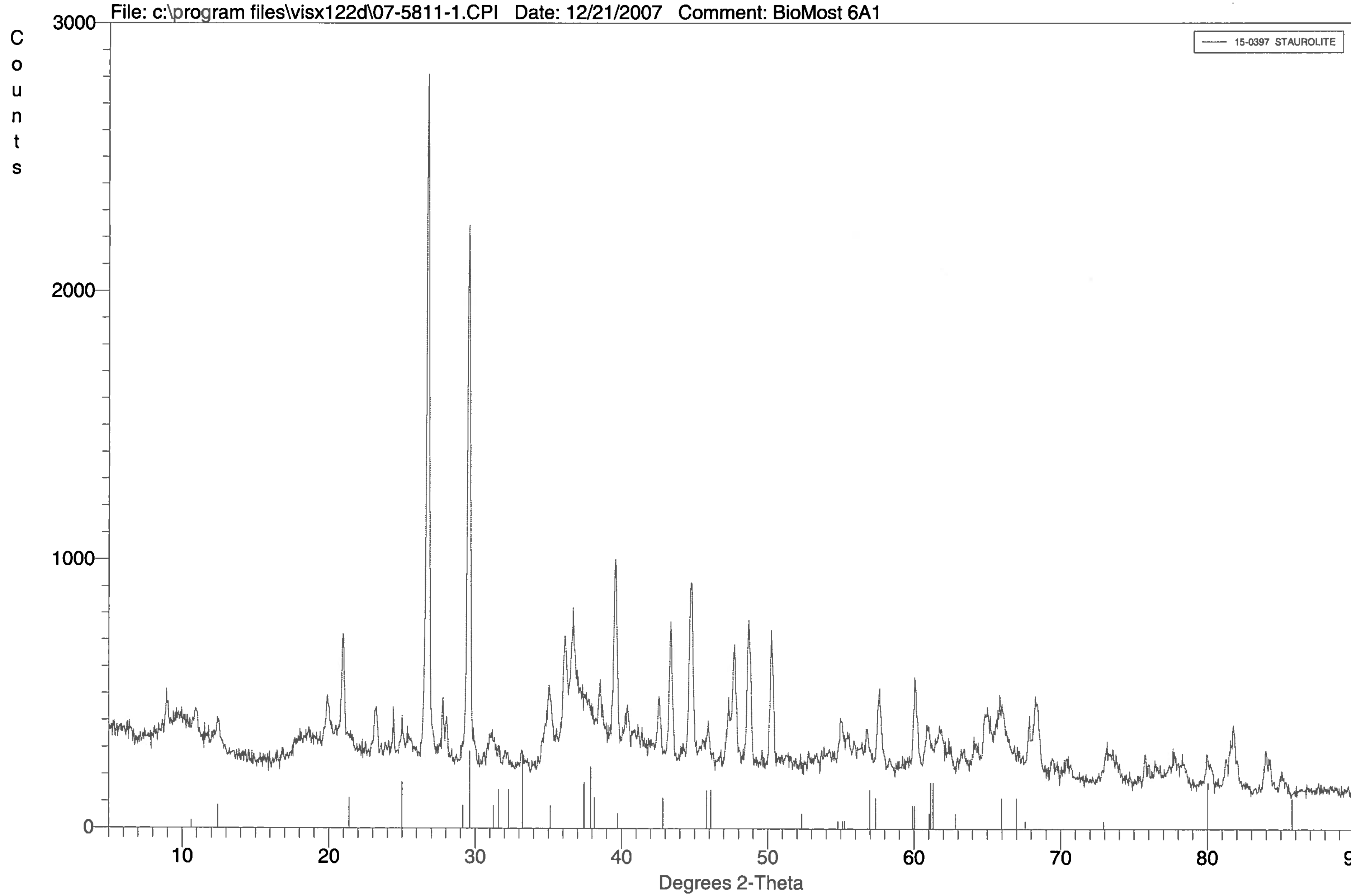


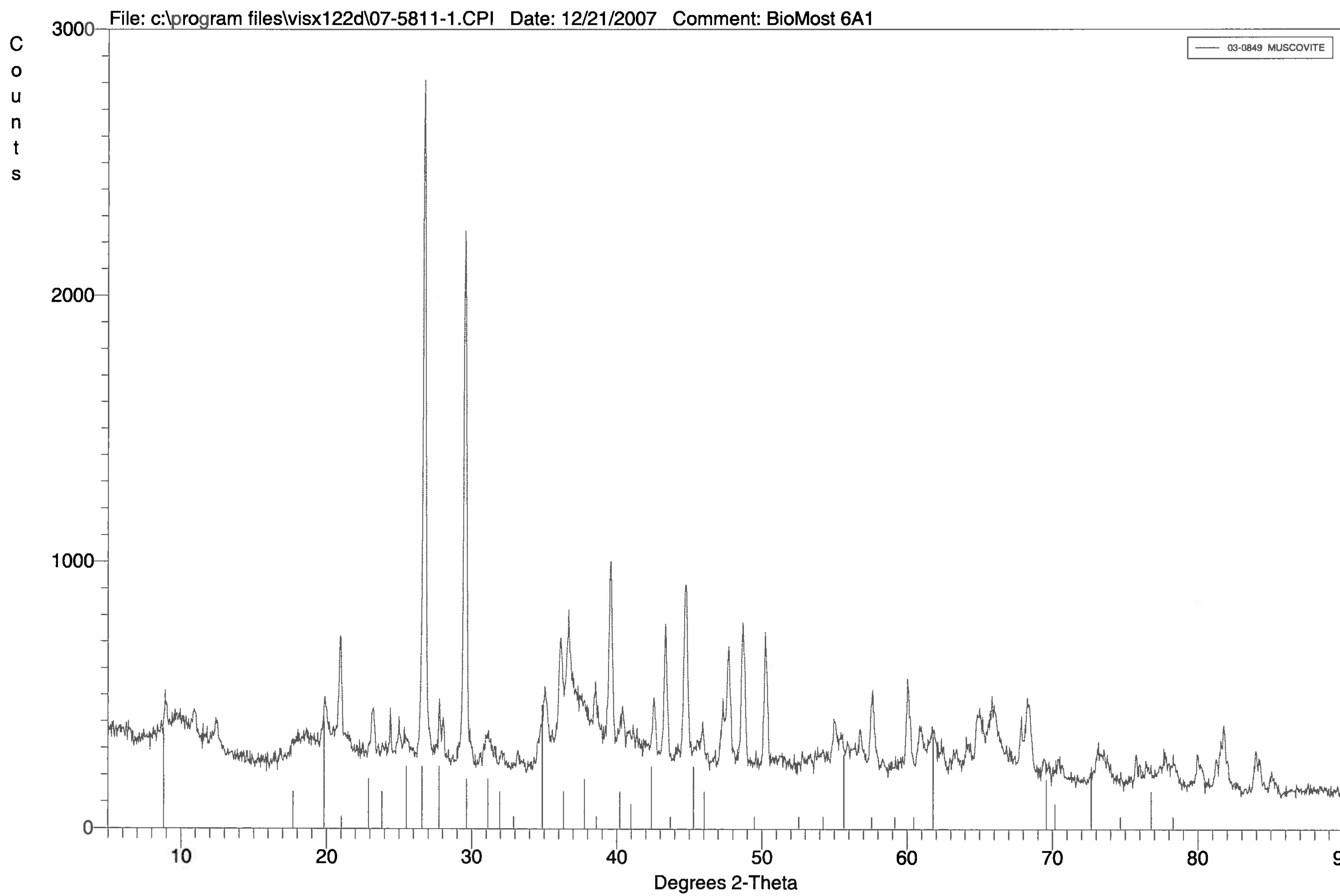
KG 01/09/08

Activation Laboratories Ltd



KG 01/09/08

Activation Laboratories Ltd



KG   01/09/08

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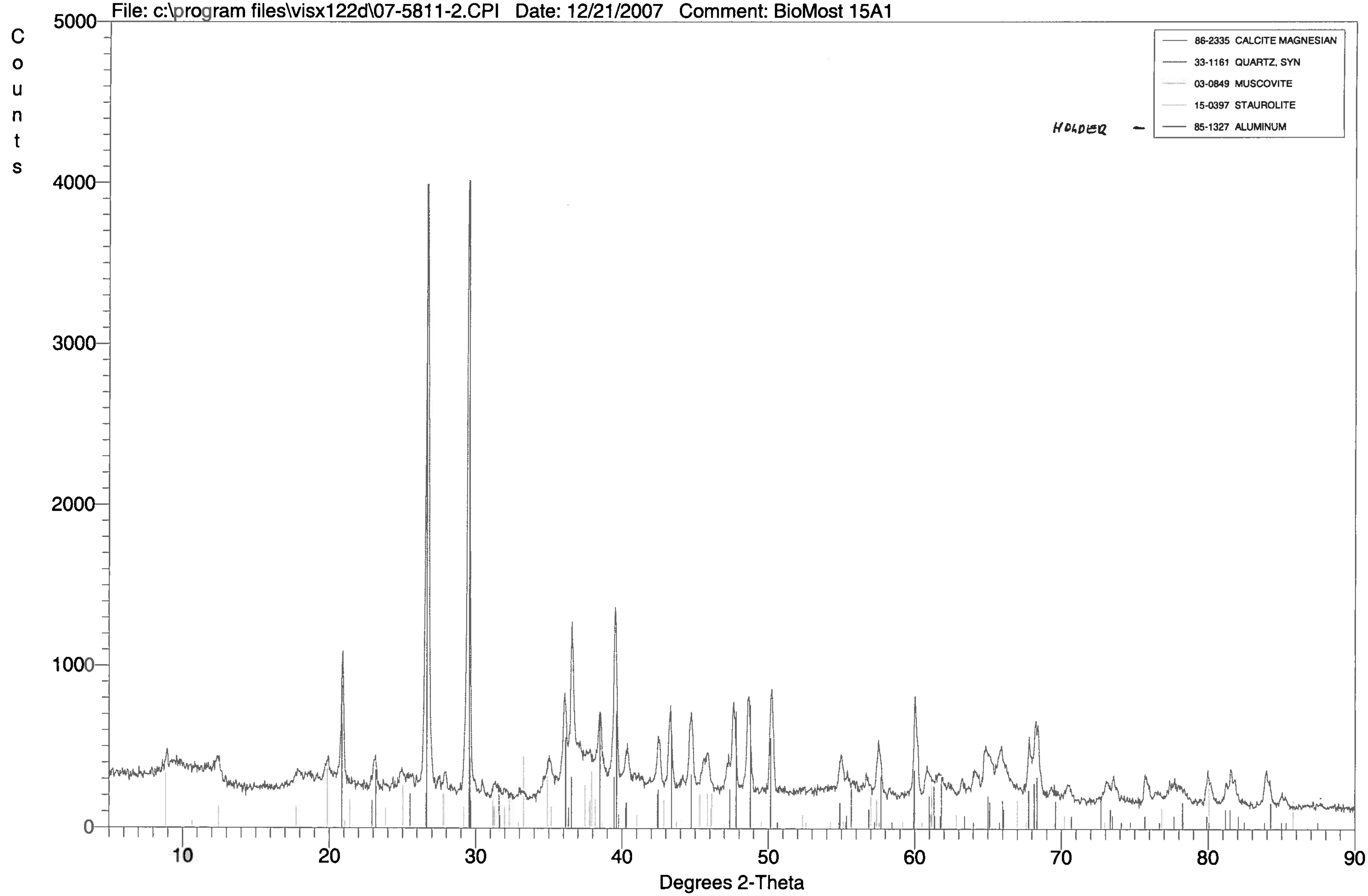

