Inventory & Analyses of Abandoned Mine Drainage Iron Oxide Deposits in Northeastern Pennsylvania For Resource Recovery Potential[1]

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Abstract: The prevalence of iron oxide precipitate deposited for decades in Anthracite and Bituminous coal region watersheds of Eastern Pennsylvania has allowed the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR) to take the lead in developing a new technical innovation for abandoned mine drainage (AMD) water treatment. EPCAMR works in Appalachian coal communities to assist under-served populations, community groups, and local governments, to reclaim abandoned mine lands, restore streams, and build community support for education programs in watersheds impacted by AMD.

EPCAMR is working collectively with the Office of Surface Mining (OSM) Watershed Internship Program, the Luzerne Conservation District, Earth Conservancy, and the PA Department of Environmental Protection, US Geologic Survey, and the US Environmental Protection Agency (EPA) Region III. EPCAMR plans to complete an extensive compilation of the estimated volume (tons) of iron oxide precipitate coating thousands of miles of streams in PA. EPCAMR is working with Hedin Environmental, a leading private consultant company in the field of AMD remediation, on research and development related to the recovery process of iron oxide deposits to see if they can be marketed as a resource in Eastern PA. Hedin Environmental has already received a patent for a system producing pigment-grade iron oxide recovered from AMD in Western PA. No such patent exists for the quality of pigment that can eventually be produced in Eastern PA. EPCAMR will gather samples of the iron oxides for analysis of pigment strength

EPCAMR is sampling dozens of high iron, alkaline AMD discharges loaded with iron precipitate, either on stream bottoms or within treatment systems operated/maintained either by the Commonwealth of PA or community watershed associations. Examples of uses include wood stains, paint pigments, and mulch dyes. In addition to the potential for resource recovery, the results of this field data are being compiled into a Microsoft Access database utilizing ArcGIS 9.0, ArcPad 6.0, and a hand-held GPS Magellan Meridian Platinum Unit in order to better identify the location of AMD impacts within EPCAMR's region for prioritization of future watershed restoration plans.

Keywords: EPCAMR, AMD, watersheds, anthracite, bituminous, iron oxide, iron oxide pigment, resource recovery, AML, GIS, discharges

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The goals and objectives for the EPCAMR Iron Oxide Resource Recovery Project are as follows:

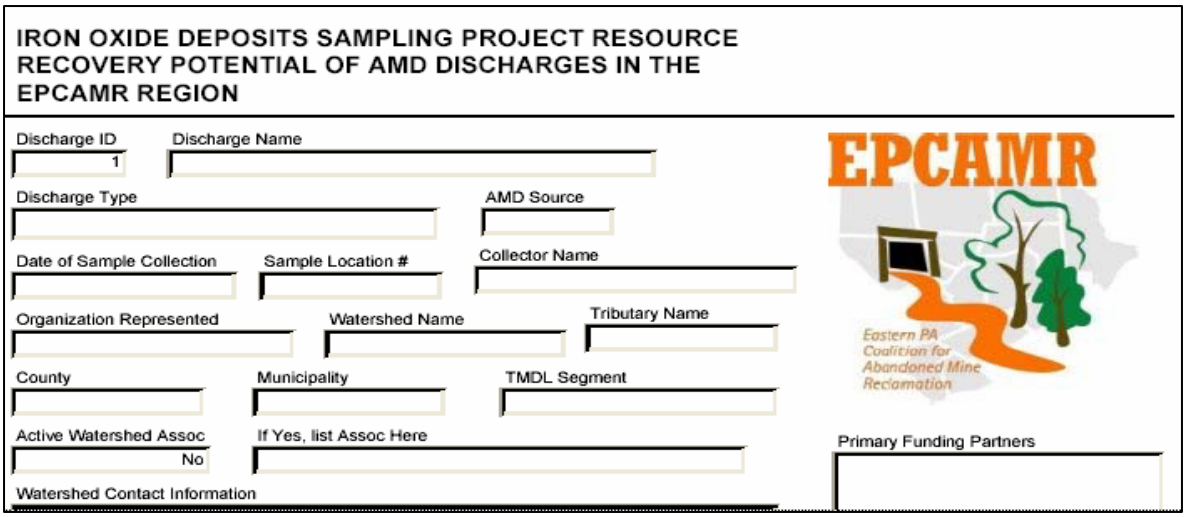
- Assess project data parameters
- Contact affected watershed groups
- Sample and photo inventory sites
- Incorporate data into a GIS/GDB
- Sample testing
- Compile results of chemistry/metals analyses
- Develop markets interested in iron oxide product

During the assessment of the project data parameters, EPCAMR, with the assistance of Mr. Robert Hedin (Hedin Environmental), set forth the Iron Oxide Sampling Criteria. Historic names and sample dates were recorded for each AMD discharge and compared to local names given by community member's who accompanied EPCAMR staff to the sites. Iron oxide sample locations were recorded as an Origin Point, Mid-Point, or Terminal Point, with each having a unique global positioning system (GPS) coordinates recorded in longitude and latitude. The collector name(s) were also identified and who they represented. The watershed name, tributary name, county, municipality, USGS quad sheet, and Total Maximum Daily Load (TMDL) Segment were also identified (Figure 1 and 2).

