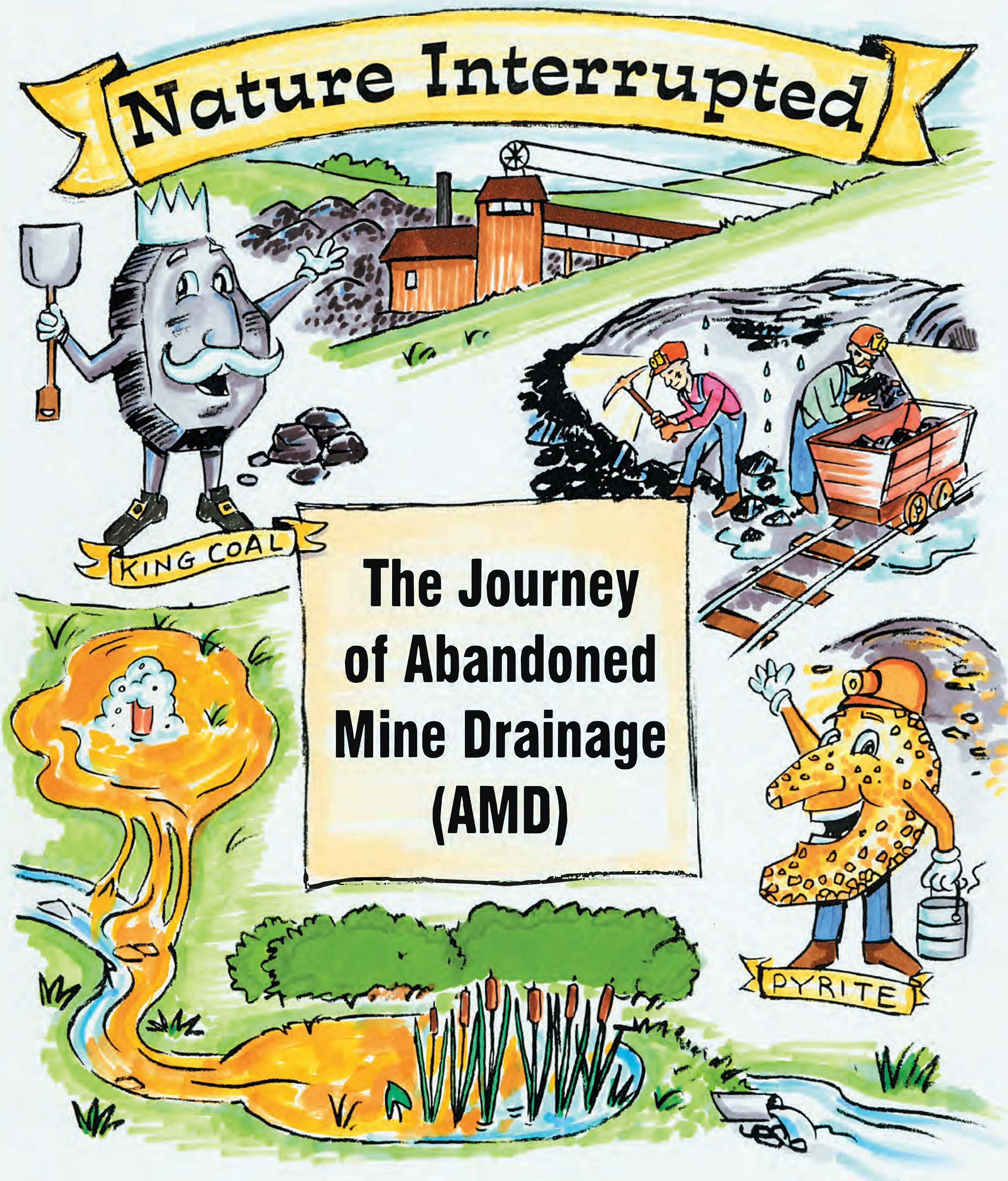

The Journey of Abandoned Mine Drainage (AMD)

An activity guide to learn about the effects of abandoned mine drainage throughout Appalachia

Nature Interrupted

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Funded by
The Pennsylvania Department of Environmental Education
Growing Greener Grant Program

Coordinated by
Saint Vincent College Environmental Education Center

Nature Interrupted

The Journey of Abandoned Mine Drainage (AMD)

A cooperative project of the Saint Vincent College Environmental Education Center, Kiski-Conemaugh Stream Team, Western Pennsylvania Conservancy Watershed Assistance Center, Department of Conservation of Natural Resources-Keystone State Park, Westmoreland Conservation District, Roaring Run Watershed Association, Western Pennsylvania Coalition for Abandoned Mine Reclamation, Mountain Watershed Association, The Pennsylvania State University Cooperative Extension in Westmoreland County, AMD & Art

Support provided by Loyalhanna Watershed Association, Cambria County Conservation District, Powdermill Nature Reserve, Jennings Environmental Education Center, Fayette County Conservation District, Indiana County Conservation District

The Pennsylvania Department of Environmental Protection's Growing Greener Grant Program funded this project.

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http://amrclearinghouse.org/AMDED/amded.html

Contents

Preface

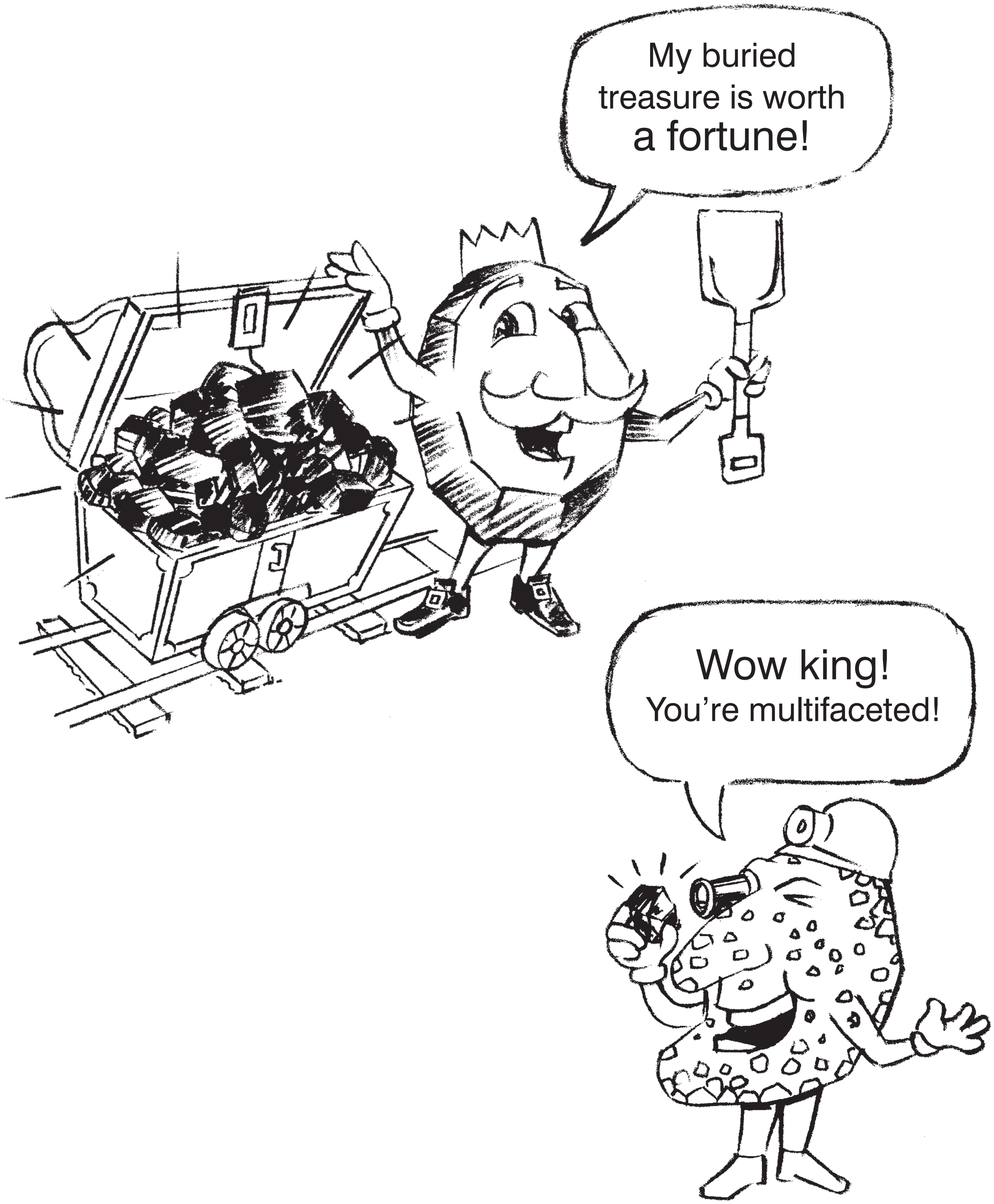
Throughout Pennsylvania, abandoned coal mines have severely degraded land and water quality, posing serious risks to the community at large. Contaminated water from these abandoned mines is a major water pollution problem in Pennsylvania, affecting an estimated 2,500 miles of streams in the state. In southwestern Pennsylvania, abandoned mine drainage (AMD) is the number one non-point source problem affecting water quality.

Despite the significant impact of mine drainage throughout the region, the Pennsylvania Environmental Readiness for the 21st Century Commission Survey Report conducted by the Pennsylvania Center for Environmental Education in 1999 found that "Commonwealth citizens have surprisingly little knowledge about non-point source pollution, electricity generation, air pollution, and wetlands."

Fifteen regional watershed organization's environmental outreach and county conservation districts collaborated in development, dissemination, and evaluation of the AMD curriculum. The goal of the AMD Curriculum is to increase AMD and watershed restoration awareness and literacy throughout the southwestern Pennsylvania region; provide training and resources for traditional and nontraditional educators, including watershed groups, to aid in more effective teaching of the issue; and establish an informal network of partnerships for the development and implementation of effective programs and outreach activities relating to mine drainage remediation and watershed protection.

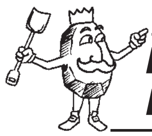
Each lesson plan was designed to be utilized by classroom teachers, environmental educators, watershed groups, colleges, and universities.

Discovering Black Treasure



Our Country's Coal History

Adapted from American Coal Foundation, http://www.teachcoal.org/lessonplans/history.html, ©2003
Developed by Gwen Johnson, Kiski Conemaugh Stream Team, Johnstown, PA



About This Activity...

Prep Time Required:
1 hour

Grade Level:
Middle School, High School

Subjects:
History, Language Arts, Science, Social Studies

Duration of Activity:
2 class periods with additional time for research

Pennsylvania Standards Addressed:
3.3.8.A2, 3.4.6-8.A1, 3.4.6-8.B1, 3.4.6-8.B3, 3.4.6-8.B4, 3.4.7.D3

Setting:
Classroom, computer lab, and/or library

Vocabulary:
Coal
Coke
Electricity
Fossil Fuel

Prerequisites:
Knowledge of coal mining, coal use, electricity

Summary:
Examine a timeline of coal mining in the United States and research how the policies of coal-dependent companies have changed over the past fifty years, affecting the economy of our country.

Materials:
- Transparencies of "Timeline of Coal in the United States," go to http://www.teachcoal.org/lesson plans/pdf coal_timeline.pdf, also included Library resources and Internet access
- Overhead projector

Objective:
Students will be able to:
- familiarize themselves with key dates in the history of coal mining in the United States.
- research coal-dependent companies in the United States.
- assess the effects that the coal industry has had on the economy of the United States, both directly and indirectly.

Background:
Coal is a **fossil fuel** composed of plant and animal matter formed over millions of years. Coal is primarily composed of carbon, hydrogen, oxygen, and nitrogen, the main elements of organic matter. Coal is used to generate heat, produce **electricity**, and make steel and other industrial products. Large industrial and manufacturing companies use coal for heating and powering plants. Railroad companies that deliver coal are also dependent upon its production in order to sustain their business. It is used around the world as fuel and is second only to petroleum as the most consumed source of energy.

The simple burning of coal produces heat for homes and various industries, and is also the major fuel for producing electricity. Coal is burned to turn water into steam, which turns the blades of a turbine driving a generator to produce electricity. Coal is used for almost 50% of the U.S. electricity production and 40% of the world's electricity.

Coke is produced when coal is heated without air at about 1000ºC (1832ºF). Coke is a hard material of almost pure carbon and is used to smelt iron ore for the production of steel. Historically, steel companies have been large consumers of coal, using coke to produce steel. Coal tar is a sticky black liquid derived from coke and is used for paving roads and tarring roofs. Coal tar is separated into different compounds producing a variety of products such as plastics, paints, synthetic fibers, and drugs.

Coal is the most abundant fossil fuel in the country, and has been used for thousands of years as a natural resource. Throughout history, it has been used in various ways including ammunitions production and powering locomotives. The U.S. has about 24% of the world's coal supply. With the world's increasing need for energy, coal is a high demand resource.

Procedure:
Warm-up:

Review the sequence of events listed on the Timeline of Coal in the United States, highlighting the various discoveries, inventions, and uses of coal over time. Explain to students that coal has been and continues to be important to the economy of the United States. Whether used to bake pottery, power steam engines, provide electricity, or produce steel, coal is an essential resource for our country.

Activity:

Ask students if they know what types of companies are dependent upon coal. Tell them that electric companies are the major consumers of coal, accounting for 80 percent of its use.

Divide the class into three large groups. Students can work in smaller teams of two or three students within a larger group to conduct their research.

Assign one group to research an

electric company, another group to research a railroad company, and the last group to research a steel company. Each research team should answer the following questions:

- When was the company founded?
- How many people does it currently employ?
- Approximately, how many people does the company provide services for?
- How does it use coal?
- Over the past fifty years, how has the company changed? Does it employ more or less people? Does it rely more or less upon coal?

Provide students with the following companies and links to begin their research:

Pacific Gas and Electric
(http://www.pge.com)

Union Pacific Railroad
(http://www.uprr.com/aboutup/history/)

Bethlehem Steel
(http://www.bethsteel.com/)

After groups have completed their research, allow each group to present their findings to the class. Record the number of people employed by each company, as well as the number of people served by each company, on the blackboard or overhead projector. Add up the total employees and customers.

Explain to the class that these companies are representatives of each industry, and that there are more coal-dependent companies in the United States, employing and serving thousands of people.

Wrap-Up/Conclusion:

Ask students what they think would happen if the United States stopped mining coal; what would the chain of events be with regard to employment and services? How would this affect our economy?

Be sure the students can also answer the following questions: When was coal discovered in the United States? How was it first used? What do you know about how coal was first mined? What changes in the mining and use of coal have occurred in the past century? Why is coal important to the United States?

Assessment:

- Have students prepare an editorial about the role that coal has played and continues to play in the economy of the United States. Encourage students to focus on one particular industry and the role that coal plays in its production and growth. Students may choose to suggest alternatives to coal in order to sustain the industry, or they may support the increase in coal production to grow the industry, and, therefore, the economy.

Extensions:

- Students who are sensitive to the workers affected by coal production may be interested in researching more about the unions in these industries. Direct them to the following links to find out how the workers in these industries form a collective bargaining entity to support one another.

United Steel Workers of America (USWA)
(http://www.uswa.org/)

United Mineworkers of America (UMWA)
(http:/www.umwa.orghomepage.shtml)

Transport Workers Union (TWU)
(http://www.twu.org/)

Purchase the *Coal Today CD ROM* (http://www.teachcoal.org/teacherstore/video.html), which allows students to play interactive games that introduce coal, its use, and the importance of electricity to our lives.

- Students may be interested in continually improving efficiency of machines or appliances that once used coal. Students may research how appliances in the home have become more energy efficient over time.

Adaptations:

Students who have weaker writing skills may opt to make a videotape of them discussing the role of coal in the economy of the United States, rather than presenting a written report.

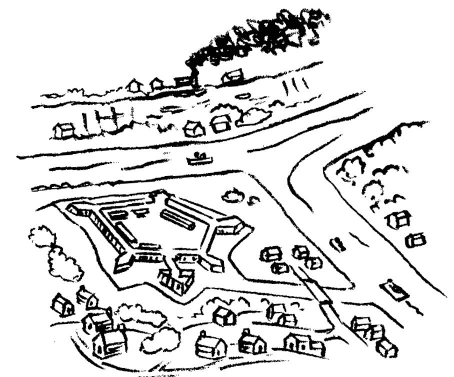
Resources:

American Coal Foundation, http://www.teachcoal.org/lessonplans/history.html, 2003.

Timeline of Coal in the United States

1000 A.D.
Hopi Indians, living in what is now Arizona, use coal to bake pottery made from clay.

1673-74
Louis Jolliet and Father Jaques Marquette discover "charbon de terra" (coal) at a point on the Illinois River during their expedition to the Mississippi River.

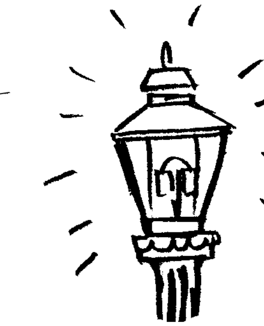


1700s
First coal use in Pittsburgh area (Mount Washington)

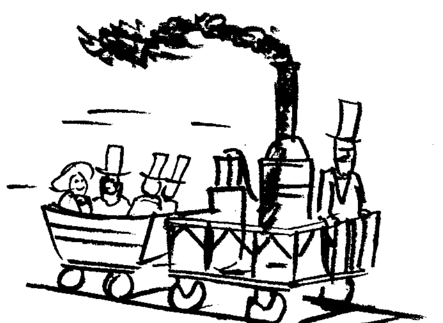
1701
Coal is found by Huguenot settlers at Manakin on the James River, near what is now Richmond, Virginia.

1748
The first commercial recorded commercial U.S. coal production form mines in the Manakin area.

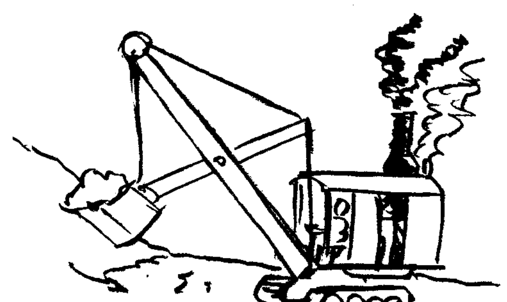
1762
Coal is used to manufacture shot, shell, and other war material during Revolutionary War.



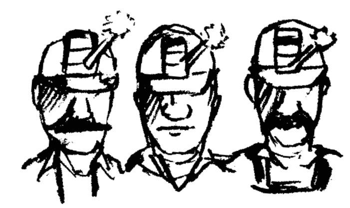
1816
Baltimore, Maryland, becomes the first city to light streets with gas made from coal.



1830
The first commercially practical American-built locomotive, the Tom Thumb, is manufactured. Early locomotives that burned wood were quickly modified to use coal almost entirely.

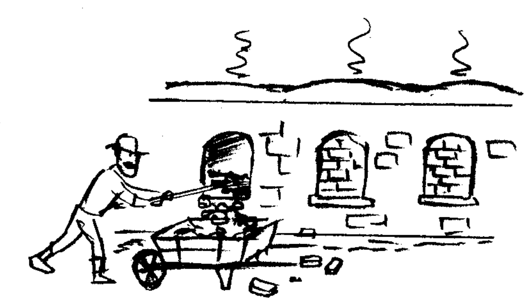


1839
The steam shovel is invented and eventually becomes instrumental in mechanizing surface coal mining.

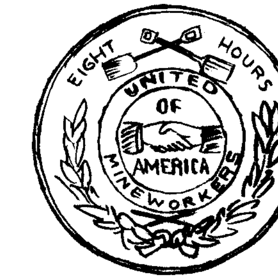


1848
The first coal miners' union is formed in Schuylkill County, PA.

1866
Surface mining, then called "strip" mining, begins near Danville, Illinois. Horse-drawn plows and scrapers are used to remove overburden so the coal can be dug and hauled away in wheelbarrows and carts.



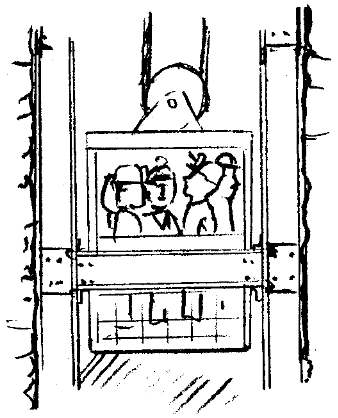
1875
Coke replace charcoal as the chief fuel for iron blast furnaces.



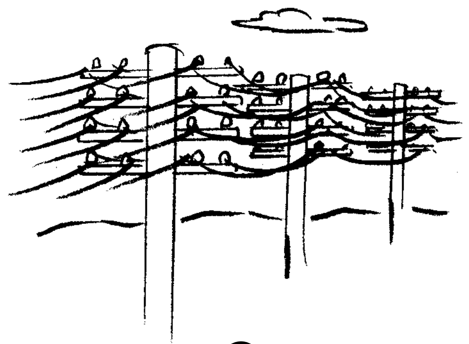
1890
The United Mine Workers of America is formed.

Source: http://www.teachcoal.org/lesssonplans/pdf/coal_timeline.pdf

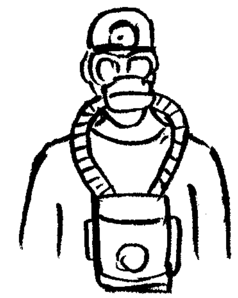
Timeline of Coal in the United States



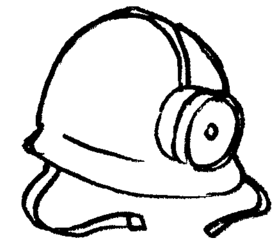
1896
Steel timbering is used for the first time at the shaft mine of the Spring Valley Coal Co., where 400 feet of openings are timbered with 15-inch beams.



1901
General Electric Co. builds the first alternating current power plant at Ehrenfeld, Pennsylvania, for Webster Coal and Coke Co., to eliminate inherent difficulties in long-distance direct-current transmission.

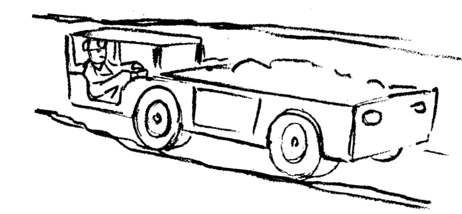


1912
The first self-contained breathing apparatus for mine rescue operations is used.

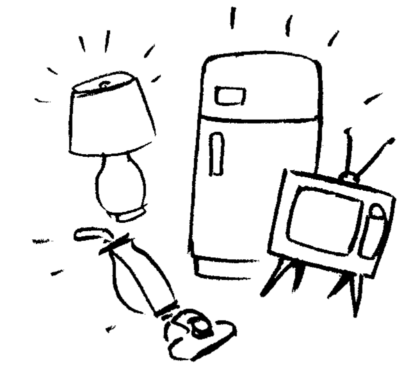


1930
Molded, protective helmets for miners are introduced.

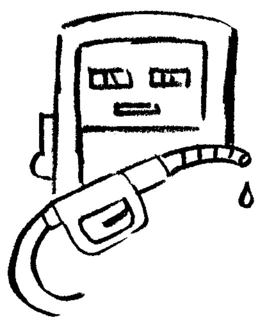
1933
NRA
National Industrial Recovery Act - gave miners right to organize 40 hour work week, etc.



1937
The shuttle car is invented.

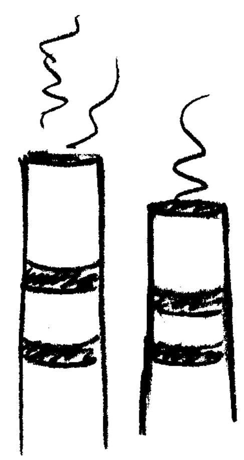


1961
Coal becomes the major fuel used by electric utilities to generate electricity.

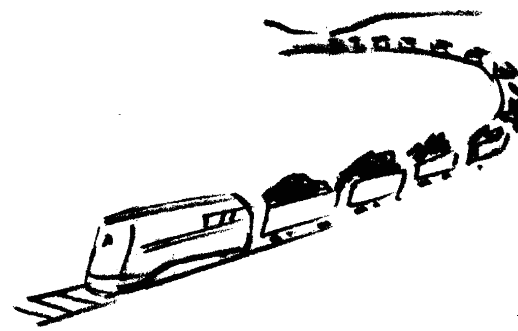


1973-74
Oil embargo by the Organization of Petroleum Exporting Companies (OPEC) focuses attention on the energy crisis and results in increased demand for U.S. coal.

1977
Surface Mining Control and Reclamation Act (SMCRA) passed.

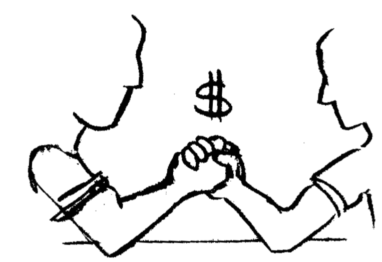


1986
Clean Coal Technology Act passed.

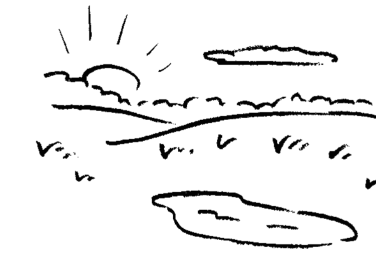


1990
U.S. coal production tops one billion tons in a single year for the first time.

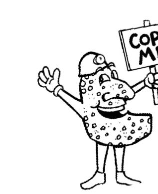
1995
The National Coal Association and the American Mining Congress merge into the National Mining Association, representing coal -and minerals-producing companies.



1996
Energy Policy Act goes into effect, opening electric utility markets for competition between fuel providers.



2002
Coal mining companies reclaim two millionth acre of mined land.



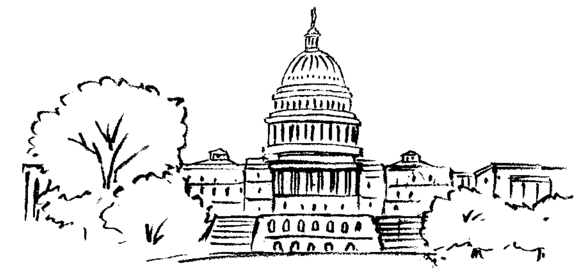
Source: http://www.teachcoal.org/lesssonplans/pdf/coal_timeline.pdf

Timeline of Coal-Energy Legislation

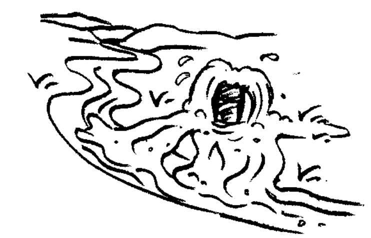
1890
United Mine Workers of America formed.

1891
First Federal Mine Safety statute passed.

1910
United States Bureau of Mines founded.

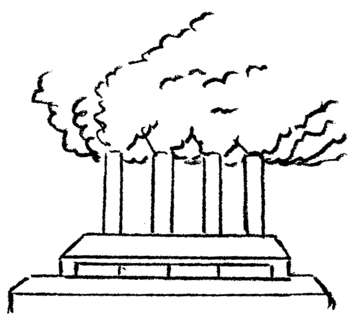


1941
The U.S. Coal Mine and Health Safety Act passed by Congress.



1948
U.S. Water Pollution Control Act created.

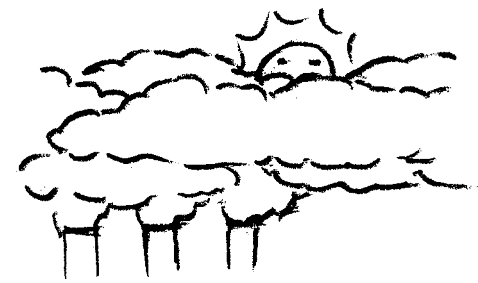
1952
Federal Coal Mine Safety Act passed.



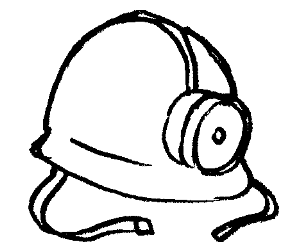
1955
Federal Air Pollution Control Acts began.

1965
Federal Water Pollution Control Administration created. (Now known as Environmental Protection Agency- EPA)

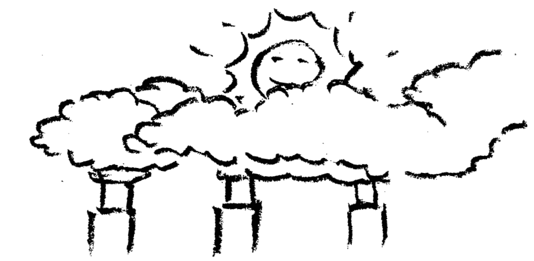
1969
The U.S. Coal Mine Health and Safety Act started



1970
First Clean Air Act enacted



1973
Mining Enforcement and Safety Administration (MESA) founded.



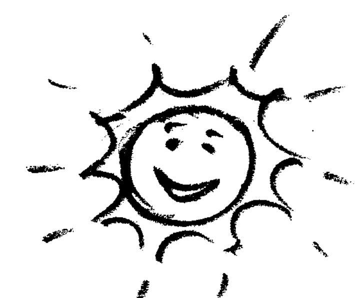
1976
Clean Air Act amended.

1977
Federal Mine Safety and Health Act passed.

1977
The Surface Mining Control and Reclamation Act created.

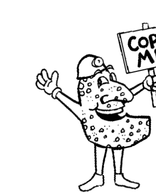
1984
Clean Coal Technology Program instituted.

1990
Clean Air Act amended.



2002
Clear Skies Initiative proposed.

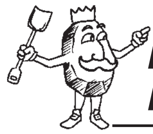
2003
Clean Air Act's New Source Review provision changed.



Source: http://www.efmr.org/xtra/coalenergy.doc

History Is Alive!!

Developed by Danielle K. Ross, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
30 minutes

Grade Level:
Middle School,
High School

Subjects:
History, Language Arts,
Social Studies

Duration of Activity:
1-2 class periods, plus additional time outside class

Pennsylvania Standards Addressed:
3.4.6-7.B1, 3.4.12.B1,
4.5.6.A, 4.5.7.E

Setting:
Classroom

Vocabulary:
Coal
Coal Energy
Coal Mining
Fossil Fuels
Industrial Revolution

Summary:
Students interview an individual formerly or presently involved in the coal industry. They organize and write a report from the interview discussing what the student learned during the interview.

Materials:
- Computer access
- Paper
- Pencils, pens
- Interview Worksheet

Objectives:
Students will be able to:
- organize their thoughts into coherent questions.
- demonstrate proper speaking and organizational skills by interviewing a community member.
- write a report from interview notes.

Background:
Coal has been an important resource in the world for many thousands of years. In the 1300s, Native Americans used coal in many ways, including heating and cooking. In the mid-1700s, the first coal mine opened in Virginia. Coal was used to power steam trains, which was a major mode of transportation in the early history of the U.S. During the **industrial revolution**, coal became a major source of energy for heating homes, electricity, and cooking.

Coal is a very important resource in the United States. Many states' economies rely indirectly and directly on coal mining. Pennsylvania is a major contributor to the coal industry with 82 underground mines and 225 surface mines, which distribute more than 75 million tons of coal each year. PA produces about 7% of the U.S. coal supply and employs over 9,300 miners. About 58% of the electricity used in Pennsylvania is produced by coal in 23 coal-fired power plants. PA uses more than 57 million tons of coal and ranks fourth in coal use.

Many people are involved in the coal industry directly and indirectly. These combined contributions of the coal industry to Pennsylvania's economy total more than $10 billion per year.

Because **coal mining** has such a long and vivid history in Pennsylvania, many people have worked in or around coal mines, and have been affected either directly or indirectly by the industry. There is a rich history in coal mining. The legacy from past miners has been passed down to present miners. This activity will allow students to learn some history first hand from someone who has experienced working in a mine.

Procedure:
Warm-up:

Find historic photographs of coal miners and coal mines. Photographs can be found at various sites on the internet.

Show the class the photographs. Tell the class that each of these people has a story. Ask the class if they could ask the miners in the picture any questions about their lives, what would they ask them.

Write the questions the students would ask the miners on the board. Tell the students to think of someone they know who was involved or is involved in the coal industry. Would any of these questions be appropriate to ask the person they know?

Activity:

Tell the students they are going to interview the person they know involved in the coal industry. The person should be directly or can also be indirectly involved in the coal mining industry. They can interview someone who worked or works in a coal mine, such as a grandparent, father, uncle, or neighbor. It can also be someone who uses coal everyday, for instance, someone who works for an electric company that uses coal.

After the students have decided on an interviewee, allow students to brainstorm in groups to determine some questions to ask in addition to the questions written on the board. Some appropriate questions they may want to use are:

- Where were you born?

- Where did you live when you were growing up?
- How old were you when you started in the mine?
- Why did you first start working in the mine?
- What was the name of the mine and where was it?
- What were your wages?
- What jobs did you have in the mine?
- Did you like working in the mine?
- What was the greatest change you saw in coal mining as you continued to work there?

Collect the students' questions and interviewee names and relationship to the student in order to evaluate them for appropriateness.

Allow the students time to contact their interviewee to establish an interview time.

During the interview, students should take notes on the responses to the questions using index cards or paper, or tape record the interview. After the interview is complete, the students should review their notes and make appropriate corrections.

Wrap-up/Conclusion:

After the interview, the students should write a short report about the interview and present their findings to the class.

Assessment:

- After all the students have presented their interview results, the class should determine if there are any similarities between the individuals' answers. The teacher can ask the class the following questions directly to the class or in a worksheet:
  - What were the wages during the time period?
  - Was the work strenuous?
  - Did the people enjoy the work, or were they forced to work there?
  - What were the conditions like?
  - Were there any common themes between the individual interviews?
  - Were there any differences between the interviews?

Extensions:

Activities:

A retired coal miner or a member of a coal mining community can speak to the class about their experiences. The students can write questions and interview the speaker in the classroom.

A guest resource person can act out the role of a miner for the interview (i.e. from a local park or facility with an environmental education staff) or a teacher or parent could act as a miner, if they properly researched the role.

Videos:

October Sky. Universal Studios. 1999.

Silver Cinders: *The Legacy of Coal and Coke in Southwestern PA* (56 minutes)

Field Trips:

Visit a local coal mining community or coal mine. Students can see first hand the history behind coal mining in Pennsylvania.

A trip to the Windber Coal Heritage Center, which tells the story of a community created and maintained by a coal company devoted to serving the company and the people employed by it. The Heritage Center is located at 501 15th Street, Windber, PA 15963-0115. The Center's phone number is (814) 467-6680, or toll-free (877) 826-3933. Access the Center on the World Wide Web, http://www.progressfund.org/wmain.htm.

Explore Keystone State Park Visitors Center and treatment ponds (coal history and abandoned mine drainage treatment). Also, visit Keystone State Park for a "Coal Mining Times" program on the work and homelife of a miner of the early 1900s. Call 724-668-2566 for details.

Adaptations:

For younger students, invite a guest speaker into the class who was previously involved in the coal industry. Have the students prepare questions to ask the speaker. After the presentation, summarize with the students the speakers' feelings about the coal industry, and the history of the industry.

Students can videotape their interview with permission. The class can watch the interviews, and the tapes can be kept as a class record and for future class use.

Resources:

American Coal Foundation. 2003. http://www.teachcoal.org/

The Windber Coal Heritage Center. 1999-2004. http://www.progressfund.org/wmain.htm

Tour-Ed Coal Mine & Museum
748 Bull Creek Road
Tarentum, Pa 15084
724-224-4720
info@Tour-EdMine.com
http://www.tour-edmine.com/
Memorial Day to Labor Day,
Open daily: 10 AM to 4 PM
(Closed Tuesdays);
Saturday and Sunday:
1 PM to 4 PM
Groups by appointment
Admission Price and
Group Rates

Interview Worksheet

Name: ____

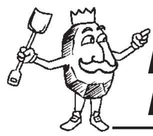
Person Interviewed: ______________________________________

Date Interviewed: ____

Directions: Write the questions asked during the interview and the answers provided by the interviewee on this sheet. Use this sheet to prepare your report.

The Impact of Coal in the Industrial Revolution

Adapted from numerous sources listed in lesson plan.
Developed by Roz Robitaille, Kiski-Conemaugh Stream Team, Johnstown, PA



About This Activity...

Prep Time Required:
2 hours

Grade Level:
7-12

Subjects:
History, Social Studies

Duration of Activity:
2 class periods (introduction and follow-up) with additional time for research

Pennsylvania Standards Addressed:
3.4.6-8.A1, 3.4.6-7.A3, 3.4.6-8.B1, 3.4.7.B2, 3.4.6-8.B3, 3.4.6-8.B4, 3.4.6-8.C1, 3.4.6.D2, 3.4.12.A1, 3.4.12.A3, 3.4.12.B1, 3.4.10.E5, 3.4.12.E5, 3.4.12.E6

Setting:
Classroom, computer lab, and/or library

Vocabulary:
Canal
Industrial Revolution
Invention

Prerequisites:
none

Summary:

Students use the Internet and /or library to understand life before the **Industrial Revolution**, investigate the impact of inventions on the Industrial Revolution, particularly the use of coal in steam power, and describe the importance of transportation in the Industrial Revolution.

Materials:

- Books and websites mentioned below

Objectives:

Students will be able to:

- describe the relationship between technology and the Industrial Revolution
- discover that the process of **invention** involves not only creativity, but also planning, trial and error, and refinement
- describe how inventions have affected people, both historically and in the present

Background:

What is a revolution? And what has it to do with coal?

Coal is an important element that helped “fuel” the Industrial Revolution. During and prior to the Industrial Revolution, it was abundant in Britain and in several Colonial states of America. After being used in smaller amounts for heating, coal was later put to use, producing power for driving stream engines, which would help expand the production and transport of manufactured goods. As the population and need for these goods grew, there was also an increase in demand for coal.

According to the American Heritage Dictionary, 4th Edition, one of the definitions of a revolution is “a sudden or momentous change in a situation.” Although the term “sudden” is debatable, the Industrial Revolution certainly was “momentous.” The approximate 200 years could quite possibly be considered sudden in the context of the long history of humankind.

The Industrial Revolution was a time of dramatic change, from hand tools and handmade items to products, which were mass-produced by labor-saving machines. These machines began to replace human labor-intensive industry and produced more goods more quickly. The large machines had to be housed in factories rather than homes, and people had to leave their homes to work for the owners of the machines.

This was the beginning of work and pay by the hour rather than by the product. More and more items were produced, which made the items cheaper to buy. The items could then be purchased by the poor, not only by the rich or elite segments of society. The quality of life improved for some people, but not for all. With increased production came increased pollution and terrible working conditions for many.

The Industrial Revolution quickly changed the way goods were made and sold, and how people lived and worked. It involved the:

- development of power driven machinery
- use of money in more complicated ways
- growth of towns
- improvement in transport

The Industrial Revolution started in England in the 18th Century, and spread to the United States, Canada, and other European countries in the 19th Century. The 20th century saw its spread to pockets of Asia, Africa, and South America.

Historians differ on the exact dates of the Industrial Revolution in England, but it is agreed that it occurred sometime in the period between 1750 and 1830 A.D. Some important inventions, such as the printing press, had occurred prior to 1750, and some people were already using wind, water, and steam power to produce energy. However, these were used only on a small scale.

What was life like before the Industrial Revolution? Before the revolution, most people lived by working the soil to grow their own food and by producing cloth in their homes. They were peasants who were essentially self-employed or worked on a small scale for a merchant. This was called a “domestic system.” Spinning and weaving occupied the family almost all year except for the time they spent growing food during the seasons of planting and harvesting.

Whole families were involved in this small-scale production. They may have sold some of their products locally if they had produced more than they needed. Most people lived in small towns or villages, and the roads between them were simply pack-horse trails, not conducive to traveling long distances.

Prior to the use of machines, people and animals provided the power. Then water and wind provided power. The inventions of steam-powered machines revolutionized industry and made possible the increases in production that characterize the Industrial Revolution.

An invention is a new device, method, or process developed from study and experimentation. Several inventions preceding and during the Industrial Revolution helped bring about the drastic changes that occurred in the manufacturing process. Of particular significance were the inventions of Thomas Newcomen, James Watt, and Matthew Boulton in the perfection of steam-driven power.

The Coal Connection

The Industrial Revolution resulted also increases in the extraction of coal from mines. Initially, in the United States, the plentiful forests provided wood as fuel for the manufacturing processes. Eventually, the forests were denuded and another source of power had to be used. The vast amounts of coal located in several states provided that fuel.

Initially, coal was dug out manually by pick and shovel and hauled to the surface by men, women, and children using muscle power. Eventually, animals sped up the process by hauling loads of coal in carts on rail. Workers in the mines endured harsh and dangerous conditions: working lying down or on hands and knees in 2-4 foot high tunnels, in the dark except for candlelight, and in cold, wet environments. Working in underground coal mines was hazardous. There were two major engineering problems: the need to drain water from the mine, and a system to ventilate the mine to provide fresh air to the miners. In addition, methane gas, often a byproduct of the coal mining process, could catch fire and explode.

Eventually, machines for cutting and loading coal were invented and took over some of the jobs of the miners. Output increased and the number of miners needed to produce larger quantities of coal decreased. In addition, steam engines provided the power to ventilate the mines and drain water from them. Other inventions helped reduce the danger of working in the mines, although mining is still considered a dangerous occupation today.

Transportation

The transport of goods during the Industrial Revolution was a major problem. Roads were undeveloped and bridges were few and far between. Over the years, the necessity of moving goods to increasing markets to the west fueled the construction of **canals**, which would connect industrial sites to other industrial sites and/or population centers by enabling transport by boat and barge. Gradually, land roads were improved; however, the major improvement in transportation came with the introduction of the railroads.

Steam Power and Coal

Before steam power, only two other forces (besides muscle power) drove machinery: windmills and waterwheels. Steam would provide the third and far more powerful source of power. Thomas Savery, Thomas Newcomen, and James Watt, in a later partnership with Matthew Boulton, in succession, would invent and re-invent various improved versions of the steam engine. Robert Fulton is generally held to be the inventor of the steamboat. However, many others contributed to this endeavor.

The development of the steam engine is probably the most important technical achievement of the Industrial Revolution. Coal was the fuel used for the newly mechanized manufacturing plants and eventually in steamboats and locomotives.

Procedure:

Warm-up:

Ask the students if they know how items they use are manufactured or produced. Examples are pencils, computers, clothes, and the food they eat. Ask students if they have ever considered how these items were invented. Did someone just simply think of it and produce it? Was it that simple?

Activity:

Assign the students the task of researching the process of inventing something. Inventions, although often attributed to one person, are sometimes the result of trial and error by many persons over time, each one improving on what was done before. The steam engine and the steamboat are good examples for research. Technical drawings of the different improvements in the steam engine could be an option for some students.

Ask students to research and compare life before and after the Industrial Revolution and to provide specific examples to prove their point of view. Look up the lives of people working in mines or factories and compare to the lives of the industrialists, such as Henry Clay Frick or Andrew Carnegie. Did the Industrial Revolution improve people's lives or make them worse?

Ask the students to find other important inventions during the time of the Industrial Revolution, either in Great Britain or the United States.

Ask students to document the improvements in transportation and relate it to population shifts and industrial output in the U.S.

Ask the students to compile a list of inventions which changed the way coal miners work from the pick and shovel method to current practices.

Wrap-up/Conclusion:

Students will present their findings through writing an essay or a descriptive timeline of the invention of a significant product.

Students will debate the negative and positive aspects of life before and after the Industrial Revolution.

Assessment:

- Students will be evaluated on how well they document the cause and effect of events that occurred during the Industrial Revolution through their research on inventions.

Resources:

http://inventors.about.com/library/inventors/blsteamengine.htm

www.uml.edu/tsongas/programs/pdfs/invfact.pdf

http://yale.edu/ynhti/curriculum/units/1981/2/81.02.06.xhtml

http://encarta.msn.com/encyclopedia_761577952_2/Industrial_Revolution.html

http://www.history.ohio-state.edu/projects/coal/mechanization/Productivity.htm

http://www.eh.net/encyclopedia/adams.industry.coal.us.

Hindle, Brooke and Lubar, Steven. Engines of Change: The American Industrial Revolution, 1790-1860. Smithsonian Institution Press, Washington, D. C., 1986.

Clare, John D. Editor. Industrial Revolution. Gulliver Books, Harcourt, Brace, & Co. New York: 1994.

Clarke, Penny. Growing up during The Industrial Revolution. B. T. Barsford Ltd. London: 1980.

Hooker, Richard. "The European Enlightenment; The Industrial Revolution," 1966. www.wsu.edu:8080/~dee/ENLIGHT/INDUSTRY.HTM

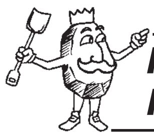
Knox, Diana. The Industrial Revolution. Greenhaven Press, St. Paul, MN: 198

Lindquist, Willis. The Universal History of the World: The Industrial Revolution and Nationalism Volume XII. Golden Press, New York: 1966.

Ross, Stewart. Documenting History, The Industrial Revolution. Scholastic, Inc., Danbury, CT: 2001.

Human Life Before Coal

Developed by Missy Shull and Gwen Johnson, Kiski Conemaugh Stream Team, Johnstown, PA



About This Activity...

Prep Time Required:
30 minutes

Grade Level:
6-8

Subjects:
History

Duration of Activity: 40 minutes

Pennsylvania Standards Addressed:
3.4.6-7.B1, 3.4.7.B3, 3.4.6.B4, 3.4.6.E2

Setting:
Classroom

Vocabulary:
Agricultural Revolution
Coke
Deforestation
Hunters and Gatherers
Peat
Sea Coal

Prerequisites: Students should be familiar with early American colonial life.

Summary:

This lesson is designed to make students consider other sources of "power" before the discovery of coal. They will simply discuss other ways in which they might power their everyday electric products.

Materials:

- Transparency
- Overhead projector

Objectives:

Students will be able to:

- Identify the use of key utilities prior to coal by comparing and contrasting sources such as heat, light, food, and shelter before and after the use of coal.

Background:

It is believed that the Chinese were the first to use coal for fuel. Marco Polo, upon returning to Italy from China, wrote of the Chinese use of coal. Romans in Scotland used "**sea coal**". Centuries later, coal resurfaced in Britain. At first, coal was unusable because most homes did not have chimneys, instead just a hole in the floor, causing the fumes to be overwhelming. Settlers in the New World were also overwhelmed with the unlimited supply of wood available for fuel and coal was forgotten. Burning wood, and water wheels, were used for power. However, when the iron industry had depleted the wood supply, coal became cheaper to burn than wood and hence, more popular. When the wood supply became scarce and expensive, the search for coal was on.

Coal fueled the Industrial Revolution. Coal and its derivatives such as **coke**, were used to make iron and then steel with less impurities. As railroads stretched across the continent, railroad engines were fueled by coal.

Coal was found in exposed hillsides, as can still be seen today in road cuts. Often, coal, in exposed seams, could be found in a person's backyard. Such places were called "country mines". Weathering **Peat**, which is partially decayed matter found primarily in bogs, is very soft and contains a lot of water. This is harvested, dried, and burned for fuel in countries such as Ireland, Scotland, and Canada, where it is locally abundant. Peat is an economic alternative to other fossil fuels, but it too is a non-renewable resource. Also, peat is found in wetlands, which provide habitat to a large array of plants and animals and naturally purify water.

Changes in energy use

Before the industrial revolution and even before the agricultural revolution, our ancestors were **hunters and gatherers**. Women collected plants, roots, bark, berries, nuts, and flowers for food. Men hunted wild game or fished to add meat to their diets. Early hunter-gatherers were nomadic, moving from place to place. Scientists believe this was one form of plant dispersal and affected animal habitat. Settlements were developed later and pollution became more of a concern. Runoff from waste piles and sewage caused water pollution, which caused disease. Hunter-gatherers' population remained steady and small, because they did not need a large population to perform their activities, as manpower sufficed, and a small population was easier to move and maintain. They lived within their means and made conscious decisions to control their population.

The **agricultural revolution** spawned from a number of things including the facts that some hunter-gatherers already planted small gardens to supplement their diets, the domestication of animals provided more energy to harvest the crops, and since one farm could support a number of people, others could expand culturally. Hunting and gathering was phased out and social structures began to change.

Agriculture had a major impact on habitat. In the beginning, slash-and-burn techniques were used to clear land for farms. Then land was plowed and irrigated. As habitats were converted to farmlands, species became extinct, climate changed, fuel supplies diminished, soil eroded, water was polluted, diet complexity changed, and population increased.

Wood, bone, and stone tools were given up for metal tools. New inventions such as the steam engine, population growth, and changes in society among other things, brought about the industrial revolution, which was marked by the use of fossil fuels.

Prior to the mass production of goods, objects were made in the home or through small workshops. Farms were self-sustaining. The barter system was utilized for the exchange of goods.

Procedure:

Warm-up:

The teacher will ask students how they used electricity today. Then ask students to imagine life without electricity and the items that use it.

Activity:

In groups, students will compare, contrast, and list sources of heat, light, food, shelter, tools, etc. before coal was regularly used versus how we derive such things today. As a class, discuss the lists and record the findings on a transparency. Then, read the above background to students and have them, in groups, add to their list.

Wrap-Up/Conclusion:

Students will share their lists and discuss, in greater detail, life before the regular use of coal.

Assessment:

- The teacher will orally assess the responses of the class. As home work, students should choose a primitive form of energy and expand upon the advantages and disadvantages of that energy source. Possible choices include fire, animal, wind, water, peat, and coal.

Extensions:

- The students can write an essay or several short journal entries on a day in the life of an early American settler, to which coal was not available. Invite a colonial re-enactor to speak to the class about a typical day. Visit the local historical society.

Adaptations:

Older students can research and map early settlements and explain the reason for their locations.

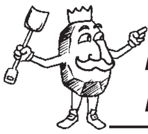
Resources:

Accepting the Challenge. Will Taylor, Margaret Dunn, and Shaun Busler. A Slippery Rock Watershed Coalition publication.

Environmental Science. Karen Arms. Saunders College Publishing, 1994. Second edition.

October Sky

Taken from Saint Vincent College Environmental Education Center: AMD Education Modules, Saint Vincent College, Latrobe, PA
Developed by: Beth Langham, Saint Vincent College Environmental Education Center



About This Activity...

Prep Time Required:
5 minutes

Grade Level:
Middle School
High School

Subjects:
English, Literature, History, Science

Duration of Activity:
3 hours

Pennsylvania Standards Addressed:
3.4.6-7.B1, 3.4.6-8.B3, 3.4.6.B4, 3.4.8.B4, 3.4.10.B1, 3.4.12.B1, 3.4.10.C3, 3.4.10.D3, 4.5.7.E, 4.5.10.E

Setting:
Classroom

Vocabulary:
Company Towns
John L. Lewis
Mining
Unions

Prerequisites:
Understanding of vocabulary words

Summary:
By viewing the movie October Sky, students can observe the life of a coal miner and several social impacts of living in a coal town. Students will discover what the mineworkers experience by "owned" by the mine owners.

Materials:
- October Sky movie (108 minutes)
- TV/VCR
- Discussion Materials

Objectives:
After watching the movie "October Sky", students will be able to:
- describe the conditions the miners experienced while working in the mine.
- discuss how mining companies owned the town and essentially the workers.
- summarize the hardships faced by young men, especially sons of miners as they tried to "get out" and become something else.
- complete a project required by the teacher.

Background:
The movie is based on a true story is set in Coaltown, (Coalwood in the movie), West Virginia in 1957, where coal **mining** is king and no one can escape life underground. But when high schooler Homer Hickman, Jr. sees the Soviet satellite Sputnik streak overhead, he aims for the stars and a new destiny in the incredible true story of hope, determination and triumph. With the help of his teacher and three buddies, Homer sets out to build his own model rocket and get out of Coalwood. His father is a coalminer and expects Homer to follow in his footsteps because; no one from Coalwood ever goes to college unless they receive a sports scholarship, like his brother. With a limited education and a series of model rocket misfires that threaten to flatten his dreams, Homer overcomes seemingly impossible odds to fulfill his vision. Homer wins a scholarship to College through his model rocket work and eventually works for NASA.

Procedure:
Warm-up:
Miner's gear - hard hat, lamp, long sleeve shirt
Mining Town - The Company owned the stores, the schools and the houses, and if anything needed fixed, the company carpenter had to fix it and you might have to wait several weeks/months.
How they mined – Room and Pillar Method

Activity:
Have students watch the video and take notes and observations about living in a coal-mining town and working in a coal mine.

Observations to be made:
- The mining towns of West Virginia existed for the sole purpose of mining coal. The coal company owned everything in the town: the stores, the church, the schools and the houses in which the miners lived. If a miner was incapacitated and could no longer work, his family was forced to move out of the company owned house, which meant leaving town. Often, when the father was injured, the children had to work in the mines to pay the rent and remain eligible to live in company owned housing. If a miner died in themines, his family had a very short time (usually two weeks) to move. The coal company didn't want the grim reminders of the dangers of the mine to be around too long. Coaltown (Coalwood in the movie), where Homer lived, was one of the better **company towns**, but it was still subject to harsh practices by the mine owners.
- The film does not present a sympathetic view of the United Mine Workers local in Coalwood. This is a departure from the book. While Homer's father was the manager of the mine and a company man through and through and while he thought that the reasons for the strike were trivial, the truth of the matter was not so clear.

Moreover, the Union men supported the Rocket Boys long before Homer's father did and they were instrumental in facing down the company's representative when he wanted to shut down the boys' test firing range (it was on a massive expanse of tailings from the mine). For a film that shows the difficulties the miners had in organizing the United Mine Workers Union and in gaining recognition from the mine owners, see Matewan.

• There are two principal methods of mining coal. Strip-mining coal close to the surface is the most economical, but also the most environmentally destructive. Power equipment of various kinds (power shovels or drag lines) removes the earth and rock to expose the coal. The coal is then broken up and loaded onto trucks or railroad cars. When the coal is not located close to the surface, the second method, underground or deep mining isused. A shaft is dug to the location of the coal seam, either vertically, on a slant or, if the coal is located in a mountain, horizontally. The coal is cut, using machines or controlled explosions. The key to deep mining is controlling cave-ins, dispersing methane gas and carbon dioxide, and suppressing coal dust. Pillars of coal are left to help support the roof. Steel beams are laced across the roof to prevent the rock from coming down onto the heads of the miners. In some mines the roof behind the coalface is allowed to collapse as the face moves forwardalong the seam. Huge fans and complicated ventilation systems are used to draw out the gases and bring in clean air. Coal dust is highly combustible and must be strictly controlled. Limestone dust is sprayed in the mine to keep the coal dust in check. The work in the deep mines is automated as much as possible. Continuous mining machines combine the separate steps of cutting, drilling, blasting and loading the coal at rates as high as 10.8 metric tons of coal per minute. The coal is then transferred by electric trolley to the surface where it is taken to preparation plants to be screened, washed, sorted by size and crushed before shipment.

• In a mine, coal dust pollutes the air and literally covers everything. A common ailment among miners is black lung disease (pneumoconiosis) caused by inhaling coal dust.

Homer's father was suffering from this disease. The mine owners failed to compensate miners for this occupational hazard. The Federal Government has stepped in and set up a health and worker's compensation plan for the miners.

• The book is better than the movie and contains a number of wonderful vignettes that are not in the film. For example, as the boys proceeded to build more complex rockets Homer realized that they needed to learn calculus to take the next steps in rocket design. Homer and the science teacher convinced the principal of the high school to offer a new course in calculus. The enrollment was limited to six people, the exact number of boys involved in the effort to make the rockets. No one expected anyone else at the school to sign up for the class. However, the girl that Homer had a crush on signed up too, and since Homer's grades in math were the worst of any of the applicants, he was excluded from the class. The principal at this point was not sure that the Rocket Boys were really up to any good and called them "bombers," a reference to their first effort which had blown up Homer's mother's fence. The principal would not increase the enrollment in the class by one person to allow Homer to take it. Initially, Homer felt that his dreams of a career in rocketry were over, but in the depths of his depression, he found a calculus text on the bookshelf at home. There were notes in the book in his father's handwriting showing that his father, who had never gone to college but who was called upon to supervise engineers, had taught himself calculus. Homer began to study the text and the other members of the club helped him. Homer learned calculus without the class, to his own amazement and that of his teachers and the principal.

• Also in the book, and not in the film, is a clear explanation of how the Rocket Boys got the precision nozzles necessary to fly their rockets. After Homer's father had sent the first machinist to help them, Mr. Bikovsky, into the mine as punishment, the town coalesced behind the Rocket Boys. Homer then convinced the supervisor of another mine machine shop to make the nozzles and Homer's father permitted company time and company materials to be used. A fundamental truth shown by this story is that to perform amazing feats, not only do people need to be committed and work hard, they often need the support of their community. In addition, they need to seek out and get that help. This is especially true in today's complex environment.

- The sequence in which Homer goes to work in the mine is fictional and not in the book. This event rings true, however, because if a man was injured or died, the mine owners provided no benefits for the miner and his family.

Wrap-up/Conclusion:

Discuss, as a class, the impact of the movie using the questions below.

Discussion Questions:

- What was the first thing that the miners did on their way down the elevator to the mine?
- A reference was made to the company carpenter in the film, who made the reference and what did it refer to?
- What happened when someone "pulled" a pillar too close?
- Where could you make the most money, by working underground or by working above ground in the machine shops?

- Where was the launch pad at, and what was it?
- What was the theme of this film? What were the filmmakers trying to tell us? Were they successful? Justify your answer.
- What did you learn about the life and times of a coal miner in the 1950's from this movie?
- Did all of the events portrayed in the film ring true? Describe the scenes that you found especially accurate. Which sequences didn't seem to match reality? Why?
- How big is the coal industry today? To what extent does the United States still rely on coal for power and for coke for the steel mills? Are there still coal towns today?
- Why did Homer's father want him to work in the mine? Was his father being a good parent in wanting Homer to follow in his footsteps?
- Why did Homer volunteer to work in the mine when his father was ill? What would have happened to the family if no one had been working in the mine even though his father was still recuperating from injuries he had received saving miners' lives?
- Describe how Homer's father felt about his youngest son at the beginning of the film, when Homer first started experimenting with rockets, after Homer had gone to work in the mine, when Home quit the mine, and at the end of the film.

Have the students complete one of the projects below.

Possible Projects:

- Students can be asked to write an essay on any of the discussion questions described above.
- The class can be asked to take positions on and to debate any of the discussion questions.
- Change the ending of the film. (This can be done by the teacher describing a new ending or permitting the class or different groups of students to choose their own ending.) Break the class into groups to create a storyboard or a script of an altered version of the film accommodating the new ending, if necessary, changing the order of the scenes.

Assessment:

- Teacher will evaluate the student participation during the discussion of the film and check notes taken during the film. (Objective 1)
- Teacher will verbally check during the discussion the student will discuss how mining companies owned the town and essentially the workers. (Objective 2)
- Teacher will check the summaries for the student understanding of the hardships faced by young men, especially sons of miners as they tried to "get out" and become some thing else. (Objective 3)
- Teacher will evaluate student understanding through the correctness of/participation in the project assigned. (Objective 4)

Extensions:

- Students can research **unions** and the benefits they provided to the miners.
- Students can research **John L. Lewis**, one of the most important figures in the formation of mine unions.
- Students can also read the book the movie was based on Rocket Boys or more recently renamed October Sky after the success of the movie.
- Students can learn about and build their own model rockets.

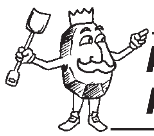
Resources:

Many of the questions and facts have been compiled from teachwithmovies.org.

Classroom Cinema, by Richard A. Maynard, 1977, Teachers College Press, New York.

America At Work: Mining

Developed by Kathryn Thalhauser, Saint Vincent College Environmental Education Center, Latrobe PA



About This Activity...

Prep Time Required:
5 minutes

Grade Level:
4-5th grade

Subjects:
History, Science

Duration of Activity:
1-2 45 minute class periods

Pennsylvania Standards Addressed:
3.1.4.C1, 3.2.4.A4, 3.3.5.A2, 3.4.5.B1, 3.4.4.B2, 4.1.4.A, 4.2.5.C,

Setting:
Classroom

Related Vocabulary:
Crude
Fossil fuel
Geologists
Molybdenum

Prerequisites:
Elementary level reading

Summary:
Students will read through a book about mining, and answer questions about the book. They will apply what they learn to their very own surroundings, and investigate abandoned mine drainage in relationship to mining.

Materials:
1 copy for each student:
- Book: America at work: Mining, see resource section
- Mining Worksheet

Objectives:
Students will be able to:
- Read through the book, "Mining"
- Answer questions related to the book
- Apply their knowledge to their own surroundings
- Investigate the relationship between mining and abandoned mine drainage.

Background:
The mining that occurred long ago has led to the problem we face today: Abandoned mine drainage (AMD). The mines that were emptied of coal in the past were left empty to fill up and flood with groundwater. The water filling the mine caused the pyrite that was left behind to dissolve into iron and sulfide particles. When this water exits the ground and reacts with oxygen, the iron turns to iron oxide (or rust), and the sulfide turns to sulfate and emits a foul odor (like rotten eggs). The iron oxide coats the bottom of the stream, causing little bugs (macroinvertebrates) to get STUCK. They cannot breathe or see and if the population of macros decreases, the entire food chain is disrupted. Abandoned mine drainage causes environmental problems, which in turn causes problems for recreational activities. Entire communities can be and are disrupted from this problem.

Procedure:
Warm-up:
To get the students interested, go around the room and ask each of them what their parents do at work. Then introduce the book by telling them that the children in this book have parents who work in the mining industry. Ask students as a group if they know anyone who works in the mining industry or if they have previous experiences to share related to mining.

Activity:
After the class discussion, divide students into groups of 2-3 to read the book (change group number according to class size and number of books, or you can read aloud for entire class if you so desire). Hand out mining worksheet beforehand, so the students can fill it out as the book is read. Tell them they will be graded on worksheet so that they are more prone to pay attention!

Wrap-up/Conclusion:
Go over the answers to the worksheet (see answer key). Have students discuss their answers to last question. Ask them what they learned that they hadn't known previously.

Assessment:
- Grade students on their answers to the worksheet.

Extensions:
- Have each group of students or individual student create a mini report/poster on how they think mining relates to abandoned mine drainage. Give them a very brief introduction to AMD and then have them go home and research the topic at libraries/internet sources/books. Tell students to either write a ONE-PAGE report or create a poster board on the subject. It will be graded on effort, not necessarily information. This will merely get students thinking about AMD in relationship to the information they learned about mining in the book.

Mining Worksheet

Name: ____

1. What are two things that are needed to start a mine?

2. Describe what it is like in a mineshaft underground? Why is it windy?

3. Name at least 5 things related to mining underground in a mine.

4. Describe what molybdenum looks like.

5. What two things are combined to make stainless steel?

6. T/F Mines only exist in Pennsylvania.

7. What is overburden and explain what it has to do with coal mining.

8. Name three fossil fuels and how they are formed.

9. What is another term for a dry oil well?

10. How are oil products transported around the world? What is a risk associated with these types of transportation?

11. Name at least 5 items created by oil by-products.

12. Name five types of pollution that comes from mining.

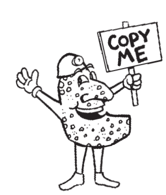
13. What are the four R's?

R R R R

14. Look at Trish and Jamie's list of things made from steel or oil. What two items were you most surprised by?

15. Now look around the classroom and come up with your own list!

a.	g.
b.	h.
c.	i.
d.	j.
e.	k.
f.	l.



TEACHER'S ANSWER SHEET — MINING WORKSHEET

1. a. find a large deposit of valuable minerals
   b. get government permission

2. It is damp, warm, breezy and very dark.
   It's windy because air is circulated. Fumes and dust are removed and humidity is controlled.

3. Ventilation shaft, ore cage, drilling machine, front end loader, mine cart, ore cage shaft, underground machine shop, cage, elevator shaft

4. It is ore that is silver, white and gray in color

5. Molybdenum and liquid iron

6. False. There are mines all across the United States.

7. Overburden is vegetation, topsoil, and rock covering coal. It is scooped out to get to the coal, but will be dumped back into the mine pit after coal removal, so that the area can be reclaimed.

8. Coal: dead organic matter squashed by mud/sediment
   Oil/gas: below ocean floors when dead animals and plants were sealed in airless pockets under deposits of shale

9. Dusters

10. Tanks, trucks, rail tankers, ocean tankers and pipelines. OIL SPILLS!

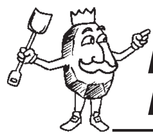
11. Paint, animal feed, medicine, glue, explosives, detergents, and plastics.

12. Plant/wildlife disturbed or destroyed
    Minerals/oils cannot be replaced
    Air pollution- toxic smoke harming atmosphere
    Water Pollution
    Oil Spills

13. Reduce, reuse, recycle, refuse

Types of Coal & the Reserves

Taken from Saint Vincent College Environmental Education Center: AMD Education Modules, Saint Vincent College, Latrobe, PA
Developed by Beth Langham, Saint Vincent College Environmental Education Center



About This Activity...

Prep Time Required:
30 minutes

Grade Level:
Middle School,
High School

Subjects:
Environment, History, Design, Art, Geology

Duration of Activity:
3-4 hours

Pennsylvania Standards Addressed:
3.3.8.A2, 3.4.6-7.B1, 3.4.7-8.B2, 3.4.6.B3, 3.4.7.D3, 3.3.10-12.A2, 3.4.10-12.B1, 4.1.10-12.B, 4.3.7-12.A, 4.3.7-10.B

Setting:
Classroom/Library

Vocabulary:
Anthracite Bituminous
Lignite
Sub-bituminous

Prerequisites:
Understanding of renewable/nonrenewable resources

Summary:
Students will examine the types of coal, what the uses of each are and where they are found all over the world. Newspaper ads will be designed focusing on a particular type of coal, where it is found and why you should buy it or help support a campaign to stop the harvesting.

Materials:
- Student Handouts
  A. Letters
  B. Research Information Sheet
- Paper/Poster board for the Display Ad Design
- Miscellaneous supplies to design the ad
- Power Point Slide Show for presentation if necessary
- Library/Internet access for research purposes presentation if necessary

Objectives:
Students will be able to:
- list the types of coal.
- illustrate the locations of the remaining coal reserves are around the world.
- describe at least 3 uses for each type of coal.
- identify alternative fuels for use as primary sources for energy.
- design a full-page newspaper ad.
- present the ad to the "board" for approval.

Background:
Coal is the most plentiful fuel in the fossil family and it has the longest and perhaps the most varied history. Coal has been used for heating since the cave man. Archeologists have also found evidence that the Romans in England used it in the second and third centuries (100-200 AD). Coal is second only to oil as an energy source in the world. America has more coal than any other fossil fuel resource; 1/4 of all the known coal in the world is in the United States.

There are enough minable coal reserves in the world to last over 200 years at the current rate of consumption. Whereas, there are 45 years of oil and 70 years of natural gas, which also tend to be concentrated in specific regions unlike coal. The United States generates 50% of its electricity from coal.

Coal formation is dependent upon many things: material, pressure, heat and time. The type of coal formed depends upon the mix of the requirements. The four types of coal are: **Lignite**, **Sub-bituminous**, **Bituminous**, and **Anthracite**.

Procedure:
Warm-up:

Show the students the 4 types of coal and a map of the world. Ask students where each type of coal comes from. Is coal only found in America or is it all over?

Activity:

Research and develop a full page ad for a national newspaper.

- Inform the students that they have been hired as an advertising agent for a national newspaper. It is their first day on the job and a coal company that wants to promote coal use has approached some, while an advocate group that wants to stop the mining of the coal resources has approached some.
- It is the student's job as the advertising designer to research the information the client wants in their ad and providing a full-page mock up to the board and justification of why the ad will promote their cause. An accepted ad will provide a significant increase in salary.

The hand out at the end includes all the information.

Wrap-up/Conclusion:
After the students have researched and produced their mockup ad, they are to

present it to the board for final approval. The board shall consist of the entire class and any free teachers willing to participate.

Assessment:

The presentation as well as the ad should be evaluated using the rubric provided.

- Teacher will collect the informational sheet completed by the student.
- Teacher will evaluate the full-page newspaper ad using the rubric provided.
- Teacher will evaluate the presentation of the ad to the “board” for approval.

Extensions:

- A debate between coal companies and environmental organizations could be used to further discuss the availability and ramifications of coal.

Sample Letter

Coal Will Keep Us Warm
125 Coal Mine Road
Mineville PA, 10034

To Whom It May Concern:

It is the mission of our organization to promote the use of coal as the primary source of energy in our country. We are currently running a national campaign to support this cause and request that you provide a full-page mock up ad for a national newspaper to be run at the earliest convenience.

The following items should be included in the ad and your presentation should provide justifications for their inclusion:

- The types of coal
- The uses of each type
- The available and minable resources, in this country and abroad.
- Reasons for coal to be the primary source of energy

The ad should be catchy, fun and accurate. Following completion of the mock up, a presentation shall be made to the board of directors for final approval. The presentation will be held in a professional setting where it is important to be fully informed of the wants and needs of the client and the reasons for the ad design you created. As this is a National Campaign, all information must be thoroughly researched and accurate.

Please direct any questions or comments to me at the above address.

Thank You,

Mr. Kohl M. Einer

Sample Letter

Environment for the Future
207 Sunshine Lane
Save, PA 10054

To Whom It May Concern:

It is the mission of our organization to stop the use of coal as the primary source of energy in our country. We are currently running a national campaign to support this cause and request that you provide a full-page mock up ad for a national newspaper to be run at the earliest convenience.

The following items should be included in the ad and your presentation should provide justifications for their inclusion:

- The percentages of available resources, in this country and abroad.
- Reasons for coal to not be the primary source of energy.
- Alternative fuels and their expected length of availability
- Environmental concerns

The ad should be catchy, fun and accurate. Following completion of the mock up, a presentation shall be made to the board of directors for final approval. The presentation will be held in a professional setting where it is important to be fully informed of the wants and needs of the client and the reasons for the ad design you created. As this is a National Campaign, all information must be thoroughly researched and accurate.

Please direct any questions or comments to me at the above address.

Thank You,

Ms. Theresa Hugger

Scoring Rubric

Topic	5	4	3	2	1
Display Ad	Completed and Professional looking	Completed with effort, but not professional looking	Completed with very little effort	Started but not completed	Not started
Research Completed *(Check the Research informational sheet)*	Sheet thoroughly completed and extra information collected	Sheet thoroughly completed	Sheet completed with minimum information	Sheet partially completed	Sheet not started
Preparedness	Presentation is completed and prepared to present to the Board	Presentation is completed but not prepared to present to the Board	Presentation is started, but not prepared to present to the Board	Presentation is not started, and has not been prepared to present to the Board	Presentation is not started and student refuses prepare to pres-ent to the Board
Presentation	Presentation was excellent and professionally presented	Presentation was satisfactory	Presentation was completed with minimum requirements	Presentation was completed, but minimum requirements were not met	Presentation was not completed and no effort was made
Accuracy	Information was 100% accurate	Information was 75% accurate	Information was 50% accurate	Information was 25% accurate	Information was completely inaccurate

Research Information Sheet

Use this informational sheet to complete the research necessary to produce the Newspaper Ad for your client.

Types of Coal	Uses of Each Type

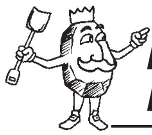
The available coal resources, in this country and abroad. (MAP)
Also provide percentages and states will reserves/resources that are minable.

Why should coal be used as the primary source of energy.

List Alternative Fuels and why they should or should not be considered as a primary source of energy.

Old Miner

Developed by Beth Langham and Angela Belli, Saint Vincent College Environmental Education Center, Latrobe, PA
Leanne Griffith, Westmoreland Conservation District, Greensburg, PA
Nicki Foremsky, Penn State Cooperative Extension, Westmoreland County, PA
Kate Tantlinger, Kiski Conemaugh Stream Team, Johnstown, PA



About This Activity...

Prep Time Required:
15 minutes

Grade Level:
Elementary

Subjects:
History, Science

Duration of Activity:
20 minutes per round

Pennsylvania Standards Addressed:
3.4.4-5.A1

Setting:
Classroom

Vocabulary:
(See character list)
Barometer
Foreman
Impurities
Sprags
Refuse
Toxic Gas
Ventilation

Prerequisites:
See other History lessons

Summary:
Students will play a card game based on Old Maid in order to learn about the life and community of a miner at the beginning of the 19th century.

Materials:
- Copies of Old Miner cards for each group (Make 2 copies of each page except for page with single Old Miner card....copy this card only once.)
- Description of each character list

Objectives:
Students will be able to:
- Learn the different jobs that are necessary for the process of coal mining in the 1800's.
- Describe the ways of life of the early coal miner.

Background:
Our area has a very rich coal mining history. Many years ago, Pennsylvania was the frontier of this new country. The poorest settlers and immigrants chose to move to the frontier since the land was so inexpensive due to the many dangers of living there. These early settlers were immigrants that came from many different countries; therefore, many of them could not communicate with each other because they spoke different languages. Even though these people came from very different backgrounds, they all had the same goal. They were looking for a way to support their families. Some of these early settlers supported their families through farming. Many others chose to support their families through coal mining. These settlers and immigrants were the roots of the early steel industry of which coal played a big part.

The miners and their families lived in small coal towns called patches. Since there wasn't much in the way of transportation in those days, it was important that the miners lived close to where they worked. The coal companies provided housing for their employees. The big mine bosses, like the **foreman**, were given nicer housing on one side of town, while the miners and their families lived in small 4-room houses on the other side of town. The foreman was in charge of all the men working in the underground mine. He was more educated than most of the men and had a lot of responsibility. The mine companies set up stores for the miners and their families; however, since there were no other stores nearby, the mine companies could set their prices very high. Between the store prices and rent for housing, the coal companies would get back most if not all of their money. Since the mineworkers were typically poor immigrants who couldn't speak the language, it was easy for the coal companies to take advantage of them.

The early coal mining jobs were extremely difficult and dangerous. The coal had to be removed by hand using shovels and picks. The early miners had to work very long hours for very little pay. Their typical workday consisted of about 10 to 12 hours, 6 days a week. The miners were paid by the amount of coal they produced not by how long they worked. Coal is found underground; therefore, the miners had to work underground where it was very dark and damp. In order to get to the coal, the miners would have to tunnel underground by removing tons of rock. The rock man was the first man called in to use explosives in order to open up a main entry into the mine. Once in the mine, the miners had to worry about being injured or trapped by falling debris. They also had to work with the constant threat of poisonous gases building up and either harming them physically or exploding. Canaries were kept in cages in the mines to help detect any **toxic gas** buildup. Since canaries were so much smaller than the men, they would be affected by the gas much sooner and would thereby act as a warning system. In addition to the canaries, a fire boss was in charge of checking special instruments called **barometers** before the miners went into the mine for the day. These barometers would let the fire boss know if the gas was moving freely throughout the mine. He would also test before each shift with a flame safety lamp in different areas to make sure that gases were not building up which could cause an explosion. Fans and **ventilation** shafts would circulate the air in the mines to try to reduce the risk of toxic or explosive gases building up. Young boys, who were called trappers, were responsible for opening and closing the underground ventilation doors.

When the miners found a seam of coal, they would dig out the rock that ran horizontally underneath the coal. This is called undercutting. Then they would dig paths through the coal vertically and would use either wedges or explosives to break off the coal. The coal was then shoveled into wooden or steel cars. Workers called trimmers would level the cars off so that none of the precious coal would spill off on the ride to the surface. Once this was done, the cars were pulled to the surface by mules or in the deep mines by steam engines. In the mines that used mules to pull the coal to the surface, a man would be employed to take care of and run an underground barn. He was known as the barn boss. In the mines where locomotives were used, a man called the track boss was responsible for seeing that the track was built and maintained from the area where the miners were working to the surface. The motorman was in charge of running the engine, and the spragger was in charge of slowing the cars down. There were no brakes in those days, so the spragger would have to jam pieces of wood or **sprags** into the wheels to slow the cars down.