KG   01/09/08

Activation Laboratories Ltd

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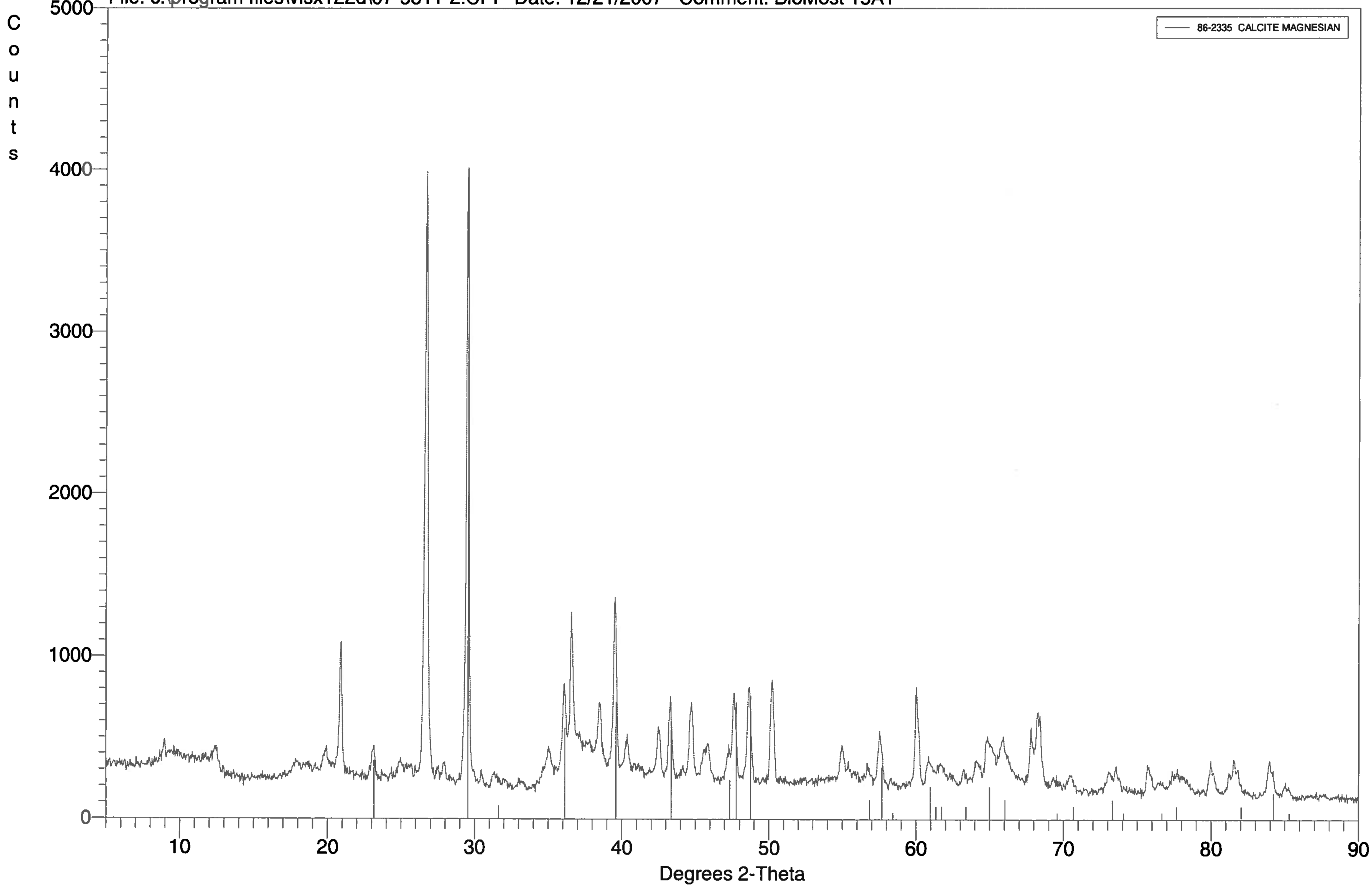
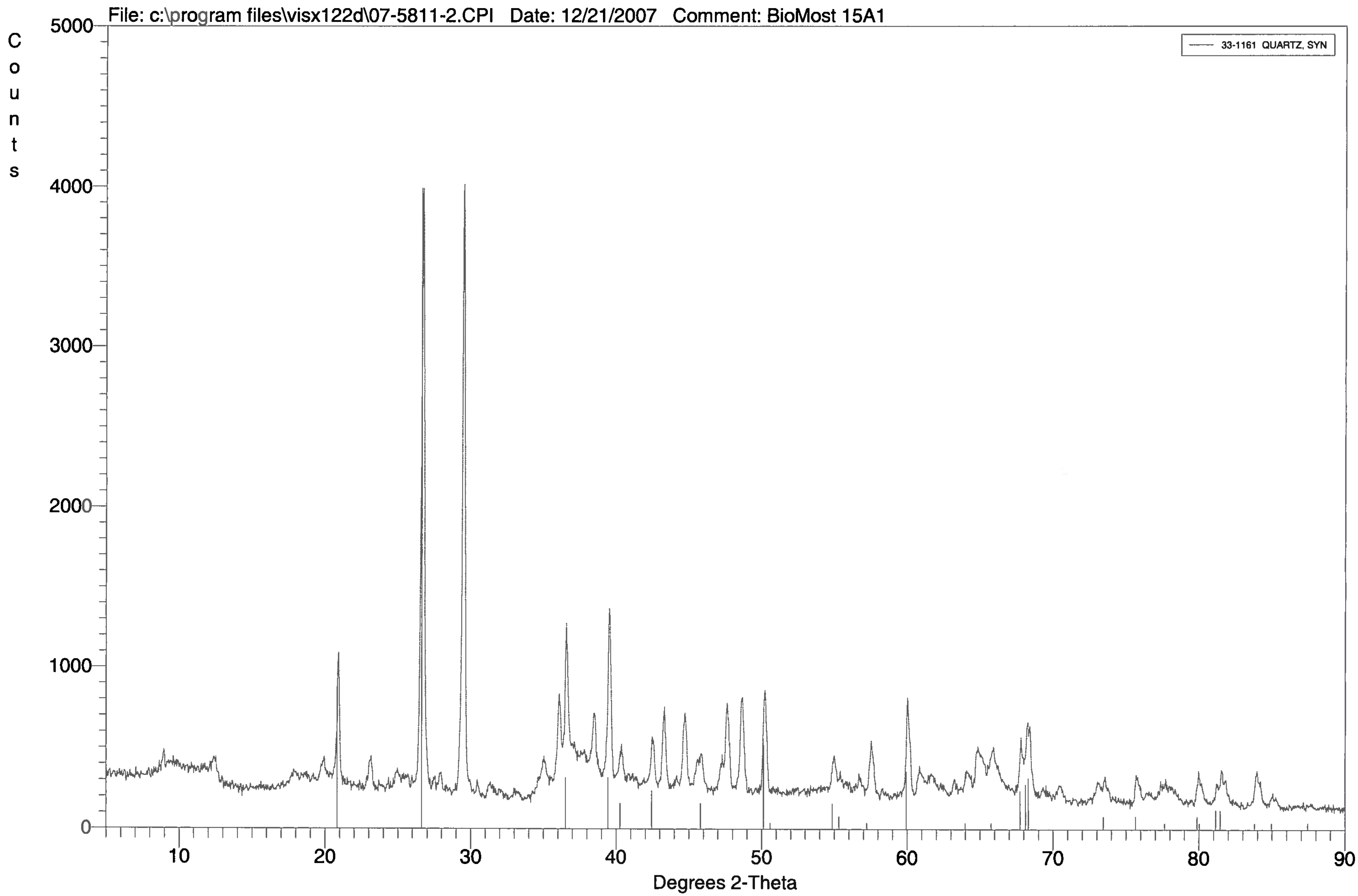


KG 01/09/08

Activation Laboratories Ltd



KG   01/09/08

Activation Laboratories Ltd

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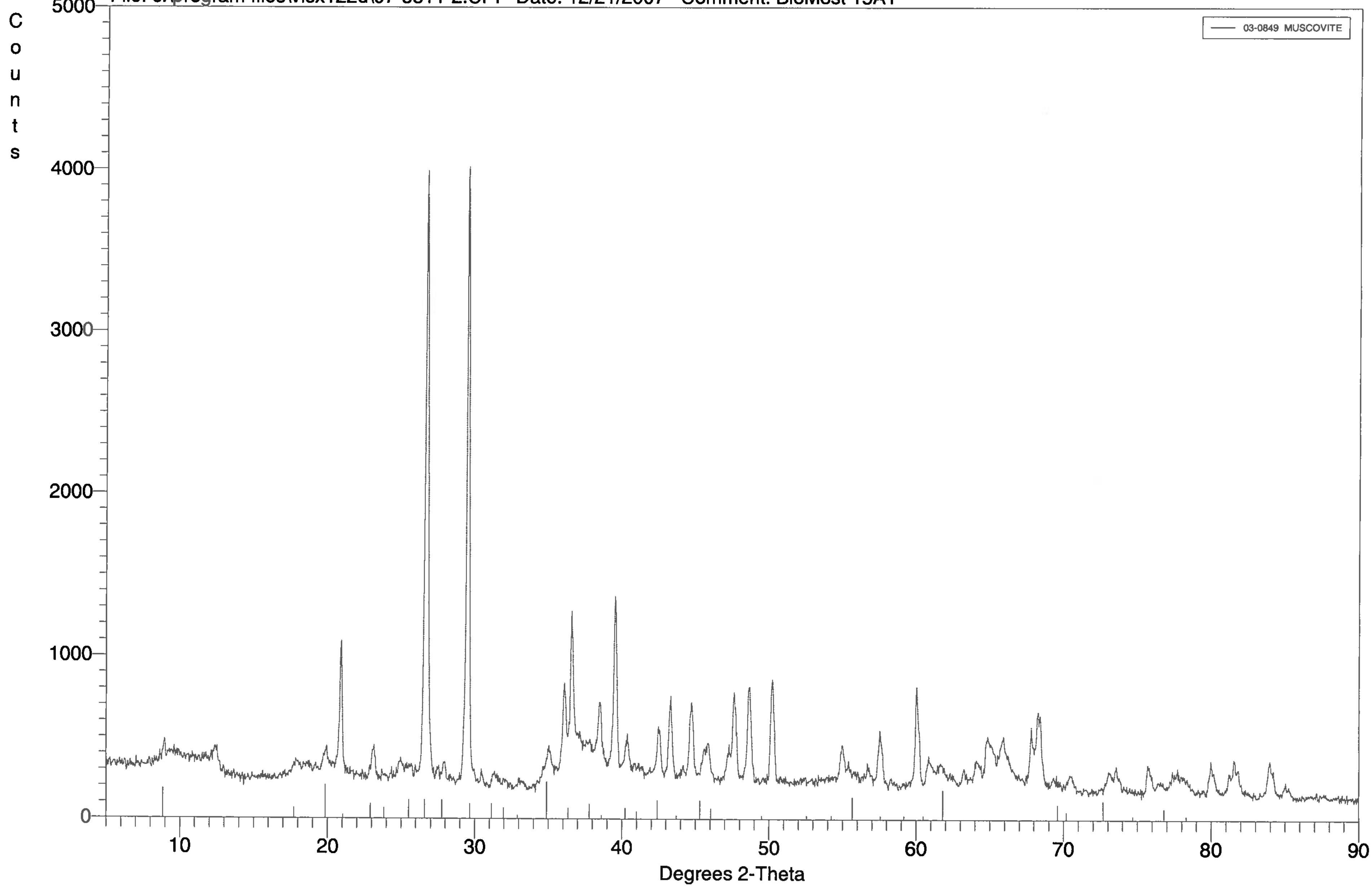

KG 01/09/08

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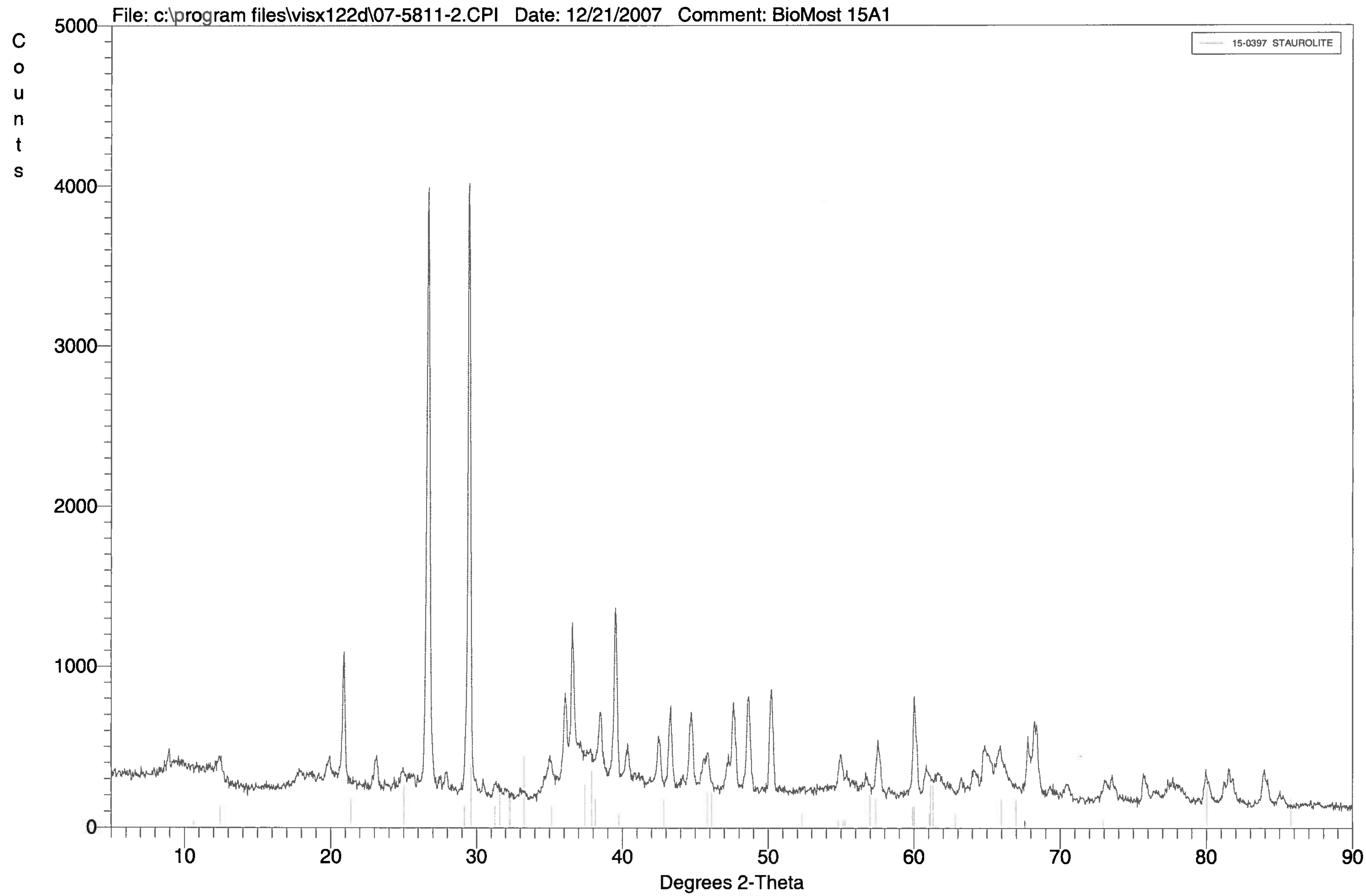

KG 01/09/08

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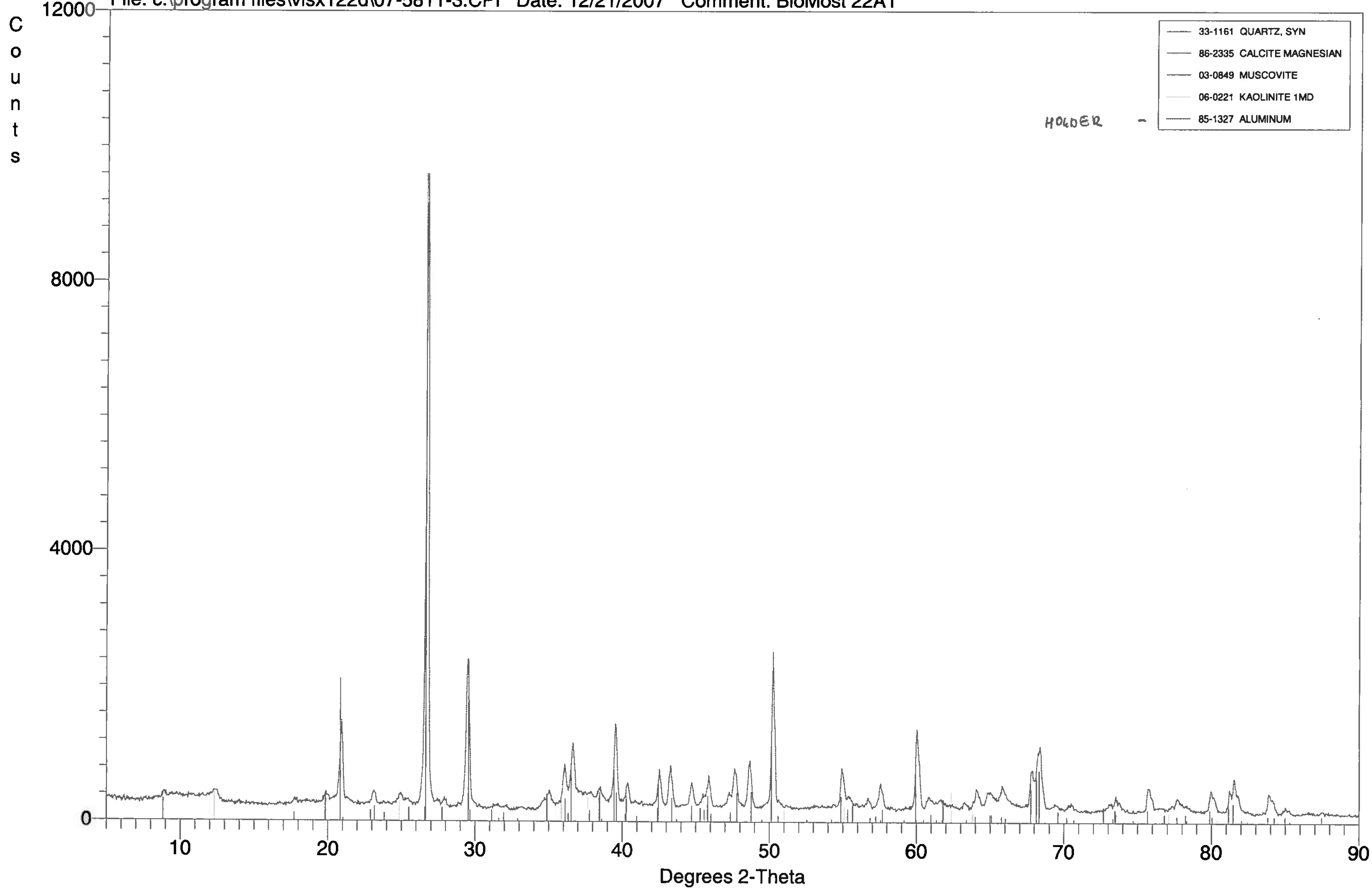

