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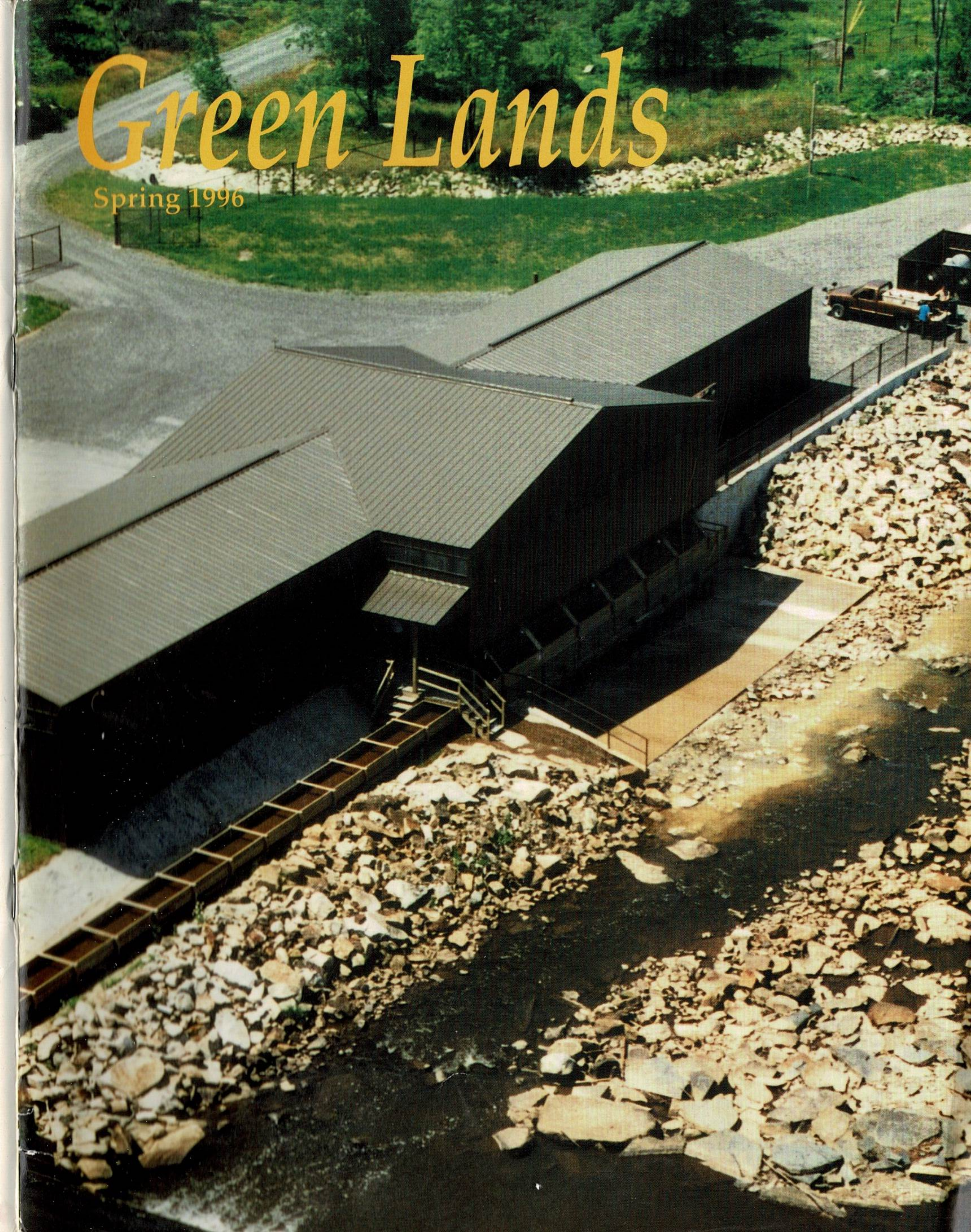
Spring 1996



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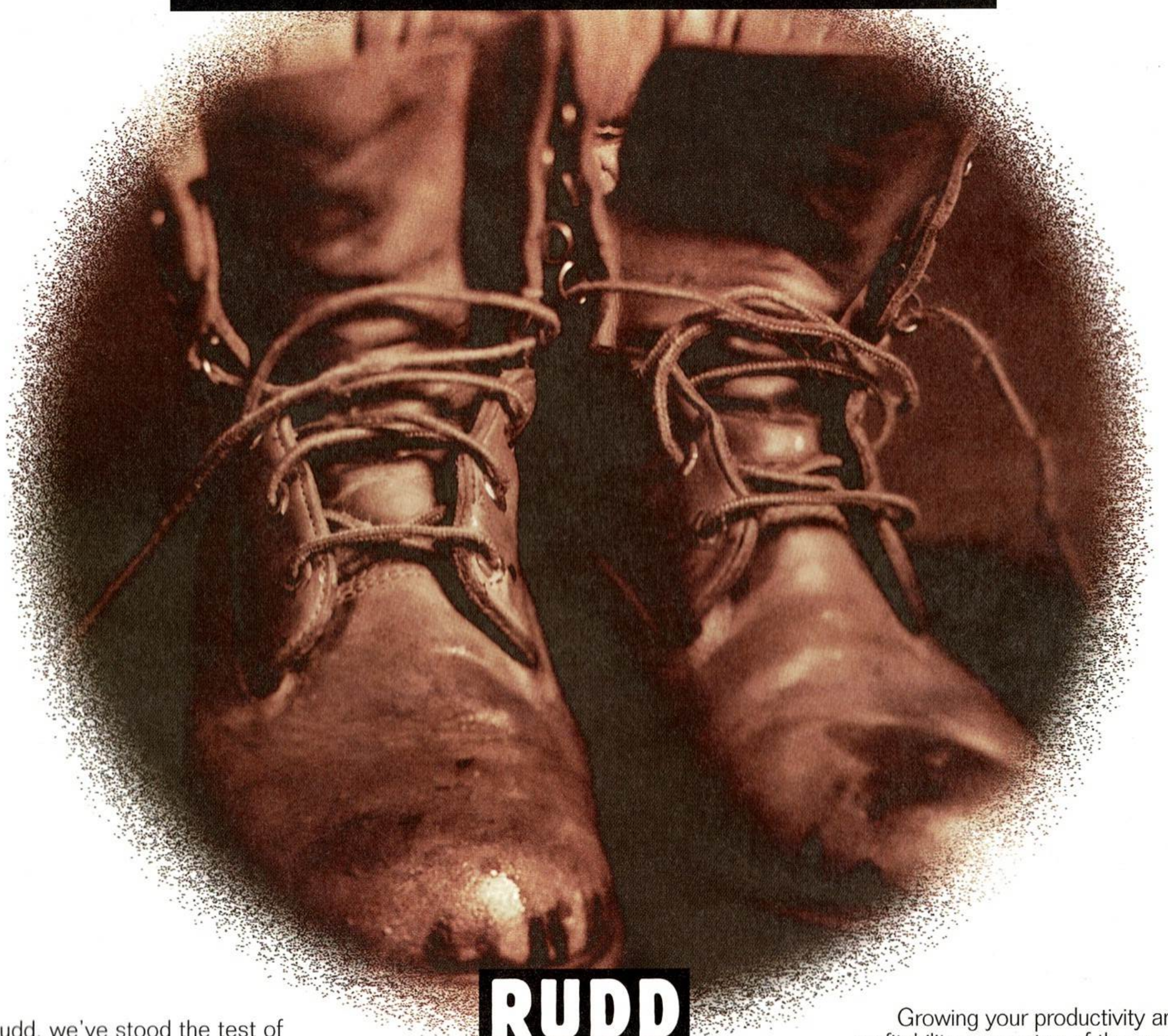

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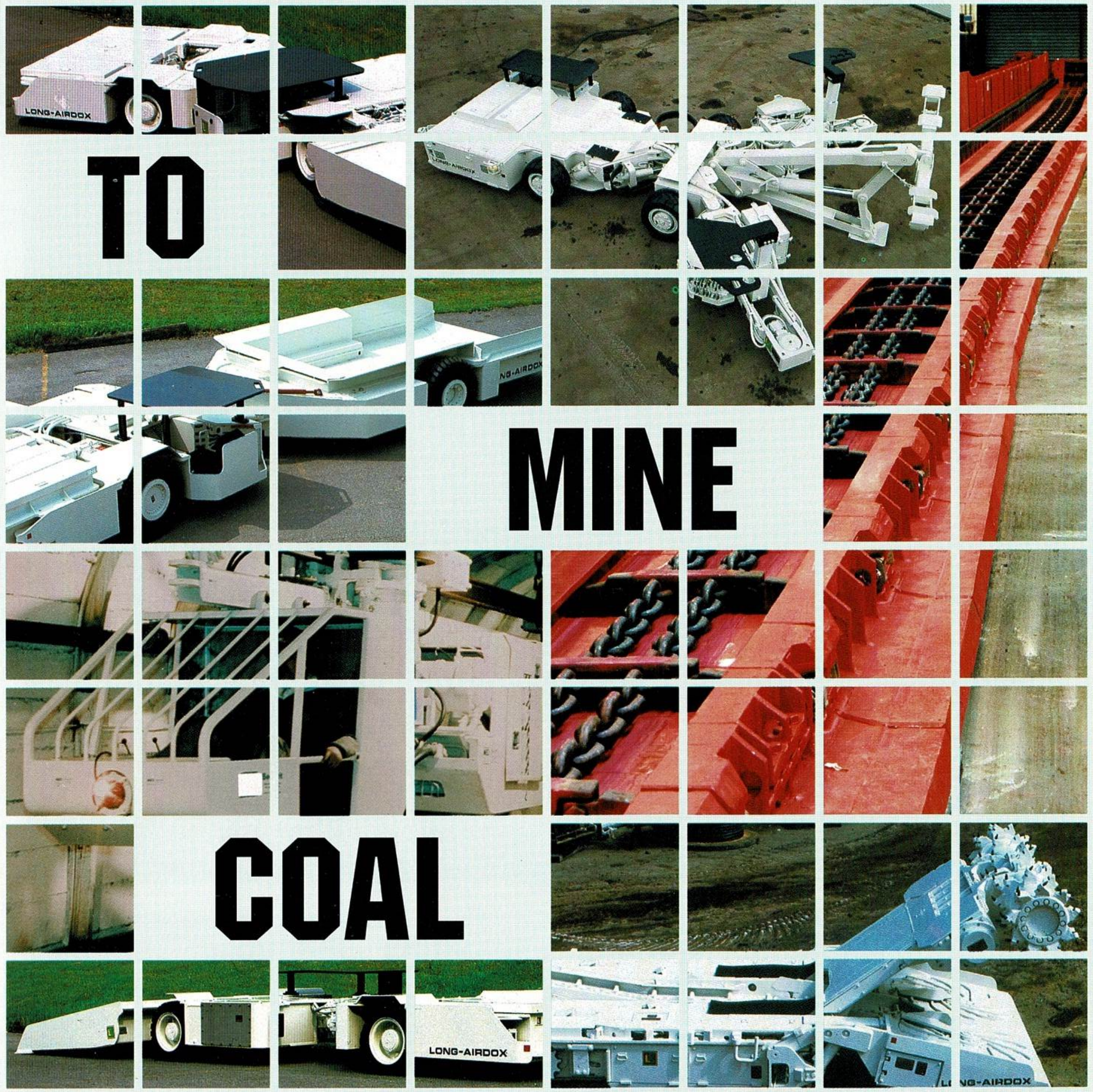