Once the cars reached the surface, the dock boss would inspect the coal cars to make sure they were not filled with "dirty" coal or coal that had too much debris mixed in it, such as rock. Remember, the miners got paid by the amount or weight of coal produced. If a miner was caught putting a lot of heavy rocks in his car, the dock boss could lay him off for a while. Once the coal was inspected, the weighman would weigh the coal and remove the miner's "check" from the car to give the miner credit for the amount of coal he mined that day. Then the check boy would collect the checks from the weighman to hang them on a pegboard so that the miners could collect them to use again the next day. After the coal was weighed, it was dumped onto a conveyer belt, where boney pickers would then sort through the coal removing by hand any debris or **impurities** mixed in the coal, such as rock or sulfur. Men called slate wheelers would then remove the **refuse** to a dump pile. Now the coal was ready to be loaded onto either wagons or railcars to make its final trip to the customer.

In addition to coal mining being hard and dangerous work, the danger extends to outside the mine as well. Exposure to the mining environment over a long period of time can lead to many health problems. The constant exposure to cool, damp conditions led to different forms of arthritis and other bone and muscle problems. When the coal would drop to the ground in the mines, it would send off a very fine, black coal dust that the miners would take into their lungs. This led to a condition called Black Lung Disease, which over time made it very difficult for the miners to breathe.

Procedure:

Warm-up:

Go over each character and their job. Find a short story that goes over the story of mining. <u>Coal Mines, Coke Yard, Company Stores</u> (Yellow Book) See for background and warm-up activities.

Characters:

Old Miner
Canary
Frank the Foreman
Track Boss
Boney Pickers
Slate Wheeler
Trimmer
Fire Boss
Mules
Barn Boss
Trappers
Dock Boss
Chuck Check Weighman
Check Boy
Rock Man
Motorman
Stanley Spragger

Activity:

Play a round of Old Miner with the rules from the card game Old Maid.

1. Shuffle cards. Deal one card at a time until all cards are dealt.
2. Each player places, face up on the table, all the matching pairs in his or her hand.
3. The dealer picks a card from the player on his right. If it matches a card in the dealer's hand, the dealer places the pair on the table, face up. If it does not make a pair, the dealer places it in his or her own hand.
4. The next player does the same, selecting a card from the player on his or her right.
5. The game continues until all pairs have been matched. The player who is left with the Old Miner card loses the game - and becomes the Old Miner.

Wrap-up/Conclusion:

Ask students why wouldn't you want to be the Old Miner? Why wouldn't you want to be someone who mined all of his life? How old do you think the Old Miner is? (Health effects like black lung, etc.)

Assessment:

- Show students pictures and have students explain the roles of the characters. Can the mine function without all of the characters? Do you think mining today is similar to back then?

Adaptations:

Set of cards with roles of miners today. Talk about the change of technologies used for mining.

Resources:

Coal mines, coke yards, company stores

Passport to the Allegheny Ridge curriculum

Old Miner Character Descriptions

Canary: In old mining days, canaries were taken in a cage underground, as a warning system. When canaries collapsed or died, miners knew that there was a toxic gas in the mine. Because of a canaries' small body size, they were effected by the gas much quicker than miners would be.

Frank the Foreman: He was in charge of all the men working underground. He had to be a U.S. citizen, of good moral character, at least 23 years old, and able to read and write. They were required to pass a test, and undertook a large amount of responsibility.

Track Boss: He directed the laying of track up the main place where coal was hauled. He laid connections, kept the bolts tight and well bonded so that the "motor" could run.

Boney Pickers: After the weighing of coal, the cars were tipped onto a conveyer belt. Boney pickers had to remove by hand impurities such as slate, rock and sulfur missed by the dock boss.

Slate Wheeler: Took the refuse set aside by boney pickers to the dump.

Trimmer: Leveled cars off neatly, so no coal would spill off on a long and bumpy railroad ride.

Fire Boss: He had a very big responsibility. Each day, he would check a barometer at the lamp house. If the barometer fell, this meant gas was traveling freely through the mine. Then, three hours before each shift, he would inspect each working place with an approved flame safety lamp. If the flame inside elongated when held near the roof, that meant that there was gas present.

Mules: Men working in smaller mines used mules instead of motors. The mules hauled the coal. Some actually lived underground in the mine!

Barn Boss: You guessed it! The Barn boss was in charge of mules in the underground mule barn. This saved time, because it would have taken over an hour usually to drive mules from outside.

Trappers: Young boys who worked as doorboys in old time mines. They were among the lowest paid mine workers, averaging at $1.60 per day. They were responsible for the opening and closing of underground ventilation doors.

Dock Boss: He was in charge of checking the out coming coal cars for dirty coal. He could lay a miner off for several days if he found enough dirty coal!

Chuck Check Weighman: Company man who weighed the coal and gave credit to the man whose name coincided with the small metal "check" that hung on their car.

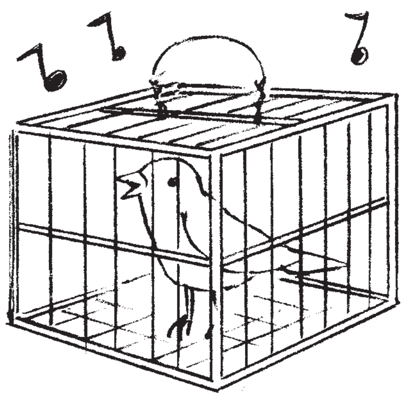
Check Boy: Collected "checks" and replaced them on a pegboard for the miners to have the following day.

Rock Man: He was called in to blast down enough rock to open up the desired height for the main entry.

Motorman: The man who ran the motor. The motor was a small locomotive run by electricity from trolley wires, used to haul coal.

Stanley Spragger: Helper to the motorman. This term comes from the days before brakes. To stop the cars, the brakeman carried "sprags" (short pieces of wood), which were jammed into the spokes of the wheels.

Old Miner Playing Cards

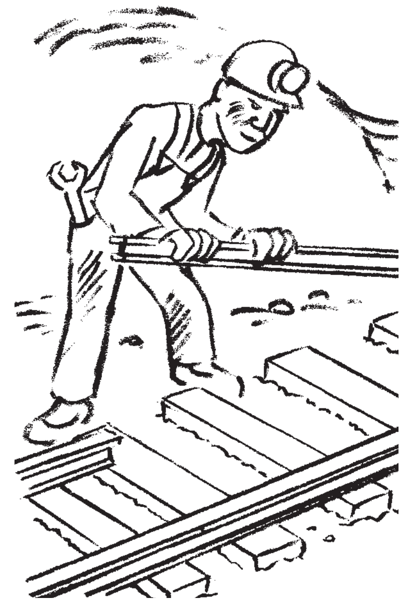


Canary

Nature Interrupted – The Journey of AMD
OLD MINER

Frank the Foreman

Nature Interrupted – The Journey of AMD
OLD MINER

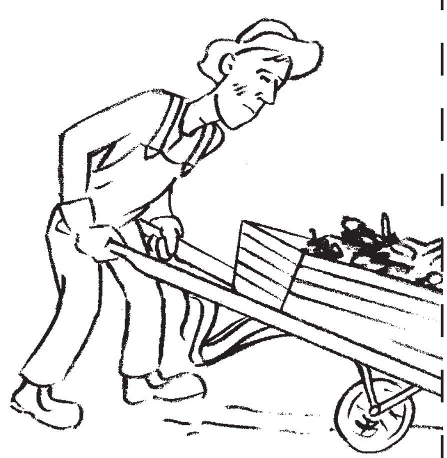


Track Boss

Nature Interrupted – The Journey of AMD
OLD MINER

Boney Pickers

Nature Interrupted – The Journey of AMD
OLD MINER



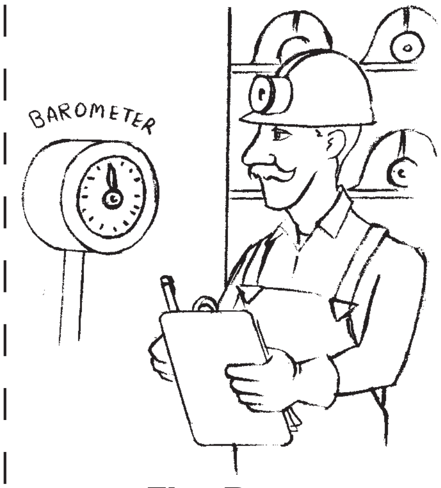
Slate Wheeler

Nature Interrupted – The Journey of AMD
OLD MINER

Trimmer

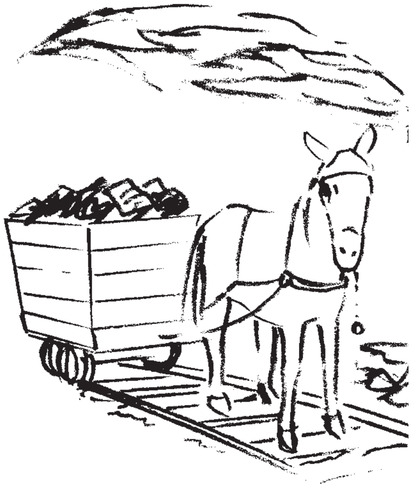
Nature Interrupted – The Journey of AMD
OLD MINER

Old Miner Playing Cards



Fire Boss

Nature Interrupted – The Journey of AMD
OLD MINER

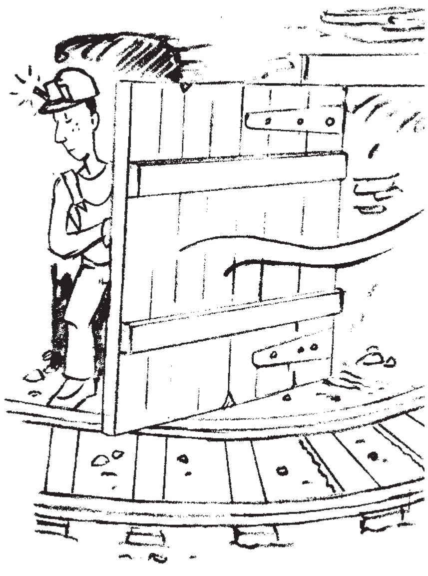


Mules

Nature Interrupted – The Journey of AMD
OLD MINER

Barn Boss

Nature Interrupted – The Journey of AMD
OLD MINER



Trappers

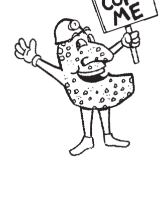
Nature Interrupted – The Journey of AMD
OLD MINER

Dock Boss

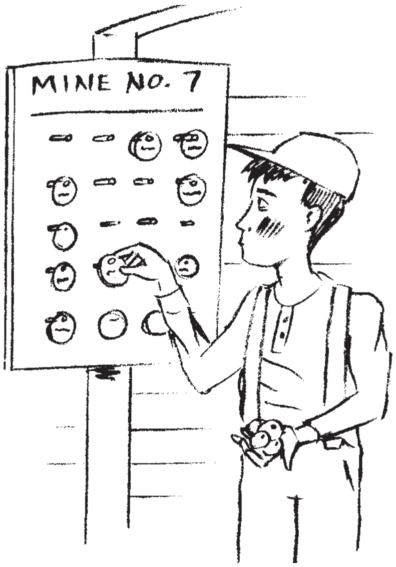
Nature Interrupted – The Journey of AMD
OLD MINER

Chuck Check Weighman

Nature Interrupted – The Journey of AMD
OLD MINER



Old Miner Playing Cards

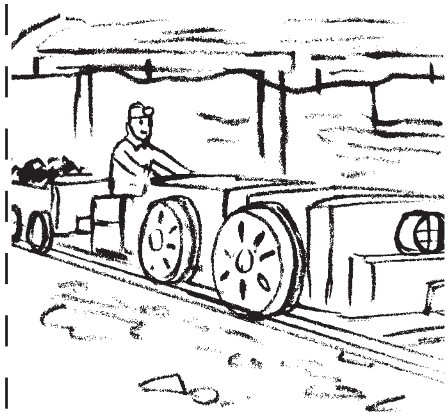


Check Boy

Nature Interrupted – The Journey of AMD
OLD MINER

Rock Man

Nature Interrupted – The Journey of AMD
OLD MINER



Motorman

Nature Interrupted – The Journey of AMD
OLD MINER

Stanley Spragger

Nature Interrupted – The Journey of AMD
OLD MINER

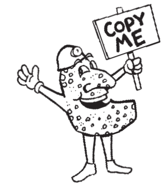
Old Miner Playing Cards

Old Miner

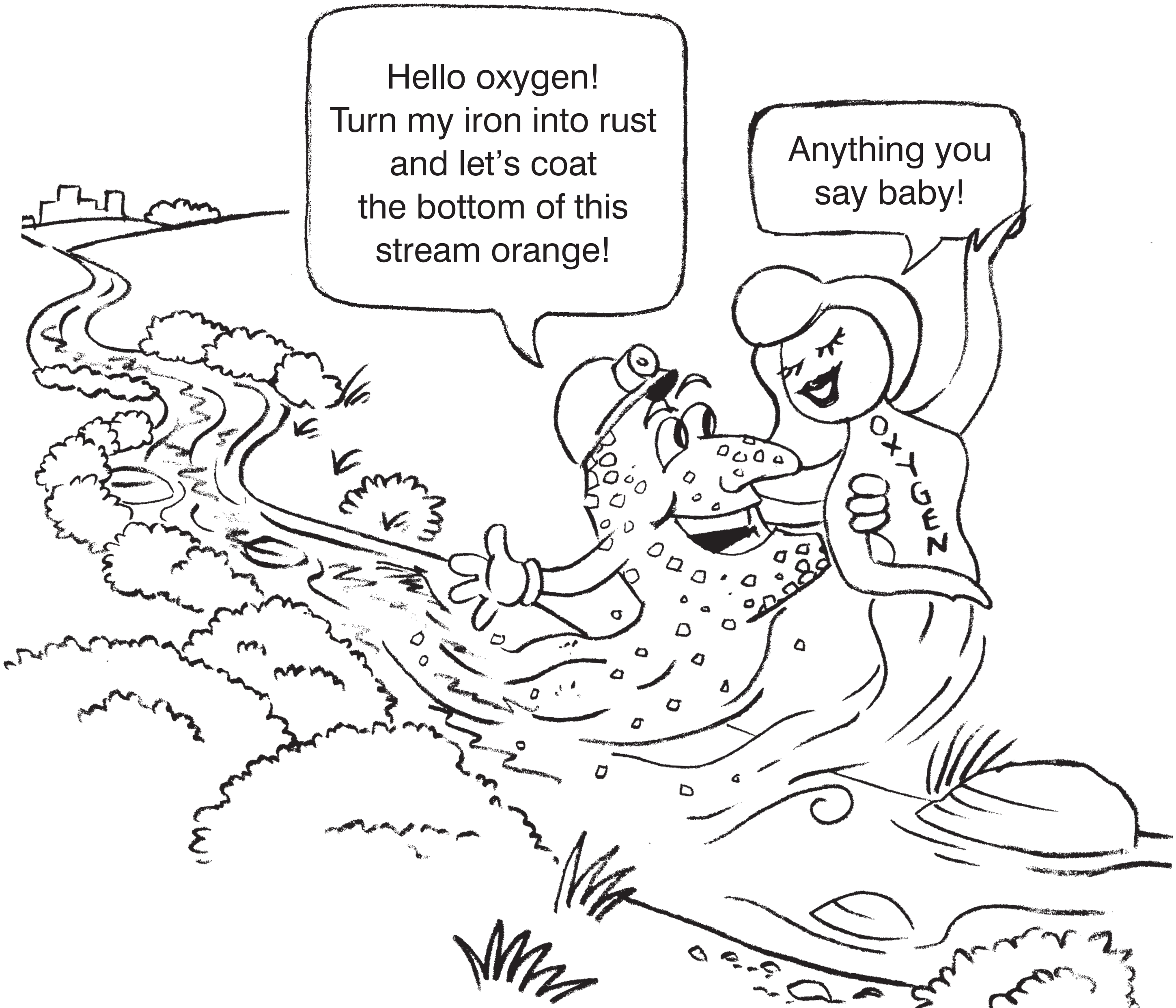
Nature Interrupted – The Journey of AMD

OLD MINER

TEACHERS:
Copy this page only once!

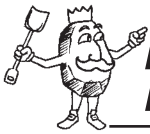


Following Pyrite's Trail



Mine Water Melody

Developed by Beth Langham, Kate Thalhauser, & Angela Belli, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
10 minutes

Grade Level:
Lower Elementary

Subjects:
Science, Music, Gym (with hand movements)

Duration of Activity:
1-2 class periods

Pennsylvania Standards Addressed:
4.2.2.C, 4.5.PK.C, 4.5.1.C, 4.5.2.C

Setting:
Classroom/music room

Vocabulary:
Dissolves
Iron
Mine Drainage
Pyrite
Sulfur
Wetlands

Prerequisites:
Knowledge of the song "The Wheels on the Bus"

Summary:

Students learn a song to understand how abandoned mine drainage (AMD) forms, how it negatively impacts a stream, and can be adapted to how AMD can be treated with a wetland.

Materials:

- Song sheets
- Tape machine or cd player

Objectives:

Students will be able to:

- Learn how AMD is formed
- Learn what AMD does to a stream

Background:

Pyrite or fool's gold is found in most coal mine sites. Abandoned **mine drainage** (AMD) is formed when groundwater comes in contact with **pyrite** (iron sulfide). The pyrite **dissolve**s into the water and forms iron ions and sulfide ions. The sulfide reacts with oxygen to form sulfate and acid. The **iron** usually stays dissolved until it reaches the surface. If the pH of the discharge is increased above 3, the oxygen in the air reacts with the iron to form iron hydroxide, an orange gelatinous solid.

These reactions can be used to illustrate a wide variety of chemical reactions. The reaction of iron and sulfide with oxygen is an example of an oxidation-reduction reaction. The formation of acid in the reaction could lead to acid-base reactions if it is neutralized by limestone in the soil. The reaction to form iron hydroxide is also a precipitation reaction.

Procedure:

Warm-up:
Sing the song "wheels on the bus go round and round"

Activity:
Teach the students the parody to "wheels on the bus go round and round" Could have words up on chalkboard or transparency. Discuss each verse so that the students understand the steps. Have the students sing the song again.

Repeat song including hand motions with lyrics.

Wrap-up/Conclusion:

Discuss what the new lyrics of the song meant, have the students talk about what was happening in the water, and why.

Assessment:

- Are the students singing? Are they using appropriate hand motions?

Extensions:

- Have students put on a play or make up another song about a happy stream.
- Students could give a presentation of song to another class or group of people.

Adaptations:

Students could bring in instruments or make noise makers that represent each stage of mine drainage formation.

Resources:

Sing a Song of Nature
Durby Peterson and Jean Warren
Totline Publications
ISBN: 1-57029-187-X

Song Lyrics

To Be Sung to the tune of: "The Wheels on the bus"

The rain from the sky goes into the ground, into the ground, into the ground
The rain from the sky goes into the ground
On a rainy day!

The pyrite in the mine dissolves away, dissolves away, dissolves away
The pyrite in the mine dissolves away
Under the ground

The water comes out and goes glub glub, goes glub glub, goes glub glub
The water comes out and goes glub glub
When it leaves the mine

The smell of the water is from sulfur, from sulfur, from sulfur
The smell of the water is from sulfur
We all say P-U!

The iron in the water turns orange orange orange, orange orange orange,
orange, orange orange,
The iron in the water turns orange orange orange,
When it hits the air.

The iron coats the rocks on the bottom of the stream, the bottom of the stream,
the bottom of the stream,
The iron coats the rocks on the bottom of the stream,
And the bugs get stuck.

It's hard for the bugs to breathe and see, breathe and see, breathe and see,
It's hard for the bugs to breathe and see,
In cloudy water.

Now the stream is sad sad sad, sad sad sad, sad sad sad,
Now the stream is sad sad sad,
Cause it's dying (unhealthy)

The people in the town are gonna clean it up, gonna clean it up, gonna clean it up,
The people in the town are gonna clean it up,
So the bugs can play!

Movements to Song

1st verse:
Fingers moving down like rain

2nd verse:
Shimmies down with body

3rd verse:
Shoulder shrug on each glub

4th verse:
Pinch nose and wave smell away

5th verse:
Spin around

6th verse:
Make X with arms in front and spread open

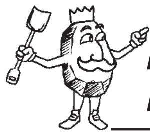
7th verse:
Partly cover eyes and mouth

8th verse:
Rub eyes like crying

9th verse:
Shovel!

AMD Summary Tree

Developed by Jen Baer, Mountain Watershed Association, Melcroft, PA



About This Activity...

Prep Time Required:
15 minutes

Grade Level:
Middle School,
High School

Subjects:
Art, English,
Environmental Science

Duration of Activity:
2 Class periods, plus possible outside research time

Pennsylvania Standards Addressed:
3.4.7-8.B1, 4.2.7-8.A, 4.2.10.A, 4.2.8-10.B, 4.2.6.C, 4.2.10.C, 4.5.7.C, 4.5.12.C, 4.3.7.D, 4.3.12.D

Setting:
Indoor/Classroom

Vocabulary:
Aesthetic Effects
AMD
Ecological Effects
Economic Effects

Prerequisites:
Knowledge of AMD, its effects and formation

Summary:
Students use library and internet resources to make an AMD learning tree which summarizes the effects of **AMD** in the environment.

Materials:
- Paper (sheets for each student)
- Large posterboard or sheet of paper (for classroom display)
- Pencils, Pens, Markers
- Internet access
- Library access

Objective:
Students will be able to:
- summarize possible effects of AMD using a learning tree.

Background:
Abandoned mine drainage (AMD) affects a variety of items in a watershed; however, often times these items are interconnected. For example, AMD polluting a stream can affect the water quality, wildlife habitat, groundwater quality, and ultimately, the water quality for residents. Through this activity, the students will use all of the information they have been presented through the other lessons to see how one environmental problem can impact every aspect of life.

Procedure:
DAY1
Warm-up:
As a class, review some of the effects of AMD and write the ideas on the board.

Activity:
Allow students to research the effects of AMD in the library and on the internet.

DAY2
Warm-up:
Define the difference between **economic effects**, **aesthetic effects**, and **ecological effects**. Show the class an example of a learning tree and briefly go over the concept. (A sample learning tree is attached. The tree can be expanded with more extensive branching.)

Activity 1:
Give students a sheet of plain paper. Demonstrate on the board how to draw the learning tree trunk and three main branches. Label the trunk ABANDONED MINE DRAINAGE (AMD). Label the branches ECONOMIC EFFECTS, AESTHETIC EFFECTS and ECOLOGICAL EFFECTS.

Have students draw the tree trunk and branches and label them on their piece of paper.

Using the information from their research, students should draw smaller branches and list the effects of AMD on each branch.

Activity 2: (optional)
Combine students into small groups. Give them a new sheet of paper. Make a combined learning tree using the answers on each individual's sheet.

Activity 3: (optional)
Have students create a large AMD learning tree on the board and share their answers.

Activity 4: (optional)
Create a large AMD learning tree as a wall hanging. Students can include photographs, graphs, statistics and anything visually stimulating to enhance the wall hanging.

Wrap-up/Conclusion:
Discuss the effects and impacts of AMD on the environment.

Assessment:
- Give the students a quiz or complete a worksheet of the various affects of AMD.

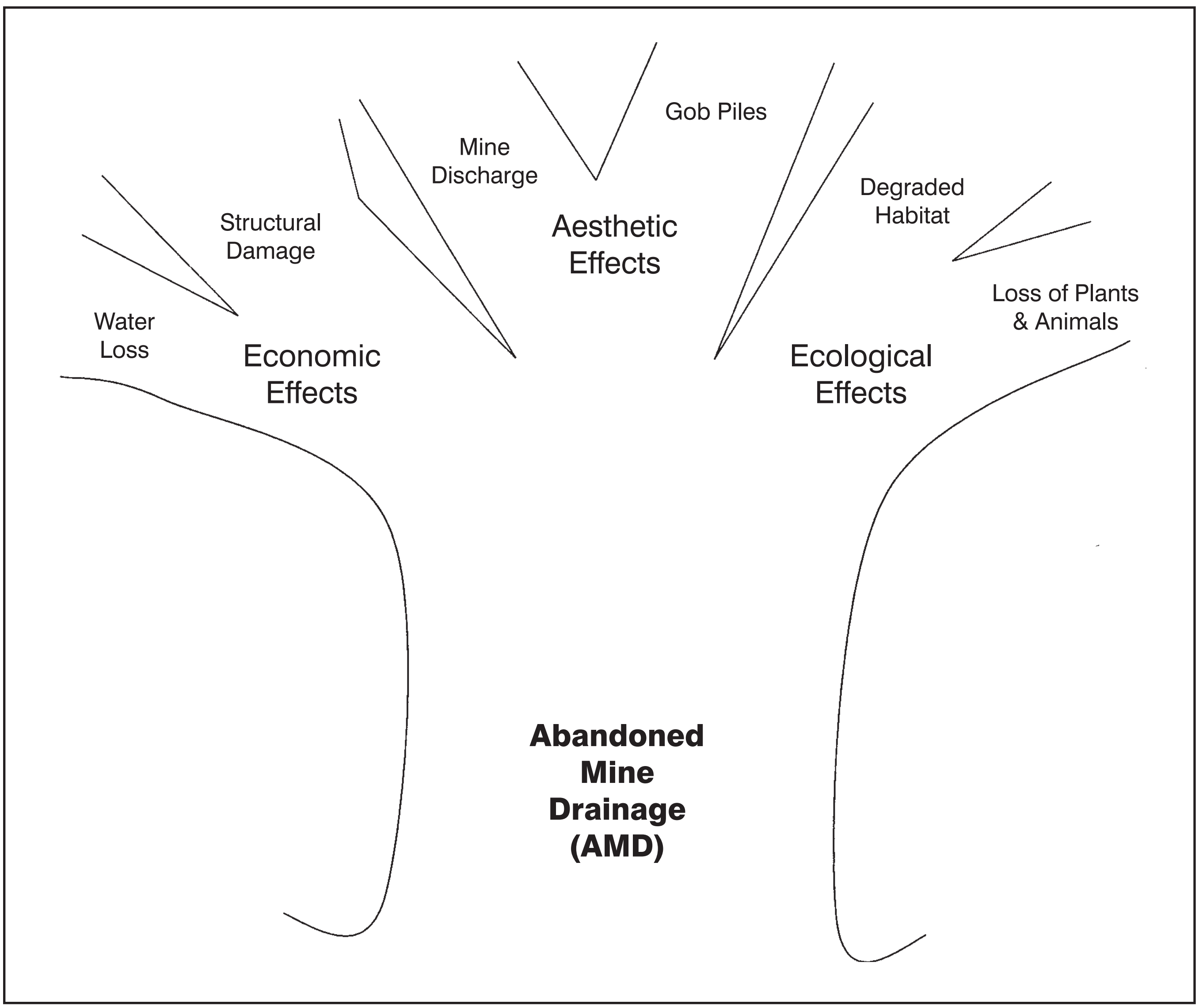
Extensions:
- Have the students make flyers or invitations to other grades/classes or parents to learn about AMD by visiting their AMD learning tree.

- Students can make posters to display about AMD and the effects of AMD on the environment, which include various photographs from sites impacted by AMD.
- The class can take a field trip to an AMD treatment facility* to see the various ways communities treat this type of pollution.
  *Saint Vincent College (724) 805-2330
  *Keystone State Park (724) 668-2566
- Field trip to or video of an AMD treatment site, such as a passive wetland system. This allows the students to visualize what they have been discussing.

Adaptations:

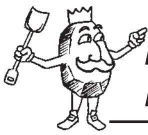
Younger students can collect and draw pictures of the effects of AMD and make a collage to present to the class.

Example of AMD Learning Tree:



Color by Number

Adapted from Goodbye Orange Water Activity Book, Saint Vincent College Environmental Education Center, Latrobe, PA
Developed by Laura Riddle, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
20 minutes

Grade Level:
Lower Elementary

Subjects:
Art, Math, Science

Duration of Activity:
30 minutes

Pennsylvania Standards Addressed:
4.5.PK-1.C, 4.5.3.C

Setting:
Classroom

Vocabulary:
AMD

Prerequisites:
Students must be able to identify numbers.

Summary:
Students are introduced to abandoned mine drainage identification by coloring an activity page.

Materials:
- Crayons, markers, or colored pencils
- Copies of color by number picture (one per student)

Objective:
Students will be able to:
- visually identify abandoned mine drainage in a stream.

Background:
The source of the abandoned mine drainage (**AMD**) in this picture is a bore-hole. Boreholes are usually drilled to make a well. Sometimes they are drilled to relieve water pressure, which is causing water to come out of the ground in an undesirable location, like someone's basement. If a borehole is drilled in a place of high water pressure, the water will shoot up into the air. The height of the water depends on the pressure of the water underground.

Procedure:
Warm-up:
Ask students to think of types of water pollution and write their ideas on the board. If they do not come up with AMD on their own, add it to the list. Give students additional background of AMD as needed, including origination, environmental effects, etc.

Activity:
Have the students color the picture following the number key at the bottom of the picture.

Wrap-up/Conclusion:
Ask students what they notice about the colors in the picture. Ask the students where the orange water is originating.

Show students photographs of AMD impacted streams from the enclosed CD Rom or AMD Education Website. Students should be directed to identify the mine drainage in the photographs.

Assessment:
- Students should bring in photographs of mine drainage impacted streams from their local community.

Extensions:
- Have the students list as many ways that orange water can be unhealthy to a stream. What other animals can students add to the picture?

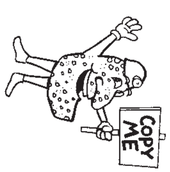
Adaptations:
- Use color in the key at the bottom of the activity page to aide in coloring the numbers correctly.
- Instead of copying a picture for every child, the teacher can make a transparency and have the students draw and color their own picture.

Resources:
- More AMD related activities for kids are available in the Goodbye Orange Water Activity Book developed by Saint Vincent Environmental Education Center. This activity can be accessed on the web at http://facweb.stvincent.edu/eec/.

Color by Number

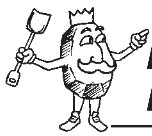
1=orange   2=light green   3=dark green   4=brown

5=blue   6=gray   7=tan



Pollution Poetry

Developed by Kathryn Thalhauser, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
10 minutes

Grade Level:
Elementary/Middle School

Subjects:
English, Science

Duration of Activity:
1-2 45 minute class periods

Pennsylvania Standards Addressed:
3.1.2.C, 3.4.4-8.B1, 3.4.4-5.B2, 4.5.1-2.C, 4.5.4.C, 4.5.8.C, 4.3.7.D

Setting:
Classroom

Vocabulary:
Adjectives
Adverbs
Diamonte poem
Participles

Prerequisites:
Understanding of grammar

Summary:

Students investigate the meaning of abandoned mine drainage (AMD) creatively by designing several different poems. Individually and in groups, they will learn how abandoned mine drainage is formed, the problems associated with it, possible treatment options and the end result of treated water, while simultaneously reviewing or learning parts of speech.

Materials:

- Paper, pencils or crayons
- Poem format sheet
- List of words that could be used (for younger grades)
- Dictionaries
- Books or photograhs about AMD (see resources for a list of examples)

Objectives:

Students will be able to:

- Learn about Abandoned Mine Drainage (AMD)
- Express their thoughts on AMD through poetry
- Use proper grammar to establish a simplified **diamonte poem**

Background:

Abandoned Mine Drainage (AMD) is drainage caused by, or flowing from coal mines. It can be acidic or alkaline, with high levels of dissolved metals. Surface mining, deep mining, bore holes (drilled to relieve pressure in deep mines), and refuse piles are examples of where AMD can begin. AMD creates toxic chemicals in water, a decrease in aquatic life, stream bottom coating, and stream discoloration. An orange color indicates the presence of iron, a gray color indicates aluminum is present, and black shows that there is manganese present in the water.

The two main methods of treatment are categorized as passive treatment and active treatment. Passive treatment is when naturally occurring chemical and biological reactions are used in a controlled environment. AMD can be passed through wetlands, diversion wells, open limestone channels, anoxic limestone drains, and vertical flow reactors. They are lower in cost and have lower maintenance than active treatment systems. Active systems use strong alkaline chemicals such as lime or ammonia to neutralize acidic discharges. AMD needs to be treated so that the aquatic system being affected can be restored to its natural state. The simplified reaction of the formation of AMD containing iron is:

Pyrite (in coal) + oxygen + water
iron hydroxide (rust) + sulfuric acid

Procedure:

Warm-up:

To get the students thinking about Abandoned Mine Drainage (AMD), and what it actually is, have students brainstorm through poetry! First, explain to students the format of the poem:

Diamonte poem

1st line: noun
2nd line: two **adjectives** (describing the noun)
3rd line: three **participles** (verbs + -ing) describing the action of the noun
4th line: two **adverbs** describing action
5th line: any one word that you most associate with the noun.

Draw the format of the poem (see format sheet) on the chalkboard so that they can use that format for warm-up poem. Use format sheet later in lesson.
Then put the students into groups of three and give students a number: 1, 2 or 3.
Assign students the following words:
1's: Abandoned
2's: Mine
3's: Drainage
Have students investigate their word using dictionaries, books and/or the internet and come up with a diamonte poem, using each assigned word as the first line in the poem.

Activity:

Have the students come back together as a class, and use the poems they came up with as a means for discussion. First, have the mini-groups share their collective poems: Abandoned first, Mine second and Drainage third. Write down some of the words used to describe abandoned mine drainage in their poems on one side of the chalkboard (Save the other side for later). After the students are finished sharing, read them a book or show them photographs of AMD and lead a discussion about the actual meaning and effects of AMD. Have students discuss AMD and ask them why their initial poems might not be quite right. If a group did have the right meanings in their poems, discuss that as well.

Suggestions:

For older students, have them collectively come up with some descriptive words that could be used as the topic of another diamonte poem (put that on the other side of the chalkboard). For younger students, give them a word bank and go over each word to make sure they understand why it is included.
Show students the following examples:

Examples

Abandoned Mine Drainage
Orange, Harmful
Flowing, Polluting, Troubling
Quietly, Unfortunately
There

Wetlands
Helpful, Diverse
Flowing, Living, Growing
Quietly, Happily
Assist

Have children work in groups of 4. Break up abandoned mine drainage into four separate parts: How AMD began, the problems associated with AMD, How we help it/Treatment, The end product. Assign each person a number 1-4.

1: How AMD began
2: Problems associated with AMD
3: Treatment of AMD
4: The end Product after treatment

Each student should choose his or her topic noun that fits the topic assigned to him or her. When picking their topic noun, students can use a word from their word bank, one that the class brainstormed collectively, or think one up on their own. The students should bring the teacher their topic noun and the teacher will then give them the poem format sheet. After students have completed their poems, move on to wrap-up/conclusion.

Wrap-up/Conclusion:

Have the students present their collective poems to the class. Start with how it began, then the problems associated with it, treatment, followed by the end product! Discuss the differences or similarities between the first group of poems vs. the second group of poems. Use words on the chalkboard to compare their initial reaction to the concept vs. their reaction after they were taught what AMD means.

Assessment:

- Teacher could assign points to completing the poem and then presenting the poems.

Adaptations:

For younger students, use the words handout. For older students, have them come up with their own words. If they are having a difficult time, have them call out words and put a large list on the chalkboard for everyone to share.

Another lesson could be to give different groups an object, such as a piece of coal, a cattail or some iron oxide. Have students use these poems to describe what they see in front of them. Then, as a class discuss how these things relate to abandoned mine drainage.

This lesson plan uses a simplified version of the diamonte poem. The actual format could get complicated with AMD. For older students or maybe for homework after this lesson plan, use actual format:

Structure:

line 1 - one noun (subject #1)
line 2 - two adjectives (describing subject #1)
line 3 - three participles (ending in *-ing*, telling about subject #1)
line 4 - four nouns (first two related to subject #1, second two related to subject #2)
line 5 - three participles (ending in *-ing*, telling about subject #2)
line 6 - two adjectives (describing subject #2)
line 7 - one noun (subject #2)

In this version, subject #1 and #2 are opposites. In line 4, the subject of the poem changes. This version could be used to describe AMD before cleanup and after cleanup!

Abandoned Mine Drainage Word Bank

How It All Began:

MINING
IRON
SULFIDE
PYRITE
CHEMISTRY
ROOM AND PILLAR

Problems:

ORANGE WATER
POLLUTION
UNHEALTHY ORGANISMS
SMELLY
ALUMINUM
DEPRESSED COMMUNITIES

Treatment:

WETLANDS
ACTIVE SYSTEMS
NEW LAWS
LIMESTONE
NONPROFIT GROUPS
EDUCATION
GOVERNMENT

End Result:

HEALTHY ORGANISMS
CLEAN WATER
FISHING
SWIMMING
PREVENTION FOR FUTURE
IRON OXIDE PIGMENT
THRIVING COMMUNITIES

Use this section for descriptive word ideas:

Abandoned Mine Drainage Diamonte Poem Format

1st line: Noun

2nd line: two adjectives describing the noun

3rd line: three participles (verb + -ing) describing the action of the noun

4th line: two adverbs describing the action

5th line: one word that you most associate with the noun

Use the word related to your assigned topic to start off your poem:

____

____________________ , ____________________

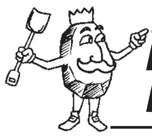
____________________ , ____________________ , ____________________

____________________ , ____________________

____

Do We Have a Pollution Problem?

Developed by Danielle K. Ross, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
50 minutes

Grade Level:
Middle School,
High School

Subjects:
Language Arts

Duration of Activity: 50 minutes, with outside class research time

Pennsylvania Standards Addressed:
3.4.6.D2, 4.1.12.C, 4.2.8.A, 4.5.7.C, 4.3.7.D, 4.3.12.D, 4.5.7.E, 4.5.10-12.E

Setting:
Classroom and library

Vocabulary:
Abandoned Mine Drainage
Habitat Macroinvertebrate

Prerequisites:
Knowledge of mine drainage formation and treatment; library or Internet research

Summary:
Students write an informational report to their community about AMD and its effects on the environment using various sources.

Materials:
- Internet Access
- Library Access
- Paper
- Pencils

Objectives:
Students will be able to:
- write an organized, informational report on AMD and its effects on the environment.
- gather information from a variety of sources, including the library and the internet appropriate for the topic.

Background:
When mine water exits the abandoned coal mine is exposed to the air, oxygen reacts with the iron creating iron hydroxide. Iron hydroxide (yellow boy) settles on stream bottoms creating a thick sludge that may negatively impact aquatic life, including algae, **macroinvertebrates**, and fish – possibly killing the organisms in a stream.

Abandoned mine drainage (AMD) is a major pollutant of watersheds in Southwestern PA.

Procedure:
Warm-up:

Show the students a photograph of a stream contaminated with AMD, or a mixture of iron oxide sludge and water in the classroom. (Photo available on enclosed CD Rom or the AMD Education Website.) Ask the students to describe the water and if they think any animals could live in the water. Discuss where students have seen streams with iron hydroxide in their communities. Explain to students that the water is contaminated with AMD, a major water pollutant of southwestern PA.

Inform the students of the origins of AMD in Pennsylvania, and what has led to this pollution in streams. Many people are not aware of the severity of this pollution in PA.

Activity:

Using various media, have the students write an informational report on AMD and its effects. The audience of their papers are their neighbors and family members.

The students should use the internet and various library sources to find sources and information on AMD.

In their papers, the students should include the following: a background on where AMD originates, how AMD pollutes streams and creeks, how AMD affects the stream **habitat**, and some ways to prevent this pollution.

Wrap-up/Conclusion:
In groups of 3-4 students, have the class brainstorm essay topics before beginning their research. Students should choose a topic and create an outline for their essay.

Assessment:
- Listen to the students as they are brainstorming to determine understanding.
- Evaluate the essays for effort, correctness, completeness, and grammar.

Adaptations:
Students can make a photo essay about AMD with captions describing each picture.

Resources:

- Websites students can use for research:

http://www.dep.state.pa.us.dep/deputate/minres/bamr/amd/science_of_AMD.htm

http://www.dep.state.pa.us/dep/deputate/minres/bmr/act54/sec6.htm

http://www.dep/state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/Coal_Mining_in_Pennsylvania.htm

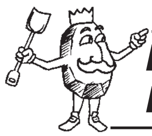
http://www.dep.state.pa.us/

http://facweb.stvincent.edu/eec/

http://amrclearinghouse.org/

Sentence Mix Match

Developed by Danielle K. Ross, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
50 minutes

Grade Level:
Elementary

Subjects:
Language Arts

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
3.1.2.C2, 3.4.4.B, 4.3.K.B

Setting:
Classroom

Vocabulary:
Noun
Predicate
Subject
Verb

Prerequisites:
Introduction to abandoned mine drainage, wetlands, and watersheds – – in order to complete the sentences.
Basic english grammar vocabulary (noun, verb, etc.)

Summary:
Students create sentences about Abandoned Mine Drainage (AMD) and watersheds by finding their matching subject or predicate phrase.

Materials:
- Two sets of Cards (3x5) of two different colors;
- Write enough sentences with subject and predicate phrases for all students (sample sentences included).
- Each card of one color will have a subject phrase, and each card of the other color will have a predicate phrase.

Objective:
The student will be able to:
- define **subject** and **predicate**
- create sentences using subject and predicate phrases involving AMD.
- correctly use words in sentences involving AMD.

Background:
Forming sentences is an essential part of everyday life. People form sentences when they are speaking with each other, writing letters, giving speeches, etc. Correct sentence structure is used in every discipline from English to Science and Ecology. People must be able to effectively communicate with each other in order to make informed decisions about a variety of issues.

Basic sentences are formed using subject and predicate phrases. The subject of a sentence usually comes at the beginning of the sentence. It consists of a **noun** phrase and indicates the topic of the sentence. The predicate phrase follows the subject. It consists of a **verb**, which indicates the action or state of being of the subject. Science is an important discipline in which sentence writing is used often. Scientists write reports, proposals, evaluations, etc. in order to discuss their topic of choice. These papers are composed of complex sentences based on the subject and predicate sentence structure.

Hundreds of years of coal mining in Pennsylvania has led to thousands of miles of polluted streams. Abandoned mine drainage (AMD) from old coal mines is one of the major sources of water pollution in the state. AMD can be acidic and contain many dissolved chemicals, including iron, sulfur, aluminum, and manganese. When the mine water leaches to the surface, it comes into contact with oxygen and several chemical reactions occur. AMD can be harmful to the wildlife and plants living in streams and other areas. For example, iron can precipitate into iron oxide at the surface and coat the bottom of streams and creeks. These areas, in turn, become contaminated and poor habitat for organisms.

Wetlands are unique places that provide excellent habitat for wildlife, and also clean/filter contaminated water. A wetland, or passive treatment system, can be used to filter out some of the contaminants in the AMD, particularly iron oxide. Wetlands are a cost-effective way to clean water and create areas of natural beauty for people and wildlife.

This activity uses sentences with vocabulary from AMD, wetlands, and watersheds to introduce students to forming sentences. The students will match subject and predicate phrases by finding their "partner" within the class.

Procedure:
Warm-up:
Tell the students that they will be completing sentences today describing AMD and wetlands. Show the students the different colored cards and explain to them that each sentence will be made up of the phrases on the cards, one of each color per sentence. Tell the students that one color of cards is the subject phrases of the sentences, and the other color is the predicate phrases.

Activity:
Distribute to each student one card of either a subject phrase or a predicate

phrase. Be sure that both parts of each sentence are distributed so that everyone is able to find a match.

Give the students time to find his/her sentence match. After the students find their match, they must stay together and sit down.

After everyone has found his/her match, have the students tell you which color cards have the subject and predicate phrases.

Next, have each pair stand and read their sentence to the class, and have the class determine if the sentence is correct. If the sentence is incorrect, the students should correct it.

Wrap-up/Conclusion:

Ask the students to define and give examples of subjects and predicates.

Discuss other sentences related to AMD, wetlands, watersheds, etc. that contain subjects and predicates.

Assessment:

- Give students a worksheet of scramble sentences, and have the students correct each sentence.
- Have the students write their own sentences about AMD, wetlands, and/or watersheds identifying the subject and predicate of each sentence.

Extensions:

- Create a crossword puzzle using sentences about AMD, wetlands, and watersheds (Sample crossword puzzle included).
- Create a worksheet consisting of incomplete sentences (about AMD, wetlands, and watersheds) in which students complete the sentences using their own ideas.

Adaptations:

Instead of making cards, a worksheet can be distributed in which the students can match the sentences working independently or in pairs.

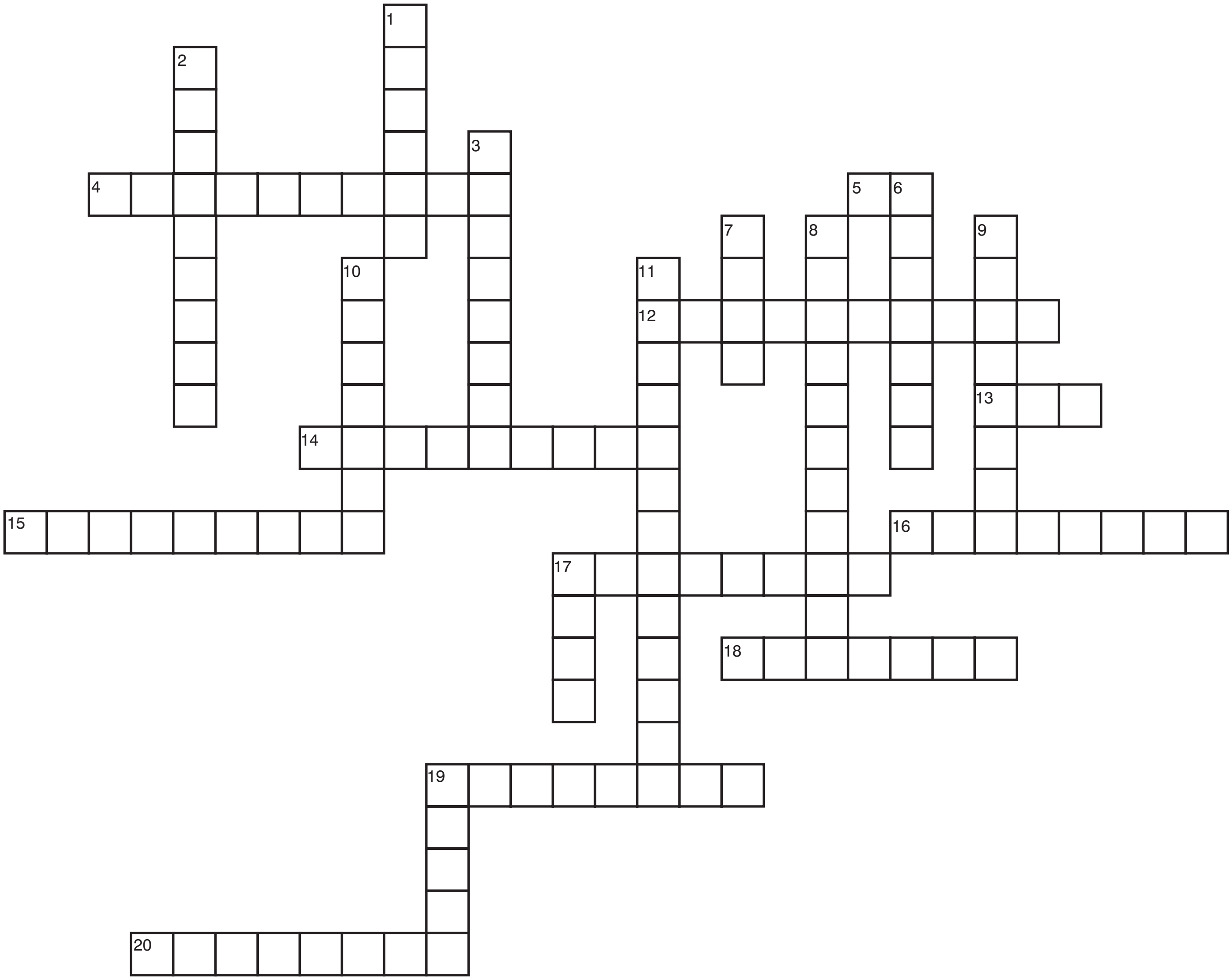
Older students can create their own sentences and cards before playing the game.

Sample AMD, Wetland, and Watershed Sentences

** There can be multiple answers for some.*

Subject Phrase	Predicate Phrase
The abandoned mine	fills with water.
The mine	caves in.
Pyrite	dissolves in the mine water.
Pyrite	contaminates the mine water.
Mine water	reaches the surface.
Pyrite	can be called fool's gold.
Wetlands	provide wildlife habitat.
Wetlands	clean rust from water.
Bullfrogs	live in wetlands.
Cattails	help filter iron oxide from water.
Many insects and other animals	lay eggs in wetlands.
AMD means	abandoned mine drainage.
Limestone	treats acidic mine water.
Muskrats	eat cattail rootstalks.
Clean water	leaves a wetland.
Wetlands	protect against flooding.
Mine water	comes from underground.
Water	is a valuable resource.
Mine water	is contaminated.
Coal	is an energy source.
Abandoned mine drainage	hurts wildlife.
Bore holes	are called bubblers.
Wetlands	hold water for a long time.
Abandoned mine drainage	contaminates streams.
Ducks and geese	nest in wetlands.
Biologists	study wildlife.
Iron oxide	is a dye.
Acidic mine water	kills plants and animals.
Many insects	call wetlands home.
Many chemicals	are dissolved in mine water.

AMD Criss-Cross

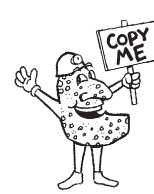


ACROSS

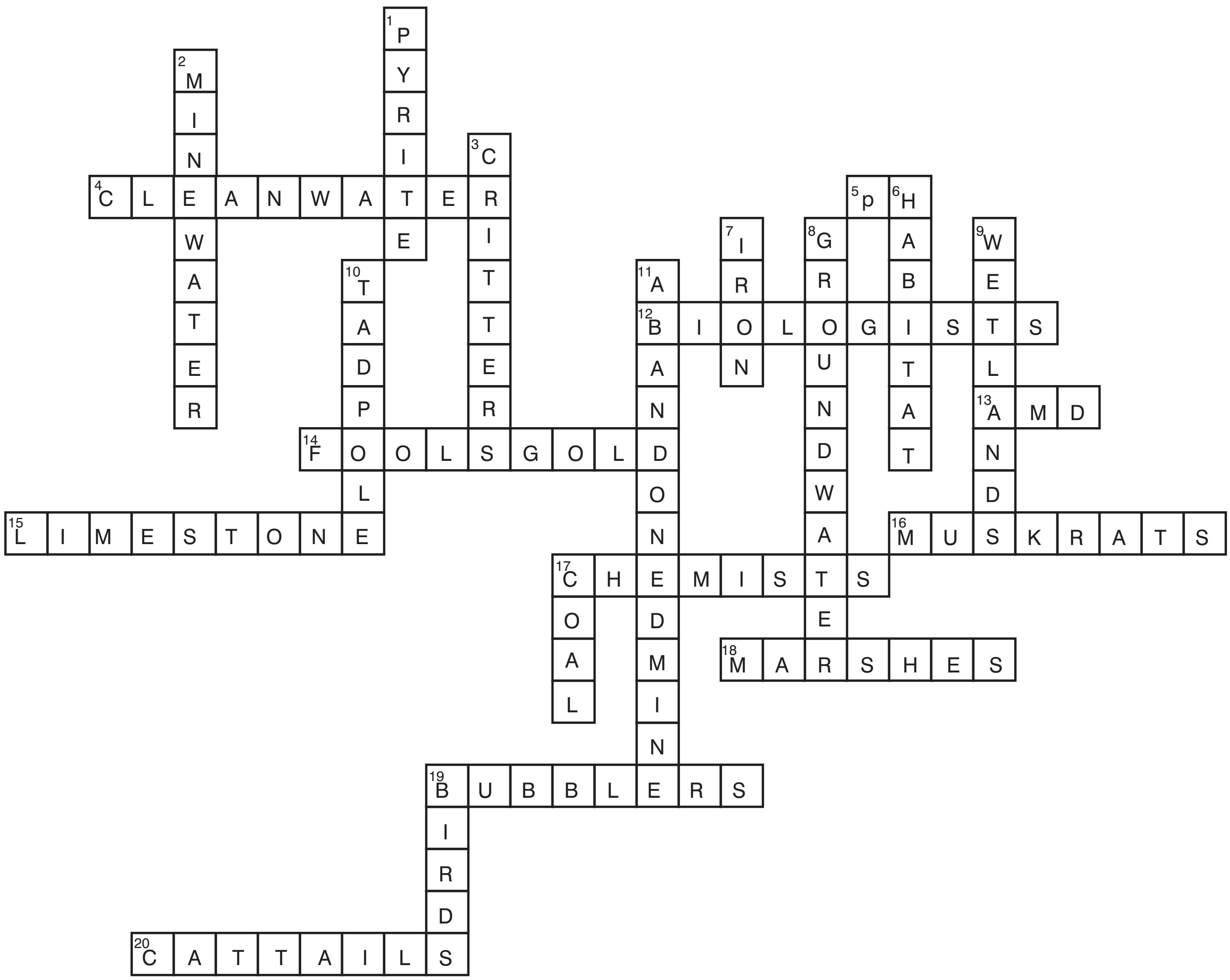
4. ________ leaves a wetland.
5. ________ is a measure of how much acid or base is in a solution.
12. ________ are people who study wildlife.
13. ________ is short for abandoned mine drainage.
14. ________ is pyrite's common name.
15. ________ is used to treat acidic mine water.
16. ________ eat cattail rootstalks.
17. ________ are scientists who study chemistry.
18. ________ are a type of wetland.
19. ________ are man-made boreholes.
20. ________ help filter iron oxide from water.

DOWN

1. ________ dissolves in mine water.
2. ________ reaches the surface.
3. ________ lay eggs in wetlands
6. ________ is the natural home of a plant or animal.
7. ________ oxide is orange particles.
8. ________ is water within the Earth.
9. ________ provide wildlife habitat.
10. A ________ grows into a frog.
11. An ________ is underground and fills with water.
17. ________ is a valuable energy source.
19. ________ nest in wetlands.



TEACHER'S ANSWER SHEET — AMD CRISS CROSS



ACROSS

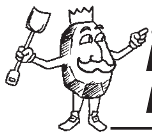
4. **Clean water** leaves a wetland.
5. **pH** is a measure of how much acid or base is in a solution.
12. **Biologists** are people who study wildlife.
13. **AMD** is short for abandoned mine drainage.
14. **Fool's gold** is pyrite's common name.
15. **Limestone** is used to treat acidic mine water.
16. **Muskrats** eat cattail rootstalks.
17. **Chemists** are scientists who study chemistry.
18. **Marshes** are a type of wetland.
19. **Bubblers** are man-made boreholes.
20. **Cattails** help filter iron oxide from water.

DOWN

1. **Pyrite** dissolves in mine water.
2. **Mine water** reaches the surface.
3. **Critters** lay eggs in wetlands
6. **Habitat** is the natural home of a plant or animal.
7 **Iron** oxide is orange particles.
8. **Groundwater** is water within the Earth.
9. **Wetlands** provide wildlife habitat.
10. A **tadpole** grows into a frog.
11. An **abandoned mine** is underground and fills with water.
17. **Coal** is a valuable energy source.
19. **Birds** nest in wetlands.

Where Does the Iron Go?

Adapted from "Water Wonders" in Project Learning Tree Pre K-8 Environmental Education Activity Guide *(Washington, D.C.: American Forest Foundation ©2003).*
Developed by Danielle K. Ross, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
1 hour 30 minutes

Grade Level:
Upper Elementary,
Middle School

Subjects:
Life Science,
Earth Science, Ecology

Duration of Activity:
One or two 50 minute periods

Pennsylvania Standards Addressed:
3.2.4.A4, 3.4.3.A2, 3.4.5.B2, 4.1.4.E, 4.2.4.A, 4.2.7-8.A, 4.2.7-8.B, 4.2.5-6.C, 4.5.4.C, 4.5.8.C, 4.3.4.D, 4.3.7.D

Setting:
Large room or area

Vocabulary:
Bubbler
Iron oxide
Particle
Precipitation
Reaction
Sediment
Watershed
Wetland

Prerequisites:
Knowledge of mine drainage, how its formed and the problems that it causes.

Summary:

Students simulate iron particles from abandoned mine drainage traveling through a watershed, witnessing the various areas impacted by iron oxide. After completing their journey, the students write stories about their travels.

Materials:

- 9 boxes, about 6 inches on a side (Gift boxes used for coffee mugs are a good size)
- A bell, whistle, buzzer, or other noisemaker
- Pictures and labels for each box (attached)
- 9 labeled pictures for each station
- Iron Particles Travel Log

Objectives:

Students will be able to:

- describe the movement of iron from a mine throughout a **watershed**.
- identify the states of iron as it moves through the watershed.
- identify areas that aide in removing iron from abandoned mine drainage.

Background:

Most people think that water coming out of the ground is clean water; this is not always the case. Water that has filled abandoned mines begins to dissolve the minerals still remaining in the mines, such as pyrite, sandstone, shale, and limestone. The pyrite dissolves into iron and sulfate **particles**.

When the water reaches the surface, it contains contaminants that can be devastating to watersheds, e.g. by lowering pH and coating areas with iron hydroxide. Areas with abandoned mine drainage (AMD) commonly have large deposits of orange colored **iron oxide**.

Iron oxide can be devastating to stream and river areas by coating stream bottoms, providing poor habitats for organisms to live. Areas, such as **wetlands** can be used to essentially filter out the iron precipitate in order to keep nearby streams and rivers clean and habitable for wildlife. This activity will explore where iron can travel after it leaves an abandoned mine, and the affects the iron can have on various habitats and organisms.

Procedure:

Warm-up:

Ask the students to identify the main components of mine water, and what occurs to the mine water after it reaches the surface and comes in contact with oxygen. Ask the students to identify various places iron can go after it reaches the surface from a mine.

Activity:

Tell the students that they are going to become iron particles moving through a watershed system.

Categorize the places that the iron can move through into the nine stations: Mine, **Bubbler**, Wetland, Plant, Stream, Rocks, Pond, Soil, and Animals. On larger pieces of paper copy the labeled pictures of each station and put them in locations around the room. Students can also illustrate station labels as an additional warm-up activity.

Assign the students to groups of 2-4 depending on class size, assigning the jobs: dice roller, travel log recorder, travel director, leader, etc.

Have students identify the different places that the iron can travel in the watershed journey. Explain that the iron begins its journey dissolved in mine water before it can reach the surface. Sometimes the iron particles will not go anywhere and become trapped in an area. Be sure that the students understand that after the mine water reaches the surface, the iron precipitates into iron oxide.

Tell the students they will be demonstrating the movement of iron from one location to another in our "watershed." The students will move in their groups as one unit, each student maintaining their assigned jobs through the entire activity.

For this game, rolling the die at each station determines where the iron will go. The groups will all begin their journey by lining up behind the MINE station. Each group will roll the die and go to the location indicated. If a STAY is rolled, the group stays at the station and goes to the end of the line.

When the groups proceed to the next station, they get in line. When they reach the front of the line, they roll the die and proceed to station indicated.

The travel log recorder of each group should keep track of his/her group's movements using the given table.

The beginning and ending of the game is designated by the sound of a bell or buzzer, etc.

Wrap-up/Conclusion:

Have the students use their travel records to individually write a story about the places the iron has traveled. In the story, they should include a description of the conditions necessary for the iron to travel to each location in the watershed, and how the locations depicted would be impacted/affected by the iron, e.g., stream visibility, animal health. The students can be as creative as they wish, making it interesting for others to read about their journey. For example, "I was a lonely invisible iron particle trapped deep in the darkness. One day, I had an incredible ride to the surface where it was bright and sunny, and I met a new friend, named oxygen."

Assessment:

- Have students write a creative story describing their travels (WRAP-UP).

Extensions:

- Another approach to this activity can be dividing the class in half. As half the class plays the game, the onlookers observe and track the movements of the other students. The class will then switch for the next round.
- Have older students teach the activity to younger students, explaining the affect of iron on each location.
- Have the students adapt the game by adding locations, changing the dice, etc.
- Have the students investigate how iron is treated to clean watersheds, i.e., various active and passive treatment systems. The students can further adapt the game by incorporating these locations into the activity.

Adaptations:

For younger students, the table and dice can be adapted to contain only pictures so that students can match and circle pictures for each station. Instead of a written summary, younger students can be given a worksheet that assists them in summarizing their journey and the affects of iron in the watershed.

Older students can assist in the design of the activity by choosing the station locations to include.

Resources:

"Water Wonders." In *Project Learning Tree Pre K-8 Environmental Education Activity Guide.* Washington, D.C.: American Forest Foundation, 2003.

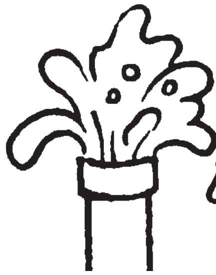
Iron Particle Travel Dice Labels

STATION	DIE SIDE LABELS	EXPLANATION
Mine	Two sides *bubbler*	Iron dissolved in water (mine water) is pushed to the surface by underground pressure.
	One side *stream*	Iron dissolved in water seeps into stream.
	One side *wetland*	Iron dissolved in water flows into nearby wetland.
	Two sides *stay*	Iron dissolved in water remains in the underground abandoned mine.
Bubbler	Two sides *wetland*	Dissolved iron flows into a wetland.
	Two sides *stream*	Dissolved iron flows into a stream.
	One side *pond*	Dissolved iron flows into a pond.
	One side *stay*	Dissolved iron remains near the bubbler.
Wetland	One side *animal*	Precipitated iron particles (orange iron oxide) collect on animal living in the wetland (perhaps a frog or a macroinvertebrate).
	One side *plants*	Iron particles (orange iron oxide) collect and stick to plants, like cattails.
	One side *soil*	Iron particles (orange iron oxide) stick to each other and sink to the bottom forming sediment.
	Three sides *stay*	Iron particles remain within the wetland.
Plants	One side *animal*	Iron particles stick to an animal that touches the plant (perhaps a frog).
	One side *soil*	Iron particles become part of the soil after the plant dies.
	Four sides *stay*	Iron particles (orange iron oxide) stick to each other and collect on the plants (perhaps a cattail).
Stream	One side *animal*	Iron particles collect on animals that live in the stream (perhaps a fish or macroinvertebrate).
	Two sides *rocks*	Iron particles collect on rocks in the stream making the rocks orange.
	One side *pond*	Iron flows into nearby lake.
	Two sides *stay*	Iron particles (orange iron oxide) collect and remain suspended in stream.

Iron Particle Travel Dice Labels

STATION	DIE SIDE LABELS	EXPLANATION
Rocks	Two sides *animal*	Iron particles (orange iron oxide) stick to an animal that rests on the rock.
	One side *soil*	Iron particles settle and fall on soil.
	Three sides *stay*	Iron particles (orange ion oxide) collect and stick to rocks.
Pond	One side *animal*	Iron particles (orange iron oxide) collect and stick on an animal that lives in the pond.
	One side *rocks*	Iron particles (orange iron oxide) collect and stick to rocks in the pond.
	One side *plants*	Iron particles (orange iron oxide) stick to plants that live in the pond.
	One side *stream*	Iron particles flow through the pond and into a nearby stream.
	Two sides *stay*	Iron remains in the pond.
Soil	One side *rocks*	Iron particles (orange iron oxide) in the soil collect on nearby rocks.
	One side *stream*	Iron particles get washed into stream by a rainstorm.
	Two sides *plants*	Iron particles (orange iron oxide) collect on the roots of a plant.
	Two sides *stay*	Iron remains in the soil.
Animal	One side *wetland*	Iron particles (orange iron oxide) wash off into wetland.
	One side *rocks*	Iron particles are deposited on rocks.
	One side *stream*	Iron particles wash off into stream.
	One side *pond*	Iron particles suspend into pond.
	Two sides *stay*	Iron particles (orange iron oxide) remain stuck to animal.

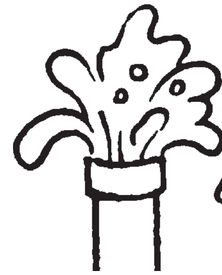
Mine Box



Move to Bubbler

Iron dissolved in water is pushed to the surface by underground pressure.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Bubbler

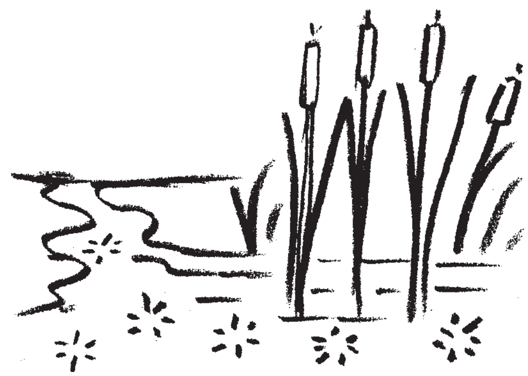
Iron dissolved in water is pushed to the surface by underground pressure.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Stream

Iron dissolved in water seeps into stream.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Wetland

Iron dissolved in water flows into nearby wetland.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Mine

Iron dissolved in water remains in the underground abandoned mine.

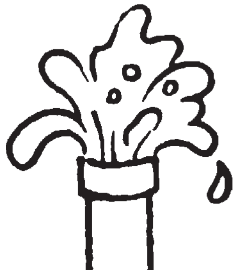
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Mine

Iron dissolved in water remains in the underground abandoned mine.

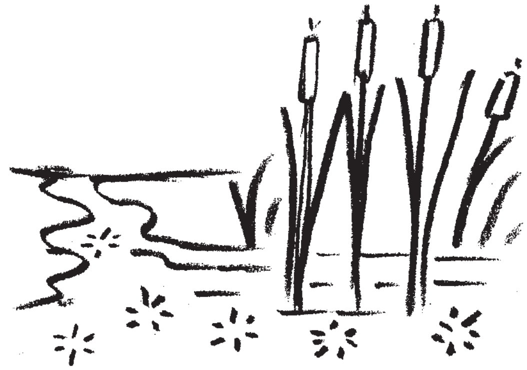
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Bubbler Box



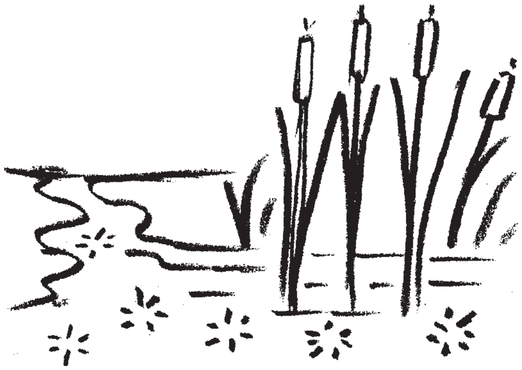
Stay in Bubbler
Dissolved iron remains near the bubbler.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Wetland
Dissolved iron flows into wetland.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Wetland
Dissolved iron flows into wetland.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Stream
Dissolved iron flows into a stream.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

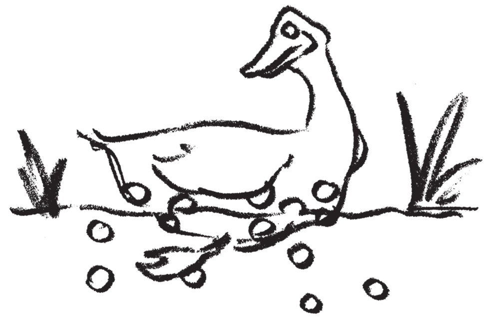
Move to Stream
Dissolved iron flows into a stream.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Pond
Dissolved iron flows into a pond.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

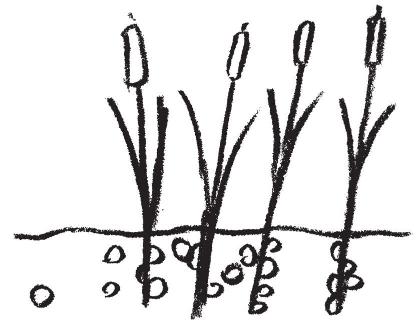
Wetland Box



Move to Animal

Precipitated iron particles (orange iron oxide) collect on an animal living in the wetland.

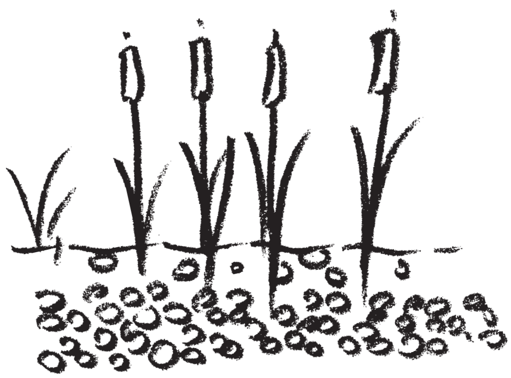
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Plants

Iron particles (orange iron oxide) collect and stick to plants, like cattails.

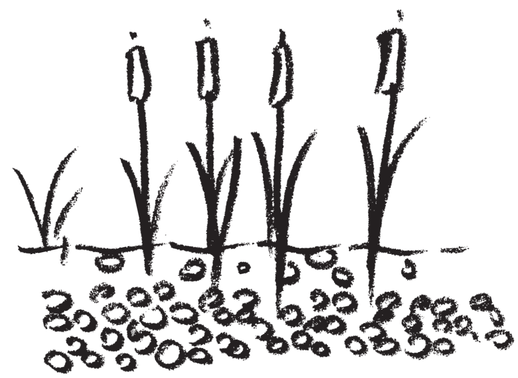
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Wetland

Iron particles remain within the wetland.

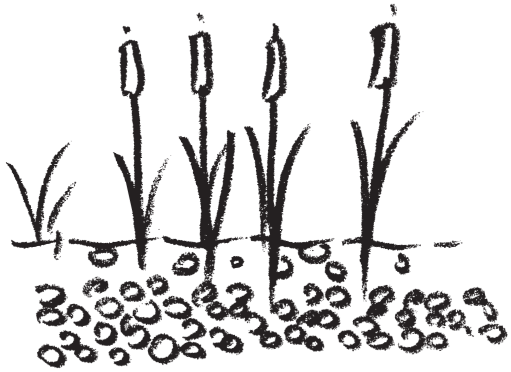
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Wetland

Iron particles remain within the wetland.

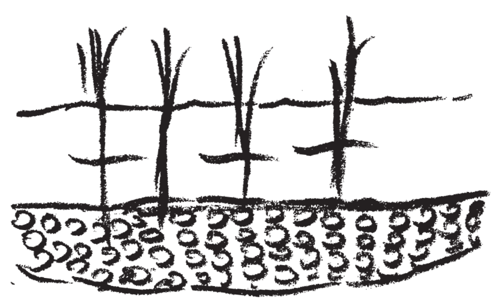
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Wetland

Iron particles remain within the wetland.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

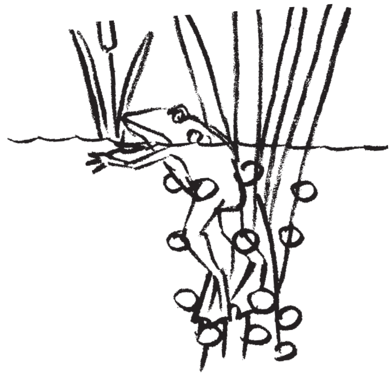


Move to Soil

Iron particles (orange iron oxide) stick to each other and sink to the bottom forming sediment.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

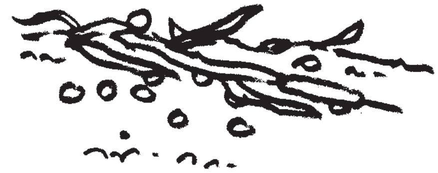
Plant Box



Move to Animal

Iron particles stick to an animal that touches the plant (perhaps a frog).

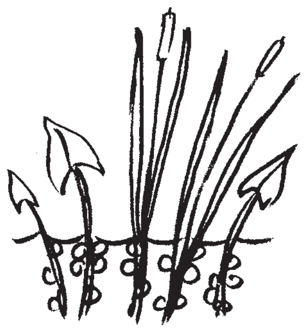
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Soil

Iron particles become part of the soil after the plant dies.

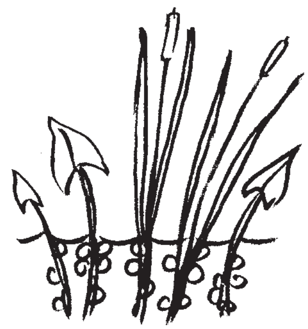
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Plants

Iron particles (orange iron oxide) stick to each other and collect on the plants, including cattails.

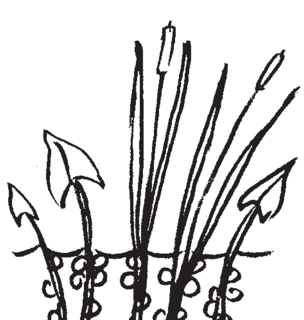
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Plants

Iron particles (orange iron oxide) stick to each other and collect on the plants, including cattails.

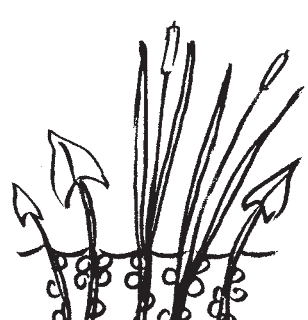
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Plants

Iron particles (orange iron oxide) stick to each other and collect on the plants, including cattails.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

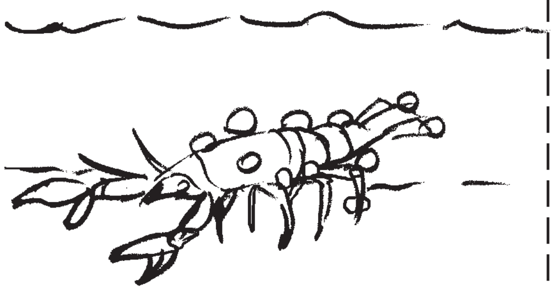


Stay in Plants

Iron particles (orange iron oxide) stick to each other and collect on the plants, including cattails.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stream Box



Move to Animal

Iron particles collect on animals that live in the stream.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Rocks

Iron particles collect on rocks in the stream making the rocks orange.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Rocks

Iron particles collect on rocks in the stream making the rocks orange.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Pond

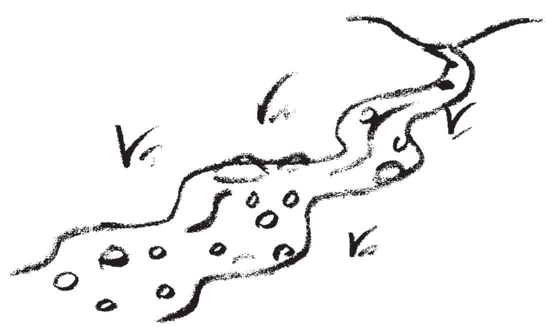
Iron flows into nearby pond.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Stream

Iron particles collect and remain suspended in stream.

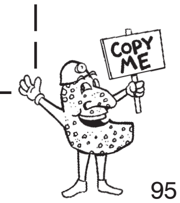
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Stream

Iron particles collect and remain suspended in stream.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Rock Box

Move to Animal

Iron particles (orange iron oxide) stick to an animal that rests on the rock.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Animal

Iron particles (orange iron oxide) stick to an animal that rests on the rock.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Soil

Iron particles settle and fall on soil.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Rocks

Iron particles (orange iron oxide) collect and stick to rocks.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Rocks

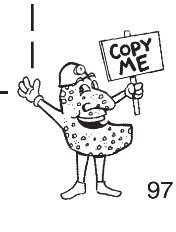
Iron particles (orange iron oxide) collect and stick to rocks.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

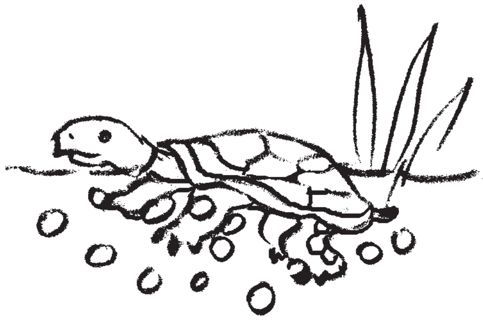
Stay in Rocks

Iron particles (orange iron oxide) collect and stick to rocks.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Pond Box



Move to Animal

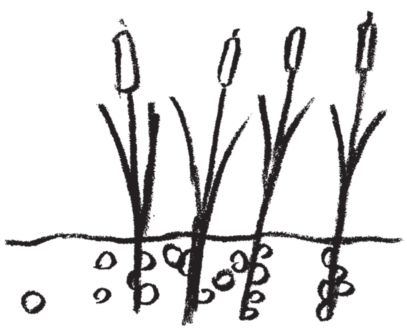
Iron particles (orange iron oxide) stick to an animal that lives in the pond.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Rocks

Iron particles (orange iron oxide) collect and stick to rocks in the pond.