KG 01/09/08

Activation Laboratories Ltd

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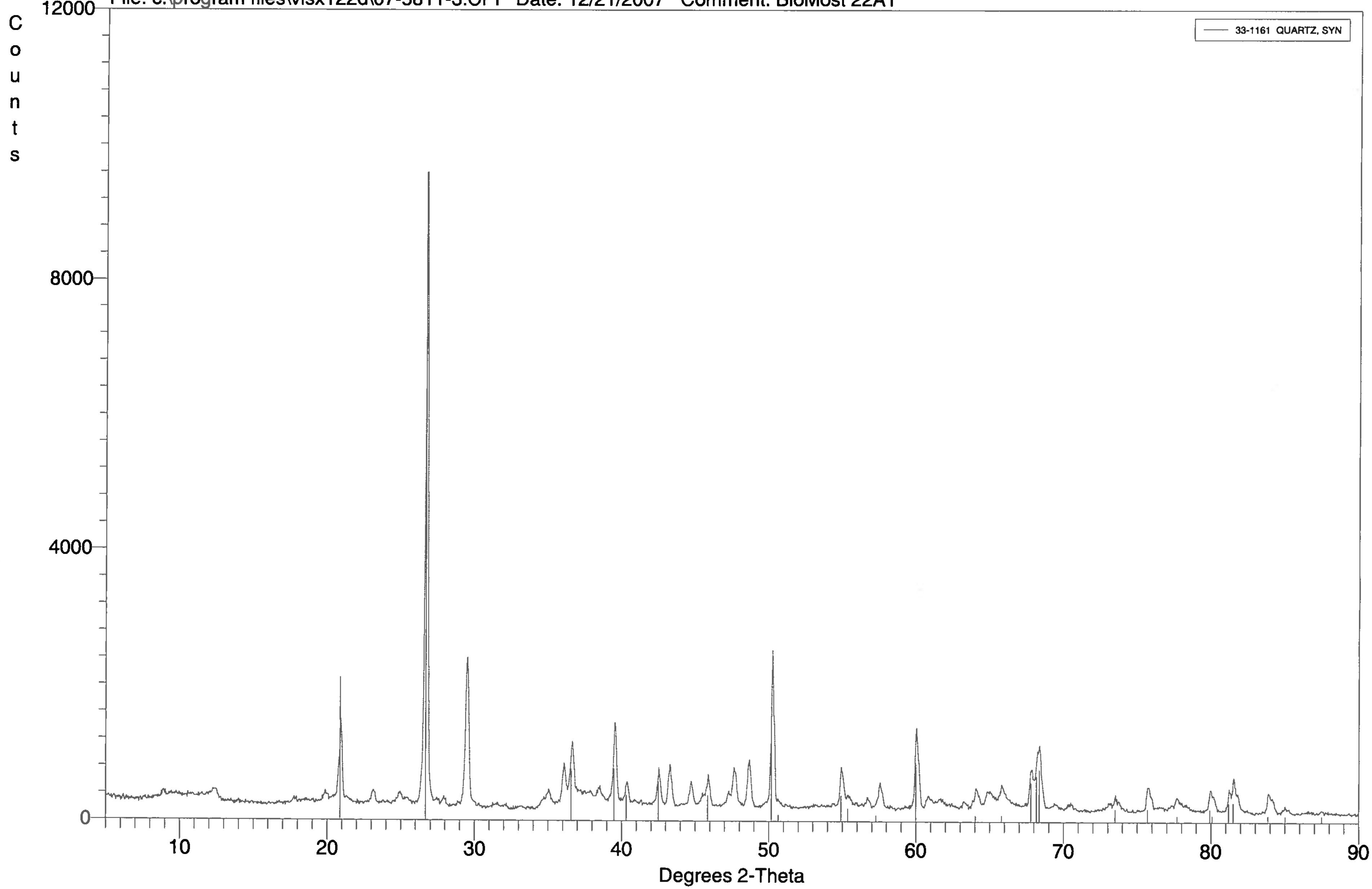
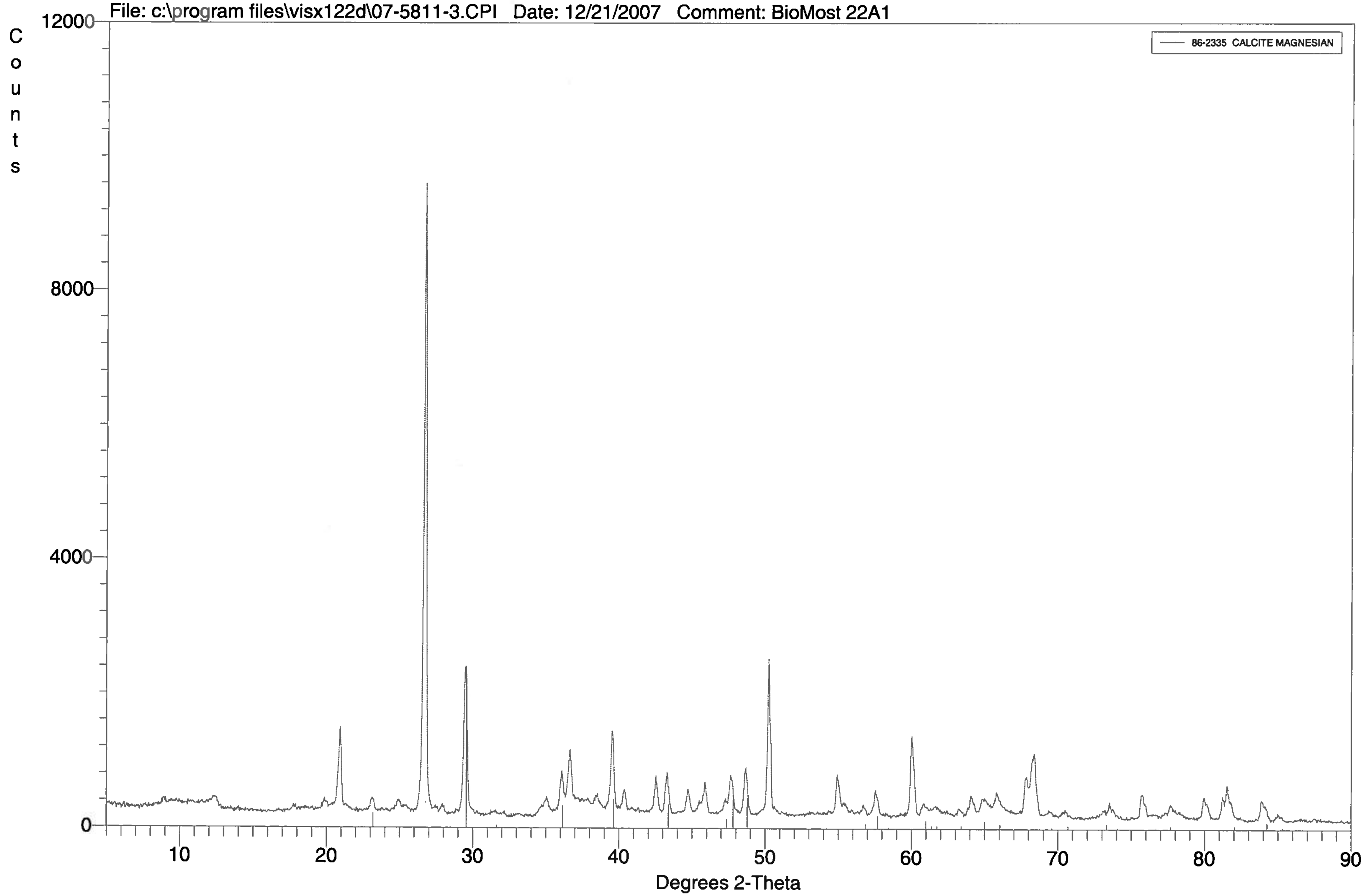


KG   01/09/08

Activation Laboratories Ltd



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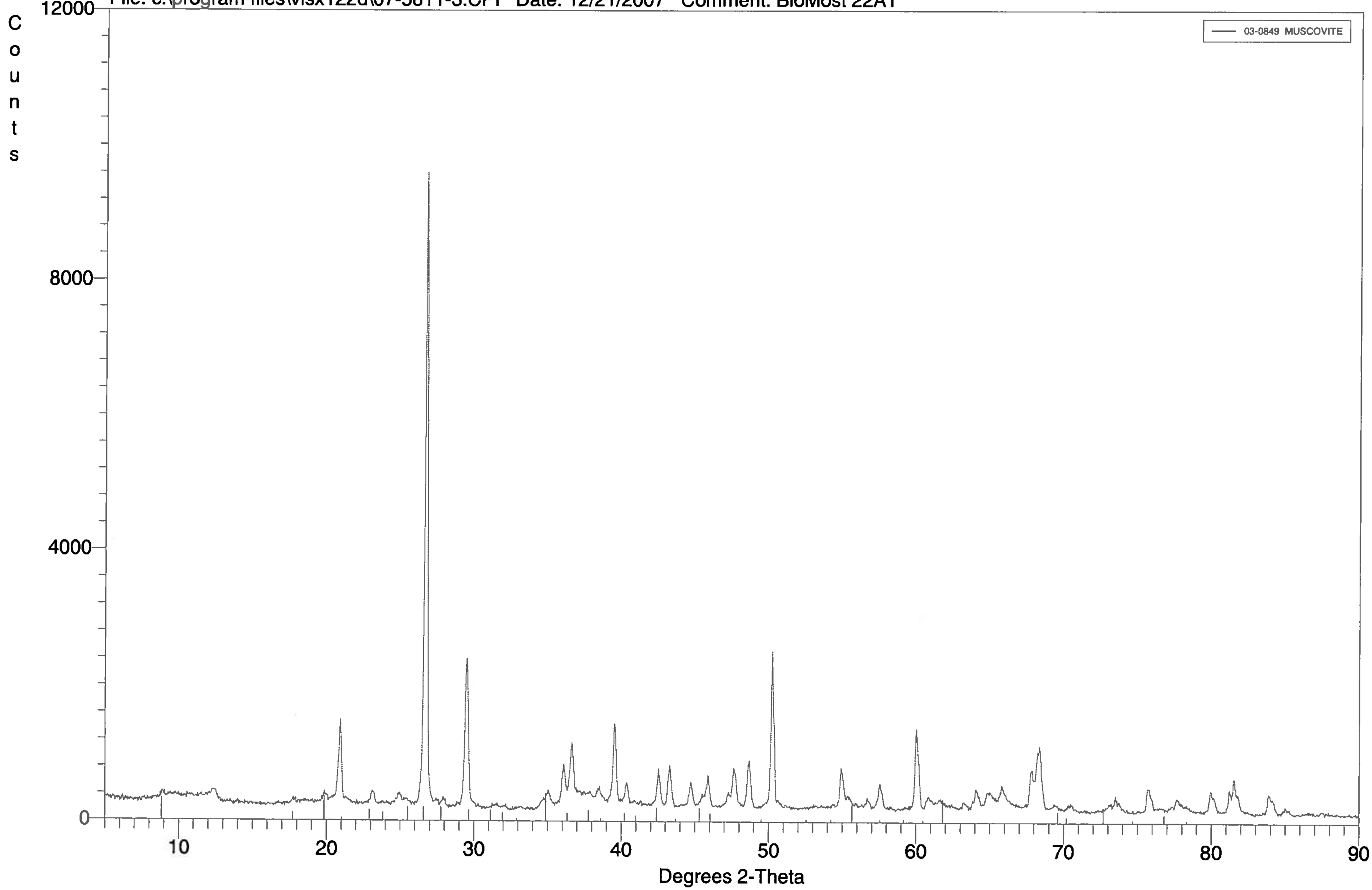
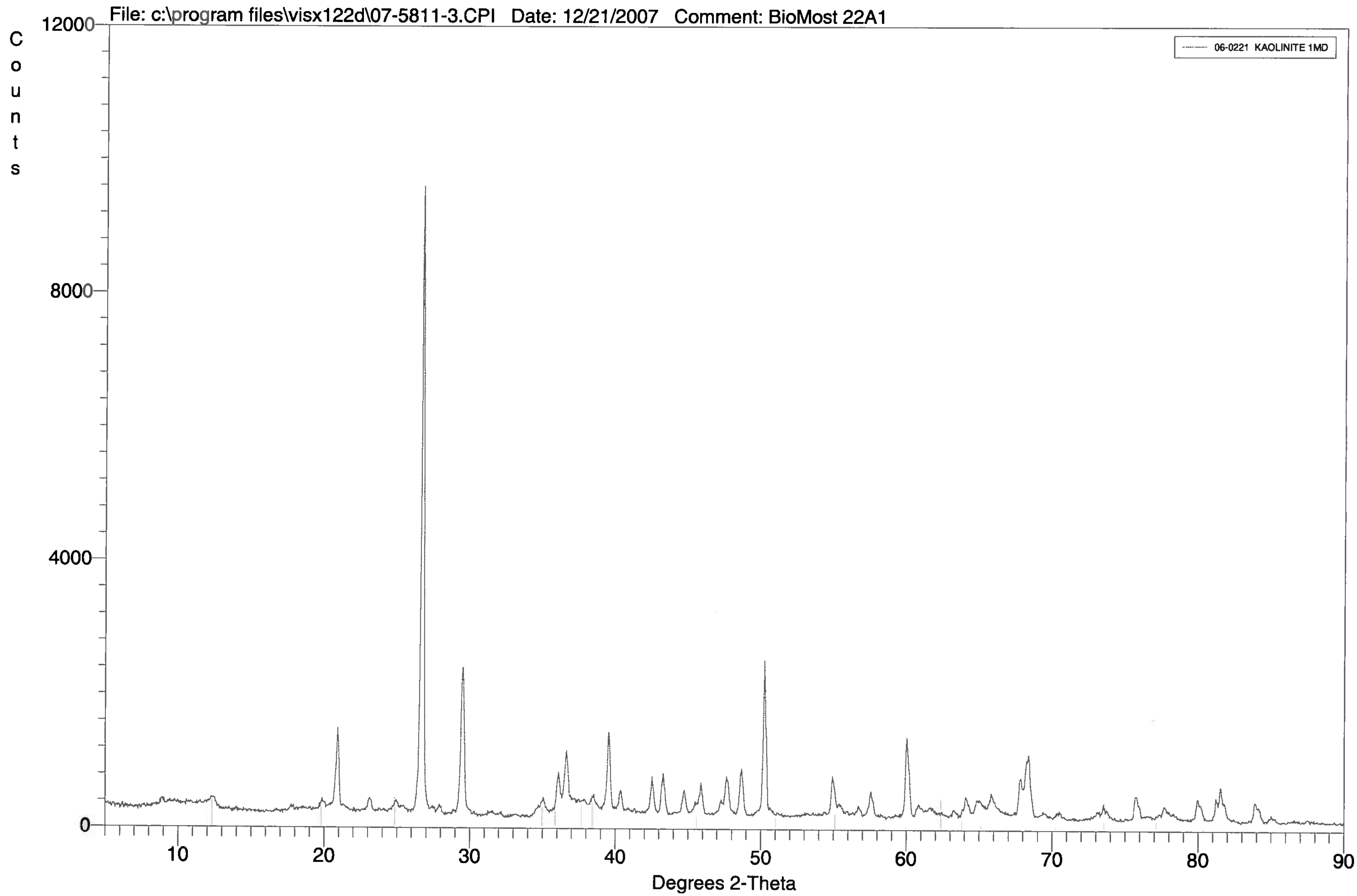