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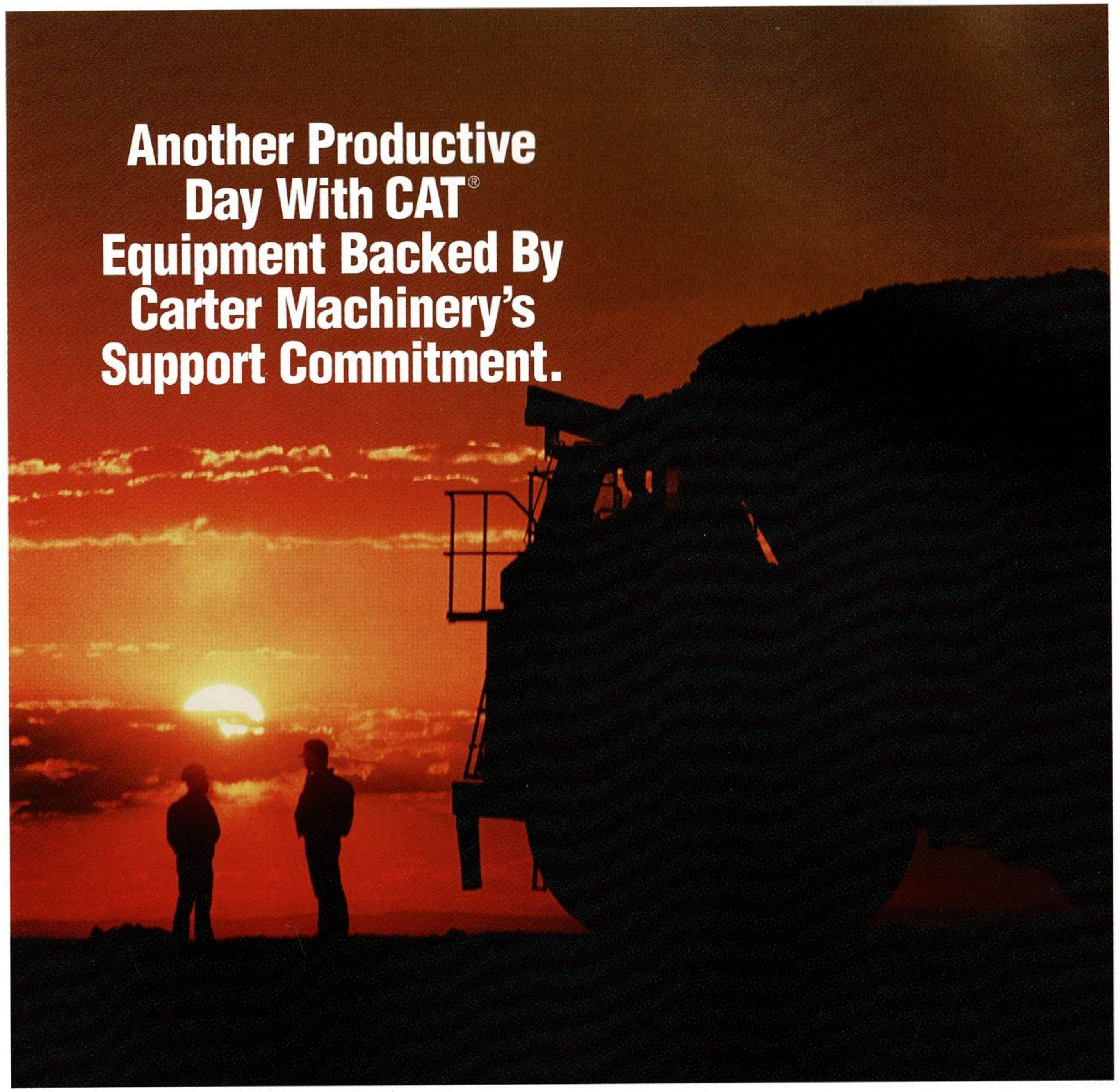

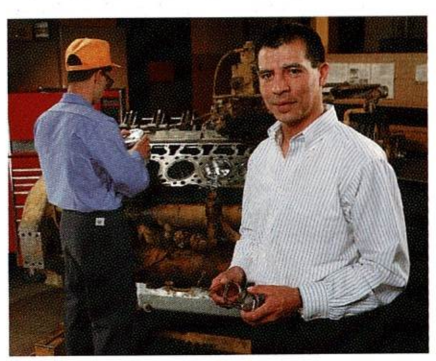

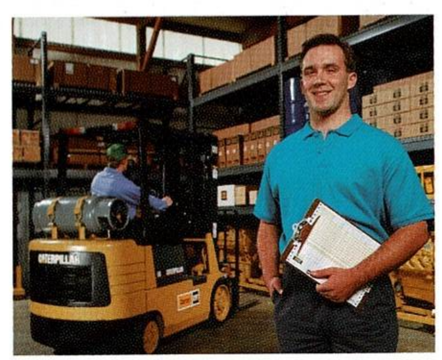

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Volume 26 Number 2

Green Lands
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with offices at 1624 Kanawha Boulevard East
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(304) 346-5318, FAX 346-5310.

Our Cover
The Blackwater River Limestone Station is one of the outstanding success stories of West Virginia's Abandoned Mine Land program, restoring the famous Blackwater Falls area to its former glory. Cover story on page 12.

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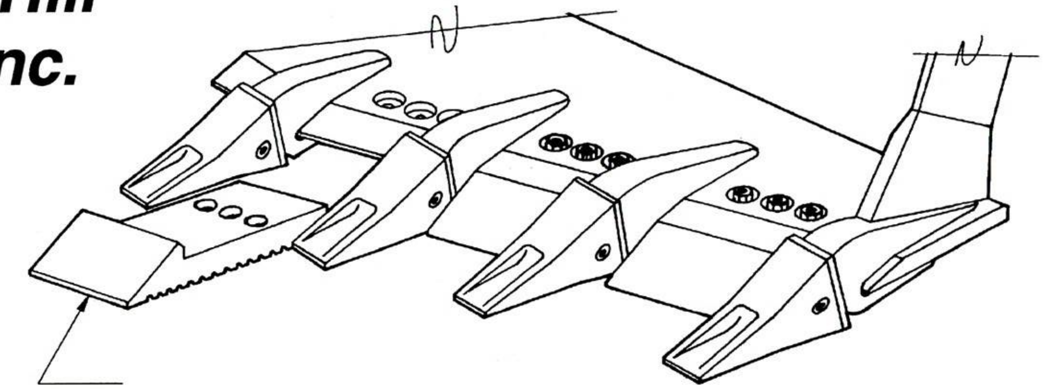

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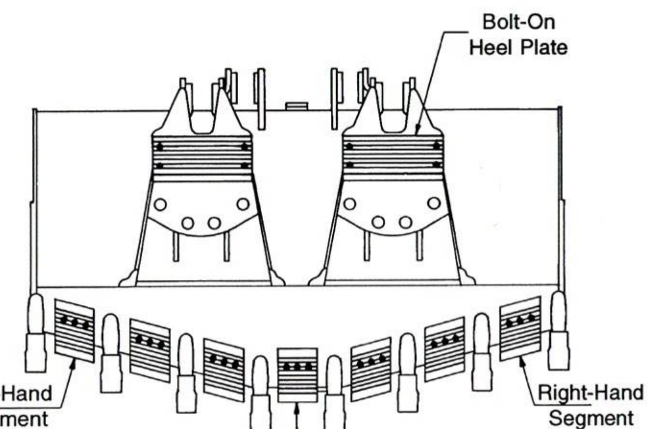

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Association Notebook

Leo A. Vecellio, Sr.

Accepting the first Reclamation Award from DNR Director T. R. Samsell in 1968 .

Leo Vecellio, Sr. passes away

Leo A. Vecellio, Sr., the first President of WVMRA passed away on Thursday, April 18 at his home in Palm Beach, FL at the age of 80. Leo was a founding member of the Association 30 years ago and served as the organization's first chairman, at that time called president.

He was born in October, 1915 at Amherstdale and grew up in Beckley. He graduated from Virginia Tech 1938, where he played four years of varsity football and served three terms as class president. He ended his collegiate years as President of of the Corps of Cadets.

As a young civil engineer, Leo Vecellio first worked for Gilbert Construction Co. Soon after he went into business with his father and brother-in law, founding the construction firm of Vecellio & Grogan in 1938.

Following World War II service in the Pacific theater, he returned to Beckley to build V&G from a small contractor into one of the top 200 construction companies in the US, with a work force of 2,000. The company entered the mining business in 1949 and experienced tremendous growth in the 1950's and early 60's. At the peak of business, Ranger Fuel and Sterling Smokeless were producing four million tons annually. Both companies were sold to the Pittston Coal Group in 1970.

In 1978, he acquired a winter home in Florida and expanded his business to that state, establishing PAVEX Corp., an asphalt producing and contracting company Later, he started White Rock Quarries, an aggregate producer. Both companies grew to leadership status in their respective industries. The Florida operations also include Ranger Construction Industries, Inc., Ft. Pierce Contracting Corp. and Stuart Contracting Co.

In 1978, he was selected "West Virginia University Coal Man of The Year." In 1982, he was named "West Virginia Italian-American of the Year.'

In 1988, alma mater Virginia Tech recognized him as "Distinguished Alumnus of the Year." The latest award designated Leo as the Tech graduate of 50 years or more with "a distinguished record of professional achievement and service to society."

In 1972 he started the Enrico Vecellio Family Foundation, in memory of his father and of his son Enrico Charles, who died of leukemia at 18. The foundation started with a single $2000 scholarship and grew to an endowed fund supporting some 40 college students. The Foundation also supports some 35 other institutions, including the Boy Scouts Of America and medical research on leukemia and eye disease.

Leo Arthur Vecellio, Sr. is survived by his wife Evelyn, son Leo, Jr., daughter Patricia Rogers and grandsons Chris and Michael Vecellio.

Ironically, he passed away as the Association which he played such a key role in founding is preparing to celebrate its 30th anniversary.

New members

During the last winter and spring meetings, the Board of Directors approved 14 companies for new membership, including five in the General Division and nine in the Associate Division.

Welcome to the following companies and their representatives:

GENERAL DIVISION - Colby Coal Co., Kingwood, WV, represented by Jeffery S. Sisler; **D R M Coal Processing, Inc.**, Beaver, WV, represented by Donald R. Miller; **Drummond Co., Inc.**, Jasper AL, representative - Bruce Windham; **Fola Coal Co., Inc.**, Charlottesville, VA, represented by Donald B. Sult; and **Princess Beverly Coal Co.**, Charleston, WV, represented by Peter K. Moran.

ASSOCIATE DIVISION - Chubb Group of Insurance Companies, Pittsburgh, PA, represented by Kelly O'Leary; **D-A Lubricant Co.**, Charlotte, NC, represented by Mark Stanley; **Daniels Law Firm**, Charleston,WV, represented by Norman T. Daniels, Jr.; **Gauley Eagle Holdings, Inc.**, Craigsville, WV, represented by Dan A. Permenter; **Gopher Surveying Co.**, Premier, WV, represented by Michael Rose; **Performance Solutions**, Beaver, WV, represented by Jim Ballmer; **R. Duffy Walls & Associates**, Washington, DC, represented by Daniel B. Scherder; **Stemtite, LLC**, Maryland Heights, MO, represented by Mike Culivan; and **W. W. McDonald Land Co.**, Logan, WV, represented by Glenn T. Yost.

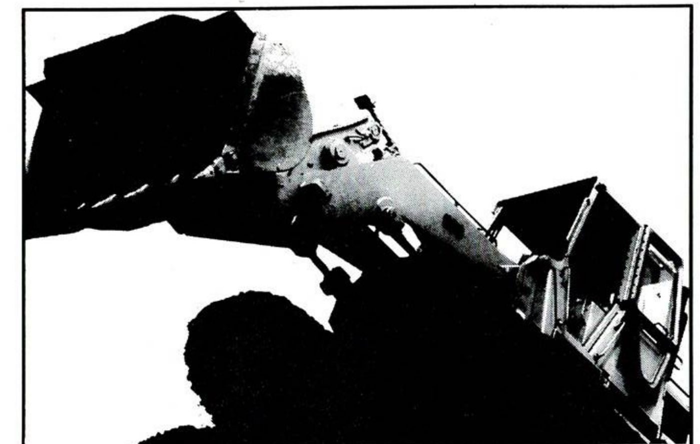
USGA names Joe England

Joe England, longtime WVMRA member and President of the Logan Corp. has been named to the prestigious Executive Committee of the United States Golf Association. Joe comes by his golf involvement naturally. His father was a member of the Executive Committee 30 years ago. He also shares a hometown (Huntington) with former USGA President Bill Campbell.

