Hydrogeology and Hydrogeochemistry of a Large Mountaintop-Removal Coal Mine in Eastern Kentucky: Report of Water-Quality Data

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Figures

Figure 1.	Location of Eastern Kentucky Coal Field within the Appalachian Coal Field of the eastern United States	.8
Figure 2.	Location of sampling site within the Star Fire Mine	.8

Tables

7	Laboratory analytical methods	Table 1.
WQOpenFile.xls	Results of laboratory analysis with field records	Table 2.
SPMWlevel.xls	Water-level data for spoil monitoring wells	Table 3.
SFireRain.xls	Rainfall data from Star Fire Mine site	Table 4.
LNFK-flow.xls	Flow data from Long Fork	Table 5.
SPRG1-flow.xls	Flow data from Spring 1	<u>Table 6</u> .
LNFK-YSI.xls	Real-time water-quality data from Long Fork	Table 7.
SPRG1-YSI.xls	Real-time water-quality data from Spring 1	<u>Table 8</u> .
TPOL-YSI.xls	Real-time water-quality data from the Trout Pond outlet	<u>Table 9</u> .

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The purpose of this paper is to present raw water-quality data collected from sites within the Star Fire Mine, a mountaintop-removal mine located in the Eastern Kentucky Coal Field section of the Appalachian Plateaus Province (see Fig. 1). The mine operated on a continuous basis from 1981 through 1998, during which time approximately 1,000 acres of land was mined by blasting and dragline methods. Research by the Kentucky Geological Survey was initiated at the Star Fire site in 1989, with the goal of gaining an understanding of the processes governing groundwater occurrence, movement, and geochemical evolution within a large body of spoil. Water-quality data were used at the Star Fire site to describe the hydrochemical facies that developed in the mine spoil, confirm recharge zones and groundwater flow regimes, and document temporal and spatial water-quality changes (Kemp, 1990; Wunsch and others, 1996, 1999).

Water-quality samples were collected from surface- and groundwater sites at various intervals over a periods of 10 years, between April 1991 and November 2000. Surface-water sites include Chestnut Gap Branch (CGBR on Figure 2), and spoil discharge points at Spring 1 (SPRG1), Long Fork Spring (LFSP), Long Fork (LNFK), and the Trout Pond outlet (TPOL). The CGBR site is a point where surface water from Chestnut Gap Branch can be observed flowing into the spoil. Spring 1, Long Fork Spring, and Trout Pond outlet are the major discharge points for the three major groundwater flow systems, as described by Wunsch and others (1996, 1999), whereas discharge at Long Fork represents the total outflow of the spoil body. Groundwater samples were collected from 14 monitoring wells located within the spoil (Fig. 2). Wunsch and others (1996) described well location considerations, drilling techniques, and well construction design for the monitoring wells, as well as the relevance of the sampled surface-water sites. Monitoring wells 4, 6, and 7 were drilled into the Spring Gap hollow fill; wells 10 and 14 into the Long Fork hollow fill; and wells 5 and 8 through 13 into the Buried Interior Plateau.

Field parameters collected during sampling were pH, specific conductance, temperature, and oxidation-reduction potential (Eh), all in accordance with U.S. Geological Survey guidelines for sampling and collecting (USGS, 1980). Well purging and sample collecting were performed using a 2-in.-diameter submersible pump or by bailing those wells that could not be pumped. Water samples were analyzed in the laboratory for concentrations of 30 dissolved metals, five major ions, total dissolved solids, and alkalinity (as CaCO₃). Each sample split included aliquots of raw water, field-filtered water, and acidified field-filtered water collected for laboratory analyses.

This report also includes data collected from monitoring wells 2 and 3. These wells were constructed during the early phases of the research, and were drilled and constructed using methods that were later found to be inadequate to withstand the structural instability of the thick spoil body. Results from these samples were not used for interpretation by Wunsch and others (1996, 1999). Monitoring well 1 (Fig. 2) was used for water-level recording and as an input for dye collected at various surface-water stations at Trout Pond outlet. These data were collected to study the occurrence of unusually high amounts of aragonite precipitation from water discharging from this area of the spoil (Wirth and Wunsch, 1998).

In addition to field and laboratory water-quality analyses, this report also includes separate spreadsheet files containing water-level data from wells in the spoil, and data collected by continuous data-logging instruments. This includes daily rainfall data collected by a tipping-bucket method rain gauge installed at the mine site, flow data from Long Fork and Spring 1, and real-time water-quality data from Long Fork, Spring 1, and Trout Pond outlet.

Analytical Methods

Field Measurements

Field measurements were recorded with one of two portable water-quality instruments. If the data reported for a particular sample in <u>Table 2</u> include Eh (millivolts), then field measurements were recorded using a YSI model 3560 water-quality monitoring system with a flow-through chamber. If the reported data

include dissolved oxygen (DO, in mg/L or % saturation), then the measurements were recorded using a Horiba U-10 measurement system. If both Eh and DO are reported for a particular sampling event, then only Eh was measured with the YSI system, and the other measurements were made with the Horiba system.