The search centered on high iron concentrations in the EPCAMR Region, preferably alkaline in character, and pre-existing AMD remediation passive treatment systems. No sampling of permitted discharges on active mining sites was included in the project, although future thoughts are to follow up with the active anthracite mining and bituminous operations in the EPCAMR Region to see if they are interested in becoming partners in the Iron Oxide Resource Recovery Project.

When an AMD passive treatment system was sampled and assessed, the type of treatment system was noted in the database as either an aerobic wetland, anaerobic wetland, diversion well, successive alkalinity producing system (SAPS), anoxic limestone drain, oxic limestone drain, open limestone channel, instream limestone sand dosing, or a limestone rotating drum system. Primary funding partners were also listed in the database along with a set of global positioning system (GPS) latitude and longitude coordinates for each system. Active watershed associations, along with a contact person, were listed if they were responsible for the treatment of the AMD

passive treatment systems. EPCAMR hopes that a large GIS database of AMD passive treatment systems in the region will be developed. Ideally, each system will have a GPS coordinate system that may enable other community groups and the PA Department of Environmental Protection to share information on treatment system technologies, successes, failures, and ongoing operation, maintenance, and repair issues.


IRON OXIDE DEPOSITS SAMPLING PROJECT RESOURCE RECOVERY POTENTIAL OF AMD DISCHARGES IN THE EPCAMR REGION

Discharge ID: 1
Discharge Name
Discharge Type
AMD Source
Date of Sample Collection
Sample Location #
Collector Name
Organization Represented
Watershed Name
Tributary Name
County
Municipality
TMDL Segment
Active Watershed Assoc: No
If Yes, list Assoc Here
Primary Funding Partners
Watershed Contact Information

EPCAMR
Eastern PA Coalition for Abandoned Mine Reclamation

Figure 1. Top Portion of the EPCAMR Iron Oxide Resource Recovery Database Form

EPCAMR staff described the discharge type as either from an underground or an above ground source. Included in the database was whether or not the discharge type was coming from a borehole, mine tunnel, a shaft, or seep. Discharge flow was characterized as either being high, medium, low, or stagnant. At many of the sites, there were no constructed weirs to accurately measure flows, although, it is EPCAMR's intention to join databases populated with flow data from the PA DEP-Bureau of Abandoned Mine Reclamation and the District Mining Offices. Particulate matter was also described at each of the sites to reflect the amount of leaves, rocks, sticks, stones, garbage, debris, and or woody debris that needed to be removed or screened prior to processing the iron oxide from the discharges. Road access was also characterized as either being accessible by haul road, single lane, path, trail, or off the main road. Access to the sites will become a future factor once large construction equipment and vehicles are factored into the process.

Field pH, field alkalinity, and field acidity were sampled in the field during each sample visit. An estimated channel width was recorded at each of the three sampling locations. The average depths of the iron oxide sediment deposits were also recorded. Finally, a linear length of the

AMD discharge segment or the TMDL segment was used to help determine the volume of iron oxide deposits in a given reach of stream or discharge location.

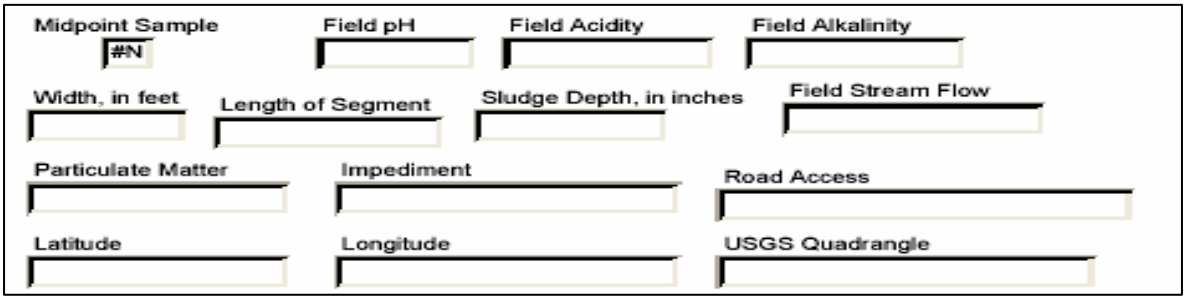


Figure 2. Middle Portion of the EPCAMR Iron Oxide Resource Recovery Database Form

Sketch plans were also recorded on the back of the field data sheets for each of the sites sampled as well as a digital photographic inventory of the sites with color pictures of upstream, downstream, and AMD discharge cross-sections (Figure 3).