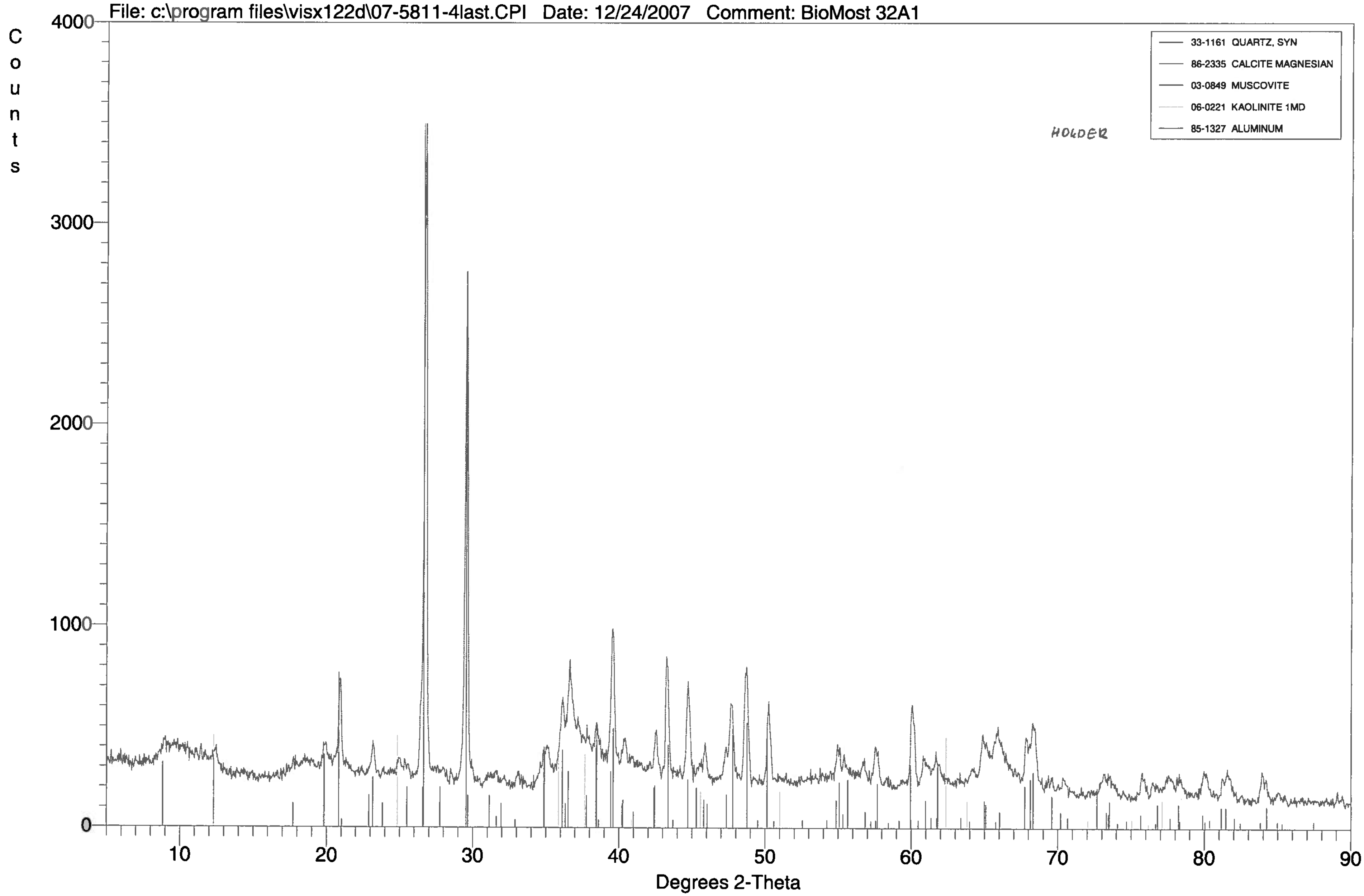
KGc   01/09/08

Activation Laboratories Ltd



KG 01/09/08

Activation Laboratories Ltd



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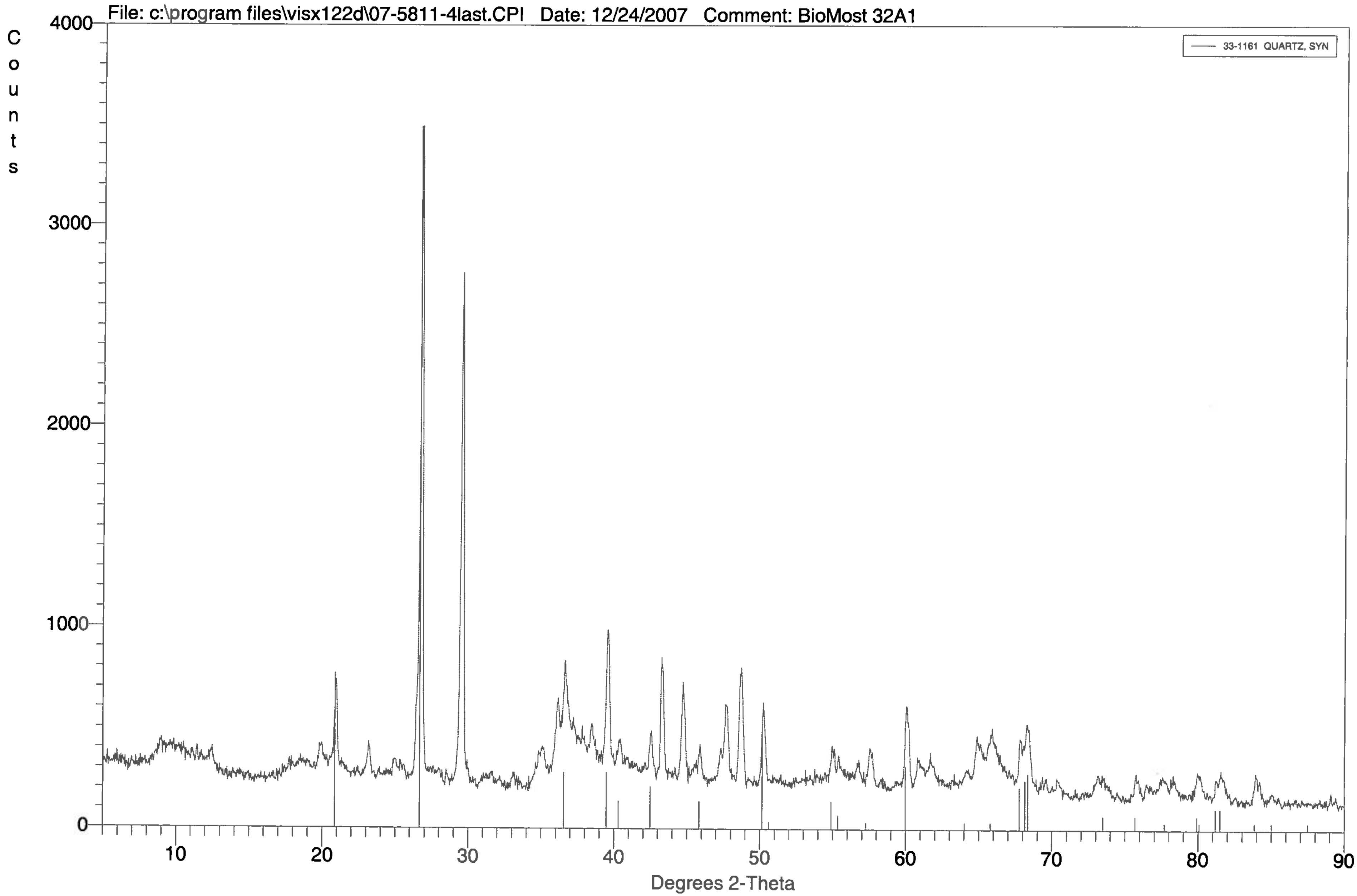
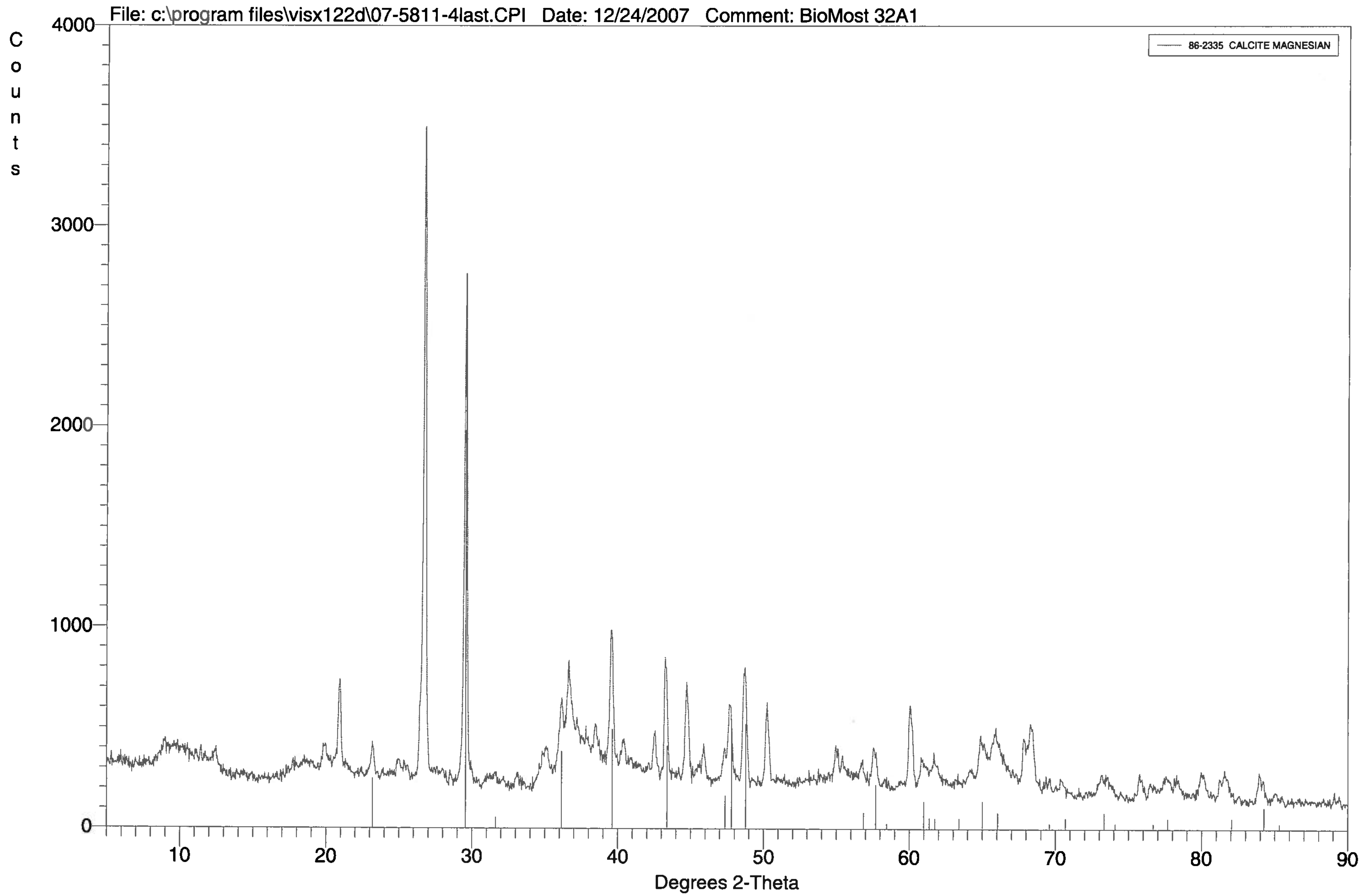


KG   01/09/03

Activation Laboratories Ltd



KG 01/09/08

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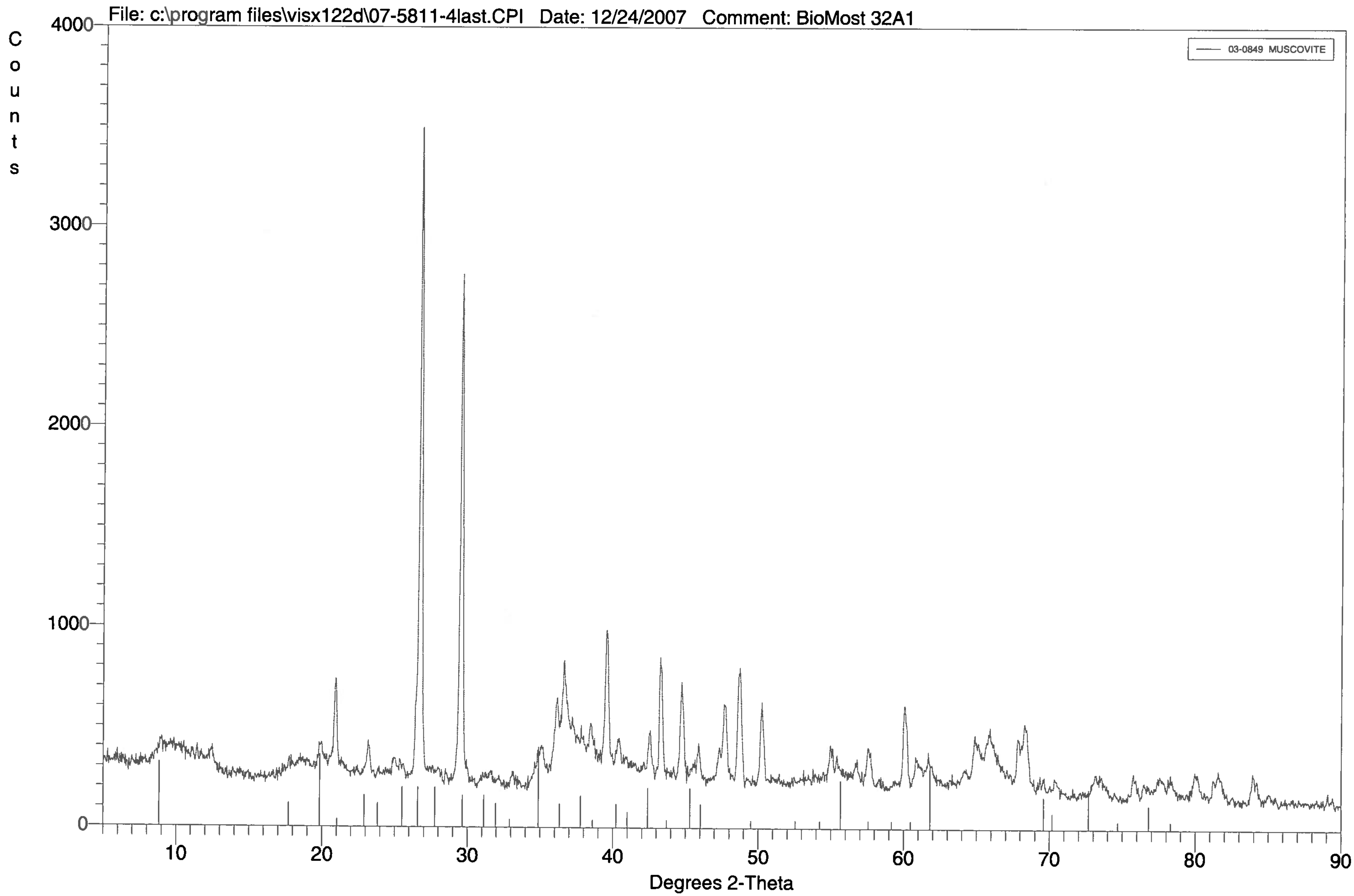