The USGA was founded in New York 102 years ago, for the purpose of holding an amateur championship event, but its centerpiece ultimately became the U.S. Open. It quickly became, and has remained, the undisputed governing body of amateur golf in the United States.

The organization has grown to encompass a staff of 188 and an annual operating budget of $56 million. The Executive Committee also oversees the USGA Foundation, which provides financial support for a variety of projects, from turfgrass research to junior player development programs.

In Joe England, the Committee could hardly have gained a more qualified new member. A graduate of the University of Richmond and the Harvard School of Business, Joe is President of the West Virginia Golf Association. In the USGA, he has served on the Green Committee, the Sectional Affairs Committee, and has been a Rules Official at the last 11 U.S. Opens.



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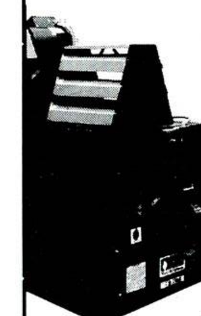

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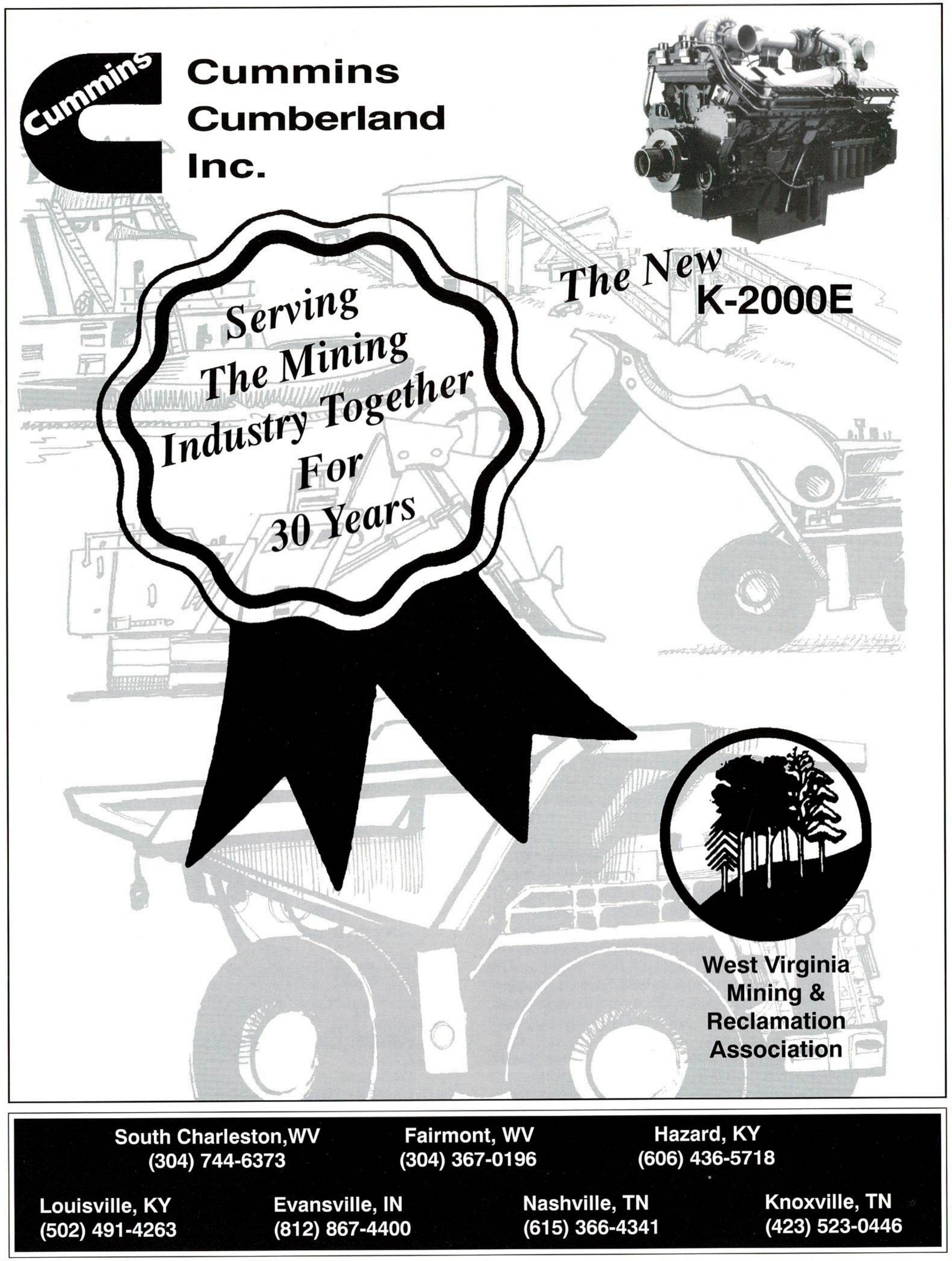
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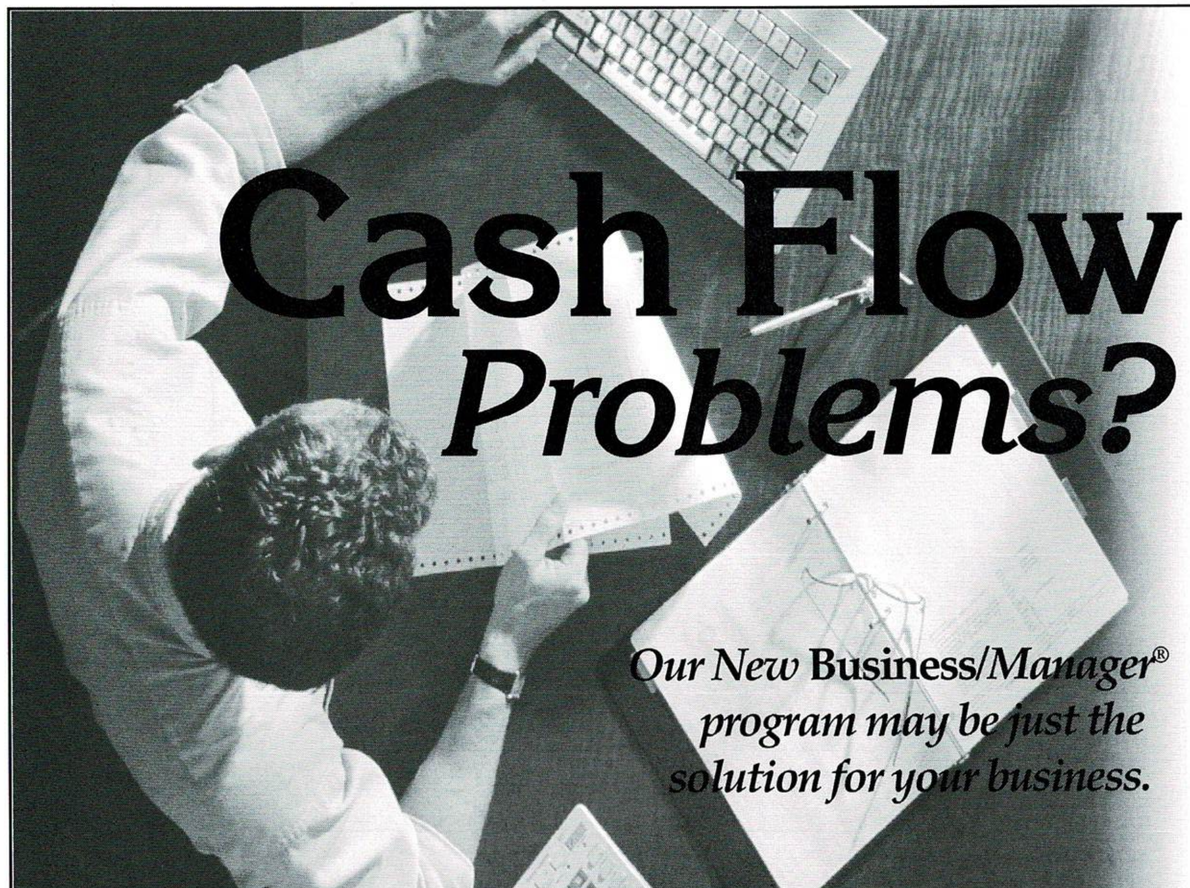

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The Blackwater River Limestone Station, built with $1 million in AML funds, opened in September, 1994.

Limestone treatment station neutralizes AMD

Blackwater treatment a great success

One of the most famous of West Virginia's natural attractions is Blackwater Falls. Home to one of the most visited facilities in a celebrated State Park system, the name comes from the 67 foot drop in the Blackwater River near the town of Davis. The river then rushes through a narrow canyon, descending at a rate of 136 feet per mile for 12 miles to its confluence with the North Fork River.

Still dropping at 90 feet per mile, the Blackwater joins the Dry Fork at Hendricks to form the Black Fork. Three miles later, at Parsons, the Black Fork joins with Shavers Fork to form the Cheat River, one of West Virginia's primary waterways.

In rugged, scenic and sparsely populated northeast West Virginia, woods and waters are an important part of the social and economic lifestyle and the Blackwater area is a key element. For many years, however, the watershed has been adversely affected by acid mine drainage, which is formed by oxidation of minerals found near coal seams, and associated with mining activity in those areas.

As the country moved into a more environmentally conscious era, concern for the condition of the watershed increased, but funding for a meaningful cleanup was simply not available. Then the Surface Mining Control and Reclamation Act of 1977 levied a per ton tax on coal mining for the purpose of restoring land and water damaged by mining from previous decades.

In recent years, the Abandoned Mine Lands program run by West Virginia's Division of Environmental Protection has devoted more resources and attention to water quality. In 1994, DEP found the answer for the Blackwater area. In September of that year, State officials dedicated the Blackwater River Limestone Station.

Beaver Creek, which enters the Blackwater River at Davis, and the North Fork of the Blackwater, which enters downstream four miles from the west, were the main sources of the acid water. This is the section that includes Blackwater Falls and Blackwater Gorge.

'results have far exceeded the most optimistic expectations'

Prior to establishment of the station, the acidic waters of the Blackwater were neutralized by the natural alkaline flows of the Dry Fork. This permitted a smallmouth bass fishery to exist downstream in the Cheat, but its productivity was limited by the consumption of the Dry Fork's alkalinity in the acid neutralization process. The Blackwater station enabled the alkalinity of the Dry Fork to extend much farther downstream, thereby increasing the productivity of the Cheat fishery.