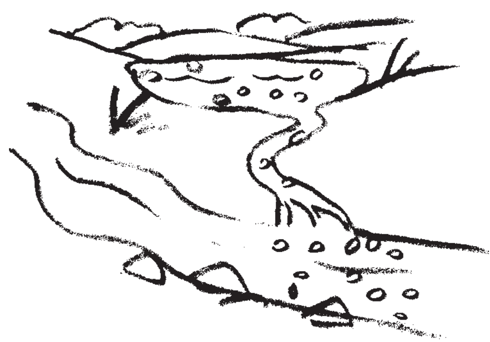
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Plants

Iron particles (orange iron oxide) stick to plants that live in and near the pond.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Stream

Iron particles flow through the pond and into a nearby stream.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Pond

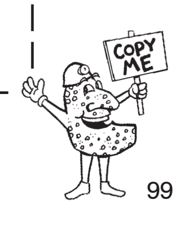
Iron remains in the pond.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

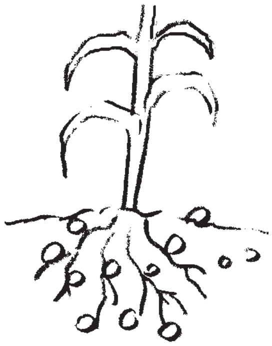
Stay in Pond

Iron remains in the pond.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Soil Box

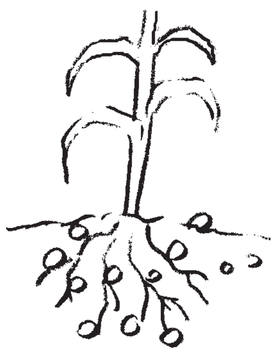


Move to Plants
Iron particles (orange iron oxide) collect on the roots of a plant.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

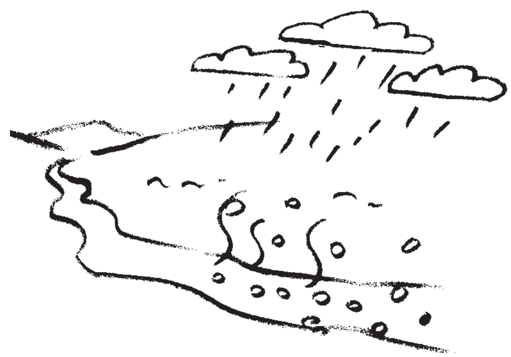
Move to Rocks
Iron particles (orange iron oxide) in the soil collect on nearby rocks.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Plants
Iron particles (orange iron oxide) collect on the roots of a plant.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Stream
Iron particles get washed into stream by rainstorm.

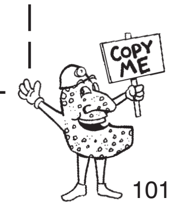
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Soil
Iron remains in the soil.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Stay in Soil
Iron remains in the soil.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Animal Box

Move to Wetland

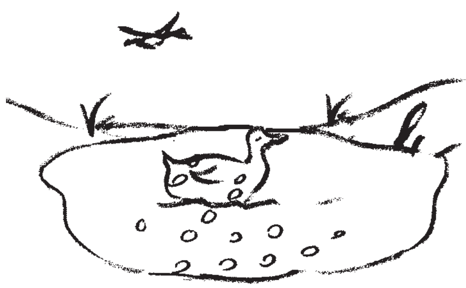
Iron particles (orange iron oxide) wash off animal into wetland.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?

Move to Rocks

Iron particles (orange iron oxide) deposited on rocks.

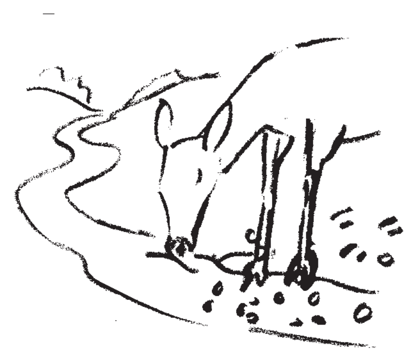
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Pond

Iron particles (orange iron oxide) suspend in pond.

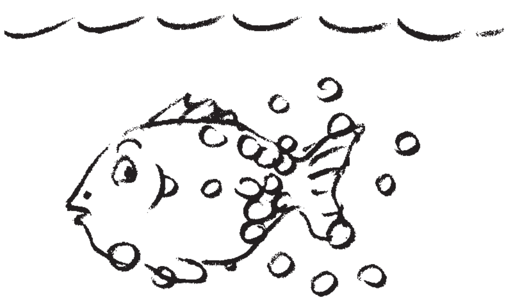
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Move to Stream

Iron particles wash off animal into the stream.

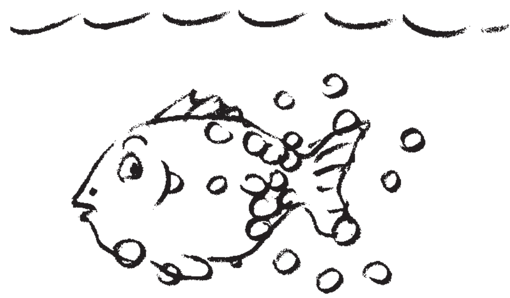
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



Stay in Animal

Iron particles (orange iron oxide) remain stuck to animal.

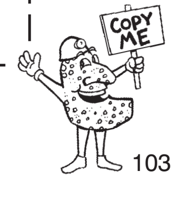
Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



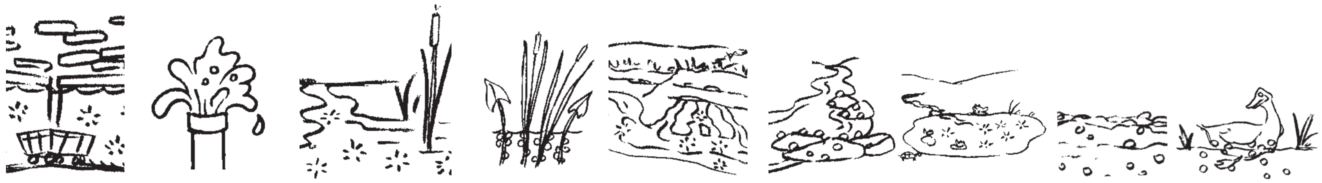
Stay in Animal

Iron particles (orange iron oxide) remain stuck to animal.

Nature Interrupted – The Journey of AMD
WHERE DOES THE IRON GO?



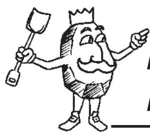
Iron Particle Travel Log



Stop 1:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 2:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 3:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 4:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 5:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 6:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 7:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 8:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 9:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 10:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 11:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 12:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 13:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 14:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 15:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 16:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 17:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**
Stop 18:	**Mine**	**Bubbler**	**Wetland**	**Plants**	**Stream**	**Rocks**	**Pond**	**Soil**	**Animals**

How is Mine Drainage Formed?

Developed by Dr. Caryl Fish, Department of Chemistry, Saint Vincent College, Latrobe, PA



About This Activity...

Prep Time Required:
10 minutes

Grade Level:
Middle School,
High School

Subjects:
Chemistry, Earth Science,
Physical Science

Duration of Activity:
30 minutes

Pennsylvania Standards Addressed:
3.2.8.A2, 3.2.7.A4,
3.2.C.A2, 3.2.C.A4,
3.2.12.A4

Setting:
Classroom

Vocabulary:
Oxidation-Reduction Reaction
Pyrite

Prerequisites:
Knowledge of basic chemistry, science

Summary:
Students read information about AMD and complete worksheets about how mine drainage is formed.

Materials:
- Reading Handout
- Worksheet
- Crossword Puzzle

Objectives:
Students will be able to:
- explain how mine drainage is formed.
- Define chemical terms. (oxidation-reduction reaction, precipitation reaction, acid-base reaction)

Background:
Pyrite or fool's gold is found in most coal mine sites. Abandoned mine drainage (AMD) is formed when groundwater comes in contact with **pyrite** (iron sulfide). The pyrite dissolves into the water and forms iron ions and sulfide ions. The sulfide reacts with oxygen to form sulfate and acid. The iron usually stays dissolved until it reaches the surface. If the pH of the discharge is increased above 3, the oxygen in the air reacts with the iron to form iron hydroxide, an orange gelatinous solid.

These reactions can be used to illustrate a wide variety of chemical reactions. The reaction of iron and sulfide with oxygen is an example of an **oxidation-reduction reaction**. The formation of acid in the reaction could lead to acid-base reactions if it is neutralized by limestone in the soil. The reaction to form iron hydroxide is also a precipitation reaction.

Procedure:
Warm-up:

Show students photographs of mine drainage discharges and ask what they notice about the photographs. Ask the students if they know what the orange color is from.

If you have mine drainage available, hold up a beaker of the fresh drainage. It should be clear. Ask the students if they would drink the water (don't let them). They might be able to smell the rotten egg smell of sulfide in the drainage. Then, slowly add 3% hydrogen peroxide (from the drug store). The iron hydroxide should start to precipitate and turn the solution orange and cloudy. Ask the student where the orange color came from.

Activity:

Have students read the student handout. There are several different parts. You could have each student in a group read a different part and then explain his or her section to the rest of the group. The student should then complete the worksheet and crossword puzzle in groups.

Wrap-up/Conclusion:
Have each group explain to the entire class a step in the formation process.

Assessment:
- Observe students' understanding of the activities as they work together to complete the worksheets and discuss AMD formation.

Extensions:
- Take a field trip to an AMD treatment facility and/or an AMD impacted watershed to see the affects of the pollution on the environment.

Adaptations:
Younger students can just explain steps in the formation process to the class in a general form, and not complete the worksheets.

Mine Drainage Formation Student Reading Handout

Abandoned Mine Drainage

Orange water flows through beautiful valleys. White powder coats the bottom of a clear mountain stream. A huge fountain of smelly water pours out of the edge of a stream. Water that should be full of life is dead. These and thousands of other similar scenes are found all throughout the Appalachian Mountains. What's going on here? … Abandoned Mine Drainage!

Mine drainage is formed in coal mines. Many of these mines were abandoned by the mining companies years before. Water coming out of the coal mines contains metals that leave orange, white, and black solids when they mix with the air. The water can also contain acids (strong chemicals that can burn your skin). Both metals and the acid are harmful to the fish and bugs that live in the streams.

Forming Mine Drainage

Mine drainage is formed first in the coal mines. After all the coal has been removed from the mines, the mining companies remove the last supports that hold up the roof of the mines. Eventually, the mine fills up with water and the roof collapses. In the roof material, there is a mineral called pyrite. Pyrite is also called Fool's Gold because it looks very much like gold. Pyrite though is made of iron and sulfide. The pyrite breaks up into small pieces when the mine caves in. These pieces are surrounded by water. Slowly, the iron and the sulfide dissolve into the water.

The water in the mines is part of the groundwater system. Groundwater is the water that seeps slowly into the ground and fills spaces between pieces of rock and soil. Groundwater moves very slowly from the places it seeps in to places where the groundwater flows out of the ground. You may have seen a flowing spring or a wetland where groundwater flows out of the ground. If groundwater has been in a mine, it is now mine drainage. It has in it particles of iron and sulfide. These particles are so small that you can't see them, so the mine drainage might look clear when it first comes out of the ground. But, often it smells like rotten eggs from the sulfide.

As the water moves through the ground, it can dissolve other metals as it contacts rocks and minerals. The most common metal in rocks is aluminum and mine drainage can dissolve the aluminum. Other metals commonly found in mine water include manganese, calcium, and magnesium.

Once the mine drainage comes up out of the ground, it mixes with oxygen in the air. When that happens, the oxygen reacts with the iron, sulfide, and other metals. When the oxygen reacts with the iron, it forms an orange-yellow solid called iron oxide. The process of forming a solid from a clear solution is called precipitation and the solid is called a precipitate. The orange solid is very sticky and slippery. It coats the bottom of the streams with a sticky, orange mess. The orange precipitate can make the water cloudy and more difficult for the animals to see. It is also slippery, so insects that cling to rocks have a hard time holding on. The orange solid in a stream makes it difficult for plants and animals to survive there.

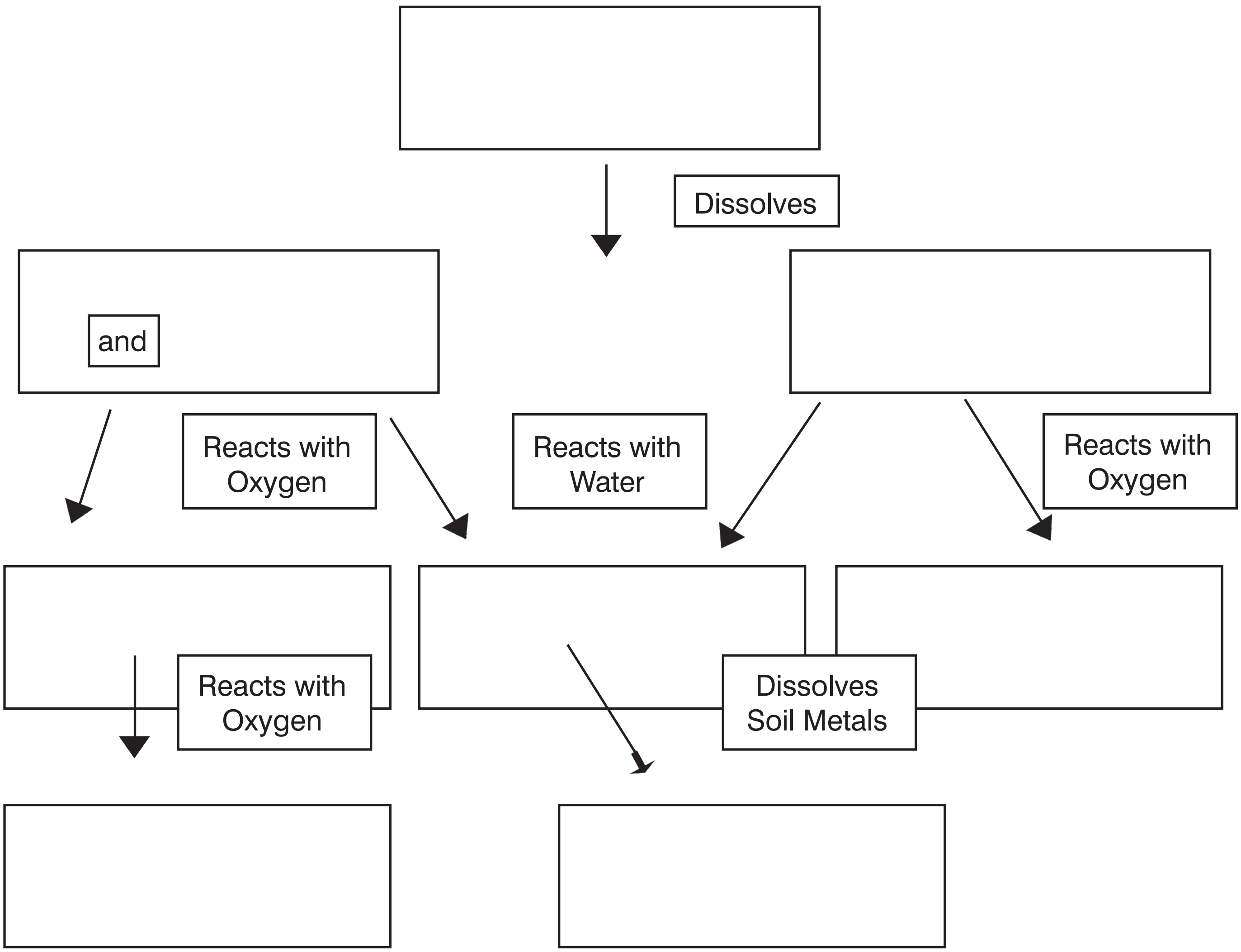
The oxygen also reacts with the sulfide and forms sulfate and acid. This can happen below ground as well if there is a little bit of oxygen still in the mines. The sulfate makes the water taste bad, but the acid makes the water uninhabitable for most plants and animals.

Aluminum is particularly harmful to animals that live in the water. A very tiny amount of aluminum can kill fish and other animals. The aluminum also forms a precipitate when it flows into a stream. This white precipitate can cling to the gills of the water animals and makes it impossible for them to breathe.

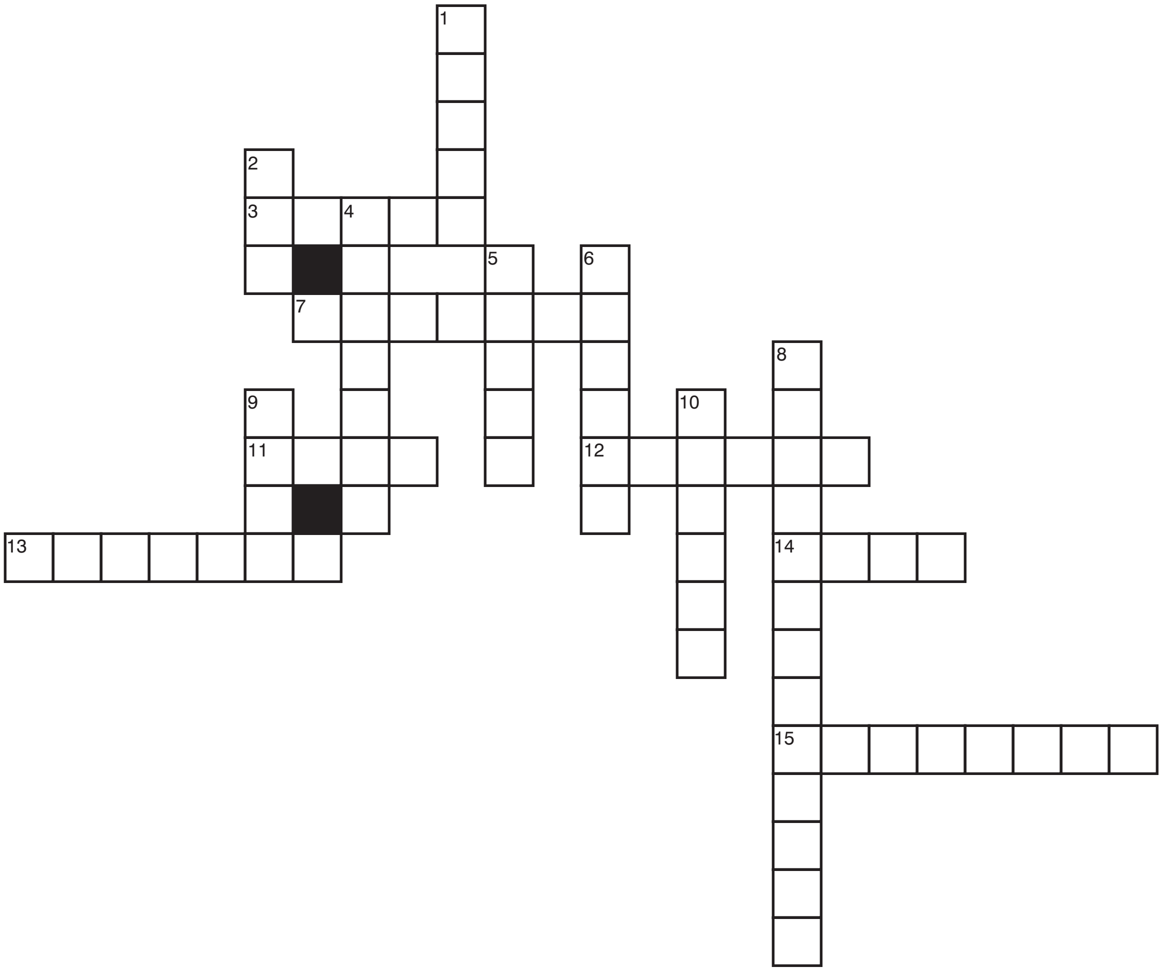
Abandoned mine drainage is a serious problem throughout Appalachia. It has turned beautiful mountain streams into lifeless orange ditches. The mine drainage is formed in the abandoned coal mine from the mineral pyrite. Because it contains high amounts of metals and acid, mine drainage can have serious impacts on stream life. Because of these problems we need to find ways to clean up the mine drainage.

Mine Drainage Formation Student Worksheet

Directions: Use the reading to fill in the blanks in the following diagram.



Mine Drainage Formation

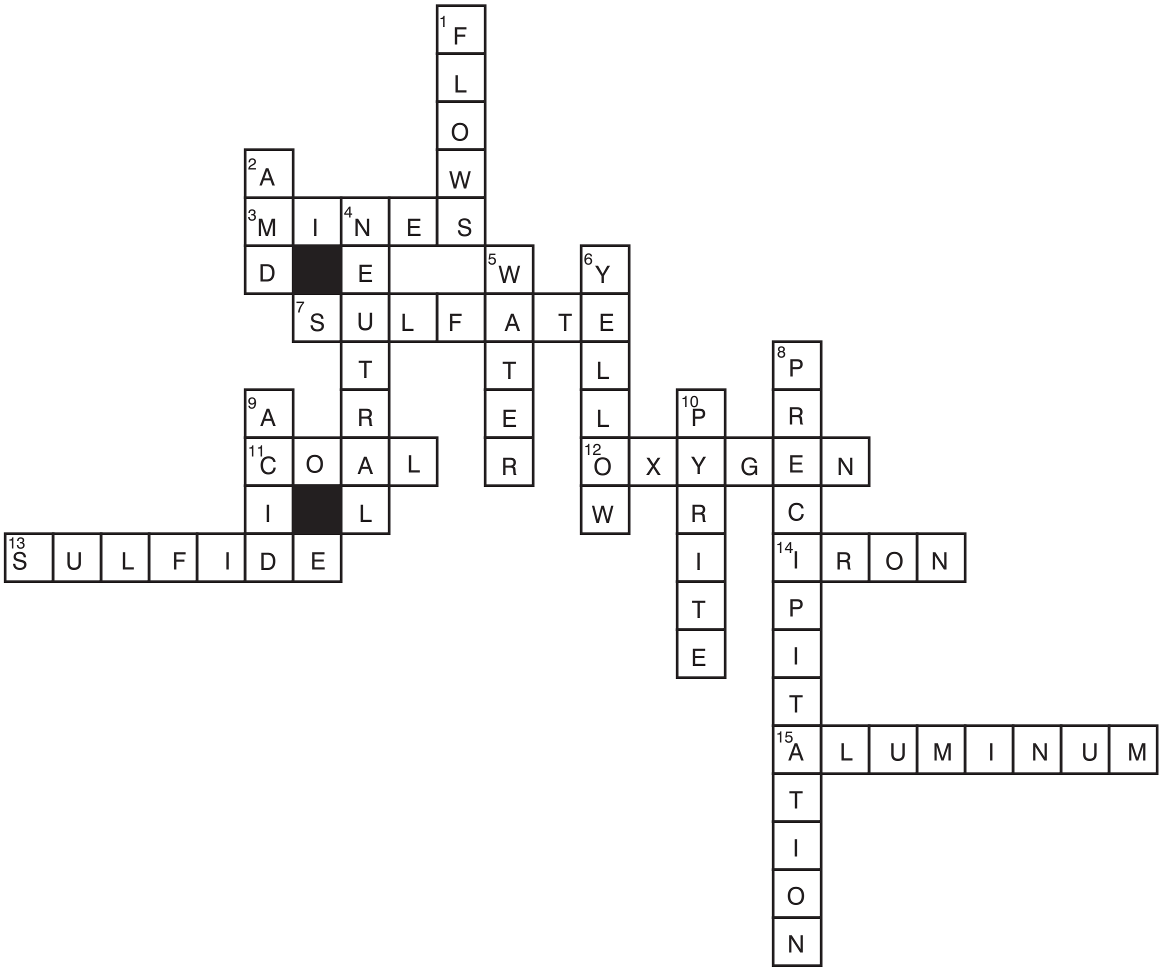


ACROSS

3. Places where coal is extracted
7. The form of sulfur found underground
11. The black rock mined for fuel
12. The part of air that reacts with iron and sulfide
13. The form of sulfur found above ground
14. ______ oxide; the orange solid formed in AMD
15. A metal that dissolves from the soil when water is acidic

DOWN

1. How water moves
2. Abandoned mine drainage, for short
4. When a solution is neither an acid nor a base
5. The liquid that carries iron and sulfide to the surface
6. A local name for the orange solid in AMD ______ boy
8. The chemical process that forms a solid from a clear solution
9. Vinegar or lemon juice, for example
10. Another name for Fool's Gold



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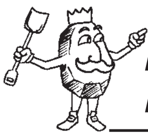
10. Another name for Fool's Gold

Acid-Producing Potential of Pyrite

Developed by Beth Langham, St. Vincent Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
3 hours

Grade Level:
High School

Subjects:
Chemistry, mathematics

Duration of Activity:
3-4 class/lab periods

Pennsylvania Standards Addressed:
3.2.C.A2, 3.2.10.A4, 3.2.C.A4, 3.2.12.A4, 3.4.10.D3, 4.1.12.E, 4.2.10.B, 4.5.10.C, 4.5.10.C, 4.3.10.D

Setting:
Laboratory

Vocabulary:
acid-base accounting
acid producing potential
neutralize
overburden
pyrite

Prerequisites:
Laboratory safety, titrations, unit factoring

Summary:

Coal Mining has left large volumes of mining overburden and waste soils throughout the United States. Many of these tailings are now causing problems with water quality. The EPA and individual states have now taken action to clean up problem areas and to prevent further environmental degradation from proposed mining projects. In order to determine the most effective method to clean up existing sites and as part of the regulatory process for land disposal of mine overburden, testing must be performed to determine the potential acid generating materials in the tailings. A preliminary step is to determine the Acid Producing Potential (APP) of the mine overburden and waste material, or how much acid will be produced from disturbing the minerals, especially pyrite.

Materials:

Special Chemicals and Equipment need per 24 Students

- 1.0 g Pyrite (FeS_2), powder
- 1 L Hydrogen Peroxide, 30% (H_2O_2)
- 1 L 4 M Hydrochloric Acid (HCl)
- 100 mL 1 M Sodium Hydroxide (NaOH)
- 100 mL 0.1 M Sulfuric Acid (H_2SO_4)
- 10 g Calcium Carbonate (CaCO3)
- 2400 mL 0.025 M Sodium Hydroxide (NaOH)
- 1200 mL 0.025 M Hydrochloric Acid (HCl)
- 4 g Unknown Sample (mine overburden sample dried, < 70 mesh, well mixed)
- 2 vials pH Paper
- 4 Centrifuges capable of handling 50 mL centrifuge tubes
- 96 Plastic centrifuge tubes with caps, 50 mL
- 12 pH Meters with magnetic stirrers and stirbars

Note: An artificial sample of mine overburden can be made by mixing 2-4 grams of pyrite and 1-4 grams of calcium carbonate with 100 g of Ottawa Sand. This mixture needs to be ground to a uniform powder.

Objective:

Students will be able to:

- Work in cooperative learning groups to study how Abandoned Mine Drainage (AMD) forms.
- Explore the chemicals that can be used to neutralize acidic mine drainage
- Compete titrations
- Observe chemical reactions and determine the net acid producing potential of Pyrite.

Background:

Mine **overburden** and waste soils (commonly referred to as mine tailings) are the waste products generated during mining and milling operations. Surface deposition of these waste products results in exposure to the atmosphere, precipitation, and ground or surface water. Many of these tailings possess the potential to react with oxygen and water generating products that adversely affect the pH and heavy metal composition of nearby soils and streams. The generation of acidic abandoned mine drainage can also be influenced by the biological activity of microorganisms.

Acid Base Accounting is a static procedure that can be used to predict if a sample mine overburden material will be an acid producer or a **neutralizer**. The **acid producing potential** in a rock is tied directly to the amount of sulfides bound up in the rock in various forms. Sulfides are crystalline substances that contain sulfur combined with a metal or semi-metal, but no oxygen. The most common forms are **Pyrite** and Marcasite (FeS_2). Other forms include $Fe_{1-x}S_x$, Fe_3S_4, FeS, $CuFeS_4$, ZnS, PbS, HgS, and CoAsS. When these sulfide minerals in mine overburden weather upon exposure to water and air, toxic metal ions and hydrogen ions are released into the environment. The sulfide ion is oxidized into soluble sulfate ions. Since pyrite is the most common mineral in mine tailings, iron III ions are released in rather high concentrations. In acidic runoff (<pH 3), the iron ions are soluble. The pH of acidic runoff from mine tailings will usually increase as

a result of dilution from other water sources. This increase in pH causes soluble iron ions to precipitate out of solution in the form of iron III hydroxide, a gelatinous, reddish-orange solid. This precipitate called "yellow boy" coats the bottom of the stream creating an unsightly and unnatural condition in the riparian environment.

The primary requirements for acid generation are:

- sulfide minerals in the overburden
- water or a humid atmosphere
- an oxidant (usually oxygen in the form of O_2)

The primary factors which determine the rate of acid generation are:

- pH
- temperature
- oxygen content of the gas phase, if saturation is less than 100%
- oxygen concentration in the water phase
- degree of saturation with water
- chemical activity of Fe^{3+}
- surface area of exposed metal sulfide
- chemical activation energy required to initiate acid generation
- biological activity (such as iron oxidizing bacteria)

Acid Producing Potential

In nature, exposed sulfide minerals react with oxygen and water to produce acid. A simplified version of this reaction is

$$4\ FeS_{2(s)} + 15\ O_{2(aq)} + 14\ H_2O_{(l)} \rightarrow 4\ Fe(OH)_{3(s)} + 8\ SO4^{2-}_{(aq)} + 16\ H^+_{(aq)} \quad (1)$$

This reaction is too slow to observe in the laboratory. We will use a strong oxidant, hydrogen peroxide, to increase the kinetics of the reaction. The H_2O_2 can be thought of as supplying the O_2 and H_2O in a more reactive form; in fact, the decomposition reaction ($2\ H_2O_2 \rightarrow O_2 + 2H_2O$) does occur naturally. Substituting hydrogen peroxide into the balanced equation gives

$$4\ FeS_{2(s)} + 30\ H_2O_{2(aq)} \rightarrow 4Fe(OH)_{3(s)} + 8\ SO_4^{2-}{}_{(aq)} + 16\ H^+_{(aq)} + 16\ H_2O_{(l)} \quad (2)$$

Mine overburden material may also contain buffering capabilities in the form of calcium carbonates. This would have a function of neutralizing the acid producing potential of the sulfide minerals. A simplified set of chemical equations showing this is

$$CaCO_{3(s)} + 2\ H^+_{(aq)} + SO_4^{2+}{}_{(aq)} \rightarrow CaSO_{2(s)} + H_2CO_{3(aq)} \quad (3)$$

$$H_2CO_{3(aq)} \leftrightarrow H_2O_{(l)} + CO_{2(g)} \quad (4)$$

Acid production and neutralization may be occurring at the same time in the mine tailings. Generally, the rate of acid production exceeds the rate of acid neutralization. A common treatment for acid producing mine overburden is to amend it with lime (calcium carbonate). You will need to know the acid producing potential of the overburden pile so you can determine how much calcium carbonate to add to the tailings pile.

To determine the neutralizing potential of a sample, a known amount of hydrochloric acid is added to the sample and heated. The amount of acid neutralized by any carbonates in the sample is determined by back titration.

As you can imagine, there is a complex set of chemical and biological reactions and conditions that occur over time in mine overburden which determine its potential pollution generating capabilities. In this laboratory experiment, we will look only at the net acid producing potential of mine overburden samples and quantify it in terms of moles of H^+ produced per 100 g of sample. In order to obtain the net acid producing potential of a sample we must determine the acid producing potential of the sample and the neutralizing potential of the sample and subtract these two values.

Safety Considerations

- Wear eye goggles at all times.
- Hydrogen peroxide (30%) is a very strong oxidant. Wear protective gloves and eye goggles when handling this solution.
- Hydrochloric acid and sodium hydroxide are very caustic. Use caution and wash any spills on your skin with plenty of water.

Waste Disposal Procedures

- Solutions containing tailings samples, pyrite or any heavy metals should be disposed of the waste container designated for this lab.
- Only neutralized wash solutions not containing heavy metals can be disposed of down the sink.

Procedure:

Warm-up:

Students should read the lab and prepare a flowchart for completion of the lab.

Activity:

Students will experiment with Pyrite, the main component of the Mine Drainage found in the streams in Pennsylvania. Pyrite or iron sulfide will dissolve in water forming iron hydroxide and sulfuric acid.

Using crushed pyrite, the students will determine the net acid producing potential of a mine overburden sample and express the results in moles H^+/100 g of sample. In actual practice, the net acid producing potential of mine overburden is expressed as tons of $CaCO_3$ required to neutralize 1000 tons of material with the intention that the mine overburden would be amended with $CaCO_3$ to a depth of 1 foot.

For more information, pictures and other experiments related to acid mine drainage, please visit The Colorado School of Mines website at http://www.mines.edu/fs_home/jhoran/ch126/index.htm.

TO BE COMPLETED PRIOR TO THIS LAB: Unit factoring & Titrations & Acid/Bases!!!

If time is limited, one group can complete the Acid producing potential and one group can complete the Neutralizing Potential, then share the data.

Wrap-up/Conclusion:

Students should complete a written report or memo to a company describing the results that were found.

Assessment:

- Visual evaluation of student laboratory practices including safety and lab skills.
- Assessment of the report or memo describing the results.

Extensions:

- Possible field trip to an actual DEP or associated laboratory that would conduct testing for acid producing potential or other chemical tests.

Resources:

Jim Horan, Colorado School of Mines

Helpful Comments:

Part 1 - Familiarization Exercise-Neutralizing Potential

- If students have a hard time writing the reaction for the neutralization of sulfuric acid with calcium carbonate, first have them identify the reactants as sulfuric acid and calcium carbonate. They should also be able to identify the gas evolved as carbon dioxide based on the fact that it puts a match out. The only other possible gases evolved in this reaction could be hydrogen or oxygen. Hydrogen would "pop" in the presence of a flame and oxygen would cause the flame to burn brighter. If they are having trouble determining the other products, inform them that the carbon dioxide and another product came from the decomposition of the carbonic acid (H_2CO_3), an unstable product of the reaction. What could that product be? The white precipitate in an insoluble salt formed by this reaction.

$$CaCO_{3(s)} + 2H^+_{(aq)} + SO_4{}^{2-}{}_{(aq)} \rightarrow CaSO_{4(s)} + H_2CO_{3(aq)}$$

$$H_2CO_{3(aq)} \rightleftarrows H_2O_{(l)} + CO_{2(g)}$$

- Remind students that these reactions are an oversimplification of what really happens in the tailings pile. Yet, these simple reactions are sufficient to determine the acid producing and acid neutralizing potential of a natural sample with some degree of accuracy.

- The acid producing potential of pure pyrite is determined in order to compare this value to the theoretical value obtained from the chemical equation. If exactly 0.0150 grams of pyrite are treated with hydrogen peroxide, the theoretical APP can be determined with a little stoichiometry:

$$0.0150 \text{ g } FeS_2 \times \frac{1 \text{ mole } FeS_2}{119.975 \text{ g } FeS_2} \times \frac{4 \text{ moles } H^+}{1 \text{ mole } FeS_2} = 5.0 \times 10^{-4} \text{ moles } H^+$$

- Titrations involving iron are some what troublesome. Generally, the actual acid producing potential of pyrite will be slightly lower than the theoretical value (sometimes 10-15% lower).

- The acid neutralizing potential of calcium carbonate is determined in order to compare this value to the theoretical value obtained from the chemical equation. If exactly 0.0150 grams of calcium carbonate are treated with hydrochloric acid, the theoretical ANP can be determined with a little stoichiometry:

$$0.0150 \text{ g } CaCO_3 \times \frac{1 \text{ mole } CaCO_3}{100.09 \text{ g } CaCO_3} \times \frac{2 \text{ moles } H^+}{1 \text{ mole } CaCO_3} = 3.0 \times 10^{-4} \text{ moles } H^+$$

Part II

- Hydrochloric acid is added to the sample to remove any substances in the sample that will interfere with the ability of sulfide minerals to produce acid. For example, any carbonates must be removed from the sample because they will neutralize some of the acid produced by the oxidation of sulfide minerals. The excess hydrochloric acid must be thoroughly washed off before oxidizing the sulfide minerals.

- An adaptation for advanced students is to use a pH meter for the titrations. If students have never done a titration with a pH meter before, inform them that we will titrate the solution to and endpoint of pH 7 or the inflection point. Have the students discuss what they know about a titration curve. Diagrams of titration curves and discussion about the essential features of a titration curve should increase understanding and provide hints about the correct procedures and techniques to utilize. Data collection should involve recording at least 10-15 measurements so that a complete curve can be derived from the pH and volume measurements. Be sure to remind students to titrate the sample well past pH 7 to obtain a complete titration curve.

- A standard deviation of 10% is acceptable in this titration. We are dealing with a natural sample and titrations involving iron solutions are troublesome.

Part III

- If the paste test is below pH 3, there is no reason to perform a titration. We can say with confidence that the acid neutralizing potential of the sample is zero. If it is slightly above 3, it may or may not have any neutralizing capacity. A titration should be performed to determine the neutralizing potential, if any.

- Discuss the concept of a back titration if students do not understand the procedure. Ask students how they will use their results to obtain the neutralizing capacity of the sample.

- Once again, a standard deviation of 10% is acceptable since we are working with a natural sample.

Summary

- To determine the net acid producing potential, students should subtract the neutralizing potential from the acid producing potential. Students should express their results in meq H^+/100 g sample. If students also want to express their results as tons of $CaCO_3$/1000 tons of sample, they should use direct stoichiometric relationships based on the reaction of hydrogen ions neutralized by calcium carbonate.

  For more information, pictures and other experiments related to acid mine drainage, please visit Jim Horan's website at http://www.mines.edu/fs_home/jhoran/ch126/index.htm

Acid Producing Potential

Part I - Familiarization Exercise

In this part, you will observe the chemical weathering of pyrite and determine the Acid Producing Potential of Pure Pyrite.

1. Test the pH of a drop of H_2O_2 using pH paper. Place a small amount (about 0.01g) of pyrite (FeS_2) in a small test tube. Add 15 drops of 30% hydrogen peroxide (H_2O_2). When vigorous bubbling occurs (about 3-5 min.), test the gas evolved with a burning and then with a glowing wood splint. Observe the reaction for about 5 minutes or until the bubbling stops. Test the solution again with pH paper. Then add 5 drops of 1 M NaOH solution. Record your observations. Briefly explain your observations in terms of the appropriate chemical equations:
   A. What is the decomposition reaction for hydrogen per oxide?
   B. What happens to pyrite when mixed with water and exposed to oxygen?

pH of H_2O_2 ______________________

glowing splint __________ burning splint __________

Gas evolved __________ pH after 5 minutes __________

Observations ______________________________

____

____

CHEMICAL REACTIONS:

A.

B. $\_\_ FeS_2 + \_\_ O_2 + \_\_ H_2O \rightarrow \_\_ Fe(OH)_3 + \_\_ SO_4^{2-} + \_\_ H^+$

2. Accurately weigh 0.015g of pyrite (FeS_2, powder). Record your mass to the nearest 0.0001 g. Transfer the sample to a 50 mL centrifuge tube. Add 5 mL of 30% H_2O_2 to the pyrite. Keep the cap off the tube and support the tube in a beaker. The reaction may go on for 15-30 minutes, getting very active and hot in the middle. During the quieter reaction times, mix the solid into the solution gently.

Mass of Pyrite ____________

Observations ______________________________

____

____

____

3. After the reaction stops, add 3 mL more of 30 % H_2O_2 and allow this to react completely. Then heat in a water bath at 80-90°C for a few minutes to decompose any excess peroxide.

Initial Volume of NaOH in Buret ________________

Volume of NaOH Used to reach pH = 7.0 __________

If using the Bromothymol Blue Indicator, the color will turn blue/green at pH 7.0.

4. Transfer the contents of the centrifuge tube to a 250 mL beaker and bring the volume up to about 100 mL with D.I. water. Add 10 drops of bromothymol blue indicator and titrate the sample with a standardized 0.025 M NaOH solution, swirling after each addition until pH equilibrates. Determine the volume of NaOH required to reach the end point of pH=7.0.

Observations ______________________________

____

____

____

5. Using the balanced equation, determine the acid producing potential of pure pyrite and compare this to the theoretical value obtained by a chemical equation of the reaction between pyrite and hydrogen peroxide.

Answer should be in Moles H^+ / 100 g of FeS_2

HINT:

Mass of Sample: ______________

Concentration of NaOH: __________

Actual Volume of NaOH needed to Titrate to a pH 7: _______

Theoretical

Actual

Percent Error = (Actual - Experimental) / Experimental x 100

Acid Producing Potential

Part II - Acid Producing Potential of Mine Overburden

In this part you will examine an unknown mine overburden sample to determine the Acid Producing Potential.

1. Accurately weigh a sample of your unknown. The sample should weigh close to 0.5 to 0.7 g. Record your mass to 0.0001g. Transfer to a 50 mL centrifuge tube.

   Mass of sample ____________

---

2. Add 10 mL of 4 M HCl to the centrifuge tube. Cap, Shake, let stand for 30 minutes until the reaction is complete. Shake again.

   Observations ____
   ____
   ____

---

3. Centrifuge, then decant acid into a waste container.

---

4. Add 40 mL of D.I. H_2O, shake, let the tube set for a couple minutes, and decant into a waste container. Repeat this procedure at least 3 more times or until the pH reaches at least 4.5.

---

5. After washing, add 5 mL of 30% H_2O_2 to the overburden sample. Keep the cap off the tube and support the tube in a beaker. The reaction may go on for 15-30 minutes, getting very active and hot in the middle. During the quieter reaction times, mix the solid into the solution gently.

---

6. After the reaction stops, add 3 mL more of 30 % H_2O_2 and allow this to react completely. Then heat in a water bath at 80-90°C for a few minutes to decompose any excess peroxide.

---

7. Transfer the contents of the centrifuge tube to a 250 mL beaker and bring the volume up to about 100 mL with D.I. water. Add 10 drops of bromothymol blue and titrate the sample with a standardized 0.025 M NaOH solution, swirling after each addition until the pH equilibrates. Determine the volume of NaOH required to reach the end point of pH=7.0.

   Initial Volume of NaOH in Buret ____________
   Volume of NaOH Used to reach pH = 7.0 ____________
   If using the Bromothymol Blue Indicator, the color will turn blue/green at pH 7.0.

---

8. Determine the acid producing potential of your unknown and report the findings.

   Answer should be in Moles H+ / 100 g of Sample

Neutralizing Potential

Part I - Familiarization Exercise

In this part, you will observe the neutralization of sulfuric acid with calcium carbonate and determine the acid neutralizing potential of calcium carbonate

1. Add 15 drops of 0.1 M sulfuric acid (H_2SO_4) to a second test tube. Use pH paper to determine the pH. Now add a tiny amount of calcium carbonate ($CaCO_3$). Test the gas produced in this reaction using a burning and then a glowing wood splint. Keep adding small amounts of $CaCO_3$ until the bubbling stops. Determine the pH after the reaction. Explain your observations using a chemical equation.

   A. What happens to $CaCO_3$ when mixed with H_2SO_4?

pH of H_2SO_4 ______________________________

glowing splint ____________ burning splint ____________

Gas evolved ____________

pH after reaction ____________

Observations ____

____

A. Reaction:

---

2. Accurately weigh 0.015 g of calcium carbonate. Transfer your sample to a 250 mL beaker. Pipet 5.00 mL of a standardized 0.1 M HCl solution. Allow the reaction to go for about 20 minutes, mixing occasionally. Bring the volume to about 100 mL in your beaker by adding D.I. water. Heat this solution to boiling to drive off CO_2. Let cool. Add 10 drop of bromothymol blue and titrate the sample with a standardized 0.025 M NaOH solution, swirling after each addition until pH equilibrates. Determine the volume of NaOH required to reach the end point of pH=7.0.

Mass of Sample _______________

Volume of 0.02M NaOH Needed to bring pH to 7.0 _________

If using the Bromothymol Blue Indicator, the color will turn blue/green at pH 7.0.

---

3. Determine the acid neutralizing potential of the calcium carbonate and compare it to the theoretical value obtained by a chemical equation of the reaction between calcium carbonate and hydrochloric acid

   Answer should be in Moles H^+ / 100 g of $CaCO_3$

HINT:
Mass of Sample: ___________________

Concentration of NaOH: _____________

Actual Volume of NaOH needed to Titrate to a pH 7: ________

Theoretical

Actual

Percent Error = (Actual - Experimental) / Experimental x 100

Neutralizing Potential

Part II - Neutralizing Potential of Mine Overburden

In this part you will examine an unknown mine overburden sample to determine the Acid Producing Potential.

1. A paste test is a quick way to determine if your sample does not have any neutralizing potential. Add about 0.25 g of sample to a watch glass. Add a drop or two of D.I. H_2O until a thick paste is formed. Now dip a piece of pH paper in the paste and let it set there for a few minutes. If the pH of the paste test is below 3.5, then the acid neutralizing potential of the sample is zero. If the pH test is above 3.5, the sample may contain carbonates or other buffers that will contribute to the neutralizing potential of the sample. If so, determine the neutralizing potential in according to the procedure in step 2.

   pH of paste ______________

---

2. Accurately weigh a sample of your unknown. The sample should weigh between 0.25 and 0.35g. Record the mass to 0.0001g. Transfer your sample to a 250 mL beaker. Pipet 5.00 mL of a standardized 0.1 M HCl solution. Allow the reaction to go for about 20 minutes, mixing occasionally. Bring the volume to about 100 mL in your beaker by adding D.I. water. Heat this solution to boiling to drive off CO_2. Let cool. Add 10 drops of bromothymol blue and titrate the sample with a standardized 0.025 M NaOH solution, swirling after each addition until pH equilibrates. Determine the volume of NaOH required to reach the end point of pH=7.0.

   Mass of Sample ______________

   Volume of 0.02M NaOH Needed to bring pH to 7.0 ______________

   If using the Bromothymol Blue Indicator, the color will turn blue/green at pH 7.0.

---

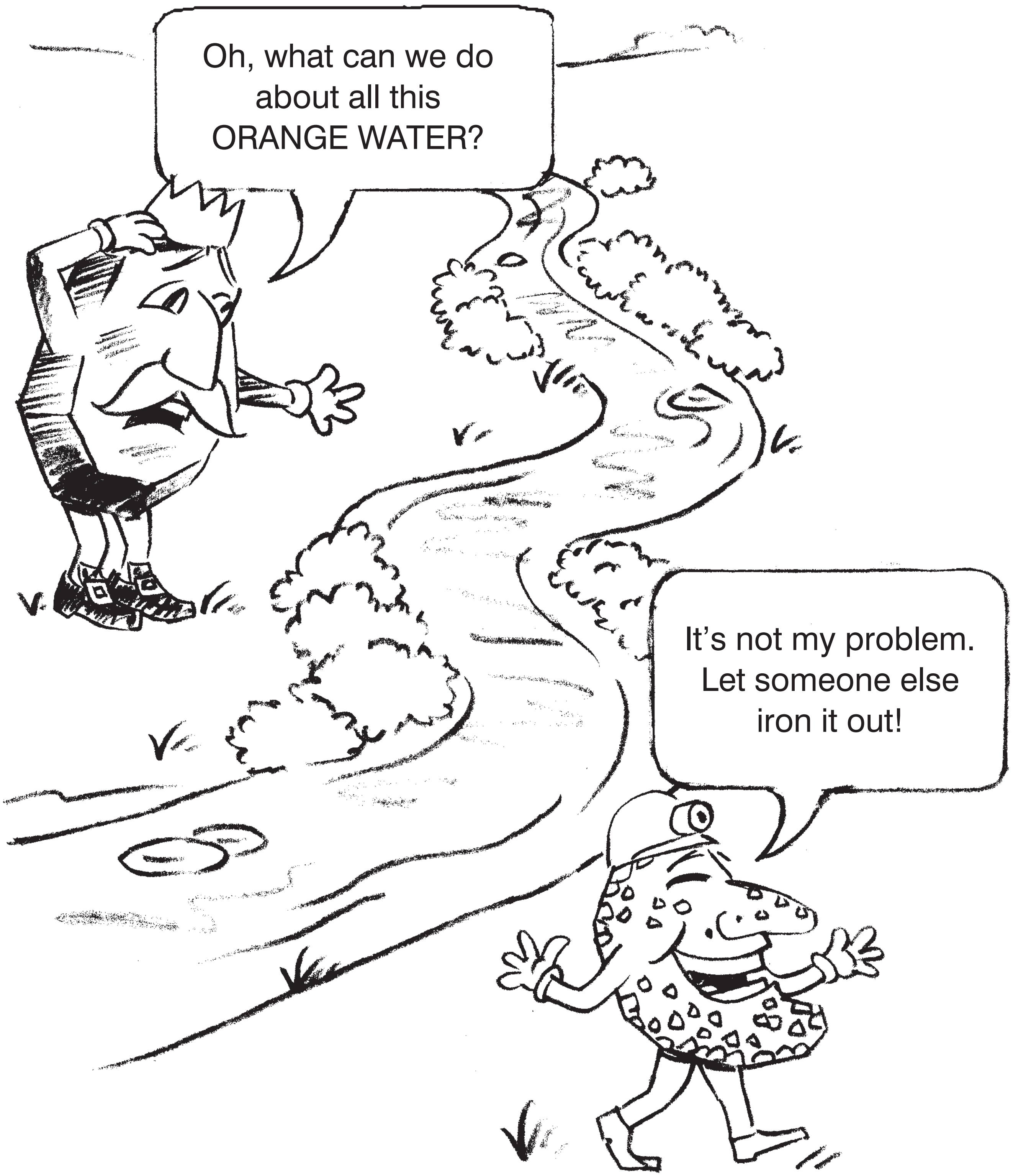
3. Determine the acid neutralizing potential of your unknown and report the findings.

   Answer should be in Moles H^+ / 100 g of Sample

Summary

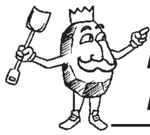
Determine the net acid producing potential of your mine overburden sample. Express the results in moles H^+/100 g of sample. In actual practice, the net acid producing potential of mine overburden is expressed as tons of $CaCO_3$ required to neutralize 1000 tons of material with the intention that the mine overburden would be amended with $CaCO_3$ to a depth of 1 foot. Can you figure out how to report your results in terms of tons of $CaCO_3$ /1000 tons of sample?

Finding Troubled Waters



Let's Build a Watershed

Adapted from National 4-H Sportfishing Program
Developed by Jennifer Bennett, Western Pennsylvania Conservancy, Blairsville, PA



About This Activity...

Prep Time Required:
10 minutes

Grade Level:
Upper Elementary,
Middle School

Subjects:
Biology, Ecology, Science

Duration of Activity:
10-30 minutes

Pennsylvania Standards Addressed:
4.1.4.A, 4.2.4.A, 4.2.7-8.A, 4.2.5-6.C, 4.5.4.C

Setting:
Classroom or outside

Vocabulary:
Drainage Basin
Storm Sewer
Watershed

Prerequisites:
Knowledge of Water Cycle

Summary:

Students build a model **watershed** to examine how land use can influence aquatic habitats. They use food coloring in the watershed to determine how landscape influences water flow.

Materials:

- Newspaper
- Plastic tarp or garbage bag
- Spray water bottles
- Water
- Food dye or Kool-Aid
- Gumballs

Objectives:

Students will be able to:

- build a model watershed.
- describe a **drainage basin**.
- describe factors about the landscape which influence the path water takes.
- describe how land use can influence aquatic habitats.
- explain the meaning of the phrase "we all live downstream."

Background:

Precipitation that falls on land either soaks into the ground or runs off into nearby streams. Streams usually follow well-defined paths or channels. The channels then converge into a river. These small streams, channels, and rivers drain a particular well-defined land area. This area is commonly referred to as a watershed.

A watershed is the land area drained by these particular bodies of water. Elevated lands, primarily hills and mountains, define the land area of a watershed. Elevated lands separate one watershed from one another by causing precipitation run-off to flow in different directions (down one side or another).

All watersheds eventually empty their waters into larger bodies of water, such as the Mississippi River or the Chesapeake Bay. These larger bodies of water then transport their waters to the seas and oceans. Watersheds can be enormous or quite small. Large, well-established watersheds supporting major rivers are known as drainage basins.

Understanding what a watershed is and how it functions helps students to comprehend connectedness. Some of the precipitation that falls in your backyard runs off to ditches, **storm sewers** and creeks. Eventually, it flows into streams, lakes or rivers. The water is then used by others for drinking, swimming, fishing, and other activities. Wildlife is dependent upon these waters, too.

Procedure:

Warm-up:

Ask the students if they know of any nearby lakes, streams, and rivers. List the names on the board.

Tell the students that these bodies of water are all parts of watersheds. Ask the students for definitions of a watershed.

Ask the students if they can think of any ways people use land, such as farming, parking lots, etc. that would influence nearby waterways.

Inform the students that they will be making a watershed model to examine how water flows through the landscape, and how people's actions influence water flow.

Activity:

Crumple newspaper sheets and form a pile. Use at least six sheets; use more to make a larger watershed. Cover newspaper pile with plastic tarp or garbage bag. This is the watershed.

Students with spray bottles will simulate precipitation over the watershed by spraying the plastic.

Students should observe and describe how water gathers and flows, due to gravity to lower end of watershed, especially the paths run-off takes (simulated streams and rivers). If necessary show how small streams gather and collect other streams and how these larger streams gather others forming rivers.

Ask students to analyze what they observed and relate that to places in their area where they drink, swim, and/or fish. Then ask what things in the model influence the path water takes as it moves through it. They should identify factors like climate, slope of land, composition of the ground, amount of rain, etc.

Human disturbances, such as pollution or erosion, can be simulated with food dye or kool-aid. Ask the students to observe what happens to water downstream of this spill. Ask the students to describe what they observed and how human activity in the watershed can affect downstream habitats. Ask students to describe activities in their own watersheds that might impact the water where they swim and/or fish.

Wrap-up/Conclusion:

Have students list things that influence the path that water takes. Have students illustrate how human activities positively and negatively affect the watershed.

Assessment:

- Have students take a quiz or write an essay on what they have learned.

Extensions:

- Draw maps of watersheds, build a more detailed watershed or take a walk along a stream.

Adaptations:

For younger students, create a living watershed by using students as the mountains. Have half of the class sit in a group on the floor. Place a large tarp on top of students, creating the hills and valleys of the watershed. Have the other half of class drop gumballs (or something similar) onto the tarp and explain the movement of the gumballs.

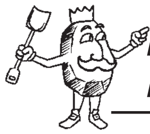
For older students, have them build their own watersheds in a plastic tray using modeling clay, or whatever materials they choose.

Resources:

"Build a Watershed: Just Add Water." from
http://www.4hfishing.org/resources/aquatic_ecology_pdfs/6a_build_a_watershed.pdf

Macro Rummy

Developed by Laura Riddle, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
1 hour 30 minutes

Grade Level:
Middle School,
High School

Subjects:
Biology, Ecology, Math, Science

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
3.1.7.A1, 3.1.12.A, 3.1.12.A2, 4.1.12.C, 4.5.10.D

Setting:
Classroom

Vocabulary:
Biomonitoring
Collector
Ecosystem
Macroinvertebrate
Predator
Parasite
Scraper
Shredder
Sensitive
Taxonomy

Prerequisites:
Knowledge of biodiversity, habitat, insects.
Review macroinvertebrate sensitivity chart.

Summary:

Students become familiar with various macroinvertebrates, biodiversity, and functional feeding groups by playing a game of rummy with macroinvertebrate playing cards.

Materials:

- Deck of macroinvertebrate cards, attached (need to photocopy and assemble them) 1 copy/set per group

Objectives:

Students will be able to:

- understand macroinvertebrate identification, functional feeding groups, and pollution sensitivity.

Background:

Macroinvertebrates are insects very low in the food chain of an aquatic **ecosystem**. They eat algae, bacteria, fungi, organic materials, and other insects. In turn, fish, birds, and other larger aquatic organisms eat the macroinvertebrates. Macroinvertebrates also function to recycle nutrients and organic matter. Their pollution sensitivity and overall diversity aids in determining the quality of a stream. These insects are classified according to their sensitivity to pollution; thus, the more pollution **sensitive** species present in a stream, the better the quality of water. In addition, stream diversity is also important because a greater number of species can also indicate better water quality.

Biomonitoring is the study of macroinvertebrates to assess the health of a stream. In order for macroinvertebrates to be used in biomonitoring, professionals, students, etc. must identify and classify the organisms. Macroinvertebrates can be classified in many different ways. One such way is through **taxonomy**, a system of classification based on evolution, which has categories within categories. The specific taxa, from most to least inclusive are: Kingdom, Phylum, Class, Subclass, Order, Family, Genus, and Species. Normally, it is sufficient to classify only down to the Order to determine the health of the stream, but more intensive studies classify macroinvertebrates down to the Species. To classify, scientists use the scientific names of the macroinvertebrates, but most laypersons are more familiar with their common names, for example insects from the Order Plecoptera are commonly known as stoneflies.

Another classification system of macroinvertebrates is based on their pollution tolerance. Some aquatic insects are very sensitive to pollution, changes in their habitat, and natural disturbances; others can withstand a certain amount of pollution or disturbance. Some insects even thrive in polluted or otherwise low quality water. Different rating number systems have been invented, assigning numbers to macroinvertebrates based on their pollution sensitivity. In order for scientists to give streams a water quality rating, a sample of macroinvertebrates is collected using standardized methods. The insects are then identified and scored. Finally, a calculation is performed taking into account the pollution rating of each macroinvertebrate, the number of species, and the abundance of each species found.

Macroinvertebrates can also be classified according to their method of obtaining food into functional feeding groups. For example, macroinvertebrates called **scrapers** scrape their food, usually algae, from the surface of rocks into their mouths. Some species of mayflies and snails eat in this manner. Another functional feeding group is the **predator**. A predator is an insect that eats other live insects by either hunting or lying in wait. **Shredders** are insects that mash up large organic matter such as twigs or leaves, which have fallen into the stream. **Collectors** gather small organic matter and sometimes the waste of larger organisms. Collectors can be further divided into feeding groups by the way they collect. Some caddisflies, for example, build encasings around them and spin fine nets in which they filter out their food. These types of collectors are called Collector Filterers. A midge, on the other hand, finds food by crawling around on the bottom of the stream and is classified as a Collector Gatherer. **Parasites**, like leeches, are another functional feeding group. These organisms live off of other organisms.

Procedure:

Warm-up:

- Have students brainstorm about what makes a healthy stream. Examples: shade, dissolved oxygen, diversity of life, good chemistry, no toxins, etc.
- Explain what a macro is and show pictures.
- Explain why macros are important to a stream.
- Show chart of macro pollution sensitivity.
- Explain why sensitive species are worth the most points.
- How does AMD affect streams?
- Show students pictures of macroinvertebrates and explain what the word macroinvertebrate means.
- Explain why we use macroinvertebrates for stream health.

Activity:

Rules for Macro Rummy

Object

The object of the game is to get rid of all the cards in a player's hand. This can be done by melding, laying off, and discarding. Melding is laying cards down in books/sets/matches or in sequences/runs. A book or set is three or more cards of the same rank (Example: 3 or 4 Kings/Caddisflies). A sequence is three or more consecutive cards of the same suit (Example 10 Dragonfly, 9 Crayfish, 8 Blackfly Larva). Laying off is adding to a meld already on the table. Discarding is putting a card on the discard pile.

Dealing

Deal 7 cards per player. Use two decks of cards if more than 5 people are playing.

Play

1. Deal cards and put the rest into a stock pile. Dealer flips top card of the stock pile forming a discard pile. When adding to the discard pile, cards should be overlapped so that all the cards in the discard pile are visible.

2. The player to the left of the dealer picks a card from the stock pile or the discard pile. If a card is chosen from the discard pile, it must be melded immediately. The player may also take a card from anywhere in the discard pile, but must also take all the cards on top of the desired card. The bottom, or desired, card must also be used immediately in a meld.

3. The player may put any possible melds down in front of them. If a card was chosen from the top of the discard pile, it must be used in a meld. The player may put down as many melds as they would like. The person may also lay off in the same turn as much as desired. When laying off onto another's meld, the laid off card should be placed in front of the player laying off because they will earn the points of the card.

4. After finishing play, the player must discard. If the top card was picked from the discard pile, it cannot be used to discard. If more than one card was picked up from the discard pile the card on the top of the pile may be discarded.

5. If the stock pile runs out, play continues until no one can play using the discard pile.

6. Play ends when someone runs out of cards.

Scoring

Animals are listed in increasing tolerance to pollution according to the Stroud Biotic Index.

- Ace – Stone Fly – 15 high or low (shredder)
- King – Caddisfly – 10 (collector filterer)
- Queen – Hellgrammite – 10 (predator)
- Jack – Mayfly – 10 (scraper)
- 10 – Dragonfly Nymph – 10 (predator)
- 9 – Crayfish – 9 (predator)
- 8 – Blackfly Larva – 8 (collector gatherer)
- 7 – Midge – 7 (collector gatherer)
- 6 – Pouch Snail – 6 (scraper)
- 5 – Damselfly – 5 (predator)
- 4 – Sowbug– 4 (collector gatherer)
- 3 – Leech –3 (parasite)
- 2 – Flatworm – 2 (parasite)

Each player adds up the value of the cards melded, subtracts the value of the cards remaining in the hand. **Divide total points by the number of cards melded.** Keep track of each round and determine if your hand represents an excellent, very good, good, fair, or poor stream based on the DEP Water Quality Rating system. Keep playing rounds until someone reaches 27 or an Excellent Water Quality Rating.

Example

	Round 1	Round 2	Total
Bob	Excellent	Excellent	
Joe	Fair	Poor	

DEP Water Quality Rating System:

Excellent = 27+, or 5 or more

Very Good = 22-26 or 4

Good = 17-21 or 2 or 3

Fair = 11-16 or only 1

Poor = <11 or no

Wrap-Up/Conclusion:

At the end of one round, ask students to observe everyone's score and melds.

Explain to the class that a player may have had more cards melded, but a lower overall score.

In a stream, a large number of insects does not indicate that a stream is healthy. Having a number of different species including those that are sensitive to pollution gives the best water quality score.

Assessment:

- Indicate how AMD could impact a stream. What macroinvertebrates would live in an AMD stream? Which cannot?
- Have students write how macroinvertebrates are important to a stream.

Extensions:

- Students can identify live or preserved macroinvertebrates. If live specimens are used, the students can determine if the stream from where the organisms were obtained is considered a healthy stream.
- Students can also use the cards as flash cards to learn the functional feeding groups of the insects.

Adaptations:

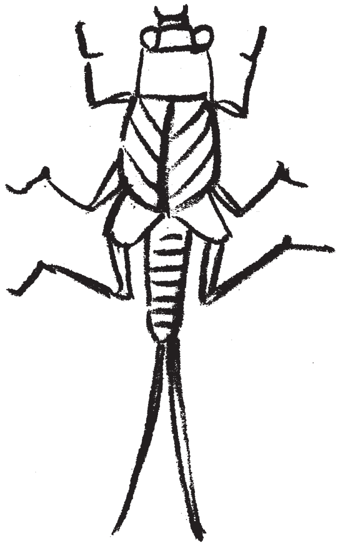
To use with younger children, play any card game that can be played with regular cards, such as Go Fish or Old Maid.

Resources:

Voshell, J. Reese, Jr. 2002. *A Guide to Common Freshwater Invertebrates of North America*.   Blacksburg, Virginia: The McDonald & Woodward Publishing Company.

Macro Rummy Cards

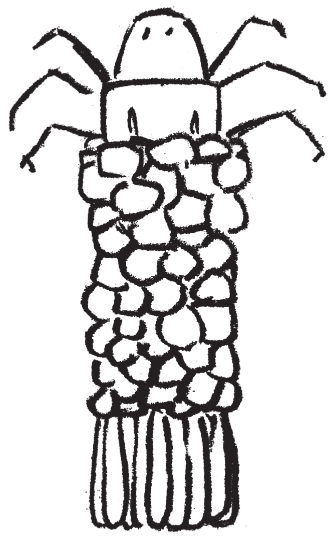
A **A**



A **Stonefly** **A**

Nature Interrupted – The Journey of AMD
MACRO RUMMY

K **K**



K **Caddisfly** **K**

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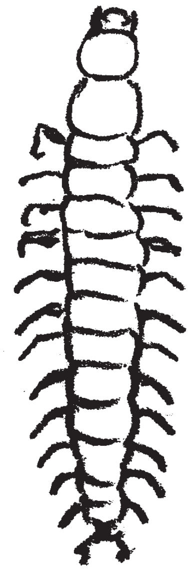
MACRO RUMMY

Q **Q**



Q **Hellgrammite** **Q**

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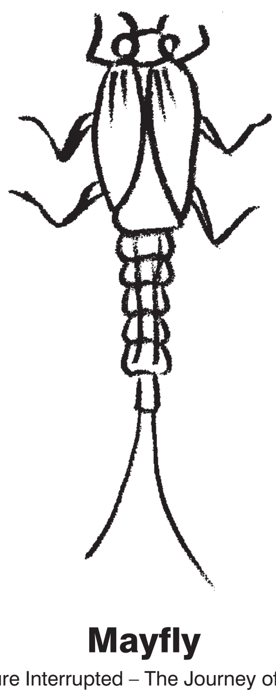
MACRO RUMMY

J **J**



J **Mayfly** **J**

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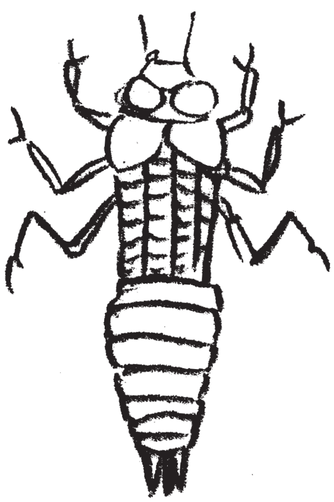
MACRO RUMMY

10 **10**



Dragonfly Nymph
10 **10**

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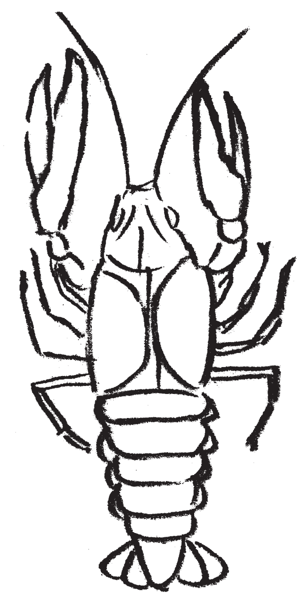
MACRO RUMMY

9 **9**

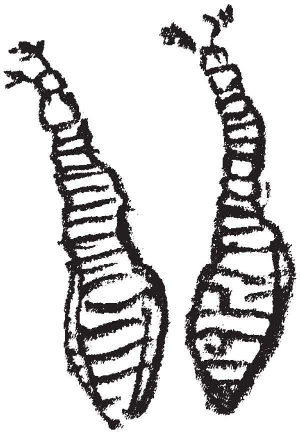


9 **Crayfish** **9**

Nature Interrupted – The Journey of AMD
MACRO RUMMY

Macro Rummy Cards

8 8



8 Blackfly Larva 8

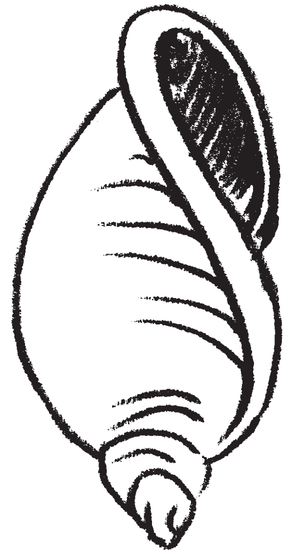
Nature Interrupted – The Journey of AMD
MACRO RUMMY

7 7

7 Midge 7

Nature Interrupted – The Journey of AMD
MACRO RUMMY

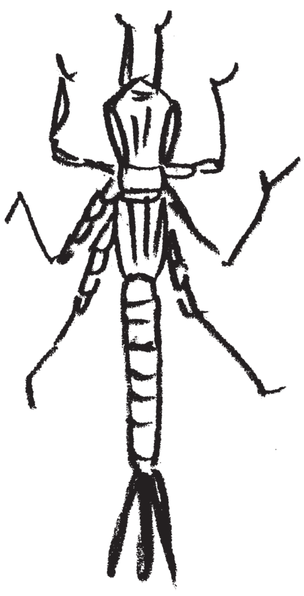
6 6



6 Pouch Snail 6

Nature Interrupted – The Journey of AMD
MACRO RUMMY

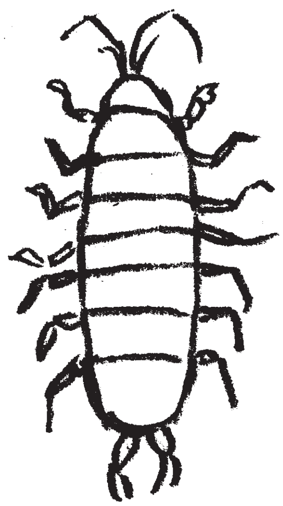
5 5



5 Damselfly Nymph 5

Nature Interrupted – The Journey of AMD
MACRO RUMMY

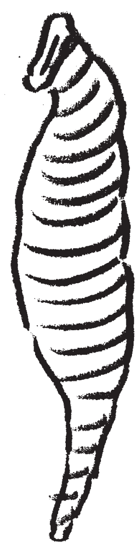
4 4



4 Aquatic Sowbug 4

Nature Interrupted – The Journey of AMD
MACRO RUMMY

3 3



3 Leech 3

Nature Interrupted – The Journey of AMD
MACRO RUMMY

Macro Rummy Cards

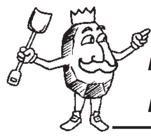
2 2

2 **Flatworm** 2

Nature Interrupted – The Journey of AMD
MACRO RUMMY

Visual Assessment of a Watershed

Adapted from USDA Visual Assessment Protocol, developed by the Natural Resources Conservation Service Aquatic Assessment Workgroup, National Water and Climate Center Technical Note 99-1, Issued December 1998.
Developed by Jennifer Bennett, Western Pennsylvania Conservancy, Blairsville, PA



About This Activity...

Prep Time Required:
30-45 minutes

Grade Level:
High School

Subjects:
Environmental Science

Duration of Activity:
3 hours

Pennsylvania Standards Addressed:
3.4.10.D3, 4.1.10-12.B, 4.1.12.C, 4.5.10.D, 4.2.10.A, 4.2.10.B, 4.3.10.B, 4.3.10.D

Setting:
First half to an hour inside, remainder outdoors near stream

Vocabulary:
Watershed Assessment

Related Vocabulary:
Active channel width
Aggradation
Bank stability
Canopy cover
Channel condition
Embeddedness
Fish Barriers
Insect/invertebrate habitat
Instream fish cover
Nutrient Enrichment
Reach
Riparian zone
Water appearance

Prerequisites:
Knowledge of watersheds, knowledge of stream ecosystems

Summary:
The influence of land use on aquatic habitats is examined as students perform stream assessments by collecting data using a visual assessment protocol.

Materials:
- Notebook
- Stream Visual Assessment form
- Scoring Description form
- Assessment Scores form
- Pens, pencils
- Clipboard

Objective:
Students should be able to:
- perform a **watershed assessment** by looking at varying physical factors related to streams
- improve problem solving skills
- develop analytical skills
- describe how land use can influence aquatic habitats

Background:
A stream is a complex ecosystem in which several biological, physical and chemical processes interact. Changes in any one characteristic or process have cascading effects throughout the system and result in changes to many aspects of the system.

It is also important to recognize that streams and flood plains need to operate as a connected system. Most systems would benefit from increased complexity and diversity in physical structure. Structural complexity is provided by trees fallen into the channel, overhanging banks, roots extending into the flow, pools and riffles, overhanging vegetation and a variety of bottom materials. This complexity enhances habitat for organisms and also restores hydrologic properties that often have been lost.

Flooding is necessary to maintain the flood plain biological community and to relieve the erosive force of flood discharges by reducing the velocity of the water. Flooding and bankfull flows are also essential for maintaining the instream physical structure. These events scour out pools, clean coarser substrates (gravel, cobbles, and boulders) of fine sediment, and redistribute or introduce woody debris.

Chemical pollution is a factor in most streams. The major categories of chemical pollutants are oxygen depleting substances, such as manure, ammonia and organic wastes; the nutrients nitrogen and phosphorus; acids, such as from mining or industrial activities; and toxic materials, such as pesticides and salts, or metals contained in some drain water.

Procedure:
Scoring sheets are attached with this lesson plan.

Warm-up:
Hand out scoring sheets and go over each category with students. Make sure they understand each category of the assessment. Show photographs of a good stream and an impaired stream. Go over vocabulary. Have students break into groups of three or four.

Activity:
This assessment will tell students how the stream is doing. They'll need to look at sections of the stream that are representative of different conditions. As students do the assessment, they should discuss how the functioning of different aspects of the stream work to keep the system healthy. After students are done, talk about the results of the assessment.

The assessment is recorded on a two-page worksheet. The stream visual assessment protocol worksheet consists of two principal sections: **reach** identification and assessment. The identification section records basic information about the reach, such as name, location, and land uses. Space is provided for a diagram of the reach, which may be useful to locate the reach or illustrate problem areas. On this diagram draw all tributaries, drainage ditches, and irrigation ditches; note springs and ponds that drain to the stream; include road crossings and note whether they are fords, culverts, or bridges; note the direction of flow; and draw in any large woody debris, pools, and riffles.

The assessment section is used to record the scores for up to 13 assessment elements. Not all assessment elements will be applicable or useful for your site. Do not score elements that are not applicable. Score an element by comparing your observations to the descriptions provided. If you have difficulty matching descriptions, try to compare what you are observing to the conditions at reference sites for your area. The overall assessment score is determined by adding the values for each element and dividing by the number of elements assessed. For example, if your scores add up to 76 and you used 12 assessment elements, you would have an overall assessment value of 6.3, which is classified as fair. This value provides a numerical assessment of the environmental condition of the stream reach. This value can be used as a general statement about the "state of the environment" of the stream or (over time) as an indicator of trends in condition.

Once students are comfortable with scoring sheets, take them to a stream reach (any size works, but a reach of approximately 100 to 150 feet works best) to begin their assessment. Have each group walk the reach and assess the reach based on the categories below. Students will score each category based on the descriptions. Once students are done, bring groups back together and compare scores.

Wrap-up/Conclusion:

Discuss each groups findings and their reasoning behind scores given. Discuss why any problems may have arisen in that stream reach.

Assessment:

- Have students write a report on their findings and what recommendations they may have on how to remedy any problem areas.

Extensions:

- After students do the visual assessment, have them collect macroinvertebrates or take chemical samples. This will give the students the overall picture of the stream reach and how each aspect interacts to make one complete community.

Adaptations:

Students can do an assessment for a whole watershed as a semester project. Pick a small watershed so students will be able to complete it in a semester. Students can then analyze the data they have collected and get the overall rating of the watershed.

Resources:

USDA Visual Assessment Protocol. National Water and Climate Center Technical Note 99-1, Issued December. Developed by the Natural Resources Conservation Service Aquatic Assessment Workgroup.