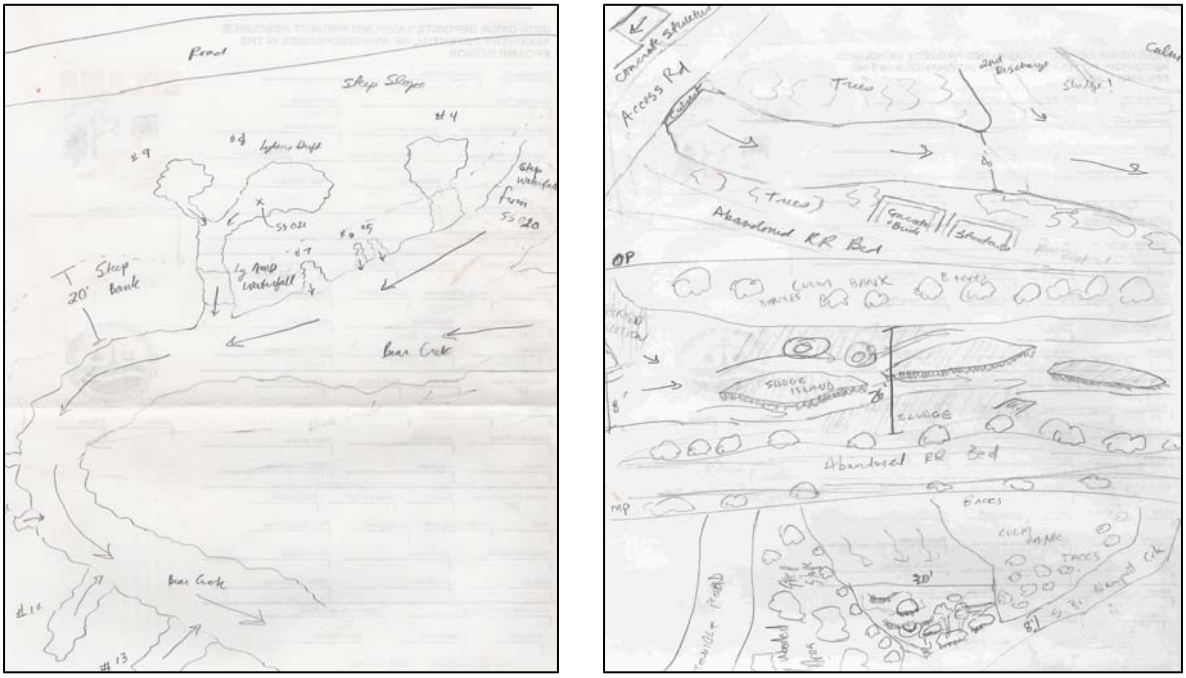


Figure 3. Typical Sketch Plans Drawn by EPCAMR staff at a given AMD location

Our ultimate goal was to devise a method to generate an approximate tonnage, by volume of iron oxide sediment deposits contained within the AMD discharge channels that could be extracted. To help assist EPCAMR with the volume calculation, the US Department of Agriculture-Soil Conservation Service (USDA-SCS) Trapezoidal Channels Dimensions List Publication was used and each of the AMD discharges' channel dimensions were assigned with a

dimension as listed in the publication that most closely resembled it's actual dimensions (**Equation 1**).

$$t = b + 2zd \qquad A = [d\,(b+t)]/2 \qquad V = Al \qquad (1)$$

Where:

t = ***Top width (feet)***
b = ***Bottom width (feet)***
z = ***Stream channel shape and run ratio (i.e., Trapezoidal 1:1)***
d = ***Depth of sludge (feet)***
A = ***Cross sectional area (square feet)***
V = ***Volume of sludge (cubic feet)***
l = ***Length of discharge before it meets a stream, another discharge, etc. (feet)***

GIS/GPS Equipment Used

EPCAMR used the following GIS/GPS Equipment and database software to perform the field collection of data, water quality sampling, iron oxide deposit sampling, and in-house mapping:

- ArcGIS 9.0
- ArcPad 6.03
- Microsoft Access Dbase
- Hand-held GPS Magellan Meridian Platinum Unit (Figure 4)
- HP IPAQ 4500 Handheld Unit

Figure 4. Magellan hand held GPs unit.