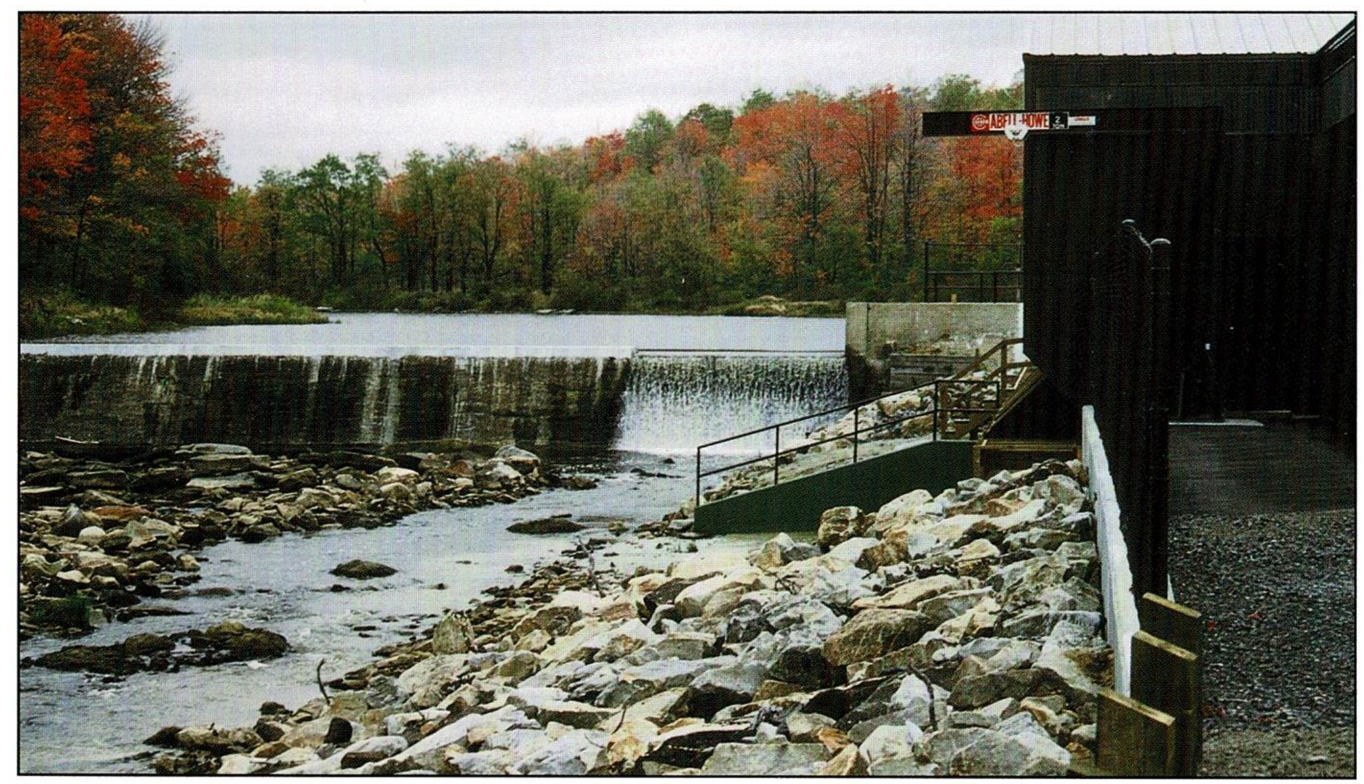
Constructed with more than $1 million in AML funds on the banks of the Blackwater River in scenic Tucker County, the station was designed to raise the pH of six miles of the river. But the results have far exceeded the most optimistic expectations, according to West Virginia AML Chief Pete Pitsenbarger, and the effects of the treatment plan also extended much further downstream than anticipated. The entire 12 miles of river below the station have been neutralized, enabling the Blackwater Canyon to support a year-round trout fishery.

Depositing up to 9.5 tons of crushed limestone per day, the station neutralizes AMD entering the Blackwater River from the Beaver Creek watershed.

The Blackwater station is patterned after a facility built by the Division of Natural Resources in the Cranberry River watershed. Because of its previous experience, DNR provided the engineering and design for Blackwater, and also operates and maintains it, with annual operating costs of about $80,000.

The station is powered by stream flow. It contains six drums which feed limestone directly into the river. It is self-regulating, in that the stronger the water flow, the more limestone is released. DEP officials monitor the station daily, but it can operate on its own for up to a week at a time.

In addition to the environmental and aesthetic benefits, the project is having a positive effect on the local economy as fishing and general outdoor recreation increase. As funds are made available, DEP plans to expand the station treatment program to other affected watersheds in the state.



Six drums feed crushed limestone directly into the Blackwater River. Powered by the river itself, the treatment is increased proportionately as stream flow increases.

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Budget battle cuts AML appropriations

Congressional infighting is having an adverse effect on appropriations for West Virginia's Abandoned Mine Lands program. Though the program is funded through a per ton tax on coal production, the AML section of West Virginia's Division of Environmental Protection must apply to the federal Office of Surface Mining each year for construction and administrative grants. That money is made available through Congressional appropriation.

Though the money is there, it is not available, due to the battle of the budget.

The assessment, set by the Surface Mining Control & Reclamation Act of 1977, is 35¢ a ton for surface coal and 15¢ for underground tonnage. At current production levels the annual nationwide tax amounts to more than $250 million. About $50 million of that total is contributed by West Virginia companies. Through February, 1996, $4,036,611,383.19 had been collected since the program's inception, $483,068,324.91 of that in West Virginia.

The AML program has been quite successful, restoring land mined in a less environmentally conscious era, at no cost to the ordinary taxpayer. It also provides income and employment for dozens of construction and mining companies and hundreds of workers. However, the momentum of the program has been threatened by the current squabble over government spending.

The unappropriated balance in the federal fund at the end of fiscal year 1995 was $1.6 billion. Meanwhile, state programs like West Virginia are getting only enough funding to cover administrative costs. Last year, West Virginia should have received nearly $23 million, including $4.5 million for the Emergency Program and $12 million for AML construction projects. Instead, the State is forced to fund its current construction projects with leftover money from previous grants.

Current plans call for a total of 35 projects to be bid in 1996 at an estimated cost of $17 million. Work will be done in 15 of the state's coal counties.

West Virginia's AML program has continued its emphasis on improving the state's water supply. About one in five projects will include some form of passive water treatment and several water systems will also be funded.

To date, the program has overseen the completion of more than 400 projects totaling nearly 5,000 acres and touching every coal producing county of the state.

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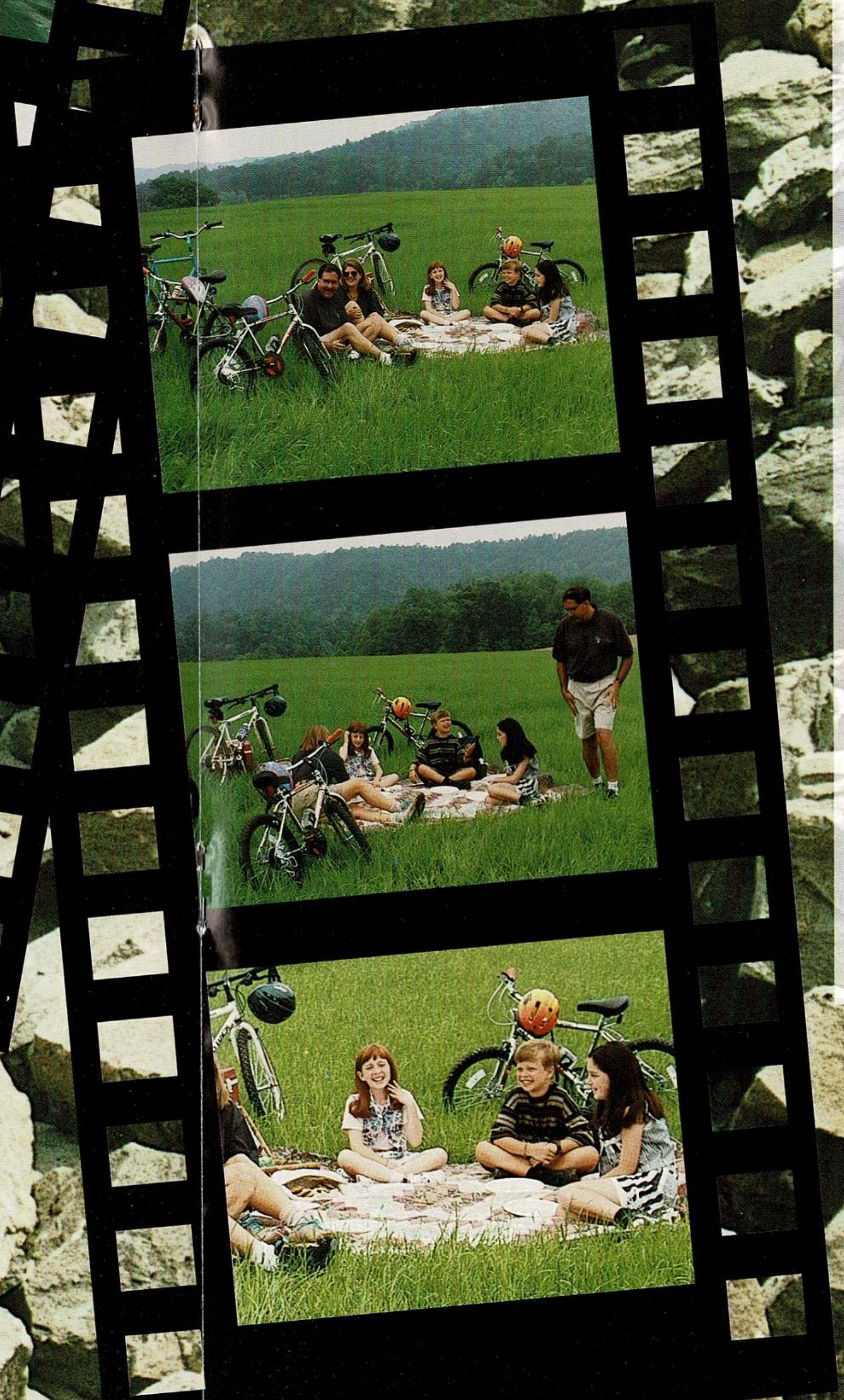

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Greens Run, an acid laden tributary of the Cheat River, is the first designated area to benefit from the "River of Promise" progam.

Making big strides on Greens Run

The coal industry in West Virginia gets a lot of blame for environmental problems associated with outdated mining practices. On the other side, the modern industry must be credited with going far beyond requirements of the law and the call of duty in reversing environmental damage.

Technological advances and innovative engineering have enabled the industry to keep pace with energy market demands, while complying with a myriad of environmental laws and regulations promulgated over the last generation. These advances have even allowed coal companies to extract minerals from previously "mined-out" areas, while reclaiming the site to modern standards.

While examples of environmentally friendly coal operations abound in West Virginia, Anker Energy, headquartered in the old coal city of Morgantown, has raised the process to a new level.

Last May, Anker President John Faltis led his company into an ambitious project to restore one of the state's most acid laden waterways to its former pristine condition of long ago.

On that occasion, Faltis made Anker the first signee to the "River of Promise" agreement, committing his company's considerable expertise and resources to a pilot project on Greens Run, a tributary of the Cheat River. Co-signing were Robert J. Uram on behalf of the federal Office of Surface Mining, Eli McCoy of the WV Division of Environmental Protection, Frank Jernejcic for the WV Division of Natural Resources and Dave Bassage for the "Friends of the Cheat," a local environmental group.

The Cheat River is among 1% of U.S. rivers to classified as "excellent" whitewater (Class III and higher rapids). It was also on the 1995 Ten Most Endangered Rivers list published by the conservation organization American Rivers.

Anker Energy's affiliate, Patriot Mining Co., operates the Albright Ash Facility, located across the river from the put-in point for raft tours through the Cheat's lower canyon. Patriot built the facility to handle flyash which is used to treat acid mine drainage at the site of an old refuse site.

Anker's experimental practice of creating barrier layers of alkaline flyash has resulted in significant improvement in the site's ground water quality. Even so, opaque yellow waters and crystalline but dead streams flows nearby, as they have since as far back as the turn of the century.

Phase 1 at Greens Run involved construction of an anoxic limestone drain to neutralize an acid seep from an old highwall.

John Faltis explained his company's interest in the project. "The Surface Mining Control and Reclamation Act promises that mining will be a temporary activity. Since 1977, the coal industry as done a great job of living up to that promise. But our unique opportunity as miners is that we are able in many instances to help restore watersheds through current mining activity, or through the use of coal combustion byproducts. we can help make good on that promise, even retroactively.

"This is good business practice," Faltis continued. "It's good for local economic development to restore watersheds to their recreational and fishing potential. It's just good for our communities."

From its headwaters in Pocahontas, Randolph and Tucker Counties, the Cheat River flows 157 miles north through West Virginia to the Pennsylvania state line. It is one of the longest free-flowing rivers in the eastern U.S. Its headwaters spring from the Allegheny Highlands (being drained by Shavers Fork and Dry Fork), and from Canaan Valley (being drained by the Blackwater River). It is an area of high-relief, and contains more land over 4,000 feet in elevation than any other drainage in West Virginia. Streams in the Cheat River Basin are characterized by steep gradients, rock channels, and high water flow velocities. It flows through spectacular mountain scenery and steep canyons, and serves a multi-million dollar per year commercial whitewater industry.