KG 01/09/08

Activation Laboratories Ltd

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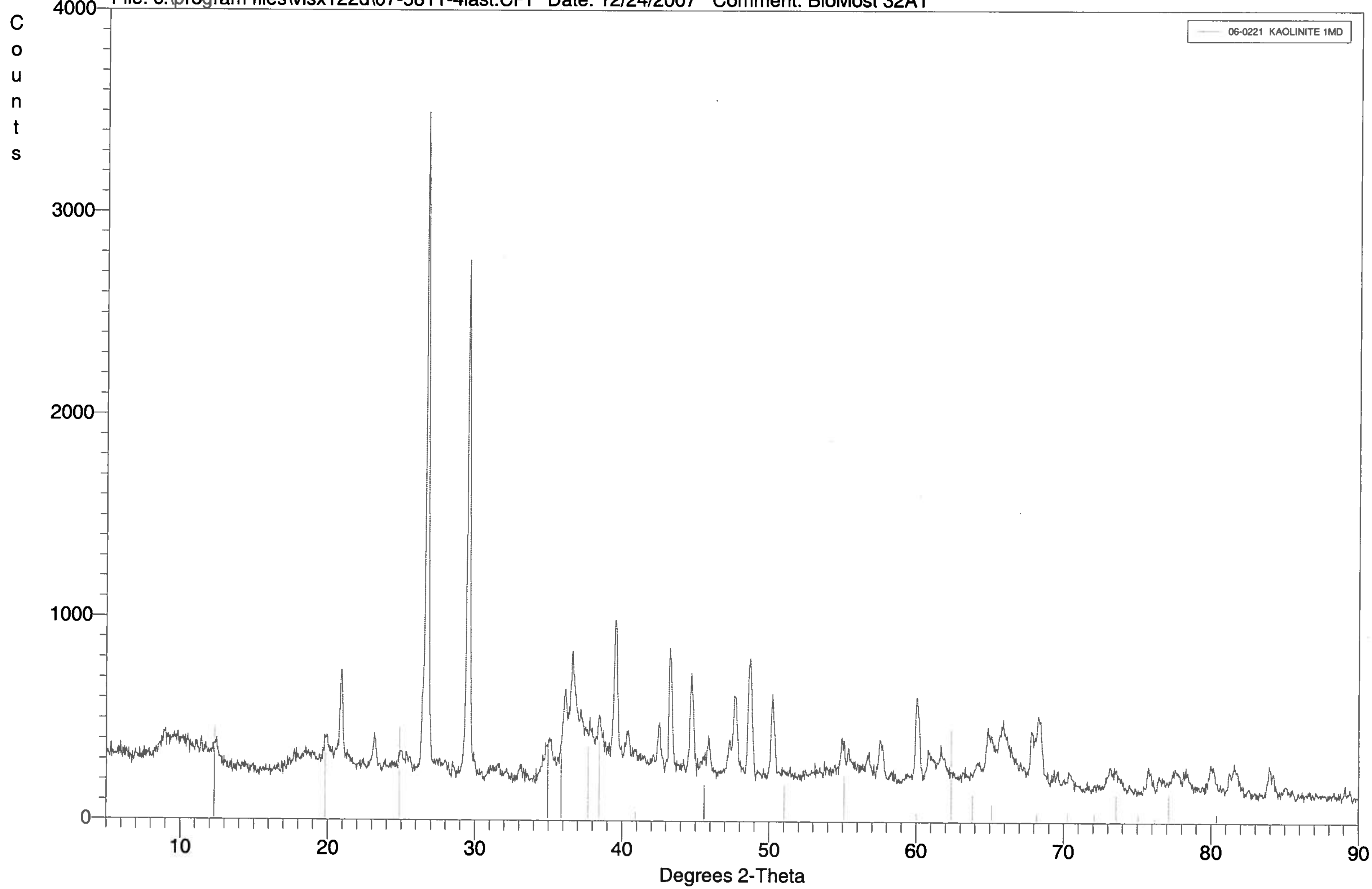
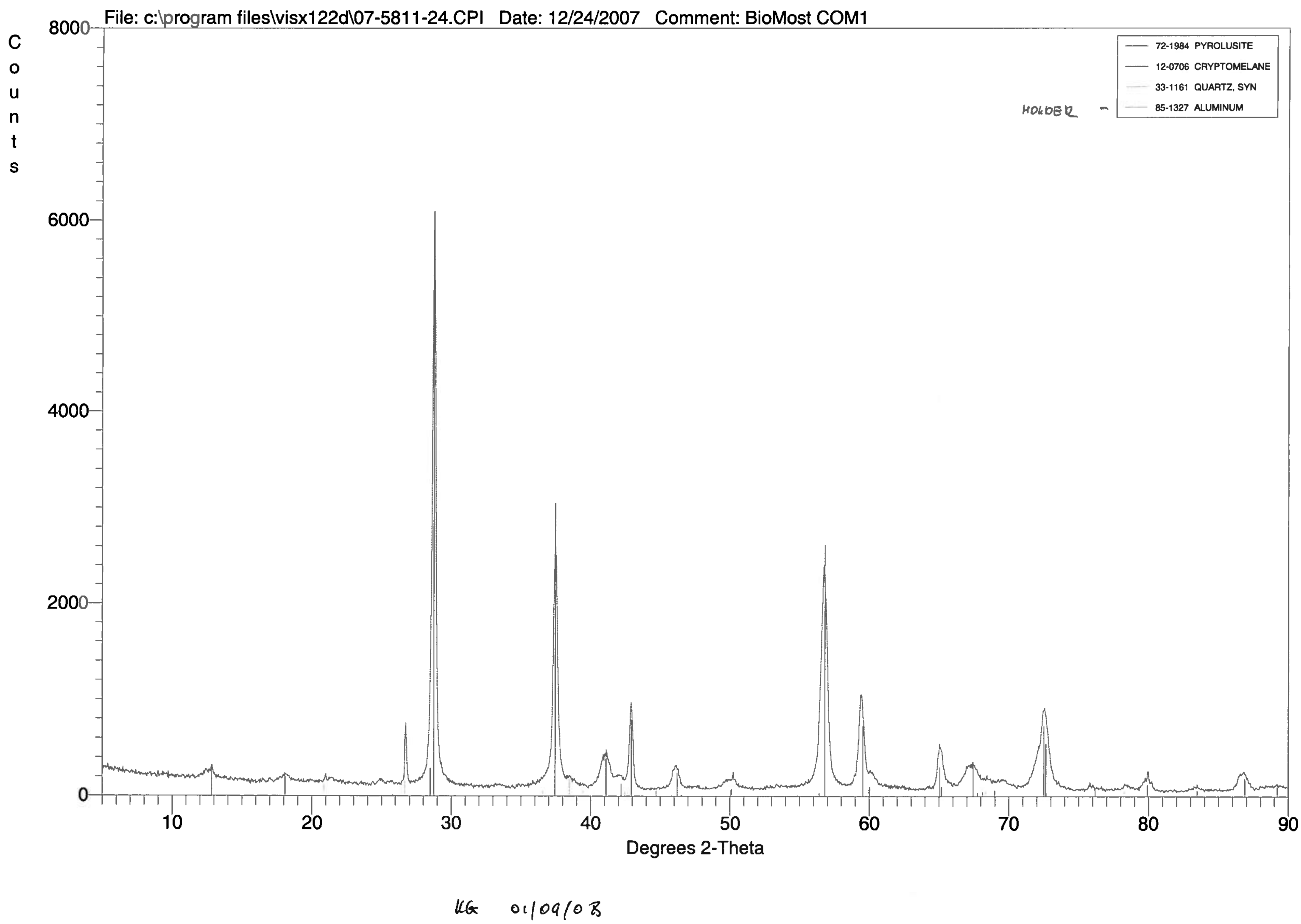


KG 01/09/08

Activation Laboratories Ltd



Activation Laboratories Ltd

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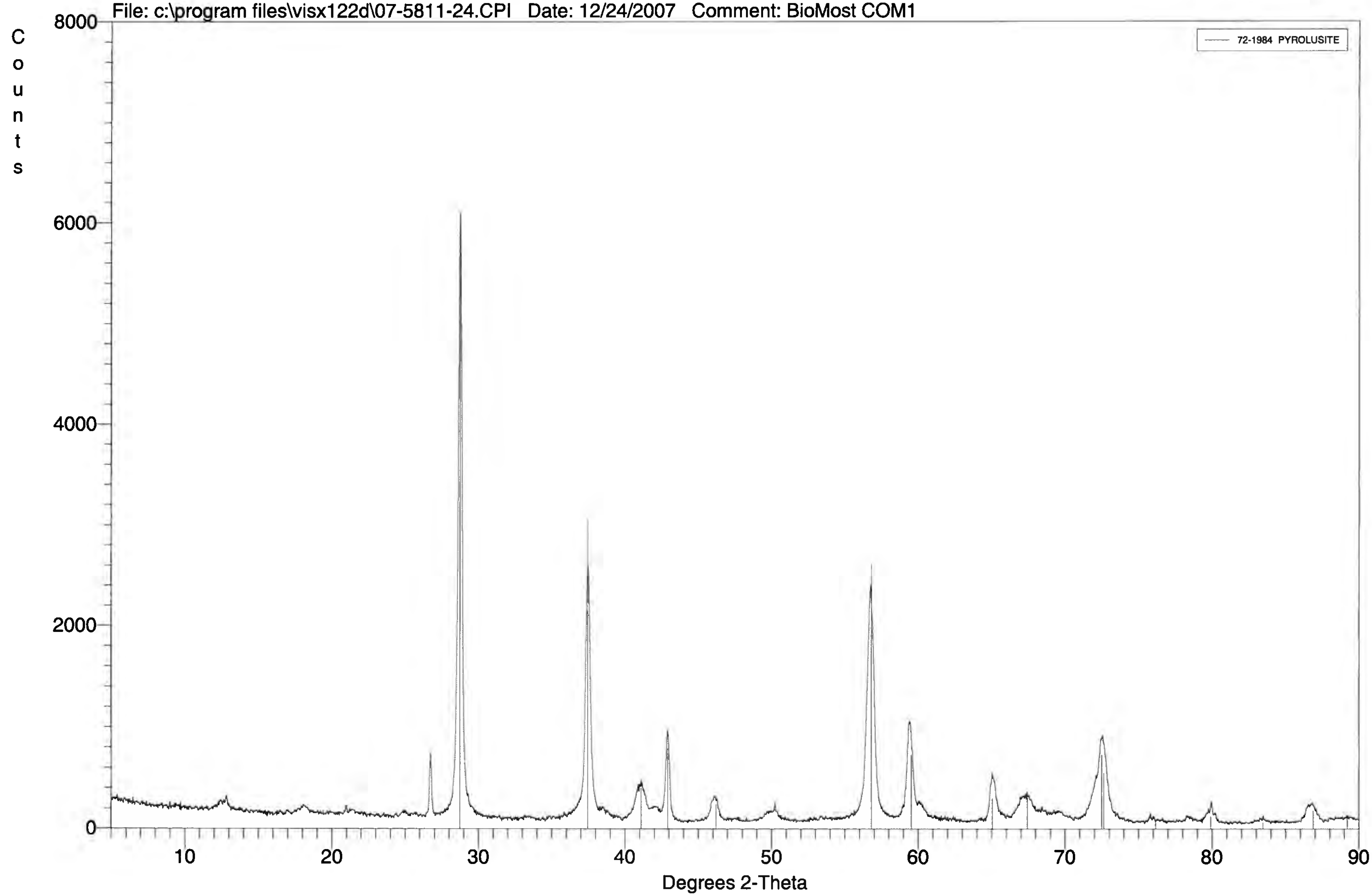
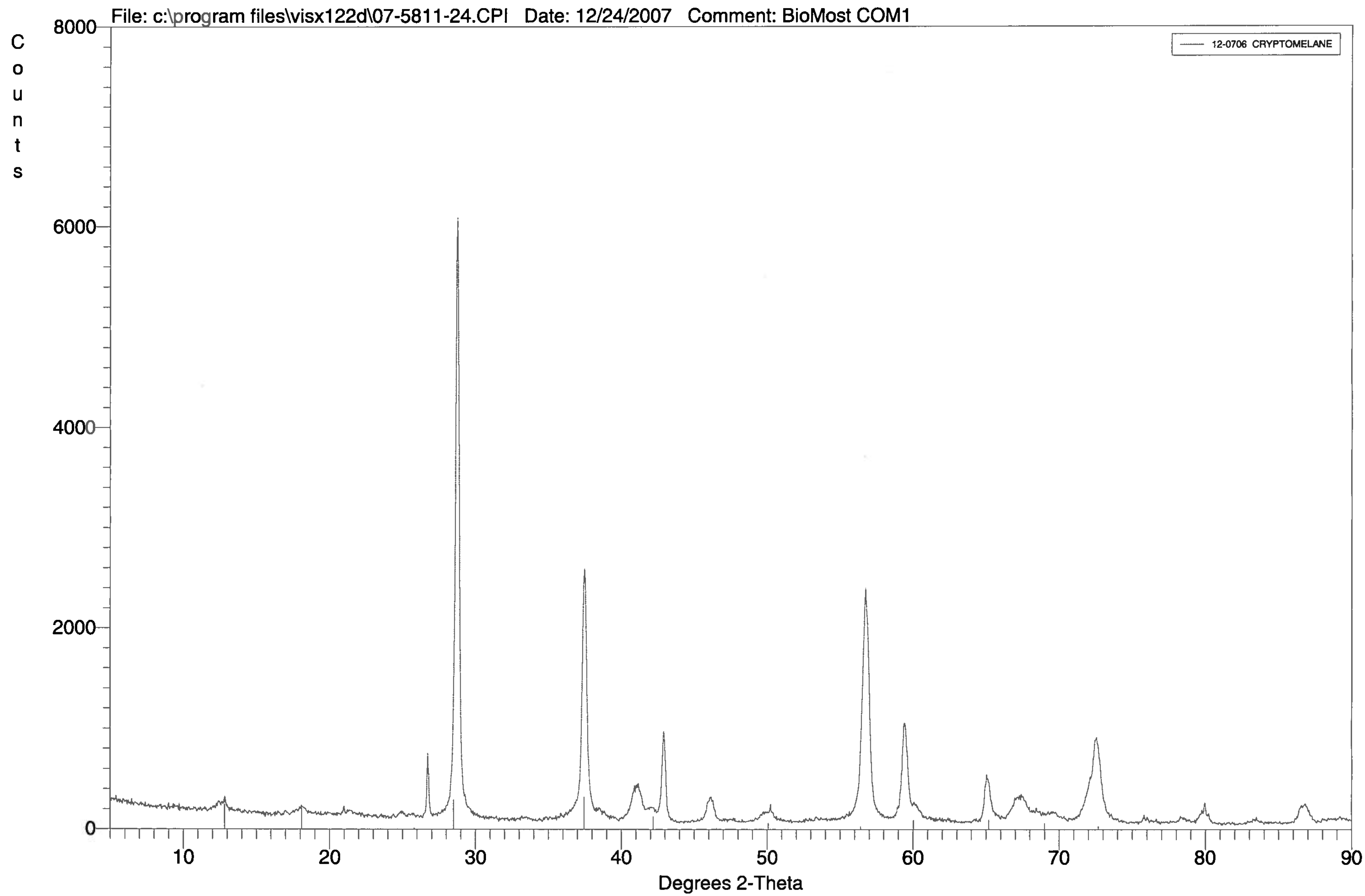