Measurements were made in monitoring-well water after purging three well volumes. At surfacewater sites, measurements were recorded when instrument readings had stabilized. Electrical conductivity measurements recorded with the YSI system were corrected to 25°C and reported as specific conductance (μ S/cm). The Horiba system has automatic temperature correction and reports specific conductance.

All field instruments were calibrated on a daily basis during sampling using calibration procedures as prescribed by the manufacturers. Other field instruments (Orion pH meters, Cole-Parmer and Hanna conductivity meters) were taken into the field as backup instruments, and periodically used to confirm measurements recorded by the primary instruments.

Laboratory Analysis

All laboratory analyses were performed at the KGS water-quality labs in accordance with EPAapproved analytical methods. Sample splits were prepared in the field and transported to the lab in properly sterilized bottles. For dissolved-constituent analysis, filtration was performed in the field using either highcapacity inline filters (45 μ m pore size) or flow-through filter stands with disposable 45 μ m filter discs. If sample preservation was required by analysis protocol, the samples were acidified at the time of collection, and kept at a temperature of 4°C until delivered to KGS labs.

Table 1 shows the laboratory analyses performed, and the methods used for analysis. As research needs changed during the project, the list of analytes changed also. Therefore, not all analytes listed in Table 1 will appear in the water-quality data tables.

Data Format

<u>Table 2</u> shows analytical and field results from samples collected at the Star Fire site. The first column identifies the sample using sequentially assigned sample numbers. The alphabetic values identify the sample site, followed by the two-digit sample number (e.g., CGB02 = Chestnut Gap Branch, sample 2). The letters "MW" identify the site as a groundwater monitoring well, followed immediately by the monitoring well's number and the two-digit sampling number (e.g., MW401 = monitoring well 4, sample 1; MW1007 = monitoring well 10, sample 7).

The next five columns describe the physical setting and location of each sampling site. The universal transverse Mercator zone 17 coordinates of each site are listed under "UTM N" (meters northing) and "UTM E" (meters easting), followed by the site elevation in feet above mean sea level. The next physical descriptor is the site type, followed by the 7.5-minute quadrangle in which the site is located. The next two columns are the sampling date and time. Since sampling intervals were not consistent throughout the duration of the research, particular notice should be given to sampling dates.

The physical descriptors are followed by five columns that contain results from field-measured parameters, temperature (°C), pH (standard units), specific conductance (μ S/cm), Eh (millivolts), and dissolved oxygen (mg/L). For the remainder of the laboratory analyses, all results are reported in parts per million (or mg/L). The reported metals values are for dissolved metals only. The results listed for bicarbonate are calculated based on alkalinity and pH. A less than (<) sign indicates that the results are below the method detection limit (MDL), which is indicated by the preceding value.

The data presented here have been checked for quality, and suspect laboratory results were reanalyzed to verify reported values. Some problems with field instruments were occasionally encountered, and, if identified, those measurements were not included. Corrections for field conditions were made for Eh measurements and to correct electrical conductance measurements to specific conductance when automatic temperature compensation was unavailable. Otherwise, no changes to raw data have been made.

Water-Level Data

For the duration of the project, water levels in the spoil monitoring wells were periodically recorded using electronic water-level measuring tapes. Water-level records for some of the wells may be incomplete because of well collapse or burial by advancing surface mining. The data are found in <u>Table 3</u> (file: SPMWlevel.xls). The data table includes the elevation of each well at the surface, the data of water-level measurement (mm/dd/yy), the elevation of the water level at time of measurement (feet above sea level), and any field notes about the well condition.

Rain Data

Rainfall data were collected on site from 1/10/91 through 9/30/98. From 1/10/91 to 11/15/95, data were collected by a tipping-bucket rain gauge connected to a Telog pulse-recording data logger. During this period, the data logger did not record data unless a pulse from the tipping-bucket was sent to the recorder. Therefore, only those days in which rainfall occurred have records in the data set. From 2/02/96 through 9/30/98, data were logged using a device that recorded the number of buckets tipped during a user-specified period. Therefore, after 02/02/96, each day has recorded rainfall data, even if the rainfall amount is zero. Each tipped bucket represents 0.01 in. of rain.

Rainfall data are found in <u>Table 4</u>. The rain data files contain four columns of data. The first column is the date of rain measurement in mm/dd/yy format, followed by the date in Julian time. The third column is the amount of daily rainfall in inches. The last column designates the type of rainfall recorder, either pulse counter or pulse averages. Original electronic data files from field recorders along with associated field notes are archived by the Kentucky Geological Survey, and may be accessed upon request.