Industrial activities in the upper, middle, and lower Cheat consist of logging operations, underground and surface coal mines, and numerous abandoned coal mines. Water quality ranges from excellent to very poor. In the river's lower 20 miles, it becomes so severely polluted by acid mine drainage (AMD) from historic surface and underground coal mines that it is effectively dead. AMD continues to be the largest environmental water quality problem in this region of West Virginia, and this continuing problem results in loss of fish and wildlife, aesthetic damage due to unsightly orange stains on river sediments, degraded drinking water, and limited opportunities for recreation.

The watershed contains several significant recreational areas, including Canaan Valley State Park, Blackwater Falls State Park, Coopers Rock State Forest, Dolly Sods, Seneca Rocks, Spruce Knob, and a portion of the Monongahela National Forest.

The upper portion of the Cheat River includes the Blackwater River and its tributaries, Dry Fork and its tributaries and Shavers Fork. The Blackwater River and Dry Fork form the Black Fork above Parsons. The Black Fork River has recently been turned into a net alkaline stream due to the application of limestone powder from a limestone drum station facility near Davis (see page 12). Shavers Fork is a low-buffered stream, naturally low in pH due to the organic acids from forest cover in the area.

The anoxic limestone drain was engineered from water properties data gathered over a six month period.

Although some abandoned underground mines exist in the area drained by Shavers Fork, the stream is not affected significantly by mine drainage as compared to the Blackwater River and other tributaries in the lower Cheat.

The middle portion of the Cheat River extends from Parsons to Rowlesburg. The streams entering the Cheat in this portion are generally classed as having very good to fair water quality. Therefore, the impact of AMD on this section of the river is negligible.

The lower Cheat begins at Rowlesburg and proceeds to the state line north of Morgantown. The greatest and most degrading AMD problems exist in this stretch of Cheat River. It is estimated that 86% of the acid load that enters the Cheat River enters in this lower section. Of the 25 major tributaries that enter the lower Cheat, seven tributaries contribute nearly 95% of the acid load to the Cheat.

Greens Run is a tributary of the Cheat River in Preston County. The stream drains an area of about 7,500 acres north of Kingwood. It flows eastward into the Cheat River opposite of Muddy Creek. Greens Run has three major sections, including the main stem, called the North Fork, the Middle Fork, and the South Fork. The North Fork of is not severely impacted by AMD and contributes little acidity to the total acid load in Greens Run. The Middle Fork has several point sources of AMD. The South Fork is also damaged by AMD, and it has been selected for a limestone fines dumping project by the WV Division of Natural Resources. The limestone fines project will dump finely ground limestone directly into the stream for acid neutralization. Limestone continues to dissolve over time as it washes down the stream and decomposes.

Volunteering $200,000 in 1995 to begin the acid abatement program, Anker began the actual work last summer. Troy Titchenell, an Anker land agent who grew up on Green's Run, heads the project's technical committee which also includes Dave Broschart of DEP, Peter Zurbuch of DNR, and geologist/environmentalist Richard DiPretoro.

Anker Energy presented a conceptual plan for abatement of AMD in the Middle Fork of Greens Run to the DEP and the federal Office of Surface Mining . Three point sources of AMD were located in this creek and water samples were taken from these three sources and analyzed. One source flows from the base of an abandoned highwall and is the result of past surface and deep mining in the 1960's. The second is a drainage pond. The third source is a seep from another highwall on the site.

The AMD abatement project on the Middle Fork of Greens Run is divided into three phases. The first phase, now completed, involved construction of an anoxic limestone drain (ALD) to treat the drainage from the #3 seep. Phase 2 will involve removing the pond by filling it with alkaline fly ash and reclaiming the area around the pond. Phase 3 will include treating the # 1 seep by the use of an ALD or the placement of limestone in the stream to act as an open limestone channel.

It was determined that the AMD from seep #3 could be treated with the use of an ALD. An adequate amount of space was available for excavation, and access to the area was good. The road leading to the site was upgraded for hauling materials and equipment. The data used for the design of the passive treatment system were gathered over the course of six months and this information was inserted into the equations for sizing an ALD.

Water began coming out of the ALD in December, 1995. Based on the few samples collected, the ALD is adding alkalinity to the water and raising pH, while iron concentrations decreased an average of 54%. The "River of Promise" program is up and running.

The Greens Run cleanup is but the first step toward the ultimate goal of a Cheat watershed that can support fish and wildlife. At present, about 20 miles of river upstream from Cheat Lake are devoid of life. The magnitude of the problem is great and Anker sees its contribution merely as seed money, which will eventually by supplemented by federal and State reclamation funds, as well as commitments from other private sources.

For his outstanding leadership role in creating the "River of Promise" cooperative agreement, John Faltis became the first recipient of the "Trailblazer Award," presented by OSM. OSM Director Robert Uram presented the award to Faltis at last summer's groundbreaking ceremonies for the Greens Run Project.

The Trailblazer Award credits Faltis with developing the necessary partnerships among government, industry and community to create the Green's Run project, and acknowledges Anker Energy's dedication of financial, engineering and construction resources to the "River of Promise" agreement.

The "River of Promise" is the first joint effort by a coalition of industry and environmentalists, as well as federal and state agencies, to affect an entire watershed.

The citation for Faltis' Trailblazer Award reads as follows:

"Change can occur when a person has the vision and seizes the moment to act on an inspiration. That person is the Trailblazer, the one who creates a path for others to follow. Accordingly, the Trailblazer Award is presented to acknowledge those individuals who have put footprints on a new path for helping people and the environment, and to recognize leaders who are guiding future generations through responsible stewardship of our outdoor environment.'

Anker Energy President John Faltis (l) receives the first "Trailblazer Award from OSM Director Rober Uram (c) and U.S. Assistant Interior Secretary John Garmendi.

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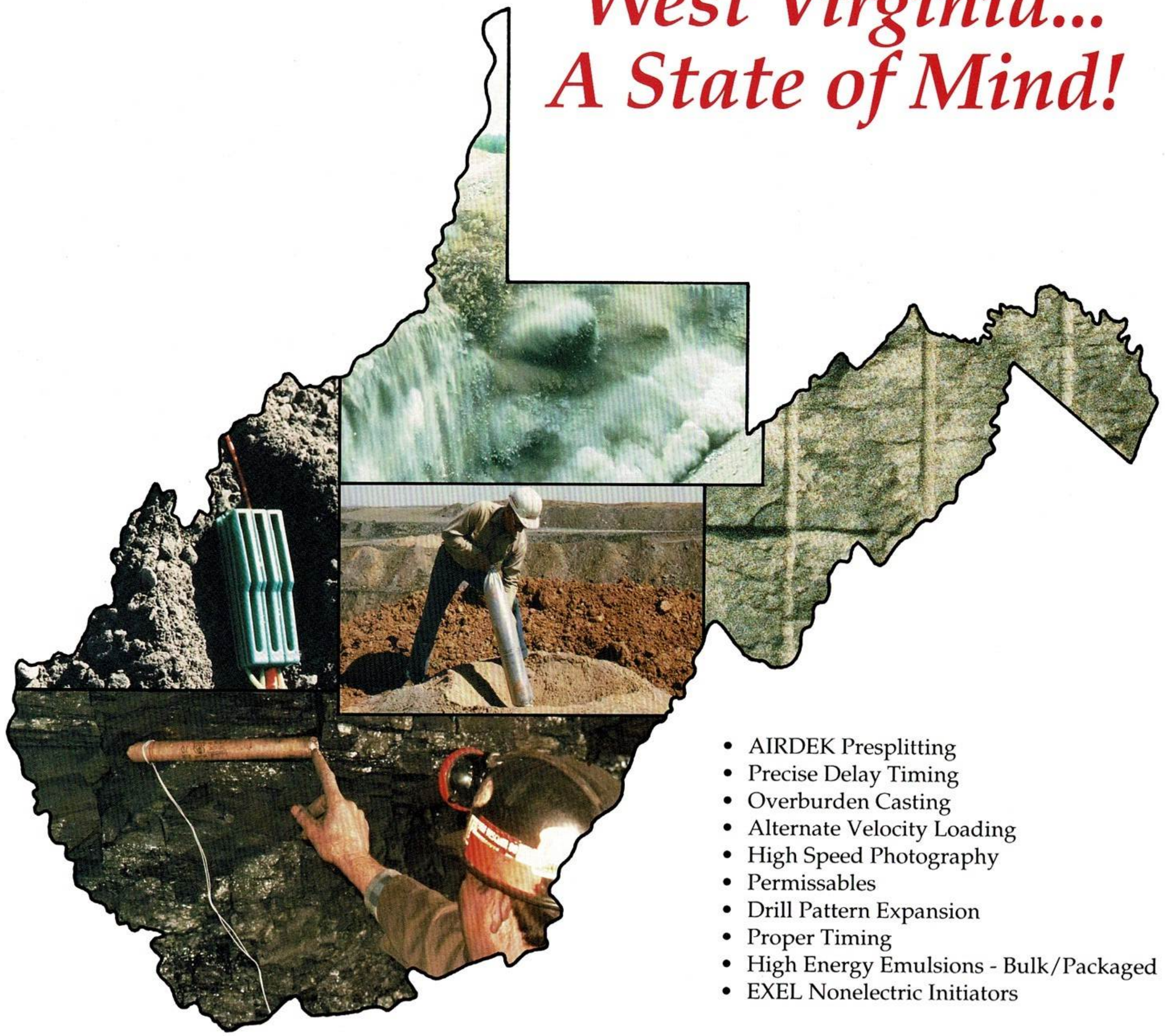

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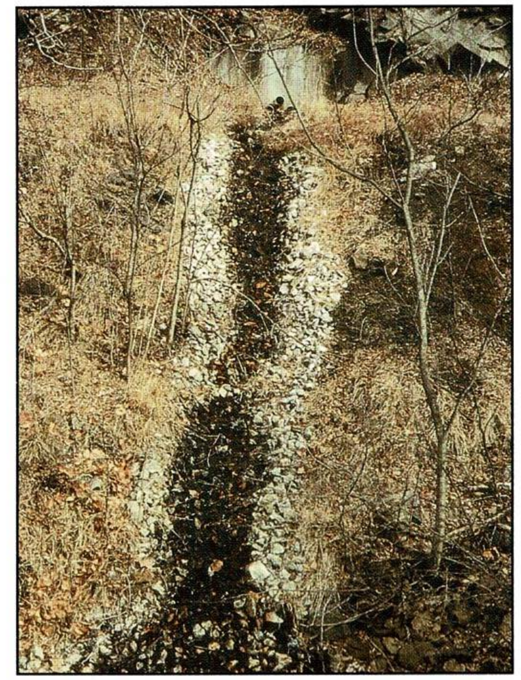
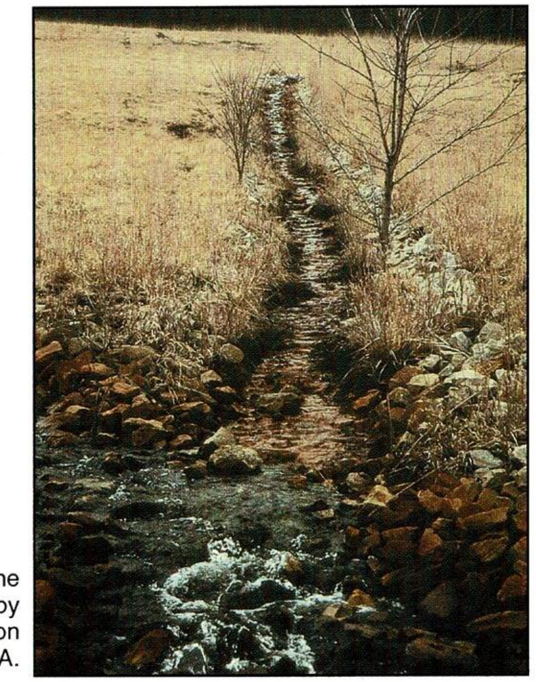


At left - Open sandstone-lined channel constructed by NRCS at the Coval/Graceton site in Indiana County, PA.