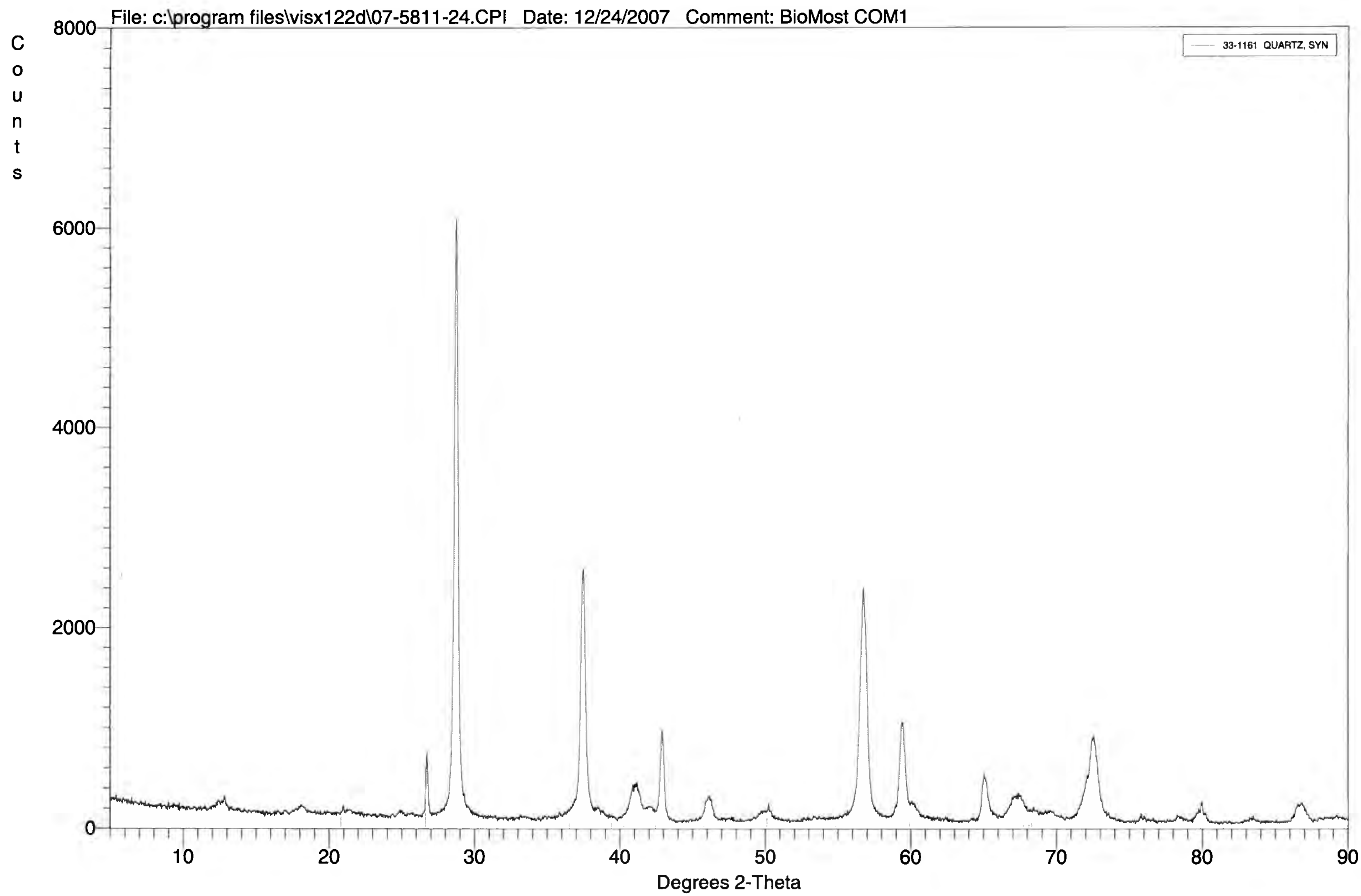
KG 01/09/08

Activation Laboratories Ltd



KG 01/09/08

Activation Laboratories Ltd



KG 01/09/08

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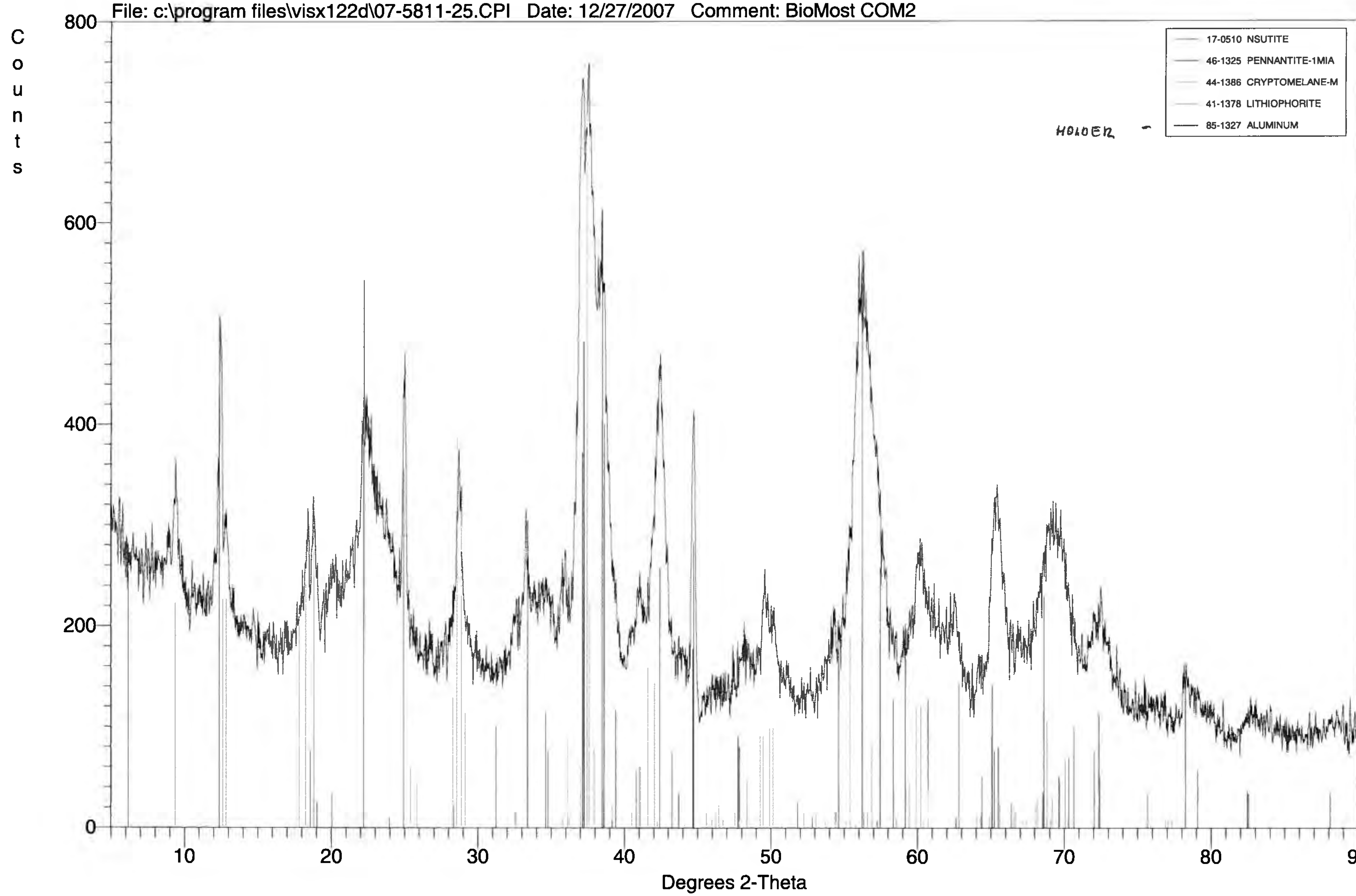

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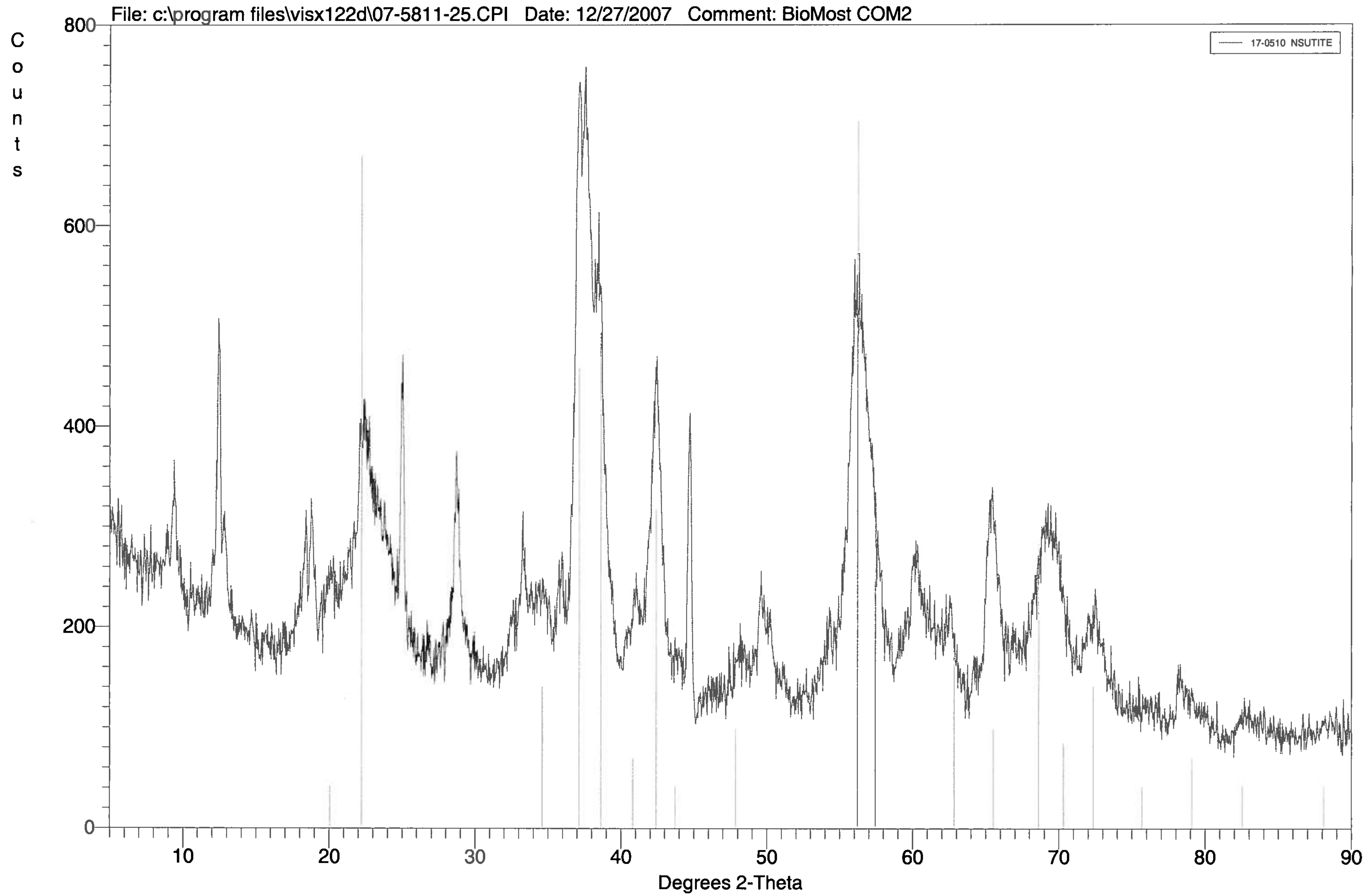
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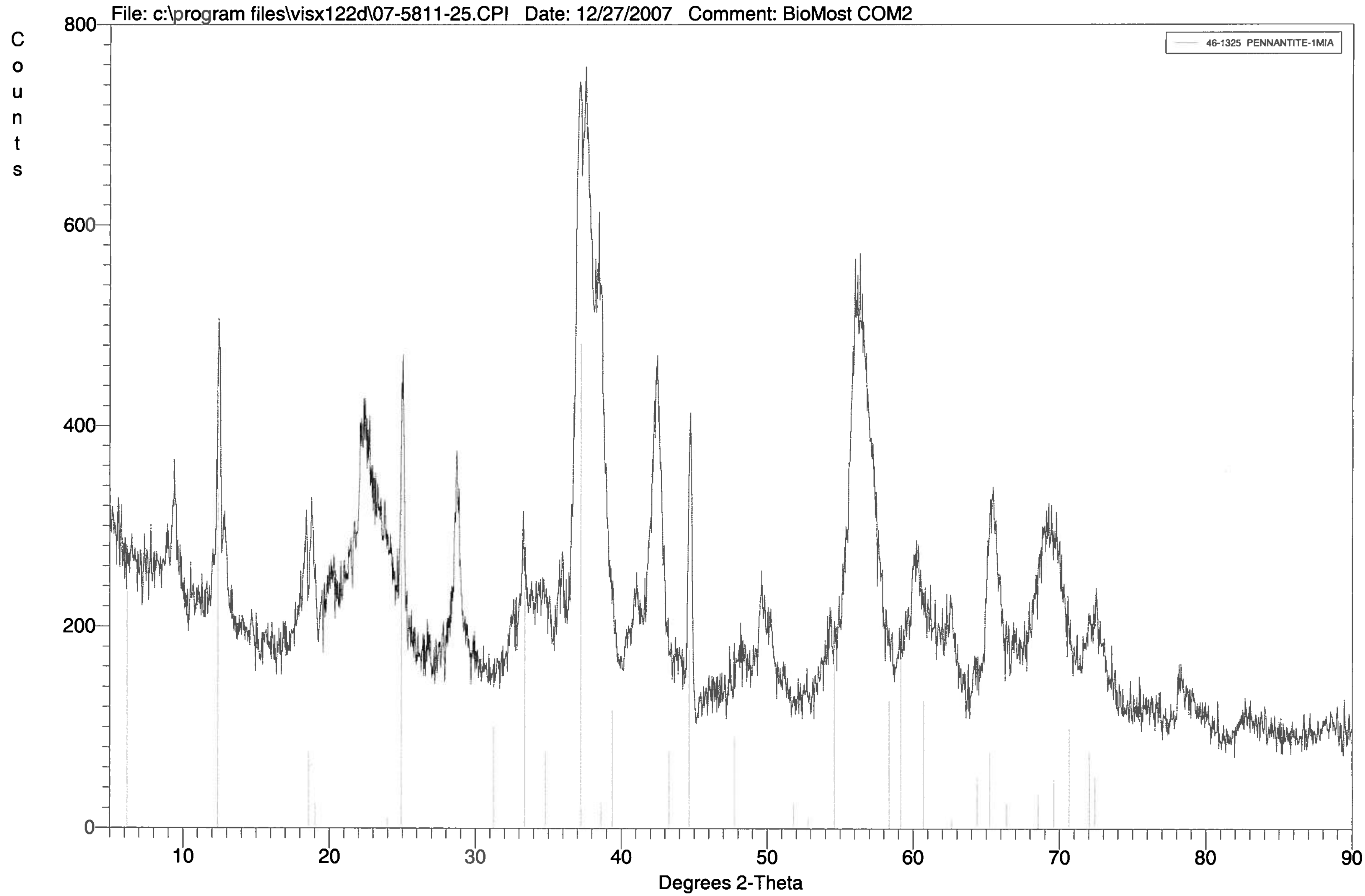
KG 01/04/08