ESRI's ArcGIS 9.0 was used to display and edit the GPS data and to generate the maps showing the geographical locations of each of the AMD discharges sampled throughout the EPCAMR Region. ESRI's ArcPad 6.03 was recently purchased (fall 2004) with EPCAMR Staff learning to use the field mapping applications of the unit and how to transfer data from our Hand-

held GPS Magellan Meridian Platinum Unit to the HP IPAQ 4500 Unit. Additional adapters had to be purchased to provide the connectivity needed to synchronize both of the units. The pending results indicate that the EPCAMR Staff still need time to learn all of the functions of the unit before we can fully utilize the HP IPAQ 4500 Unit with ArcPad 6.03 effectively in the field.

After assessing and evaluating the types of data parameters needed for the data form to document each individual sampling site, it was determined Microsoft Access® would provide EPCAMR with the flexibility needed to design a base data form that could accommodate several types of data formats, as well as eventually be exported into ArcGIS 9.0 for data manipulation in mapping. We found out early on that the Microsoft Access® data form had to be recreated in ArcPad 6.03 in a different format. When entering the data into Microsoft Access®, EPCAMR had several categories utilizing drop-down lists from which the person transferring the data from the data forms to electronic form could select (Figure 5, Table 1).

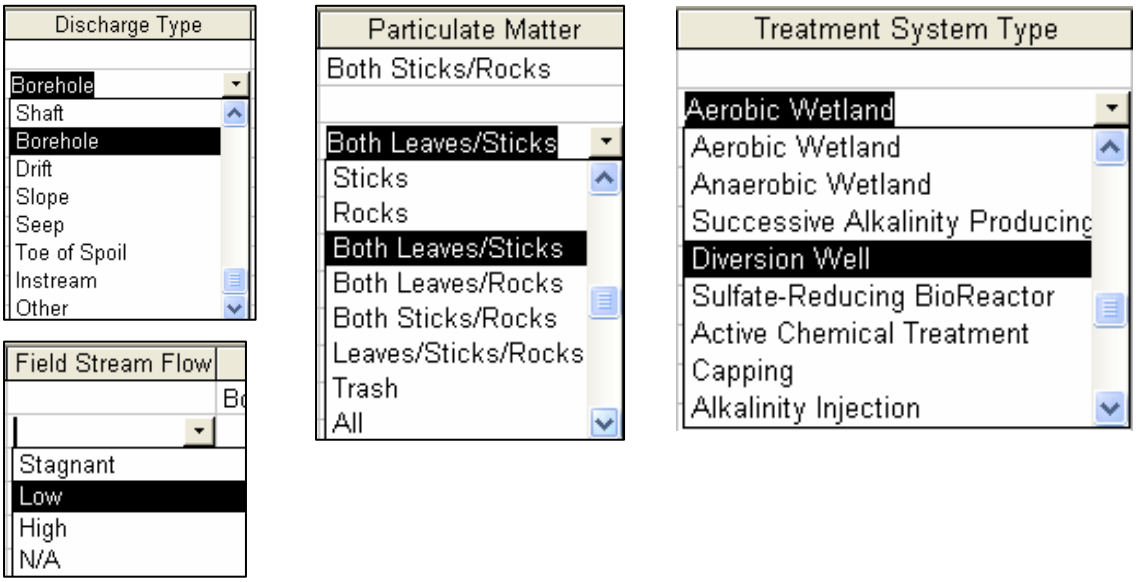


Figure 5. Examples of Screen Shots from the Drop-Down Lists

Microsoft Access - [SludgeDischarges : Table]

File Edit View Insert Format Records Tools Window Help Type a question for help

Discharge ID	Discharge Name	Discharge Type	AMD Source	Sample Location ID	Watershed
1					
2	Dundee Outfall	Borehole	Underground	SS002-TS	Nanticoke
3	Beaver Dam Outfall	Instream	Underground	SS003	Nanticoke
4	Espy Run Treatment Wetlands	Shaft	Underground	SS004-TS	Nanticoke
5	Espy Run Discharge	Instream	Underground	SS005	Nanticoke
6	Site 19- Scot Ridge Mine Tunnel	Seep	Underground	SS006-TS	Shamokin (
7	Site 20 - Coalbert Mine Breech	Borehole	Underground	SS007	Shamokin (
8	Site 21- Maysville Borehole/Discharge	Borehole	Underground	SS008	Shamokin (
9	Site 15- Corbin Mine Drift	Drift	Underground	SS009-O	Shamokin (
10	Site 12- Excelsior Stripping Pit	Tunnel	Underground	SS010-O	Shamokin (
11	Site 49- Sterling Discharge	Shaft	Underground	SS011-O	Shamokin (
12	Site 57- Cameron Discharges	Shaft	Underground	SS012-O	Shamokin (
13	Site 52- Cameron Discharges	Shaft	Underground	SS013-O	Shamokin (
14	Site 42- Carbon Run Treatment	Shaft	Underground	SS014-O	Shamokin (
15	Old Forge Borehole	Borehole	Underground	SS015-O	Lackawann
16	Duryea Outfall	Shaft	Underground	SS016-O	Lackawann
17	Gravity Slope Outfall	Slope	Underground	SS017-O	Lackawann