At right - Open limetone channel constructed by PADER at the Coval/Graceton site in Bedford County, PA.

Acid Mine Drainage Treatment With Open Limestone Channels

Paul F. Ziemkiewicz, David L. Brant, and Jeffrey G. Skousen
National Mine Land Reclamation Center and West Virginia University

Abstract

Acid mine drainage (AMD) is often associated with mining of pyritic coal and metal deposits. AMD associated with coal mines in the eastern U.S. can have acidity and iron concentrations ranging from the teens to the thousands of mg/l. Aluminum and manganese can be present in concentrations ranging from zero to the low hundreds of mg/l. Much attention has been devoted to developing inexpensive, limestone (LS)-based systems for treating AMD with little or no maintenance. However, LS tends to coat with metal hydroxides when exposed to AMD in an oxidized state, a process known as "armoring". It is generally assumed that once armored, LS ceases to neutralize acid. Another problem is that the hydroxides tend to settle into and plug the pore spaces in LS beds forcing water to move around rather than through the LS. While both promlems are caused by the precipitation of metal hydroxides, armoring and plugging are two different problems. Plugging of LS pores can be avoided by maintaining a high flushing rate through the LS bed. Armoring, however, occurs regardless of water velocity. This study investigated the influence of armoring on LS solubility and the implications of armoring and plugging on the construction of open limestone channels (OLCs) for treating AMD. We evaluated the AMD treatment performance of armored and unarmored LS in oxidizing environments both in laboratory and field studies. The results showed ferric and aluminum hydroxide floc remained suspended in solution until the LS was allowed to dry. As the floc dried, the LS became armored. The laboratory study treated AMD with armored LS (ALS) from two field sites and unarmored LS (ULS). ALS dissolved 25 to 33% more slowly than ULS. The field study surveyed 3- to 8-year-old, rock-lined waterways constructed for erosion control. One waterway was constructed of sandstone rip-rap and seven others were constructed with LS. The results indicated that OLC's, though armored, continued to reduce acidity at rates similar to those of the laboratory study. The results were used to verify a dissolution kinetics model that predicts the required dimensions of an OLC for treatming a specific AMD flow and acidity.

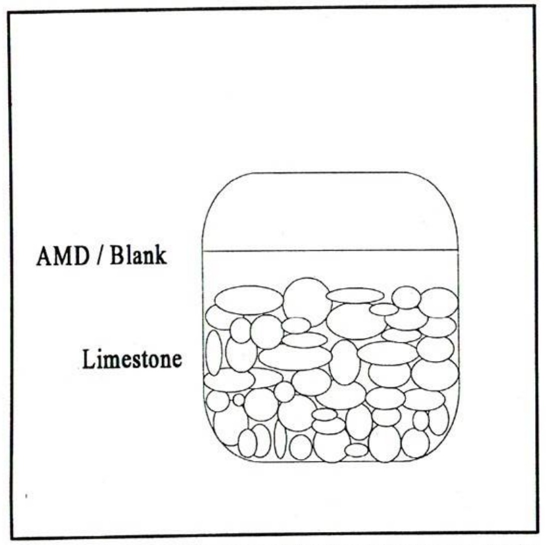


Figure 1. Container used for the laboratory study filled with limestone and AMD or deionized water.

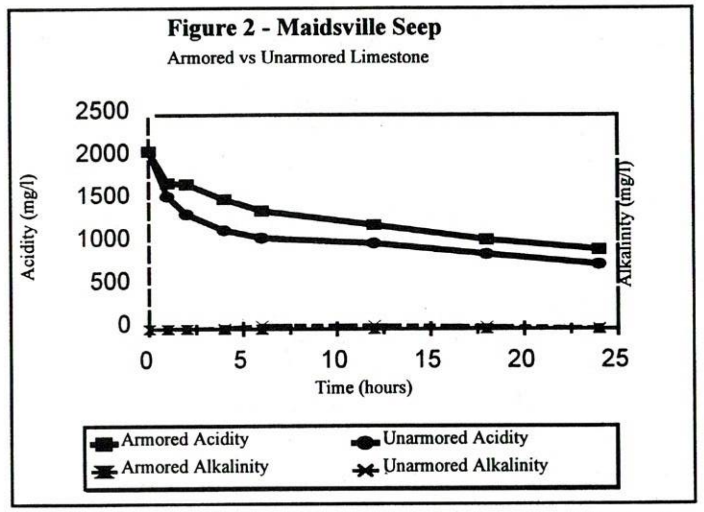


Figure 2. Acidity reduction and alkalinity generation of Maidsville Seep AMD with armored and unarmored limestone.

Introduction

Acid mine drainage (AMD) continues to be one of the largest problems facing the mining industry. AMD originates from active and abandoned mine lands (AML) as pyrite (FeS_2) or other metal sulfides associated with the mineral deposit are exposed to oxidizing conditions. Upon exposure, the sulfide minerals progress through a combination of auto-oxidation and microbial oxidation reactions to produce large amounts of acid, iron and sulfate. This acidity then dissolves other minerals releasing ions such as manganese and aluminum. The resulting solution is AMD. Upon reaching a stream, AMD alters the chemical balance: it consumes alkalinity, introduces metal ions and generally degrades its biological productivity. If sufficiently severe, AMD will also render the receiving waters unfit for human, agricultural, industrial or recreational use (Atlas and Bartha 1987).

AMD can be treated with alkali chemicals, which is the method of choice for most active mines. This is expensive and must continue long after mining has ceased. An alternative is passive treatment. Passive treatment refers to any zero to low maintenance AMD treatment scheme. These systems are of increasing interest as state, industry and federal partnerships are formed to rehabilitate watersheds damaged by historic mining. Passive systems offer low maintenance, inexpensive, and long-term solutions to AMD remediation (Brodie 1990, Hedin 1989). Anoxic limestone drains (ALDs), wetlands, or a combination of both are the most often used passive systems (Faulkner and Skousen 1994). Wetlands are effective in handling low acid loadings but often encounter difficulties or fail under high loading. Problems with ALDs occur when ferric iron, aluminum, or ferrous iron and dissolved oxygen are present. Under these conditions, metals will precipitate and armor the LS (ALS) reducing its dissolution efficiency compared to unarmored LS (ULS). Precipitates may occlude all of the pore volume within the drain preventing water from contacting the LS.

Studies by Pearson and McDonnell (1974, 1975a, 1975b) found that ALS dissolved at about 20% the rate of ULS. Ziemkiewicz et al. (1994) conducted a preliminary study of OLCs on field sites and developed a spreadsheet to estimate LS volumes and channel dimensions for treating AMD. OLCs will become armored, presumably reducing their dissolution rate to 20% of ULS. But unlike ALDs, plugging of LS pores can be controlled by maintaining high flows and the armoring effect can be accounted for by adding a design factor of five (Ziemkiewicz et al. 1994).

This study compares the AMD treatment efficiency of armored and unarmored LS in the laboratory. In addition, a field study was conducted to survey existing open LS-lined waterways to evaluate the effects of ALS on AMD treatment.

Experimental Design: Laboratory Study

The lab study was conducted using containers (2 liter, high-density polyethylene) filled with 2.3 kg (5 lbs) of 5 - 10 cm (2 - 4 in) ALS or ULS (Figure 1). One of five sources of AMD or deionized water (blank) (1.2 liters) was added to each of the containers. The two sources of ALS were from Robinson Run (RR) and Dola, WV. The ULS was from the Deer Valley formation provided by Action Mining in Somerset County, PA. The five AMD sources (all Pittsburgh coal bed) were: Maidsville Seep near Morgantown, WV; Shaw Mines Run and Weir-11, near Meyersdale, PA; Coal Run, near Salisbury, PA; and a synthetic AMD containing only sulfuric acid and deionized water. Only 13 of the 18 possible LS/water combinations were used (Table 1), and each of the selected combinations had 3 replications.

The method for estimating the solubility of ALS vs ULS was adapted from Watzlaf and Hedin (1993). Water samples (60 mls) were collected with 60-ml plastic syringes from containers in duplicate (one sample for general water chemistry and one for metals analysis) at the following time intervals after water introduction: 0 hr., 1 hr., 2 hrs., 4 hrs., 6 hrs., 12 hrs., 18 hrs., and 24 hrs. The samples were filtered (0.45 micron) and metal analyses samples were acidified with 1 ml of concentrated nitric acid prior to submission to the NRCCE Analytical Laboratory for analysis. The parameters tested were: pH (electrode), electrical conductivity (conductivity bridge), alkalinity and acidity (Brinkman auto-titrator), and concentrations of iron, aluminum, manganese, calcium, magnesium (Leaman Labs inductively coupled plasma spectrometry), and sulfate (Milton Roy Spectronic 20) (Clesceri et al. 1989).

Table 1. Water and limestone combinations used in the laboratory study. Each combination checked had three replications.

Water	Robinson Run ALS	Dola ALS	ULS
Maidsville	X		X
Shaw Mines		X	X
Weir-11		X	X
Coal Run		X	X
Synthetic AMD		X	X
Deionized Water	X	X	X

Table 2. Characteristics and performance of a sandstone open channel and eight OLCs at field sites in Pennsylvania and West Virginia (SS=sandstone, LS=limestone).

Site	Flow (gpm)	Length (ft)	Rock type	Slope (%)	Acidity (mg/l) Initial	Acidity (mg/l) Final	Acid Loss (%)	Rate of Acid loss (%ft)
Coral/Graceton	350	720	SS	10	550	540	2	.0028
Morg Airpt W	30	150	LS	14	410	360	12	.0800
Morg Airpt E	20	90	LS	20	355	330	7	.0780
Eichleberger #2	100	160	LS	20	510	325	36	.2250
PADER	25	37	LS	60	2600	2500	4	.1080
PA Game Com.	128	35	LS	45	330	125	62	1.7710
Cottage Town	80	450	LS	9	32	28	13	.0290
Opawsky	240	150	LS	9	30	15	50	.3333

Experimental Design: Field Study

The field study surveyed existing rock-lined waterways on AML sites containing AMD (Table 2). These waterways were constructed for erosion control or stream bank stabilization only. One waterway was constructed with sandstone and the other seven waterways were made with LS. Two water samples (250 mls each) were collected at identified distances along the channels (one for general water chemistry and one for metals analysis) and analyzed as described above (Clesceri et al. 1989). The samples were field filtered (0.45 micron) and acidified with 1 ml of nitric acid for metals analysis or cooled to 4°C for general chemistry. Flows were measured with a Marsh - McBirney model 2000 Flo-Mate electromagnetic flow meter for larger flows (> 95 l/min or 25 gpm) or a calibrated bucket and a stopwatch for smaller flows (< 95 l/min or 25 gpm). Distances were measured with a 100 foot surveying rope.

The results of water quality analyses from field channels were plotted against our kinetics spreadsheet (RBOLD) designed to predict the dimensions required to treat AMD with OLCs (Ziemkiewicz et al. 1994). RBOLD translates ALS dissolution kinetics into a spreadsheet which estimates the reduction in acid load for a given LS channel, or estimates the size of a channel required to achieve desired acid load reductions.

Description of Field Sites

NRCS Coral/Graceton Site - The Coral/Graceton site is located adjacent to U.S. Route 119 immediately northeast of the towns of Coral and Graceton in Indiana County, PA. The channel is 220 m long, 3 m wide and 0.1 m deep (720 x 9 x 0.5 ft) on a 10% slope, and was constructed with sandstone. The flow of AMD through the channel, measured at the source and mouth of the rock lined waterway, was 1323 l/min (350 gpm) and the acidity at the source was 550 mg/l.

