Tension reached the breaking point when mining engineers and geologists armed with old maps, their knowledge of the mines, and their Global Positioning Satellite devices gave the word: “Dig here.” There was no margin of error. Time loss and the risk of flooding the Quecreek miners’ only place of refuge loomed as the deadly outcomes of digging the wrong shaft. They got it right. On July 28, nine exhausted miners were hoisted to the surface where they were embraced by their families. An entire nation breathed a collective sigh of relief.

For a time, public interest and the media lingered on the spectacle. Good questions arose about our national dependence on coal and the accompanying safety risks that go along with its use. Many of these questions are still waiting for answers.

Story of black diamonds

Let’s start with one that is relatively easy to answer: What is coal? Most of us think of coal only in terms of deep mines or in terms of stripped-off mountaintops. We think of huge machines, hard labor, and all of the hazards that go along with an industry that
has figured heavily in our nation's history.

But the story really starts long before the first settlers arrived. It starts with land and plants that look nothing like coal and the underground seams where it is found today. Think of the Everglades in Florida or the Okefenokee Swamp in Georgia. Coal begins to form in swamps and bogs like these.

Geologist Glenn Stratcher of East Georgia College defines coal as rock formed from the remains of plant materials. “Anything that comes from a plant can go into the process of making coal,” he says. On a much smaller scale, animal remains are also included.

As the growing season passes, plants growing in swampy areas die and their remains fall into the water. There, they start to decompose, but do so very, very slowly. That’s because in the still water of swamps and bogs, there is not enough dissolved oxygen to meet the requirements for most decomposers—bacteria and fungi.

“More material dies and falls in on top of that previous material, and more [organic remains] falls on top of that. So what you start out with initially gets buried deeper and deeper in the swamp as time goes by,” explains Stratcher. He notes that coal in Pennsylvania can be between 200 and 300 million years old. The term fossil fuel is applied to fuels like coal that trace their origins to these long-dead plants and animals preserved in the earth.

Coal formation goes through a number of stages. The initial stage is peat—a loose brown collection of plant material. Over time, successive forms of coal are lignite, bituminous, and finally anthracite. Each successive form contains a higher percentage of carbon, releasing more heat for a given weight when burned.

Actually, each successive form represents organic material buried deeper in the earth over a longer period of time. As overlying sediments pile up, both the temperature and the pressure increase. About 3–7 feet of compacted organic matter transforms under temperatures ranging from 100 °C to 200 °C to yield about 1 foot of bituminous coal—the most common form in the United States.

**Our dependence on coal**

Worldwide, people have been digging coal out of the earth for more than 1,000 years. Coal mining in Pennsylvania dates back to colonial America, but both here and elsewhere, the demand for coal soared during the 19th century as the Industrial Revolution got under way.

Coal may not be the first thing you think of as you hit a light switch or open your refrigerator, but more than half of the energy consumed in the United States today is traced to coal fuel. Today, coal is not often burned directly in furnaces to provide heat for buildings. But it remains the major source of energy for creating steam. Hot steam turns turbines in power plants, and electricity is the result.

Although residents of the northeastern states had an opportunity to ponder life without electricity when the power grid went down last June, few of us can imagine anything longer than a temporary blackout. Health, safety, transportation, manufacturing, entertainment—in short, life as we know it is dependent on a stable power supply. And underlying that power supply is coal.

As Barry Commoner, an environmental activist and author once put it, “There is no such thing as a free lunch.” What is the real price of our dependence on coal? We’ve already noted how tragedy can strike in the mining industry. Are there other risks?

**Coal is risky business**

Burning coal releases a range of pollutants into both air and water. Most notable among these pollutants are oxides of sulfur and nitrogen—both causing air pollution and the production of acid rain. The burning of coal may also release mercury into the environment, which collects into waterways to be ingested by fish. Consuming mercury-contaminated fish puts humans at risk for kidney and nervous system damage.

Concentrated pollutants released into the air by burning coal can bring about tragic results. One such incidence was the infamous killer smog that settled on London in December 1952. A long cold spell kept coal fires burning longer than normal, and a weather condition called a “temperature inversion” kept the smoke at ground level. The result was thousands of deaths in four days.

Although no one was killed in 2000 when millions of gallons of gooey, sticky coal mine wastes broke through the walls of an impoundment, several streams in Kentucky were horribly polluted. The wildlife population that depended on the river for food was immediately devastated.

Sometimes the health effects of coal exposure take years to develop. Black lung disease, which is characterized by scarring and inflammation that make every breath a chore, results from years of inhalation of tiny coal particles. Today, one coal miner in 20 has some form of the disease, according to the American Lung Association. Although coal particles can cause a long-term illness, it is methane that can be responsible for more immediate and equally deadly effects.