Stream Visual Assessment

Owner's name ______________________ Evaluators' name ______________________

Stream name ______________________ Reference site ______________________

Perfect Reach ______________________ Date ______________________

Reach location: Latitude ______________ Longitude ______________

Land use(%): row crop ________ grazing/pasture ________ forest ________ residential ________

industrial ________ Conservation Reserve ________ other: ________

Weather conditions: today ______________________ Past 2-5 days ______________________

Active channel width (bankfull) ______________________

Dominant substrate:

boulder ______ cobble ______ gravel ______ sand ______ silt ______ mud ______ bedrock ______

Site Diagram

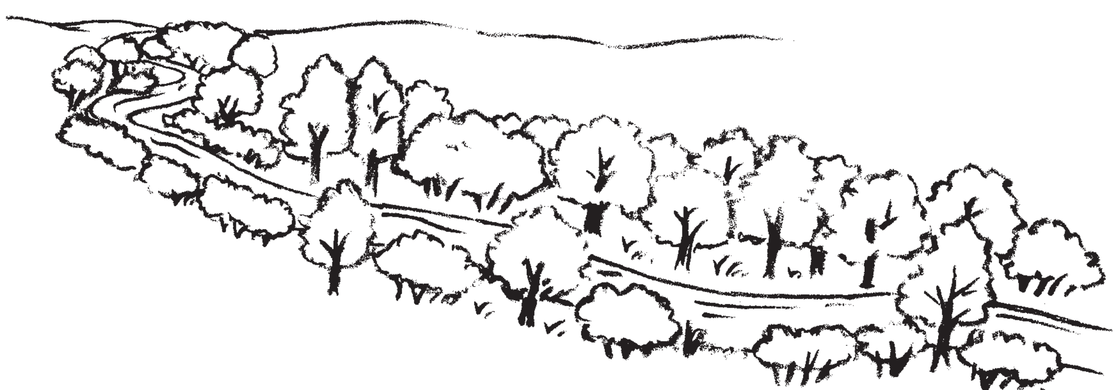
Scoring Descriptions

Each assessment element is rated with a value of 1 to 10. Rate only those elements appropriate to the stream reach. Record the score that best fits the observations you make based on the narrative description provided.

Channel Condition

Natural channel; no structures, dikes. No evidence of down-cutting or excessive lateral cutting.	Evidence of past channel alteration, but with significant recovery of channel and banks. Any dikes or levies are set back to provide access to an adequate flood plain.	Altered channel; <50% of the reach with riprap and/or channelization. Excess **aggradation**; braided channel. Dikes or levees restrict flood plain width.	Channel is actively down-cutting or widening. >50% of the reach with riprap or channelization. Dikes or levees prevent access to the flood plain.
10 9 8	7 6 5 4	3 2	1

Aggradation: The process by which a stream's gradient steepens due to increased deposition of sediment.
Keys: look for things like down cutting, lateral cutting, altered or widened sections, dikes, levies or other obstructions.



Riparian Zone

Natural Vegetation extends at least two active channel widths on each side.	Natural vegetation extends one active channel width on each side. Or If less than one width, covers entire flood plain.	Natural vegetation extends half of the active channel width on each side.	Natural vegetation extends a third of the active channel width on each side. Or Filtering function moderately compromised.	Natural vegetation less than a third of the active channel width on each side. Or Lack of regeneration. Or Filtering function severely compromised.
10 9	8 7 6	5 4	3 2	1

Active channel width: Elevation on the bank marking the normal maximum water flow before flooding occurs.
Keys: Related to ACTIVE channel width, an example would be a 5' wide stream. 10' = 2x active channel width.

Scoring Descriptions

Each assessment element is rated with a value of 1 to 10. Rate only those elements appropriate to the stream reach. Record the score that best fits the observations you make based on the narrative description provided.

Bank Stability

Banks are stable; banks are low (at elevation of active flood plain); 33% or more of eroding surface area of banks in outside bends is protected by roots that extend to the base-flow elevation.	Moderately stable; banks are low (at elevation of active flood plain); less than 33% of eroding surface area of banks in outside bends is protected by roots that extend to the base-flow elevation.	Moderately unstable; banks may be low, but typically are high (flooding occurs 1 year out of 5, or less frequently); outside bends are actively eroding (overhanging vegetation at top of bank, some mature trees falling into stream annually, some slope failures apparent).	Unstable; banks may be low, but typically are high; some straight reaches and inside edges of bends are actively eroding as well as outside bends (overhanging vegetation at top of bare bank, numerous mature trees falling into stream annually, numerous slope failures apparent).
10 9 8	7 6 5 4	3 2	1

Keys: **<u>All</u>** outside bends in streams erode, even the most stable streams may have 50% of its banks bare and eroding. A healthy riparian corridor with a vegetated floodplain contributes to bank stability. The roots of perennial grasses or woody vegetation typically extend to the baseflow elevation of water in streams with eroding bank heights of 6 feet or less.

Water Appearance

Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks.	Occasionally cloudy, especially after storm event, but clears rapidly; objects visible at depth 1.5 to 3 ft; may have slightly green color; no oil sheen on water surface.	Considerable cloudiness most of time; objects visible to depth 0.5 to 1.5 ft; slow sections may appear pea-green; bottom rocks or submerged objects covered with heavy green or olive-green film. Or Moderate odor of ammonia or rotten eggs.	Very turbid or muddy appearance most of the time; objects visible to depth <0.5 ft; slow moving water may be bright-green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface. Or Strong odor of chemicals, oil, sewage, other pollutants.
10 9 8	7 6 5 4	3 2	1

Keys: Remember to look at the water, not the substrate. If you dipped a glass in the water, what would the water look like?

Scoring Descriptions

Each assessment element is rated with a value of 1 to 10. Rate only those elements appropriate to the stream reach. Record the score that best fits the observations you make based on the narrative description provided.

Nutrient Enrichment

Clear water along entire reach; diverse aquatic plant community little algal growth present.	Fairly clear or slightly greenish water along entire reach; moderate algal growth on stream substrates.	Greenish water along entire reach; abundant algal growth, especially during warmer months.	Pea green, gray or brown water along entire reach; severe algal blooms create thick algal mats in stream.
10 9 8	7 6 5 4	3 2	1

Keys: Looking for algae and other aquatic vegetation, some is good, but can't be excessive.

Fish Barriers

No barriers.	Seasonal water withdrawals inhibit movement within the reach.	Drop structures, culverts, dams or diversions (<1ft drop) within the reach.	Drop structures, culverts, dams or diversions (>1ft drop) within 3 miles of reach.	Drop structures, culverts, dams or diversions (>1ft drop) within the reach.
10 9	8 7 6	5 4	3 2	1

Keys: You are looking for withdrawls, culverts, dams and diversions. Anything that is imposed or constructed by man that would impede fish passage.

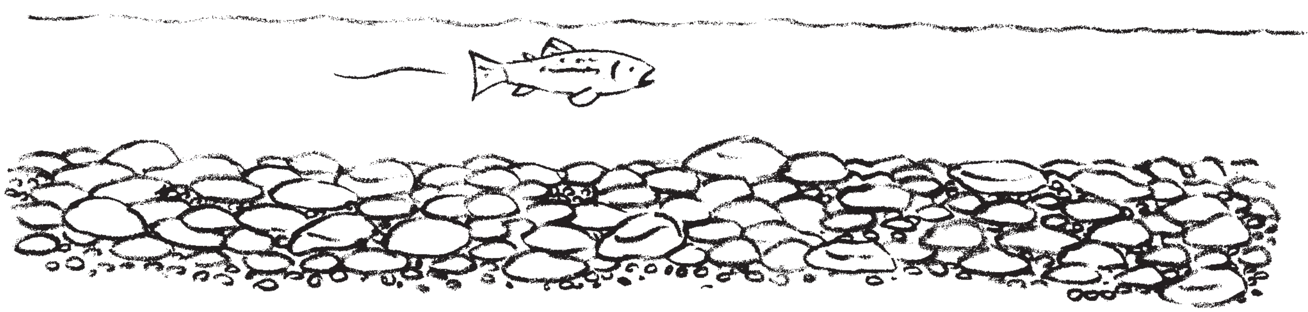
Instream Fish Cover

>7 cover types available	6 to 7 cover types available	4 to 5 cover types available	2 to 3 cover types available	None to 1 cover type available
10 9	8 7 6	5 4	3 2	1

Cover types: Logs/large woody debris, deep pools, overhanging vegetation, boulders/cobble, riffles, undercut banks, thick root mats, dense macrophyte beds, isolated/backwater pools, other:___________

Scoring Descriptions

Each assessment element is rated with a value of 1 to 10. Rate only those elements appropriate to the stream reach. Record the score that best fits the observations you make based on the narrative description provided.



Embeddedness

Gravel or cobble particles are <20% embedded.	Gravel or cobble particles are 20 to 30% embedded.	Gravel or cobble particles are 30 to 40% embedded.	Gravel or cobble particles are >40% embedded.	Completely embedded.
10 9	8 7 6	5 4	3 2	1

Keys: Embeddedness is defined as the degree to which objects in the stream bottom are surrounded by fine sediment. Only evaluate this item in **riffles & runs**. Measure the depth to which objects are buried by sediment. Be sure that you are looking at the entire reach, not just one riffle. To help better define embeddedness, picture a rock. If the average sediment in the stream covers the bottom 20% of the rock than you would check 20%. If the rock is covered 1/3rd of the way by sediment then it is 30% embedded.

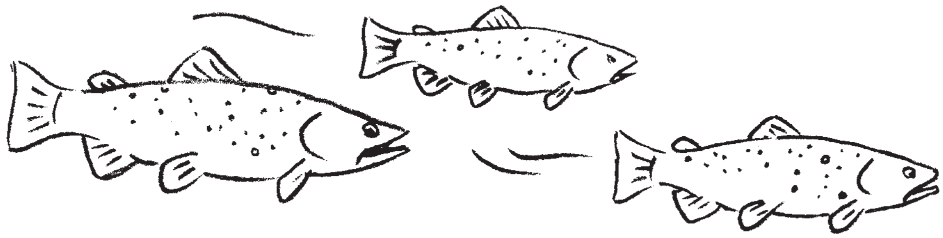
Insect/invertebrate Habitat

At least 5 types of habitat available. Habitat is at a stage to allow full insect colonization (woody debris and logs not freshly fallen).	3 to 4 types of habitat. Some potential habitat exists, such as overhanging trees, which will provide habitat, but have not yet entered the stream.	1 to 2 types of habitat. The substrate is often disturbed, covered, or removed by high stream velocities and scour or by sediment deposition.	None to 1 type of habitat.
10 9 8	7 6 5 4	3 2	1

Cover types: Fine woody debris, submerged logs, leaf packs, undercut banks, cobble, boulders, coarse gravel, other: __________

Scoring Descriptions

Each assessment element is rated with a value of 1 to 10. Rate only those elements appropriate to the stream reach. Record the score that best fits the observations you make based on the narrative description provided.



Canopy Cover

Keys: This pertains to waterways where channel is 50' or less.

Coldwater fishery

>75% of water surface shaded and upstream 2 to 3 miles generally well shaded.	> 50% shaded in reach. Or >75% in reach, but upstream 2 to 3 miles poorly shaded.	20 to 50% shaded.	<20% of water surface in reach shaded.
10 9 8	7 6 5 4	3 2	1

Warmwater fishery

25 to 90% of water surface shaded; mixture of conditions.	>90% shaded; full canopy; same shading condition throughout reach.	(Intentionally blank)	<25% water surface shaded in reach.
10 9 8	7 6 5 4		1

Average score between coldwater and warmwater fisheries= ________ *(Record this number in the canopy cover box on scores section)*

Scoring Descriptions

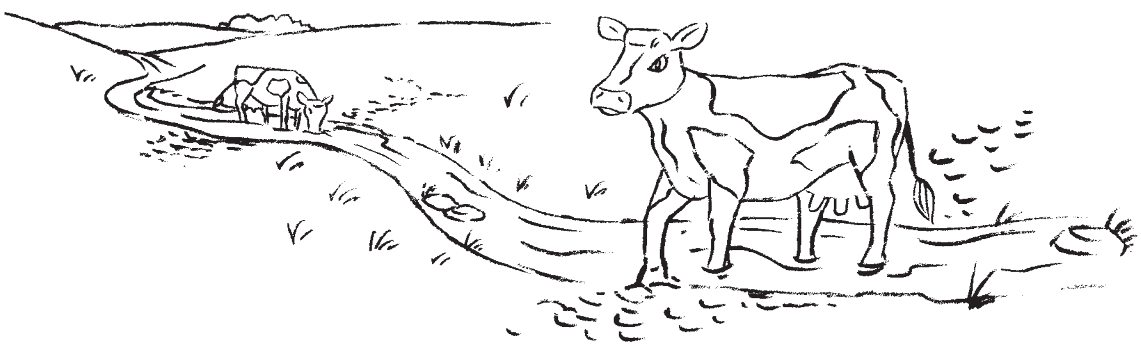
Each assessment element is rated with a value of 1 to 10. Rate only those elements appropriate to the stream reach. Record the score that best fits the observations you make based on the narrative description provided.

Abandoned Mine Drainage (if applicable)

(Intentionally blank)	Evidence of iron staining (orange or yellow). Or Noticeable iron precipitate (orange or yellow).	Iron precipitant visible, muddy orange appearance.	Heavy iron precipitate, noticeable kill zone. Or White precipitate visible (aluminum), rotten egg smell.
	5 4	3 2	1

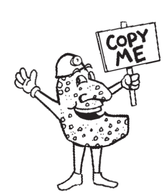
Sewage (if applicable)

(Intentionally blank)	Noticeable odor, excess plant growth and siltation.	Noticeable odor, excess plant growth. And Questionable pipe and black stream substrate.	Visible pipe with effluent, heavy odor.
	5 4	3 2	1



Manure Presence (if applicable)

(Intentionally blank)	Evidence of livestock access to riparian zone.	Occasional manure in stream or waste storage structure located on the flood plain.	Extensive amount of manure on banks or in stream. Or Untreated human waste discharge pipes present.
	5 4	3 2	1



Assessment Scores

Channel condition

Riparian zone

Bank stability

Water appearance

Nutrient enrichment

Fish barriers

Instream fish cover

Embeddedness

Invertebrate habitat

Canopy Cover

Score only if applicable

AMD

Sewage

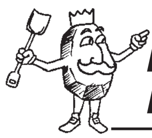
Manure presence

Overall score ____________
(Total divided by number scored)

<6.0	**POOR**
6.1-7.4	**FAIR**
7.5-8.9	**GOOD**
>9.0	**EXCELLENT**

Watershed Education

Developed by Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
15 minutes

Grade Level:
High School

Subjects:
Science, Geology & Science, Environmental Education

Duration of Activity:
Minimum one 45 minute session, best suited for two 45 minute sessions

Pennsylvania Standards Addressed:
4.2.10.A, 4.2.10.B

Setting:
Classroom

Vocabulary:
Delineation
Waterbasin
Watershed

Prerequisites:
Knowledge of computers, maps

Summary:

Students will define waterbasins and watersheds, then delineate the boundaries of their local waterbasin/ watershed using maps.

Materials:

- Highlighters
- Pen
- Pencil
- Rulers
- State map
- Topographic maps of area
- Clear plastic sheets
- Dry erase markers
- Computer/Internet access for teacher and students

Objectives:

Students will be able to:

- Define waterbasin and watershed and give several differences.
- Draw and highlight a river system on a map and delineate rough boundaries of the waterbasin.
- Identify which waterbasin and watershed their school is located in.
- Delineate on a topographical map the more accurate boundaries of a small watershed.

Background:

Have you ever wondered where rain goes when it falls? Stop sometime and watch a stream or river flowing by - does it end up in our drinking water? What things keep water clean in nature and in the water we drink? The land areas filter water naturally as it passes through on the surface or into ground water.

Waterbasins and **watersheds** are two ways that we classify water boundary units. Waterbasins are large land areas that are drained by a major river system. Watersheds are smaller land areas that are defined as the area that is drained by one stream or river.

Students can delineate or outline the land area for a waterbasin by following the course of a river from source to mouth and identifying all of the tributaries for the river. Watersheds are best delineated using a topographic map. Start by again identifying all the tributaries and intermittent streams on the topographic map (cover with the plastic sheet and use dry erase markers or call up the topographic map on the internet and screen), then every inch from the mouth to the source, draw a small line perpendicular to the stream. Using your ruler follow that perpendicular line until you hit the highest elevation and mark it with a dot. Do this on either side of the stream for each mark. Connecting the dots along lines of highest elevation will **delineate** the watershed.

Procedure:

Warm-up:

Discuss Background topics.
Anticipation Guide Questions:

- Agree or Disagree: Our community has a safe water supply.
- Agree or Disagree: There is enough clean water in nearby areas to support all the people living here now and in the future.
- Agree or Disagree: What gets dumped into or taken out of local streams and rivers is more important than what happens to the land surrounding the rivers.

Teachers may discuss anticipation questions with the class after they have filled them out, or may prefer to wait until after the lesson, discussing if answers have changed and why students agreed or disagreed.

Activity:

Pupil Investigations:

- When it rains here, where does the water go? (ground water, runoff, evaporates, etc..) What bodies of water are located near here?
- In groups, take out your state map and locate the Chesapeake Bay. Highlight it with your marker, also highlight the town we are in and the nearest stream.

- For the next 10 minutes you will be connecting these two points, by highlighting the waterways that connect the two, you may go from either direction flowing from smaller to larger, or from large to small.
- This is the path that our water takes as it flows toward the Atlantic Ocean. Now we want to look more specifically at where the water comes from - the land. Locate a major river that flows into the Chesapeake. Highlight ALL the smaller rivers AND every stream that flows into that major river.
- Using your ruler draw a rough outline of the land that your highlighting encompasses. This would be the waterbasin of the _________ river.
- How much land is included in your outline? Miles/acres? Waterbasins are so large there are only 5 of them in Pennsylvania. (They are the Delaware, Susquehanna, Potomac, and Ohio - the there are two waterbasins we combine into one since they both flow into the Great Lakes). They are named after the major rivers that drain that land area. Now we want to look more closely at the water drainage area for this school. Where does water go when you wash your hands or shower in gym class?
- On computers have students go to the DCNR, Bureau of TopoGeo at www.dcnr.state.pa.us/topogeo/maps&photos.htm (or check with your state's Department of Natural Resources) Have students call up the topographic map of the local stream or river. Review specifics of topographic maps as needed.
- On your locate the mouth of the river/stream where your water flows. If in a larger watershed, use you may wish to not include the entire watershed if it involves using several "topo" maps. Using +'s (or some other mark easily visible on the map) spaced at one-inch intervals, trace the flow of the stream to its source. At every mark draw a line (imaginary if necessary) perpendicular to the stream. Follow the perpendicular line until you reach the highest elevation before cresting a major ridge and make a dot (*, ^, etc…) at this point. Do this for each side of the stream.
- When you connect the dots, the line will show the **delineation** of your watershed that follows small topographic variations and ridge and mountaintops.
- When students have delineated their local watershed, have them work in their groups to answer the general question below or have them complete a report on one of the five major waterbasins. In Pennsylvania, many of the answers will be available at DEP homepage, however many other resources are available online (see below).

Questions:

- How much water do Pennsylvanian's citizens use everyday?
- What are the 3 places in North America where PA's water empties into an ocean?
- Name 3 of PA's major industries that impact our water resources?
- Gather information on one particular waterbasin to share with the class.

Assessment:

- Assessment may take several forms depending on the route chosen by the teacher. Students may give oral presentations on their waterbasins as groups. Students may submit written reports on their waterbasins. Teachers may review or check questions at the end of the exercise. All options should include discussion of the anticipation questions, emphasizing the importance of watersheds on local water availability and their effects on the flora and fauna downstream.

Resources:

Useful Internet Resources:
The state of Pennsylvania has several good web resources. The Department of Environmental Protection (DEP) and the Department of Conservation and Natural Resources (DCNR) both have much of the information used to create this lesson.

Pennsylvania's Department of Environmental Protection
www.dep.state.pa.us

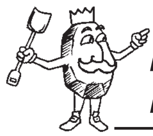
The Pennsylvania Department of Conservation and Natural Resources
www.dcnr.state.pa.us

DEP has more laws and in depth materials used in managing the state's water resources. DCNR, Bureau of state parks has a new curriculum called Watershed Education where lessons similar to this are located and teachers can input data from their stream investigations onto the statewide database.

Watershed Notebooks
/dep/deputate/watermgt/Wc/Subjects/WSNoteBks/SHEDHOME.htm

Is There Mine Drainage Impacting This Stream?

Taken from Saint Vincent Environmental Education Center: AMD Education Modules, Saint Vincent College, Latrobe, PA



About This Activity...

Prep Time Required:
60 minutes

Grade Level:
Middle school/
High school

Subjects:
Biology,
Environmental Science

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
3.1.6-7.A1, 3.4.7.D3,
4.1.10.A, 4.2.7-10.C,
4.5.10.C

Setting:
Classroom/hallway/outside

Vocabulary:
Diversity
Habitat
Macroinvertebrate
Pyrite
Sedimentation

Prerequisites:

Summary:

Students will complete a biological sampling activity in which they will determine the types of organisms collected and calculate the water quality rating. The information obtained about the types and amounts of organisms found will be applied to illustrate how the insects sampled can become an indicator for streams impacted by abandoned mine drainage (AMD).

Materials:

- 1 - 100 foot roll of blue paper – *Stream #1*
- 1 - 100 foot roll of brown paper – *Stream #2*
- 15 medium to large rocks – *Stream Bottom*
- 10 artificial green plants – *Aquatic Plants*
- 15 pressed leaves – *Leaf Litter*
- Brown lunch bags
- Masking tape
- Pencils
- Chalkboard, chalk
- Sheet A - *Macroinvertebrate Cards* (3 sheets for each group of two students)
- Sheet B - *Macroinvertebrate Cards* (3 sheets for each group of two students)
- Stream Health Checklist Worksheet

Objectives:

Students will be able to:

- Correctly identify organisms using a taxonomy key
- Correctly calculate **macroinvertebrate diversity**

Background:

Part I: Abandoned Mine Drainage (AMD)

The 'Pittsburgh coal seam' has been called the single most valuable mineral deposit ever discovered. A population map of western Pennsylvania reveals patterns similar to the map of Pennsylvania bituminous coal deposits. Most of the population of western Pennsylvania is still concentrated around the Pittsburgh seam because, historically, towns developed around the mining of coals and associated industries. Bituminous coal is a soft, black coal that is used in making 'coke,' the fuel that burns so hot it melts iron ore, and makes possible the manufacturing of steel. The Pittsburgh seam produced most of our nation's coal until the 1970's, and is still a major economic resource. In the early 20th century, coal was the major source of energy. To feed such a large demand, coal deposits were harvested and resources used without worry of the cost to the environment. When a coal mine became depleted, it was simply abandoned and a new one dug in a nearby vein.

Much of the damage abandoned coal mines have done to our streams is a result of water seeping through the ground and coming into contact with the remnants of the mine. This water eventually works its way back to the surface of the ground and forms a discharge. The problem with water interacting with the mine is that minerals easily dissolve into the water. 'Roof rubble,' the drainage composed of loosened earth which falls from the ceiling of an abandoned mine shaft, is typically **pyrite** (iron sulfide). Pyrite has a large surface area so it dissolves easily dissolves into water. The discharge from such mines contains a large amount of iron, resulting in the distinctive orange coloring.

Pyrite + oxygen ⟶ Iron Hydroxide (orange solid) + Acid

Chemistry of Mine Drainage

Pyrite Dissolves:
FeS_2 (s) + $^7/_2 O_2$ (g) + H_2O (l) ⟶ Fe^{+2} (aq) + 2 SO_4^{-2} (aq) + 2 H^+ (aq)

Iron (II) is oxidized:
$2Fe^{+2} + ½\ O_2 + 2H^+ \longrightarrow 2Fe^{+3} + H_2O$

Formation of Iron Hydroxide (above pH 3)
$Fe^{+3} + 3\ H_2O \longrightarrow Fe(OH)_3\ (s) + 3\ H^+$

Further pyrite dissolution (below pH 3)
$FeS_2 + 14\ Fe^{+3} + 8\ H_2O \longrightarrow 15\ Fe^{+2} + 2\ SO_4^{-2} + 16\ H^+$

Abandoned Mine Drainage disrupts the healthy function of a stream ecosystem in a variety of ways.

- **Habitat** Bottom:
  Abandoned Mine Drainage "sludge" is both a slippery and sticky substance, somewhat the consistency of toothpaste. When mine drainage enters a stream, the iron oxide sludge mixes with the water forming a cloudy precipitate in the stream (orange color). The cloudy condition of the stream does not allow sunlight to penetrate to the bottom of the stream. This condition does not allow the macroinvertebrates to survive.

- **Sedimentation**:
  Abandoned Mine Drainage "sludge" makes the water in a stream become turbid as pieces of iron begin to form and precipitate out of solution. The "rusty" pieces of iron make the water in a stream cloudy, therefore block sunlight from reaching the photosynthetic organisms and aquatic plants. This process destroys the producers in an aquatic food chain, thus destroying the healthy balance of "who eats who".

- Lowers Dissolved Oxygen:
  Abandoned Mine Drainage utilizes the existing dissolved oxygen in the stream in the oxidation reaction as mine water enters a stream. It is the dissolved oxygen or DO in the water that allows macroinvertebrates or other gill-breathing organisms to survive and thrive in a stream.

Part II: Macroinvertebrates, a Stream Health Indicator

Aquatic macroinvertebrates are found in lakes, streams, ponds, marshes and puddles and help maintain the health of the water ecosystem by eating bacteria and dead, decaying plants and animals. Overall water quality effects which types of organisms can survive in a body of water. "Water quality" may include the amounts of dissolved oxygen and the levels of algal growth, pollutants that may be present and the pH level. Some macroinvertebrates such as stoneflies, mayflies and water pennies require a high level of dissolved oxygen and their abundance is an indication of good water quality. Other macroinvertebrates can survive at a lower dissolved oxygen level because they can come to the surface to get oxygen through a breathing or "snorkel" tube or carry a bubble of air with them around their bodies or under their wings.

There are several reasons why macroinvertebrates are used as water quality indicators:

- **Aquatic macroinvertebrates are an important part of the food chain found in and around a body of water.**
  Aquatic macroinvertebrates are a link in the aquatic food chain. In most streams, the energy stored by plants is available to animal life either in the form of leaves that fall in the water or in the form of algae that grows on the stream bottom. The algae and leaves are eaten by macroinvertebrates. The macroinvertebrates are a source of energy for larger animals such as fish, which in turn, are a source of energy for other animals and even man.

- **Aquatic macroinvertebrates differ in their sensitivity to water pollution.**
  Some aquatic macroinvertebrates cannot survive in polluted water. Others can survive or even thrive in polluted water. In a healthy stream, the macroinvertebrate community will include a variety of pollution-sensitive macroinvertebrates. In an unhealthy stream, there may be only a few types of non-sensitive macroinvertebrates present.

- **Aquatic macroinvertebrates provide information about the quality of a stream over long periods of time.**
  It may be difficult to identify stream pollution with water analysis such as pH and dissolved oxygen, which can only provide information for the time of sampling. Even the presence of fish may not provide information about a pollution problem because fish can move away to avoid polluted water and then return when conditions improve. However, most aquatic macroinvertebrates cannot move to avoid pollution. A macroinvertebrate sample may provide information about pollution that is not present at the time of sample collection.

- **Aquatic macroinvertebrates are relatively easy to collect.**
  Useful aquatic macroinvertebrate data is easy to collect without expensive equipment. The data obtained by taking a macroinvertebrate survey can serve to indicate the need for additional data collection on water sample.

The life cycle of a macroinvertebrate goes from egg to adult form and they can undergo either complete or incomplete metamorphosis. Complete metamorphosis has 4 stages, egg, larvae, pupa and adult. Organisms, which undergo complete metamorphosis, include true flies, beetles and caddis flies. Many of these organisms are aquatic for the egg and larval stages, but not in the adult stage. Incomplete metamorphosis has 3 stages, egg, nymph and adult. Organisms that undergo incomplete metamorphosis include stoneflies, mayflies, dragonflies and true bugs. Many of these organisms, such as dragonflies, do not live in an aquatic ecosystem as adults. Other species such as true bugs, which include the backswimmers, water scorpions and the water striders, are examples of macroinvertebrates, which spend their entire lives in the water. The length of the life cycle of a macroinvertebrate can vary from less than 2 weeks for some midges and mosquitoes and two years or longer for some stoneflies, dragonflies and Dobson flies.

Procedure:

Warm-up:

- Brainstorm with the students what conditions are necessary for a healthy stream ecosystem.
- The teacher will write student responses on the board.
- Ask the students what would happen to the stream if these conditions were eliminated or altered?
- Ask the students how they would assess the health of the stream?
- Ask the students what would happen to the stream if these conditions were eliminated or altered?
- Today we are going to learn one way that scientists determine if a stream is unhealthy due to mine drainage.

Activity:

The Activity – Stream Game

• Show students photographs or sample jars of macroinvertebrates used to monitor stream quality. Discuss with the students where you would find these organisms in a stream (under rocks, buried in sediment, clinging to leaf litter, around aquatic plants, etc.)

• Following the Game Set-up Diagram, in a hallway or in a classroom, roll out the blue paper and tape down the paper to the floor. This BLUE paper will represent the high quality stream in which the students will collect macroinvertebrates. Randomly place rocks, plastic plants, and leaves on top of the paper roll. –OR- Use the Blue Stream #1 Located in Module. Using Sheet A Macroinvertebrates, randomly place macroinvertebrates face down along the stream, under rocks, around plants, and within leaf litter, etc.

• With a partner, each group of students receives a brown bag (this is their net). They are to sample upstream to downstream collecting at least 15 macroinvertebrates, two must be collected from under rocks, two from around a plant, and two from leaf litter, and place them into their brown bag. They are not to look at the types of macroinvertebrates being collected as they take their samples.

• Using a check mark for each macroinvertebrate, students record the types of macroinvertebrates collected in Stream #1 Column on the Stream Health Checklist Worksheet.

• After all groups have sampled Stream #1. On the other side of the hallway or classroom, roll out the brown paper and tape down the roll of brown paper. This BROWN paper will represent the poor quality stream in which the students will collect macroinvertebrates. Randomly place the rocks, plants, and leaves on top of the brown paper. –OR- Use Orange Stream #2 found in Module. Using Sheet B Macroinvertebrates, randomly place macroinvertebrates face down along the stream, under rocks, around plants, leaf litter, etc.

• Students repeat step #3.

• Using a check mark for each macroinvertebrate, students record the types of macroinvertebrates collected in Stream #2 Column on the Stream Checklist Worksheet.

• Students calculate the total number of tolerant, somewhat sensitive, and sensitive macroinvertebrates for each stream on the chart at the bottom of the Stream Checklist Worksheet, then complete the questions found on the bottom of the worksheet.

• The teacher should create a class Stream Checklist Worksheet on the blackboard. Collect class results to show data from the class and record on the chalkboard.

Wrap-up/Conclusion:

- Discuss the results of their macroinvertebrate collection for stream #1 and stream #2. Have students compare numbers and types of macroinvertebrates found in each stream.
- Review with the students why some species of macroinvertebrates were found in stream #1 and not found in stream #2.
- Ask students if they knew what type of pollutant makes a stream appear "Orange-Colored"? Pass around photographs of orange colored streams.
- Why are these streams orange? What are some possible reasons as to why these streams appear orange? (Answer: Abandoned Mine Drainage).

Assessment:

- The teacher will visually check to see if each student's collected macroinvertebrate were correctly identified. (Objective 1)
- The teacher will verbally prompt students, through discussion and review, to complete the Stream Health Checklist. (Objective 2)

Extensions:

- Students could develop a matching game in which pictures of streams polluted and not polluted are matched with the corresponding macroinvertebrates found in those streams.
- Have students sample the stream game using all the same species of macroinvertebrates, and have students discuss the health of the stream.

Resources:

Credits:

Jennifer Brashear – Macroinvertebrate Cards, Saint Vincent College

Books:

Firehock, Karen. Hands on Save Our Streams: Izaak Walton League of America, 1996.

Websites:

The purpose of this page is to provide students, citizen volunteers, and others interested in benthic macroinvertebrates and/or biomonitoring with assistance in identification of specimens and to provide information on the habitat and general ecology of common benthic macroinvertebrates.
http://www.iso.gmu.edu/~avia/intro.htm

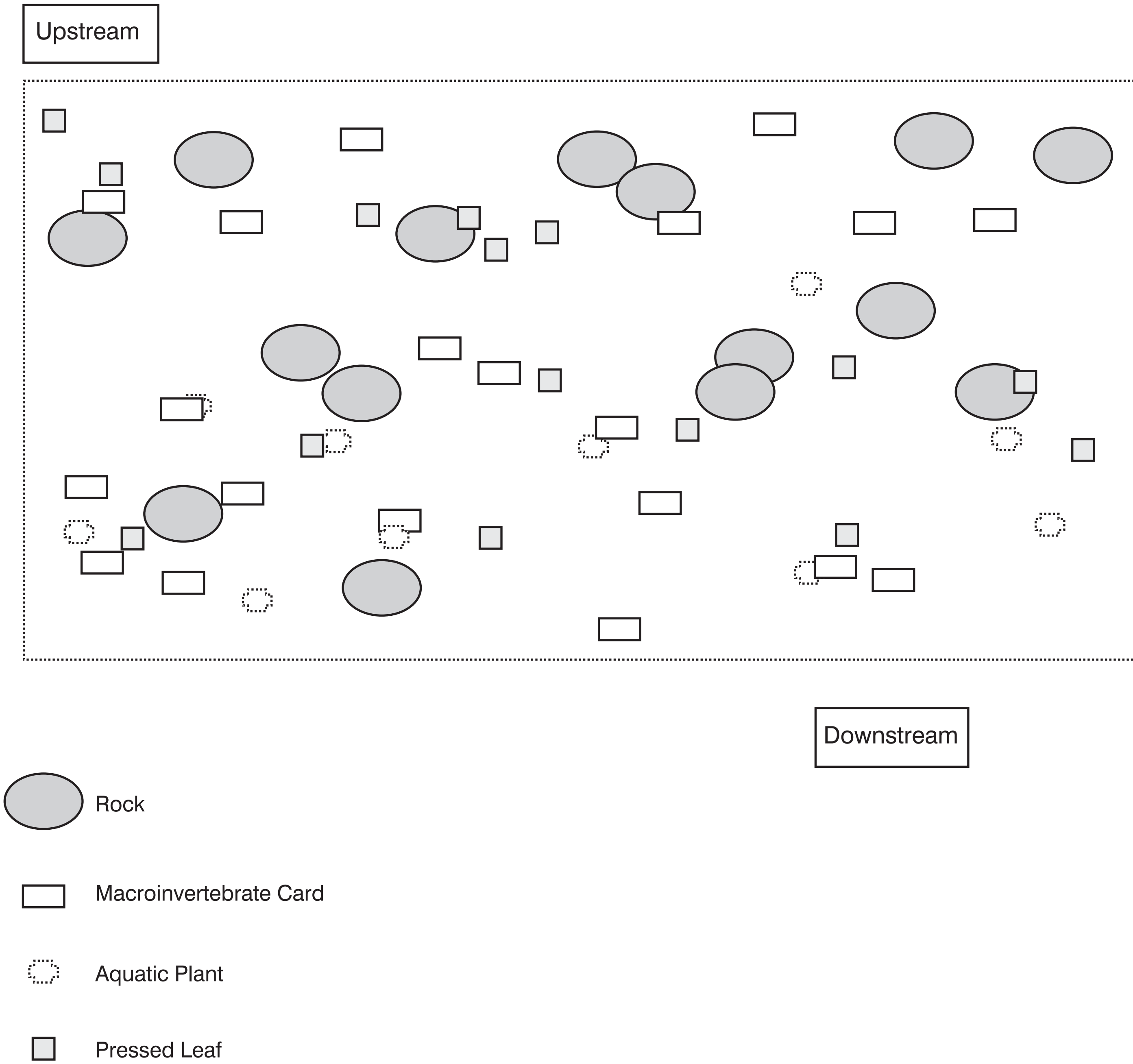
A page of links to several aquatic macroinvertebrate keys. Insect larvae can be quickly and easily identified down to family level by making a series of choices that correctly match observable traits.
http://www.net1plus.com/users/tdriskell/macroinvertebrates.html

Biological Stream Assessment
http://water.nr.state.ky.us/ww/introtxt.htm

April J. Cleveland, Water Quality and Aquatic Macroinvertebrates. http://www4.ncsu.edu/~ajclevel/macroinvert.html

The Science of Abandoned Mine Drainage and Treatment
http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_amd.htm

Stream Game Set-Up



Stream Health Checklist

Organism	Tolerance	Stream #1	Stream #1
Caddisfly Larva	Sensitive		
Mayfly Nymph	Sensitive		
Stonefly Nymph	Sensitive		
Gilled Snail	Sensitive		
Dobsonfly (Hellgrammite)	Sensitive		
Dragonfly Nymph	Somewhat Sensitive		
Damselfly Nymph	Somewhat Sensitive		
Crayfish	Somewhat Sensitive		
Clam	Somewhat Sensitive		
Sowbug	Somewhat Sensitive		
Midge Larva	Tolerant		
Rat-tailed Maggot	Tolerant		
Leech	Tolerant		
Flat Worm	Tolerant		
Pouch Snail	Tolerant		
Aquatic Worms	Tolerant		

Macroinvertebrates	Stream #1	Macroinvertebrates	Stream #2
Sensitive		Sensitive	
Somewhat Sensitive		Somewhat Sensitive	
Tolerant		Tolerant	

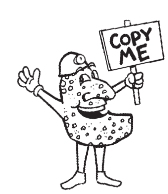
1. Was there a difference in types of macroinvertebrates found between Stream #1 and Stream #2?

   Yes ____ No ____

2. Where did you find more tolerant species of macroinvertebrates?

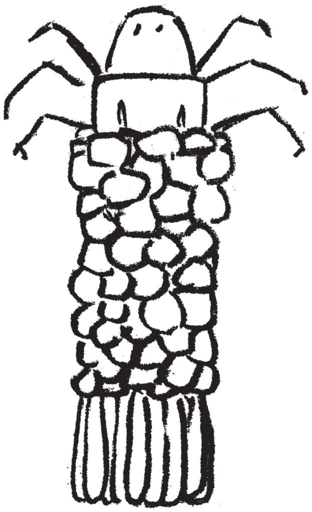
   Stream 1 ____ Stream 2 ____

3. Why were more tolerant species found in this stream?



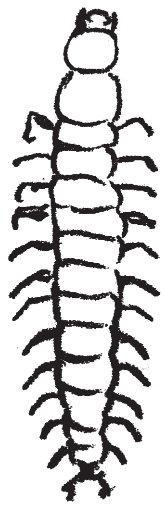
Macroinvertebrate Cards

Sheet A – High Quality Stream



Caddisfly Larva

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?



Hellgrammite

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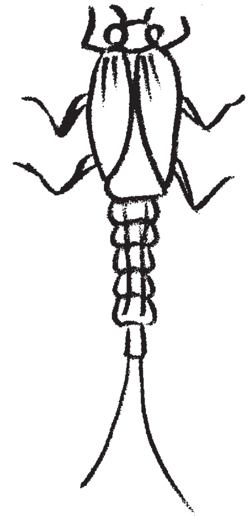
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?



Mayfly Nymph

Nature Interrupted – The Journey of AMD
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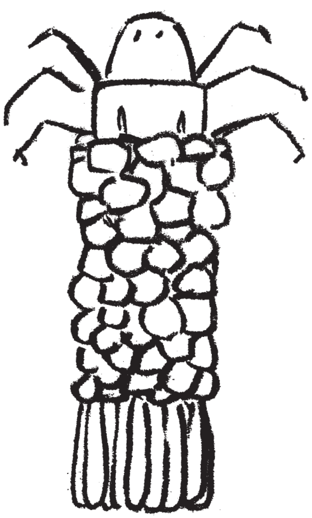

Caddisfly Larva

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IS THERE MINE DRAINAGE
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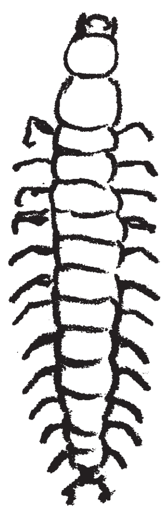

Hellgrammite

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
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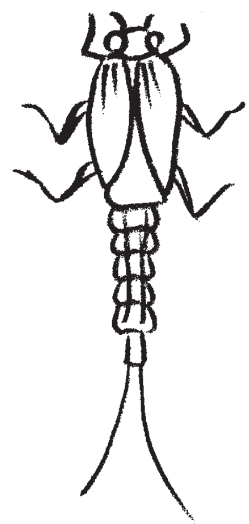

Mayfly Nymph

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?

Macroinvertebrate Cards
Sheet A – High Quality Stream

Gilled Snail

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
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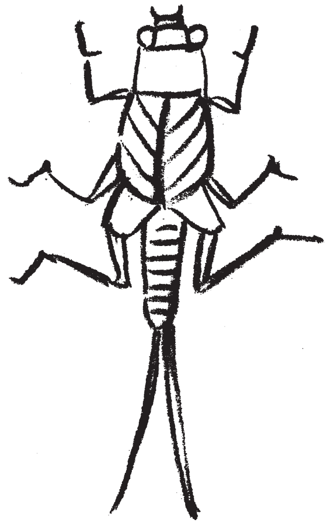

Stonefly Nymph

Nature Interrupted – The Journey of AMD
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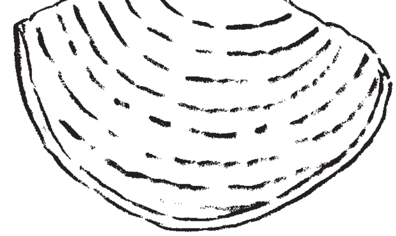
IMPACTING THIS STREAM?



Clam

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
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Gilled Snail

Nature Interrupted – The Journey of AMD
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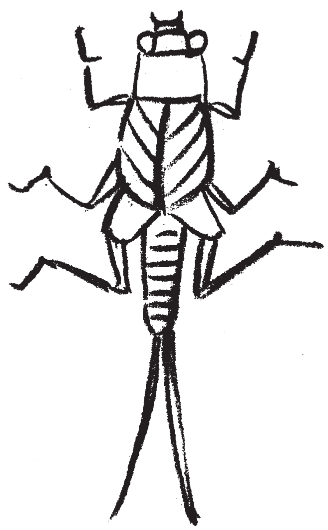
IMPACTING THIS STREAM?



Stonefly Nymph

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
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Crayfish

Nature Interrupted – The Journey of AMD
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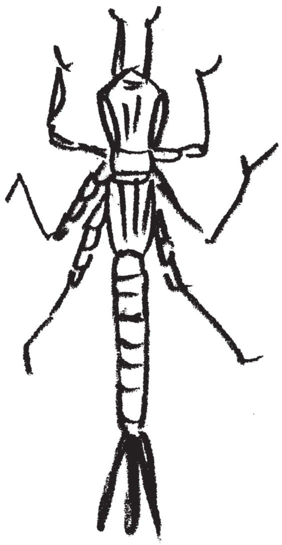
Macroinvertebrate Cards
Sheet A – High Quality Stream



Damselfly Nymph

Nature Interrupted – The Journey of AMD
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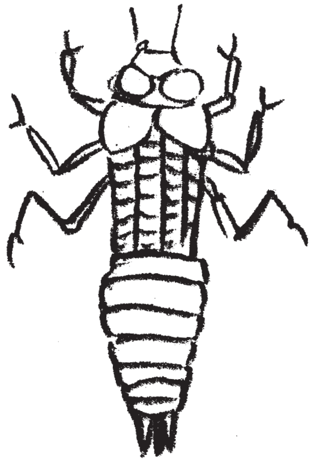
IMPACTING THIS STREAM?



Dragonfly Nymph

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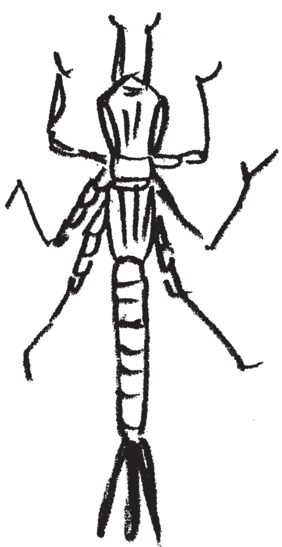

Damselfly Nymph

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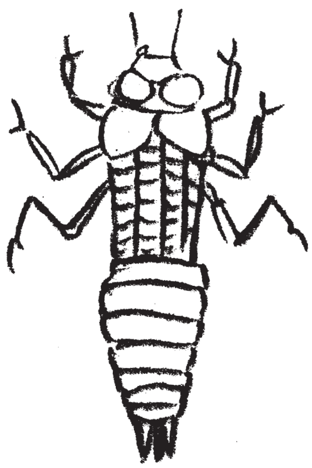
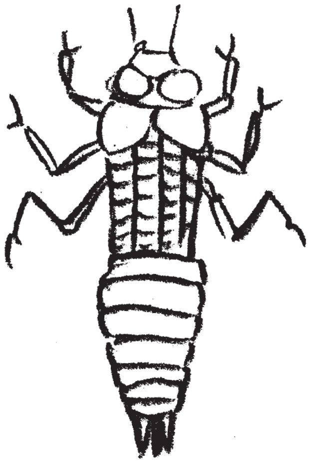


Dragonfly Nymph

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?

Macroinvertebrate Cards
Sheet B – Low Quality Stream



Dragonfly Nymph

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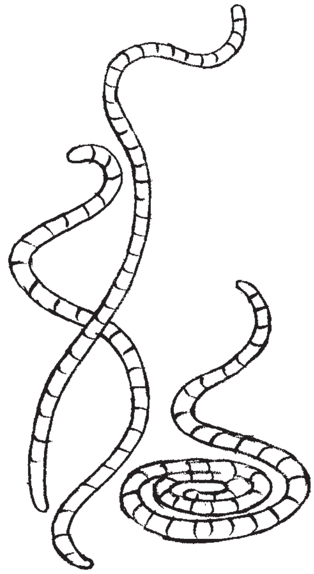

Aquatic Worms

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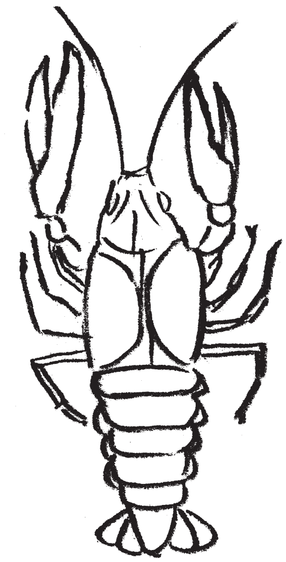
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?



Crayfish

Nature Interrupted – Journey of AMD
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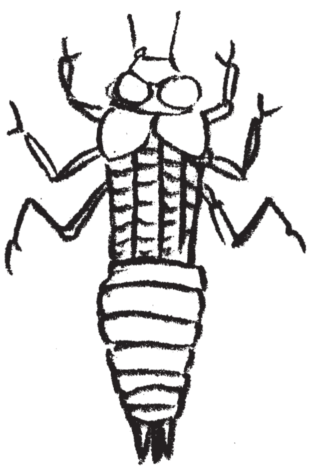

Dragonfly Nymph

Nature Interrupted – The Journey of AMD
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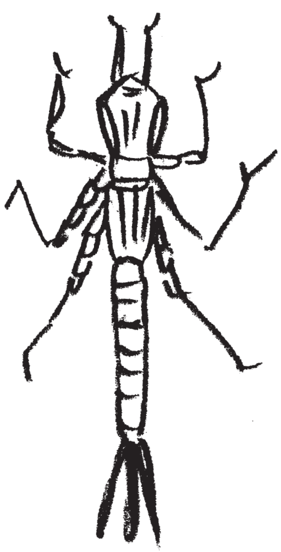

Damselfly Nymph

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
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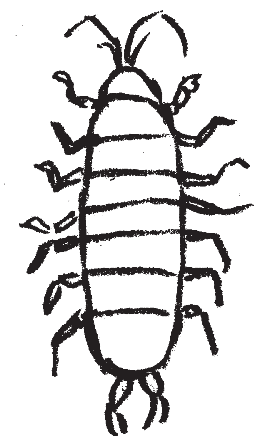

Sowbug

Nature Interrupted – The Journey of AMD
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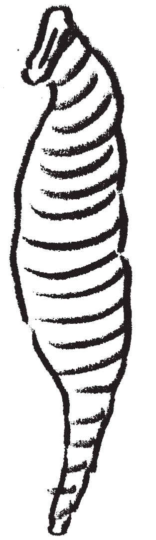
Macroinvertebrate Cards
Sheet B – Low Quality Stream



Leech

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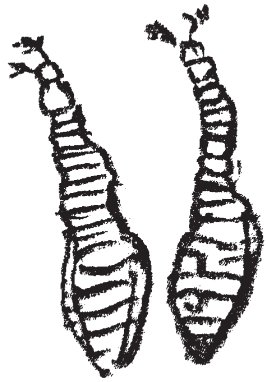

Blackfly Larva

Nature Interrupted – The Journey of AMD
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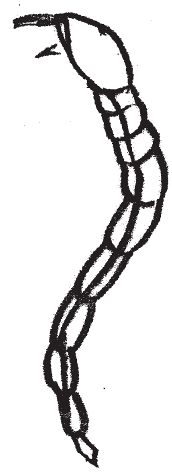
IMPACTING THIS STREAM?

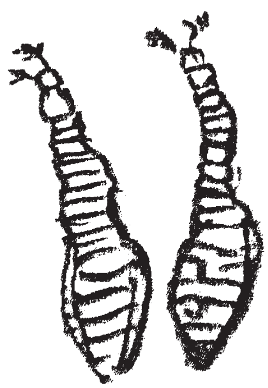


Midge Larva

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?

Flatworm

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?



Blackfly Larva

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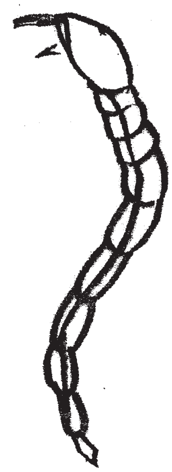

Midge Larva

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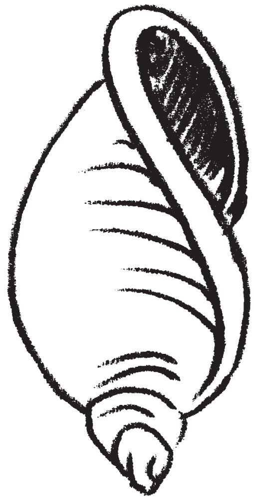
Macroinvertebrate Cards
Sheet B – Low Quality Stream



Pouch Snail

Nature Interrupted – The Journey of AMD
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Rat-Tailed Maggot Larva

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
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Pouch Snail

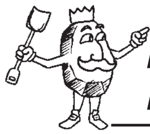
Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?

Rat-Tailed Maggot Larva

Nature Interrupted – The Journey of AMD
IS THERE MINE DRAINAGE
IMPACTING THIS STREAM?

Holy Macro Bingo

Beth Langham and Angela Belli, Saint Vincent College Environmental Education Center, Latrobe, PA
Leanne Griffith, Westmoreland Conservation District, Greensburg, PA
Nicki Foremsky, Penn State Cooperative Extension, Westmoreland County, PA
Kate Tantlinger, Kiski Conemaugh Stream Team, Johnstown, PA



About This Activity...

Prep Time Required:
30 minutes

Grade Level:
Elementary

Subjects:
Science

Duration of Activity:
45 minutes

Pennsylvania Standards Addressed:
3.1.3.A1, 3.4.3.B1, 3.1.4B5, 3.1.4.C1, 3.1.4.C2, 3.4.5.B1, 4.1.2.D, 4.5.1.C

Setting:
Classroom

Vocabulary:
Macroinvertebrate
Sensitive

Related Vocabulary:
Benthic
Facultative
Tolerant
Water quality indicator

Prerequisites: Conduct lesson plan "Macro Rummy"

Summary:
Students play bingo game to familiarize themselves with the bugs (macroinvertebrates) that live in streams. They are introduced to macros as indicators of water quality.

Materials:
- Blank macro bingo cards
- Macro card handouts for students to cut
- Teacher cards
- Bingo marking pieces (could be home-made or recycled pieces of candy, beans, beads, etc.)
- Scissors
- Glue sticks
- Macro sensitivity chart (for teacher's use)

Objectives:
Students will be able to:
- Define the term macroinvertebrate
- Recognize or identify macroinvertebrates found in aquatic ecosystems
- Recognize that certain species are used to indicate water quality.

Background:
Macroinvertebrates are insects that are very low in the food chain of an aquatic ecosystem. They eat algae, bacteria, fungus, organic material, and other insects. In turn, macroinvertebrates are eaten by fish, birds, and other larger aquatic animals. Macroinvertebrates also function to recycle nutrients and organic matter in their ecosystem. These aquatic insects can be helpful in determining the quality of a stream, because they can be classified according to their sensitivity to pollution. Thus the more **sensitive** species present the better the quality the water. Diversity is also important, so the greater number of species present, the better the quality of the water. Biomonitoring is the term that describes the study of macroinvertebrates to assess the health of a stream

To be used for biomonitoring, professionals, students, etc. must identify the invertebrates. Macroinvertebrates can be classified in many different ways. Macroinvertebrates can be classified by their taxa. This is a system of classification based on evolution, which has categories within categories. The specific taxa are: Kingdom, Phylum, Class, Subclass, Order, Family, Genus, and Species. Normally it is sufficient to classify only down to the Order to determine the health of the stream, but more intensive studies would classify macroinvertebrates down to the Species. Macroinvertebrates also have common names, for example we call insects from the order Plecoptera, Stoneflies.

Over years of study people have come up with a classification of the insects based on their pollution tolerance. Some aquatic insects are very sensitive to pollution, changes in their habitat, and natural disturbances, while others can withstand a certain amount of pollution or disturbance. Some insects thrive in polluted waters or otherwise low quality water. Different number systems have been invented which assign numbers to macroinvertebrates according to their pollution sensitivity. To give a stream a Water Quality Rating a sample of invertebrates is collected using a standardized methods. Then the insects are identified and scored. Finally a calculation is done which takes into account the pollution rating, number of species, and abundance of each species found.

Procedure:
Warm-up:
Students will learn what a macroinvertebrate is.

Activity:
Students will cut out and randomly place pictures of macroinvertebrates onto their bingo (MACRO) cards. Students will mark their bingo spaces with chips/holders/beans, etc.

Teacher holds up a card and reads the name of the macro (similar to saying b-1, teacher will say “mayfly nympth). Teacher cards could be made into overheads to help show the card that was called.

When student gets 5 in a row, student yells MACRO! for bingo.

Game could be over or the health of the stream could be determined based on sensitivity of macros in the bingo row.

Wrap-up/Conclusion:

Talk about sensitivity of macros and how they are used as indicators. Have each student add up points for entire card and determine quality. Use sensitivity chart for discussion.

Teacher should explain that in order to evaluate a stream, you need hundreds of macros instead of just 5 from bingo.

Assessment:

- Identification quiz ….teacher holds up card and students have to write down or orally name the correct macro. for advanced, identify sensitivity of macro as well.

Adaptations:

Could be used as a matching game with just pictures of macros for younger students. Assign point values to determine the stream quality of your bingo line.

Save macro bingo cards to re-use at a later date.

Instead of naming macro, describe what it does. (ex. This bug only eats when it is a larvae and does not eat as an adult. cranefly larvae).

Resources:

Wonderful Wacky Water Critters
University of Wisconsin - Extension
Extension Publications
45 N. Charter Street
Madison, WI 53715

Key to Macroinvertebrate Life
PA Fish and Boat Commission
UWEX Environmental Resource Center
Developed by the University of Wisconsin - Extension in cooperation with the Wisconsin Department of Natural Resources

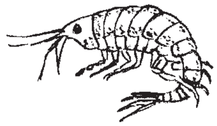
Macro Bingo Card

M	A	C	R	O

Macro Name	Sensitivities		
	Tolerant	**Facultative**	**Sensitive**
Alderfly Larva		X	
Amphipod or scud		X	
Backswimmer	X		
Blackfly Larva	X		
Caddisfly Larva			X
Cranefly Larva		X	
Crayfish		X	
Damselfly Nymph		X	
Dobsonfly or Fishfly Larva		X	
Dragonfly Nymph		X	
Fishing Spider			X
Giant Water Bug	X		
Gilled Snail			X
Isopod or Aquatic Sowbug		X	
Leech	X		
Mayfly Nymph			X
Midge Larva	X		
Planaria or Flatworm	X		
Predaceous Diving Beetle		X	
Rat Tailed Maggot Larva	X		
Riffle Beetle		X	
Stonefly Nymph			X
Water Boatman	X		
Water Mite	X		
Water Penny		X	
Water Scorpion	X		
Water Strider	X		
Whirligig Beetle		X	