Table 1. Screen Shot of the Sludge Discharges Microsoft Access® Database

Materials Used

In addition to the high tech GIS/GPS equipment and software used to build the project iron oxide sample inventory, the following low-tech field equipment were also necessary to make the initial phase of the Iron Oxide Resource Recovery Project a success (Figure 6):

- Cabela chest waders
- Sony Mavica digital camera
- Tupperware containers
- Mesh screen
- Aluminum forms holder
- Ice cream scooper
- Quart-size storage bags
- Family-size empty chicken soup can
- 10-pk. floppy diskettes
- 8-pk. AA batteries
- 15’ extendable pole
- AMD Hach Testing Kit
- Igloo Cooler

Figure 6. Field Testing Equipment

Once the data parameters, the data sampling form, and sampling equipment were in place, the next step was to notify those watershed groups affected by AMD within EPCAMR's coverage area (Figures 7 and 8). Nearly 70 such groups exist in the EPCAMR Region of Northeastern PA alone. A mass email was sent to initially contact those group representatives of the watersheds containing stream sites assumed to have met the iron oxide sampling criteria.

Follow-up phone contact was made to schedule dates and times for EPCAMR staff to meet with these representatives to assist in sampling sites.

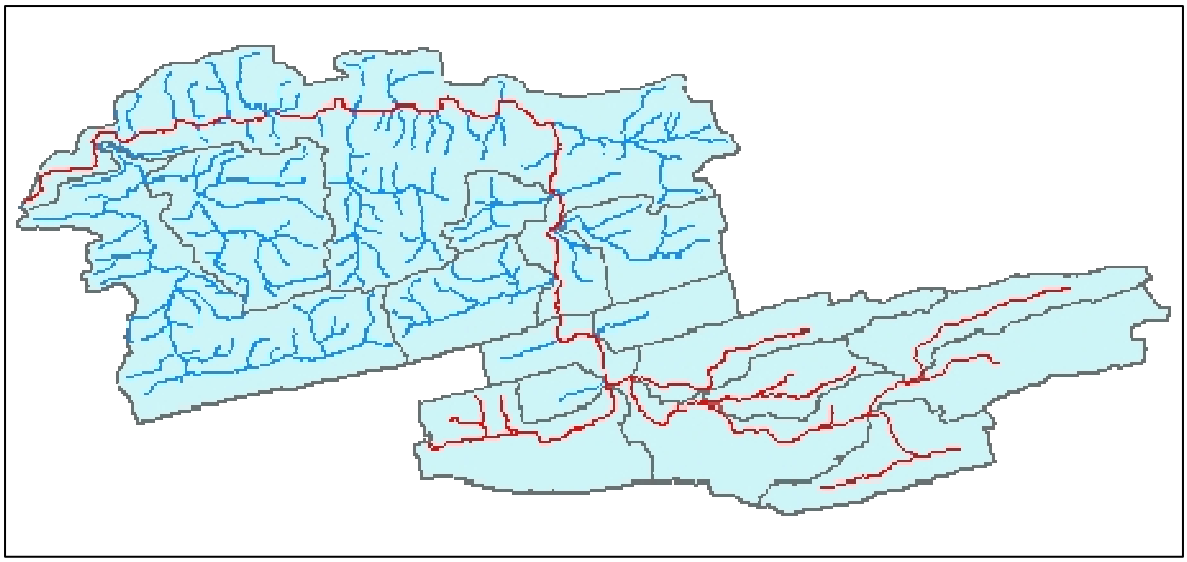


Figure 7. Watershed Map of the Shamokin Creek Watershed Showing the Streams Impacted by AMD on the Federal 303 (d) List of Impaired Waters

Figure 8. Corbin Mine Drift, Coal Township; Northumberland County, PA

Discharge Name	Sample ID	County	Ph	Acidity	Alkalinity	Sludge Depth (In.)	Tons
Site 15- Corbin Mine Drift	SS009-O	Northumberland	4.2	290.7	0	36	6.73

Table 2. Analysis of the Corbin Mine Drift Iron Oxide Estimated Sludge Volume

At the Corbin Mine Drift location, in the Shamokin Creek Watershed, in the Western Middle Anthracite Coal Fields, the iron oxide content that was analyzed in the laboratory was 97% pure iron oxide (Table 2).