Activation Laboratories Ltd



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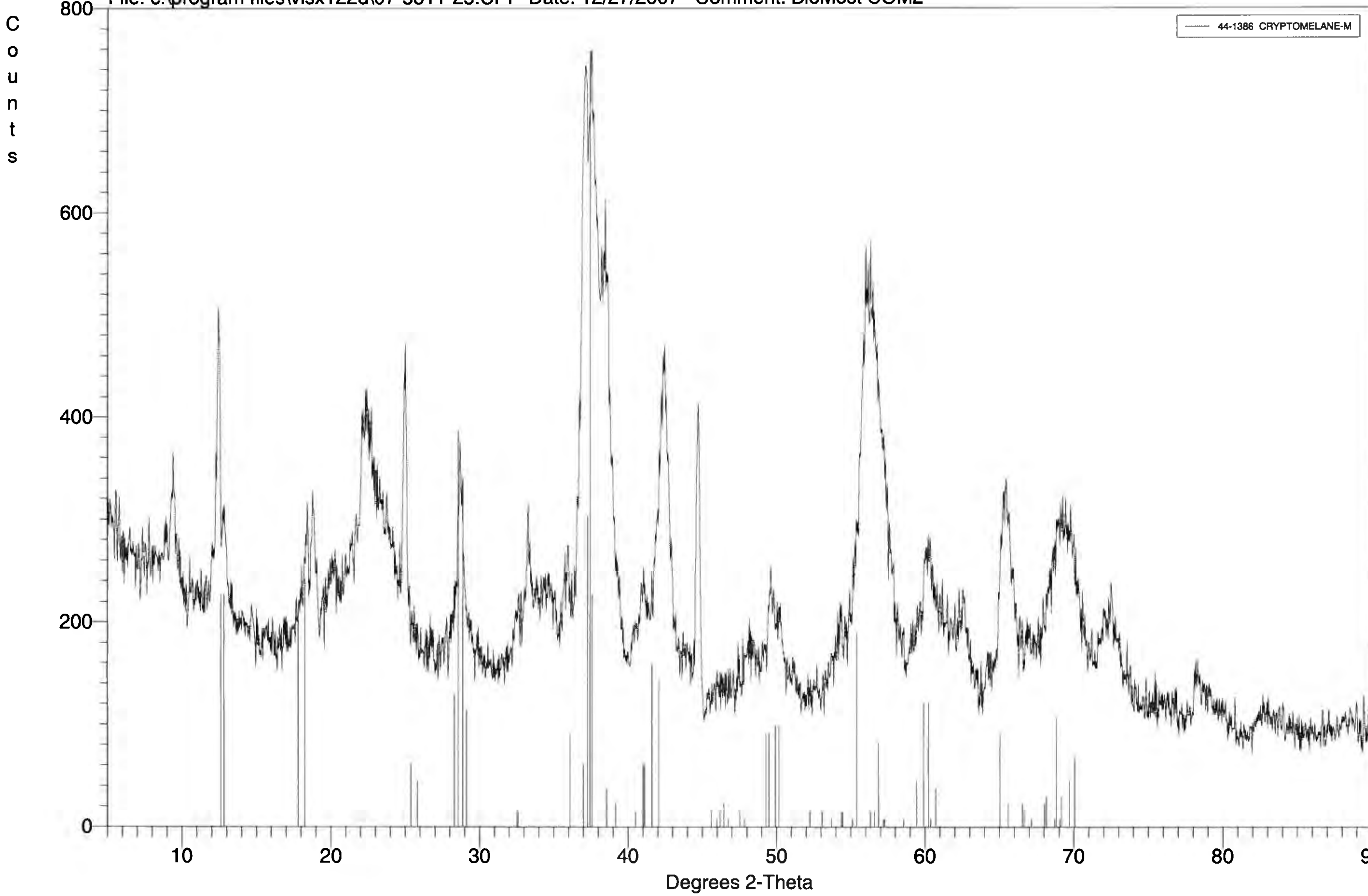

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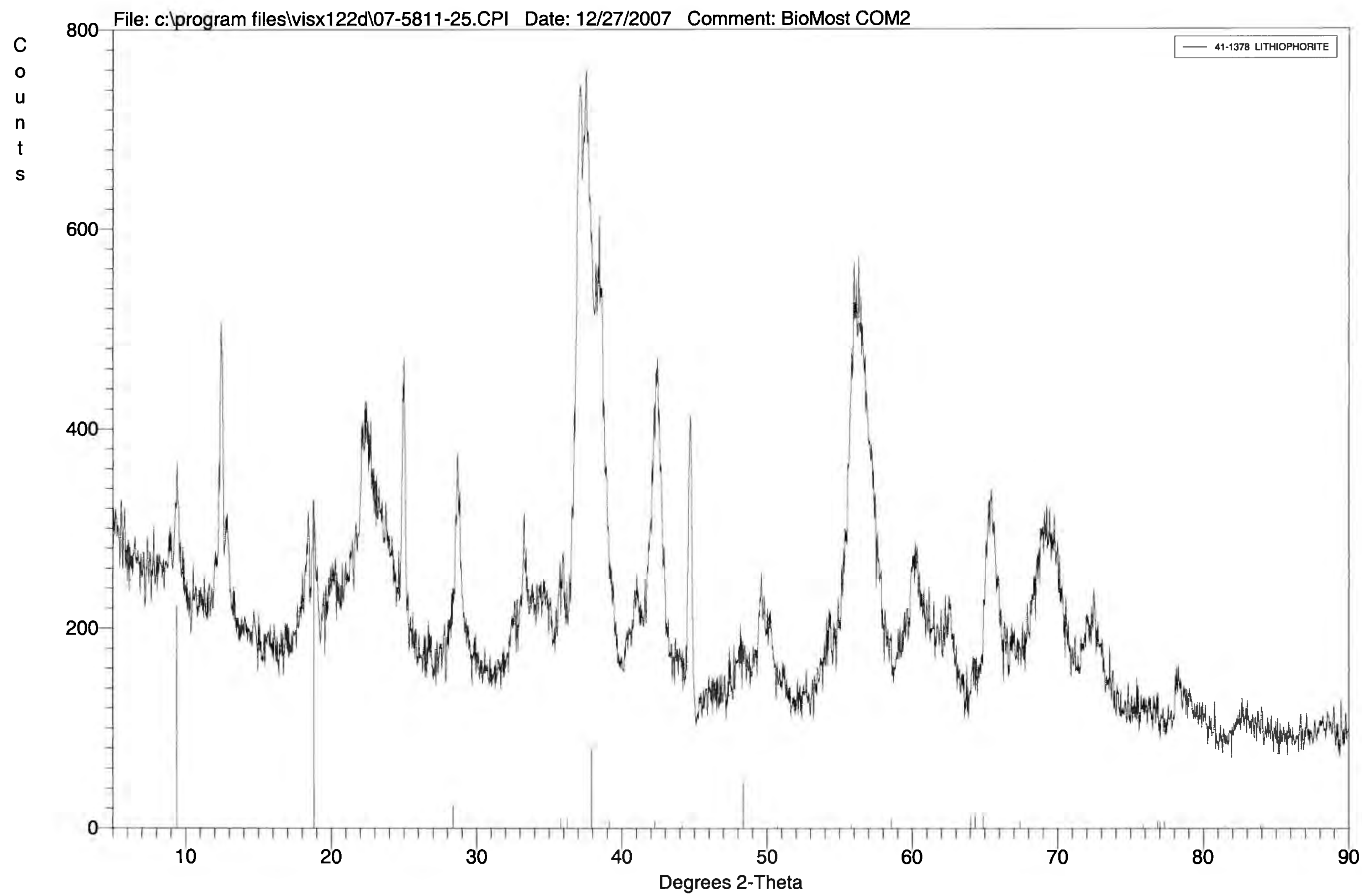
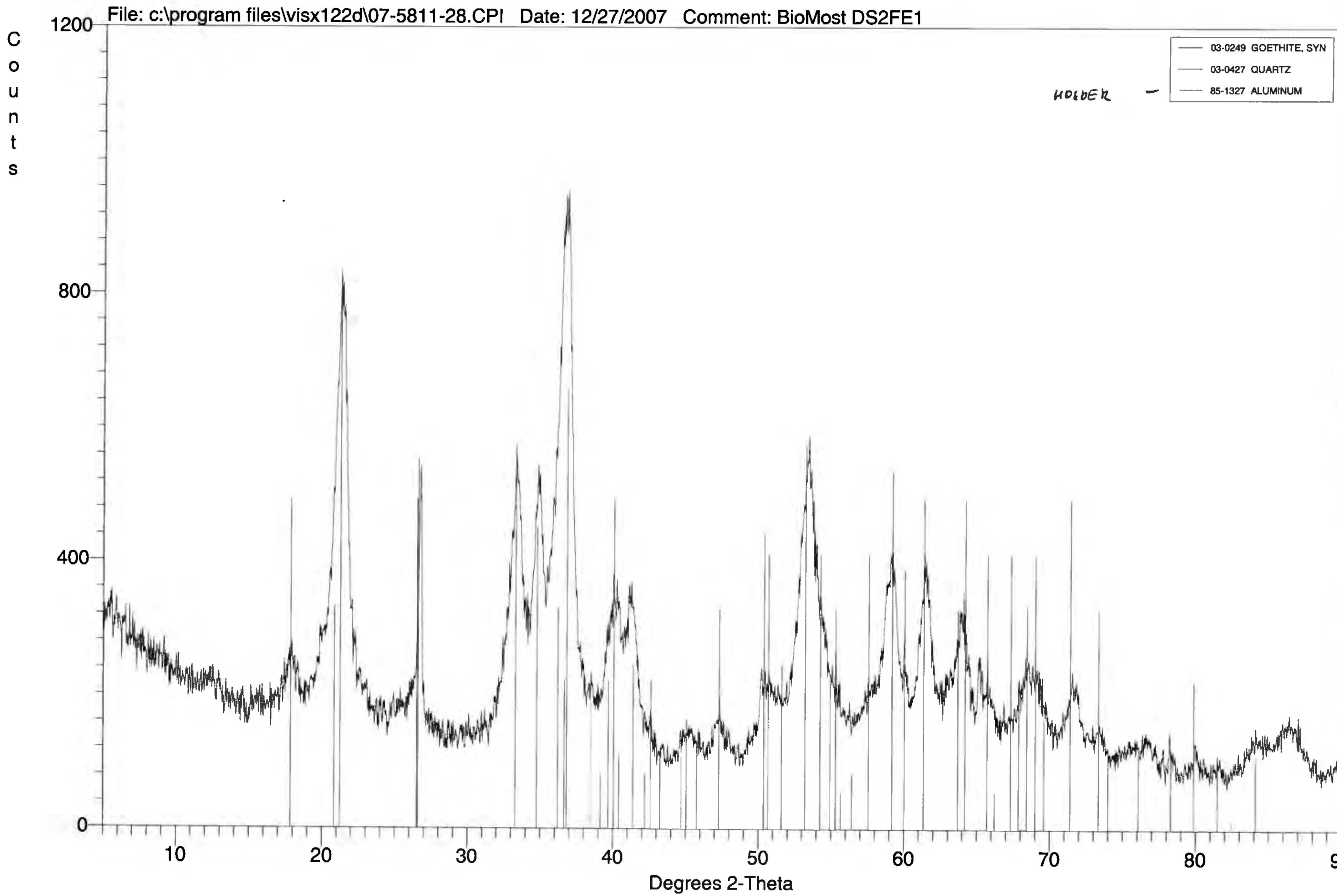
Activation Laboratories Ltd