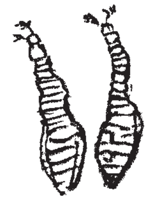
Macro Bingo Card Handouts

Alderfly Larva

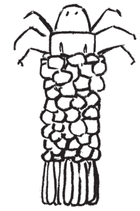


Amphipod or scud

Backswimmer



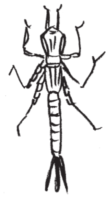
Blackfly Larva



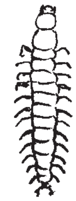
Caddisfly Larva

Cranefly Larva

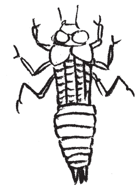
Crayfish



Damselfly Nymph



Dobsonfly or Fishfly Larva

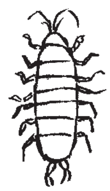


Dragonfly Nymph

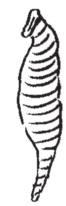
Fishing Spider

Giant Water Bug

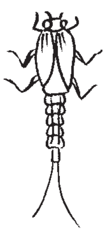
Gilled Snail



Isopod or Aquatic Sowbug



Leech



Mayfly Nymph

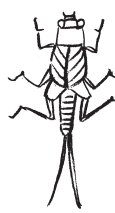
Midge Larva

Planaria or Flatworm

Predaceous Diving Beetle

Rat Tailed Maggot Larva

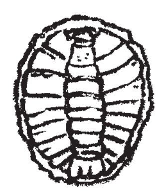
Riffle Beetle



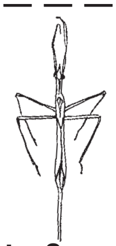
Stonefly Nymph

Water Boatman

Water Mite



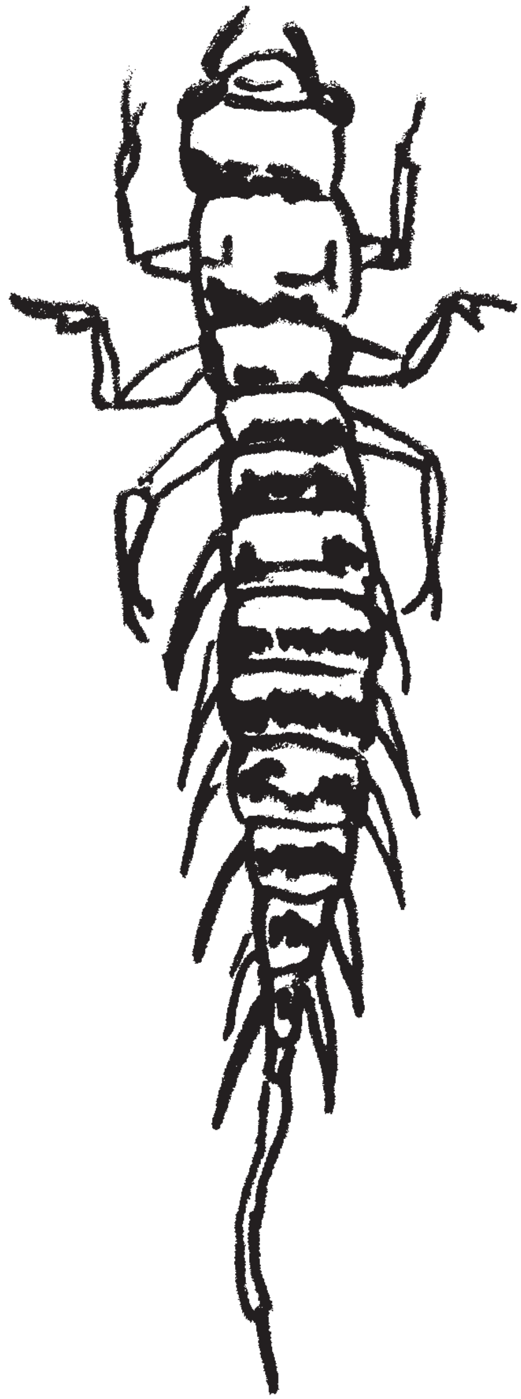
Water Penny



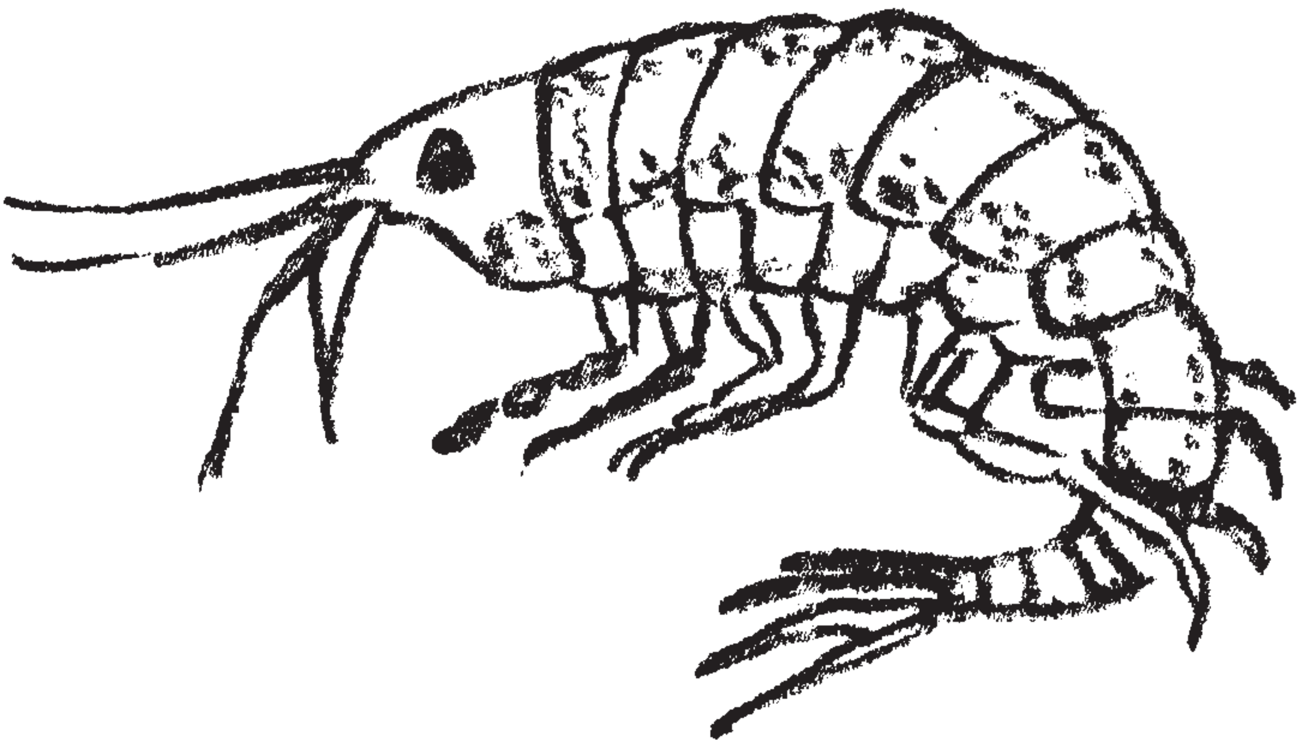
Water Scorpion

Water Strider

Whirligig Beetle



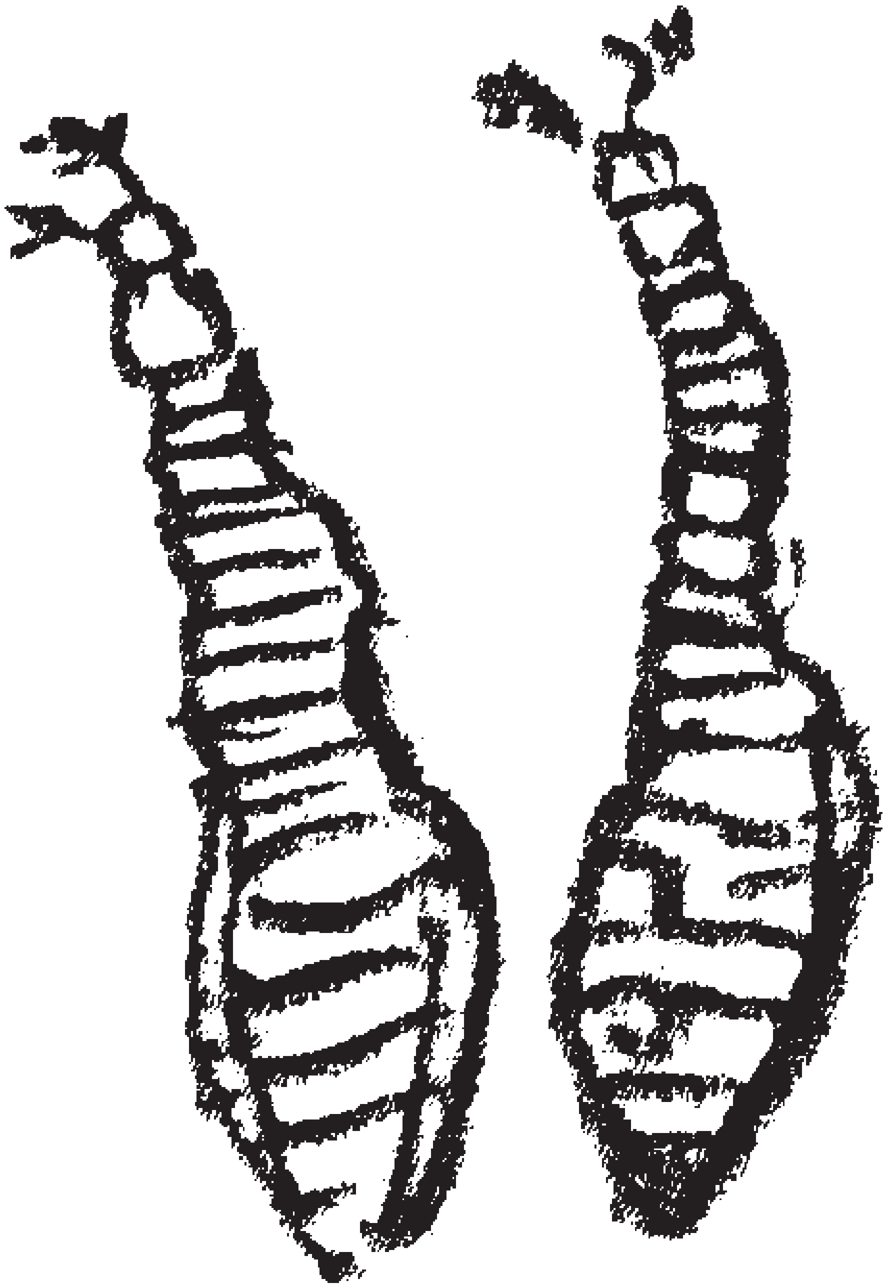
Alderfly Larva



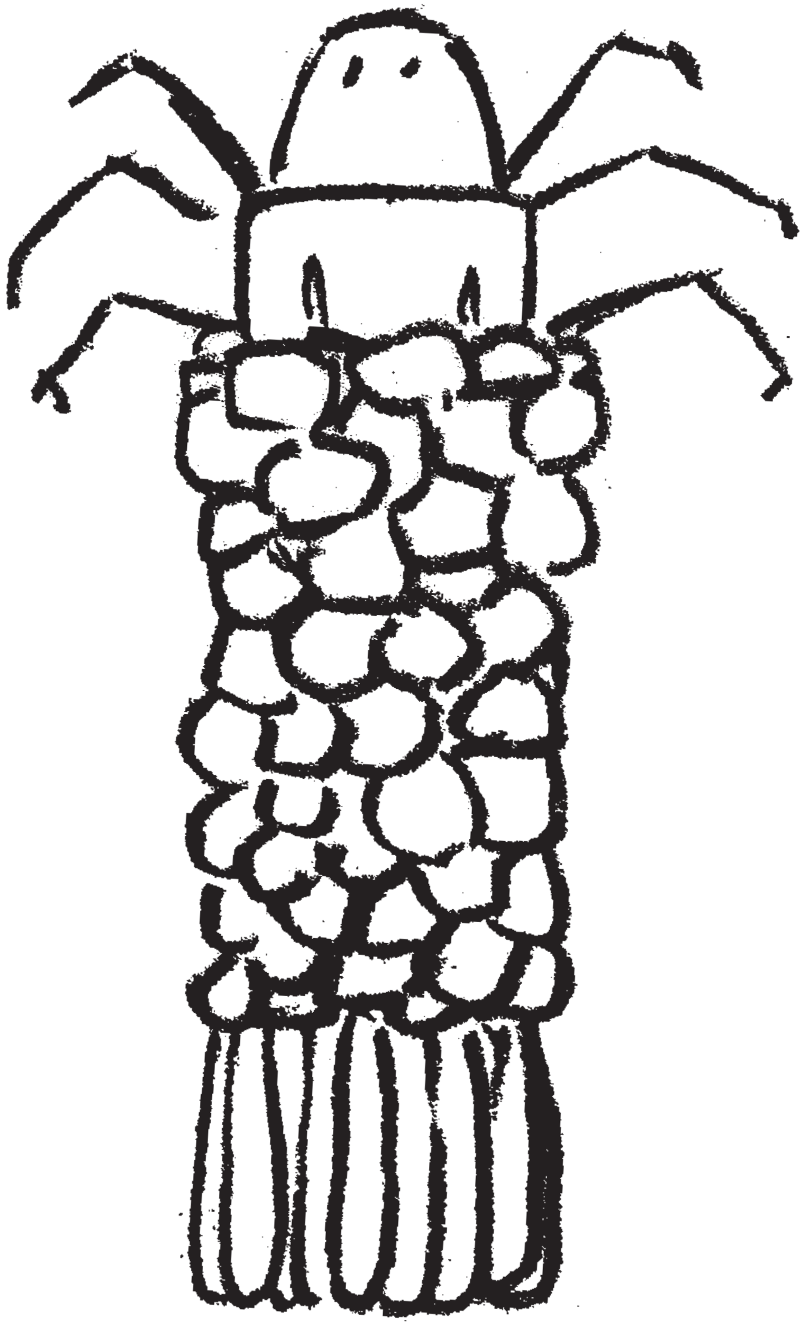
Amphipod or scud

Macro Bingo Teacher Cards

Backswimmer



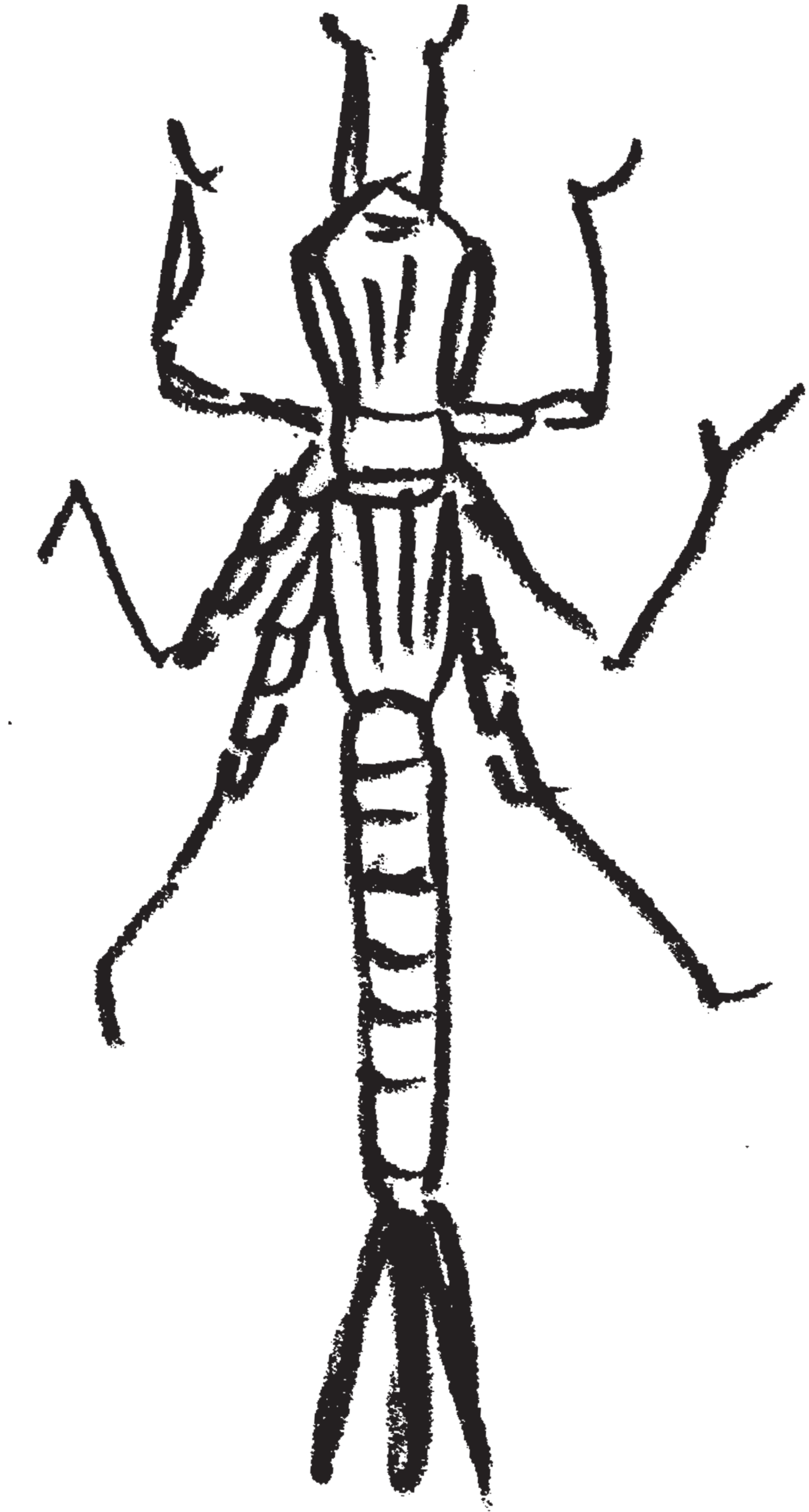
Blackfly Larva



Caddisfly Larva

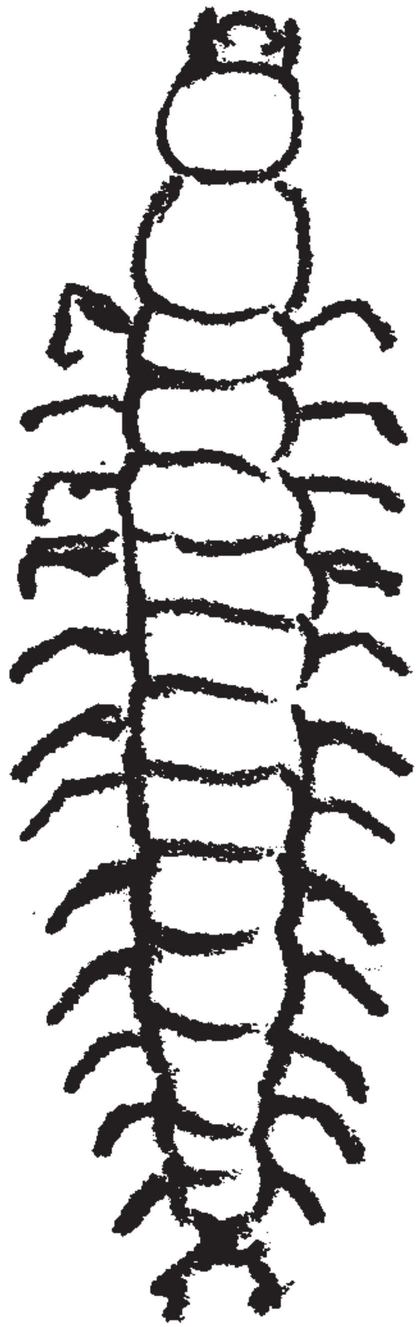
Cranefly Larva

Crayfish



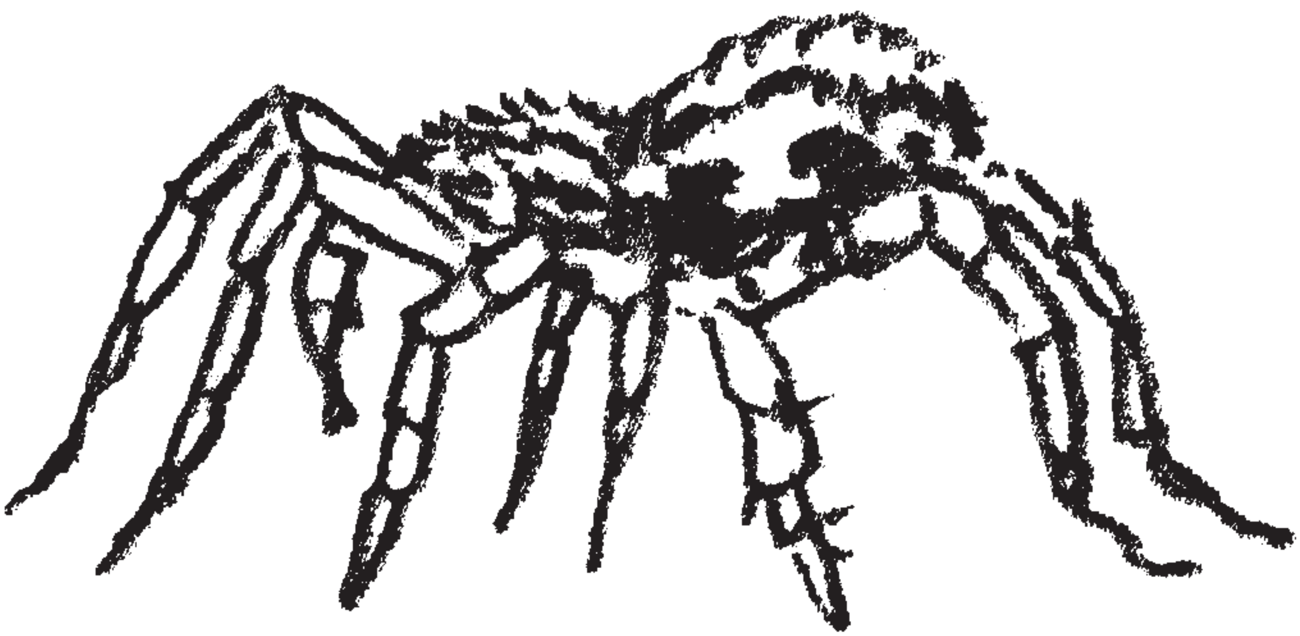
Damselfly Nymph

Macro Bingo Teacher Cards

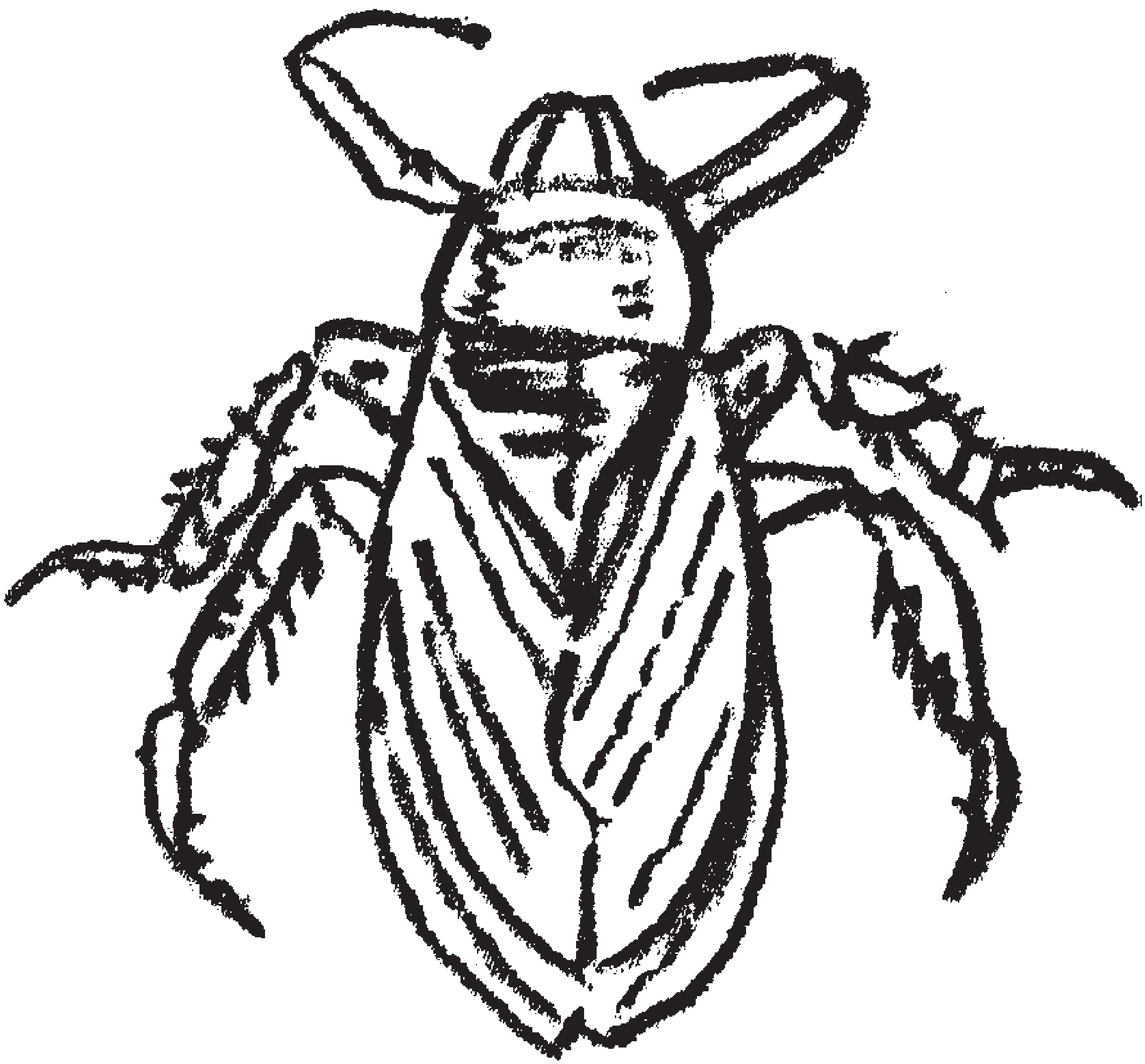


Dobsonfly of Fishfly Larva

Dragonfly Nymph

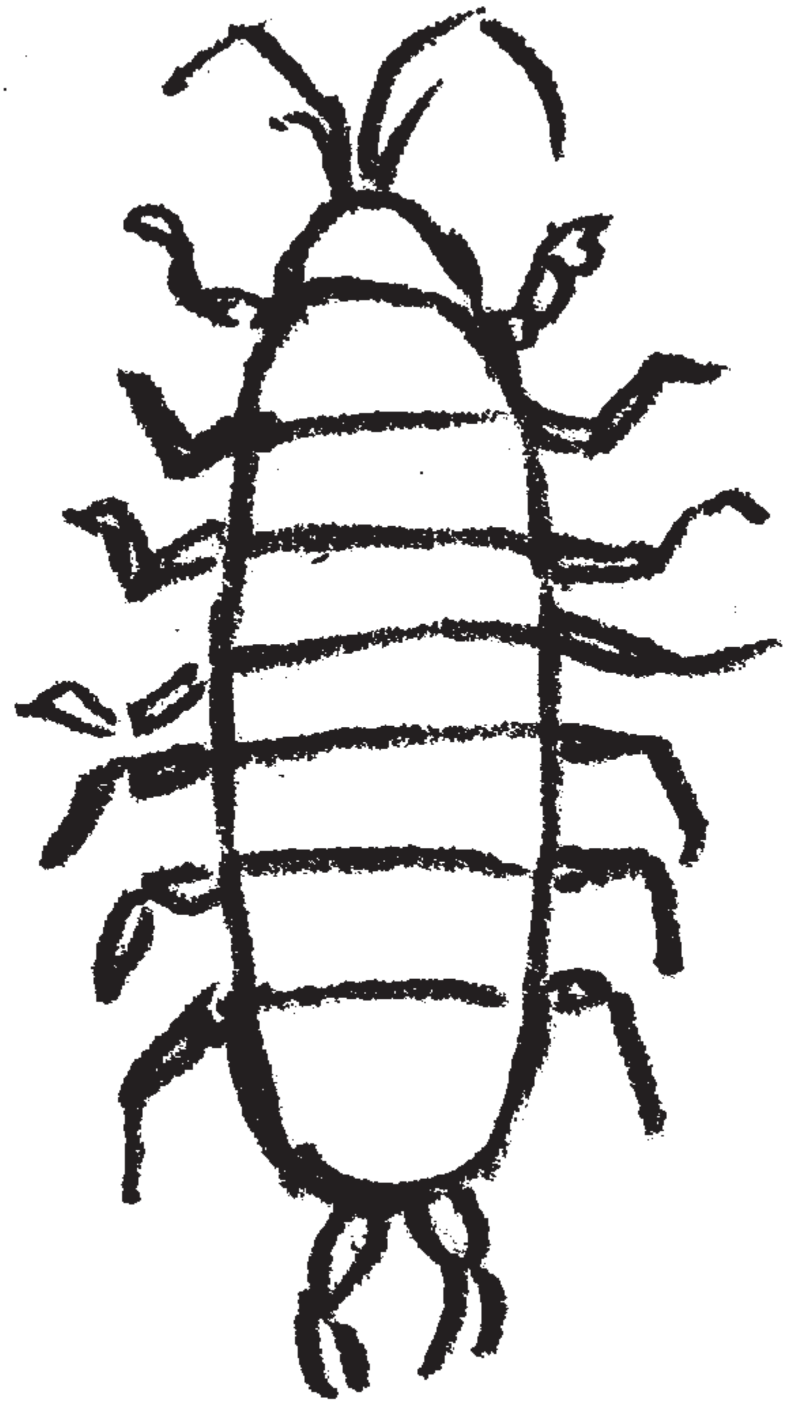


Fishing Spider

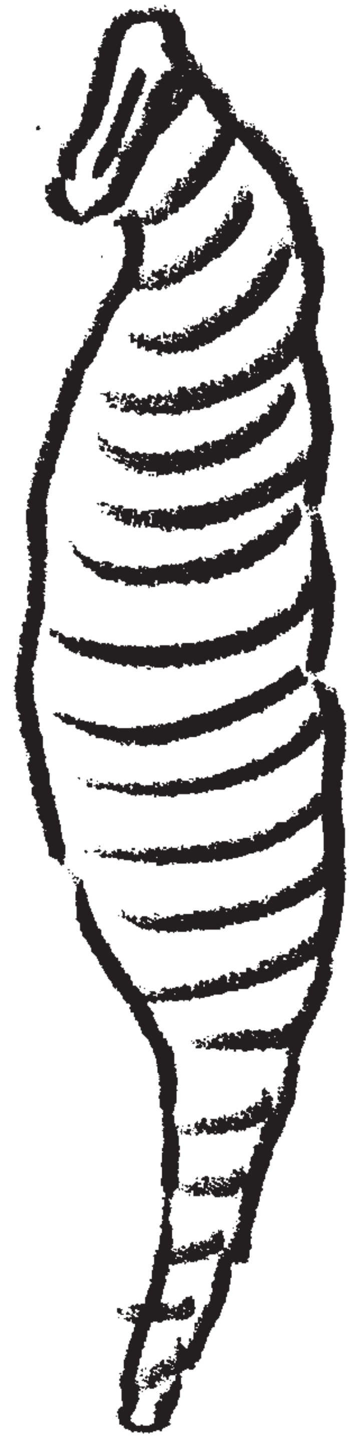


Giant Water Bug

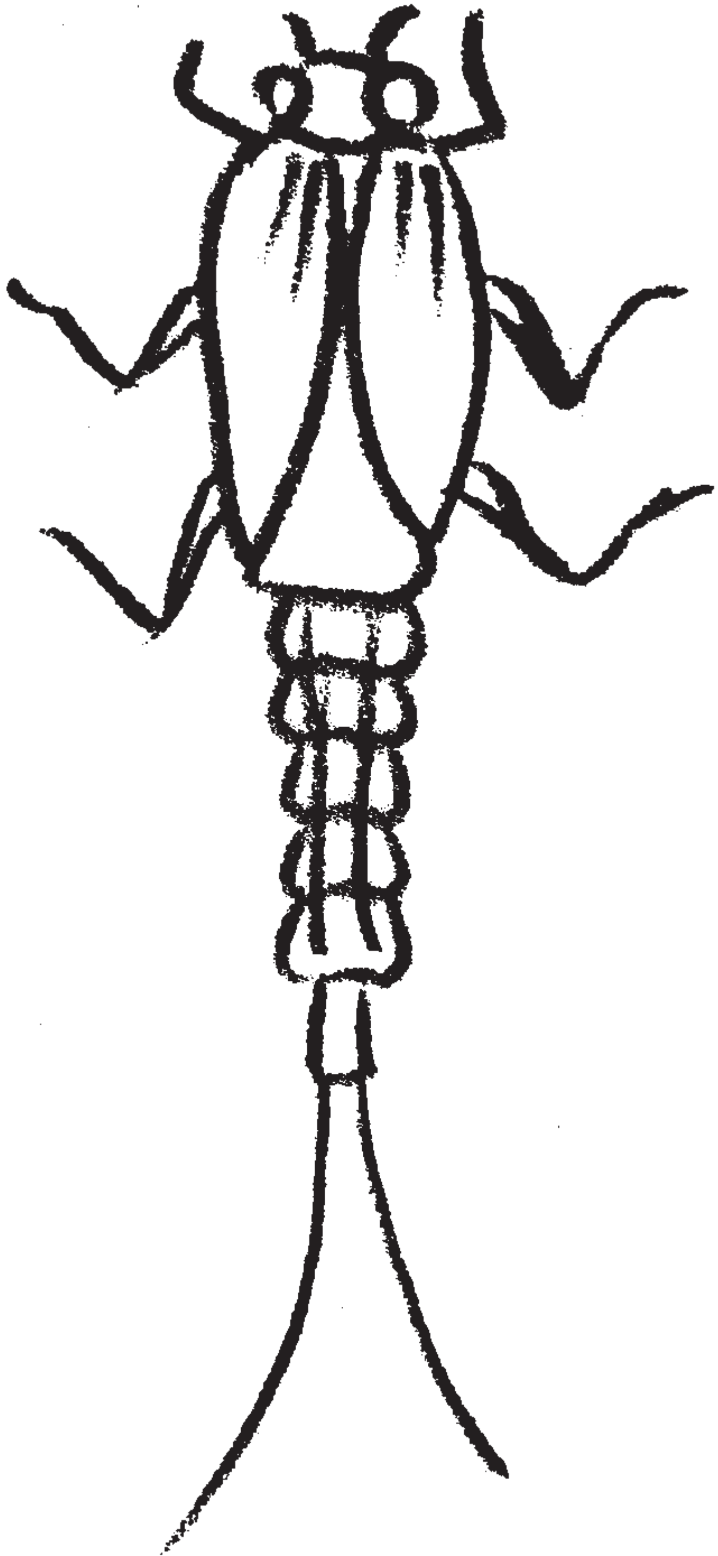
Gilled Snail



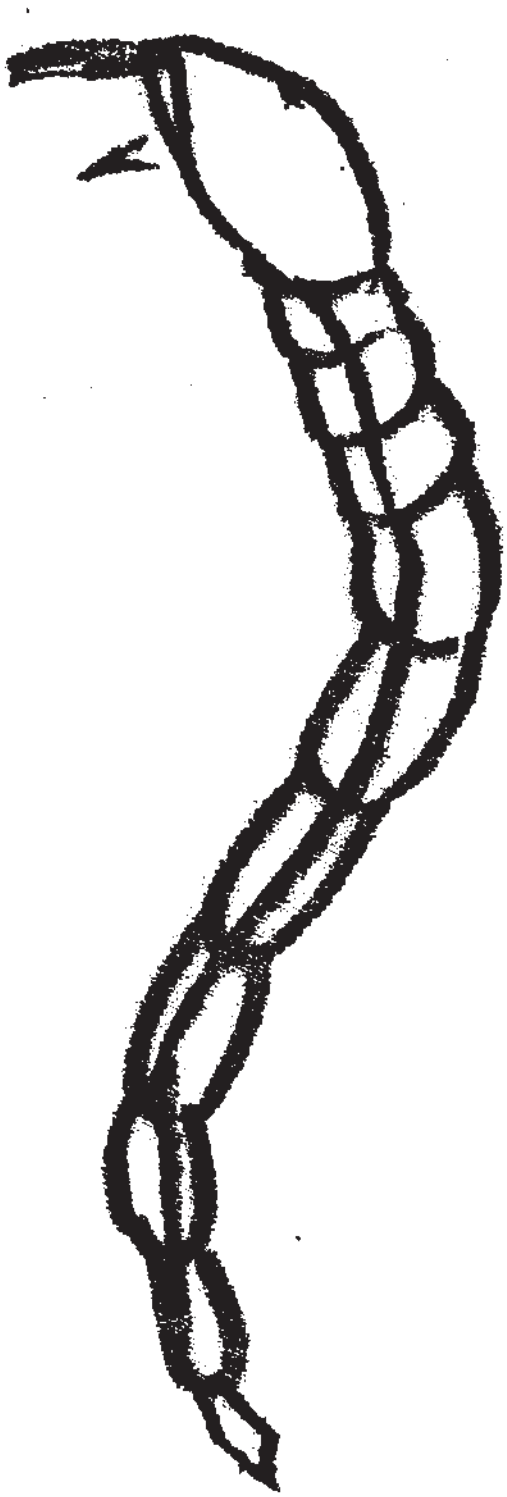
Isopod or Aquatic Sowbug



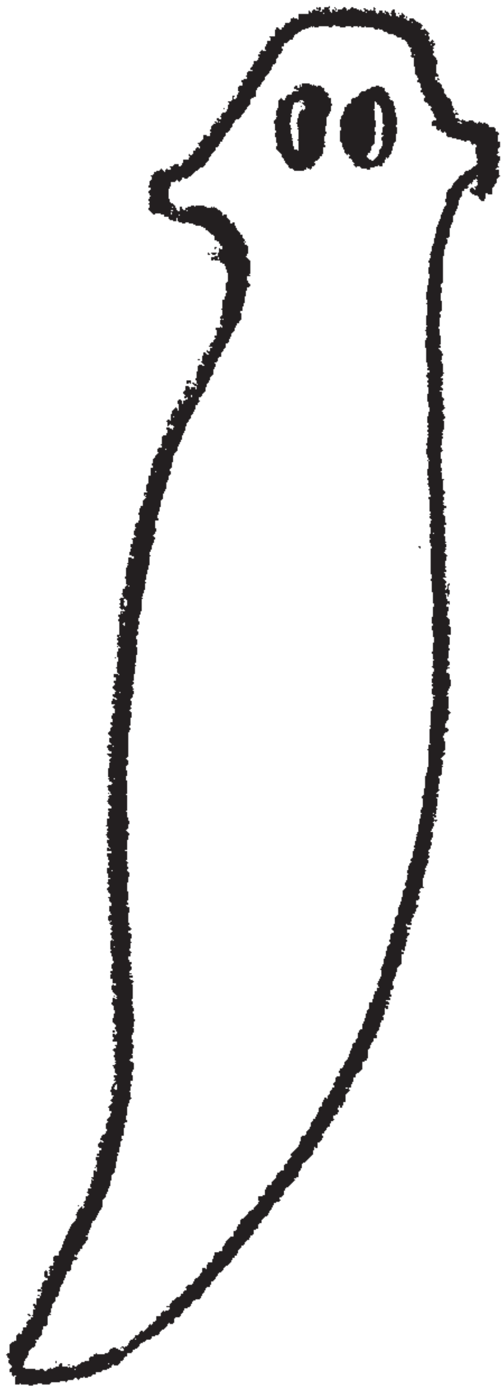
Leech



Mayfly Nymph

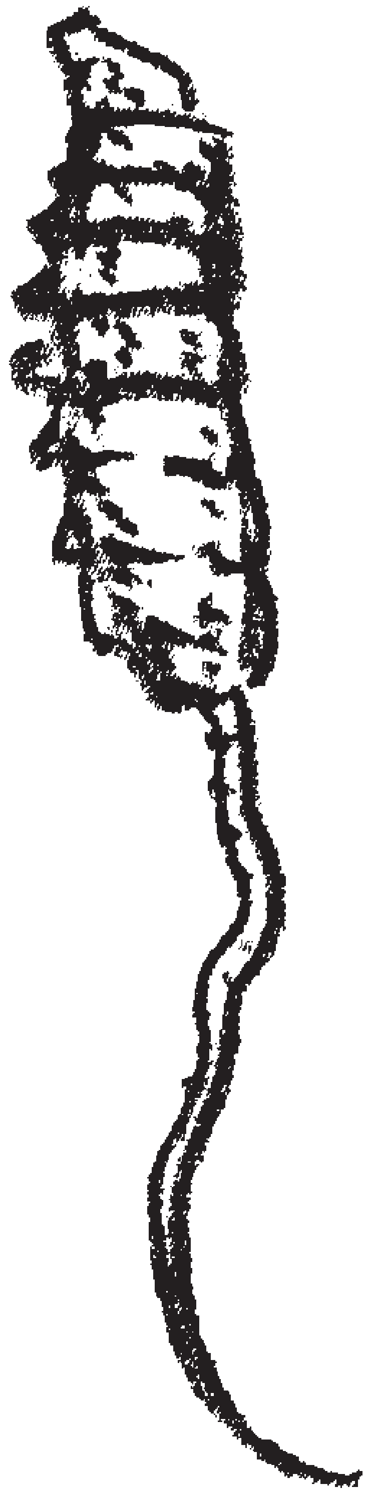


Midge Larva

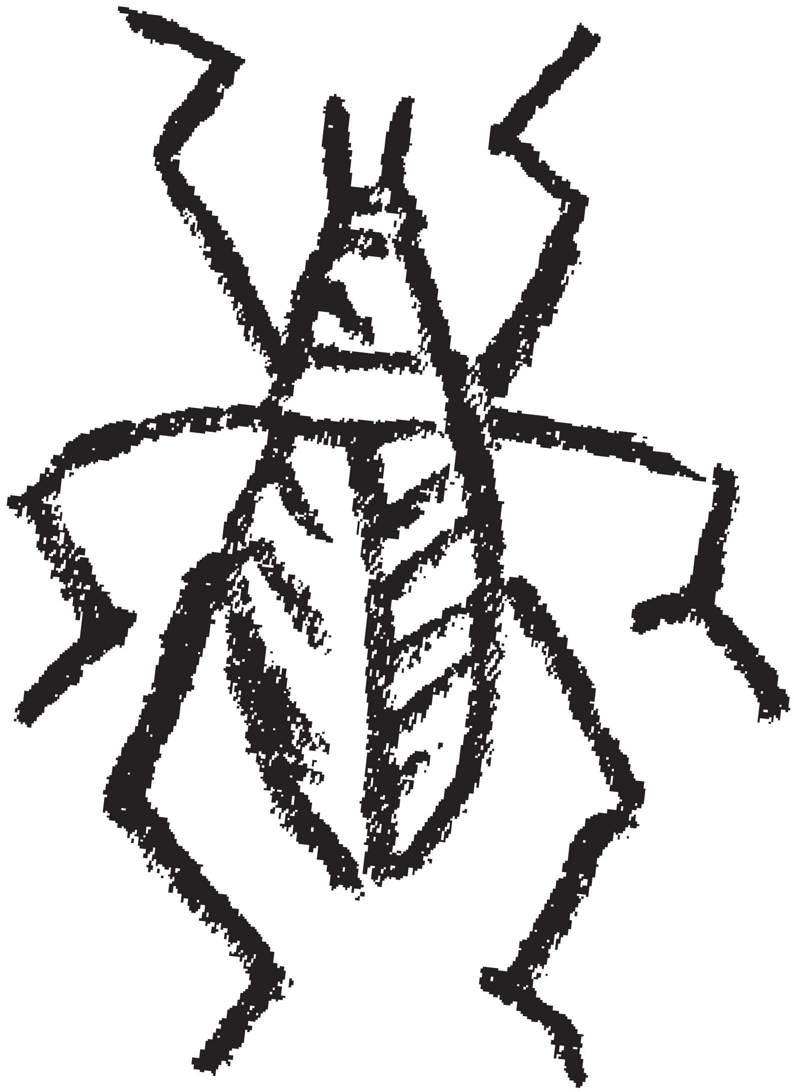


Planaria or Flatworm

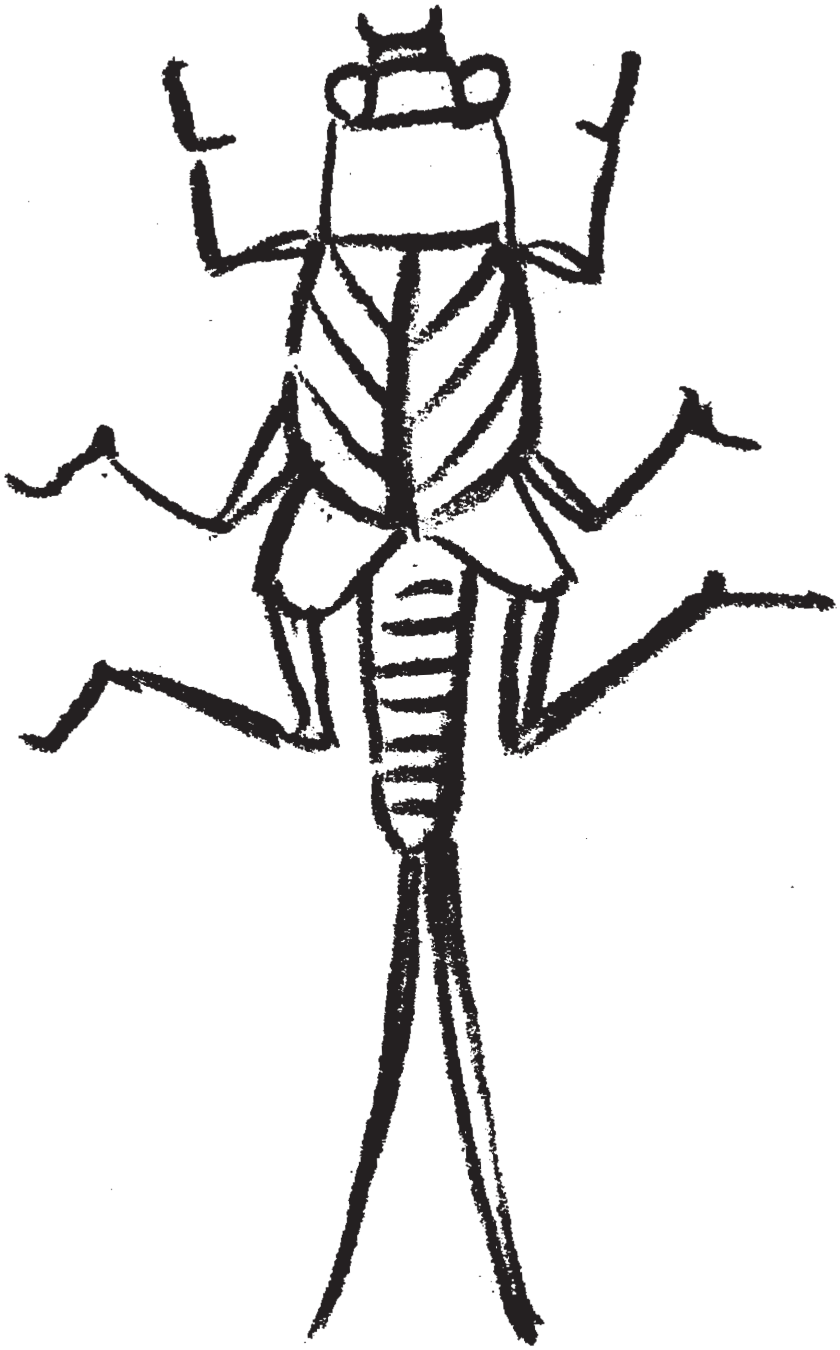
Predaceous Diving Beetle



Rat Tailed Maggot Larva

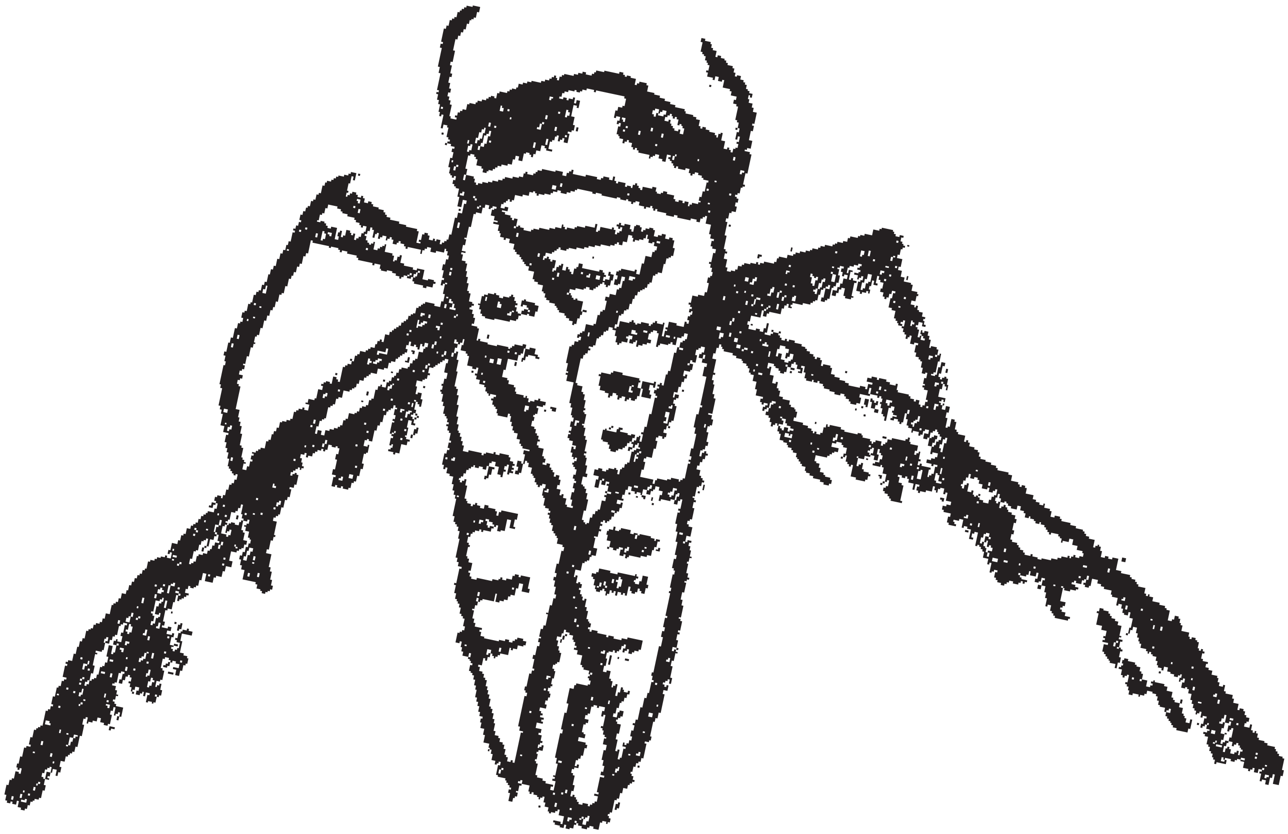


Riffle Beetle



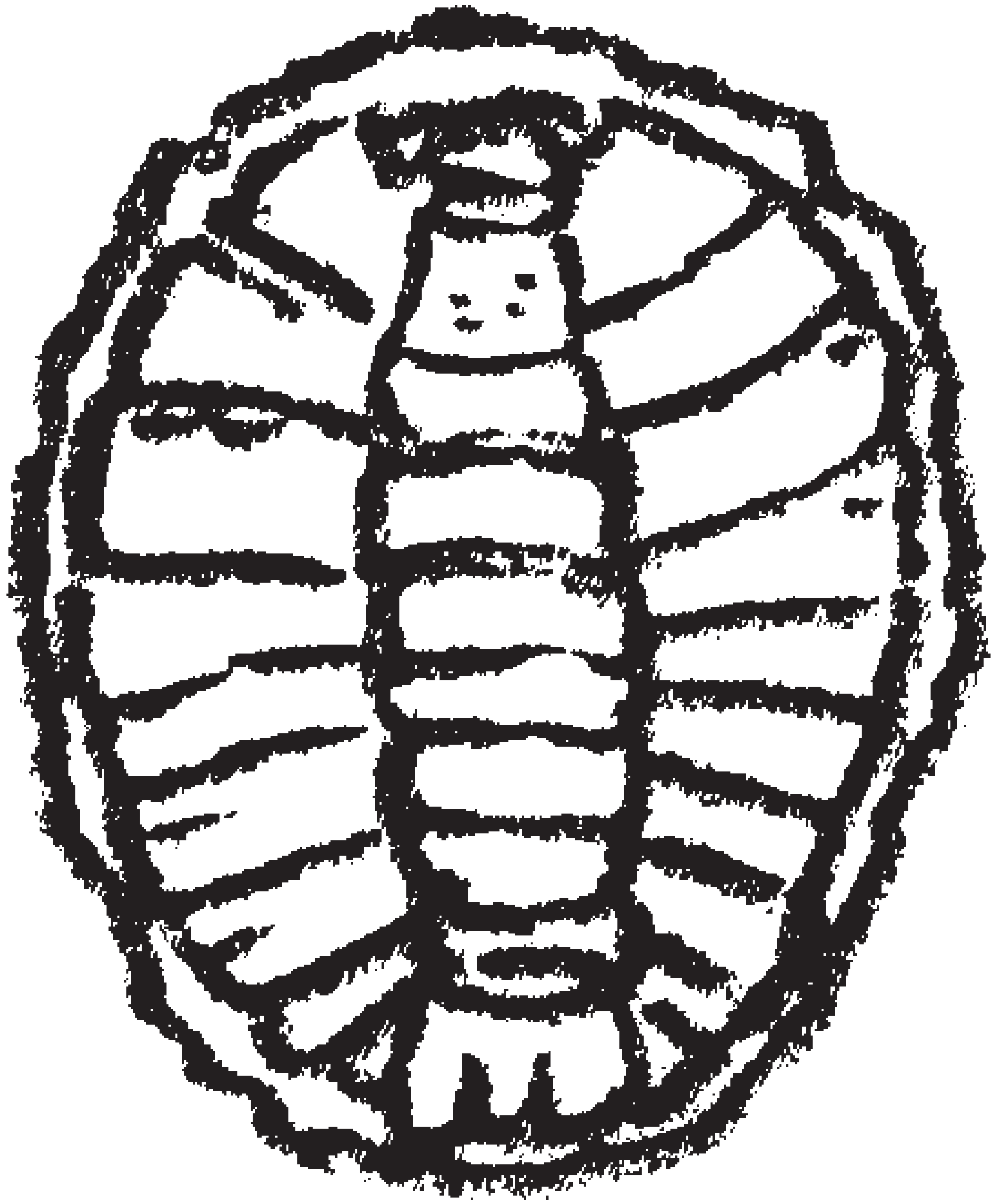
Stonefly Nymph

Macro Bingo Teacher Cards

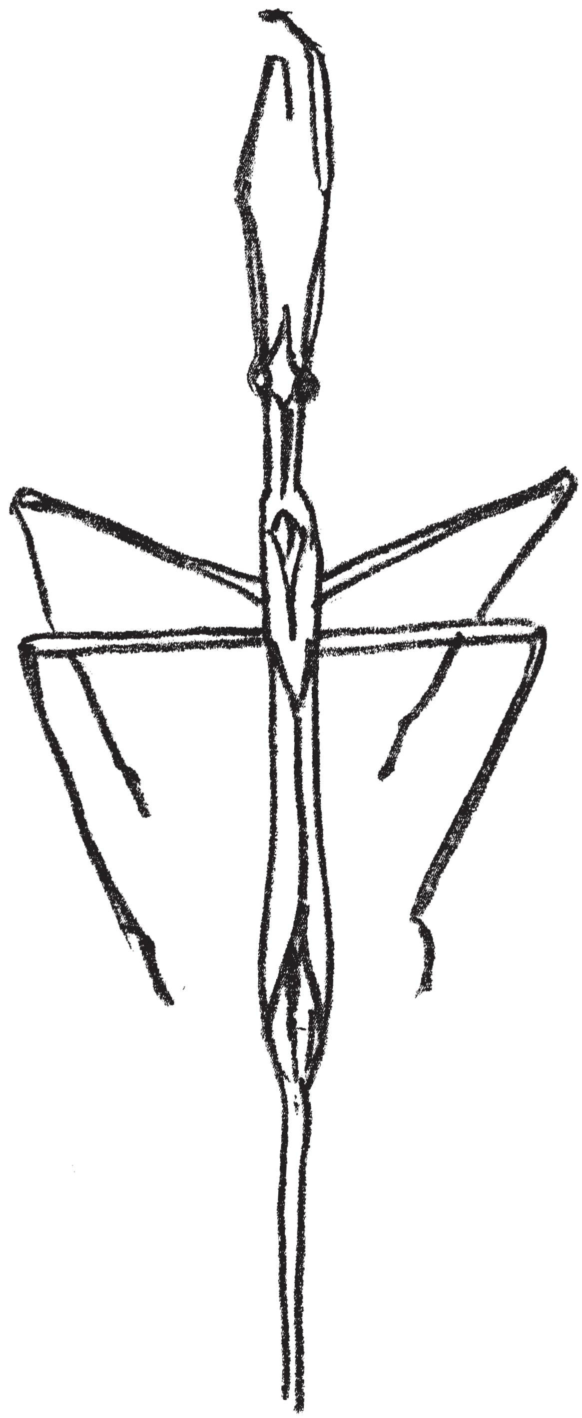


Water Boatman

Water Mite

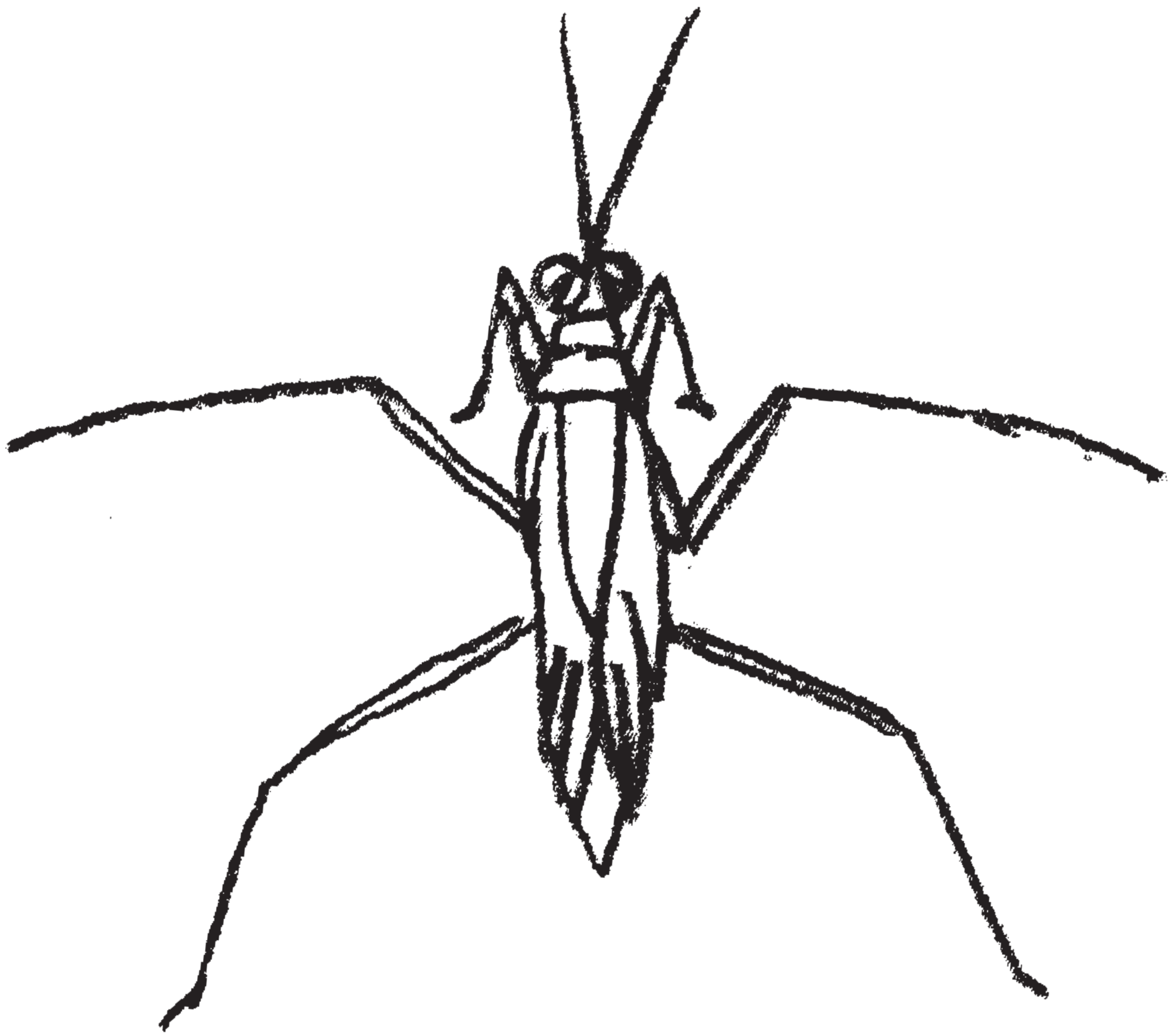


Water Penny

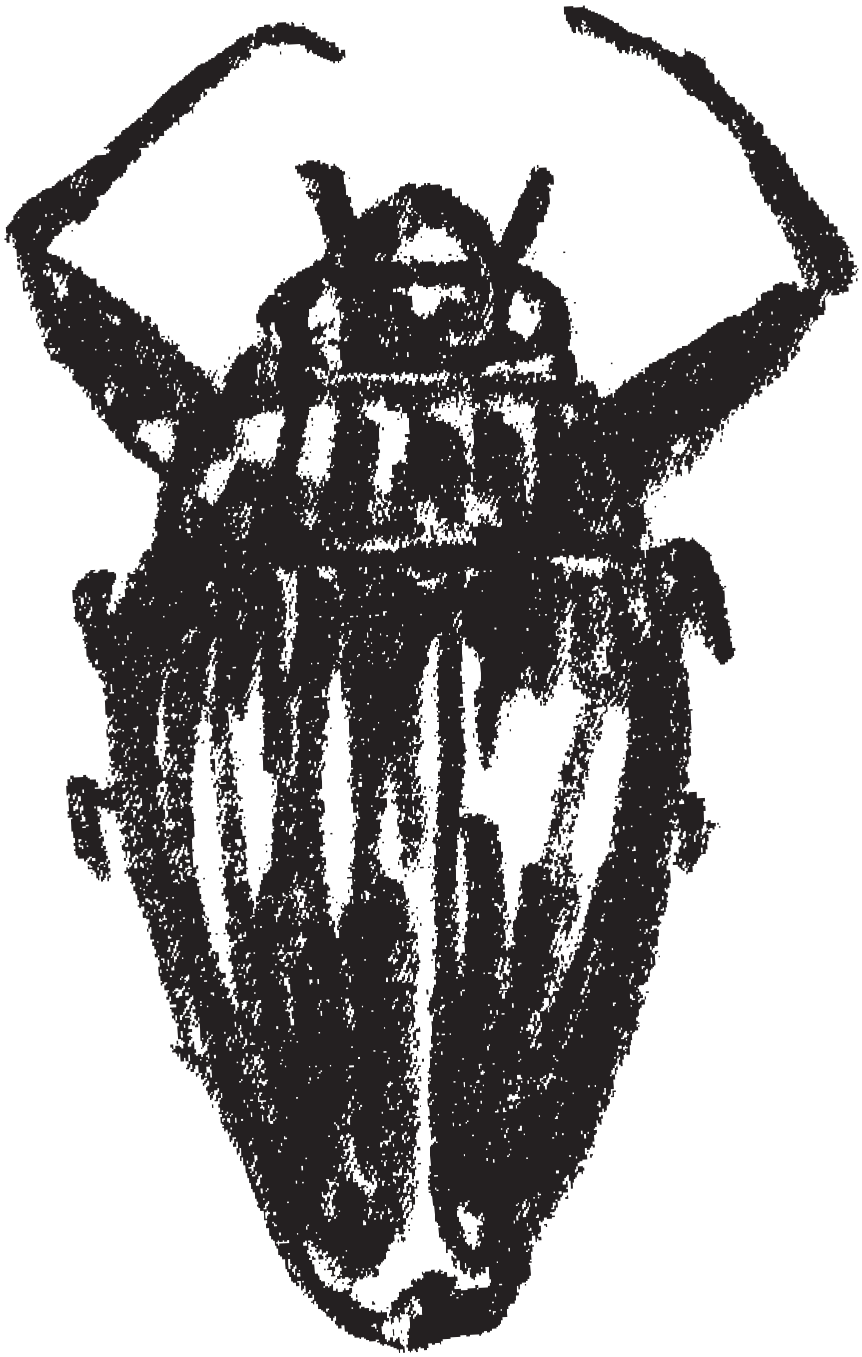


Water Scorpion

Macro Bingo Teacher Cards

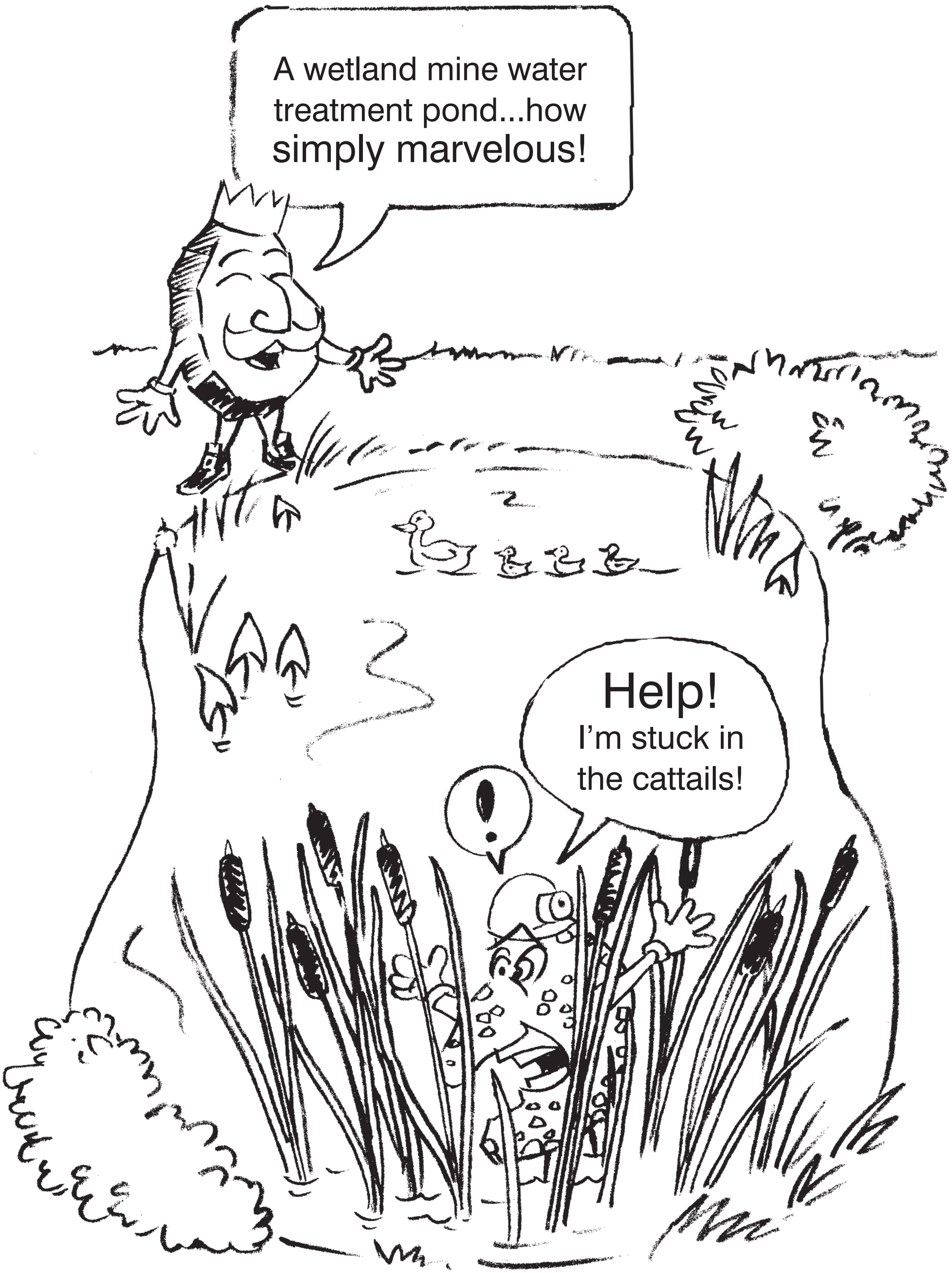


Water Strider



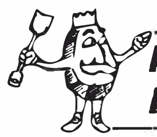
Whriligig Beetle

Reconstructing Nature



Iron Clad Memory

Developed by Laura Riddle, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
1 hour

Grade Level:
Elementary

Subjects:
Science

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
3.4.5.B2, 4.5.2.C

Setting:
Classroom

Vocabulary:
Acidic
Basic
Insoluble
pH
Precipitate
Solution

Prerequisites:
Knowledge of matching, elementary science

Summary:

Students play a game of memory, which identifies some methods in which iron is removed from abandoned mine drainage (AMD).

Materials:

- 4 sets of memory cards (cards attached): 30 iron (orange cards), 10 plants (green cards), 10 oxygen (white cards), 10 pH (blue cards)– Note: Cards require gluing. Each memory card should be backed with a blank white card or white memory card.
- Mine water
- Tap water
- Flask
- Jar or beaker
- Hydrogen peroxide
- 2 clear glasses
- Sugar
- Glue

Objective:

Students will be able to:

- list materials needed to remove iron from mine water.
- explain how iron can be removed from mine drainage.

Background:

Water seeping from an underground coal mine or running over a strip mine is referred to as abandoned mine drainage (AMD). This water can contain dissolved iron, sulfur, aluminum, manganese, and be **acidic or basic**. When mine water comes in contact with oxygen at the surface, a series of reactions occur converting iron and other metals into metal oxide **precipitates**, or solids, that are **insoluble**. The particles of various metal oxides coagulate and eventually sink to the bottom of the **solution**, or stream.

Iron oxide is a major metal oxide pollutant from AMD contaminating many streams in the area. In order for the dissolved iron to be converted into iron oxide, a few essential ingredients are required. First, oxygen needs to be present. The iron and oxygen react chemically to form the iron oxide precipitate. Next, the **pH** of the water must be near neutral, or 7, in order for the iron oxide to become insoluble. After the compound forms, individual iron molecules clump together and stick to other particles until the iron oxide becomes so heavy that it sinks to the bottom of the stream bed. The iron oxide can also stick to plants, animals, rocks, etc. near the stream.

This activity mimics how oxygen, pH, plants, and other iron oxide molecules aide in precipitating dissolved iron out of solution.

Procedure:

Warm-up:

Demonstrations:

a. Obtain a color photograph of a stream polluted with mine drainage and show to the students. Photographs located on CD or the AMDEC website.

b. Solution – Have two glasses, or beakers, filled with water. Pour some sugar into the water and stir until dissolved. Ask the students if they can see the sugar? Explain that the sugar molecules are mixed in with the water molecules. It is difficult to see the sugar molecules because there are so many water molecules.

c. Precipitation – Obtain a sample of mine water from a polluted stream or by contacting your local watershed office. Put the water into a glass flask, beaker, or jar. Ask the students to compare the mine water with the plain water and the sugar water. Have the students smell the solutions (by wafting). Discuss the differences. The smell of the mine drainage comes from sulfur. Next, pour some hydrogen peroxide into the mine water. A reaction has taken place and a precipitate has formed. The precipitate is visible by the cloudiness, or turbidness, of the water, as well as the color of the water. Allow the solution to sit untouched for a couple of hours. Later, have the students examine the beaker and note how the precipitate is at the bottom of the flask. The flask can be shaken again and the precipitate will settle again to show how the precipitate is insoluble.

Activity:

Objective:

To collect as many pairs as possible. This memory game identifies some materials that can remove iron from AMD. Plants (green cards), oxygen (white cards), and a neutral pH (blue cards) all are items that can potentially remove the iron. Matching the iron (orange cards) with any other color card represents this material removing iron from the water.

To play, divide the class into 4 groups and arrange the cards in a single layer face down. Have the first player turn over two cards. If the player has a match, he/she puts the match aside and picks up two or more cards. The same player continues until a match is not picked. Then the player to the left takes a turn. After all of the cards are used, the game is over and the player with the most matches wins.

Wrap-up/Conclusion:

At the conclusion of the game, the players should explain how one of his/her matches demonstrates how iron is removed from AMD. For example, an orange/green match shows iron particles sticking to plants.

Assessment:

- Each student should be able to explain one of the three things needed to remove iron from AMD.

Extensions:

- Have students draw pictures of plants and animals they might find in a wetland.

Adaptations:

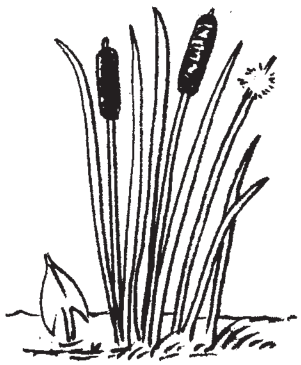
For older students, when they get a match, have them give an example and explain why that term is related to AMD.

Memory Cards

MEMORY	MEMORY	MEMORY
MEMORY	MEMORY	

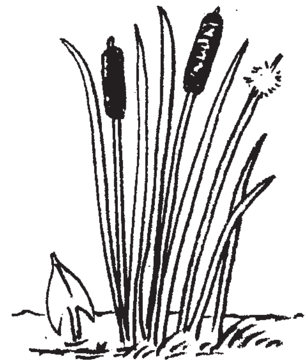
Note for Teachers:
All other cards (ie. plants, pH, oxygen, and iron) should be backed up with this card.

Memory Cards



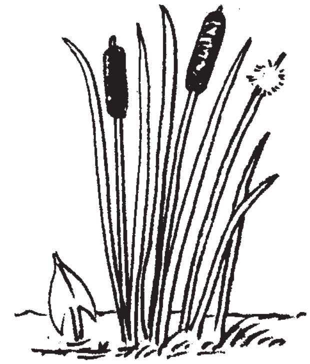
PLANTS

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



PLANTS

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



PLANTS

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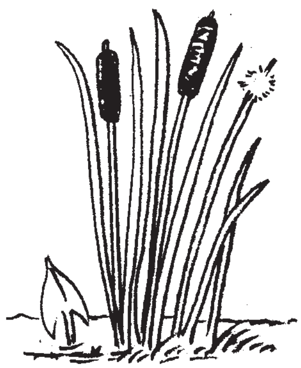
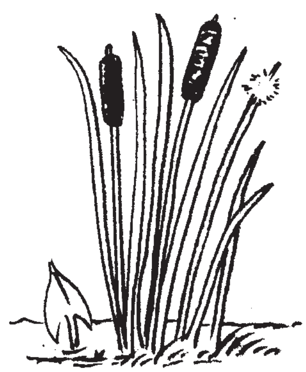
IRON CLAD MEMORY



PLANTS

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



PLANTS

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

Memory Cards

ACID	pH 1	
ACID	pH 2	Lemon Juice
ACID	pH 3	Vinegar
ACID	pH 4	Tomato Juice
ACID	pH 5	Black Coffee
ACID	pH 6	Milk
NEUTRAL	pH 7	Pure Water
BASE	pH 8	Baking Soda
BASE	pH 9	Antacid
BASE	pH 10	Hard Soap
BASE	pH 11	Ammonia
BASE	pH 12	
BASE	pH 13	
BASE	pH 14	Lye

pH

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

ACID	pH 1	
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ACID	pH 4	Tomato Juice
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pH

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

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pH

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

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pH

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

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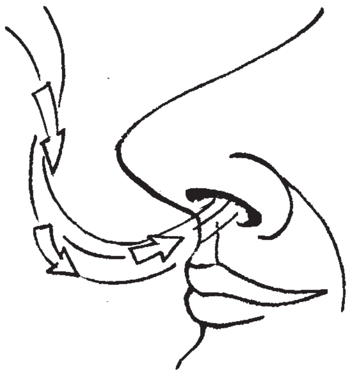
pH

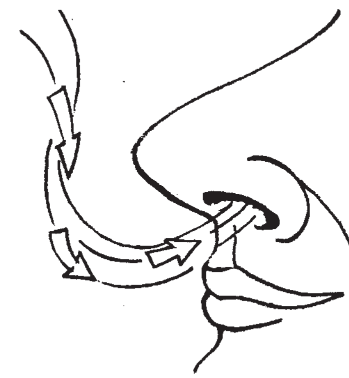
Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

Memory Cards



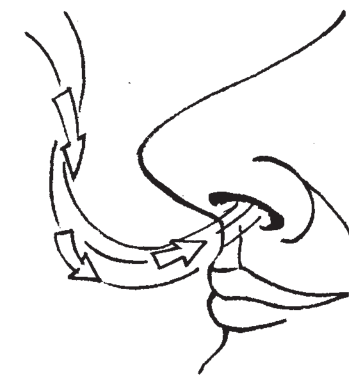
OXYGEN

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



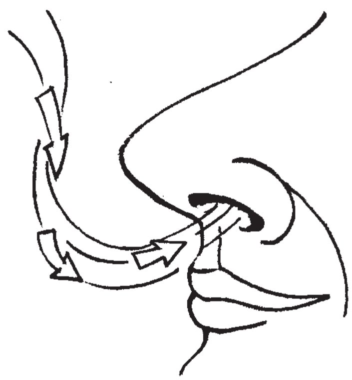
OXYGEN

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



OXYGEN

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



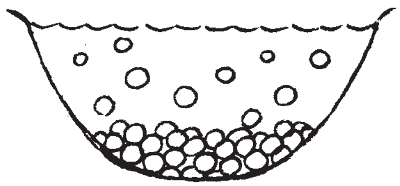
OXYGEN

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

OXYGEN

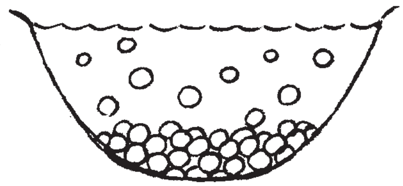
Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

Memory Cards



IRON

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



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Nature Interrupted – The Journey of AMD
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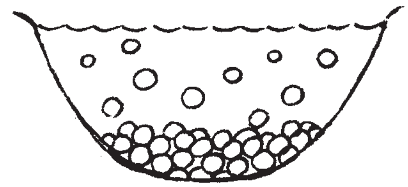
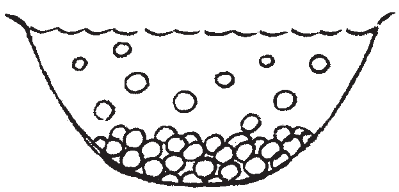


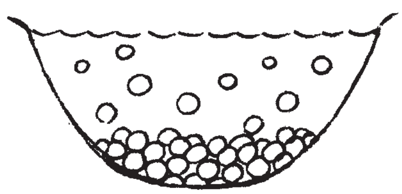
IRON

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY



IRON

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

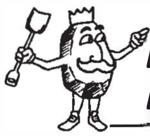


IRON

Nature Interrupted – The Journey of AMD
IRON CLAD MEMORY

The Impact of Conserving Our Limited Resources

Adapted from from Agriculture Awareness Foundation of PA- Pennsylvania Ag in the Classroom.
Developed by Leanne Griffith, Westmoreland Conservation District, Greensburg, PA



About This Activity...

Prep Time Required:
5 minutes

Grade Level:
K-8

Subjects:
Environment and Ecology

Duration of Activity:
10 minutes

Pennsylvania Standards Addressed:
3.4.4.E2, 4.3.K.B, 4.4.3.B, 4.3.4.A, 4.4.7.A, 4.4.7.B

Setting:
Classroom

Vocabulary:
Conserve
Preserve

Prerequisites:
None

Summary:

The teacher will use an apple to demonstrate to students the small percentage of the earth that is available to grow food on to feed more than 6 billion people each day.

Materials:

- Apple
- Cutting board
- Knife

Objectives:

Students will be able to:
- Learn the importance of conserving the natural resources on earth.

Background:

Each of us consumes natural resources. Our day-to-day activities depend on the food, energy and materials we take from the earth. The water we drink and the air we breathe are vital to our health. Fuel for our transportation and metal, stone and lumber for our buildings come from the earth. The electricity that lights up our homes, the power to heat and cool our homes…these things come from natural gas and oil pumped out of the ground, coal stripped from mines and the dams on our rivers.

All of these things lead to our dependence on nature, which puts a heavy burden on the environment. Some of us take these things for granted. It is important for us to understand where our privileges come from and how we can use these natural resources wisely. We should take only what we need and reuse whenever we can. We should try to prevent ecological damage from occurring and fix what has already taken place.

Procedure:

1. Cut an apple into quarters
   a. 3/4 of apple is water
   b. 1/4 is land to live on
2. Cut 1/4 of apple into quarters
   a. 1/4 is desert
   b. 1/4 is mountains
   c. 1/4 is too cold—tundra
   d. 1/4 is to live on
3. Cut one of these quarters into quarters again.
   a. 1/4 is too swampy
   b. 1/4 is too dry
   c. 1/4 is too rocky or steep
   d. 1/4 is to live on
4. Peel the last piece
   a. The piece of apple left represents land that is too sandy, too fragile (rainforest) or has been paved over
   b. The piece of peel that is left represents the amount of land that is available for producing food for the people of the world
   c. That is why preserving the world's top soil is so important

Warm-up:

Discuss the difference between **conserve** and **preserve**.

Activity:

Using an apple to represent the world, follow the steps to demonstrate the importance of taking care of land.

Wrap-up/Conclusion:

After the demonstration with the apple has been completed, discuss with students why it is important for all people to use natural resources wisely. Ask students for ideas on what they can do to help conserve our natural resources.

Assessment:

- Following wrap-up and conclusion, ask students to express what they learned about why it is important to take care of the land and water. This could be done in quiz or essay format.

Adaptations:

A similar experiment/demonstration can be done using ¾ wedge of an apple that demonstrates only 1% of the water on earth is potable.

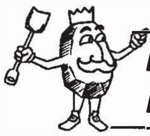
Resources:

Ag Awareness Foundation of PA

Pennsylvania Ag in the Classroom
Project Food, Land & People

Exploring the Process of Sedimentation

Developed by Bruce Golden, Western Pennsylvania Coalition for Abandoned Mine Reclamation



About This Activity...

Prep Time Required:
1 hour

Grade Level:
High school

Subjects:
Chemistry, Earth Science, Environmental Science

Duration of Activity:
45 minutes

Pennsylvania Standards Addressed:
3.2.10.B1, 3.4.12.B2, 4.1.10.E, 4.1.10.B

Setting:
Classroom

Vocabulary:
Density
Sedimentation
Viscosity

Prerequisites:
Knowledge of the formation of abandoned mine drainage and its environmental impacts; general science concepts such as density and viscosity; ability to algebraically rearrange an equation.

Summary:
Using sand, students will learn through experimentation what sedimentation is and the importance of Stokes Law, and finally how the two of these apply to abandoned mine drainage in Pennsylvania.

Materials:
- Packets of sand (coarse, medium and fine)
- Water
- Mineral oil
- Ruler
- 6 test tubes
- Watch or stopwatch capable of measuring seconds

Objectives:

Upon completion of the lesson, 10th grade students will be able to:

- write an explanation of the process of sedimentation, to include:
- Understand the importance of Stokes Law in describing the relationship of particle size to settling time
- List at least 3 real world examples of sedimentation
- Explain how sedimentation is both a problem and a remedy for abandoned mine drainage.

Background

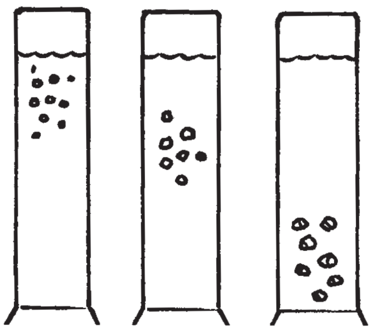
Abandoned mine drainage (AMD) often has high levels of pollutants called heavy metals. Iron and aluminum are the most common. Iron is often visible in AMD polluted streams as orange water. The orange color can also be seen on the stream's banks and rocks. At low water periods, it may look like the stream bottom has been painted orange. The iron in AMD is actually in the form of rust-like compounds called iron oxides and iron hydroxides. There are several different kinds of these oxides, but to keep things simple, we'll refer to them as iron oxide. Iron oxide is an orange solid present as very fine particles. In a stream polluted with AMD, the churning action of the moving water keeps much of the iron oxide suspended in the water for some distance, while some of it settles by gravity to the stream bottom. Over time, more and more iron oxide accumulates to form a harmful, slippery sediment that smothers aquatic insects and disrupts the food web.

This lesson explores a process called **sedimentation**. Sedimentation is the process that describes the settling of solid particles by gravity to the bottom of a liquid. A particle will sink to the bottom of a liquid if it is denser than the liquid. Sedimentation of iron oxide particles causes the orange coating on stream bottoms. Similarly, the accumulation at the bottom of a bottle of orange juice or salad dressing is caused by sedimentation. We shake the bottle to suspend the particles in the liquid, but as soon as the shaking stops, the particles immediately start to settle.

To understand this better, we will look at the process of sedimentation in more detail. Stokes Law describes the rate (velocity) at which a particle will settle to the bottom of a liquid. Here is a synopsis of what Stokes Law says:

- The rate is dependent on the size of a particle. Larger particles settle faster than smaller particles
- The rate is dependent on the **viscosity** (thickness) of the liquid. A particle will fall faster in water than in pancake syrup (an inverse relationship of rate to viscosity).
- The rate is dependent on the difference in densities of the particle and the liquid. In water, a particle of a given size made of lead will fall faster than one made of plastic.

A Visual Concept of Stokes Law



Stokes Law is mathematically expressed as:

$V= 2r^2g(d_p\text{-}d_l)/m$

Where

- g=acceleration of gravity
- d_p=**density** of particle
- d_l=density of liquid
- m= viscosity of liquid
- v=velocity
- r=radius of particle (assume it is spherical)

Another common way of expressing Stokes Law mathematically is

$V= Kr^2$, where $K=2g(d_p\text{-}d_l)/ m$

Using Sedimentation as a means to remove pollutants

Sedimentation can also be exploited to remove pollutants.

Iron Oxide

What we want to do is keep the iron oxide from getting into the stream in the first place. A solution is to construct a treatment system that first captures the polluted mine water at the point where it emerges, then directs the water into a pond where the water will be calm enough to allow settling of the iron oxide particles. The iron oxide will be collected on the bottom of the pond, and clean water from the pond will be released into the stream.

Ponds constructed for this purpose are called settling ponds or sedimentation ponds. They work well for removing fairly high concentrations of iron oxide, but they usually allow some of the iron oxide to pass on through. Sometimes a second settling pond is constructed to capture more of what was missed by the first.

It has also been shown that shallow ponds that have aquatic plants such as cattails can also serve to remove iron oxide particles from the water, primarily by filtration in their roots. These ponds are called aerobic wetlands. Aerobic wetlands work best if the iron oxide concentrations are relatively low to begin with, and they do a good job of removing most of the iron oxide. A common strategy is to follow a settling pond with an aerobic wetland.

Sewage/solid waste treatment systems

Municipal solid waste treatment systems employ sedimentation to separate solid material from water as a step in purifying waste water.

Other Situations where Sedimentation is Important

Soil Erosion and Sedimentation

Runoff of rainwater over land may cause erosion of soils, as may fast running water along stream banks. This action suspends and transports soil particles to streams and rivers. Sedimentation of this material within other parts of the stream may lead to a variety of problems.

Sedimentation as a geological process

Over eons, sedimentation and accumulation of various materials has led to the formation of geological rock strata. For example, limestone is made out of the accumulation of calcium remains of aquatic organisms.

Procedure:

Warm-up:

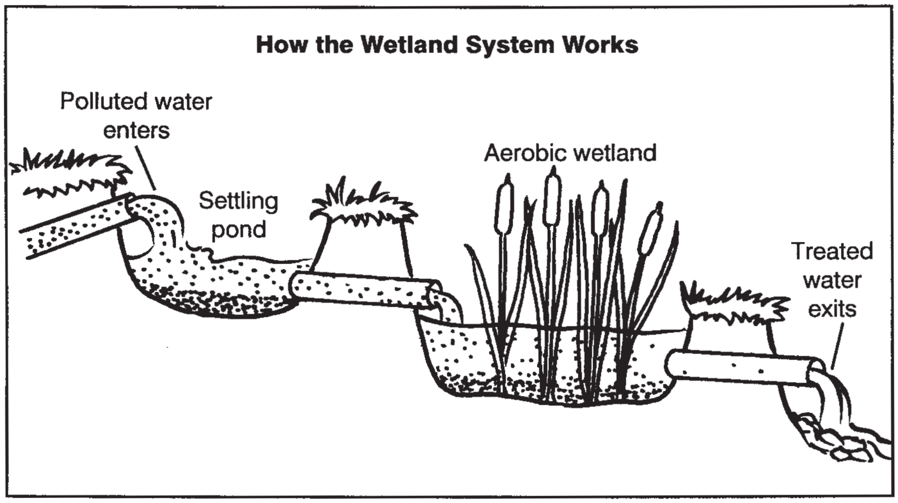
Having bottles of Italian salad dressing and orange juice, ask class why they need to be shaken prior to use. Ask what happens if they're allowed to set for a period of time. Ask what other products might also require mixing. Ask students to speculate on why particles accumulate on the bottom of the bottles.

Activity:

This experiment will demonstrate Stokes Law using sand. Three grades of sand (coarse, medium and fine) will be used representing 3 particle sizes.

- Place a small amount of coarse sand in a clean test tube. The sand should be 2 to 4 mm deep.
- Fill the test tube about three quarters full with water.
- While holding the test tube upright in your hand, cover the top of the test tube tightly with your thumb and shake vigorously to thoroughly mix the sand with the water. Immediately following shaking, observe the behavior of the particles as they settle to the bottom of the liquid. In particular, measure the number of seconds it takes for the particles to settle to the bottom. You can use a watch, or simply count "one thousand one, one thousand two,... etc.
- Measure the height (in cm) of the water in the test tube using a ruler. Record both time and height of the water column. Determine the velocity of the particles (cm/sec). Velocity= distance traveled/time required to travel that distance
- Calculate the approximate particle size using Stokes Law Equation and the following information:
  - Density of water = 1 g/cm^3
  - Density of sand = 2.1 g/cm^3
  - Viscosity of water = 0.01 g/ cm sec
  - Viscosity of mineral oil = 0.3 g/ cm sec
  - Acceleration of gravity = 980 cm/ sec^2
- Repeat the experiment for medium and fine sand samples

  Mineral oil has a much higher viscosity than water (it is thick and resistant to flow). Particles fall slower through a thick liquid.
- Instead of using water, repeat the experiment using mineral oil for coarse, medium and fine sand.



Teacher notes:

Students should observe that the larger sizes of sand settle quicker than the smaller particles, qualitatively verifying Stokes Law. The settling action is fairly quick in water, from a second to several seconds, making accurate time measurements difficult. With mineral oil, which is much more viscous than water, the effect of particle size on the velocity will be much more pronounced than with water and easier to measure.

The choices of sand in water and sand in mineral oil were made to enable experimentation to be done in a normal class period. The particle sizes of iron oxides are very much smaller than those used in these experiments and consequently the settling times are measured in hours instead of seconds.

Wrap-up/Conclusion:

Sedimentation is a very important physical process occurring in numerous settings. For abandoned mine drainage, sedimentation of heavy metals onto stream bottoms degrades the streams by altering the habitat of aquatic insects and disrupting the food web. As a means of treating heavy metal pollution from abandoned mine drainage, sedimentation is a process that is purposely employed to remove the metals from the polluted water.

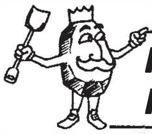
Assessment:

Written explanation of the process of sedimentation, to include:

- The importance of Stokes Law in describing the relationship of particle size to settling time.
- Citation of at least 3 real world examples of sedimentation
- An explanation of how sedimentation is both a problem and a remedy for abandoned mine drainage.

AMD Shuffle—Wetland Card Game

Developed by Nicki Foremsky, Penn State Cooperative Extension, Westmoreland County, PA



About This Activity...

Prep Time Required:
Initial prep time: 2 hours
Daily prep time: 15 minutes

Grade Level:
Middle School
High School

Subjects:
Ecology, Chemistry, Science

Duration of Activity:
25-30 minutes

Pennsylvania Standards Addressed:
3.4.6.B2, 3.4.7.B2, 3.4.10.B2, 4.1.12.E, 4.2.8-10.A, 4.2.7-10.B, 4.2.6.C, 4.5.8.C

Setting:
Classroom

Vocabulary:
Alkalinity
Aluminum
Iron
Low pH

Prerequisites:
Introductory knowledge of AMD, passive treatment and pH

Summary:

Students play a card game that demonstrates how AMD treatment ponds remove metals and pollutants from the water and provide land for wildlife to return to normal.

Materials:

- Copies of the playing cards and game board

Objectives:

Students will be able to:

- understand that AMD treatment ponds remove metals and pollutants from the water and provide land for wildlife to return to normal.

Background:

Abandoned mine drainage (AMD) from old coal mines pollutes streams and waterways in Pennsylvania. AMD can be harmful to wildlife and plants living in the streams and other areas. Mine drainage is harmful because it may be acidic, (having a **low pH**), and may contain many other pollutants including dissolved metals such as iron and aluminum or have a pronounced "rotten egg" sulfur smell. When mine water leaches to the surface, it comes in contact with oxygen and several chemical reactions occur. For example, iron can precipitate into iron oxide and coat the bottom of streams and creeks which covers and destroys habitat for aquatic organisms. Additionally, dissolved aluminum is very toxic to fish and can cause fish kills.

Treatment of streams polluted with Abandoned Mine Drainage includes a series of steps. If the water is acidic, the first step is to raise the pH and increase the alkalinity of the water. Raising the pH and alkalinity can be accomplished by adding limestone. Secondly, removing the metals can be accomplished by plant uptake or metal adsorption to the substrate (coating the rocks or clinging to the cattails).

Procedure:

Warm-up:

Explain to the players that streams polluted with AMD usually have metals like **iron** and **aluminum** that hurt wildlife. Therefore, your initial hand of pollution cards represents a polluted stream. You want to clean up the stream by treating the AMD with a treatment pond.

There are three piles of cards: One pile for Pollution Cards, one pile for Challenge Cards, and one "pick-up" pile for the mixture of Wildlife, Treatment, and Action Cards. Deal all pollution cards to players. Players will take one card from the pick-up pile and discard at least one card each round until one player has no more pollution cards. Each player will then count up the points in their hand—Pollution Cards are negative, Nuisance Wildlife are negative, clean water cards are positive, and good Wildlife Cards are positive. The player with the most points wins because they have the cleanest stream.