Real-Time Flow Data

Continuous discharge data were recorded at Long Fork from 9/18/86 through 4/21/01 using an ISCO 4150 flow logger. This device was initially installed into a 3-ft-diameter culvert that collected the discharge, and later into a downstream trapezoidal wier. Velocity and level data and accompanying computer software used those measurements to calculate flow. Flow was calculated at 30-min intervals, but has been condensed in this report to cumulative daily discharge and average daily discharge. Flow data for Long Fork can be found in <u>Table 5</u>.

Flow data from Spring 1 were collected from 2/26/97 through 3/18/99. Discharge was measured at this site using a trapezoidal flume installed a few feet below the spring discharge point. Average water level in the flume was recorded every 30 minutes, and discharge was calculated using an equation governed by flume geometry. Flow data at this site have also been condensed to cumulative daily discharge and average daily discharge. Flow data for Spring 1 can be found in <u>Table 6</u>.

Each flow data file contains four columns. The first column is the data of flow measurements in mm/dd/yy format, followed by the date in Julian time. The third column contains the cumulative daily discharge in gallons, and the fourth column contains the daily average flow rate in gallons per minute.

Real-Time Water-Quality Data

During different times within the study period, continuous water-quality measurements were collected at Long Fork, Spring 1, and Trout Pond outlet. At each of these sites a YSI-6000 unit was employed to measure pH, temperature, specific conductance, dissolved oxygen, and turbidity. The continuous measurements were averaged over a 30-min period and recorded by the unit's self-contained data loggers. Calibration of the instruments was performed monthly, with occasional periods of down time during cleaning. Two of the YSI units were employed to allow overlapping dates between the three sites.

Data at the Long Fork site were collected from 11/27/96 through 2/05/98, and again from 10/15/98 through 9/20/00. Spring 1 water-quality data were collected from 11/24/96 through 7/09/98. Data at Trout Pond outlet (station 1) were collected from 4/07/98 through 9/14/00. These data files also include comments regarding removal and redeployment of the instruments and notes on condition of the

instruments. The data files from the YSI water-quality loggers are rather large files, and are found in the following tables:

Table 7 (Long Fork data)

Table 8 (Spring 1 data)

Table 9 (Trout Pond outlet data)

Each data file consists of 10 columns. The first column is the date and time of water-quality measurement in mm/dd/yy hh:mm:ss format, followed by the date and time in Julian format. The third column is water temperature in °C. The fourth column is specific conductance in milli-Siemens per centimeter. The fifth column is dissolved oxygen content in milligrams per liter, followed by dissolved oxygen in percent saturation in the sixth column. The seventh column is pH in standard units, and the eighth column is turbidity in Nephalometric turbidity units (NTU). The ninth column is a report of recorder battery health in volts, and the last column contains any pertinent field notes.

References Cited

- Kemp, J.E., 1990, Hydrogeologic characterization of surface mine spoil, Star Fire Mine, eastern Kentucky: Lexington, University of Kentucky, master's thesis, 102 p.
- U.S. Geological Survey, 1980, National handbook for recommended methods for water-data acquisition; chapter 2—Ground water: U.S. Geological Survey Work Group 2, 147 p.
- Wirth, K.A., and Wunsch, D.R., 1998, Aragonite precipitation from alkaline groundwater derived from mine spoil at the Star Fire Mine, eastern Kentucky: Geological Society of America annual meeting, Toronto, Canada, October 26, 1998.
- Wunsch, D.R., Dinger, James S., and Graham, C.D.R., 1999, Predicting ground-water movement in large mine spoil areas in the Appalachian Plateau: International Journal of Coal Geology, v. 41, nos. 1– 2, p. 73–106.
- Wunsch, D.R., Dinger, J.S., Taylor, P.G., Carey, D.I., and Graham, C.D.R., 1996, Hydrogeology, hydrogeochemistry, and spoil settlement at a large mine-spoil area in eastern Kentucky: Star Fire tract: Kentucky Geological Survey, ser. 11, Report of Investigations 10, 49 p.

Table 1. Laboratory analytical methods.					
Ana	Method				
Dissolved Metals:					
Aluminum	Magnesium	SW846-6010A			
Antimony	Manganese	Inductively coupled plasma			
Arsenic	Nickel				
Barium	Phosphorus				
Beryllium	Potassium				
Boron	Selenium				
Cadmium	Silicon				
Calcium	Silver				
Chromium	Sodium				
Cobalt	Strontium				
Copper	Sulfur				
Gold	Thallium				
Iron	Tin				
Lead	Vanadium				
Lithium	Zinc				
Chloride	SW846-9056				
Bromide	SW846-9056				
Fluoride	SW846-9056				
Sulfate	SW846-9056				
Alkalinity	EPA 310.1				
Bicarbonate	Calculated				
Nitrate-nitrogen	SW846-9056				
Total dissolved solids	EPA 160.1				



Figure 1. Location of Eastern Kentucky Coal Field within the Appalachian Coal Field of the eastern United States



Figure 2. Locations of sampling sites at the Star Fire Mine.