Figure 9. Excelsior Stripping Pit, Coal Township, Northumberland County, PA

Discharge Name	Sample ID	County	Ph	Acidity	Alkalinity	Sludge Depth (In.)	Tons
Site 12- Excelsior Stripping P	SS010-O	Northumb	5.6	222.30	51.30	30	56.10

Table 3. Analysis of the Excelsior Stripping Pit Iron Oxide Estimated Sludge Volume

At the Excelsior Stripping Pit location, in the Shamokin Creek Watershed, in the Western Middle Anthracite Coal Fields, the iron oxide content that was analyzed in the laboratory was 90% pure iron oxide (Figure 9, Table 3).

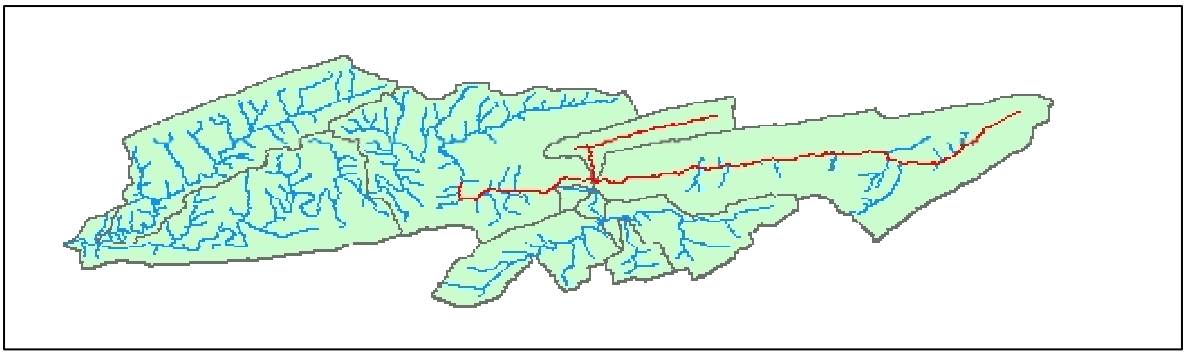


Figure 10. Watershed Map of the Wiconisco Creek Watershed Showing the Streams Impacted by AMD on the Federal 303 (d) List of Impaired Waters

Figure 11. Lykens Water Level Tunnel, Wiconisco Township, Dauphin County, PA

Discharge Name	Sample ID	County	Ph	Acidity	Alkalinity	Sludge Depth (In.)	Tons
Lykens Water Level Tunnel	SS018-O	Dauphin	6	76.95	17.10	12	98.74

Table 4. Analysis of the Lykens Water Level Tunnel Iron Oxide Estimated Sludge Volume

At the Lykens Water Level Tunnel location, in the Wiconisco Creek Watershed, in the Southern Anthracite Coal Fields, the iron oxide content that was analyzed in the laboratory was 82% pure iron oxide (Figures 10 and 11, Table 4).

Figure 12. Unnamed Seep, Wiconisco Township, Dauphin, PA

Discharge Name	Sample ID	County	Ph	Acidity	Alkalinity	Sludge Depth (In.)	Tons
Unnamed Seep	SS019-O	Dauphin	6	68.40	17.10	36	100.99

Table 5. Analysis of the Unnamed Seep (SS019-O) Iron Oxide Estimated Sludge Volume

At the Unnamed Seep (SS019-O) location, in the Wiconisco Creek Watershed, in the Southern Anthracite Coal Fields, the iron oxide content that was analyzed in the laboratory was 94% pure iron oxide (Figure 12, Table 5).