Activity:

Your hand represents a polluted stream that will enter the treatment pond.

Pollution Cards are those with Iron, Aluminum, or Sulfur Smell. Some Pollution cards say "Take Action" which means they need another card such as **alkalinity** or limestone in order to be able to discard into the pond.

Challenge Cards are those that hinder the ability of the pond to treat the water – usually resulting in a player taking more cards or another action.

Treatment Cards are those that help clean the stream of pollution and are needed for wildlife to return.

Wildlife Cards are needed to show that the stream is getting better. Each wildlife card is worth different points based on the benefit or cost to the system. There are nuisance wildlife cards that can be discarded if needed. Some wildlife are very sensitive to pollution and require action. For example, If you pick up a sensitive wildlife card such as the Great Blue Heron while you have an Aluminum card in your hand, you must discard the Great Blue Heron, since it will not be able to survive in that environment.

The object of the game is to discard the Pollution Cards if you can. If you can't, try to pick up cards that will help you to discard them, like the alkalinities, limestone, etc. You want the cards in your hand (your stream) to no longer be polluted, but be filled with clean water and wildlife. Therefore, all of the bad Pollution Cards end up in the pond to be treated while streams gain Wildlife and Treatment Cards to represent cleaner water.

Each player adds up their points. The player with the most points wins.

Wrap-up/Conclusion:

The winning hand should represent a clean stream. Discuss why the winning hand could possibly have pollution cards and still come out the winner. Would this happen in real life?

Assessment:

Have students:

- Summarize what happened to their stream during the game. Did they luck out with high quality wildlife cards, or did they suffer a set-back when something happened to the treatment pond?
- Explain why abandoned mine drainage is harmful to aquatic organisms and wildlife. (metals and acidic water)
- Explain how passive treatment ponds function to clean water polluted by abandoned mine drainage.

Extensions:

- To study passive treatment systems and how they function in cleaning polluted water, visit the many sites with treatment ponds, such as Saint Vincent College's Monastery Run Improvement Project, or the treatment systems at Jennings Environmental Education Center and Keystone State Park.

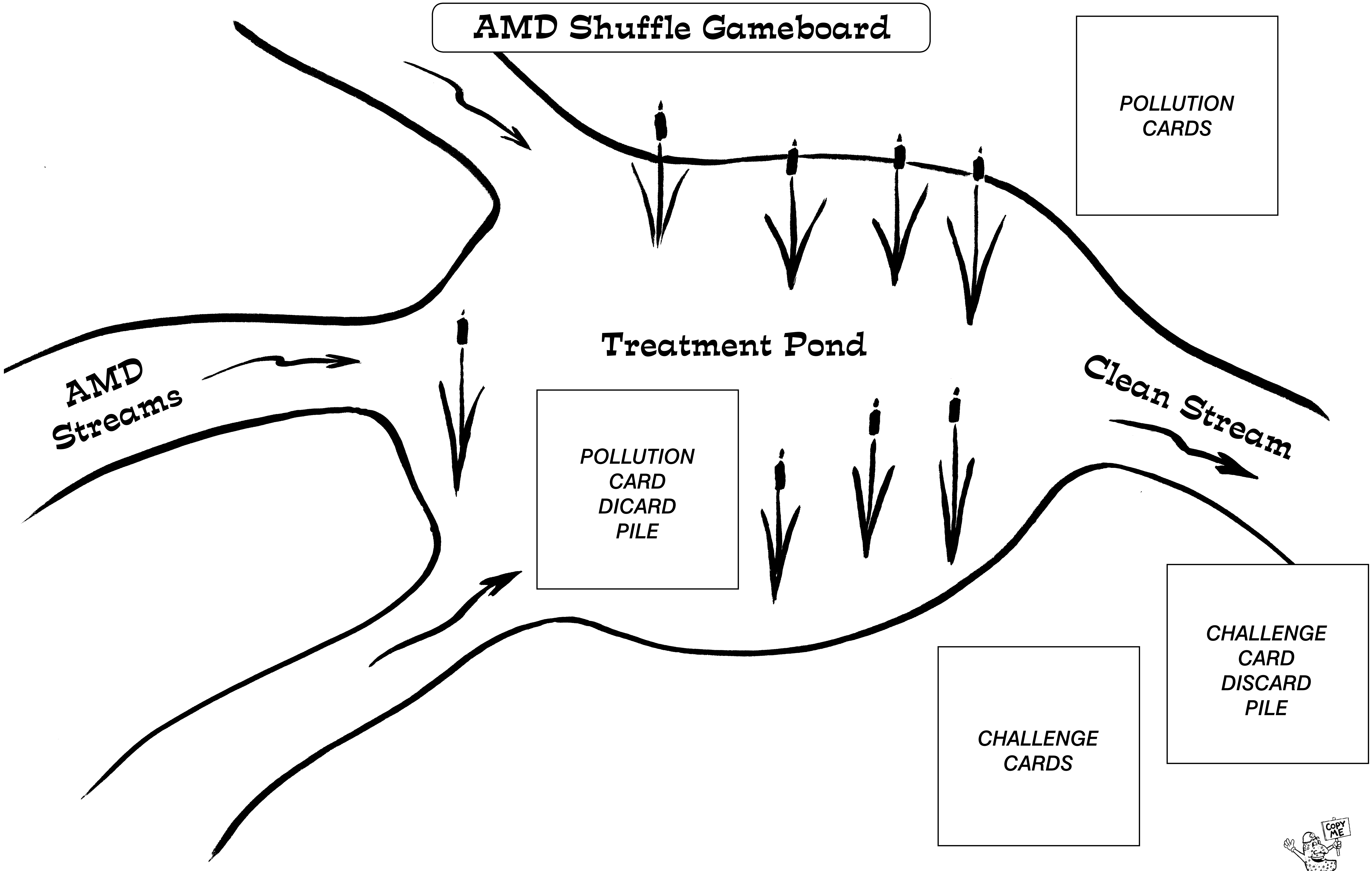
Adaptations:

For lower levels, remove the challenge cards, or have someone read the challenge cards aloud. Or, remove the "take action" cards from the pile.

Resources:

Limestone Pond Treatment lesson plan developed by Becky Reese, AMD & Art, Johnstown, PA

Passive Treatment Methods for Acid Water in Pennsylvania Fact Sheet, Penn State University
www.sfr.cas.psu.edu/water


AMD Shuffle Gameboard
POLLUTION CARDS
Treatment Pond
AMD Streams
Clean Stream
POLLUTION CARD DICARD PILE
CHALLENGE CARD DISCARD PILE
CHALLENGE CARDS
COPY ME

Wetland Card Game

Pollution Card
Iron
-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Take Action
Aluminum
-10
Need limestone or alkalinity to discard into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Take Action
Aluminum
-10
Need limestone or alkalinity to discard into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Take Action
Aluminum
-10
Need limestone or alkalinity to discard into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife
Muskrat
0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife
Muskrat
0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife
Muskrat
0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Frog
+5

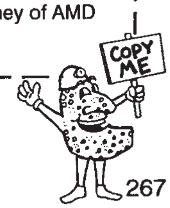
Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Frog
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Frog
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Wildlife Card

Frog

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Frog

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Frog

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Ducks

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Ducks

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Ducks

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Ducks

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Ducks

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Ducks

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Dragonflies

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Dragonflies

+5

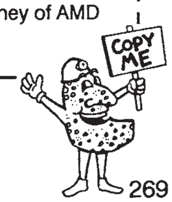
Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card

Dragonflies

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Wildlife Card
Dragonflies
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Dragonflies
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Dragonflies
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Fish
+10
If you have aluminum in your hand, must discard fish into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Fish
+10
If you have aluminum in your hand, must discard fish into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Fish
+10
If you have aluminum in your hand, must discard fish into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Fish
+10
If you have aluminum in your hand, must discard fish into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Fish
+10
If you have aluminum in your hand, must discard fish into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Fish
+10
If you have aluminum in your hand, must discard fish into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Snakes
+5

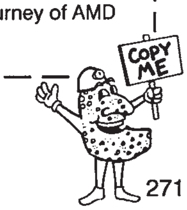
Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Snakes
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Snakes
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Wildlife Card
Snakes
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Snakes
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Snakes
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card
Cattails
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card
Cattails
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card
Cattails
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card
Cattails
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card
Cattails
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card
Cattails
+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Oxygen
+10

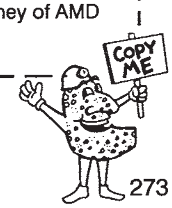
Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Oxygen
+10

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Oxygen
+10

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Nuisance Wildlife

Muskrat

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife

Muskrat

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife

Muskrat

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife

Muskrat

0

Nature Interrupted – The Journey of AMD
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Nuisance Wildlife

Muskrat

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Nature Interrupted – The Journey of AMD
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Nuisance Wildlife

Muskrat

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Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife

Muskrat

0

Nature Interrupted – The Journey of AMD
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Nuisance Wildlife

Muskrat

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Nuisance Wildlife

Muskrat

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Take Action

Iron

-5
Need a cattail card to discard

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Take Action

Iron

-5
Need a cattail card to discard

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Take Action

Iron

-5
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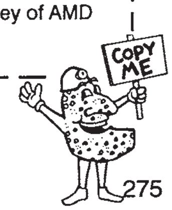
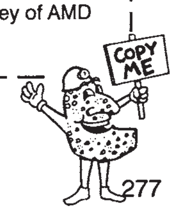
Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Pollution Card ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE
Pollution Card ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE
Pollution Card ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Iron*** -5 Nature Interrupted – The Journey of AMD AMD SHUFFLE
Pollution Card ***Take Action*** ***Aluminum*** -10 Need limestone or alkalinity to discard into treatment pond Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Take Action*** ***Aluminum*** -10 Need limestone or alkalinity to discard into treatment pond Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Pollution Card** ***Take Action*** ***Aluminum*** -10 Need limestone or alkalinity to discard into treatment pond Nature Interrupted – The Journey of AMD AMD SHUFFLE



Wetland Card Game

Pollution Card
Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Take Action

Aluminum

-10
Need limestone or alkalinity to discard into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
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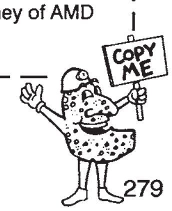
Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Pollution Card
Iron
-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
-5

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AMD SHUFFLE

Pollution Card
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-5

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-5

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Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
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Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
-5

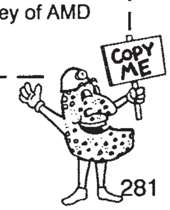
Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card
Iron
-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Pollution Card

Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Iron

-5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Sulfur Smell

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Sulfur Smell

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Sulfur Smell

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Sulfur Smell

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AMD SHUFFLE

Pollution Card

Sulfur Smell

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Nature Interrupted – The Journey of AMD
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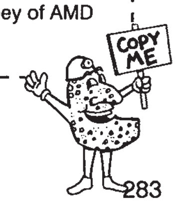
Pollution Card

Sulfur Smell

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Pollution Card

Sulfur Smell

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Sulfur Smell

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Pollution Card

Sulfur Smell

0

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Limestone is coated and no longer works

Pick up 2 cards from treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Limestone is coated and no longer works

Pick up 2 cards from treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Limestone is coated and no longer works

Pick up 2 cards from treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Muskrat lodge is used for nest by Canada Goose

Pass one pollution card to another player

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Muskrat lodge is used for nest by Canada Goose

Pass one pollution card to another player

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Muskrat lodge is used for nest by Canada Goose

Pass one pollution card to another player

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Too much water is entering the pond and can't be treated

Everyone takes one pollution card from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Too much water is entering the pond and can't be treated

Everyone takes one pollution card from pond

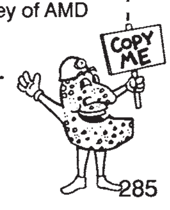
Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Too much water is entering the pond and can't be treated

Everyone takes one pollution card from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Wildlife Card ***Oxygen*** +10 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Wildlife Card** ***Oxygen*** +10 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Wildlife Card** ***Oxygen*** +10 Nature Interrupted – The Journey of AMD AMD SHUFFLE
Treatment Card ***Limestone*** +5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Treatment Card** ***Limestone*** +5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Treatment Card** ***Limestone*** +5 Nature Interrupted – The Journey of AMD AMD SHUFFLE
Treatment Card ***Limestone*** +5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Treatment Card** ***Limestone*** +5 Nature Interrupted – The Journey of AMD AMD SHUFFLE	**Treatment Card** ***Limestone*** +5 Nature Interrupted – The Journey of AMD AMD SHUFFLE
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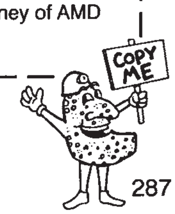

Wetland Card Game

Treatment Card

Limestone

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Limestone

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Limestone

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Limestone

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Limestone

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Limestone

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
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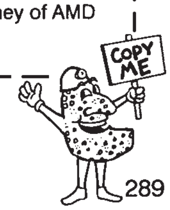
Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
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Treatment Card

Alkalinity

+5

Nature Interrupted – The Journey of AMD
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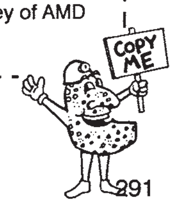

Wetland Card Game

Wildlife Card
Great Blue Heron

+15

*If you have any aluminum cards in your hand, you must discard this to treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Great Blue Heron

+15

*If you have any aluminum cards in your hand, you must discard this to treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Wildlife Card
Great Blue Heron

+15

*If you have any aluminum cards in your hand, you must discard this to treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card
Muskrat clogs outlet pipe with cattails

Pick up one pollution card from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card
Muskrat clogs outlet pipe with cattails

Pick up one pollution card from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card
Muskrat clogs outlet pipe with cattails

Pick up one pollution card from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card
Muskrat chews hole in dyke

Take 3 pollution cards from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card
Muskrat chews hole in dyke

Take 3 pollution cards from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card
Muskrat chews hole in dyke

Take 3 pollution cards from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card
Pass a card to your left

Discard this into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card
Pass a card to your left

Discard this into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card
Pass a card to your left

Discard this into treatment pond

Nature Interrupted – The Journey of AMD
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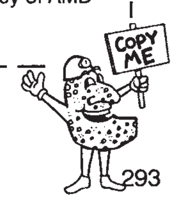

Wetland Card Game

Action Card

Pass a card
to your right

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Pass a card
to your right

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Pass a card
to your right

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Sinkhole develops in bottom of the pond

Take 4 pollution cards
from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Vandals hit the pond

Everyone take 2
pollution cards
from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Pond is covered in ice

Take 2 pollution cards
from pond and give away 1
wildlife card from your hand

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Outlet is clogged with twigs and branches

Take 1 pollution card
from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Outlet is clogged with twigs and branches

Take 1 pollution card
from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Challenge Card

Outlet is clogged with twigs and branches

Take 1 pollution card
from pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Pick up a challenge card
and do what it says

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Pick up a challenge card
and do what it says

Discard this into
treatment pond

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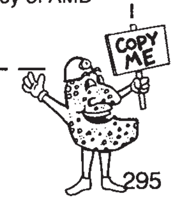

Wetland Card Game

Action Card

Pick up a challenge card
and do what it says

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

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and do what it says

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Pick up a challenge card
and do what it says

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Ask for a wildlife card
from any player

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Ask for a wildlife card
from any player

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

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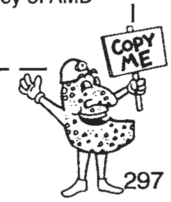
from any player

Discard this into
treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE



Wetland Card Game

Action Card

Ask for a wildlife card from any player

Discard this into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

Ask for a wildlife card from any player

Discard this into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Action Card

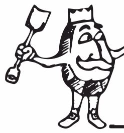
Ask for a wildlife card from any player

Discard this into treatment pond

Nature Interrupted – The Journey of AMD
AMD SHUFFLE

Environmental Management:
Stream Analysis with Relation to Acid Mine Drainage

Developed by Joy L. Wyler, South Allegheny School District & Phillip A. Lovejoy, Pittsburgh Public School District
In collaboration with D. Harrison & T. Ackman



About This Activity...

Prep Time Required:
20 minutes

Grade Level:
Highschool

Subjects:
Science

Duration of Activity:
5 days: 40 minute periods

Pennsylvania Standards Addressed:
3.3.12.A2, 3.4.12.B2, 3.4.10.D3, 4.2.10.B, 4.2.10.C, 4.5.10.C

Setting:
Local stream sites, laboratory or classroom

Vocabulary:
Coal
Ferric iron
Ferrous iron
Pyrite
Remediation
Tributary
Turbid
Wetland

Related Vocabulary:
Alkalinity
Base solution
Calibration
Cattail reeds
Diversion well
Geologist
Graphing
Limestone bed
pH scale
Spoils pile
Strip mining

Prerequisites:
- How to read and interpret a chart/graph
- Use of the scientific method
- How to read and interpret a topographical map
- How to record data, analyze results and draw conclusions
- Knowledge of the pH scale

Summary:
Through hands on approach of sampling and data analysis, students will learn about the effects of abandoned mine drainage (AMD) as it affects surface water streams and tributaries.

Materials:
- Plastic sample bottles w/cap (recommended 125 ml)
- pH meter
- pH paper
- pH meter calibrating buffer solutions
- Map (topographical)
- Notebook with pencil or pen
- Graph paper
- Marking flags
- Permanent markers
- Ice and ice chest (cooler)
- Hydrochloric acid

OPTIONAL
but strongly recommended:
- Rubber knee boots or hip waders
- Insect repellent

Objectives:
Students will be able to:
- Work in cooperative learning groups to study the effects of acid mine drainage as it affects surface water streams and tributaries
- Explore the many types of careers in environmental science
- Collect and analyze data
- Create graphs to plot the data
- Learn about careers available such as geologists, hydrologists, engineering, environmental science, biologists as well as many other professions
- Perform laboratory testing using pH paper and/or meter

Background:
What is Acid Mine Drainage (AMD)?

A watershed is the line of division between two adjacent rivers or lakes with respect to the flow of water by natural channels into them and the natural boundary of a basin. The Clean Water Action Plan was established to monitor and remediate the quality of water in our nations watersheds. It establishes standards for a watersheds nutritional and dissolved metals content and if these are exceeded the waterway must undergo immediate **remediation**.

Dissolved metals suspended in solution such as **ferric iron** and **ferrous iron**, (the orange pollution you sometimes see) as well as aluminum, and manganese all contribute to water pollution. Aluminum ranks third in the Earth's abundant elements and is the most abundant metal in the Earth's crust. Dissolved aluminum remains suspended in water between the pHs or 3 and 4. Due to its strong affinity to oxygen, aluminum rarely occurs in its natural metal states near the surface. Instead it forms many alloys with zinc, copper, manganese, magnesium and other elements with similar chemical properties. This same property is responsible for the classification of aluminum as a contaminant and neurotoxin. When introduced to aquatic environments (i.e. rivers, streams, and **wetlands**) aluminum attaches onto plant roots and inhibits the intake of oxygen. Physical abnormalities in humans and animals associated with aluminum poisoning include memory loss, tremors, muscle twitching, and several types of dementia. These apparent threats to the environment and its inhabitants are why aluminum leaching and contamination should be controlled.

Acid mine drainage is water containing iron and sulfate and sometimes other metals, such as, manganese and aluminum. It is often acidic (low pH) and is commonly referred to as acid mine drainage or AMD. AMD forms through a series of chemical and biological reactions that occur when

the **pyrite** (iron sulfide, a.k.a. fool's gold) found in **coal** and other rock strata is disturbed and exposed to oxygen and moisture as a result of mining operations. AMD may contaminate surface and ground water.
Why is it Important to Sample Streams?

To identify sources of mine drainage so that the quality of water can be improved. This is important to wildlife, aquatic (fish & frogs) and mammals (such as deer and small animals) so that they can flourish in their environment. Clean water is also important to people who use the rivers and streams for drinking water as well as for recreational uses. Water is an essential ingredient for boaters, swimmers, fisherman, and hunters.

Procedure:

Warm-up:

Sampling must be completed in a one day field trip.

- Separate students into cooperative groups of 3 or 4 students.
- Research topographical map web sites to identify potential local streams to be sampled.

Activity:

- Begin sampling procedure at the mouth of the stream.
  Helpful hint: sampling must be done starting at the mouth so that you do not collect **turbid** water. Be careful not to stir up sediment when collecting your samples.
- Have students mark and flag the location where the sample is taken. (E.g. BR-1, for Beams Run stream location No.#1).
- Take the samples (mark sample bottle XX-1).
- Record sample location in logbook. Helpful hint: Where tributaries flow into main stream, the sample should be taken approx. 10 feet up the **tributary**. The main stream should be sampled approx. 10 feet up stream infront of the tributaries entrance.
- After the stream has been sampled place all samples collected into an ice chest for transportation back to the classroom. Refrigerate immediately upon returning to classroom.
- Measure one set of samples for pH using pH paper or a pH meter if available, record results.
- Have students analyze their results by identifying any potential polluting tributaries of the stream.

Laboratory Activity – Simulation of Abandoned Mine Remediation
Create your own Acid Mine Drainage, and neutralize it the way industry would when reclaiming a mining site.

- Prepare 2 separate solutions of Ferrous Sulfate ($Fe\ SO_4$) by dissolving into water into 2 large glass beakers
- Measure pH level. (Note: Ferrous Sulfate lowers the pH due to the chemical reaction with water creating sulfuric acid ($FeSO_4 + H_20 + O_2 \rightarrow H^+ + SO_4 + Fe^{+2}$)
- In one solution slowly add a 5% NaOH, observe and record any change in color and pH.
- In the second Ferrous sulfate solution - add lye - you must prepare a lye slurry in a separate flask/ beaker first, again adding slowly while observing and recording any change in color and pH.
  (Note: A green color change should be observed immediately, if allowed to sit for several days the green sludge will change to an orange sludge – this is the iron coming out of solution. Relate this to students as the orange colored creeks they may have seen before which are most prevalent in old mining towns.)

RINSE BOTTLES BEFORE SAMPLING

COLLECTING WATER SAMPLES
CALIBRATE pH meter using buffer solutions 4.0, 7.0 and 10.0 CHECKING pH of WATER SAMPLES

Wrap-up/Conclusion:

Have the students research the mining history of your area. Also students can research methods of active and passive treatment used today to remediate abandoned mines.

Extensions:

- This program lends itself to a number of possible extensions and discussions. Aspects of water pollution can be discussed in association with what pollution does to the life of a water body. Discussions on food webs can begin with vegetation and algae growing in water and continue all the way to fish and humans. The macro invertebrates found during the program form a lower or middle area of the food web, between vegetation and minnows or larger fish. Within the macroinvertebrates there are good examples of smaller food webs because some of the organisms are grazers or detritivores on the fungus and plants (mayflies and stoneflies); some are filter feeders (caddisflies); and some are carnivores (dragon flies and damselflies). If a relatively good microscope is available, placing a drop of water on the slide and allowing students to look at it on their own will show an entire new layer of the food web in the diatoms, flagellates and other microorganisms present.
- The concept of watersheds is an important aspect of water pollution control which can be discussed either before or after the sampling program. A watershed is the land area which acts as a collection basin for rainwater which eventually flows to a single stream or river.

Watersheds can be as small as a single valley and creek or as large as the Missouri, Mississippi and Ohio River system and its myriad tributaries. This watershed encompasses 30 states in the continental U.S. stretching from Montana in the west to New York in the east, and all the way north into Canada.

- Nonpoint source pollution is another aspect of water pollution which can frequently be identified by macroin vertebrate sampling techniques. Stream sampling, along with field scouting of the watershed can frequently locate water quality problems not readily identified by conventional water quality sampling. The Louisiana Department of Environmental Quality, Office of Environmental Assessment maintains a Nonpoint Source (NPS) Program which can provide more information on this important form of water pollution. The NPS program also works with citizen environmental groups to establish Citizens' Monitoring Programs on area streams.

Teacher resources:

- National Energy Technology Laboratory – U S. Dept. of Energy
- This site will provide the topographic map needed to locate a local stream.
- United States Geological Survey
- www.coolscience.com

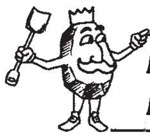
Resources:

George R. Watzlaf – U.S. Dept. of Energy

Roderick D. Brown – HBSU student

Iron Oxide Chalk Activity

Developed by Saint Vincent College Environmental Education Center, Latrobe, Pa



About This Activity...

Prep Time Required:
15-20 minutes

Grade Level:
Elementary, Middle School

Subjects:
Art, Environmental Science

Duration of Activity:
30 minutes

Pennsylvania Standards Addressed:

3.2.3.A1, 3.3.3A2, 3.4.3.B1, 3.4.3.B2, 3.2.6-7.A1, 3.2.8.A2, 3.3.5.A5, 3.4.5.B2, 4.3.3.B, 4.5.1.C, 4.5.3.C, 4.5.2.D, 4.5.4.C, 4.5..7.C, 4.3.5-7.D

Setting:
Classroom

Vocabulary:
Abandoned Mines
Iron hydroxide
Iron oxide
Recycle
Wetlands

Prerequisites:
Elementary level science

Summary:

The purpose of this activity is to emphasize recycling and what can be done with the iron hydroxide (iron oxide when dried) collected from abandoned mine wetlands.

Materials:

- Used paper (copier/printer paper)
- Tape
- Paper towels
- Cups (preferably reusable since it is about recycling)
- Newspaper
- Plastic knives or straws for stirring
- Iron oxide (Contact Saint Vincent Environmental Education Center)

Objectives:

Students will be able to:

- Make a piece of chalk out of recycled iron oxide.
- Understand what iron oxide is, and where it came from.

Background:

Passive wetland treatment technology removes iron from polluted mine water through its precipitation as iron oxide. The patented passive technology consists of interconnected ponds that are designed to promote the formation of iron oxide solids and facilitate their efficient recovery. The discharge from the production ponds is directed into constructed wetlands; where residual iron is removed and a final discharge is produced that does not pollute the receiving stream. Over time, the iron oxide is removed from the production ponds, cleaned, dewatered, and transported either directly to a customer or to a processing facility for drying, milling, and packaging as a pigment. Iron oxide pigments are lightfast, nonbleeding, nontoxic, and weather resistant so they are widely used to color concrete blocks, outdoor paints, paper, mulch, and other construction materials, such as plaster, cement, concrete, pavers, roof tile, mortar, grout, plastics. Less than one-half of the iron oxide pigments used in the United States is mined and processed domestically.

Procedure:

Warm-up:

Give the students background on **abandoned mines**, **wetlands** and how **iron hydroxide** forms, and is turned into **iron oxide**. Have students come up with a list of uses for iron oxide: how it can be **recycled**. Then tell students that they will be doing one of these things today: making chalk!

Activity:

Directions:

- Cover area or desk with newspaper
- Make a mold for chalk. Students can use a toilet tissue roll or small paper cup, but the best is a sheet of typing paper cut in half lengthwise. Roll both pieces of paper into a tube about the diameter of a dime and tape. The paper works well because it absorbs most of the water from the chalk mixture and the drying time is significantly reduced.
- Make a stopper out of paper towel for the end of the tube. Look through the tube to see if there is light coming through, if there is; reform the stopper until there is no light showing. This will ensure that the chalk mixture will not leak out the bottom of the tube.
- Mix plater of paris and water in a 1 to 1 ratio (i.e. 1 cup water to 1 cup plaster of paris) in a separate container.
- Add iron oxide, the more students add, the darker the chalk will be.
- Stir very well.
- Do not let the mixture set; it will harden quickly.
- Pour the chalk mixture into the tube and have the students hold upright or place in a cup to ensure that the tube does not fall over.

- As the paper absorbs most of the water, the top of the chalk will sink into a funnel-like shape, the students may tap the tube gently on the table to reshape the chalk top.
- Place the tubes of paper somewhere in the classroom where drying will occur.
- After 24 hours, unwrap the chalk and place somewhere in the classroom where it will continue to dry thoroughly.
  Note: if after unwrapping, the chalk has wet paper around it, students may gently use their fingers to rub off the paper.
- Enjoy!

Notes:

- Experiment with swirling by adding iron oxide and stirring very little.
- If using toilet tissue rolls, drying will take much longer.

DISCLAIMER: quality of iron oxide will determine the quality of the chalk produced. Some iron oxide will bubble and foam upon the addition and mixing with the plaster of paris, resulting in pithy/non-solid chalk.

Wrap-up/Conclusion:

Have the students use their chalk to write one thing on the chalk board

- they learned from the lesson, or
- a question they have about abandoned mine drainage/recycling.

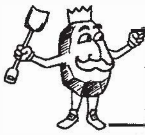
First, have students write it on a piece of paper, to avoid repetition. Students will be able to see what all other students learned. Teacher could lead discussion about these things.

Resources:

EnvironOxide™ Pigments
Iron Oxide Recovery, Inc.
195 Castle Shannon Blvd.
Pittsburgh, PA 15228

Create an AMD Treatment System

Developed by Beth Langham, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
30 minutes

Grade Level:
High school

Subjects:
Chemistry, Environmental Science

Duration of Activity:
60 minutes

Pennsylvania Standards Addressed:
3.2.10.A1, 3.4.10.C1, 3.4.12.C3, 4.1.12.B, 4.1.12.C, 4.1.12.E, 4.2.10.A, 4.2.10.B, 4.3.10.B, 4.5.10-12.C

Setting:
Classroom

Vocabulary:
Calculating
Design
Engineering
Hydrolysis
Oxidation
Presenting

Prerequisites:
Knowledge of AMD formation, math skills

Summary:

Students will examine the decisions and processes that organizations complete prior to designing a treatment system for Abandoned Mine Drainage discharges. Students will determine the type of system needed to treat a discharge and design the size of the system and develop drawings to present to the "board".

Materials:

Student Handouts (One Per Group)

- WELOS Letter
- Yellow Boy Labs Letters
- Evaluating Mine Water And Determining a Treatment System
- Passive Treatment Options
- Instructions For Determining The Treatment System - Calculation Worksheet
- Treatment System Flow Chart

- Poster Board
- Miscellaneous supplies to design the systems
- Calculators
- Power Point Slide Show/Pictures of each discharge (see enclosed cd)
- Acid Mine Drainage/Tums

Objectives:

Students will be able to:

- complete calculations needed to determine the chemistry and flow of mine water.
- (after determining the chemistry and flow of the mine water), determine the type of treatment system needed for the situation using the flowchart provided.
- (after determining the type of treatment system needed), **design** and sketch the type of system with depths, and sizes of each cell.
- (after designing the treatment system), prepare a 10 minute presentation explain the rationale for the treatment system.

Background:

The Chemical Reaction of Abandoned Mine Drainage (AMD)

The first reaction, which occurs in the mine, is the physical and chemical weathering of pyrite, which includes the **oxidation** of pyrite by oxygen to produce sulfate and ferrous iron. This reaction generates one mole of ferrous iron for each mole of pyrite oxidized.

(1) $FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+$

(1) Pyrite + Oxygen + Water → Ferrous Iron + Sulfate + Acidity

The second reaction, which occurs when the mine water comes in contact with oxygen, involves the oxidation of ferrous iron to ferric iron. Certain bacteria can increase the rate of oxidation from ferrous to ferric iron. This reaction rate is pH dependant with the reaction proceeding slowly under acidic conditions (pH 2-3) with no bacteria present and several orders of magnitude faster at pH values near 5. This reaction is referred to as the "rate determining step" in the overall acid-generating sequence.

(2) $2\ Fe^{2+} + 1/2O_2 + 2\ H^+ \rightarrow 2\ Fe^{3+} + H_2O$

(2) Ferrous Iron + Oxygen + Acidity → Ferric Iron + Water

The third reaction, which may occur, is the **hydrolysis** of iron. Hydrolysis is a reaction that splits the water molecule. The formation of ferric hydroxide precipitate (solid) is also pH dependant. The orange precipitate is seen more quickly if the pH is above about 3.5 but below pH 3.5 little or no solids will precipitate or will do so slowly.

(3) $Fe^{3+} + 3\ H_2O \rightarrow Fe(OH)_3 \downarrow + 3\ H^+$

(3) Ferric Iron + Water → Ferric Hydroxide (yellowboy) + Acidity

Reference: http://www.dep.state.pa.us/dep/deputate/minres/bamr/amd/science_of_AMD.htm

Active Treatment

Active treatment uses chemicals to add alkalinity in order to raise the pH and allow the iron and other metals to precipitate. The metals precipitate when they are exposed to air, forming the oxide of metal. Active treatment systems usually add limestone (calcium carbonate), hydrated lime (calcium hydroxide), Pebble Quick Lime (calcium oxide), soda ash briquettes (sodium carbonate) and other highly alkaline chemicals. Each chemical has certain specific application and each one is appropriate for specific situations. The group must decide based on money/funding, and the number of years the system will be needed.

Most active treatment systems are used in open mining situations, that is, mines that are currently being mined.

Passive Treatment

Passive treatment requires no machines or people; it relies on the natural chemical and biological processes. Passive treatment was discovered when research showed that existing wetlands were currently treating mine drainage. Numerous wetland treatment theories and models were tested and proved that constructed wetlands were effective in treatment. Initial wetlands were constructed and sphagnum moss was placed in as vegetation. Future experiments with other vegetation proved that cattails were an excellent alternative. Also beneficial in the removal of the dissolved metals in mine drainage is the bacteria present in wetland soils. In order to ensure the existence of the beneficial bacteria, more research on the best organic material to support the bacteria was completed. The organic materials found to assist the bacteria and wetland plants were: soil, peat moss, spent mushroom compost, straw/manure, sawdust and hay bales.

The passive treatment technologies that have been developed are specific to the chemistry of the mine water. Many times it is necessary to combine several of these systems to produce the best overall system for the drainage.

Most systems end with the settling pond and the aerobic wetland to allow the metal precipitates to settle out prior to discharging the water into the stream. The primary things needed for the dissolved iron to drop out of solution are time and oxygen. Vegetation helps to slow the water down in the wetland, when the water has to pass through a group of cattails, it must slow down. The surface area of the wetland is important, the oxidation reaction produces the precipitate, therefore, the more time the water has to react with the oxygen, the more iron that will precipitate. To increase the oxygen contact, air could be bubbled through one pond; the paths from one pond to another can contain a waterfall or pipe that would allow aeration.

When the chemistry and flow of the mine water is determined, the type of system can be considered. The system that is chosen must produce water the meets the effluent standards set by the governing officials if applicable.

Procedure:

Warm-up:

Review pH

Ask:

If something was acidic, how could be neutralize it?

What chemical could we add to mine water that had a low pH?

What do you take when you stomach is upset? Do you know what is in Tums?

Demonstration:

Use acid mine water, measure the pH, add limestone or TUMS to the solution and measure the pH again, show the students that by adding the limestone, the acid has been neutralized. You can take it one step further and add hydrogen peroxide to the neutralized mine water and the iron should begin to precipitate out of solution and settle to the bottom.

When mine drainage is created, acid is produced and therefore, many of the metals that are found in rocks and soil are dissolved into the mine water as it travels under the ground. Most people recognize mine water from the orange color, often called "yellow boy", this is actually the precipitation of iron from the mine water. When mine water exits the mine, it is colorless and if the water is acidic (low pH), the iron and other metals will stay in solution until the pH increased. If the mine water has a neutral pH, the iron will begin to precipitate after contact with oxygen. If you have acid mine drainage entering the stream and stream does not have a well-buffered system, the pH isn't raised. If this is the case, you may not see the orange color until several miles downstream.

If you are treating acid mine drainage, the acidity must be removed in order for further treatment to take place, because the iron and other metals will not oxidize and drop out or precipitate until the pH is higher. The acid mine drainage also will destroy the ecosystem that assists with the final treatment phase.

Several types of alkaline materials are available to treat acid mine drainage:

- Powdered lime – for smaller flows
- Limestone (Calcium Carbonate $CaCO_3$)
- Hydrated Lime (Calcium Hydroxide CaOH)
- Quick Lime (Calcium Oxide CaO)
- Soda Ash briquettes (Sodium Carbonate $NaCO_3$)
- Caustic Soda (Sodium Hydroxide NaOH)
- Anhydrous Ammonia (NH_3)

When the pH of the mine water is raised, the metals can react with oxygen and precipitate out of solution as the metal hydroxide. The pH solubility of the common metals found in mine water (from most soluble to least soluble) is: Mn > Fe >Al. That means that at a pH of 6, aluminum and iron will precipitate, but manganese will stay in solution.

After the pH is raised and the metals react with oxygen to form a precipitate, the water then must be diverted to a settling pond or a wetland to allow the precipitate time to settle. If you have alkaline mine drainage, the wetland or settling ponds are all that is needed.

After investigating the chemistry of the mine water several things must be considered when determining the type of treatment system to install: amount of land, cost, and amount of time treatment is needed.

Activity:
Development of a Passive Treatment System for Abandoned Mine Drainage

- Split the student up into groups, being sure that each group has individuals with varying talents.
- Handout the "WELOS" Letter, one to each group.
- Discuss what the WELOS Organization needs, and why.
- Handout the sheet titled, "Evaluating Mine Water and Determining a Treatment System".
- Discuss the "Passive Treatment Options" with the students to ensure their understanding and knowledge.
- Handout the "Yellow Boy Labs" Letters (one per group), each group would have a different discharge.
- Hand out "The Steps To Evaluating An AMD Discharge And Creating A Treatment System", the "Instructions for Determining a Treatment System", and the Flow Chart.
- Have the students use the data obtained through analysis completed by "Yellow Boy Labs" to complete the worksheet. The worksheet will guide students through the process of determining the appropriate system.
- After **calculations** are complete, have the students determine the treatment system by using the flow chart.
- Have the students design the treatment system; they can complete an **engineering** type drawing or complete a 3-D model.

Wrap-up/Conclusion:

After the students have determined the type of system, developed a drawing, aerial and cross sectional, have them prepare a presentation to bring to you, their boss, and the Department of Environmental Protection. The presentation should include a poster, PowerPoint or handouts showing the reasons for their choice and the drawing they have developed. The presentation should end with how the system will be evaluated for effectiveness.

Assessment:

- The teacher will check the student's completed "instructions for determining the treatment system" worksheet. (Objective 1)
- The teacher will evaluate the accuracy of the type of treatment system needed for the situation, using the answer key. (Objective 2)
- The teacher will evaluate the treatment system design and sketch produced by the student to ensure necessary items have been addressed. (Objective 3)
- The teacher will evaluate the student's presentation for knowledge, content, formal speaking skills, and use of media. (Objective 4)

Resources:

AMD Discharges in the Loyalhanna Watershed, PowerPoint Slides to show all the discharges evaluated by "Yellow Boy Labs" are available on enclosed cd or from Saint Vincent College Environmental Education Center.

Evaluating Mine Water And Determining a Treatment System

When pyrite is exposed during mining, contact with water will cause the mineral to weather. This can take place in abandoned mines or during active mining operations. Most of the active mining sites use active treatment, which involves the constant addition of chemicals, with motors, pumps and instruments, to increase the pH (in the case of Acid Mine Drainage) and settling ponds to remove the precipitated metals. This treatment is costly and may need to be continued long after the mining is complete.

Until the 1977 Surface Mining Control and Reclamation Act (SMCRA) took effect, the mining companies were not required to minimize the disturbances of the streams and groundwater systems. These past mining techniques often exposed pyrite and mine operators did not know that the mineral they were exposing would create the problems we have today.

We have now acquired the knowledge and technology to clean up Abandoned Mine Drainage sites through the use of Passive Treatment technologies in which there is little maintenance and the cost is much less in relation to active treatment. Passive systems have a large initial start up cost and are dependent on the availability of the land for development of wetlands or settling ponds.

Passive treatment requires no machines or persons; it relies on the natural chemical and biological processes. Passive treatment was discovered when research showed that existing wetlands were currently treating mine drainage. Numerous wetland treatment theories and models were tested and proved that constructed wetlands were effective in treatment. Initial wetlands were constructed and sphagnum moss was placed in as vegetation. Future experiments with other vegetation proved that cattails were an excellent alternative. Also beneficial in the removal of the dissolved metals in mine drainage is the bacteria present in wetland soils. In order to ensure the existence of the beneficial bacteria, more research on the best organic material to support the bacteria was completed. The organic materials found to assist the bacteria and wetland plants were: soil, peat moss, spent mushroom compost, straw/manure, sawdust and hay bales. The passive treatment technologies that have been developed are specific to the chemistry of the mine water. Many times it is necessary to combine several of these systems to produce the best overall system for the drainage. Most systems end with the settling pond and the aerobic wetland to allow the metal precipitates to settle out prior to discharging the water into the stream. The primary things needed for the dissolved iron to drop out of solution are time and oxygen. Vegetation helps to slow the water down in the wetland, when the water has to pass through a group of cattails, it must slow down. The surface area of the wetland is important, the oxidation reaction produces the precipitate, therefore, the more time the water has to react with the oxygen, the more iron that will precipitate. To increase the oxygen contact, air could be bubbled through one pond; the paths from one pond to another can contain a waterfall or pipe that would allow aeration.

When the chemistry and flow of the mine water is determined, the type of system can be considered. The system that is chosen must produce water the meets the effluent standards set by the governing officials if applicable.

Passive Treatment Options

Aerobic Wetlands

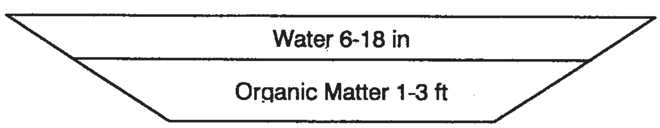
Aerobic or oxidizing wetlands are a low cost and low maintenance way of treating Abandoned Mine Drainage. These wetlands are usually man-made with large cells or ponds in succession to provide treatment for alkaline mine drainage. The cells are usually lined with plastic or clay to prevent seeping and are planted with wetland plants such as cattails. The process is simple; allow the mine water enough time to react with the oxygen in the air to precipitate the metals. The first cell or pond in an aerobic wetland is usually deeper so that cattails will not grow, this will allow the water a larger surface area and a longer reaction time with oxygen. The typical water depth is 6" – 18", but different levels are used to increase performance. Shallow ponds will freeze more quickly in winter months, but deeper ponds allow the precipitate to buildup.

After the precipitate is formed, the water needs slowed down to allow the precipitate to settle to the bottom of the wetland. Vegetation in the remaining cells slows the water down, and it provides another surface for the precipitate to stick.

Disadvantage, the oxidation of the mine water may increase the acidity and lower the pH.

MINIMUM SIZE OF THE WETLAND (acres):

[Fe Loading (lb/day)/180 lb/acre/day] + [Mn Loading (lb/day)/9 lb/acre/day]

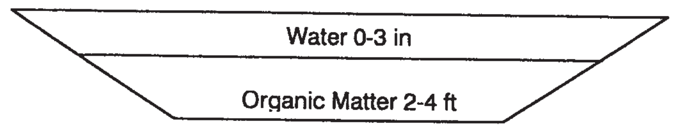


Anaerobic/Compost Wetlands

Anaerobic or non-oxygenated wetlands are very similar to aerobic wetlands. The major difference is that the mine water flows through a layer of thick, oxygen-free compost, usually spent mushroom compost with 10 percent calcium carbonate, to breakdown the sulfates and remove the oxygen. Other compost materials include peat moss, wood chips, sawdust or hay. The iron reducing bacteria is active at low pHs and can survive in low oxygen environments. In order to breakdown the sulfates, the oxygen is consumed, thus providing a low oxygenated water after this step. When the oxygen is removed from the sulfate, the sulfide ion is free to react with the metals and precipitate as metals sulfides. Typical compost depth is 12" – 24" with cattails or other wetland vegetation and 0" – 3" of water.

Again, this is a low cost way of treating Abandoned Mine Drainage and active mining discharges.

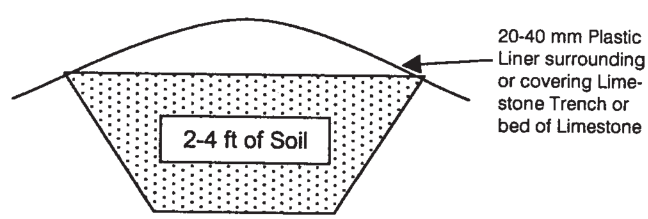
There are a couple limitations of the anaerobic wetland: (1) flow and chemistry determine the holding time, (i.e. larger the flow rate, the longer the holding time), (2) if the pH is less than 3, and it is not possible to increase the holding time, the addition of alkalinity is needed to increase the pH, (3) the effectiveness of the system is decreased in the winter months due to the bacteria being less active, (4) the organic layer may need replaced as the microbes break down and consume the material, and the precipitation can clog the bottom of the cells and require maintenance, (5) the wetlands can accept discharges with an acidity up to 500 mg/L.



Anoxic Limestone Drains

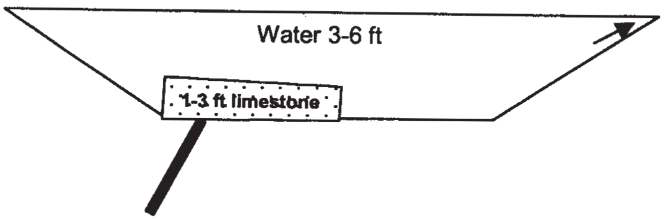
Anoxic Limestone Drains are trenches of limestone in which the acid mine drainage is channeled through. The mine water must have a dissolved oxygen less than 1.50 mg/L. As the mine water flows through the limestone, it is dissolved and the water pH increases and the alkalinity is increased. The oxygen is eliminated through the used of a cover to ensure that the limestone does not get armored.

Anoxic Limestone Drains can produce water between 275 and 300 mg/L of alkalinity, depending on the retention time of the water within the ALD. Retention times 14-15 hours is standard practice.



Limestone Ponds

A Limestone Pond is a pond that is constructed on the mine drainage seep or at the discharge. The mine water flows up through the limestone and the pH increases and the alkalinity increases. Limestone ponds are useful for net acidic discharges with iron concentration less than 5 mg/L.



Vertical Flow Wetland/Alkalinity Producing Systems

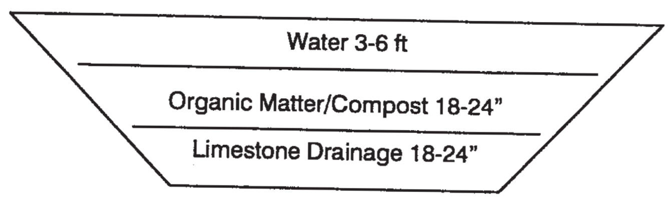
Alkalinity Producing Systems combine anoxic limestone drains or limestone ponds with anaerobic wetland. This process is used when there is high acidity and high metal concentrations. Often times it is necessary to do the process several times to increase the pH and alkalinity enough, this is called successive alkalinity producing systems (SAPS).

The Mine water will flow into the SAPS ponds to react with oxygen and allow the precipitation and settling of metals. The water exits the pond or cell through a lower point, which forces the water to travel through an anoxic layer with organic matter or compost to remove oxygen and then through limestone. The removal of the oxygen is important to stop iron from armoring the limestone, which decreases the effectiveness. The water then flows through a pipe to an outlet where it can be aerated, held in a sedimentation pond or filtered through a wetland for settling of precipitates. This process can be repeated as many times as are necessary to increase the pH and remove the precipitates.

This system can also be used with a seep of mine drainage, by reversing the layers, the organic layer would be placed on top of the seep with limestone on top of that, and as the water seeps up through the bottom, the bacteria do their thing and then the limestone increases the pH and alkalinity. These systems are called Reverse Alkalinity Producing Systems.

When looking at these systems, the topography and the amount of land available need to be considered, depending on the contaminants; a large system may be needed. The land must be conducive to the flows needed for the treatment system. Clogging of the pipes and systems may occur from the organic matter and the limestone may need replaced if armored or depleted.

The Alkalinity Producing Systems usually have 3'-6' of free standing water to provide enough pressure to force the water down through the 18" – 24" of compost and through 18" – 24" of limestone containing drainage pipes. They are sized based on retention times typical retention times are 12 – 15 hours, and the amount of limestone necessary is calculated using the equation of the ALD.



EPA - A Citizens Handbook to Address Contaminated Coal Mine Drainage

Steps to Evaluating an AMD Discharge And Creating a Treatment System

1. Examine what the customer needs, what tests are needed, what the discharge is like, etc. (Read the WELOS letter)
2. Read the handout – Evaluating Mine Water and Determining a Treatment System.
3. Read the handout – Passive Treatment Options. Make notes as the information needed for each option.
4. Request the analytical results from Yellow Boy Labs for the WELOS Organization.
5. Complete - Instructions For Determining The Treatment System worksheet.
6. Use the Flow Chart to determine the system type required.
7. After you have determined your system, design your system. The design should include depths including additives, i.e. compost, size of each cell, overall size and aerial and cross sectional views.
8. Prepare a 10-minute presentation to bring to your superior and the Department of Environmental Protection. The presentation should include a poster, PowerPoint or handouts showing the reasons for your choice and the drawing you have developed. You should end the presentation with how the system will be evaluated for effectiveness (i.e. chemical analysis), be specific as to what will be monitored.

The following are some tips for your system:

1. The detention time of the water is important in the development of the wetland. The length of the wetland should be twice as long as it is wide.
2. The water can be slowed down by planting emergent plants (such as cattails, *Typhus latifolia*), and by designing a series of cells or ponds or by placing deflectors, or baffles, throughout the wetlands.
3. The sides should be designed with 18° to 27° slope. This maximizes stability, makes it easier for equipment that is building or maintaining the wetlands to operate, and to some degree discourages (but is not guaranteed to eliminate) mosquitoes.
4. The cells and the wetland should have a slight downward slope from the influent to effluent. If *Typhus latifolia* are to be planted, surface water column depths of more than 50 cm are usually detrimental.
5. The wetland must be lined with a clay liner or an artificial liner to ensure that the groundwater will not mix with the treatment water.
6. It system must be designed to handle the highest average monthly flow rate that occurs during a twelve-month period.
7. It must have inlet and outlet structures that will allow for flow measurement and water sampling, (pipe outlet for bucket and stopwatch measurements, weir, flume, etc.).

WELOS Letter

We Love Our Stream
999 Wetland Drive
Waterfront, PA 11111
(724) 145-1234

Ms. Sabrina Eager
Director of Labs
Wetlands Are Us
96 West Heron Street
Springdale, PA 19786

Dear Ms. Eager,

Our organization, WELOS, is in the process of applying for funding for the development of a passive wetland treatment system to treat an abandoned mine drainage discharge currently entering the stream. In order to receive funding, it is required that we show proof of the chemistry and flow of the water to be treated, as well as the proposed plans for the wetland.

We need your company to run some independent tests to help us learn as much as possible about the discharge so that we can pass the information on to our engineer to design the wetland. The following parameters need determined: flow, total iron, and manganese, pH, Alkalinity, Acidity, and sulfate concentration.

The discharge is alkaline, but the iron content seems to be relatively high. Although the discharge has a relatively low flow, it has been captured, and exits via a pipe therefore, a bucket and stopwatch flow should be fine.

Due to the nature of several of the tests, it will be necessary for you to collect the samples and record flow values. We will need at least three months of data to proceed. Please contact me at the above number with any questions.

Sincerely yours,

Yvonne X. Michaels
President
WELOS

Instructions for Determining the Treatment System

Using the letter from the Yellow Boy Labs, the information provided and the flow chart, determine the type of treatment system needed for your abandoned mine water.

Compute the following data from the information provided.

1. Calculate the average flow for your discharge site:

2. Calculate whether the discharge is net acidic or net alkaline (use the average acidity and alkalinity for this calculation.): acidity – alkalinity = positive, the water is net acidic, negative, the water is net alkaline.

3. Calculate the average iron for your discharge site:

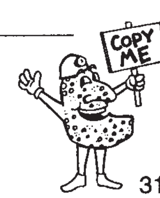
4. Calculate the average dissolved oxygen value for your discharge site, it is greater than or less than 1.5 mg/L?

5. Calculate the average aluminum value for your discharge site, is it greater than or less than 5 mg/L?

6. Calculate the average acidity value for your discharge site, is it greater than or less than 300 mg/L if your iron was greater than 5 mg/L, or is it greater than or less than 200 mg/L if your iron was less than 5 mg/L?

FILL IN THE CHART TO ASSIST WITH DETERMINATION OF THE TREATMENT SYSTEM:

Highest Flow	______________	Average Alkalinity	______________
Lowest Flow	______________	Average Acidity	______________
Average Flow	______________	Net Acidity	______________
Average Total Iron	______________	Average Dissolved Oxygen	______________
Average Total Aluminum	______________	Average Total Manganese	______________



7. Follow the Flow chart using the information from the handout, data from above and your letter from the analysis lab to determine the type of system that would treat the water most effectively.

8. If your discharge has net alkaline water, the size of your treatment system can be determined by using the loading rates and using the following equation:
Calculate the Loading rates of the iron and manganese:
To calculate the loading rates in pounds per day, multiply the flow rate (gpm) by the metal concentration (mg/L). Be sure to unit factor to convert gpm and mg/L to lbs/day.
Hint: 1.05 quarts = 1 L, and 454 g = 1 lb
Loading rate for Iron:

Loading rate for Manganese:

Size of wetland:
[Fe Loading (lb/day)/180 lb/acre/day] + [Mn Loading (lb/day)/9 lb/acre/day]

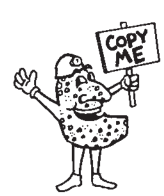
9. On another piece of paper, develop a drawing of the system from the information provide in the treatment options descriptions include depths and amounts.

HELP!!!!!

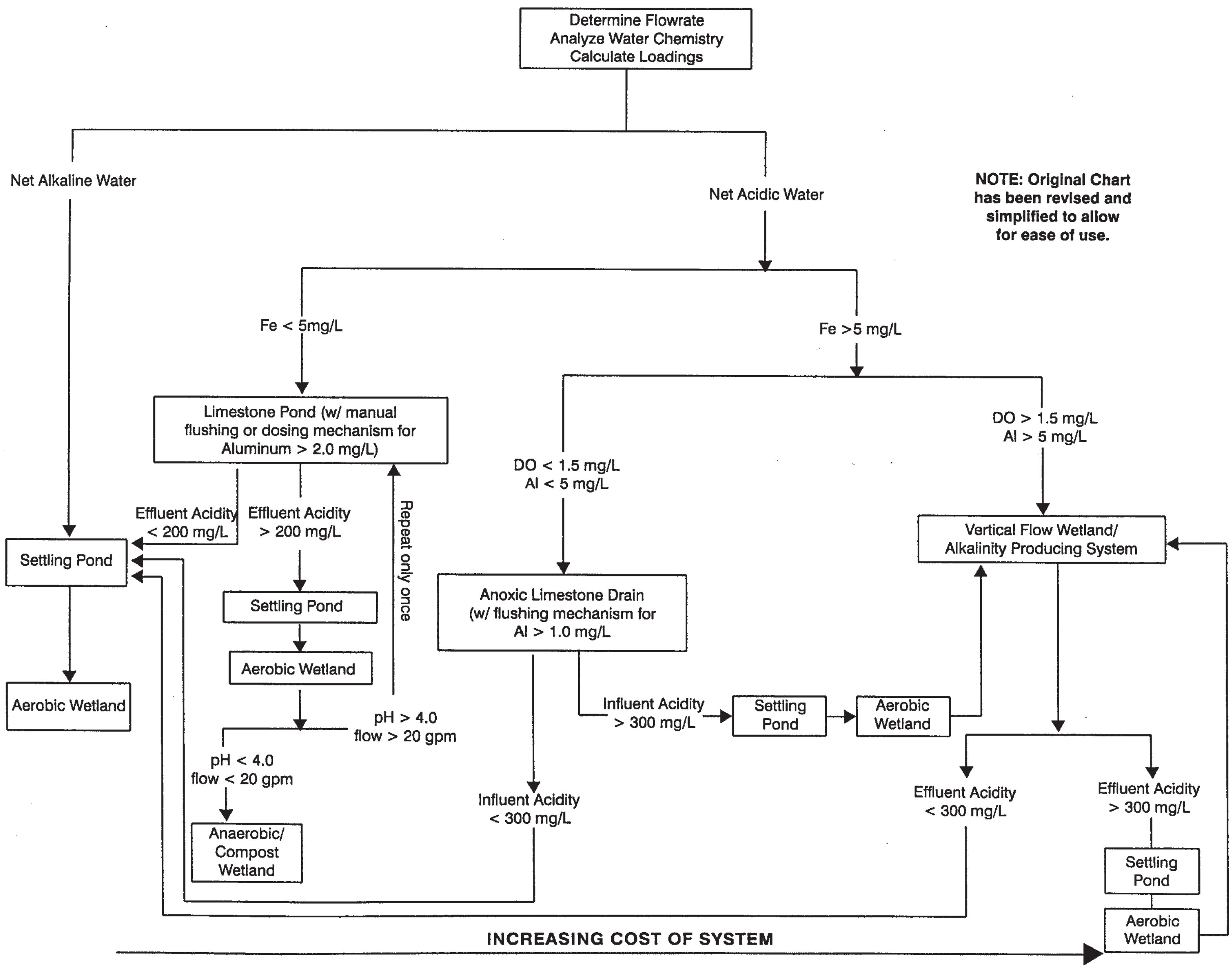
Calculating Average:
Add up all the numbers and divide the answer by the number of values used in the addition.

Conversion Factors
1.05 quarts = 1 L
454 g = 1 lb
1000 ml = 1L
60 min = 1 hour
24 hours = 1 day

lbs/day = (Average Iron * Average Flow)/83.2



Treatment System Flow Chart



Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

Sample Site: Lower Saxman Discharge

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	1065	0.06	5.7	54.0	42.0	571	44.7	5.0	0.549
2-15-02	2061	0.10	5.7	58.0	42.0	172	51.4	5.3	0.524
3-24-02	1822	0.18	5.7	56.0	61.0	445	42.9	4.7	0.465
4-17-02	1756	0.23	5.6	52.0	79.8	439	46.3	4.5	0.436
5-20-02	1724	0.75	5.7	52.0	81.8	385	45.1	5.3	0.635
6-15-02	1692	0.75	5.6	48.0	96.6	535	43.2	5.1	0.616
7-19-02	1740	0.55	5.6	48.0	98.4	506	48.6	5.0	0.626
8-21-02	1812	0.34	5.6	46.0	102.2	509	50.3	5.7	0.724
9-10-02	1895	0.75	5.7	46.0	90.6	520	51.3	5.5	0.753
10-5-02	2060	0.18	5.6	52.0	93.8	495	52.2	5.9	0.662
11-9-02	2425	0.26	5.7	54.0	69.2	488	53.7	4.82	0.474
12-6-02	1812.5	0.35	5.6	54.0	95.6	529	48.2	4.79	0.451

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer

Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

Sample Site: Upper Saxman Discharge

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	1025	0.6	5.4	38.0	66.0	473	47.1	4.9	1.91
2-15-02	920	1.26	5.3	32.0	68.0	599	45.6	5.4	2.38
3-24-02	3738	0.8	5.4	36.0	66.0	403	52.4	5.9	2.28
4-17-02	208	0.54	5.5	44.0	58.0	486	43.4	5.2	1.90
5-20-02	220	0.86	5.1	26.0	90.0	392	44.0	5.7	3.01
6-15-02	188	1.01	5.2	24.0	109.0	604	41.9	5.7	3.31
7-19-02	326	1.15	5.2	22.0	117.4	543	47.9	5.9	3.09
8-21-02	196	0.97	5.2	28.0	116.4	529	51.9	6.3	2.82
9-10-02	563	0.58	5.4	30.0	126.4	570	50.7	5.8	2.33
10-5-02	1812	0.39	5.4	34.0	116.6	495	50.2	5.9	1.98
11-9-02	1574	0.71	5.5	44.0	101.2	470	54.4	4.8	1.55
12-6-02	2695.2	0.92	5.6	44.0	85.6	575	51.0	5.2	1.60

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer

Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

Sample Site: Getty Run Discharge

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	16.51	6.42	2.8	0.0	455.6	800	27.8	6.84	40.4
2-15-02	22.66	8.81	2.8	0.0	460.4	785	28.3	7.02	39.5
3-24-02	28.62	6.10	2.8	0.0	429.4	796	23.8	7.77	42.0
4-17-02	121.96	4.50	2.8	0.0	445.8	696	24.0	6.05	38.0
5-20-02	362.70	3.62	2.8	0.0	673.6	1208	40.0	7.90	61.6
6-15-02	28.62	10.17	2.8	0.0	502.6	805	46.9	7.63	41.9
7-19-02	50.25	9.46	2.8	0.0	541.0	901	49.8	8.14	43.0
8-21-02	65.62	7.18	2.7	0.0	581.2	924	64.4	8.46	50.3
9-10-02	91.21	8.63	2.7	0.0	648.6	907	72.6	5.82	49.0
10-5-02	135.80	8.12	2.7	0.0	745.4	1168	83.8	7.18	59.1
11-9-02	91.21	7.85	2.8	0.0	735.5	1085	81.2	7.75	42.7
12-6-02	95.67	7.64	2.7	0.0	697.5	1107	85.9	8.10	52.9

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer

Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

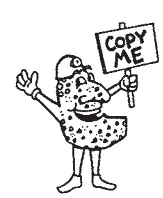
Sample Site: Hawk Discharge

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	15	0.66	3.4	0.0	307.4	1367	4.6	27.7	34.4
2-15-02	19	0.73	3.4	0.0	239.4	1087	3.5	30.1	33.6
3-24-02	10	1.47	3.4	0.0	251.6	1048	2.24	25.5	25.5
4-17-02	14	0.55	3.3	0.0	307.4	1036	4.5	26.7	29.3
5-20-02	11	0.67	3.4	0.0	308.2	1012	3.9	25.9	24.9
6-15-02	9	0.76	3.4	0.0	308.4	1048	2.98	25.1	28.3
7-19-02	2	0.46	3.3	0.0	249.4	1207	2.65	29.3	32.3
8-21-02	5	0.56	3.4	0.0	261.6	1284	3.78	25.7	31.7
9-10-02	18	0.46	3.4	0.0	310.2	1175	4.03	28.3	25.9
10-5-02	16	0.47	3.3	0.0	285.3	1076	4.08	30.2	33.4
11-9-02	10	0.59	3.3	0.0	245.9	1302	5.67	24.9	27.7
12-6-02	18	0.99	3.5	0.0	299.1	1258	5.24	30.0	30.1

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer



Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

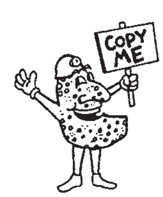
Sample Site: Crabtree Discharge

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	1000	0.55	6.1	158.0	0.0	380	81.5	2.9	1.52
2-15-02	6348	0.34	6.1	146.0	1.8	732	71.1	2.8	1.78
3-24-02	3450	0.28	6.1	154.0	28.6	747	84.6	2.6	0.99
4-17-02	2435	0.45	6.0	166.0	19.0	902	80.4	2.4	0.66
5-20-02	2269	0.38	6.1	166.0	30.0	587	79.4	2.6	0.67
6-15-02	1845	0.60	6.2	170.0	33.0	842	77.3	2.4	0.54
7-19-02	1692	0.78	6.2	166.0	34.6	881	88.2	2.4	0.45
8-21-02	1813	0.16	6.1	164.0	42.0	840	84.5	2.8	0.69
9-10-02	1692	0.25	6.2	160.0	60.8	882	89.1	3.0	0.97
10-5-02	2319	0.39	6.3	162.0	24.4	766	85.6	3.4	1.24
11-9-02	3738	0.70	6.1	150.0	33.4	789	71.0	3.6	2.79
12-6-02	5680	0.94	6.0	142.0	32.8	711	64.8	3.0	2.14

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer



Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

Sample Site: Loyalhanna Borehole

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	115	1.50	6.0	78.0	0.0	306	21.9	2.2	0.0
2-15-02	120	0.50	6.4	140.0	0.0	597	44.0	3.7	0.0
3-24-02	156	0.43	6.2	142.0	0.0	425	41.9	3.4	0.0
4-17-02	126	0.98	6.2	88.0	0.0	409	34.3	3.2	0.0
5-20-02	56	0.46	6.2	134.0	0.0	429	39.8	3.7	0.0
6-15-02	93	0.28	6.2	136.0	0.0	550	36.8	3.5	0.0
7-19-02	122	1.53	6.2	134.0	0.0	528	41.7	3.7	0.0
8-21-02	NA	NA	6.2	138.0	0.0	513	45.5	3.9	0.0
9-10-02	NA	NA	6.3	140.0	0.0	526	40.5	3.4	0.0
10-5-02	139	0.21	6.2	138.0	0.0	490	46.5	4.2	0.0
11-9-02	172	1.74	6.3	140.0	0.0	502	42.9	4.1	0.0
12-6-02	146	1.55	6.3	137.0	0.0	496	39.5	3.9	0.0

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer

Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

Sample Site: AV Pipe

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	171	0.20	6.2	128.0	48.0	483	36.9	3.0	0.0
2-15-02	144	0.09	6.2	126.0	16.0	390	38.3	2.9	0.0
3-24-02	90	0.15	6.0	90.0	0.0	413	48.9	2.8	29.0
4-17-02	152	0.19	6.2	152.0	0.0	364	46.7	3.3	0.0
5-20-02	122	0.25	6.2	160.0	0.0	418	46.0	3.7	0.0
6-15-02	135	0.30	6.3	162.0	0.0	491	41.9	3.5	0.0
7-19-02	134	0.09	6.3	158.0	0.0	462	45.1	3.6	0.0
8-21-02	134	0.20	6.2	152.0	0.0	482	50.3	4.0	0.0
9-10-02	149	0.23	6.2	150.0	0.0	530	48.9	4.1	0.0
10-5-02	161	0.20	6.2	146.0	0.0	504	49.1	4.4	0.0
11-9-02	160	0.16	6.2	152.0	0.0	524	51.4	4.1	0.0
12-6-02	161	1.25	6.2	164.0	0.0	428	46.9	3.9	0.0

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer

Yellow Boy Labs

100 Mine Drainage Road
Patchtown, PA 10092

Mr. I. Ron Sulfide
Defunct Mines Inc.
220 Coal Road
Abandoned, PA 19049

Dear Mr. Sulfide,

Yellow Boy Labs has completed the analysis required for your determination of the best treatment option.

Sample Site: West Derry Discharge

Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	630	1.6	2.9	0	1121	1402	185	16.3	106
2-15-02	615	0.94	2.8	0	1212	1220	180	15.6	101
3-24-02	630	0.85	2.8	0	1076	1095	164	15.4	94.8
4-17-02	595	0.8	2.7	0	1129	1206	189	16.2	104
5-20-02	660	0.75	2.7	0	1174	1154	169	14.9	98.3
6-15-02	563	0.89	2.7	0	1122	1180	179	16.4	100
7-19-02	596	0.62	2.7	0	1132	1359	197	18.8	115
8-21-02	625	0.95	2.7	0	1071	1400	150	15.1	93.5
9-10-02	625	1.05	2.7	0	1121	1243	146	16	97.1
10-5-02	690	0.6	2.7	0	1062	1286	150	17.4	104
11-9-02	643	1.8	2.7	0	1036	1317	158	17.2	99.1
12-6-02	602	0.4	2.7	0	930	1013	122	15.1	79.9

The dissolved oxygen, pH and flow were completed in the field, and the remainder of the tests were completed in the lab.

Sincerely yours,

Sandra Gooding
Lab Manager/QA/QC Officer

TEACHER'S ANSWER SHEET — CREATE AN AMD TREATMENT SYSTEM

Lower Saxman Discharge									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	1065	0.06	5.7	54.0	42.0	571	44.7	5.0	0.549
2-15-02	2061	0.10	5.7	58.0	42.0	172	51.4	5.3	0.524
3-24-02	1822	0.18	5.7	56.0	61.0	445	42.9	4.7	0.465
4-17-02	1756	0.23	5.6	52.0	79.8	439	46.3	4.5	0.436
5-20-02	1724	0.75	5.7	52.0	81.8	385	45.1	5.3	0.635
6-15-02	1692	0.75	5.6	48.0	96.6	535	43.2	5.1	0.616
7-19-02	1740	0.55	5.6	48.0	98.4	506	48.6	5.0	0.626
8-21-02	1812	0.34	5.6	46.0	102.2	509	50.3	5.7	0.724
9-10-02	1895	0.75	5.7	46.0	90.6	520	51.3	5.5	0.753
10-5-02	2060	0.18	5.6	52.0	93.8	495	52.2	5.9	0.662
11-9-02	2425	0.26	5.7	54.0	69.2	488	53.7	4.82	0.474
12-6-02	1812.5	0.35	5.6	54.0	95.6	529	48.2	4.79	0.451
Highest Flow	2425								
Lowest Flow	1065								
Net Acidity	27.75								
Average	1822.0417	0.375	5.65	51.66667	79.41667	466.1667	48.15833	5.134167	0.57625

Type of System: Anoxic Limestone Drain (no flushing mechanism) - Settling Pond - Aerobic Wetland

Iron Loading: 1047.6176 lbs/day

Manganese Loading: 111.68666 lbs/day

Acidity Loading: 1727.5992

TEACHER'S ANSWER SHEET — CREATE AN AMD TREATMENT SYSTEM

Upper Saxman Discharge									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	1025	0.6	5.4	38.0	66.0	473	47.1	4.9	1.91
2-15-02	920	1.26	5.3	32.0	68.0	599	45.6	5.4	2.38
3-24-02	3738	0.8	5.4	36.0	66.0	403	52.4	5.9	2.28
4-17-02	208	0.54	5.5	44.0	58.0	486	43.4	5.2	1.90
5-20-02	220	0.86	5.1	26.0	90.0	392	44.0	5.7	3.01
6-15-02	188	1.01	5.2	24.0	109.0	604	41.9	5.7	3.31
7-19-02	326	1.15	5.2	22.0	117.4	543	47.9	5.9	3.09
8-21-02	196	0.97	5.2	28.0	116.4	529	51.9	6.3	2.82
9-10-02	563	0.58	5.4	30.0	126.4	570	50.7	5.8	2.33
10-5-02	1812	0.39	5.4	34.0	116.6	495	50.2	5.9	1.98
11-9-02	1574	0.71	5.5	44.0	101.2	470	54.4	4.8	1.55
12-6-02	2695.2	0.92	5.6	44.0	85.6	575	51.0	5.2	1.60
Highest Flow	3738								
Lowest Flow	188								
Net Acidity	59.88333333								
Average	1122.1	0.815833	5.35	33.5	93.38333	511.5833	48.375	5.558333	2.346666667

Type of System: Anoxic Limestone Drain (no flushing mechanism) - Settling Pond - Aerobic Wetland

Iron Loading: 648.07547 lbs/day

Manganese Loading: 74.464486 lbs/day

Acidity Loading: 1251.048

TEACHER'S ANSWER SHEET — CREATE AN AMD TREATMENT SYSTEM

Hawk Discharge									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	15	0.66	3.4	0.0	307.4	1367	4.6	27.7	34.4
2-15-02	19	0.73	3.4	0.0	239.4	1087	3.5	30.1	33.6
3-24-02	10	1.47	3.4	0.0	251.6	1048	2.24	25.5	25.5
4-17-02	14	0.55	3.3	0.0	307.4	1036	4.5	26.7	29.3
5-20-02	11	0.67	3.4	0.0	308.2	1012	3.9	25.9	24.9
6-15-02	9	0.76	3.4	0.0	308.4	1048	2.98	25.1	28.3
7-19-02	2	0.46	3.3	0.0	249.4	1207	2.65	29.3	32.3
8-21-02	5	0.56	3.4	0.0	261.6	1284	3.78	25.7	31.7
9-10-02	18	0.46	3.4	0.0	310.2	1175	4.03	28.3	25.9
10-5-02	16	0.47	3.3	0.0	285.3	1076	4.08	30.2	33.4
11-9-02	10	0.59	3.3	0.0	245.9	1302	5.67	24.9	27.7
12-6-02	18	0.99	3.5	0.0	299.1	1258	5.24	30.0	30.1
Highest Flow	19								
Lowest Flow	2								
Net Acidity	281.1583333	average acidity - average alkalinity			positive=net acidic			negative=net alkaline	
Average	12.25	0.6975	3.375	0	281.1583	1158.333	3.930833	27.45	29.75833

Type of System: Limestone Pond - Settling Pond - Aerobic Wetland - Compost Wetland

Iron Loading: 0.5749019 lbs/day =lbs/day (Average Iron * Average Flow)/83.2

Manganese Loading: 4.0146851 lbs/day =lbs/day (Average Manganese * Average Flow)/83.2

TEACHER'S ANSWER SHEET — CREATE AN AMD TREATMENT SYSTEM

West Derry Discharge									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	630	1.6	2.9	0	1121	1402	185	16.3	106
2-15-02	615	0.94	2.8	0	1212	1220	180	15.6	101
3-24-02	630	0.85	2.8	0	1076	1095	164	15.4	94.8
4-17-02	595	0.8	2.7	0	1129	1206	189	16.2	104
5-20-02	660	0.75	2.7	0	1174	1154	169	14.9	98.3
6-15-02	563	0.89	2.7	0	1122	1180	179	16.4	100
7-19-02	596	0.62	2.7	0	1132	1359	197	18.8	115
8-21-02	625	0.95	2.7	0	1071	1400	150	15.1	93.5
9-10-02	625	1.05	2.7	0	1121	1243	146	16	97.1
10-5-02	690	0.6	2.7	0	1062	1286	150	17.4	104
11-9-02	643	1.8	2.7	0	1036	1317	158	17.2	99.1
12-6-02	602	0.4	2.7	0	930	1013	122	15.1	79.9
Highest Flow	690								
Lowest Flow	563								
Net Acidity	1099	average acidity - average alkalinity			positive=net acidic		negative=net alkaline		
Average	623	0.9375	2.733333	0	1098.833	1239.583	165.75	16.2	99.39166667

Type of System: Limestone Pond - Settling Pond - Aerobic Wetland - Compost Wetland

Iron Loading: 1232.5326 lbs/day =lbs/day (Average Iron * Average Flow)/83.2

Manganese Loading: 120.46473 lbs/day =lbs/day (Average Manganese * Average Flow)/83.2

TEACHER'S ANSWER SHEET — CREATE AN AMD TREATMENT SYSTEM

A/V Pipe									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	171	0.20	6.2	128.0	48.0	483	36.9	3.0	0.0
2-15-02	144	0.09	6.2	126.0	16.0	390	38.3	2.9	0.0
3-24-02	90	0.15	6.0	90.0	0.0	413	48.9	2.8	29.0
4-17-02	152	0.19	6.2	152.0	0.0	364	46.7	3.3	0.0
5-20-02	122	0.25	6.2	160.0	0.0	418	46.0	3.7	0.0
6-15-02	135	0.30	6.3	162.0	0.0	491	41.9	3.5	0.0
7-19-02	134	0.09	6.3	158.0	0.0	462	45.1	3.6	0.0
8-21-02	134	0.20	6.2	152.0	0.0	482	50.3	4.0	0.0
9-10-02	149	0.23	6.2	150.0	0.0	530	48.9	4.1	0.0
10-5-02	161	0.20	6.2	146.0	0.0	504	49.1	4.4	0.0
11-9-02	160	0.16	6.2	152.0	0.0	524	51.4	4.1	0.0
12-6-02	161	1.25	6.2	164.0	0.0	428	46.9	3.9	0.0
Highest Flow	171								
Lowest Flow	90								
Net Acidity	-139.6666667								
Average	142.75	0.275833	6.2	145	5.333333	457.4167	45.86667	3.608333	2.416667

Type of System: Settling Pond - Aerobic Wetland

Size of Wetland: 1.117587 acres

Iron Loading: 78.171121 lbs/day

Manganese Loading: 6.1497267 lbs/day

Acidity Loading: 0

TEACHER'S ANSWER SHEET — CREATE AN AMD TREATMENT SYSTEM

Crabtree Discharge									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	1000	0.55	6.1	158.0	0.0	380	81.5	2.9	1.52
2-15-02	6348	0.34	6.1	146.0	1.8	732	71.1	2.8	1.78
3-24-02	3450	0.28	6.1	154.0	28.6	747	84.6	2.6	0.99
4-17-02	2435	0.45	6.0	166.0	19.0	902	80.4	2.4	0.66
5-20-02	2269	0.38	6.1	166.0	30.0	587	79.4	2.6	0.67
6-15-02	1845	0.60	6.2	170.0	33.0	842	77.3	2.4	0.54
7-19-02	1692	0.78	6.2	166.0	34.6	881	88.2	2.4	0.45
8-21-02	1813	0.16	6.1	164.0	42.0	840	84.5	2.8	0.69
9-10-02	1692	0.25	6.2	160.0	60.8	882	89.1	3.0	0.97
10-5-02	2319	0.39	6.3	162.0	24.4	766	85.6	3.4	1.24
11-9-02	3738	0.70	6.1	150.0	33.4	789	71.0	3.6	2.79
12-6-02	5680	0.94	6.0	142.0	32.8	711	64.8	3.0	2.14
Highest Flow	6348								
Lowest Flow	1000								
Net Acidity	-130.3								
Average	2856.75	0.485	6.125	158.6667	28.36667	754.9167	79.79167	2.825	1.203333

Type of System: Settling Pond - Aerobic Wetland

Size of Wetland: 25.8251 acres

Iron Loading: 2721.4654 lbs/day

Manganese Loading: 96.352666 lbs/day

Acidity Loading: 967.50582

TEACHER'S ANSWER SHEET — CREATE AN AMD TREATMENT SYSTEM

Loyalhanna Borehole									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	115	1.50	6.0	78.0	0.0	306	21.9	2.2	0.0
2-15-02	120	0.50	6.4	140.0	0.0	597	44.0	3.7	0.0
3-24-02	156	0.43	6.2	142.0	0.0	425	41.9	3.4	0.0
4-17-02	126	0.98	6.2	88.0	0.0	409	34.3	3.2	0.0
5-20-02	56	0.46	6.2	134.0	0.0	429	39.8	3.7	0.0
6-15-02	93	0.28	6.2	136.0	0.0	550	36.8	3.5	0.0
7-19-02	122	1.53	6.2	134.0	0.0	528	41.7	3.7	0.0
8-21-02	NA	NA	6.2	138.0	0.0	513	45.5	3.9	0.0
9-10-02	NA	NA	6.3	140.0	0.0	526	40.5	3.4	0.0
10-5-02	139	0.21	6.2	138.0	0.0	490	46.5	4.2	0.0
11-9-02	172	1.74	6.3	140.0	0.0	502	42.9	4.1	0.0
12-6-02	146	1.55	6.3	137.0	0.0	496	39.5	3.9	0.0
Highest Flow	172								
Lowest Flow	56								
Net Acidity	-128.75								
Average	124.5	0.918	6.225	128.75	0	480.9167	39.60833	3.575	0

Type of System: Settling Pond - Aerobic Wetland

Size of Wetland: 0.917522 acres

Iron Loading: 58.874735 lbs/day

Manganese Loading: 5.313962 lbs/day

Acidity Loading: 0

Getty Run Discharge									
Date	Flow (GPM)	Dissolved Oxygen (mg/L)	pH	Alkalinity (mg/L as $CaCO_3$)	Acidity (mg/L as $CaCO_3$)	Sulfate (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Total Al (mg/L)
1-10-02	16.51	6.42	2.8	0.0	455.6	800	27.8	6.84	40.4
2-15-02	22.66	8.81	2.8	0.0	460.4	785	28.3	7.02	39.5
3-24-02	28.62	6.10	2.8	0.0	429.4	796	23.8	7.77	42.0
4-17-02	121.96	4.50	2.8	0.0	445.8	696	24.0	6.05	38.0
5-20-02	362.70	3.62	2.8	0.0	673.6	1208	40.0	7.90	61.6
6-15-02	28.62	10.17	2.8	0.0	502.6	805	46.9	7.63	41.9
7-19-02	50.25	9.46	2.8	0.0	541.0	901	49.8	8.14	43.0
8-21-02	65.62	7.18	2.7	0.0	581.2	924	64.4	8.46	50.3
9-10-02	91.21	8.63	2.7	0.0	648.6	907	72.6	5.82	49.0
10-5-02	135.80	8.12	2.7	0.0	745.4	1168	83.8	7.18	59.1
11-9-02	91.21	7.85	2.8	0.0	735.5	1085	81.2	7.75	42.7
12-6-02	95.67	7.64	2.7	0.0	697.5	1107	85.9	8.10	52.9
Highest Flow	16.51								
Lowest Flow	362.7								
Net Acidity	576.3833333								
Average	92.569167	7.375	2.766667	0	576.3833	931.8333	52.375	7.388333	46.7

Type of System: Vertical Flow Wetland/Alkalinity Producing System - Settling Pond - Aerobic Wetland
Vertical Flow Wetland/Alkalinity Producing System...