Morgantown Airport Site - The Morgantown Airport site is located adjacent to U.S. Routes 119/857 east of Morgantown, WV. There are two channels (both LS and heavily armored) at this location. The first channel (West) is 46 m long, 1.3 m wide and 0.1 m deep (150 x 4 x 0.5 ft) on a 14% slope. The second channel (East) is branched, with the first branch being 21 m long (70 ft) and the second branch being 27 m (90 ft) long (same widths and depth as West channel) both on 20% slopes. The flow of AMD in the West channel was 113 l/min (30 gpm) and the acidity was 410 mg/l. The total combined flow in the East channel was 76 l/min (20 gpm) and the acidities were 355 mg/l for the first branch and 335 mg/l in the second. The flow rates were equal at the sources and the mouths of each channel.

NRCS Eichleberger #2 Site - The Eichleberger #2 site is located in Bedford County, PA, 6.5 km southeast of the village of Coaldale. The channel is 49 m long, 2 m wide and 0.1 m deep (160 x 6 x 0.5 ft) on a 20% slope, and was constructed with LS that became heavily armored. The flow through the channel was consistent at 378 l/min (100 gpm) and the acidity at the source was 510 mg/l.

PADER Site - The Pennsylvania Dept. of Environmental Resources site is located in Bedford County, PA, 1.6 km west of the village of Defiance. This channel is 11 m long, 1 m wide, and 0.1 m deep (37 x 3 x 0.5 ft) on a slope of 60% with a flow of 95 l/min (25 gpm). Acidity was 2600 mg/l at the source. This channel is also constructed of LS that became heavily armored.

PA Game Commission Site - The Pennsylvania Game Commission site is also a small channel (11 m long, 1 m wide, and 0.1 m deep) on a slope of 45%. It is located on the northeast side of Vintondale in Cambria County, PA. The flow is 484 l/min (128 gpm) and acidity is 330 mg/l at the source. This channel was constructed of LS and became armored after construction.

Cottage Town Site - The Cottage Town site is located 1.6 km west of Cairnbrook in Somerset County, PA. The channel is 137 m long, 1.3 m wide and 0.1 m deep (450 x 4 x 0.5 ft) on a 9% slope with a flow of 302 l/min (80 gpm) throughout the entire length. LS was used for the construction of the channel. The LS was heavily armored and the AMD had an acidity of 32 mg/l at the source.

NRCS Opawsky Site - The Opawsky site is located in Armstrong County, PA, 1 km south of Mosgrove. This site was different from the other sites due to the construction of a wetland 46 m (150 ft) from the top of the channel. The top portion of the channel was constructed of LS for 46 m long, 2 m wide and 0.3 m deep (150 x 6 x 2 ft) on a slope of 9%. The LS was armored and the flow of AMD throughout the entire system was 907 l/min (240 gpm). The wetland covered an area of 350 m² (7.6 m by 46 m). The lower 137 m (450 ft) of the channel was also constructed of LS that was armored. The acidity at the source was 30 mg/l.

Laboratory Study Results

The initial acidity of the Maidsville seep (2080 mg/l) was reduced to 925 mg/l (56% reduction) after 24 hours with RR ALS (Figure 2). This compares to ULS that eliminated 65% of the acidity after 24 hours. The ALS from Dola completely eliminated the Shaw Mines' initial acidity of 518 mg/l in the containers after 6 hrs (Figure 3). Unarmored LS achieved 100% treatment after 4 hrs. Alkalinity production leveled off after 12 hours for both armored (75 mg/l) and unarmored (120 mg/l) LS.

The initial acidity of Weir-11 (1370 mg/l) was reduced to 20 mg/l (99% reduction) after 21 hours using Dola ALS (Figure 4). Unarmored LS treated all the acidity and produced 50 mg/l alkalinity during the same time period. Coal Run, a stream contaminated by a turn of the century deep mine, had an initial acidity of 905 mg/l (Figure 5). The Dola ALS and ULS both completely neutralized the acidity of the water after 21 hrs. Both types of LS produced net alkaline water during the same time period, producing 61 mg/l for the Dola ALS and 84 mg/l for ULS.

Deionized water was added to the three LS types used in the study to isolate the effect of armoring in the absence of acid leachate. The results indicate that the ALS initially produced some acidity but that the solutions became alkaline within the first hour. The ULS produced the highest alkalinities at 50 mg/l while Dola ALS produced 30 mg/l and RR ALS gave 40 mg/l (Figure 6).

The three LS types were treated with a synthetic AMD (0.02M H_2SO_4). The acidity was completely neutralized within 2 hrs with ALS and within 1 hr for ULS. Alkalinity generation leveled off at 67 mg/l after 18 hrs for ALS and 85 mg/l after 4 hrs for ULS (Figure 7).

Four water types used in the study were placed in cells and monitored over a 14 hr period to confirm whether any changes occurred in acidity levels on exposure to air. Figure 8 indicates that no changes occurred.

Field Study Results

The NRCS Coral/Graceton waterway was constructed with sandstone to serve as a control to LS channels. The prediction line was based on the use of LS. The resulting acidity reduction on the site was 0.0028% per ft, much less than the predicted 0.034% per ft if it would have been constructed with LS (Figure 9). The predicted value was based on the spread sheet RBOLD.

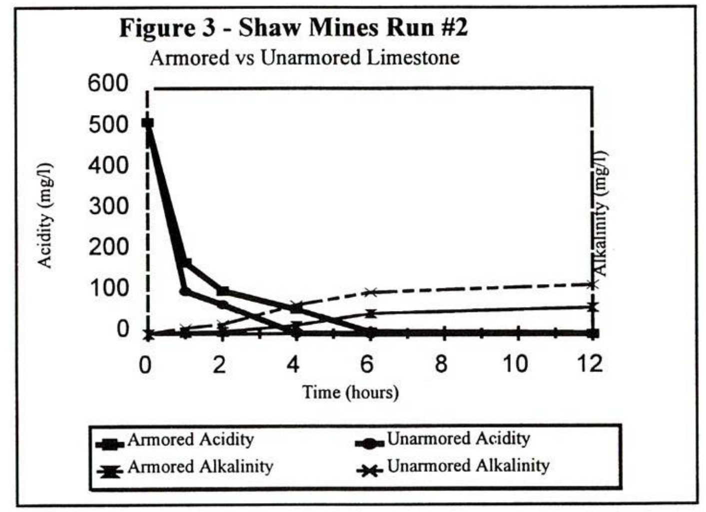


Figure 3. Acidity reduction and alkalinity generation of Shaw Mines AMD with armored and unarmored limestone.

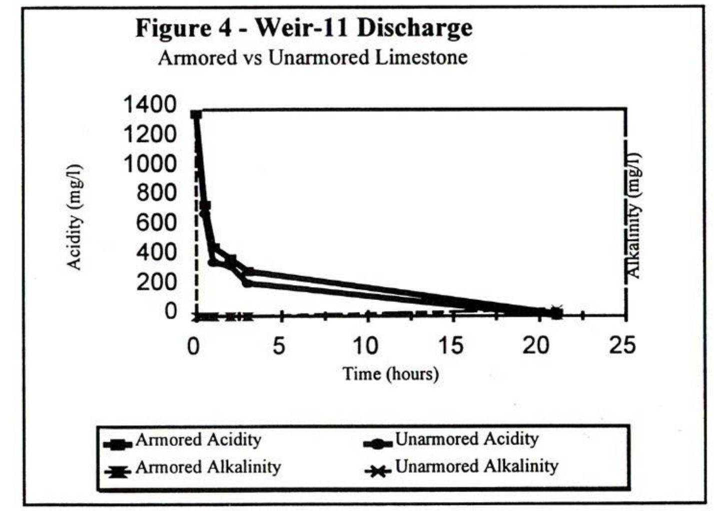


Figure 4. Acidity reduction and alkalinity generation of Weir - 11 AMD with armored and unarmored limestone.

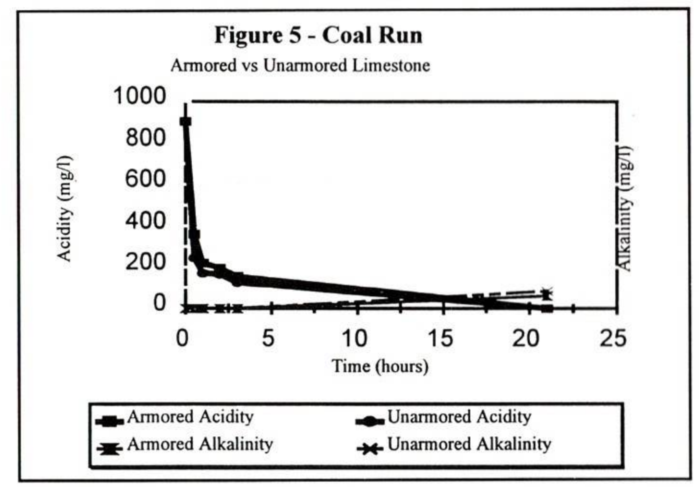


Figure 5. Acidity reduction and alkalinity generation of Coal Run AMD by armored and unarmored limestone.

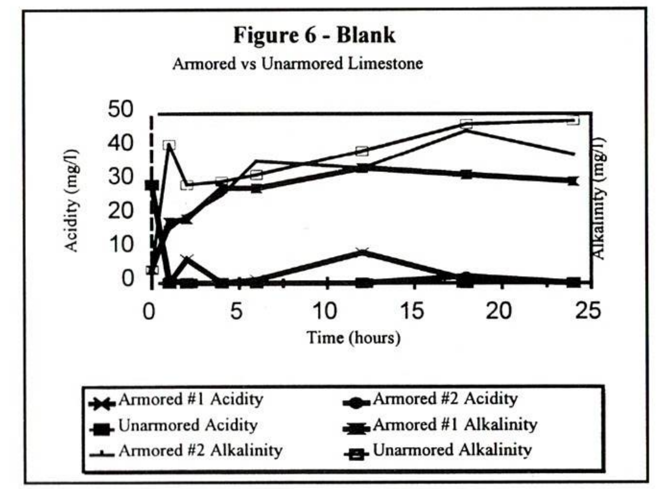


Figure 6. Acidity reduction and alkalinity generation with deionized water on armored and unarmored limestone.

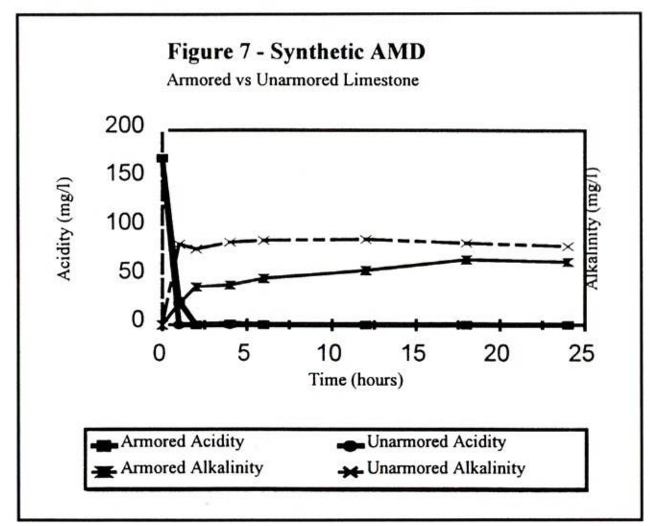


Figure 7. Acidity and alkalinity generation of Synthetic AMD with armored and unarmored limestone.