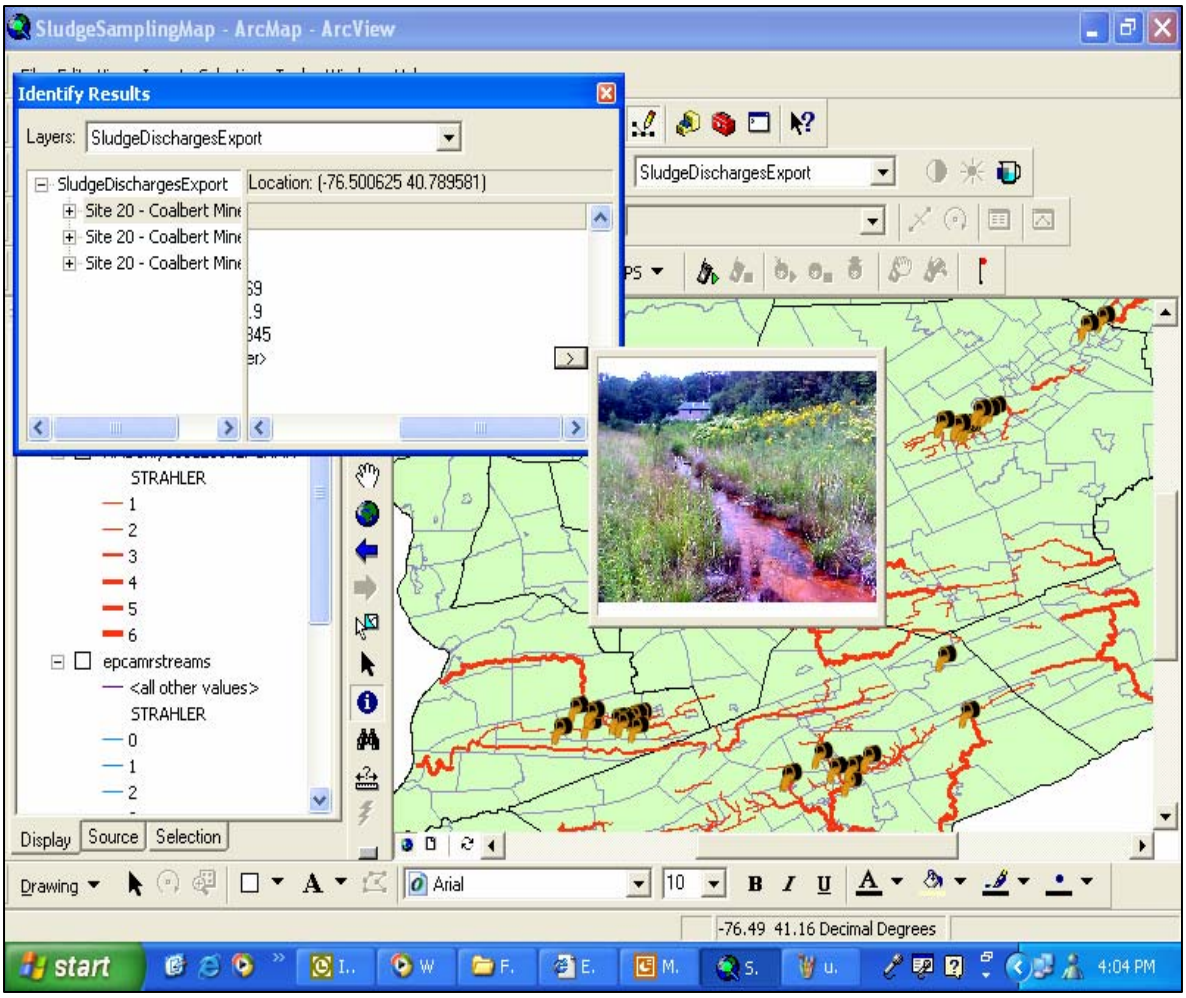


Figure 13. Screen shot of final ArcMap product of dozens Iron Oxide Sampling Locations

One of the final ArcMap products for the project was a complete geographic representation of the AMD discharge locations, along with a picture of the location, and the data parameters collected; displayed in an attached table (Figure 13). The Strahler stream classification system was also used to identify the stream order of the tributaries impacted by AMD throughout the EPCAMR Region.

There are many potential uses for the iron oxides collected by EPCAMR and will continue to collect in the Spring/Summer 2005. EPCAMR will continue to work on developing partnerships with local businesses and industries that might benefit from the re-use of the iron oxides in Eastern PA. Western PA is far ahead of Eastern PA, in that one of the prominent Congressmen, John P. Murtha, has developed a Resource Recovery Institute and has provided funding for research, development, and business applications for the iron oxides collected and sampled by

groups like EPCAMR, Southern Allegheny Conservancy, and Hedin Environmental. EPCAMR is hoping to convince several local legislators to follow suit and develop a similar program to supplement State and Federal dollars (Figure 14).