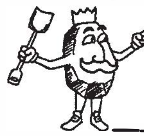
Iron Loading: 57.884653 lbs/day

Manganese Loading: 8.1655582 lbs/day

Acidity Loading: 637.01669

Puzzling Pollution Problem

Developed by Mary Ann Savering, Cambria County Conservation District, Ebensburg, PA



About This Activity...

Prep Time Required:
50 minutes

Grade Level:
High School

Subjects:
Earth Science, Biology, Chemistry, Geography

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
4.2.10.A, 4.2.10.B, 4.3.10.B, 4.5.10.C

Setting:
Classroom

Vocabulary:
Acidic
Active Treatment
Aerobic Wetland
Alkaline
AMD
Anaerobic Wetland
Anoxic Limestone Drain
Armor
Calcium Carbonate
Dissolved Metals
Diversion Wells
Hydrophytic
Open Limestone Channel
Oxidation
Oxygen
Passive Treatment
pH
Reclamation
Reduction
Substrate
Watershed

Prerequisites:
Knowledge of chemistry, oxidation – reduction reactions, passive treatment, wetlands

Summary:
Students learn the structure and function of anaerobic wetlands and open limestone channels by completing a puzzle and testing their knowledge with flashcards.

Materials:
- Poster board
- Glue stick
- Construction paper
- Laminating paper
- Scissors
- Picture of process
- Copies of Worksheet (included)
- Puzzle (picture included)
- Flashcards, cut (included)

Objective:
Students will be able to:
- understand the structures and functions of an **anaerobic wetland** and an open limestone channel.

Background:
Metals can be removed from contaminated water many ways; one of the most utilized is a **passive treatment** method that involves the construction of ponds and wetlands for the **oxidation** and precipitation of metals.

These anaerobic wetlands are used to treat abandoned mine drainage (**AMD)** that is high in **acidity** or sulfate concentrations, and are large ponds with a lower layer of organic substrate. Typically, the organic layer is made from spent mushroom compost (byproduct of the mushroom industry) containing approximately 10% **calcium carbonate**. The compost is usually 12 – 24 inches deep and can be planted with hydrophytic plants in order to improve treatment (via sulfate **reduction**) and provide wildlife habitat. These wetlands act as a reducing agent, where the compost promotes chemical and microbial processes that generate alkalinity, thus increasing **pH**. In addition, the compost removes **oxygen** from the water, which allows the sulfate to be reduced, keeping the metals from oxidizing and armoring (coating) the system or the stream. Anaerobic wetlands are similar to **aerobic wetlands** in appearance; however, they are underlain with muck (**substrate**) and a layer of limestone. The water flows horizontally through the substrate layer of the basin.

Open limestone channels are the simplest passive treatment method. In passive treatment systems, as a general rule, limestone is the favored product used in alkalinity because it is cheap, plentiful, and safe. Limestone can be used in many different situations, including: lining a trench, pond or stream bed, placing it near the surface of a stream or pond, and developing acid reducing wetlands. Specifically, open limestone channels are used in two ways. The first method simply involves adding high quality limestone to the existing stream channel. The second method involves excavating a channel and lining it with high quality limestone.

Unfortunately, these systems have a limited use. They work well with waters that have low metals and low pH. If the metal content of the water to be treated is too high, the limestone will become armored with metals and rendered ineffective.

Procedure:
Warm-up:
Show the students a photograph of a stream polluted with AMD. Photographs located on CD Rom or the AMDEC website. Tell students how the stream is polluted, and ask the class how they would try to stop or remediate the AMD if they were scientists. Explain to the students that there are many ways that AMD pollution is remediated, from passive treatment to **active treatment** methods.

Activity:
Inform the students that they will be learning about two passive treatment methods that are used to treat AMD. Contamination, particularly metal, can be removed from water in many ways. Two popular passive treatment methods are anaerobic wetlands and open limestone channels.

Describe anaerobic wetlands and open limestone channels to the class.

Have the students form a circle. Give various students pieces of the Open Limestone Channel puzzle. Have the students work on completing the puzzle. (While the students are working through the puzzle, review the terms listed on the flashcards.) This puzzle is just one example of how an Open Limestone Channel is organized.

Using the puzzle, describe the flow of AMD through the channel.

Wrap-up/Conclusion:

Ask the students to treat AMD pollution. Have the class describe how an Open Limestone Channel, specifically is used in AMD treatment.

Divide the class into groups; distribute the flash cards into groups. Have the students quiz each other on the vocabulary words learned during the class.

Assessment:

- Have the students complete the worksheet about AMD Remediation.

Extensions:

- Word jumbles and crosswords puzzles can be created using the various vocabulary words from this lesson.
- An excellent way to reinforce this lesson would be taking a field trip to an Anaerobic Wetland or an Open Limestone Channel, contact your local **watershed** organization for information.

Adaptations:

Emphasize the different plants and animals that live in a wetland. For older students, focus on the aquatic macroinvertebrate populations that inhabit wetland areas.

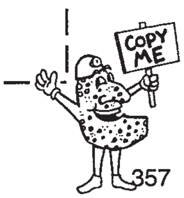
Discuss the formulas describing the sulfate reduction, which prevents the metals from oxidizing.

Students can make their own flash cards to quiz each other.

Flash cards can be adapted by using photographs of the words and the actual chemical symbols.

Flashcards

ACIDIC Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	The condition of water or soil that contains a sufficient amount of acid substances to lower the pH below 7.0 Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
ACTIVE TREATMENT Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Active treatment involves the use of chemicals and energy to remove contaminants from the water. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
AEROBIC WETLAND Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Large surface area ponds with horizontal flow. The pond usually contains cattails and other wetland species. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
ALKALINE Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Acid neutralizing or buffering capacity of water. A measure of the ability of water to resist changes in pH caused by the addition of acids or bases. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
AMD Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Abandoned Mine Drainage: Drainage of water from abandoned mines. The water had a low pH because of its contact with sulfur bearing material harmful to aquatic organisms. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
ANAEROBIC WETLAND Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Large ponds with a lower layer of organic substrate. The water flows horizontally through the substrate layer of the basin. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM



Flashcards

ANOXIC LIMESTONE DRAINS Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Buried beds of limestone that allow water to flow through it without coming in contact with oxygen. The limestone aides in increasing the pH of the water. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
CALCIUM CARBONATE Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	A salt found in nature as chalk or calcite, aragonite or limestone. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
DISSOLVED METALS Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	The total mass of dissolved mineral constituents or chemical compounds in water. They form the residue that remains after evaporation and drying. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
DIVERSION WELLS Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Simple Passive Treatment Technology. Divert water by a pipe to a downstream well, which contains limestone. The force of the water into the well results in turbulence, allowing the water and limestone to mix and "react." Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
PASSIVE TREATMENT Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Designed to remove contaminates without actively pumping chemicals into the system. Examples: wetlands, open limestone channels, anoxic limestone drain. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
pH Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	A measure of the concentration of hydrogen ions. Scale : 1 (most acidic) to 14 (most basic) Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM

Flashcards

OPEN LIMESTONE CHANNEL Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	The simplest passive treatment method. First method involves adding high quality limestone to the existing stream channel. Second method involves excavating a channel and lining it with high quality limestone. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
OXYGEN Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	An odorless, colorless gas, combines with hydrogen to form water, essential for aerobic respiration Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
RECLAMATION Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	The process of reconvening land to other forms of productive uses. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
REMEDIATION Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	Cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a superfund site or any other site. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
SUBSTRATE Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	A.Material or substance that is a reactant in an enzyme-catalyzed reaction. B. Attachment surface or bottom material in which organisms can attach or live within, such as rock substrate or sand substrate. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM
WATERSHED Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM	All land and water areas that drain toward a river or lake. Also called a drainage basin or water basin. Nature Interrupted – The Journey of AMD PUZZLING POLLUTION PROBLEM

Passive Treatment Worksheet

Name: ____

1) What is an anaerobic wetland?

2) What is the main function or purpose of an anaerobic wetland?

3) If one of these functions were missing (if a piece of the puzzle were missing), would it still function? If so why? If not, why not?

4) Of the two methods to treat AMD, this method has naturally occurring chemical and biological reactions in a controlled environment. Circle correct answer:
a. Active
b. Passive

5) Which treatment method is more expensive and has a higher maintenance. Circle the correct answer.
a. Passive
b. Active

6) As a general rule for the treatment of a passive system, what is the favored product?
a. Limestone
b. Algae
c. Iron
d. Calcium Carbonate

7) Anaerobic Wetlands are similar to Aerobic Wetlands. Choose the answer that best describes the components that make them different.
a. Substrate and Limestone
b. Limestone and Calcium Carbonate
c. Calcium Carbonate and Sulfate
d. Oxygen and Limestone

8) If an Open Limestone Channel has a steep slope, the amount of armoring will be limited because of the action of the water and the limestone. Circle one: TRUE or FALSE

9) If compost removes oxygen from the water sulfate is reduced, which keeps the metals from ______________________ and ______________________ the system or the stream.

TEACHER'S ANSWER SHEET — PASSIVE TREATMENT WORKSHEET

1) Anaerobic wetlands are large ponds with a lower layer of organic substrate. The water flows horizontally through the substrate layer of the basin.

2) They act as a reducing agent where the compost promotes chemical and microbial processes that generate alkalinity and thus increase pH.

3) Example: If there is no compost, the oxygen would still be in the water, so the sulfate would still be high and the metals in the water would continue to oxidize and armor the system or the stream.

This is only one example of many possible outcomes depending on what feature, function, or process is missing.

4) B. Passive

5) B. Active

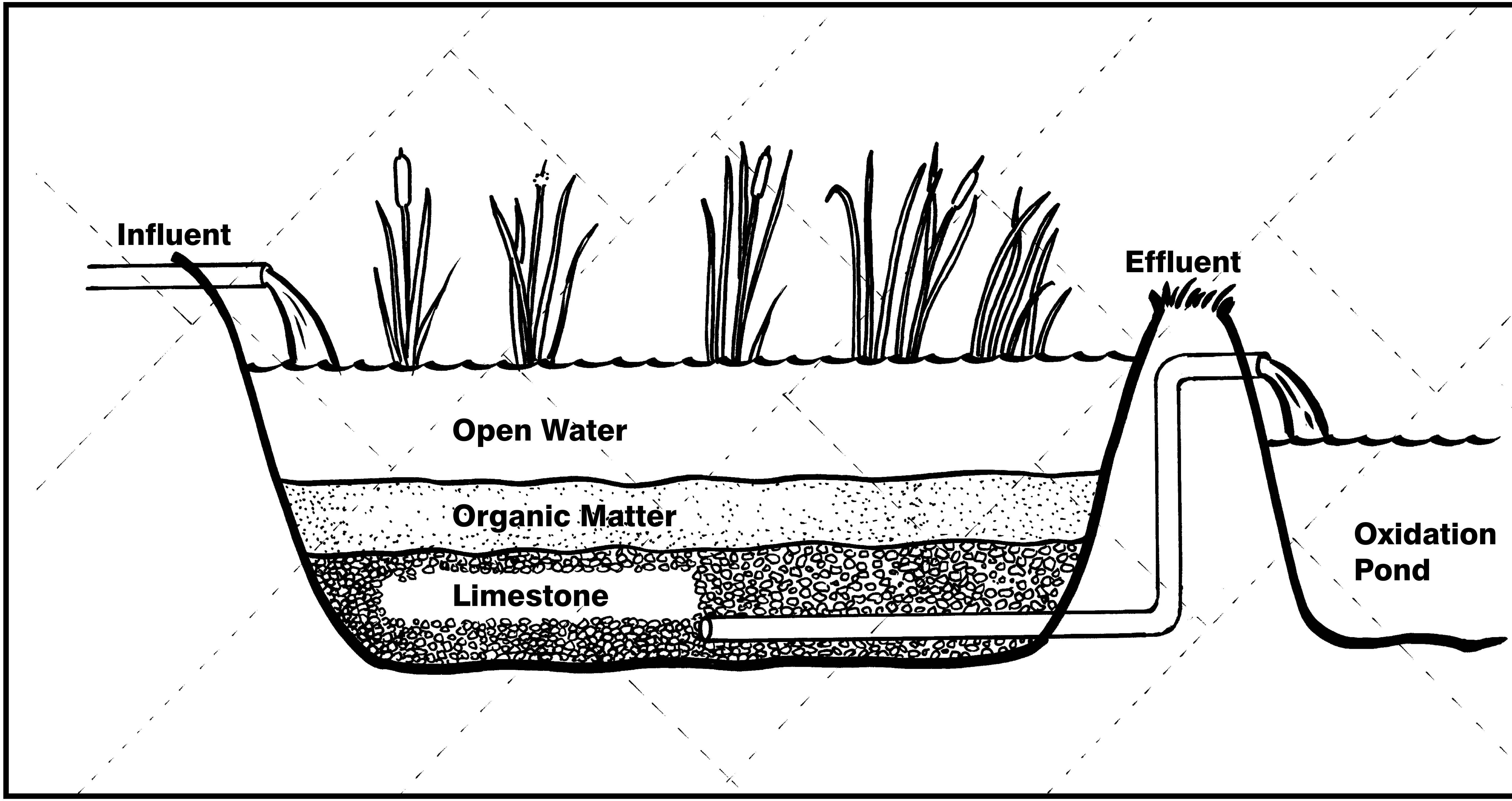
6) A. Limestone

7) A. Substrate and Limestone

8) True

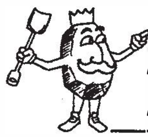
9) Oxidizing and Armoring

Open Limestone Channel Puzzle



Limestone Pond Treatment

Developed by Becky Reese, AMD & Art, Johnstown, PA



About This Activity...

Prep Time Required:
15 minutes

Grade Level:
High School

Subjects:
Biology, Earth Science, Ecology, Science

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
4.1.12.C, 4.1.12.E, 4.2.10.A, 4.2.10.B

Setting:
Classroom

Vocabulary:
Acidic
Aluminum
Discharge
Flow
Habitat
Iron
Limestone
Manganese
Precipitate
Stream
Sulfur

Related Vocabulary:
Active Treatment Aerobic
Alkaline
Anaerobic
Anthracite
Bituminous
Cattails
Passive Treatment Pyrite
Reclamation
Watershed
Wetlands
Yellow Boy

Prerequisites:
- "Puzzling Pollution Problem" lesson plan
- Knowledge of AMD

Summary:
Students learn and review vocabulary words and concepts of abandoned mine drainage and various AMD treatment systems by completing worksheets.

Materials:
- AMD treatment worksheet
- Word search worksheet
- Pencils, pens

Objectives:
Students will be able to:
- understand the basic concepts behind abandoned mine drainage and various treatment systems that humans developed to remediate their impacts on the environment.

Background:
Hundreds of years of coal mining in Pennsylvania has led to thousands of miles of pollutied streams. Abandoned mine drainage (AMD) from old coal mines is one of the single largest sources of water pollution in the state. AMD can be **acidic** and contain many dissolved chemicals, including **iron**, **sulfur**, **aluminum**, and **manganese**. When mine water leaches to the surface, it comes into contact with oxygen and several chemical reactions occur. AMD can be harmful to the wildlife and plants living in streams and other areas. For example, **iron** can **precipitate** into iron oxide at the surface and coat the bottom of **streams** and creeks. These areas, in turn, become contaminated and poor **habitat** for organisms.

The pH of the water affects the precipitation of metals out of the water. Raising the pH of the water is an initial step in the treatment of acidic AMD. There are several ways to increase the pH. One common method is the use of **limestone**, which is basic and neutralizes the acidic component of the polluted water.

Different treatment processes using limestone for acidity have been developed. Limestone ponds are constructed on the upwelling of an acid mine drain seep or underground water **discharge** point. Limestone is placed in the bottom of the pond and the contaminated water **flows** upward through the neutralizing limestone. Another method, open limestone channels are used to increase alkalinity and reduce acidity, but armoring reactions promoted by contact with the air will reduce their effectiveness somewhat.

Procedure:
Warm-up:

You are going to tell students a short story and they have to imagine they are in the story. Use as much vivid imagery as possible so that the students can have a clear picture in their mind of a stream impacted by AMD.

Have the students close their eyes. Tell them the following story.

Imagine you are walking through a forest. Feel the cool breeze of the wind from the trees on your face. Listen to the hawks squawking, and the robins chirping as you make your way through the brush. As you continue to walk, you hear the rush of water flowing. Suddenly you come across a stream. The stream has a funny smell. You continue to walk along the stream to look for wildlife, but you see nothing, not even someone fishing. You think it is strange, but as you continue to walk upstream, the funny smell gets worse. You come along an older gentleman walking his German shepherd. You ask him why no one is fishing in this stream. The man asks you if you smell the horrendous odor coming from the water. He tells you the stream is polluted. An old mine abandoned 75 years ago is leaching into the stream. The stream is so polluted and acidic now that fish and other wildlife cannot survive. He says that something should be done so that he can take his grandson fishing here before he is too old.

The stream in the story is polluted with acidic AMD. Have the students open their eyes. Ask students if they were scientists, how would they clean up this stream?

Activity:

Discuss with the students how the stream in the story was polluted. The students should understand how an abandoned mine fills with water, metals dissolve in the water, and the mine water seeps to the surface.

Be sure to inform the students that AMD is one of the most significant forms of water pollution in Pennsylvania. When the water seeps to the surface, it can pollute nearby streams killing wildlife and affecting the overall stream quality.

Discuss with the students some of the ways AMD is treated using limestone. Be sure that students understand the basic concepts behind each method, particularly limestone ponds.

Wrap-up/Conclusion:

Distribute the worksheets to the students. The students can either work in groups or individually to complete the sheets.

Assessment:

- Collect the worksheets from the students, or review the sheets as a class.

AMD Treatment Worksheet

Name ______________________________

Period ______________________________

Date ______________________________

1. Abandoned Mine Drainage is a form of ______________.
2. __________ is the abbreviation for Abandoned Mine Drainage.
3. Abandoned Mine Drainage formed from humans coal ______________ the earth for natural resources.
4. ______________ is a type of coal that is semi-soft and blocky in form, contains a lower percentage of carbon and a high percentage of metals and impurities.
5. ______________ is a type of coal that is very hard, contains a high percentage of carbon and a low percentage of metals and impurities.
6. A ______________ is a horizontal entrance into the underground mine complex.
7. A ______________ is a tunnel connecting to the underground mine complex to allow for fresh air circulation.
8. The ______________ from the mine is where the ground water becomes surface water. This point is usually from the tunnel.
9. ______________ is a mineral in coal that dissolves to turn the ground water acidic.
10. ______________ is a type of mine drainage that is relatively high in pH, turns litmus paper red.
11. ______________ is a type of mine drainage that is relatively low in pH, turns litmus paper blue.
12. Metals that dissolve in the acidic water include: ______________, ______________, ______________, and ______________.
13. ______________ beds are coated from iron oxide ______________ dropping out from the polluted water.
14. ______________ is the term used to describe the accumulation of iron oxide on the bottom of stream beds.
15. If AMD is not treated, polluted waters can devastate an entire ______________.
16. Two types of treatment for AMD are ______________ and ______________.
17. Passive treatment systems control the ______________ of the water with weirs to increase the reaction with oxygen.
18. Wetlands are used in passive treatment as part of the ______________ of the polluted water from abandon mines.
19. Aerobic and Anaerobic are two types of ______________.
20. ______________ wetlands only effectively treat water that is net alkaline.
21. ______________ or compost wetlands consist of a large pond with a lower layer of organic substrate.
22. ______________ is a type of plant commonly found in wetlands that helps to treat polluted waters.
23. Wetlands are a very diverse ______________ and support many different species of plants and animals.
24. ______________ is a rock that increases the pH of acid water.

TEACHER'S ANSWER SHEET — AMD WORKSHEET

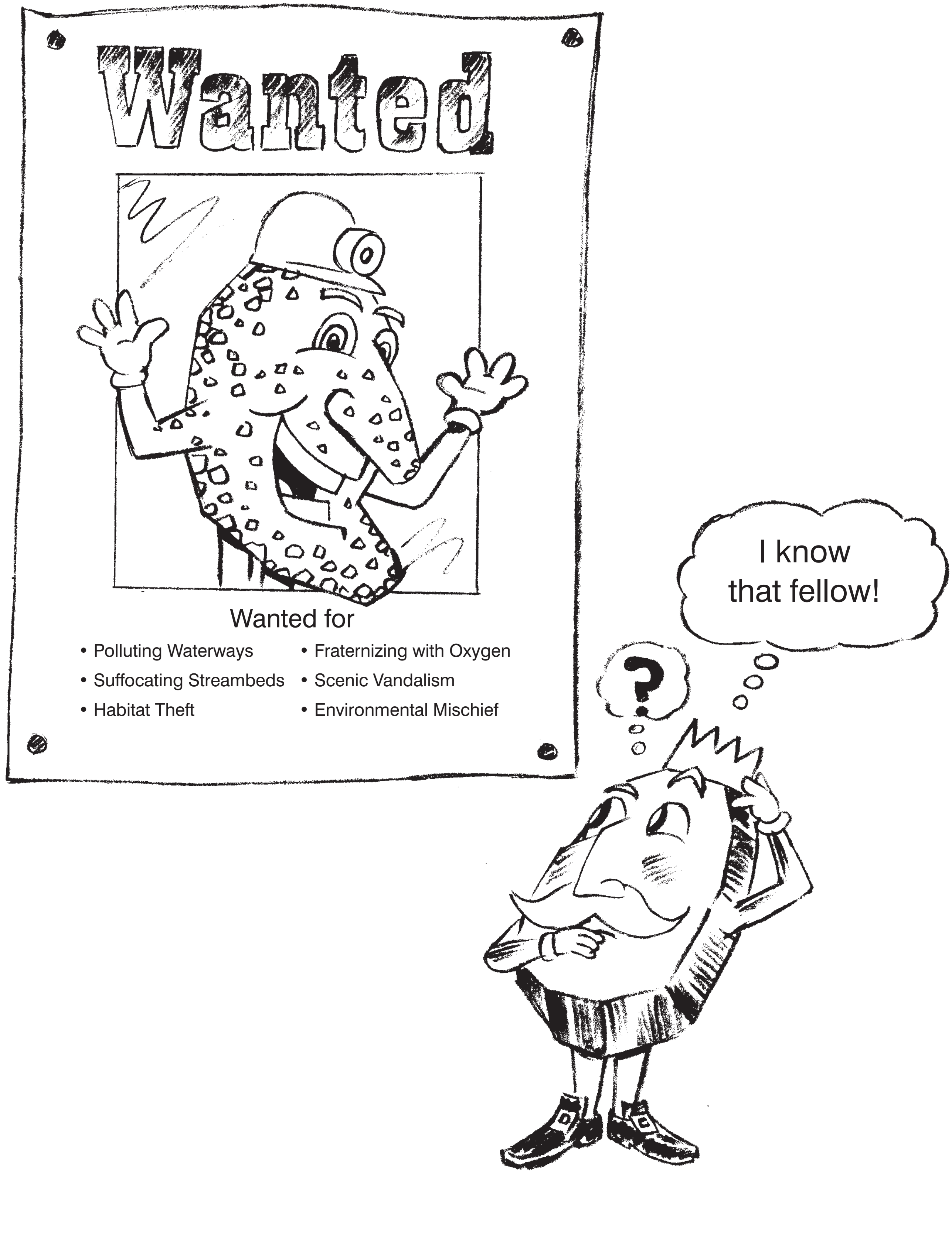
1. Pollution
2. AMD
3. Mining
4. Bituminous
5. Anthracite
6. Tunnel
7. Shaft
8. Discharge
9. Pyrite
10. Alkaline
11. Acidic
12. Iron, Aluminum, Sulfur, Manganese
13. Stream, Precipitate
14. Yellow Boy
15. Watershed
16. Active, Passive
17. Flow
18. Reclamation
19. Wetlands
20. Aerobic
21. Anaerobic
22. Cattails
23. Habitat
24. Limestone

AMD Word Search

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

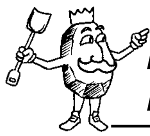
ACIDIC	AMD	COAL	LIMESTONE	PRECIPITATE	STREAM
ACTIVE	ANAEROBIC	DISCHARGE	MANGANESE	PYRITE	SULFUR
AEROBIC	ANTHRACITE	FLOW	MINING	RECLAMATION	TUNNEL
ALKALINE	BITUMINOUS	HABITAT	PASSIVE	REFUSE	WETLAND
ALUMINUM	CATTAIL	IRON	POLLUTION	SHAFT	YELLOW BOY

Examining the Environment



The Great Coal Debate

Adapted from "Hot Water" in Project WET K-12 Curriculum & Activity Guide *(Bozeman, MT: The Watercourse and Council for Environmental Education, © 1995).*
Developed by Jen Baer, Mountain Watershed Association, Melcroft, PA



About This Activity...

Prep Time Required:
20 minutes

Grade Level:
Middle School,
High School

Subjects:
Environmental Science, Government, Language Arts, Communications

Duration of Activity:
Part I: 50 minutes
Part II: 50 minutes

Pennsylvania Standards Addressed:
3.3.8.A2, 3.4.7.B1, 3.4.7.B2, 3.4.8.B2, 3.4.6.D2, 3.4.7.D3, 3.4.7.E6, 3.3`0.A2, 3.4.12.B1, 4.3.7.A, 4.3.10-12.A, 4.3.10.B, 4.5.7.C, 4.3.7.D

Setting:
Indoor/Classroom and Library

Vocabulary:
Constructive speech
Debate
Rebuttal speech

Related Vocabulary:
Mine subsidence

Prerequisites:
Knowledge of methods of mining, effects of abandoned mine drainage, mine subsidence, and reasons why we burn coal

Summary:

Students learn to present valid arguments regarding mining and burning coal using various debate strategies.

Materials:

- Index cards (3x5, 4x6)
- Pencils
- Debate Ballot

Objectives:

Students will be able to:

- apply basic strategies in debating the pros and cons of mining & burning coal.
- recognize the effectiveness of reason-based and emotion-based presentations.

Background:

Debates occur everyday, whether it is a formal **debate** during a government meeting or a more informal debate between parents and children over curfew. For every issue debated, a variety of individual views exist regarding how to resolve a problem. If a person's views are not communicated effectively, they may not be taken seriously, and important issues may be ignored.

During a debate, people are able to present their opinions in an organized, productive manner. Debating allows opposing teams to present facts so an informed decision can be made on the topic at hand. Debating involves two kinds of speeches: constructive and rebuttal.

Constructive speeches support and defend a viewpoint. During constructive speeches, each debater presents arguments supported by evidence in favor of his/her viewpoint. **Rebuttal speeches**, on the other hand, refute an opposing viewpoint. During a rebuttal speech, each presents arguments supported by evidence to disprove the opposing viewpoint.

Procedure:

Warm-up:

Ask the students for a list of topics about which people have opposing viewpoints, such as election candidates or the best football team. Discuss the different viewpoints people have regarding those issues.

Have the students brainstorm a list of controversial topics involving the mining and burning of coal. Write the ideas on the board making sure each topic has two opposing viewpoints.

Activity:

Inform the students that they are going to prepare and conduct a debate on the use of coal. Answering the question, should we continue to mine and burn coal?

Introduce the process of how debating works and the proper procedures for preparing and conducting a debate. Be sure to explain the idea that the purpose of a debate is to provide two opposing sides the opportunity to defend or argue a given viewpoint.

Part I: Preparation for the Debate

Break the class into 2 teams, one team supports using coal and the other opposes using coal. Within each group, have the students brainstorm topics they can use in their debate. Some suggested topics are listed below. Together as a class, make a list of the proposed topics and determine the order in which the points should be presented. (If there are too many points, eliminate some or combine some together.) Assign 2-4 students from each team to a topic and allow the students to research for information that supports their team's viewpoint or disproves the other team's viewpoint. Prepare the notes on index cards to be used during the debate.

Suggested Topics:

- Coal's Availability
- Efficient methods to remove all available coal
- Excellent source of energy
- Jobs for miners, transporters, etc.
- Water pollution
- Air pollution

- Structural damage to buildings and property
- Water loss
- Economics-prices for real estate in mining community vs. non-mining community

Part II: The Actual Debate

On the day of the debate, call the first groups to the front of the class to present their information by following the debate schedule provided at the end of this activity (based on the Oregon Style of Debate). Toss a coin to determine which side goes first. The rest of the class will act as judges listening to the presentations and taking notes in order to make an informed decision at the end of the debate as to whether we should continue mining and burning coal.

Either team may give the first rebuttal speech. The teams are allowed a maximum of 3 minutes for the rebuttal.

At the end of the debate, have the judges assign scores from 1 to 5 (1 being the most convincing argument) for both sections of the debate. After the scores are tabulated, the team with the lowest score wins.

In scoring, students should consider the following: organization, speaking, analysis, proof, argument, and refutation.

Wrap-up/Conclusion:

Discuss the debate as a class. How do the students feel about the results? How could they improve their points? What would they do differently for the next debate on a different topic?

Assessment:

- Have the students write a short paper that states their personal decision on the outcome of the debate. They should include why they feel the way they do and whether their opinion changed after hearing the facts presented in the debate. They should also include who made the best argument and why.

Extensions:

- Using the facts presented during the debate, students could create a fact sheet about the pros and cons of mining and burning coal for the general public. They could also include a section on alternative sources of energy.

Adaptations:

For elementary students, use the Four Corner debate method where statements are made and the students must physically move to the corner that represents how they feel about that particular statement. The four corners of the room are labeled Strongly Agree, Agree, Disagree, and Strongly Disagree.

Resources:

"Hot Water." in *Project WET K-12 Curriculum & Activity Guide.* Bozeman, MT: The Watercourse and Council for Environmental Education, 1995.

Debate Schedule	Maximum Time (minutes)
Affirmative Constructive Speech	8
Cross-examined by the Negative	3
Negative Constructive Speech	8
Cross-examined by the Affirmative	3
Negative, Rebuttal	3
Affirmative, Rebuttal	3

Debate Ballot

Team's Name: ______________________ Judge's Name: ______________________

Affirmative Number: __________ Negative Number: __________ Round: __________

DIRECTIONS: Circle the number that best describes the debater(s) you judged, and record any comments below. Remember, a score of 1= the most convincing argument, and a score of 5 = the least convincing argument.

Overall Affirmative:	1	2	3	4	5	Overall Negative:	1	2	3	4	5
Constructive Speech:	1	2	3	4	5	Constructive Speech:	1	2	3	4	5
Cross Examination Of Negative:	1	2	3	4	5	Cross Examination Of Affirmative:	1	2	3	4	5
Rebuttal:	1	2	3	4	5	Rebuttal:	1	2	3	4	5
Comments:						Comments:					

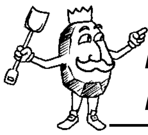
I determine the debate to have been won by ______________________. My reasons for this decision are:

____

Judge's Signature

And the Survey Says...

Developed by Jen Baer, Mountain Watershed Association, Melcroft, PA



About This Activity...

Prep Time Required:
30 minutes

Grade Level:
Middle School,
High School

Subjects:
Economics, Environmental Science, Language Arts, Math

Duration of Activity:
60 minutes to develop survey;
1-2 weeks to distribute surveys;
2 hours to analyze data

Pennsylvania Standards Addressed:
3.4.8.B1, 3.4.7.D3, 4.2.12.B

Setting:
Classroom

Vocabulary:
Average
Bias
Mine Subsidence
Overburden
Percentage
Sinkhole
Survey

Prerequisites:
Some knowledge of underground mining and mine subsidence

Summary:
Students develop, conduct, and analyze surveys for individual's knowledge of mine subsidence and the impact to the local community.

Materials:

- Paper
- Pencils/Pens
- Magazines
- Newspapers
- Computer

Objectives:

Students will be able to:

- understand the process of developing, conducting, and analyzing **surveys** by evaluating their community's understanding of mine subsidence.

Background:

Surveys are used to collect information and data from the public in order to find out their level of understanding or how they feel about a certain topic. Survey questions are clear and **unbiased** so that accurate information is collected. Closeform questions are easier to tally and analyze than open-form questions. Typically, close-form questions lead to a simple yes or no answer. Open-form questions tend to require longer answers in which an opinion on a topic is required.

Surveys can be distributed at random or at a targeted population, such as a particular community. Once the surveys are completed, the data can be analyzed by calculating frequencies, **percentages**, **averages**, and various other mathematical data. From those results, action can be taken to respond to issues. For example, establishing recycling programs because 95% of people surveyed are interested in starting a program in their community. In addition, information can be presented in support or opposition of a particular issue. For instance, information can be presented to a local water authority about the public's support of receiving public water in their community.

Mine subsidence is very pertinent in many Pennsylvania communities. Mine subsidence occurs after a coal company has removed the minerals from underground, leaving a part of the surface unsupported and vulnerable to movement. Mine subsidence is predictable in active mines using longwall or room and pillar methods; however, mine subsidence from abandoned mines is unpredictable.

There are several ways in which the ground can move, causing subsidence. A very common type of subsidence is **sinkhole** subsidence, which occurs where an underground mine is close to the surface resulting in a depression in the ground as **overburden** materials collapse into the mine. Generally, this type of subsidence is limited to a small area. A similar type of subsidence is trough subsidence, which generally occurs when the overburden sags downward, resulting in a large, shallow, broad depression in the ground, which is usually elliptical or circular in shape.

Tension cracks are another type of mine subsidence. When the ground collapses or cracks, in addition to damage to the layout of the land, considerable damage is also done to buildings, property, and groundwater. In a recent study conducted by the Pennsylvania Department of Environmental Protection (PA DEP), they reported that of the 1,855 properties surveyed in western Pennsylvania, 802 reported damage associated with mining (PA DEP 2001). They also reported that 70% of the damages have been resolved (PA DEP 2001). However, a major problem is damage caused by mine subsidence is not covered by homeowner's insurance. Homeowners have to buy a separate policy in order to have coverage for any mining damage to their buildings and this policy does not cover driveways, fences, septic tanks, etc.

Often, a building will become cracked, which allows mine drainage water to enter the house. However, a building can get mine water in it without an actual crack in the foundation. The water that enters the house can be acidic, loaded with metals, and have a foul smell, causing hundreds of dollars worth of damage and possibly making the building inhabitable.

The most common reported damage from mining is water supply damage. A private well can become contaminated, depleted, or completely lost. By law, the coal company is responsible to restore or replace any water supply that is affected while mining. Options include restoring the current well, digging a new well, or connecting the household to a public water supply. A temporary water supply, such as a water buffalo, should be in place until a permanent water supply is established. Public water supplies can also be affected by the groundwater becoming contaminated, depleted, or lost. Damage to waterlines also occurs during mine subsidence events.

Procedure:

Warm-up:

Introduce to the use of surveying by going over common surveys or polls like those found in magazines or newspapers. For example, the top 5 movies of the week or the most common concerns of being a senior in high school. Have the students cut out examples of surveys from old magazines or newspapers so that they can have examples of ways to word their questions.

Activity:

Divide the students into groups and have them brainstorm survey questions on mine subsidence (suggestions listed below). Have the students determine how long the survey should be, then assign a specific number of questions to develop to each group. Encourage the students to use close-form questions like true or false, multiple choice, or categories like age ranges so that the data can be easily analyzed.

Survey Question Suggestions:

- General questions (age, sex, highest level of education, occupation, etc.)
- General understanding of mine subsidence & how it occurs
- Impacts of mine subsidence
- Costs of water replacement, repairing structural damage
- Regulations regarding mine subsidence
- Mine subsidence insurance

After the questions are written, as a class, go over the questions, and edit them if needed in order to develop a clear and unbiased survey. A specific date to return the completed surveys should be determined so that the surveys are completed in a timely fashion.

Type the survey and make enough copies so that each student can have 4 or 5 surveys to distribute.

Have the students pass out the surveys to their family, friends, and neighbors; returning the completed surveys by the designated date.

After all of the surveys are completed, have the students tabulate the data either individually or in their brainstorming groups. Developing a tabulation form in advance will help to guide the students through this tedious process.

Wrap-up/Conclusion:

Have the students prepare a report of their findings including tally sheets, tables, and graphs. They should also write a brief description of how the survey was conducted.

Assessment:

- Have the students prepare a complete report of their survey results. In the report, they should include how they could make the public more aware of mine subsidence, if needed.

Extensions:

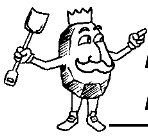
- Students can present the information at a science fair, at a township meeting, or to a watershed or other environmental group. They can become involved in handling certain issues, such as educating the public about mine subsidence insurance.

Adaptations:

For younger students, have a survey already prepared that they can take home and give to their family. This will introduce the younger student to the concept of surveying.

Who's Reclaiming Our Land

American Coal Foundation, http://teachcoal.org/lessonplans/reclamation.html, ©2003
Developed By: Gwen Johnson, Kiski Conemaugh Stream Team, Johnstown, PA



About This Activity...

Prep Time Required:
1 hour

Grade Level:
Middle School,
High School

Subjects:
Language Arts, Science, Social Studies

Duration of Activity:
2-3 class periods

Pennsylvania Standards Addressed:

3.4.7.B2, 3.4.7.D3, 4.1.12.B, 4.3.10.A

Setting:
Classroom and library with internet access

Vocabulary:
Excavation
Reclamation
Surface Mining

Prerequisites:
Knowledge of coal mining, effects of mining

Summary:
Students learn what it means to reclaim land after surface mining, research successful reclamation efforts, and prepare a presentation to the class.

Materials:
- Transparency of Deep Mining and Surface Mining (copy included)
- Terrarium or large glass bowl
- Sand
- Rocks
- Lumps of coal
- Top soil
- Plants (real or plastic)
- Plastic spoons or other digging implements
- Internet access

Objective:
Students will be able to:
- understand the need for land **reclamation** after **surface coal mining**.
- discuss the challenges faced by mining companies in reclaiming the land.

Background:
The mining and burning of coal has a long history of negative effects on the environment. The two main types of coal mining are surface, or strip mining, and underground mining. Surface mining involves the removal of coal deposits close to the earth's surface. Topsoil and rocks are removed from the surface in order to expose the coal. Explosives and heavy machinery are then used to break up those coal deposits.

Surface mining substantially disrupts the condition of the land and its surrounding ecosystem. However, land, water, and air pollution laws were not part of the coal industry's early history. Consequently, after surface mining companies removed all of the coal from an area, the land was left in disarray with no proper areas for organisms to inhabit. In 1977, the Surface Mining Control and Reclamation Act (SMCRA) was passed, requiring coal-mining sites be restored to natural areas or productive land. However, by that point there were over one million acres of abandoned coal mine sites in the United States.

These abandoned mine sites have a detrimental effect on the water quality, safety, health, and aesthetics of communities. Because of the SMCRA, mine operators are required to pay taxes, which are placed into funds used to pay for land reclamation of old sites. In order to abide by the law, protect the environment, and restore the land, mining companies implement extensive reclamation projects. During mining, companies try to mitigate damage by diverting streams, providing drainage areas, and placing native vegetation in greenhouses to use in the reclamation process.

Procedure:
Before class, place coal pieces at the bottom of the terrarium and surround them with various types of rocks. Cover the rocks with sand, then topsoil, and then plants. Place the terrarium in the front of the room so that the students can see as they enter the class.

Warm-up:

Refer to the terrarium in the front of the room. Tell the class that it symbolizes a plot of land near the school.

Ask the students for a few volunteers. Using a small spoon or shovel, have the students excavate the coal. Instruct the students to carefully remove and separate each layer (plants, sand, soil, etc.) into piles. This simulates the use of machines to remove the layers of the earth. After the coal layer has been reached, have the students remove the coal with their spoons. Discuss with the students whether they should leave the plot of land as it is. Explain to the students that by law, mining companies are required to restore mine sites so that they are as much like the before mining site as possible. Ask for some student volunteers to attempt to reclaim the terrarium to its pre-**excavation** condition (without the coal). They should replace all of the layers so they are the same as before the area was mined, except for the plants, which must be thrown away because they are dead. New grass and plants must be planted.

Activity:

Ask the students if it was easy to replace the land as it was. Reclamation is expensive and difficult.

Explain to students that when natural resources are taken from the lower layers of the earth's surface disruption to the ecosystem occurs.

Review with the class the vocabulary words coal, mine, surface mining, natural resources, and reclamation. Use the provided diagram of surface mining and deep mining as a reference for students.

Ask the students: *What is disrupted at sites where surface mining is done?* Encourage students to think about rock formations, soil, plants, wildlife, water tables, and drainage patterns, and possibly archaeological research.

Tell students that surface mining companies are required by law to restore the land to its original condition, or better, after excavating it. Ask students if they can think of how the land might be re-used after it is reclaimed. Explain that in some cases it is used for agricultural purposes. In other cases, lakes or reservoirs are created. And, in other locations, the land is reclaimed for recreational purposes. Some reclaimed lands have been used for commercial activities and service institutions such as schools. In each case, the mining company works with experts from the community to discern the best use.

Divide the class into five research groups. Explain to students that they will be researching successful (in fact, award-winning) reclamation projects. Assign each group one of the following reclamation projects: the Vindex Reclamation Project in Maryland, the Klueh Reclamation Project in Indiana, the Pleasant View Mine Project in Kentucky, the Blackwater River Limestone Drum Station in West Virginia, and the Old Ben Scout Reservation AMD (Acid Mine Drainage) Lakes in Indiana. Tell students that each of these projects was conducted by a mining company and received recognition from the federal Department of the Interior's Office of Surface Mining (OSM) for their work. Direct the students to the following links:

Vindex Reclamation Project, Maryland
Maryland Department of the Environment
(http://www.mde.state.md.us/Programs/WaterPrograms/MiningInMaryland/ReclamRevitalize/vindexReclamation.asp)
OSMRE (http://www.osmre.gov/award01md.htm)

Klueh Reclamation Project, Greencastle, Indiana
OSM (http://www.osmre.gov/sycamoretrailsproject.htm)

Pleasant View Mine Project, Kentucky
Kentucky NREPC Division of Abandoned Mine Lands
(http://www.surfacemining.ky.gov/aml/projects/pleasant_view.htm)
OSM (http://www.osmre.gov/award00ky.htm)

Blackwater River Limestone Drum Station, West Virginia
MII (Mineral Information Institute)
(http://www.mii.org/blackwater/blackwater.html)
OSM (http://www.osmre.gov/awardwv.htm)

The students should be able to answer the following questions:

- What was the original mining operation?
- When was the area last mined?
- When did the project begin?
- What were some of the environmental conditions, which needed to be considered?
- What specific measures were involved in the reclamation project?
- What was the goal of the project?
- How is the land being used now?
- Who were some of the professionals involved in the project?

Wrap-up/Conclusion:

After the groups have finished their research, they should summarize their findings with a poster, bulletin board, power point presentation, or video and present their findings to the rest of the class.

Be sure each group discusses the following:

- What made each of these projects successful?
- What expertise was necessary in order to determine the best usage of the property?
- What conditions presented the greatest challenges in fulfilling the goals of the project?
- How will the community benefit from the project?

Finally, be sure to remind students that since coal is an abundant and relatively inexpensive source of energy that easily generates electricity, coal mining will remain a mainstay of the American economy. And, as long as mining continues, mining companies will be responsible for the restoration of the land and preservation of the environment.

Assessment:

- After each group has presented their research to the class, have students take the Office of Surface Mining's reclamation quiz (http://www.osmre.gov/qtest.htm). Those that successfully answer the correct number of questions can win a small prize.

Extensions:

- Encourage students to research local reclamation laws and projects. Direct students to the OSM map (http://www.osmre.gov/map.htm) to identify local agencies and find out what work is being done in your own state. From there, they can contact the agencies or companies directly to find out more.

  Have students collect "before" and "after" photographs of various reclamation projects and display the photos with brief explanations of the projects. Additional reclamation stories can be found at the Mineral Information Institute (http://www.mii.org/reclcoal.html).

Adaptations:

Allow the students to experience their own reclamation by providing terrariums for the entire class.

Have the students make their own terrariums.

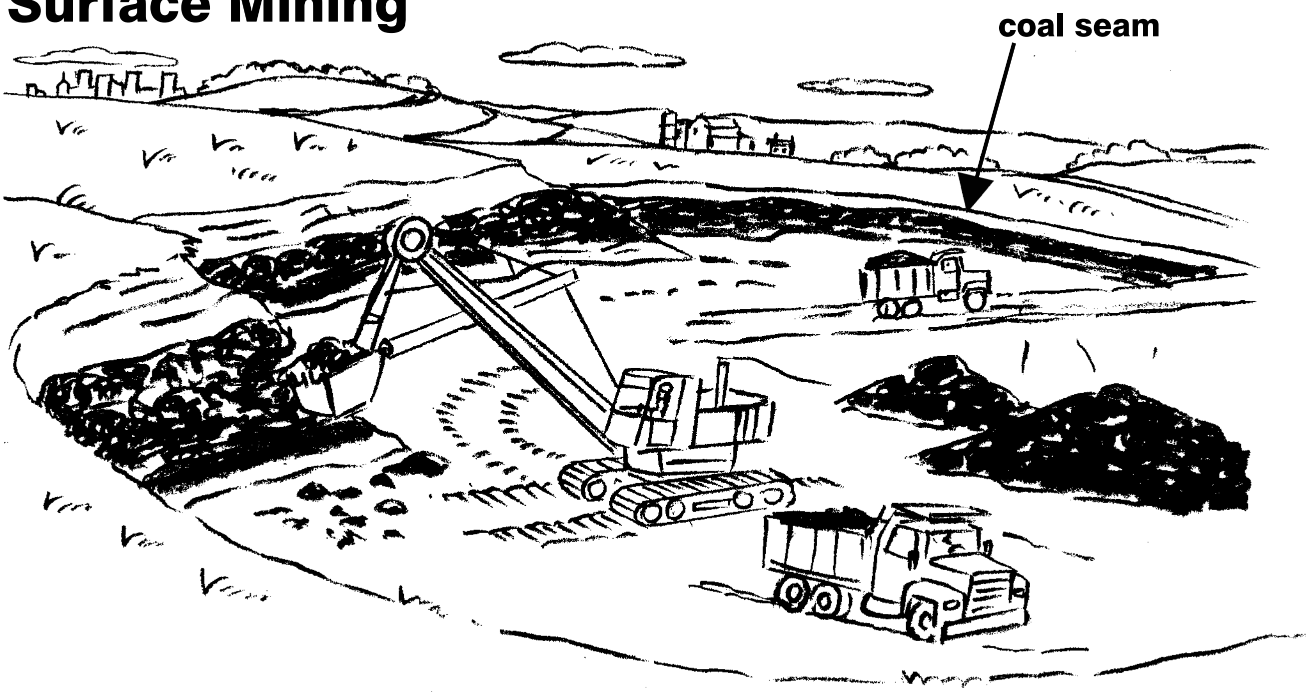
Those students with weaker writing skills should be assigned the responsibility of incorporating photographs of the reclamation projects in the displays. Encourage students to work in tandem to study and understand the internet sites about the reclamation projects.

Resources:

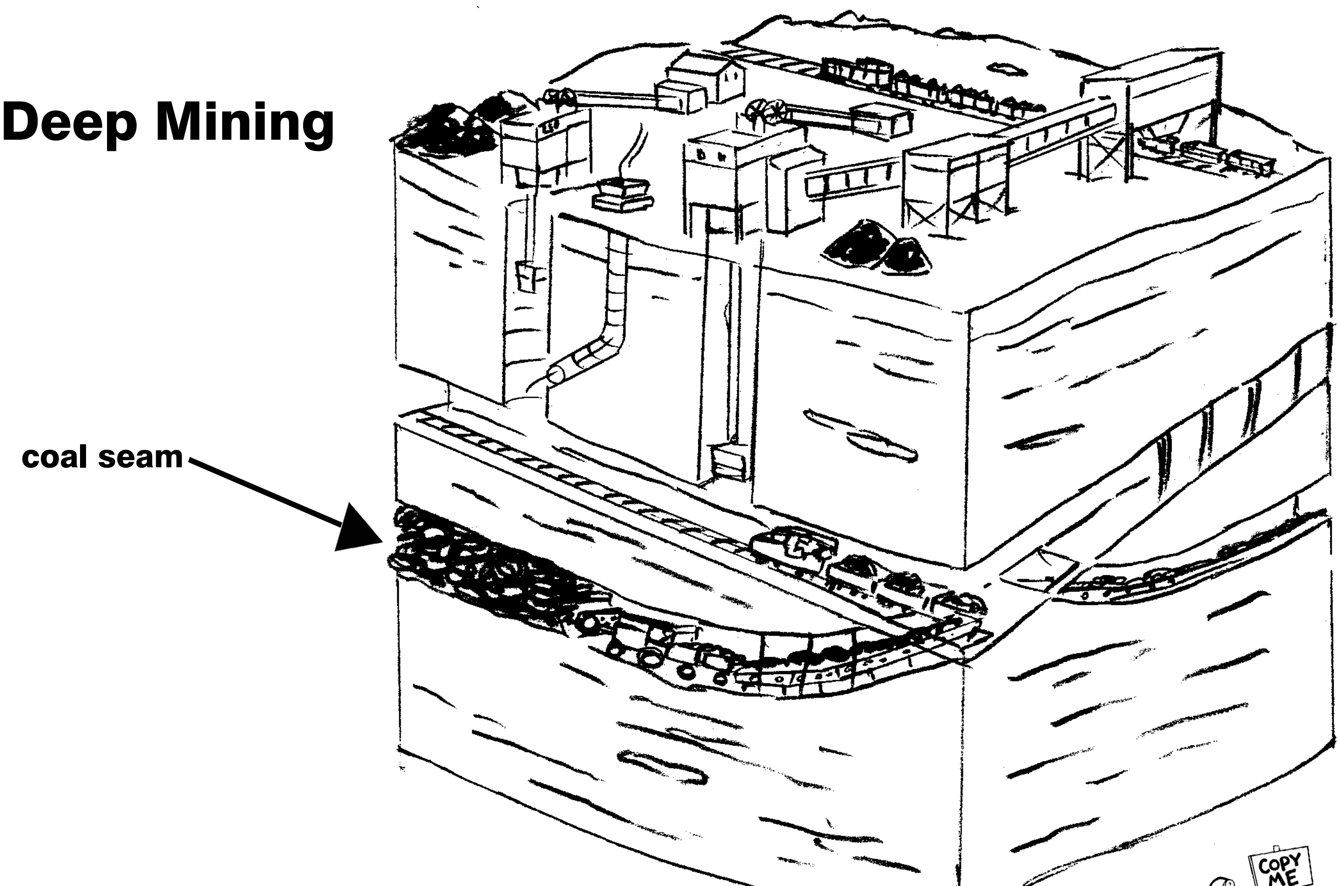
American Coal Foundation. 2003. http://teachcoal.org/lessonplans/reclamation.html

Surface Mining/Deep Mining

Surface Mining

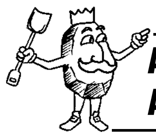


Deep Mining



The Dependency on Coal

Developed by Jen Baer, Mountain Watershed Association, Melcroft, PA



About This Activity...

Prep Time Required:
15 minutes

Grade Level:
Middle School,
High School

Subjects:
Science, Language Arts

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
3.4.7.B1, 3.4.7.D3, 3.4.7.E3, 3.3.10.A2, 3.3.12.A2, 3.4.10.B1, 3.4.12.B2, 3.4.10.D3, 4.3.10.A, 4.5.7.C

Setting:
Classroom, Library

Vocabulary:
BTU
Mine Subsidence

Prerequisites:
Knowledge of groundwater, methods of mining, uses of coal

Summary:

Students summarize newspaper articles about mine subsidence and discuss how AMD impacted their community.

Materials:

- Newspaper articles about mine subsidence (copy articles provided or have the students research for their own)
- Paper
- Pencils
- Photographs of areas affected by mine subsidence

Objectives:

Students will be able to:
- understand our dependency on coal.
- learn how coal mining affects people living in coal fields.

Background:

Coal is the most abundant fossil fuel in the world, and has been used for many thousands of years. Today, the total consumption of energy in the world is approximately 400 quadrillion **BTUs** (British Thermal Units) per year, with the U.S. consuming close to 25% of the world's energy supply. Most of the energy in the world comes from nonrenewable resources like coal, accounting for about 23%.

Coal is used to generate heat, produce electricity, and to make steel and other industrial products. Because coal is such an important resource, there are many mines and mining sites in the U.S. Mining can have some detrimental effects in some communities. For instance, mine subsidence is very pertinent in many Pennsylvania communities. **Mine subsidence** occurs after a coal company has removed the minerals from underground, leaving a part of the surface unsupported and vulnerable to movement. Mine subsidence is predictable in active mines using longwall or room and pillar methods; however, mine subsidence from abandoned mines is unpredictable.

There are several ways in which the ground can move causing subsidence: sinkhole subsidence, trough subsidence, and tension cracks. More information on these subsidence types can be found in "And the Survey Says…" activity, preceding this lesson. Often with mine subsidence, a building will become cracked, which allows mine drainage water to enter the home or business. The water that enters the house may be acidic, loaded with metals, and/or have a foul smell, ultimately causing thousands of dollars worth of damage to the building or the water supply.

Procedure:

Warm-up:

As students enter the room, randomly hand out a few photos of buildings and homes affected by mine subsidence.

Ask the students about mine subsidence and how it affects homes and other structures.

Activity:

Ask students what uses we have for coal. Present the students with the following statistics and have students research what percentage of coal is used for generating electricity.

- 68.7 million short tons of coal was produced in PA in 2002
- 1.10 billion short tons of coal was produced in the US in 2002. (www.eia.doe.gov)

Pass out copies of the articles that discuss damage from mine subsidence or have students research for their own. Possible websites to check include:
- www.pittsburghlive.com/x/dailycourier
- www.zwire.com/site/News.cfm?brd=2280
- www.observer-reporter.com
- www.post-gazette.com

The students should read their article and write a paragraph or short paper summarizing what happened and how they feel about it.

You can give students a few questions to guide them such as:

- Should people just learn to live with the side affects of coal mining?
- Should we stop using coal to generate electricity to prevent damage?
- Should the coal companies remain responsible for any damages caused from mining?
- Should new regulations be created to prevent damage or destruction of people's homes?
- Should we use an alternate way to produce electricity?
- What would it be like to watch as your house is destroyed?
- Should something else be done to protect the people in the coal fields?

Wrap-up/Conclusion:

As a class or in small groups, the students should summarize their articles and discuss their thoughts about mine subsidence.

Assessment:

- As the class discusses their thoughts, the teacher should be sure that the students understand the need for coal mining and the effects of mine subsidence.

Extensions:

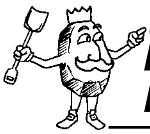
- A field trip to visit a community that has been affected by mine subsidence and visit with the residents. Have a list of questions prepared to ask the residents.
- Invite someone to the classroom to discuss their personal experiences with the students.
- View the video *"Subsided Ground... Fallen Futures, the Legacy of Long wall Mining in Southwestern Pennsylvania,"* a new documentary exposing longwall mining devastation in Greene and Washington counties. Contact your local environmental organization, Mountain Watershed Association (724-455-4200), or Tri-State Citizens Mining Network (724-229-3550) for a copy.
- Present information regarding mine subsidence at a school science fair or to your local township supervisors.
- Research alternative fuels to reduce our dependency on coal. Present these findings at a school science fair.

Adaptations:

Younger students can be shown photographs of mine subsidence, and write about how they would feel if their home was damaged.

New Life for Glade Run

Developed by Leanne Griffith, Westmoreland Conservation District, Greensburg, PA



About This Activity...

Prep Time Required:
20 minutes

Grade Level:
Middle School,
High School

Subjects:
Biology, Ecology,
Language Arts, Science

Duration of Activity:
50 minutes

Pennsylvania Standards Addressed:
3.4.6.B2, 3.4.8.C1,
3.3.10.A2, 3.4.10.E7,
4.1.12.B

Setting:
Classroom

Vocabulary:
Acid
Active Treatment
Alkaline
Passive Treatment
pH
Stream

Related Vocabulary:
Electroshock
Macroinvertebrate
Watershed

Prerequisites:
Knowledge of biodiversity, effects of AMD

Summary:
Students read and analyze "New Life in Glade Run," published in the Spring 2003 Westsylvania magazine. The article discusses a passive treatment method used to treat **acidic** AMD.

Materials:
- Article "New Life for Glade Run," copies for each student
- Anticipation Reaction Guide, copies for each student
- Question worksheet, copies for each student
- Problem/Solution Guide

Objectives:
Students will be able to:
- explain one method of treating **acidic** abandoned mine drainage (AMD) by reading an article about Glade Run located in Fayette County.
- analyze an article about Glade Run by completing an anticipation/reaction guide, a study guide, and/or a problem-solution worksheet.

Background:
Abandoned deep mines or surface mines can cause drainage that is usually highly acidic with high levels of dissolved metals. When ground water comes into contact with pyrite (iron disulfide minerals) in the mine, the pyrite dissolves in the water. Consequently, the water usually becomes high in acidity and dissolved metals. The metals stay dissolved in solution until the **pH** is raised to a level where precipitation occurs.

Many companies used chemical treatment methods to treat the effluent. In the treatment systems, the acidity is buffered by the addition of **alkaline** chemicals, e.g. calcium carbonate, sodium hydroxide, sodium bicarbonate, or anhydrous ammonia. These chemicals raise the pH to reasonable levels so that precipitates form and settle out of the solution. Chemical treatment systems are expensive and require additional costs to operate and maintain.

Passive treatment systems have been established, which allow naturally occurring chemical and biological reactions to treat AMD. Passive treatment has advantages over chemical **active treatment** systems. When a **passive treatment** system for AMD is designed, mine water chemistry and available treatment techniques should be understood. Sampling of the AMD is essential in order to select the appropriate treatment technique and assess the effectiveness of the treatment.

There is a variety of passive AMD treatment technologies: aerobic wetlands, anaerobic wetlands, open limestone channels, diversion wells, anoxic limestone drains, and vertical flow reactors. Glade Run, a headwater tributary to Dunbar Creek and Youghiogheny River, was polluted with acidic abandoned mine drainage. The **stream** had a pH level of 4.5 and no evidence of fish or aquatic insect life was found.

Several groups worked together to restore Glade Run, including the Chestnut Ridge Chapter of Trout Unlimited, Western Pennsylvania Coalition for Abandoned Mine Reclamation (WPCAMR), and California University of PA. To restore the **stream**, 500 tons of high carbonate alkaline sand was placed into the stream. The sand is fairly inexpensive and is transported easily downstream reacting with the water. After two years, tiny brook trout, proof that the trout were spawning, and diverse aquatic insects were found in Glade Run. However, the alkaline sand treatment was not a permanent solution because the sand is continuously washed away and must continuously be added.

The restoration continued with the construction of a permanent anoxic limestone drain treatment facility. The facility captures the AMD and directs it through buried and crushed limestone. The mine water is then neutralized before it reaches the surface, and the treated water is directed to a sediment pond, where metals can settle out before the water enters Glade Run.

The Glade Run Project is an excellent example of several government and non-profit groups working together for the betterment of the environment. The stream has been restored so much that a brook trout population has been found year after year. This restoration should be an example of what is possible in a region where many mountain streams are impacted with AMD.

Procedure:

Warm-up:

Hand out the Anticipation/Reaction Guide to the students. Give the students a few minutes to complete the left side of the sheet, "Response Before Lesson."

After the students have completed their responses, allow them time to discuss their answers with a partner.

Ask how many students believe that they have all of the responses correct. The students will complete the other side of the page after the lesson.

Activity:

Briefly introduce the class to various treatment methods of AMD, such as aerobic wetlands, anaerobic wetlands, anoxic limestone drains, and chemicals, in order for the students to have some background information for the reading.

Allow the students to have time to read the article. As the students finish reading, pass out copies of the questions worksheet to each student. The students can work in pairs or singly to complete the worksheet.

After the students complete the worksheet, discuss with the class the answers to the questions. Be sure that the students understand why the water needed to be treated, and why the wildlife could not live in such acidic water.

Wrap-up/Conclusion:

Ask the class to get out their Anticipation/Reaction Guide they filled out at the beginning of the lesson. Based on what they learned from the reading and class discussion, have students fill out the right hand side of the guide, "Response After Lesson."

Assessment:

- During the discussion of the questions and answer worksheet, determine if the students were able to comprehend what they read.
- After the WRAP-UP, ask the class if any of their answers in the "Response After Lesson" column are different than the answers they put before the lesson. Based on the Anticipation/Reaction Guide, ask the students what they learned from this reading.

Extensions:

- From the Glade Run article, the students should see that when problems arise in a community, it takes several groups and community members working together to find a solution. In Glade Run, the solution is used as an example throughout the Appalachian region. In small groups, have the students analyze the problem and the solution of the Glade Run Project. Distribute the Glade Run Problem/Solution Guide to the students. Divide the students into groups of 2-3 and give them time to complete the sheet. After the students are finished, discuss the students' opinions and answers.
- Take a field trip to Glade Run to test the water quality of the stream. Take a trip to Saint Vincent College to observe another type of AMD passive treatment system.

Adaptations:

Make an audiotape of the reading, so that students of varying reading abilities can learn the story of Glade Run.

Resources:

Moyer, Ben. 2003. "New Life for Glade Run." Westsylvania Vol. 7 No.1 (2003): 38-43.

This article originally appeared in the Spring 2003 issue of "Westsylvania" magazine, PO Box 565, Hollidaysburg, PA 16648. 1-800-898-3636. It is reprinted by permission of the author and publisher.

New Life for

A Westsylvania Trout Unlimited chapter spearheads efforts to restore an acid-choked mountain stream.

Story and photos by Ben Moyer

Glade Run

Many wild things live within the sound of Glade Run's chatter. Bears and bobcats lounge on the ledges, rattlesnakes wait for a mouse in the shade and ravens chuckle and growl overhead. But for 50 years there were no trout. Wild brook trout, finning and darting in the pools and runs, should have been the living soul of the place, but for five decades they were gone, banished by the acid flow from abandoned coal mines in the ridges around Glade Run's wetlands.

Glade Run showed symptoms of acid mine drainage before the restoration effort began.

Glade Run's acid runoff even threatened Dunbar Creek, a stream stocked by the Pennsylvania Fish and Boat Commission. Only the pure waters of Little Dunbar Creek diluted the acid pollution just enough to allow the hatchery-raised fish to survive in Dunbar Creek.

A headwater tributary to Dunbar Creek and the Youghiogheny River, Glade Run assembles itself in a secluded alder swamp that snakes among ridges on Pennsylvania state Game Lands 51 east of Uniontown in Fayette County. This Westsylvania stream meanders at first, as if reluctant to leave the beaver dams, flooded timber and the intimate marshes that frame its early course. But, inevitably, Glade Run plunges off its plateau and makes a torturous eight-mile dash of photogenic perfection to join Little Dunbar Creek in the valley below. Along the way, Glade is alternately turbulent and tranquil, stair-stepping downward from white cascade to shaded pool. Big timber grows all along the boulder-studded banks – hemlock, oak, yellow poplar, cucumber magnolia, beech and sweet buckeye. Dark tangles of rhododendron shade the flow. Even in summer the water feels icy on human skin.

That a stream of such remote character and scenic attraction should hold no trout was unacceptable to the Chestnut Ridge Chapter of Trout Unlimited (TU), headquartered at Uniontown. Beginning in 1996, the Chestnut Ridge chapter assembled a diverse partnership of conservation groups, state agencies, a state university, local government, businesses and individuals to restore Glade Run as a wild trout fishery. Members of Trout Unlimited, who are dedicated to the conservation, protection and restoration of North America's trout and salmon fisheries and their watersheds, also raised money and won grants to finance the work.

"It made sense to work for restoration of Glade Run," said Tom Shetterly of Charleroi and co-chairman of the chapter's Glade Run Restoration Committee. "Glade Run is high in the headwaters and it flows into Dunbar Creek, which is a regionally important trout fishery in its own right. But Glade was dragging down the water quality in Dunbar and then the Youghiogheny River at Connellsville. We felt that any improvement we could make on Glade would benefit the whole watershed downstream."

Helping Hands

Mark Killar, then a watershed specialist with the Western Pennsylvania Coalition for Abandoned Mine Reclamation, approached group members as they looked for ways to improve Glade Run. Killar told them about a low cost, but effective, treatment technique known as "alkaline sand addition" or "limestone sand addition" used on some acid-impaired streams

Glade Run begins in a mountain wetland on state Game Lands in Fayette County.

in West Virginia. The coalition Killar worked for had $20,000 available to fund a similar Pennsylvania project, and he thought Glade Run was a good candidate.

Alkaline sand addition uses finely crushed limestone to neutralize streams that sometimes run as acidic as lemon juice. State standards require that the alkaline sand be high in carbonates and low in the sediment-causing silica that can smother fish eggs and other life. In many limestone quarries, the sand is a byproduct of the crushed stone made for the construction industry.

To make it work, the material is placed in long windrows along the banks of a small stream, allowing the fine grains to slowly wash into the current. The limestone particles react with the acids in the stream, neutralizing them. The amount of alkaline sand needed for a waterway can be calculated based on the size of the watershed, the acidity of the receiving stream and the volume of flow.

In order to apply for grant funding, the group needed chemical and biological baseline data on the Glade Run watershed. It contacted the California University of Pennsylvania, which has an active environmental studies program.

William Kimmel, an aquatic ecologist and professor of biology, took an immediate interest in the Glade Run project. Kimmel and graduate student Todd Sampsel collected and analyzed water samples throughout the watershed. They documented levels of acidity averaging a pH level of 4.5, or about the same as that of a cup of coffee. The researchers found no evidence of fish or aquatic insect life the fish feed on anywhere in Glade Run or its tributaries. Their surveys did, however, discover wild trout populations and healthy insect diversity in Little Dunbar Creek above the Glade Run confluence, suggesting that the acid drainage might be the only water-quality factor preventing trout from thriving in Glade Run.

With data to justify a restoration effort, Chestnut Ridge TU applied jointly with the Fayette County Conservation District for the $20,000 mine-reclamation grant. It was awarded in 1997.

Next the group needed to find a way into remote areas of Glade Run to reach potential treatment sites. Since most of the watershed (but not the abandoned mines) lies on state game lands, the Trout Unlimited group asked the Pennsylvania Game Commission's Bureau of Land Management for permission to improve a system of abandoned logging roads leading to three excellent treatment sites – one on Glade Run's main stem, one on its Big Piney Run tributary and another on Little Piney Run. The response from the Game Commission was more positive than hoped. It authorized its local land management crews to help prepare the roads for the heavy loads of alkaline sand.

When the supervisors of Wharton Township – the township that encompasses the upper reaches of Glade Run – learned of the project, they too committed manpower and equipment. The township's front-end loader and trucks helped to remove stumps and place aggregate on the old logging roads.

Chestnut Ridge TU members and California University students photograph brook trout caught during electro-shocking. See page 39.

"When we heard about what they were trying to do on Glade Run, we just thought we ought to help out," said Wharton Township Supervisor Jim Means. "These kinds of efforts are a big plus for all the communities in our region. Clean water is a critical resource and it will only become more important in the future as people look to Western Pennsylvania for recreation and quality lifestyle. Glade Run at one time was one of the finest streams in these mountains and we didn't want to lose out on an opportunity to get something done to improve it. This project benefited not only Wharton Township, but everyone along the 'Yough' River watershed all the way to Pittsburgh."

"We had funding for treatment, but the problem we faced was accessibility for the trucks and equipment," Shetterly said. "The best sites for sand addition were more than a mile from any kind of a passable road. That's when Wharton Township and the Game Commission really helped out and made this all possible."

Coolspring Stone Supply of Uniontown donated hundreds of tons of construction-grade crushed stone to rejuvenate the logging roads. An $800 grant from Miller

The alkaline sand is placed in windrows along the stream. The current washes the material downstream to neutralize acidity.

Brewing Co.'s "Friends of the Field Program," which supports local, citizen-led conservation projects around the country, also helped pay for the cost of improving access.

Restoration begins

In the fall of 1998, the Chestnut Ridge Chapter of Trout Unlimited and its partners began the actual restoration of the Glade Run watershed. More than 500 tons of high-carbonate alkaline sand, purchased at a discount price from Bellefonte Lime Co. in Bellefonte, Centre County, were placed at the three selected locations. Twenty-two tri-axle loads of sand rolled easily over the improved logging roads. The trucks backed up near the stream bank and dumped their loads into a stockpile. Men operating front-end loaders provided by local contractors placed the sand in windrows along the stream.

Kimmel and his students noted almost immediately a reduction in the waterway's acid levels. To observe the potential influence of the treatment on fish life, the California University researchers placed brook trout in cages at several points upstream and downstream from the treatment sites. The trout at the upstream locations succumbed quickly, while those at downstream stations lived for several months and were ultimately released.

Through the initial $20,000 grant and a subsequent $22,000 Growing Greener grant from the Pennsylvania Department of Environmental Protection, the local Trout Unlimited chapter has continued annual treatments of Glade Run. Nearly 2,000 tons of alkaline sand have been placed in the watershed and water quality has continued to improve. Recent sand purchases have come from Cranesville Stone Co. in Cranesville, W. Va., to cut transportation costs.

Killar, who has remained an active participant in the Glade Run project, is now a watershed specialist with the Western Pennsylvania Conservancy's Watershed Assistance Center in Fayette County.

"Alkaline sand treatment has several advantages when used in the right situations, such as we have at Glade Run," Killar said. "The material is relatively inexpensive, and its small size allows it to be continually picked up and moved downstream by the current. The particles are constantly abrading against one another and other materials on the streambed, so that the surface is always exposed to the water and available to neutralize acid. Some efforts in the past used larger aggregate sizes, which remain immobile in the stream. The tendency is for the surface of the larger aggregates to become coated or scaled so that the limestone becomes essentially inert."

In the summer of 2000, Kimmel and Rob Ryder, the second graduate student to work on Glade Run, were convinced that the stream had improved enough to support a self-sustaining trout population. High waterfalls on Glade Run's lower reaches, however, prevented wild trout from Dunbar Creek from moving upstream naturally in response to the newly improved environment. After obtaining a "Scientific Collection Permit" from the state Fish and Boat Commission, Kimmel, his students and Chestnut Ridge TU members electro-shocked a section of Little Dunbar Creek. They collected wild brook trout from the stream, placed them in watertight containers strapped on backpacks and carried the fish over the rugged terrain to new homes.

Life returns

Two years later, the team returned on a hot and humid late-summer day, packing the heavy electro-shocking equipment through two miles of dense forest to the stream section where the wild trout had been released. Their object was to shock Glade Run fish in hopes of finding evidence that the trout had spawned.

Not long after the electric probes were placed in the current, a silvery trout darted sideways, temporarily stunned, and was quickly netted by an eager helper. Another trout was captured in the next deep hole and then the team caught a tiny fish that could almost pass through the net's mesh.

"That's what we're looking for," Kim-

mel said. "That's a young-of-the-year brook trout, and it's proof that trout are spawning here now."

Macro-invertebrate surveys conducted by Kimmel and Ryder also show that both the abundance and diversity of aquatic insects have improved in Glade Run in response to the treatment. Their chemical surveys have documented that the water's acidity levels are neutral or near neutral downstream of the treatment sites.

"None of this would have been possible without the involvement of California University," Shetterly said. "Glade Run is a rugged, remote place. And Dr. Kimmel and his students have been trekking all over those mountains since we started, taking samples and looking for insects and fish. They have the data that show this kind of treatment can work in the right situations."