Methane (CH\textsubscript{4}) is the major part of natural gas, in itself a source of fuel. It is released by the lengthy processes that result in coal formation. In coal mines, this odorless, colorless gas, trapped in rocks, can build up until it becomes a significant threat. Methane is lighter than air and is extremely flammable. The slightest spark can set it off with a loud “whoosh” and a wall of white smoke. The reaction releases a mixture of carbon dioxide, water vapor, and enough heat to cause fires and explosions.

Methane is a potent greenhouse gas. Methane can have a climate impact 20–25 times greater than 

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and it produces a spark,” explains Schatzel. To keep methane levels at regulation level, fans are installed to move air out of ventilation shafts at very high rates of speed. There are also extensive and powerful ventilation systems to provide fresh air to areas where the miners are working. And three times per hour, mandatory checks are made to see that the methane concentration is no greater than 1%.

And that’s not all. “The mining machinery is required to have detection devices called methanometers on them. The devices shut down the machinery [automatically] at 1%,” he says.

Keeping methane low is critical given the risk of ignition in a mine. “You have a piece of mining equipment that is operating, and it strikes coal or the roof or floor rock, the rock immediately above or below the coal bed—and it produces a spark,” explains Schatzel.

Explosions kill

In what was one of the worst accidents in nearly 20 years, a methane explosion in an Alabama coal mine killed 13 miners in 2001. In China, where thousands of mines are poorly ventilated, methane explosions still kill thousands of miners each year.

Explosions can occur even when methane levels are low. Tiny particles of coal dust suspended in oxygen-rich air can be another potential disaster just waiting for a spark. On April 26, 1942, 1549 people were killed by a coal-dust explosion at Honkeiko (Benxihu) Colliery, China. That was the worst single coal-mining disaster in history, according to the Guinness Book of World Records. Today, coal dust continues to pose serious risks in China and elsewhere. In May of 2002, 18 miners were killed in an explosion at a coal mine in Wentang township in China’s southern Hunan province.

Despite attempts to regulate gas and particle exposures, Schatzel is concerned that these hazards will increase as new mining methods are developed to dig out more coal in less time. “The more rapid the mining moves ahead, the more gas they [the miners] will encounter because the gas has not had an opportunity to bleed off from the coal. That presents an inherent challenge. The methane control technology really hasn’t changed dramatically from the seventies. So we try at look at new methods,” says Schatzel.

Schatzel and his colleagues are working on a mathematical model to predict the amount of methane that will be released as rapidly operating mining machines slice off huge chunks of coal from mine walls. Figuring this out, he says, is a complex process that takes into account the geologic formation, the depth of the coal bed, the rate of mining, and barriers to gas movement, such as veins of clay. “It’s an ambitious project,” he says.

Coal mines, even inactive ones, are by their very nature hazardous. Abandoned mines present their own set of threats. Certainly, the Quecreek miners found that out as they accidentally penetrated the walls of an abandoned water-filled mine. Abandoned mines can pose hazards above ground too, note professional geologists Robert Turka and Stan Michaliski of the geology and engineering firm, GAI Consultants, Inc., of Monroeville, Pennsylvania.

“You create this enormous hole in the ground! Frequently in the old mines, you’ll get a buildup of methane. It’ll move through fractures,” says Turka. There have been instances, though they are rare, in which lighter-than-air methane diffused into homes and exploded.

Mines can also threaten the safety of the environment by releasing acids that drain into streams and groundwater. Acids form when sulfide-rich minerals are exposed to air and water. Pyrite (FeS₂)—particularly common in coal mines—is readily oxidized to form sulfuric acid:

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2\text{FeS}_2(s) + 7\text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{FeSO}_4 + 2\text{H}_2\text{SO}_4
\]

The drainages containing these acids are in the range of pH 0–1 and may contain toxic heavy metals as well, thus posing a potentially lethal threat to aquatic life in ponds and rivers into which they drain.

Although acid mine drainage is a serious problem, it is not an inevitable outcome of coal mining. Ron Graham, a chemist with SGS, Inc., a Swiss-based testing and certification firm, notes that “some rock strata have inherent neutralizing potential.” Calcium carbonate (CaCO₃), which is found in some coal mines, dissolves to form a basic solution that can neutralize the acid formed from coal mining.

As an example, he notes that in the major coal mining state of West Virginia, the southeastern part of the state has little problem with acid mine drainage. In this region, calcium carbonate is abundant where coal is mined. In more northern sections of the state, acid drainage is a problem because of the relative absence of neutralizing calcium carbonate.

Coal fuels modern life and the myriad conveniences, services, and devices on which we depend. But, at the same time, coal and its pollutants threaten the environment and even our global climate. On a local level, coal mining may provide not only the jobs on which people’s livelihoods depend, but also the toxins that keep those life spans below the national average.

As the media analyzed the 2002 Quecreek Mine drama, someone speculated that the exhaustive coverage of the potential disaster may have single-handedly killed the future of an industry. They asked, “What kid could watch that drama unfold and still decide to become a miner?” Coal—mining it and consuming it—raises many questions about benefits and risks. These are important questions that will require some deep digging for answers.