Figure 14. Possible Uses for Iron Oxide in Various Markets and Industries

Problems and Realizations

Some of the problems encountered by the EPCAMR Staff during the course of the project caused minor setbacks as natural landscape features and geology made the field work challenging. Some of the experiences of the OSM Watershed Intern are shared below:

- Lack of alkalinity at most sites due to lack of limestone geology acting as a buffer for the chemistry of the streams affected
- Utilization and understanding of ArcPad toward the end of the initial stage of project that reduced field time application
- Site accessibility
- Lack of knowledge of discharge information in areas without watershed group stewardship
- Site and instream hazards (i.e., boreholes, trash, large trees, tires)
- Transferring data onto forms to electronic format
- Calculating the cross sectional area of iron sludge deposition at sample points required assistance

- Developing a standard, though project is young and not an “exact science”
- Converting data into ArcPad 6.03

EPCAMR’s future plans are to continue the Iron Oxide Resource Recovery Project in the Spring/Summer 2005, provided that another OSM Watershed Internship Grant is approved. EPCAMR is also planning on building a coalition of regional partners together to submit a proposal to the PA Department of Environmental Protection under their Innovative Grants Program on Resource Recovery. EPCAMR will continue to expand the development of current markets for the iron oxide in Eastern PA and will be seeking additional watershed group support of our efforts in the EPCAMR region to assist us in sample collection to add to the growing database. EPCAMR has already distributed the data to the participating watershed groups in the Region and has encouraged them to perform the actual sampling themselves and recording the data on EPCAMR’s Field Data Form in hard copy and forward copies to EPCAMR for inclusion in the database.

Acknowledgements

The EPCAMR Regional Coordinator and the OSM Watershed Intern would like to thank Mary Kay Gonzalez and Dr. Alan Comp-OSM for their support of EPCAMR’s project and funding for the internship position. EPCAMR would also like to thank the Luzerne Conservation District for providing the office space for the intern during the course of the summer and fall months to complete the initial phase of the Iron Oxide Resource Recovery Project. EPCAMR thanks the PA DEP Section 319 Program for providing funds from the US EPA that continues to support the EPCAMR Staff in the pursuit of innovative technologies utilizing GIS/GPS for the collection and analyses of iron oxides collected from AMD impacted streams in the EPCAMR Region.

EPCAMR appreciated the volunteer time by many local leaders in many of the watersheds that we visited to share in the experience of sampling and to stand behind our efforts to shed some positive light on the negative effects of AMD in our Region. Without the local watershed group’s knowledge of where the AMD discharges are located, EPCAMR would not have been able to easily search for them. EPCAMR would like to thank Mike Dziak and Jacqueline

Dickman from the Earth Conservancy, a partnering organization, and affiliated member organization of EPCAMR for years, for providing some additional funds that allowed the EPCAMR OSM Intern to stay on board with us for several more weeks than was expected during to continue working on the project.

The EPCAMR Regional Coordinator and OSM Watershed Intern would truly like to acknowledge the technical assistance and problem-solving skills of one of our very own, Mr. Mike Hewitt, EPCAMR Watershed Outreach Coordinator, who spent countless hours with the OSM Watershed Intern and the Regional Coordinator in the field, at the computer, on the phone with technical support at ESRI, and with the GPS and HP IPAQ Units, trying to work out the incompatibilities encountered. Mike's GIS background and experiences helped the EPCAMR team to develop a user-friendly data form and a consistent way of approaching our ultimate goal of generating a final map product that encapsulated all the data that was assessed, collected, calculated, and analyzed during the course of the project.

EPCAMR would like to thank Dan Farnham, Gemark, Inc., Ryan Koch-Pocono NE RC & DC, Chuck Cravotta-USGS, Bernie McGurl-Lackawanna River Corridor Association, staff at the PA DEP Pottsville District Mining Office and the PA DEP Bureau of Abandoned Mine Reclamation, for providing valuable input to the project that will undoubtedly allow EPCAMR to build on our initial successes in the future.

Finally, the EPCAMR Staff would like to thank Mr. Robert Hedin, Hedin Environmental, for helping EPCAMR to develop the Iron Oxide Resource Recovery Sampling Criteria and data parameters. Mr. Hedin provided the EPCAMR staff with 20 years worth of experience and first-hand knowledge of his successes in Western PA. Mr. Hedin also provided financial assistance towards the sampling of the iron oxide samples out of his own pocket to assist EPCAMR with beginning to understand how valuable a commodity the iron oxides in the Eastern PA AMD discharges just might be. Mr. Hedin's analyses of the iron oxides has shown EPCAMR that we are on the right track and that there is a strong possibility that markets can and will be developed in the near future to handle the volumes of iron oxides that are currently present in our Eastern PA AMD impacted watersheds.

Last but not least, EPCAMR would like to say thank you to Mr. Bill Winters and Karen Pierson-OSM, who provided the EPCAMR Regional Coordinator and the OSM Watershed Intern with full travel scholarships that allowed us to attend this year's Conference and make a presentation that EPCAMR believes will have applications in other States and Nations impacted by AMD and are looking at Resource Recovery of Iron Oxides.