Chestnut Ridge TU and its partners acknowledged from the beginning that alkaline sand treatment is not a permanent solution to acid mine drainage problems in the region's mountain streams. The sand is being washed away constantly and must be added to continuously.

"The alkaline sand kind of jump-started the restoration of Glade Run," Shetterly said. "But we wanted to achieve more permanent treatment that would not have to be repeated every year."

Bright future

With the Western Pennsylvania Conservancy's assistance, Trout Unlimited wrote a successful application to the state Growing Greener program for a $200,000 grant to construct a permanent anoxic (airless) limestone drain treatment facility at one of the most acidic discharge sources. The group hired Skelly and Loy Engineers of Harrisburg to design the facility. Purco Coal of Monongahela began construction in the summer of 2001, and one year later, in August 2002, the Glade Run Anoxic Limestone Drain Treatment System was dedicated.

The system captures acidic water directly from the underground mine and directs it through buried, crushed limestone. Thus the mine water is neutralized before it reaches the surface, where air triggers the chemical reactions that produce the acids. The treated water is then directed to a sediment pond where metals – such as iron, aluminum and manganese – can settle out before they enter Glade Run.

David Hess, then secretary of the state Department of Environmental Protection attended the treatment facility's dedication.

"The Glade Run project is extremely important to the quality of water throughout the Youghiogheny River watershed because it affects several streams," Hess said. "By eliminating the acidity in Glade Run, the aquatic life in the stream can hopefully return to that of the past – a stream where trout are common and abundant."

Chestnut Ridge TU plans to continue its alkaline sand additions at least through this year, when funding runs out. Kimmel and his students will continue their monitoring work in the Glade Run watershed too.

"This has been a partnership all along," Killar said. "But Chestnut Ridge TU is the heart and soul of this project. They believed when others were skeptical that something so simple could be so effective. They've committed money from their own pockets, countless hours of behind-the-scenes work planning and administering the project, and even more hours of sweat equity, not only to Glade Run but throughout the Youghiogheny watershed."

As a result of its success, the Glade Run Project has attracted attention beyond its local participants. Last August, Ryder made a presentation about Glade Run at a conference of the American Fisheries Society, held in Baltimore, Md. The conference focused on the restoration of degraded aquatic habitats.

"The Glade Run project is an excellent example of what can be accomplished by a group of dedicated partners proceeding with specific goals in mind," Kimmel said. "This stream has been restored to the extent that a self-sustaining brook trout population became possible. Scientifically, its strength lies in the comprehensive pre- and post-addition bio monitoring and bio-assessment. On a broader ecological scale, in the Appalachian region where many mountain streams have been devastated by acidification from mining and acid deposition, the restoration of even a few can be significant and may spur further action by stakeholders and governmental bodies." ■

Mark Killar of the Western Pennsylvania Conservancy's Watershed Assistance Center examines the milky appearance caused by fine particles of alkaline sand.

To help heal the waters contact:

Western Pennsylvania Coalition for Abandoned Mine Reclamation, Donohoe Center, RD12, Box 202B, Greensburg,PA 15601. (724) 837-5271.

Western Pennsylvania Conservancy, Watershed Assitance Center, 209 Fourth Ave., Pittsburgh, PA 15222. (412) 288-2777.

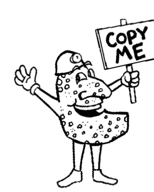
Prior Knowledge Topic Survey

Anticipation/Reaction Guide

Instructions: Respond to each statement twice: once before the lesson and again after reading it.

- Write **A** if you agree with the statement.
- Write **B** if you disagree with the statement.

Response <u>**BEFORE**</u> **Lesson**	**TOPIC:** Abandoned Mine Drainage in Glade Run	**Response** <u>**AFTER**</u> **Lesson**
	Mounds of alkaline sand can be dumped directly into an acidic stream to neutralize the acidity.	
	Limestone is an excellent neutralizer of acidic mine drainage.	
	Alkaline sand treatment has several advantages when used in the right situations.	
	Alkaline sand particles are inexpensive and easily moved down-stream by the stream current.	
	Only two years after treatment, Glade Run had proof that trout were spawning in the stream.	
	Alkaline sand treatment is a permanent method of treating AMD.	
	An anoxic limestone drain is a more permanent method of treating acidic mine discharge.	
	The water quality of one small stream affects the water quality of all downstream waterways.	
	It takes only a few dollars and a couple of dedicated people working together to plan and carry out an AMD treatment project.	
	An acidic stream with a pH of less than 3 has very little aquatic life.	



TEACHER'S ANSWER SHEET — PRIOR KNOWLEDGE TOPIC SURVEY

Anticipation/Reaction Guide

Instructions: Respond to each statement twice: once before the lesson and again after reading it.

- Write **A** if you agree with the statement.
- Write **B** if you disagree with the statement.

Response BEFORE Lesson	**TOPIC:** Abandoned Mine Drainage in Glade Run	Response AFTER Lesson
	Mounds of alkaline sand can be dumped directly into an acidic stream to neutralize the acidity.	**A**
	Limestone is an excellent neutralizer of acidic mine drainage.	**A**
	Alkaline sand treatment has several advantages when used in the right situations.	**A**
	Alkaline sand particles are inexpensive and easily moved downstream by the stream current.	**A**
	Only two years after treatment Glade Run had proof that trout were spawning in the stream.	**A**
	Alkaline sand treatment is a permanent method of treating AMD.	**B**
	An anoxic limestone drain is a more permanent method of treating acidic mine discharge.	**A**
	The water quality of one small stream affects the water quality of all downstream waterways.	**A**
	It takes only a few dollars and a couple of dedicated people working together to plan and carry out an AMD treatment project.	**B**
	An acidic stream with a pH of less than 3 has very little aquatic life.	**A**

Glade Run Study Guide

Name: ______________________________

Date: ______________________________

Instructions: Using information found in the article, answer the following questions.

1) What was missing for Glade Run for 50 years? Why?

2) What happens to acid mine water when you add alkaline sand?

3) The amount of alkaline sand needed for the waterway was calculated based on what three criteria?

4) What was the pH measurement of Glade Run before the project started?

5) Five hundred tons of ______________________ was put into the stream at three locations.

6) Why did the biologists electroshock the fish?

7) Did the numbers of macroinvertebrates increase or decrease after the alkaline sand was added? Why?

8) How was the pH measurement at the end of the study?

9) Was adding the alkaline sand a permanent solution to the problem? Why or why not?

TEACHER'S ANSWER SHEET — NEW LIFE FOR GLADE RUN STUDY GUIDE

1) What was missing for Glade Run for 50 years? Why?
   TROUT AND AQUATIC INSECT LIFE WAS MISSING BECAUSE OF THE ACID FLOW FROM THE ABANDONED COAL MINES IN AND AROUND GLADE RUN.

2) What happens to acid mine water when you add alkaline sand?
   ALKALINE SAND NEUTRALIZES STREAMS THAT ARE ACIDIC.

3) The amount of alkaline sand needed for the waterway was calculated based on what three criteria?
   THE AMOUNT OF SAND NEEDED IS CALCULATED BASED ON THE SIZE OF THE WATERSHED, THE ACIDITY OF THE RECEIVING STREAM, AND THE VOLUME OF THE FLOW.

4) What was the pH measurement of Glade Run before the project started?
   pH= 4.5 (ABOUT THE SAME AS A CUP OF COFFEE)

5) Five hundred tons of HIGH-CARBONATE ALKALINE SAND was put into the stream at three locations.

6) Why did the biologists electroshock the fish?
   1) TO COLLECT THE TROUT IN A SECTION OF LITTLE DUNBAR CREEK SO THAT THE TROUT CAN BE PLACED IN THE TREATED GLADE RUN.
   2) TO SHOCK GLADE RUN FISH IN HOPES OF FINDING EVIDENCE THAT THE TRANSPLANTED FISH SPAWNED.

7) Did the numbers of macroinvertebrates increase or decrease after the alkaline sand was added? Why?
   THE NUMBERS OF MACROINVERTEBRATES INCREASED BOTH IN ABUNDANCE AND DIVERSITY BECAUSE THE WATER HAS BEEN TREATED AND THE WATER'S pH is RESTORED TO SUITABLE HABITAT FOR WILDLIFE.

8) How was the pH measurement at the end of the study?
   THE pH AT THE END OF THE STUDY WAS NEUTRAL OR NEAR NEUTRAL.

9) Was adding the alkaline sand a permanent solution to the problem? Why or why not?
   ADDING THE ALKALINE SAND WAS NOT A PERMANENT SOLUTION BECAUSE THE SAND IS CONTINUOUSLY WASHED AWAY AND MUST CONSTANTLY BE ADDED.
   AN ANOXIC LIMESTONE DRAIN TREATMENT FACILITY WAS BUILT TO PERMANENTLY TREAT THE WATER.

Glade Run Problem/Solution Guide

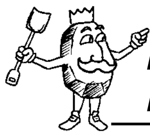
	WHO?
PROBLEM	**WHAT?** **WHY?**

SOLUTION	**ATTEMPTED SOLUTIONS**	**RESULTS**

END RESULT

AMD Around Me

Developed by Beth Langham, Saint Vincent College Environmental Education Center, Latrobe, PA



About This Activity...

Prep Time Required:
5-10 minutes

Grade Level:
Highschool

Subjects:
Social Studies, Language Arts, Environmental Science

Duration of Activity:
Several sessions of 30 to 60 minutes each

Pennsylvania Standards Addressed:
3.3.10.A2, 3.4.10.B2, 3.4.10.D3, 4.1.12.B, 4.2.10.A, 4.2.12.A

Setting:
Indoors and in the community conducting interviews

Prerequisites:
Knowledge of current events and environmental issues

Summary:

Students, acting as investigative reporters gather information about their local watershed and restoration efforts of the community. Individual persons will be interviewed to provide their viewpoint and personal assistance.

Materials:

- Writing materials
- Envelopes
- Postage
- Telephone

OPTIONAL

- Tape recorder
- Video recorder
- Camera/film

Objectives:

Students will be able to:

- describe the importance of abandoned mine drainage (AMD) treatment systems in their local community and how they have helped to improve the environment.

Background:

Students are often times writing reports on books, people or any subject. Why not have students write about their community and how active and committed people can accomplish many things. People in grass-roots organizations work tirelessly, day in and day out to help their local watershed organizations, trout clubs, and communities to make the environment a more beautiful place. Some of the people involved in these endeavors are employed by the state, local or federal government, but many are volunteers who are dedicated to making their community a better place.

People that make a significant difference in their local community feel or see something they care about, and they work to accomplish a goal. Every community has these people who contribute to the improvement of the habitat, conservation, and many other issues.

These people are most likely not well known – at least not on a media level. Students will develop new skills to discover who these people are and become investigative reporters while seeking out the story. They will use first hand interviews, and direct contact.

Procedure:

Warm-up:

Introduce to the students what the new assignment will be.

Brainstorm possible sources of information that could be used to find out about people in the community who have contributed to an AMD project or preserving the local streams. Examples might be public libraries, school libraries, city hall, government offices, telephone books, newspapers, magazines, reporters, editors on the staff of the local paper, local television news directors, and the president of local groups or clubs. The group may even place an advertisement in the paper or enlist the aid of a reporter to write a story about the class project.

Activity:

After the list has been made, students in teams of three or four draw a name at random from the list. Each group will now become a biographical research team to prepare a biography or living history of the person. In some cases, the person may have been important in the community as a conservationist, but is now deceased. In those cases, the team will have to identify relatives, friends, former employers, and other potential sources of information to interview and research.

Have each team develop a research plan. It could include the outline of any interviews they may want to conduct, whether with the person directly or with others who know or knew the individual. Discuss each team's plan with the group, and consider suggestion for improvement. After the plans have been discussed and refined, have the teams contact the people they want to meet and interview. This contact could be accomplished by sending a letter to the interviewee, stating the purposes of the research and that the students will follow the letter with a telephone call.

Once the teams have confirmed the willingness of the people to be interviewed, the teams will need to meet with them and conduct the interviews. The basic format for the interview could include any personal history details, but the major questions to be addressed might include these:

- How did you become interested in the aquatic environment?
- What prompted you to take action?
- How did you decide on the course of action you took?
- What difficulties did you encounter, and how did you overcome them?
- What do you think your contribution has been?
- What are your personal dreams and goals for aquatic habitats?
- What would your advice be to **citizens** wanting to take positive action to improve the aquatic environment?

NOTE: The list of questions could be modified to include personal interest of the students and to reflect UPON particular circumstances.

Wrap-up/Conclusion:

After the interviews and additional research are completed, have each team write a biography of its person. Once completed, ask each of the teams to give a brief oral report. Make copies of the biographies, and send each biography with a letter of thanks to the people who were interviewed and others who assisted. It is recommended that letters of thanks be sent to all who assisted in the process.

OPTIONAL: Create a visual display of all the completed biographies, complete with photographs and news clippings. Invite the local aquatic heroes and heroines to the school for a public recognition of their contributions. They could be given letters of thanks and copies of their biographies at this time. The news media could be invited, including local television, radio and newspaper reporters.

Assessment:

- Identify two people who have helped protect a local aquatic area, and describe what each did. Why are their actions important?
- What can you do – working alone or with others – to conserve or protect an area of aquatic habitat in your community?

Extensions

- Form a group in the school to address problems related to the conservation and protection of aquatic resources and habitats. What have you learned from the biographical research that can assist the group to formulate some action plans?
- View films or other media presentations to find out about other aquatic conservationists.
- Present a copy of the biographical reports to the school library or the public library to include in its collection. These reports may be important contributions to local history.

Adaptations:

Have younger children ask their parents or grandparents question(s) about the local environment and take all the answers back to the teacher to compile a bulletin board.

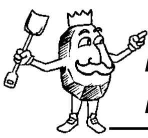
Resources:

Local watershed organizations, Department of Conservation of Natural Resources (DCNR), United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS), Local Conservation Districts

Mine-opoly–

Stewardship & Responsibility Toward the Environment

Adapted from "Hydropoly," in WOW! The Wonders of Wetlands, An Educator's Guide (Bozeman, MT: Environmental Concern, Inc. and The Watercourse, ©1995)
Developed by Missy Shull, Gwen Johnson, Kate Tantlinger, Kiski Conemaugh Stream Team, Johnstown, PA.



About This Activity...

Prep Time Required:
30 minutes

Grade Level:
Middle school
High school

Subjects:
Science

Duration of Activity:
1 hour

Pennsylvania Standards Addressed:
3.4.7.B1, 3.4.7.B2, 3.4.6.B2, 3.3.10.A2, 3.3.12.A2, 3.4.10.B2, 4.5.7.C, 4.5.8.C

Setting:
Classroom

Vocabulary:
Bony Pile

Related Vocabulary:
Co-generation
Economics
Plant
Remine
Subsidence

Summary:
A game of stewardship and responsibility. Students play a board game in order to hone their decision making skills.

Materials:
For each group:
- Game board
- Set of decision cards
- Die
- Game pieces
- Tape and scissors for game assembly

Objectives:
Students will be able to:
- explain how environmental problems erupted from mining and why mining is regulated.

Background:
Think of all the decisions you make in a day – what time to wake up, what to wear, what to eat, where you should spend your money. Some decisions are easy to make, while others can be quite difficult. Often, personal interests, values, economic factors, and peer pressure can influence your decisions. Sometimes these influences dictate how your actions impact the environment.

Prior to 1977, mining was not regulated; so mining companies could pollute the land, disregarding the impact their pollution had on the land. Also, people took their environment for granted. There was no thought of conservation because IT WAS thought THAT the environment was there SOLEY FOR THE USE OF THE PEOPLE. In addition, fuel supplies seemed endless. Wood, then coal, was plentiful and profits were through the roof. Everyone lives downstream, though, and people started realizing that they must preserve and conserve the resources nature provides.

Procedure:
Warm-up:

Ask students to list five decisions they recently made and the reaction to these decisions. Did they make the right choice or were they disappointed in the outcome? Discuss how they came to these decisions.

Then, show the students various photographs of AMD (abandoned mine drainage) impacted streams, **bony piles**, and other mine-scarred lands and ask the students how they think these places were degraded.

Activity:
Students will play "Mine-opoly," a game based on "Hydropoly" taken from the Wonders of Wetlands (WOW).

- The class should be divided into small groups from two to six players or teams and review the rules with the students.
- The decision cards should be piled and placed face down next to the game board. Each player or team of players places his or her game piece on the start space. Each player must roll the die in order to see who goes first then proceeds in a clockwise rotation.
- The first player rolls the die and moves that many spaces, following the direction of the arrows. If a player lands on a blank space, his or her turn is over; if the player lands on a space marked with "roll again" the player rolls again; if the player lands on "lose a turn" his or her turn is over and must skip his or her next turn; if a player lands on a space marked "decision card" he or she selects one of the cards off of the pile. An opponent should read the decision section of THE card aloud to the player, but not the consequences section. The player has only two minutes to make the decision (teams should discuss the questions). After the player reveals his or her decision, the person holding the card should read both of the consequences and tell the player how many spaces to move. The player's turn continues

until he or she lands on a space dictating otherwise.

- Players can only land on the winning space by rolling the exact number, not higher, on the die.

Wrap-Up/Conclusion:

Discuss the results of the game focusing on how the decisions the students made are environmentally or economically driven.

Assessment:

- The decisions students make while playing the game demonstrate their attitudes and understanding of environmental issues.

Extensions:

- Have the students play the game before discussing any economic vs. environmental issues. Once the students become familiar with the game and its concepts, have students make up scenarios and write decision cards.

Adaptations:

High school students can do research on various laws pertaining to coal mining and write several decision cards based on that law.

Resources:

"Hydropoly," In WOW! The Wonders of Wetlands, An Educator's Guide, Bozeman, MT: Environmental Concern, Inc. and The Watercourse, 1995.

Mineopoly Decision Cards

Decisions, Decisions!

Your coal company is looking for new land to mine. You can either choose to (1) strip mine 15 acres of beautiful forests and reap the rewards of a bountiful coal seam or (2) remine 30 acres of land that had been previously deep mined to recover the same amount of coal. Which will you choose?

Consequences: (1) Strip mining these forests will ruin natural habitat for a number of plant and wildlife species, while denuding the landscape! Move back 3 spaces. (2) If you mine previously deep mined land, you will be reclaiming 30 acres of land and preventing further subsidence from abandoned coal tunnels. Move ahead 3 spaces.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

You live in a city that once bustled because of the coal and steel industries. It's Election Day for a new mayor. Candidate 1 promises to increase economic growth and create 2,000 jobs by building a new power plant that uses freshly mined coal. Candidate 2 proposes to build a co-generation plant in the abandoned steel mills that will use waste coal, which older technology could not use, but will only create 1,100 jobs. Which will you vote for?

Consequences: (1) The new power plant Candidate 1 proposes to build, will encourage coal companies to mine pristine land. Move back 3 spaces. (2) The co-generation plant Candidate 2 proposes, will reclaim waste coal piles that surround the city. The environmental benefits outweigh the economic disadvantage. Move ahead 3 spaces.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

You are a kind-hearted person who donates $200 each year to a charity or non-profit organization. Whom do you donate your money to: (1) A conservation organization monitoring abandoned mine drainage and promoting environmental education or (2) a Girl Scout troop. If you choose (1) you know that your donation will be used for environmental cleanup. If you choose (2) you could ask the scouts to volunteer at an environmental cleanup activity in their community. Which do you choose?

Consequences: Both choices have their merits. In choice (1) you're sure your donation will be used towards environmental cleanup. Move ahead 2 spaces. In choice (2), there's no guarantee that the scouts will do as you asked. Move ahead 1 space.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

You are a farmer who is tired of the long day's work and wants to move to the city. You need money for your move and know that there is a valuable coal deposit under your farmland as well as a rare species of plant that grows along the boundaries of your farm. You are approached by (1) a mining company who wants to mine the land, and (2) a conservation organization that will keep the land as a nature preserve. The coal company offers you twice the money. Which do you choose?

Consequences: (1) We know the money is hard to resist, but you are being selfish. Move back 2 spaces. (2) You know the importance of biodiversity and conservation. Move ahead 3 spaces.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Mineopoly Decision Cards

Decisions, Decisions!

You are on the city council board. Two suggestions have been made to better the community. You can (1) remove the bony piles, which are an eye-sore to the community, and build a coal heritage museum or (2) build a city park in an area currently occupied by abandoned buildings. Choice (1) costs twice as much. Which will you choose?

Consequences: (1) Removing the bony piles will remediate several environmental hazards and improve the city's appearance, while promoting tourism through the new museum. Move ahead 3 spaces. (2) Building the new park also improves the city's appearance, but does not attract tourists. Move ahead 2 spaces.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

You are the president of a coal company, which has hit tough times and is desperate to make a profit. You can either (1) choose not to treat your acidic discharges, which you know is against the law, or you can (2) lay off 30 employees, who will receive half as much money while collecting unemployment checks during their time off. Which do you choose?

Consequences: (1) By not treating your discharges, you are impacting a native trout stream and risk paying heavy fines issued by the Department of Environmental Protection. Move back 2 spaces. (2) Although you hate to layoff employees, it's the safe and law-abiding choice. Move ahead 1 space.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

Your friends are planning to go to a water park this Saturday and then see the summer's blockbuster movie; however, your little brother informs you that the local watershed group is planting trees on a reclaimed strip mine that same day. He is very enthusiastic and you know they need as many hands as they can get. Which do you choose?

Consequences: (1) You act selfishly by choosing to spend the day with your friends. Move back 2 spaces. (2) By choosing to help the watershed group plant trees, you made a personal sacrifice. Move ahead 3 spaces.

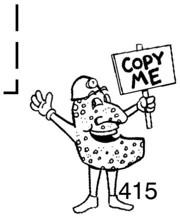
Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

Your watershed organization put out a bid to construct a passive treatment system for the worst discharge in your watershed. Company A wants to utilize an innovative treatment system, which will theoretically require maintenance every 2 years. Company B wants to implement a treatment system that has been used with success over several years, but requires maintenance every 6 months. Initial construction costs are the same, but due to the frequency of maintenance, system B will cost more in the long run. Which do you choose?

Consequences: Both are good decisions, but because you are taking a risk using Company A, move ahead only 1 space. Because Company B is using a tried-and-true method, move ahead 3 spaces.

Nature Interrupted – The Journey of AMD
MINEOPOLY



Mineopoly Decision Cards

Decisions, Decisions!

You have been fly fishing for years in the same stream. Over the years, you have noticed a decline in trout and the water appears more orange and smells like rotten eggs. You can (1) move to another river where there is an abundance of trout, or (2) contact your local watershed to get involved with the clean-up of the stream and help re-introduce trout even though it will take years for them to come back. Which do you choose?

Consequences: (1) Moving to another stream does nothing to help the current stream get healthier. Move back 2 spaces. (2) Contacting your local watershed and volunteering your time to clean up the stream shows how much you care about the environment and the trout. Move forward 3 spaces.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

The local kids want a new skate park so they can ride their bikes, skateboards, and roller blades in a safe place. You, the Mayor, seek out funds to build the new skate park. You are given two options. (1) Build the site on a current bony pile that will cost a lot of money to remove but you can sell it to a power plant for fuel and the site is very close to town so all the kids can enjoy it. (2) Build the site right beside beautiful wetlands and a healthy riparian zone. Which do you choose?

Consequences: Both choices are good ones but (1) is the best choice because you are improving the environment around the site by removing the bony pile. Yes, it will cost a lot to remove the pile but you should get most of it back by selling it. Move ahead 2 spaces. (2) Building right beside a wetland and riparian zone may have a negative effect on the area because it is too close. Move ahead 1 space.

Nature Interrupted – The Journey of AMD
MINEOPOLY

Decisions, Decisions!

You are the lead vocalist and guitar player in a rock band and have been asked to play two shows on the same day. Event (1) will be held at a local bar and they will pay you $200. Event (2) will benefit the local conservation district to plant trees along streams that have been cleaned of AMD, however you will not be paid for this show. Which will you choose?

Consequences: (1) You and your band are being greedy. Move back 3 spaces. (2) A wise decision to help out your local conservation district raise money to plant trees. What good citizens! Move forward 3 spaces.

Nature Interrupted – The Journey of AMD
MINEOPOLY

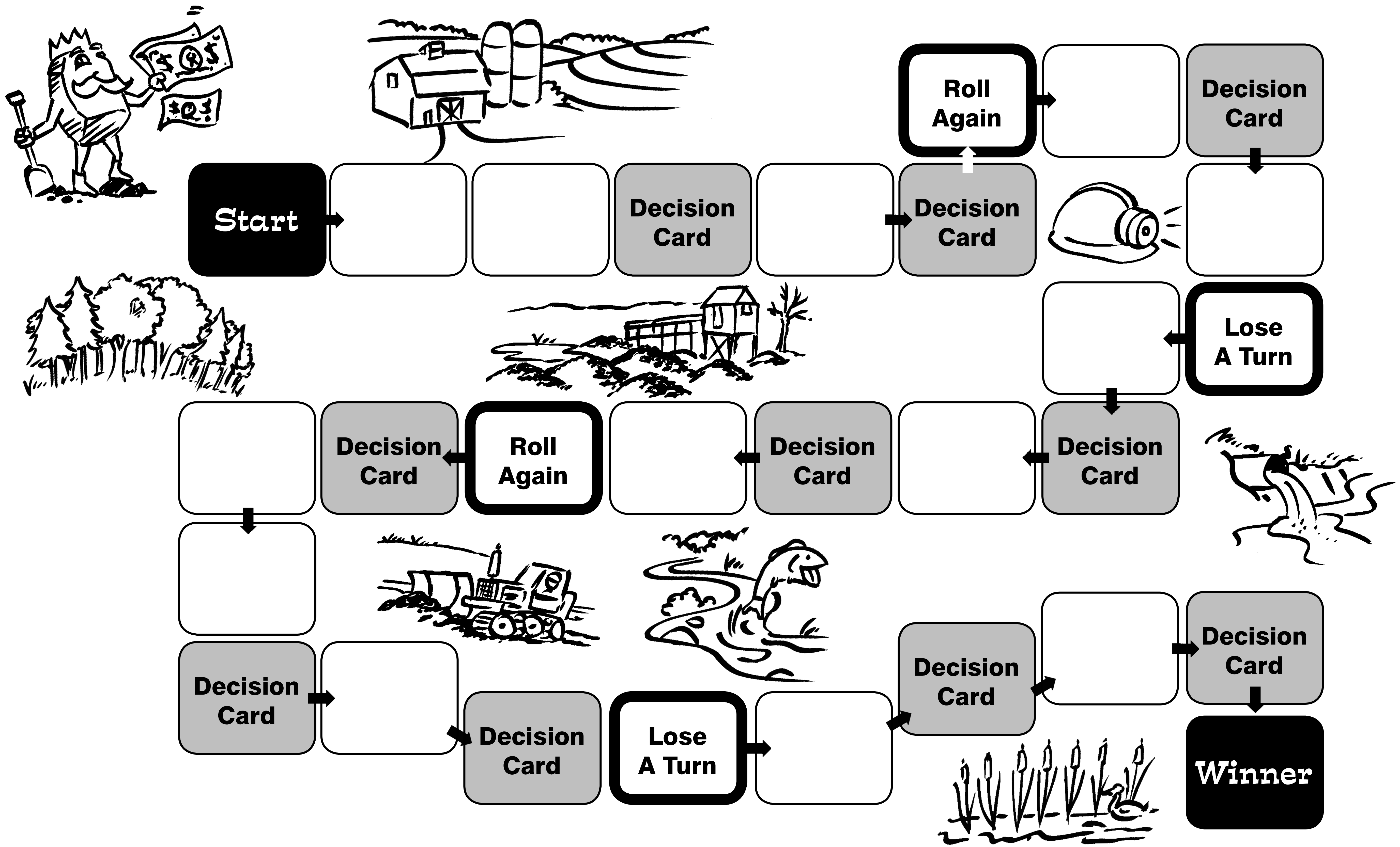
Decisions, Decisions!

You've just been hired by a reputable mining company who will be giving you full benefits and great pay that will support your family. You have discovered that they are illegally disposing of the mine water into the nearby stream. Do you (1) tell the proper officials and risk the chance of losing your job or (2) ignore the problem.

Consequences: (1) If you tell the proper officials and report the company they will be fined and HELD responsible for the clean-up. Environmentally good choice. Move forward 3 spaces. (2) What the company is doing is not only illegal but environmentally damaging and you may lose your job if the company is caught. Move back 2 spaces.

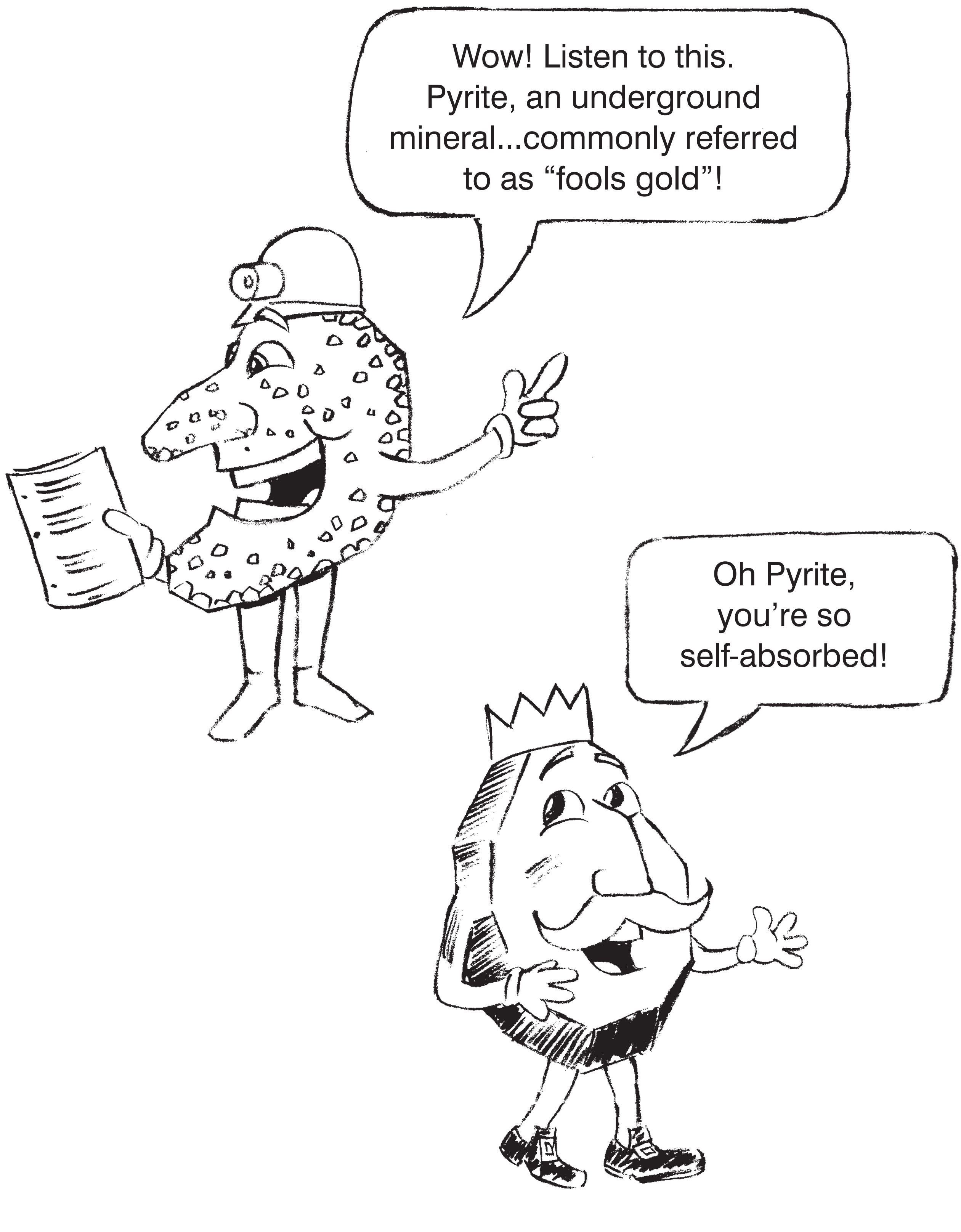
Nature Interrupted – The Journey of AMD
MINEOPOLY

Mineopoly Game Board



Adapted from "Hydropoly," in WOW! The Wonders of Wetlands, An Educator's Guide (Bozeman, MT: Environmental Concern, Inc. and The Watercourse, ©1995)

Glossary


Wow! Listen to this. Pyrite, an underground mineral...commonly referred to as “fools gold”!
Oh Pyrite, you’re so self-absorbed!

Glossary

305 (b) Report - a biennial water quality report is required of each state by the Clean Water Act. Also referred to as the Water Resource Inventory, that evaluates the water quality of all navigable waters of the state, the report inventories point sources of pollution and identifies which waters are in attainment of state water quality standards.

Acidic (Acid) - a condition in which the concentration of positively charged hydrogen ions is high and the pH is less than 7.0.

Acid/Abandoned Mine Drainage (AMD) - water that is affected by passage through, or alteration by, coal or abandoned coal mine environments. Acid mine drainage can have acceptable water quality, but often it is contaminated. Contaminated mine drainage lowers water quality and kills aquatic life (fish, insects, etc.). Contaminated acid mine drainage most often has these characteristics: 1) Low pH (high acidity) 2) High metals concentrations 3) Elevated sulfate levels 4) Excessive sediment and siltation. Acid concentrations in streams can kill many life forms and stunt the growth of others. Acidic water also can break down the metallic compounds of iron, sulfur, manganese and aluminum found in nearby rock or earthen waste piles.

Acid Mine Precipitation - substances leached out by acidic mine water are called "precipitates." Metals are commonly leached out and may be revealed by the color of the deposits left behind. White - indicates high levels of dissolved aluminum; Black - as a dark stain on creek rocks indicates manganese; Orange - indicates oxidized iron, which gives contaminated creeks their orange/yellow color.

Active Channel Width - elevation on the bank marking the normal maximum water flow before flooding occurs.

Active Treatment - involves the use of chemicals and energy to remove contaminants from the water.

Adjective - a word belonging to one of the major form classes in any of numerous languages and typically serving as a modifier of a noun to denote a quality of the thing named, to indicate its quantity or extent, or to specify a thing as distinct from something else.

Adverb - a word belonging to one of the major form classes in any of numerous languages, typically serving as a modifier of a verb, an adjective, another adverb, a preposition, a phrase, a clause, or a sentence, expressing some relation of manner or quality, place, time, degree, number, cause, opposition, affirmation, or denial, and in English also serving to connect and to express comment on clause content.

Aeration - the process of mixing air into a solution so as to allow atmospheric gases to dissolve into the solution through direct contact, stirring, forced injection, or other means.

Aerobic Wetland - a large surface area pond with horizontal surface flow, which may be planted with cattails and other wetland species.

Aggradation - the process by which a stream's gradient steepens due to increased deposition of sediment.

Agricultural Revolution - a significant change in agriculture that occurs when there are discoveries, inventions, or new technologies that change production.

Alkalinity (basic or alkaline) - a measure of the ability of a solution to absorb positively charged hydrogen ions without a significant change in pH. Also referred to as buffering capacity. Alkaline solutions have a pH greater than 7.0.

Aluminum - a common metal element found in AMD that oxidizes as a whitish powder at high pH levels.

Anaerobic Wetland - a large pond with a lower layer of organic substrate with horizontal surface flow; typically the compost layer is made from spent mushroom compost that contains about 10% calcium carbonate.

Anoxic - a condition existing or process conducted in the absence of oxygen, anaerobic.

Anoxic Limestone Drain (ALD) - a buried bed of limestone constructed to intercept subsurface mine water flows and prevent contact with atmospheric oxygen. Keeping oxygen out of the water prevents oxidation of metals and armoring of the limestone.

Anthracite - hard coal, with the highest carbon content, between 86% and 98%. It is used mainly for heating homes. Anthracite coal is found mostly in northeastern Pennsylvania.

Appalachian Clean Streams Initiative - a program sponsored by OSM to coordinate and focus AMD clean-up projects in the United States.

Aquatic Habitat - areas suited for fish and other creatures that live in wet conditions.

Armor - defensive covering for the body (especially covering [as of metal] used in combat); a quality or circumstance that affords protection; a protective outer layer (as of a ship, a plant or animal, or a cable).

Artesian Flow - a spontaneous flow resulting from internal pressure

Average - the value obtained by dividing the sum of a set of quantities by the number of quantities in the set. Also called the arithmetic mean.

Bank Stability - a slope is subject to the influence of gravity and possible pressure of ground water, which tend to cause sliding or caving. It is also subject to surface erosion from running water, wind, and alternate freezing and thawing, or wetting and drying. Weathering causes changes in particle size and composition. Bank slope stability can be attained by benching, by growth of vegetation, and by artificial protections, such as masonry walls, drainage systems to intercept or remove ground water, and fences to catch rolling pieces.

Beneficial Use Designation - states how humans use the water resource and how well it supports the biological community.

Benthic - of, relating to, or occurring at the bottom of a body of water or the depths of the ocean.

Best Management Practices (BMPs) - management or structural practices designed to reduce the quantities of pollutants--such as sediment, fertilizers, animal wastes etc.--that enter nearby streams, lakes, wetlands and groundwater.

Bias - a preference or inclination, especially one that creates an unfair judgment.

Biochemical Oxygen Demand (BOD) - a measure of the amount of oxygen necessary to decompose organic materials in a volume of water. As the amount of organic waste in water increases, more oxygen is used, resulting in a high BOD.

Biological Indices - there are three indices that the Pennsylvania EPA uses to assess the health of the biological community and deter mine aquatic life use designations.

Bituminous - a middle ranking coal formed by pressure and heat on lignite. This coal usually has a high BTU value and may be referred to as soft coal. It is the most common coal in the United States and is used to generate electricity and to make coke for the steel industry.

Boney piles - Abandoned piles of a mixture of coal, rock and clay that turns streams and creeks a shade of yellowish-orange.

BTU - British Thermal Unit. A measure of the energy required to raise the temperature of one pound of water one degree Fahrenheit.

Bubbler - an artesian flow of groundwater.

Calcium Carbonate - a compound found in nature as chalk or calcite, aragonite or limestone.

Calcite - a common crystalline form of natural calcium carbonate ($CaCO_3$) that is the basic constituent of limestone, marble, and chalk.

Calibration - the act of checking or adjusting (by comparison with a standard) the accuracy of a measuring instrument.

Canal - an artificial waterway for navigation or for draining or irrigating land.

Canopy Cover - an area covered by the crown of an individual plant species.

Cattail Reeds - an erect herb with sword-shaped leaves.

Channel Condition - the path water flows and its condition.

Channelization - an engineering technique to straighten, widen, deepen or otherwise modify a natural stream channel.

Clean Water Act (CWA) - adopted in 1972, it evolved from the 1948 Water Pollution Control Act (WPCA) and established the national goal to "restore and maintain the chemical, physical and biological integrity of the nation's surface waters."

Citizenship - belonging to the country in which a person is born

Coal - a burnable carbonaceous rock that contains large amounts of carbon. Coal is a fossil fuel-a substance that contains the remains of plants and animals and that can be burned to release energy.

Coal Mining - extracting coal from its natural deposits in the earth by any method, and the work of preparing coal so extracted for use.

Co-generation - the production of both electricity and process heat (steam) in an industrial plant.

Coke - a hard, dry carbon substance produced by heating coal to a very high temperature in the absence of air.

Collectors - macroinvertebrates that collect and eat small organic material (<1mm).

Colligative Properties - the property of a solution to have a greater boiling point and a lower freezing point than a pure substance.

Company Towns - a town or city in which all or almost all real estate, buildings (both residential and commercial), utilities, hospitals, small businesses such as grocery stores and gas stations, and other necessities or luxuries of life within its borders are owned by a single company.

Conserve - to use resources carefully, wisely and sparingly, avoiding waste.

Contaminated Coal Mine Drainage - mine runoff or discharge water containing abnormal acid or alkalinity levels, elevated sulfate and metal concentrations, and silt or other suspended solids.

Crude - a substance in its natural unprocessed state.

Debate - to engage in argument by discussing opposing points of a topic.

Deep Mine - a type of mine created to access coal buried deep underground, characterized by a set of shafts dug straight down in the ground.

Deforestation - the action or process of clearing of forests; the state of having been cleared of forests.

Delineation - a graphic or vivid verbal description.

Density - the quantity per unit volume, unit area, or unit length: as the mass of a substance per unit volume; as the distribution of a quantity (as mass, electricity, or energy) per unit usually of space (as length, area, or volume); as the average number of individuals or units per space unit.

Diamonte Poem - A poem that has seven lines and sixteen words beginning with one word of a pair of opposites.

Disassociation - decomposition of a crystal into hydrated ions, eg. $NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$.

Discharge - the quantity of water flowing past a particular point on a stream, usually measured in cubic feet per second (cfs).

Dissolved Metals - the total mass of dissolved mineral constituents or chemical compounds in water. They form residue that remains after evaporation and drying.

Dissolved Oxygen - the amount of oxygen that is dissolved in a solution. Dissolved Oxygen (D.O.) can cause armoring on limestone by oxidizing iron compounds in AMD to form iron hydroxide. D.O. is usually measured in parts per million (milligrams per liter).

Dissolves - to cause to disperse or disappear; to separate into component parts; to bring to an end; to cause to pass into solution; to become dissipated or decomposed; a become fluid.

Diversion Wells - a simple passive treatment technology, which diverts water by a pipe to a downstream well, which contains limestone. The force of the water into the well results in turbulence, allowing the water and limestone to mix and react.

Drainage Basin - area that contributes surface water to a particular stream system.

DRASTIC - a standardized system for evaluating ground water pollution potential using hydrologic settings. It was developed by the EPA and involves the mapping of relative ratings of pollution potential.

Economics - the branch of social science that deals with the production and distribution and consumption of goods and services and their management.

Ecosystem - the complex of a community of organisms and its environment functioning as an ecological unit.

Effluent - any material that flows outward from something; examples include wastewater from treatment plants and water discharged into streams from abandoned coalmines.

Electricity - electric current used or regarded as a sources of power, caused by the attraction of particles with opposite charges and the repulsion of particles with the same charge.

Electroshock - to administer a strong electric current.

Embeddedness - the degree to which dirt is mixed in with spawning gravel.

Environmental Protection Agency (EPA) - created in 1970 by President Richard Nixon, this agency of the U.S. government sets and enforces national pollution-control standards.

Excavation - the act or process of removing soil and/or rock materials from one location and transporting them to another. It includes digging, blasting, breaking, loading, and hauling, either at the surface or underground.

Exceptional Warmwater Habitat (EWH) - the most biologically productive environment. These waters support “unusual and exceptional” assemblages of highly diverse species of aquatic organisms, particularly those that are highly intolerant and/or rare, threatened, endangered or special status.

Facultative - somewhat sensitive to pollution and require good water quality.

Ferric Hydroxide - an iron compound that forms when dissolved iron in AMD is oxidized, and appears as a rusty, reddish-orange residue. It is often called yellow-boy.

Flocculate - metal precipitates that build up in streams as sediment.

Floodplain - flat area adjacent to a stream in a river valley.

Flow - quantity of water passing through a specific cross section of a body of water during a specified time.

Fossil Fuels - any naturally occurring fuel of an organic nature, such as coal, crude oil and natural gas.

Gauging Station - location at a stream channel where discharge of water is measured.

Geologist - a scientist that studies geology or the science that studies the origin, history, and structure of the earth.

GIS - Geographic Information System

GPM - Gallons per minute

GPS - Geographic Positioning System

Graphing - to represent by a graph; to plot on a graph.

Grazer - animal that feeds on algae, fungi, or bacteria that is attached to rocks and other surfaces; see also Scraper.

GW - Ground water: water found beneath the surface of the earth within the zone of saturation.

Habitat - the area or environment where an organism or ecological community normally lives or occurs.

Hunters & Gatherers - a society in which the predominant method of subsistence involves the direct procurement of edible plants and animals from the wild.

Hydrogeology - The branch of geology that deals with the occurrence, distribution, and effect of ground water.

Hydrology - the study of surface and subsurface water.

Hydrophytic - growing wholly or partially in water. Cattails are hydrophytic plants.

Index of Biological Integrity - a measure of fish species diversity and species populations.

Industrial Revolution - a rapid major change in an economy (as in England in the late 18th century) marked by the general introduction of power-driven machinery or by an important change in the prevailing types and methods of use of such machines.

Insoluble - not soluble; incapable or difficult of being dissolved, as by a liquid.

Invention - a device, contrivance, or process originated after study and experiment.

Invertebrate Community Index - based on measurements of the macroinvertebrate communities living in a stream or river.

Iron - a common metal element contained in mine rocks in the form of iron sulfide that oxidizes as a red dish, rusty colored hydroxide solid.

Iron Hydroxide - an insoluble compound.

Iron Oxide - a common compound of iron and oxygen, also known as rust.

John L. Lewis - a lobbyist for the United Mine Workers (UMW), organizer for the American Federation of Labor (AFL), and vice president of the UMW

Labor Relations - a discussion of work stoppages, strikes, and negotiations for salaries and benefit packages.

Leach - migration of atoms or compounds from mine rocks or other substances through the action of water, acid or other solvent.

Leaching - process of dissolving, washing or draining earth materials by percolation of groundwater or other liquids.

Lignite - A type of coal with the lowest carbon content, it is called “brown coal” and is used mainly for electric power generation.

Limestone - a sedimentary rock consisting mostly of calcium carbonate. It can be formed through either organic or inorganic processes. Limestone effervesces freely with any common acid.

Limited Resource Water (LRW) - applies to streams when a scientific assessment concludes they cannot support any degree of aquatic life diversity because of irretrievable factors such as acidic conditions from abandoned mine land or large-scale habitat alteration. These designations must be reviewed every three years.

Limited Warmwater Habitat (LWH) - adopted in 1978 as a temporary variance mechanism for individual stream segments with point-source problems that could not meet the goals of the Clean Water Act. It is now being phased out.

Macroinvertebrate - refers to crustaceans, insects and worms lacking a spinal column that assemble in semi-permanent populations. Study of the presence of various macroinvertebrates provides a good environmental indicator of stream health because many species are known to be either pollution tolerant or intolerant.

Manganese - a metal element found in AMD that oxidizes as a blackish stain.

Metal - elements that are solids (except mercury), have few electrons in the outermost shell, and lose electrons easily to form cations. Metals of concern in AMD include iron, aluminum, manganese, and sometimes lead, mercury, copper, and zinc.

Miscible - when any amount of solute can be dissolved in solvent.

Mitigation - the process of finding solutions to reduce the severity of flood damage.

Modified Index of Well-Being - based upon the index of well-being, which is a calculation of fish mass and density.

Modified Warmwater Habitat (MWH) - applies to streams with extensive and irretrievable physical habitat modifications that fail to attain criteria for WWH, EWH or other beneficial uses.

Molality (m) - # of moles of Solute per kg of solvent.

Molybdenum- a metallic element that resembles chromium and tungsten in many properties, is used especially in strengthening and hardening steel, and is a trace element in plant and animal metabolism.

National Pollutant Discharge Elimination System (NPDES) - created in 1972 under a WPCA Amendment, it prohibits the discharge of any pollutant without a permit.

Neutral - a condition where the concentration of hydrogen ions equals the concentration of hydroxide ions, resulting in a solution that is neither acidic nor basic (alkaline) and has a pH value of 7.0 standard units. Distilled water is a neutral liquid.

Neutralize - to cause a solution to move toward a pH reading of 7.0 standard units through chemical or biological processes.

Nonpoint Source Pollution - water pollution that results from a variety of human land uses, such as agriculture, surface mines, forestry activities, home wastewater systems and construction sites, among others. These pollution sources cannot be controlled at a single location and can only be curbed by implementing land management practices at multiple levels.

Noun - the part of speech that is used to name a person, place, thing, quality, or action and can function as the subject or object of a verb, the object of a preposition, or an appositive.

NPS - Non point Sources

NTU - National Turbidity Units

Nutrient Enrichment - a condition that results when a water body receives more nutrients than the organisms within it need for normal life, growth and reproduction.

Office of Surface Mining - the federal agency charged with enforcing SMCRA and dealing with health, safety and resource protection issues related to active mining and abandoned mine problems.

Open Limestone Channel - a simple passive treatment method in which a drainage ditch is constructed of limestone and AMD contaminated water is collected by the ditch, or limestone is placed directly into a contaminated stream.

Operculum - a body process or part that suggests a lid: as a horny or shelly plate on the posterior dorsal surface of the foot in many gastropod mollusks that closes the shell when the animal is retracted; as the covering of the gills of a fish; a lid or covering flap (as of a moss capsule or a pyxidium in a seed plant).

Overburden - layers of soil and rock covering a coal bed. It is removed prior to surface mining and replaced following coal removal.

Oxic - a condition where atmospheric, gaseous oxygen is present.

Oxidation - a reaction in which a substance loses electrons. In the case of AMD metals oxidation, the oxidizing agent is gaseous oxygen. Metal oxides are formed in the process.

Oxygen - an element constituting 21 percent of the atmosphere by volume that occurs as a diatomic gas, O_2, combines with most elements, is essential for plant and animal respiration, and is required for nearly all combustion.

Parasites - animals that get their food by taking advantage of other animals.

Passive Treatment - designed to remove contaminants without actively pumping chemicals into the system. Examples: wetlands, open limestone channels, anoxic limestone drain.

Participles - a word having the characteristics of both verb and adjective; an English verbal form that has the function of an adjective and at the same time shows such verbal features as tense and voice and capacity to take an object.

Particle - a minute quantity or fragment; a relatively small or the smallest discrete portion or amount of something; any of the basic units of matter and energy (as a molecule, atom, proton, electron, or photon).

Peat - Partially carbonized organic material, usually found in bogs.

Percentage - a fraction or ratio with 100 understood as the denominator.

Permeability - a measure of the rate of water movement through soil or other substance.

Pesticides - an agent used to destroy pests.

pH - potential of Hydrogen: a value expressed in standard units on a scale of 0-14 that expresses the concentrations of hydrogen ions. pH readings below 7 are considered acidic, while pH readings above 7 are said to be basic, or alkaline. Many species are tolerant of lower pH values (more acidic waters), but many are not. Being closer to the neutral point of pH 7 indicates healthier streams.

Plume - point in a stream where mine drainage enters and orange mine drainage is visible separate from the rest of the stream.

Pollution Sensitive - responsive to an undesirable state of the natural environment being contaminated with harmful substances as a consequence of human activities.

Pollution Tolerant - unresponsive to an undesirable state of the natural environment being contaminated with harmful substances as a consequence of human activities.

Porosity - the ratio of the volume of voids (openings) to the total volume of material. Used to describe the ability of a fluid to move through crushed rocks or other material.

PPM - Parts per million

Precipitate - an insoluble, solid product that is formed when ions combine with atoms or molecules in the air or with other atoms or compounds in a solution. Also, the process of dissolved compounds becoming solidified.

Precipitation - the process of separating mineral constituents from a solution.

Predators - mobile animals that kill and eat their prey.

Predicate - one of the two main parts of a sentence or clause, modifying the subject and including the verb, objects, or phrases governed by the verb.

Preserve - to keep in perfect or unaltered condition, maintain unchanged.

Primary Contact - suitable for full body contact recreation (e.g. swimming or canoeing). To qualify as a primary contact recreation use, a stream must have at least one pool of 100 square feet greater than a depth of three feet.

Pyrite - the iron-sulfide mineral, often called "fools gold," that is found in earthen and rock layers near coal seams. Pyrite is the usual source of the sulfur that binds with hydrogen and oxygen in rainwater to form the sulfuric acid component of AMD.

Reach - a section of river or stream.

Reaction - in chemistry, a change or transformation in which a substance decomposes, combines with other substances, or interchanges constituents with other substances.

Reclamation - the process of protecting, restoring, and possibly even improving the land before, during, and after surface mining. As coal is removed from one section of a surface mine, the land at another part is returned, regraded, and replanted.

Recreational Use Categories - Bathing Waters - swimming areas with lifeguards, bathhouses and regular water testing.

Recycle - to pass again through a series of changes or treatments: to process (as liquid body waste, glass, or cans) in order to regain material for human use; to adapt to a new use.

Reduction - a reaction in which a substance gains electrons. In AMD treatment, reduction usually involves the stripping away of oxygen atoms from sulfate or metal compounds.

Remediation - cleanup or other methods used to remove or contain a toxic spill or hazardous materials from a superfund site or any other site.

Residence time - the length of time that AMD remains in a treatment pond, wetland, ditch or other structure. Designed residence times depend on the incoming flow rate, the rate of treatment process in the structure, the contaminants in the AMD to be treated, the size of the structure, and the settling rate of solids in the discharge.

Riparian area - the area in and directly adjacent to a stream.

Scraper - animal that feeds on algae, fungi, or bacteria that is attached to rocks and other surfaces; see also Grazer.

SDWA - Safe Drinking Water Act

Sea Coal - coal that is gathered on the seashore.

Secondary Contact - suitable for partial body contact recreation (e.g. wading). There are two criteria used to evaluate recreational use attainment: fecal coliform bacteria and E. coli. A stream segment must meet at least one of these criteria to be in attainment of its use designation.

Sedimentation - the process whereby particles (suspended solids) settle out of solution. Sedimentation produces a sludge or other layers of solids at the bottom of a sedimentation, or settling pond.

Sensitive - very sensitive to pollution and require very good quality water.

Settling pond or basin - a large tank or pond designed to hold water or AMD for a long enough time to allow most of the suspended solids to settle out.

SF - Superfund

Shredders - macroinvertebrate that eats large organic material (>1mm) like leaves, pine needles, or other plant parts.

Sinkhole - a circular depression occurring in an area of land formed on limestone, gypsum or other rocks by dissolution. It drains beneath the surface of the earth, its size is measured in meters or tens of meters and it is commonly funnel shaped.

Sludge - the layer of solids that settle from a solution, including suspended silt and soil particles and precipitates formed by chemical processes.

Slurry - A mixture of water and any finely crushed solid, especially cement, clay or coal.

Solubility - the amount of material that can dissolve in a given amount of water or other solvent at a given temperature to produce a stable solution. Highly soluble substances dissolve quickly. Soluble products will not settle out of a solution unless they are precipitated.

Solute - substance that is becomes homogeneously mixed in another substance.

Solution - any substance (solid, liquid, or gas) that is evenly dispersed or distributed throughout another substance (solid, liquid, or gas); homogenous mixture.

Solvent - medium in which another substance is dissolved.

Source Water Assessment and Protection Program (SWAP) - the 1996 amendments of the Safe Water Drinking Act require all states to complete a source water assessment for every public water system by 2003. The SWAP program identifies drinking water protection areas and provides information on how to reduce the potential for contaminating the waters within those areas.

Spoils Pile - excavated dirt or soil

State Resource Waters - waters within park systems, scenic rivers, wetlands and other ecologically significant areas. The amount of pollutant loadings allowed in these waters is very limited.

Storm Sewer - an area where stormwater runs off into.

Stream - a natural body of continuously running water flowing on or under the Earth.

Strip Mining - practice of mining a seam of mineral ore by first removing all of the soil and rock that lies on top of it (the overburden)

Sub-bituminous - a glossy-black, non-agglomerating coal lower than bituminous coal in fixed carbon and with more volatile matter and oxygen.

Subsidence - the settling of waste piles or other areas at mine sites that causes the surface of the land to sink.

Substrate - the rich, organic layer of compost or other material found at the bottom of wetlands.

Subject - the noun, noun phrase, or pronoun in a sentence or clause that denotes the doer of the action or what is described by the predicate.

Successive alkalinity producing systems (SAPS) - specialized AMD treatment ponds that make use of chemical and biological process to treat the acid, metals and sulfates of AMD.

Sulfates - compounds containing sulfur and oxygen as SO_4. Elevated sulfate levels are common in contaminated mine drainage. Sulfates can bond with hydrogen ions to form sulfuric acid, or bind to calcium atoms to form gypsum solid.

Sulfur - a nonmetallic element that occurs either free or combined especially in sulfides and sulfates, is a constituent of proteins, exists in several allotrophic forms including yellow orthorhombic crystals, resembles oxygen chemically but is less active and more acidic, and is used especially in the chemical and paper industries, in rubber vulcanization, and in medicine for treating skin diseases.

Surface Mining - a mine in which coal lies near the surface and can be extracted by removing the covering layers of rock and soil.

Surface Mining Control Act of 1977 (SMCRA) - the federal law that requires mining operations to prevent water pollution, reclaim mine lands and protect other resources.

SW - Surface Water: waters on the surface of the earth.

Survey - a detailed inspection involving the gathering of sample data considered being representative of the whole.

Suspended Load - sediment in a stream or river channel carried off by the bottom fluid.

Suspension - the state of a substance when its particles are mixed with but undissolved in a fluid or solid.

SWM - Storm Water Management

Tallow - the white nearly tasteless solid rendered fat of cattle and sheep used chiefly in soap, candles, and lubricants.

Tolerant - not very sensitive and do not usually require a lot of dissolved oxygen.

Topographical map - a map that shows land elevations by use of lines that connect points of equal elevation (contour lines), water bodies, streams, buildings mine sites, roads and other land features.

Total Maximum Daily Loads (TMDL) - a TMDL specifies the maximum amount of a pollutant that a water body can receive and still meet water quality standards and allocates pollutant loadings among point and nonpoint pollutant sources. Under section 303(d) of the 1972 Clean Water Act, states, territories and authorized tribes are required to develop lists of impaired waters. These impaired waters do not meet water quality standards that states, territories and authorized tribes have set for them, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings for waters on the lists and develop TMDLs for these waters.

Tributary - a stream that flows into a larger stream or other body of water.

Turbid - having sediment or foreign particles stirred up or suspended; muddy.

Unions - an act or instance of uniting or joining two or more things into one; something formed by a combining or coalition of parts or members.

Verb - the part of speech that expresses existence, action, or occurrence in most languages.

Viscosity - the property of resistance to flow in a fluid or semifluid.

Warmwater Habitat (WWH) - designates the "typical" warm water assemblage of aquatic organisms for Pennsylvania rivers and streams. It is the principal restoration target for the majority of water resource management efforts in Pennsylvania.

Water Basin - (see watershed) the region of land whose water flows into a specified body of water, such as a river, land, sea, or ocean.

Water Cycle - the transition and movement of water involving evaporation, transpiration, condensation, precipitation, percolation, runoff, and storage.

Water Quality Indicator - a microbial, chemical, or physical parameter that indicates the potential risk for infectious diseases associated with using the water for drinking, bathing, or recreational purposes.

Water Supply Use Categories - (see below)

Public - Meets drinking water standards with conventional treatment.

Agricultural - Suitable for irrigation and livestock watering without treatment.

Industrial - Suitable for industrial and commercial use with or without treatment.

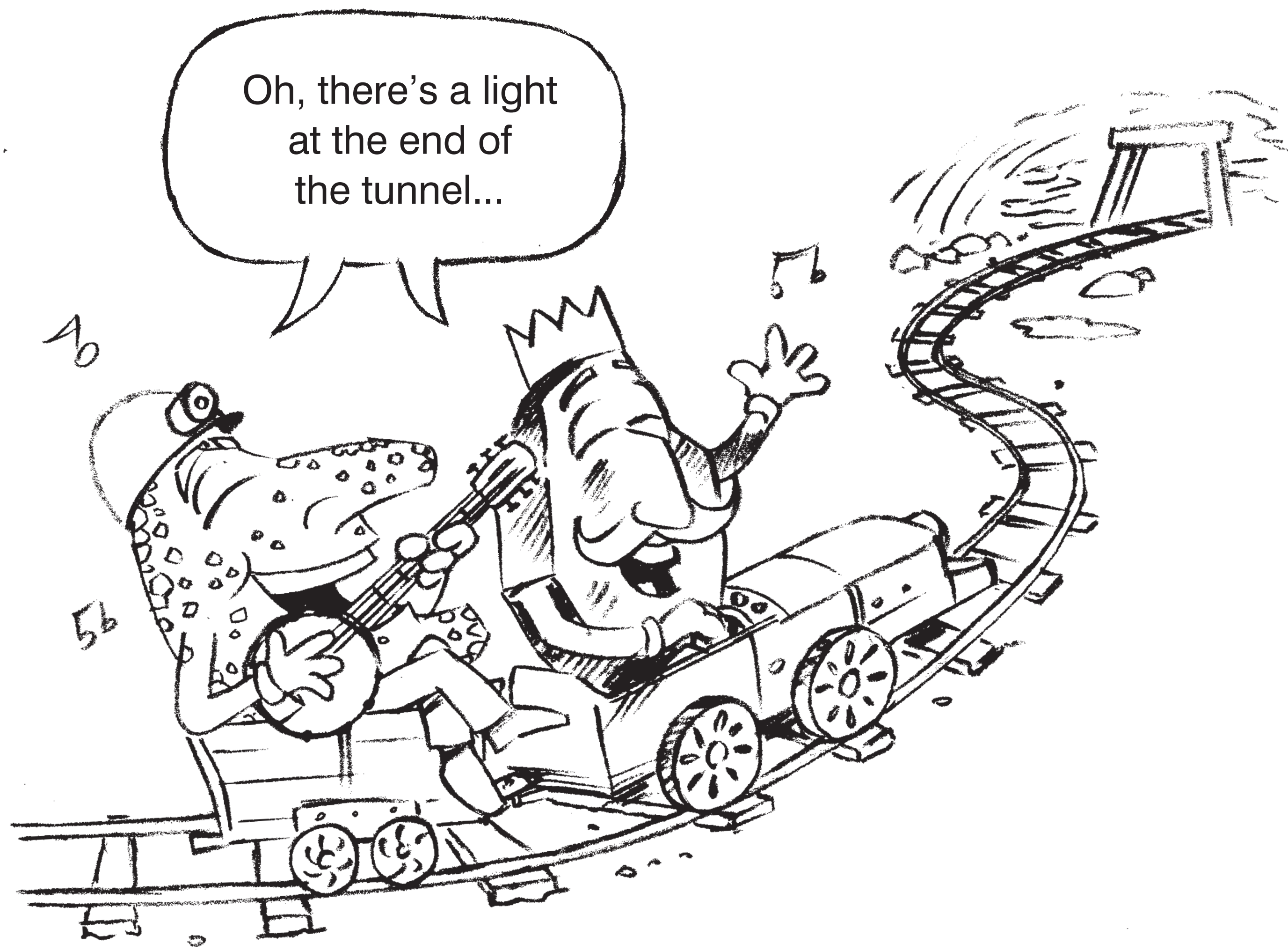
Watershed - an area of land from which water drains toward a single channel (stream).

Watershed Assessment - a tool utilized by watershed groups and communities. By taking a detailed look at watersheds, we can define conditions degrading watersheds and formulate a restoration plan based on priorities. Interests, water quality information, and remediation options determine those priorities.

Wetlands - land permanently or periodically inundated with water sufficient to establish hydrophytic vegetation and anaerobic soil conditions.

Yellow Boy - an orange/red residue and staining that is iron in its solid form.

Resources



Resources

Books

1. (America at work) Mining
   Drake, Jane and Ann Love.
   Kids Can Press 1999
   ISBN # 1-55074-508-5
   Grade Level 2-5
   Summary: Describes the mining of molybdenum ore, how it is crushed, purified and added to the steel making process. Story, conversational, labeled pictures.

2. Accepting The Challenge
   Taylor, Dunn, Busler.
   Slippery Rock Watershed Coalition
   Subject areas: History of Coal Mining, AMD Formation/ Identification Ecological effects of AMD, Economic and social effects of AMD
   Summary: Well written, easily understood by layman, some errors in facts.

3. Watershed- A Successful Voyage into Integrative Learning
   Springer, Mark.
   National Middle School Association, 1994.
   ISBN # 1-56090-088-1
   Grade Level 6-8
   AMD Formation/Identification, Ecological effects of AMD, Economic and Social effects of AMD
   Summary: Story of one school's watershed curriculum- study watershed structure and function- interdisciplinary approach.

4. Watersheds: A Practical Handbook for Healthy Water
   Dobson, Clive & Beck, Grego Gilpin
   Firefly Books, 1999
   ISBN # 1-55209-330-1
   AMD Formation/ID, Ecological effects of AMD, Economic and social effect of AMD
   Summary: Biological indicators of water quality. Good general watershed info- including pollution, sources and environmental effects.

5. Field Manual for Global Low-Cost: Water Quality Monitoring
   Stapp, William B. & Mitchell, Mark K. Kendall/ Hunt Publishing Company
   ISBN # 0-7872-3601-2
   Grade level 7-12, adult
   Ecological Effects of AMD
   Summary: Benthic Macroinvertebrates, Understanding River Ecosystems and Habitats
   Book/Lesson plan Activity

6. Rivers and Streams
   Martin, Patricia A. Fink
   Grolier 1999
   ISBN # 0-531-15969-8
   Economic and Social effects of AMD
   Summary: good general watershed info. Also, good investigations/ experiments for students.

7. Tales of the Mine Country
   McKeever, Eric.
   Eric McKeever 1995
   ISBN # 0-9643905-0-7
   History of Coal Mining, Economic and Social Effects of AMD
   Summary: A collection of memories of a small coal mining town in the anthracite region. Includes stories of: Molly Maguires, purpose of rats, fireboss, canals, lights, misc. stories. Very informative of jobs and life in a mining town, although a lot of the "facts" have not been verified and is stated as so.

8. Clairton Works-Where Good Things Come from Coal
   Book/pamphlet brochure
   History of Coal Mining
   Summary: Follows the path of coal from arrival through the coking process. Chemical recovery.

9. The Practice of Watershed Protection
   Thomas R. Schueler and Heather K. Holland
   Center for Watershed Protection, www.cwp.org

Booklet/Pamphlet & Brochures

1. You Can't Judge a Stream by its Color
   Skousen, Mains, Hamilton
   West Virginia University Extension Service
   Booklet

2. Stream Team Hands-On Education
   AMD Formation/ID Ecological Effects of AMD
   Summary: Water pollution information including major pollutants and sources.
   Pamphlet/brochure

3. Old Time Mining
   Eileen Mountjoy Cooper
   IUP, July 26, 2000
   History of Coal Mining
   Summary: Tells of the history found in the R & P Coal Company's books in Indiana, PA. Describes Room and Pillar, the different jobs in the mine and eventually machines.

Manuals

1. Save Our Streams
   Firehock, Karen
   Save Our Streams Program, 1995
   Grades 1-12
   AMD Formation/ID Ecological effects of AMD
   Summary: Mining and watershed connections

2. S.W.I.M.M Integrated Curriculum for Middle Schools
   Chesapeake Bay Foundation & PA State Department of Education
   1997
   Grade 6-10
   AMD Formation/ID Ecological effects of AMD
   Summary: Good experiments with teacher's notes concerning watersheds, mines, and water testing/ reporting actions to take to repairing environmental damage

3. SVC EEC Teacher Manual
   SVC EEC
   Grade level: teachers
   AMD Formation/ID Ecological effects of AMD, Passive Treatment
   Summary: Wetland Activities/ Lessons, SVC Elementary AMD-Wetland Preactivity Lessons, AMD Formation, treatment background

4. Wetland Tourguide Manual
   SVC EEC
   College Level/Adult
   AMD Formation/Identification Ecological effects of AMD, Treatment of AMD
   Summary: Passive wetland treatment, AMD background, Wetland and Mine Drainage lessons/activities

5. Understanding Watershed Behavior
   Schueler, Tom and Chris Swann
   www.cwp.org, October 3, 2000
   Geology, Ecological effects of AMD
   Summary: Provides a general description of a watershed, basic geology of PA, the studies of watersheds and improvements, and the future of watersheds.

6. Macroinvertebrate Manual
   Stroud Water Research Center
   Ecological Effects of AMD
   Summary: Diminished aquatic life

Lesson Plan/Activities

1. Environmental Science Activities Kit
   Roa, Michael.
   The Center for Applied Research in Education, 1993.
   ISBN # 0-87628-304-0
   Elementary
   History of Coal Mining, Geology
   Summary: Activity 1 Surface Mining: Shows impact of surface mining, uses models in hands on activities, very controlled/ everyone has a job and each round is timed. Activity 22 Fossil Fuel Extraction Cookie Mining

2. Environmental Chemistry
   Newton, David E.
   J Weston Walch, 1991.
   ISBN# 0-8251-1914-6
   Grade level 10-12
   History of Coal Mining
   Activity 2.3 Mining Fossil Fuels-Environmental Risk of Removing Fossil Fuels
   Activity 2.4 Coal Production and Consumption-Composition, combustion, fly ash.

3. The Dead River Game
   E. Nelson Swinerton
   Educational Games Union Printing Co.
   High school level
   Economic and social effects of AMD, Laws and Regulations case studies
   Summary: The Dead River simulation examines the social and economic effects of man. The participants participate in decision-making situations to improve water quality, but also keep taxes low and keep the environment natural. Can be adapted to individual situations.

4. Environmental Management: Clean Water Research as Related to Acid AMD
   Todd Mills, Lois Morris, Terry Rostcheck, Susan Tegi, George Watzlaf
   Internet
   AMD, Laws and Regulations
   Summary: This gives a nice background of AMD treatments, active and passive. Cooperative activity for students to research AMD and solutions and share their findings. Basic activites would need expanded to involved AMD in the experiment.

5. Coal Related Activities for Elementary Students
   American Coal Foundation
   Elementary
   Summary: Coal formation, types of coal, field trip ideas, cookie mining, electricity, geology/supply and demand, rewriting lyrics for using on forms of energy, coal products, coal bingo, coal time line. Variety of activities to incorporate into lessons although some are not stand alone and teachers may need more background information.

6. Coal Related Activities for Secondary Students
   American Coal Foundation
   Secondary
   History of coal mining, geology
   Summary: Formation of coal, when coal was formed, coal identification, ranks of coal, coal flowers, living history, publishing local coal mining history, mining in a nutshell, the geologist's dilemma.
   Good resource to cover coal and mining as well as history of mining families.

7. Toxic Mine Drainage Chemistry and Treatment
   Horan, Jim.
   Internet
   High school/college
   AMD
   Summary: Excellent activity to examine AMD and treatments on a small scale. The acid producing potential is good and is very similar to that used by DEP to approve current mining permits.
   Teacher note and stock room notes included. Excellent.

8. Hands on Experiments to Test for Acid Mine Drainage
   USGS
   Version 1
   Elementary
   AMD, Formation/Identification, Ecological Effects of AMD
   Summary: Field experiments-biological and chemical. Covers: Fe, Mn, Al, ways to treat AMD, groundwater, macroinvertebrates, plants.

9. Coal Mining Times
   Primas, Pam.
   1997
   General public, children oriented
   History of Coal mining
   Summary: This lesson plan involves hands-on activities that involve mining artifacts and replicas of such. It was created to familiarize family groups (campers) with coal mining of the past.

10. Wonders of Wetlands
    Kesselheim, Alan S.
    Environmental Concern Company
    ISBN# 1-888631-00-7
    K-12
    Ecological effects of AMD,
    Wetland Treatment
    Summary: Wetland ecosystem background, functions, values

11. Project WET
    The Watercourse and the Council for Environmental Education
    2000
    Kindergarden
    Geology, AMD, Formation/Identification, Ecological effects of AMD
    Summary: Models- activities relating to movement, properties and value of water. Pg 144, 136, 116 water cycle, pg. 107 make similar AMD symptom cards for identification, pg. 262 AMD ruins, pg 333 The price to pay? Glossary- useful terms for module

12. Ecological Games- The Web of Life
    Joanne Conway-www.geocities.com
    Ecological effects of AMD
    Summary: Teaches information about food chains and the components, as well as food webs and ecological pyramid.

13. Aquatic Bug Kit
    Ecological effects of AMD
    Summary: Leaf pack activity, done outdoors.
    Collect macroinvertebrates for identification.

14. Introductory Lesson- Determination of Overall Water Quality using a Quantitative Macroinvertebrate Survey
    www.ncsu.edu
    GL 6-8
    Summary: The activities enables students to identify various types of macroinvertebrates found in water ecosystems and perform a qualitative macroinvertebrate survey to determine the overall water quality of a water ecosystem.

15. Watershed Activities: Size and Occurrence of Floods
    What is a Watershed?
    GL 3-5, 6-8
    Summary: What is a watershed: demonstrates a watershed and the connection between small and large watersheds; size and occurrence of floods: Demonstration, the occurrence of floods and shows they do not necessarily occur every 10, 50 or 100 years.

Tradebooks

1. A Dragon in the Sky- The story of the Green Garner Dragonfly
   Pringle, Lawrence
   Orchard Books, 2001
   ISBN# 0-531-30315-2
   GL 2-4
   Ecological effects of AMD
   Summary: Macroinvertebrates life cycles, dragonfly website lists, food chains, predator-prey relationships, ecosystems

2. A Drop Around the World
   Barbara Shaw McKinney
   Dawn Publications, 1998
   ISBN# 1-883220-71-8
   GL K-4
   AMD Formation/Identification
   Summary: Water cycle story; follows the life cycle of a drop of water.

3. A River Ran Wild
   Cherry, Lynne
   A Gulliver Green Book-Harcourt Brace & Company, 1992
   GL K-4
   Summary: Water quality pollution, impacts-negative to rivers.

Posters

1. Surface Coal Mining and Reclamation
   U.S. Department of Interior-OSM
   GL 3-12
   History of Coal Mining
   Summary: Mining and reclamation techniques

2. Watersheds: Where We Live
   GL 3-5, 6-8
   Ecological effects of AMD, Watersheds
   Summary: A watershed poster with general information on back, as well as two activities. Available in color for grades 3-5 and 6-8 and black and white to color for grade K-2.

Videos

1. 2000 Excellence in Surface Mining Reclamation Awards
   GL All
   AMD
   Summary: Awards from 2000, shows sites and reclamation efforts

2. A Shared Commitment: The Appalacian Clean Streams Initiative
   GL All
   AMD, Formation/Identification, Ecological Effects of AMD
   Summary: Displays various AMD Treatment systems and local streams. Explains each system and how it effectively treats AMD.

3. A Page in Time
   Office of Surface Mining
   US Films & Video Production, 1997
   GL All
   Laws and Regulations Case Studies
   Summary: Explains the time line of laws for mining and reclamation. Follows the process of acquiring a permit to reclamation and bond release. Also explains the monies used to treat abandoned mine drainage.

Webpages

1. Acids, Bases, pH, watershed basics
   www.amrclearinghouse.org
   Ecological effects of AMD
   Summary: AMD chemistry: pH, dissociation of water, acids, watershed basics

2. Interesting Facts about Food Chains
   www.arcytech.org
   Ecological effects of AMD- watersheds
   Summary: Watershed behavior

3. What is AMD?
Hedin Environmental
www.hedinenv.com

4. Invertebrates as Indicators/Fish as Indicators
www.epa.gov
Ecological effects of AMD
Summary: Briefly describes why invertebrates and fish are good biological indicators of pollution. Describes biological indicators

5. AMD Chemistry
Colorado School of Mines,
www.mines.edu
Ecological effects of AMD
Summary: The article gives some chemistry information and explains briefly why water turns yellow-orange and covers the stream bed with a slimy coating.

6. http://www.epa.gov/owow/wetlands/

7. http://www.epa.gov/OWOW/wetlands/facts.html

8. http://www.saveourstreams.org/

9. http://water.usgs.gov/education.html

10. http://www.american-aquatics.com/

11. http://www.groundwater.org/KidsCorner/kidscorner.htm

12. http://ctcnet.net/scrip/

13. http://members.tripod.com/rareearth_2/acid_mine_drainage.htm

14. http://dep.state.pa.us/dep/deputate/enved/go_with_inspector/coalmine/What_is_Acid_Mine_Drainage.htm

15. http://www.osmre.gov/

16. Environmental Dictionary http://environment.miningco.com/newsissues/environment/library/weekly/blgloss.htm

17. Cartoons
http://envrionment.miningco.com/newsissues/environment/library/weekly/blcar.htm

18. American Coal Foundation
www.teachcoal.org

19. The Windber Coal Heritage Center. 1994-2000.
http://www.progressfund.org

20. "Build a Watershed: Just add water" from
http://www_4hfishing.org