VG 01/09/08

Activation Laboratories Ltd



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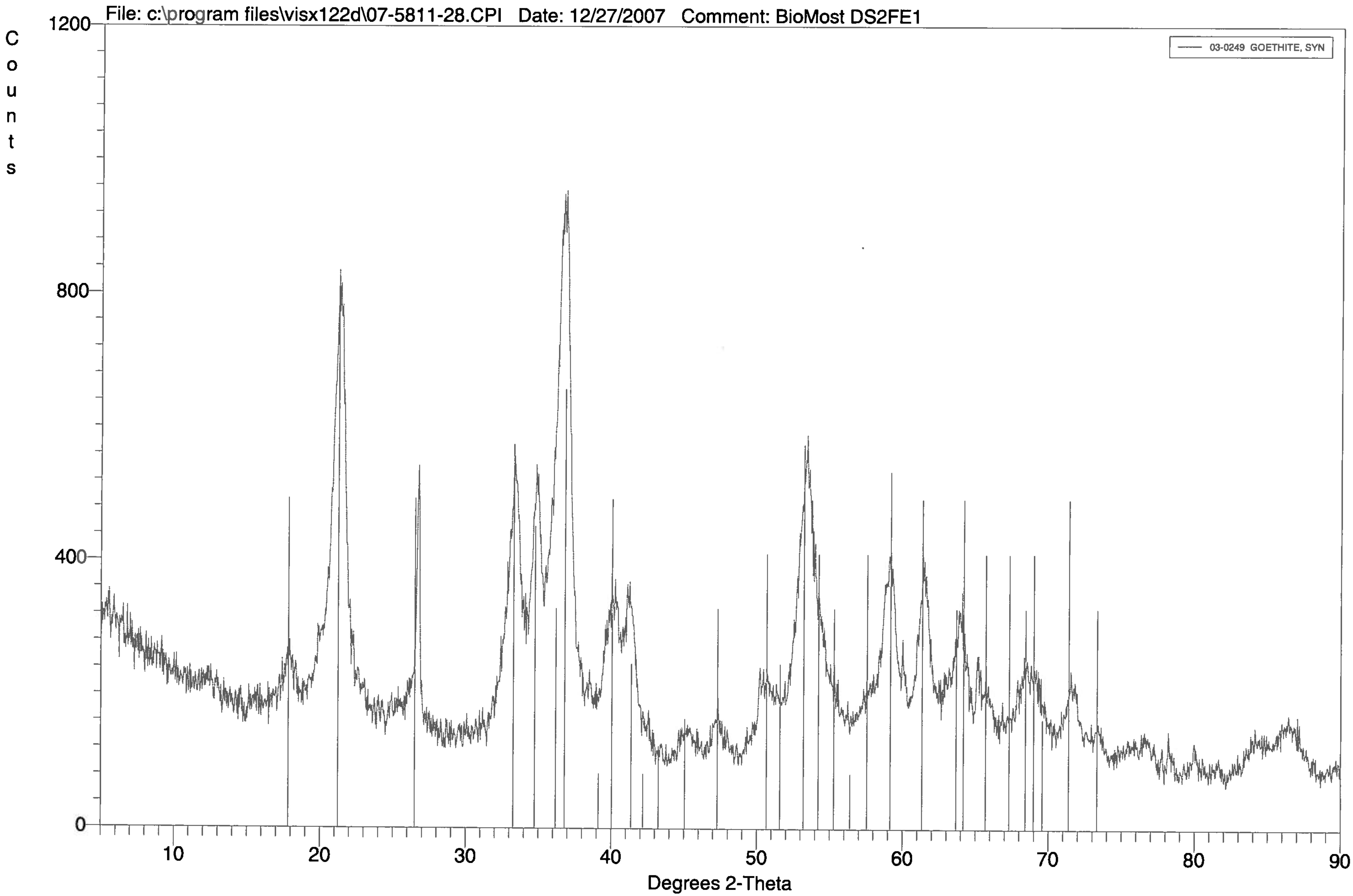
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Degrees 2-Theta

KG 01/09/08

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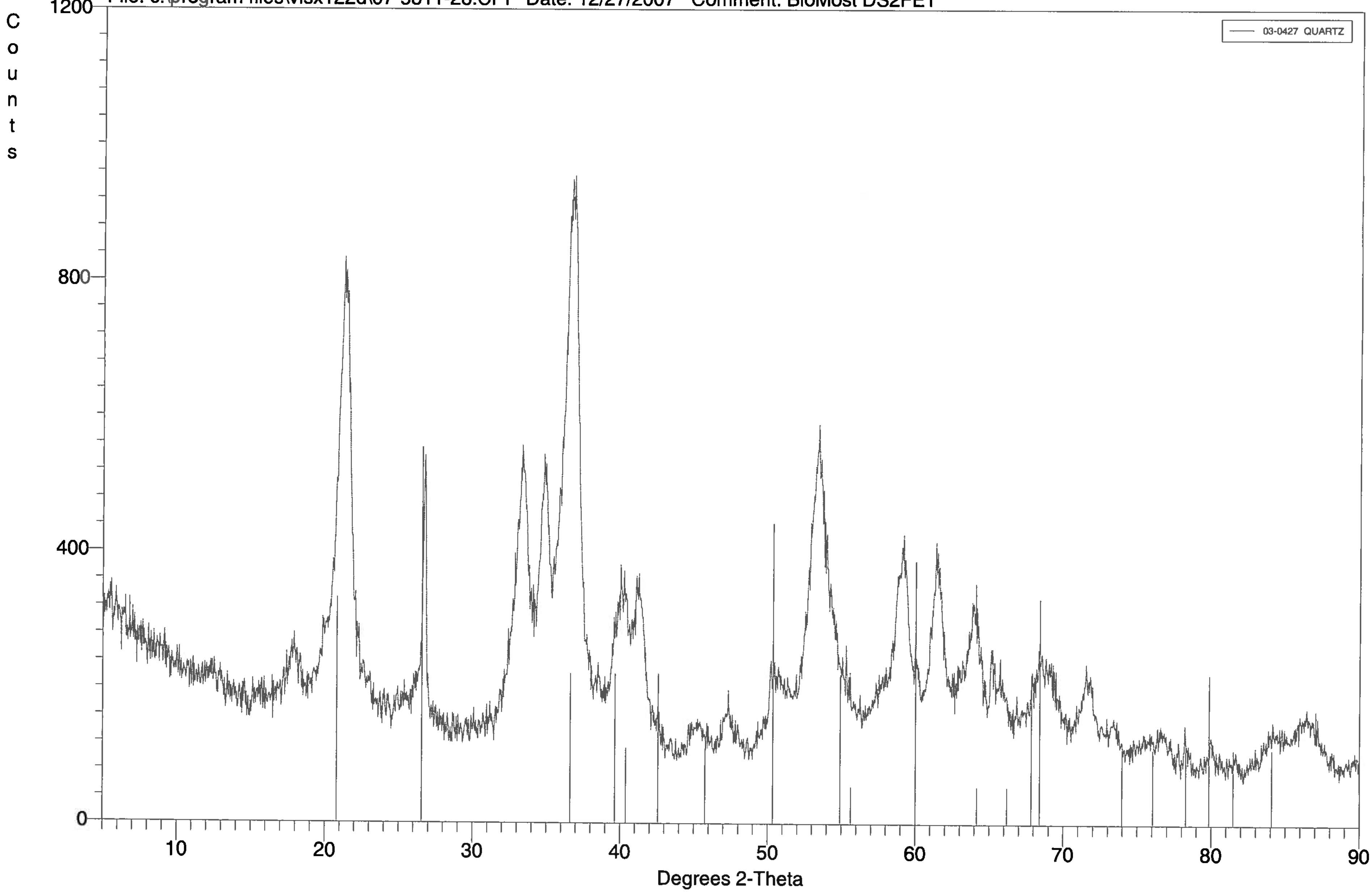
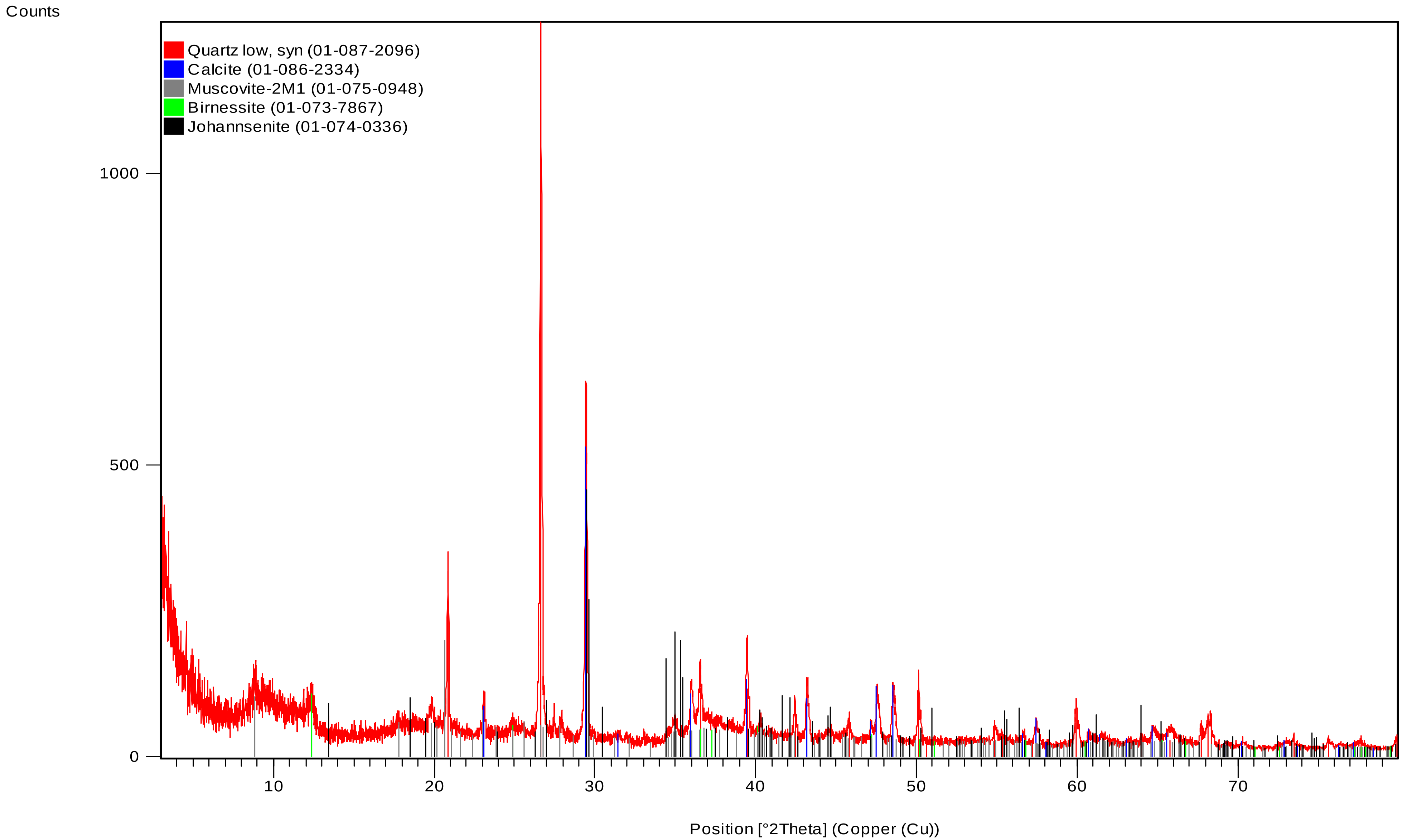


KG   01/09/08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Muscovite-2M1 (01-075-0948)
Birnessite (01-073-7867)
Johannsenite (01-074-0336)
1000
500
0
10
20
30
40
50
60
70
Position [°2Theta] (Copper (Cu))

FERRO COLOR AND GLASS
PERFORMANCE MATERIALS
251 WEST WYLIE AVENUE
WASHINGTON, PA 15301
TELEPHONE: (724) 223-5900
FAX: (724) 228-3170

FERRO

CGPM Analytical Services Laboratory
ANALYTICAL TEST RESULTS

FERRO ANALYTICAL SERVICES TEST RESULTS

Ferro Analytical Services Test Results

Ferro Color and Glass Performance Materials
Analytical Services Laboratory
251 West Wylie Avenue
Washington, Pennsylvania 15301

Prepared For:

BioMost Inc.
3016 Unionville Road
Cranberry Twp., PA 16066

ATTN: Cliff Denholm

(724) 776-0161
(724) 776-0166 (FAX)

DESCRIPTION OF SAMPLES, PROBLEM, AND ANALYSIS REQUESTED:
HMR on one set of six ceramic bowls for Pb and Cd levels.

Condition of sample as received: Samples were received as un-decorated ceramic bowl.

Date sample received: 5/11/07
Date samples tested: Samples were tested on May 14 and 15, 2007.
DTM#: 70 Rev. 5
List exceptions made to DTM: ASTM-C738

ANALYTICAL RESULTS ARE AS FOLLOWS:
Results are attached.
The following uncertainties represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2: +/-10.0% for Pb; +/-12.1% for Cd.
Pb and Cd standard provided by SPEX CertiPrep, Inc. with following certified value and uncertainties: 998 mg/L +/- 3 mg/L for Pb; 1002 mg/L +/- 3 mg/L for Cd.

REPORTING OFFICER: Hong Chen

DATE: 5/16/07

ACCREDITED

Certificate No. 0624-01

CGPM Analytical Services Laboratory
ANALYTICAL TEST RESULTS

HMR Laboratory Test Data on Glazed Ceramic Surfaces using ASTM-C738 Method

Date	May 15, 2007
Manufacturer	BioMost, Inc.
Detection Limit Pb	0.2 ppm
Cd	0.02ppm
Sample	One design of six bowls
Temperature	72°F

Ceramic Bowl	Volume of Acid (ml)	Pb (ppm)	Cd (ppm)
1	200	<0.2	<0.02[1]
2	165	<0.2	<0.02
3	165	0.2	<0.02
4	200	<0.2	<0.02
5	200	0.3	<0.02
6	N/A[1]	N/A	N/A
Average[2]		0.22	<0.02
Standard Deviation		0.04	N/A
Average + 2xSt Dev		0.30	<0.02

[1] The No 6 bowl was received as broken condition.
[2] The method requires six samples for each design.

GENERAL REPORT INFORMATION
TERMS AND CONDITIONS

Further Assistance

If further assistance is required regarding this report, please call 724-229-5639 for a reply to your questions.

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FERRO COLOR AND GLASS
PERFORMANCE MATERIALS
251 WEST WYLIE AVENUE
WASHINGTON, PA 15301
TELEPHONE: (724) 223-5900
FAX: (724) 228-3170

FERRO

CGPM Analytical Services Laboratory

ANALYTICAL TEST RESULTS

Log Number: SX58866
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FERRO ANALYTICAL SERVICES TEST RESULTS

Ferro Analytical Services Test Results

Ferro Color and Glass Performance Materials
Analytical Services Laboratory
251 West Wylie Avenue
Washington, Pennsylvania 15301

Prepared For:

BioMost Inc.
3016 Unionville Road
Cranberry Twp., PA 16066

ATTN: Cliff Denholm

(724) 776-0161
(724) 776-0166 (FAX)

DESCRIPTION OF SAMPLES, PROBLEM, AND ANALYSIS REQUESTED:
HMR on one set of six ceramic bowls for Pb and Cd levels.

Condition of sample as received: Samples were received as un-decorated ceramic bowl.

Date sample received: 3/4/08
Date samples tested: Samples were tested on March 4 and 5, 2008.
DTM#: 70 Rev. 5
List exceptions made to DTM: ASTM C738-94(2006)

ANALYTICAL RESULTS ARE AS FOLLOWS:
Results are attached.
The following uncertainties represent an expanded uncertainty expressed at approximately the 95% confidence level using a coverage factor of k=2: +/-10.0% for Pb; +/-12.1% for Cd.
Pb and Cd standard provided by SPEX CertiPrep, Inc. with following certified value and uncertainties:
998 mg/L +/- 3 mg/L for Pb; 1002 mg/L +/- 3 mg/L for Cd.

REPORTING OFFICER: Hong Chen

DATE: 3/5/08

ACCREDITED

TESTING Certificate No. 0624-01

CGPM Analytical Services Laboratory
ANALYTICAL TEST RESULTS

Log Number: SX58866

HMR Laboratory Test Data on Glazed Ceramic Surfaces using ASTM-C738 Method

Date	March 5, 2008
Manufacturer	BioMost, Inc.
Detection Limit Pb	0.2 ppm
Cd	0.02ppm
Sample	One design of six bowls
Temperature	70°F

Ceramic Bowl	Volume of Acid (ml)	Pb (ppm)	Cd (ppm)
1	117	<0.2	<0.02
2	134	<0.2	<0.02
3	140	<0.2	<0.02
4	110	<0.2	<0.02
5	112	<0.2	<0.02
6	131	<0.2	<0.02
Average		<0.2	<0.02
Standard Deviation		N/A	N/A
Average + 2xSt Dev		<0.2	<0.02

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