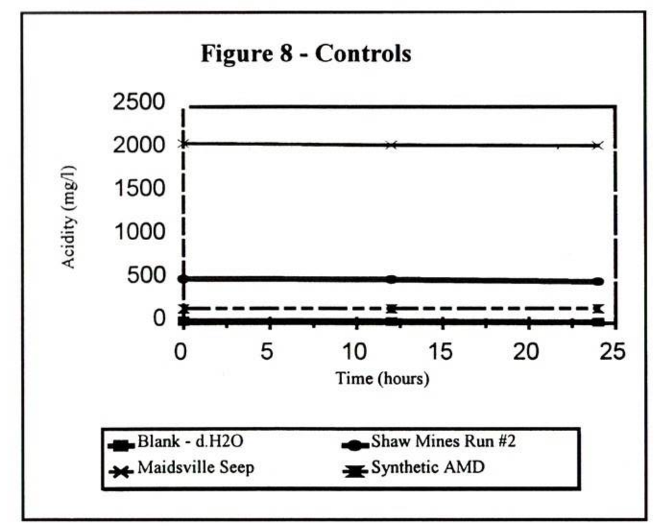


Figure 8. Acidity changes over time with three AMD sources without limestone.

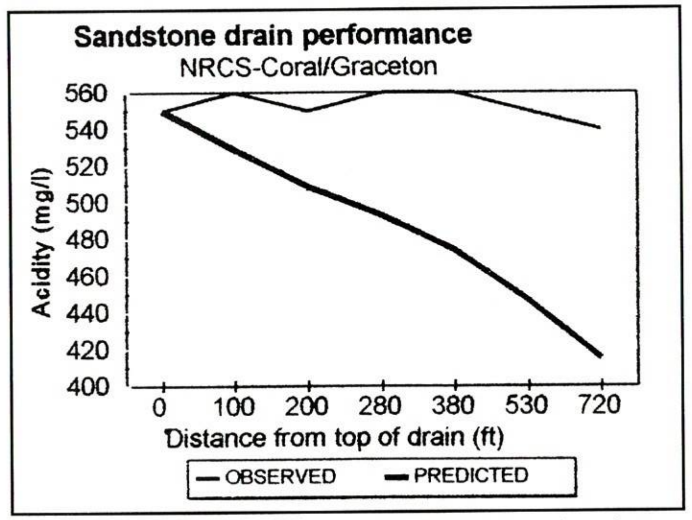


Figure 9. Observed and predicted acidity reductions from a sandstone drain at the Coral/Graceton site in Indiana County, PA.

The Morgantown Airport West channel performance was better than predicted (Figure 10). The actual acidity reduction was 0.0800% per ft compared to the predicted reduction of 0.032% per ft. The Morgantown Airport East channels also performed better than predicted with an acidity reduction of 0.0780% per ft compared to a predicted reduction of 0.020% per ft (Figure 11).

The NRCS Eichleberger #2 channel also performed better than expected with an actual acidity reduction of 0.2250% per ft compared to a predicted reduction of 0.104% per ft (Figure 12). The PADER site is a very short

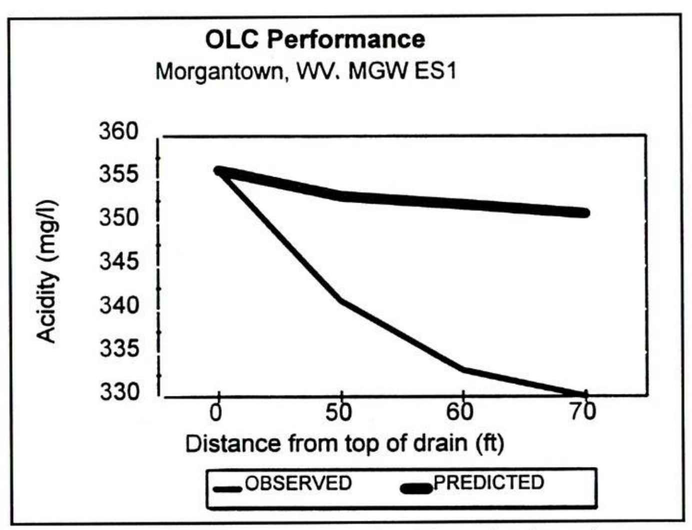


Figure 11. Observed and predicted acidity reductions of an open limestone channel at Morgantown Airport east drain.

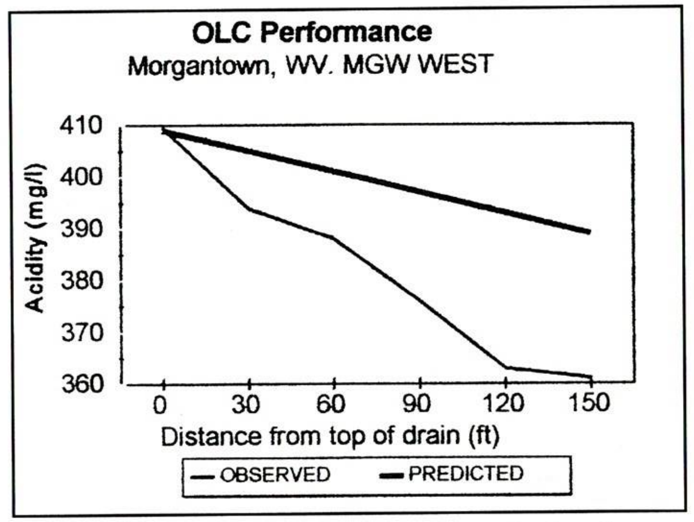


Figure 10. Observed and predicted acidity reductions from an open limestone channel at Morgantown Airport west drain.

channel with high acidity, but removes 0.1080% of the acidity per ft. This was an order of magnitude better than the predicted acidity reduction of 0.010% per ft (Figure 13). The PA Game Commission OLC is also a very short channel (Figure 14), but it shows an impressive performance (1.7710% acidity removal per ft compared to a predicted performance of 0.044% per ft acidity removal). The steep grades of these two channels really increased water velocities and enhanced LS dissolution.

The Cottage Town site has a small amount of acidity entering the channel (Figure 15) and exhibits an acidity

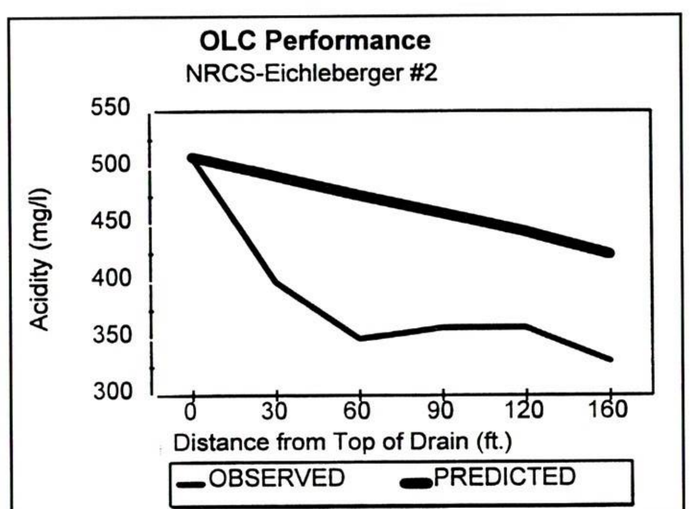


Figure 12. Observed and predicted acidity reductions fof an open limestone channel at the NRCS Eichleberger #2 site in Bedford County, PA.

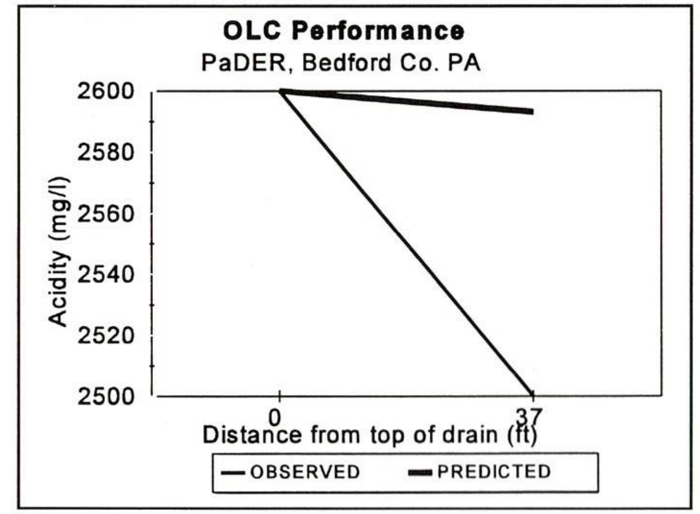


Figure 13. Observed and predicted acidity reductions of an open limestone channel at the Pa DER site in Bedford County, PA.

removal better than that predicted over the first 110 m (360 ft) of the channel (0.0870% per ft compared to 0.035% per ft predicted). Acidity increases over the last 27 m (90 ft) of the channel are due to a small source of AMD entering at the base of the channel. But this brings the overall acidity removal closer to the predicted value (.0290% compared to .0350% per ft of channel).

The NRCS Opawsky site's performance was slightly worse than predicted (0.33% acidity removal per ft compared to a predicted removal of 0.42% per ft) but still removed 50% of the acidity (Figure 16).

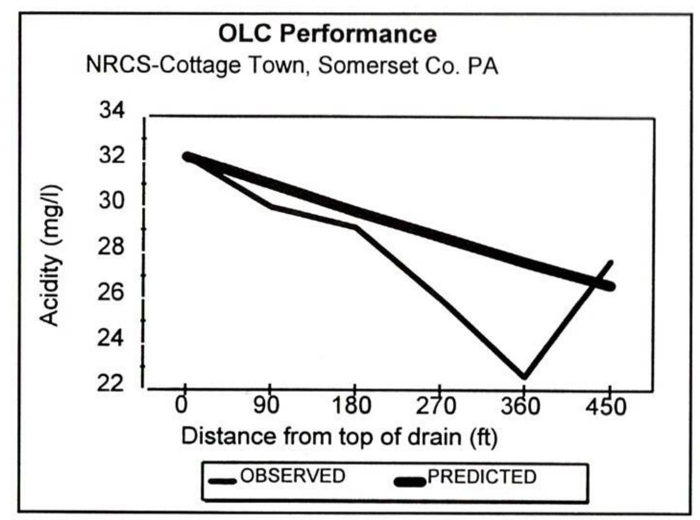


Figure 15. Observed and predicted acidity reductions of an open limestone channel at the NRCS Cottage Town site in Somerset County,PA.

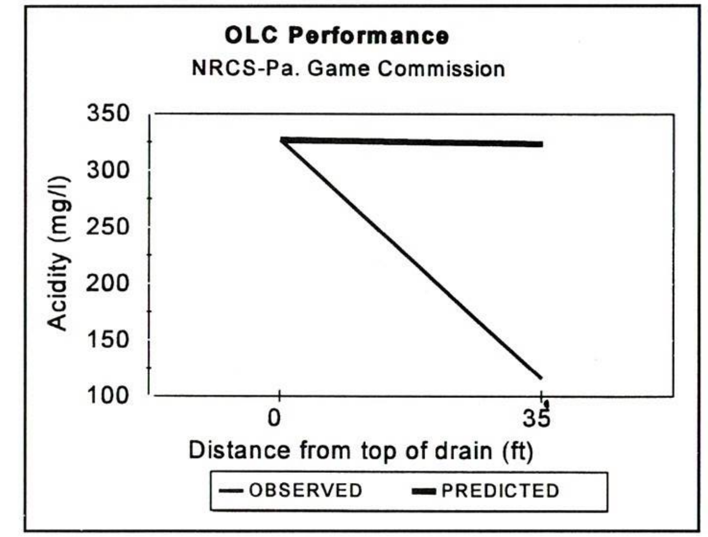


Figure 14. Observed and predicted acidity reductions of an open limestone channel at the Pa Game Commission site in Cambria County, PA.

Discussion and Conclusions

In the laboratory study, ALS treated acidity one-third to one-fourth as fast as ULS. This factor also applies to alkalinity production from ALS and ULS. These values are close to the one-fifth factor reported by Pearson and McDonnell (1974). Acidity reduction of OLCs in the field varied between 4% and 62%, and acid reductions per ft of channel were between .029 and 1.77% (Table 2). The steeper channels performed better than the two channels with shallower (9%) slopes. In the sandstone channel, acidity decreased by only 2% and by a factor of .0028% per ft of channel.

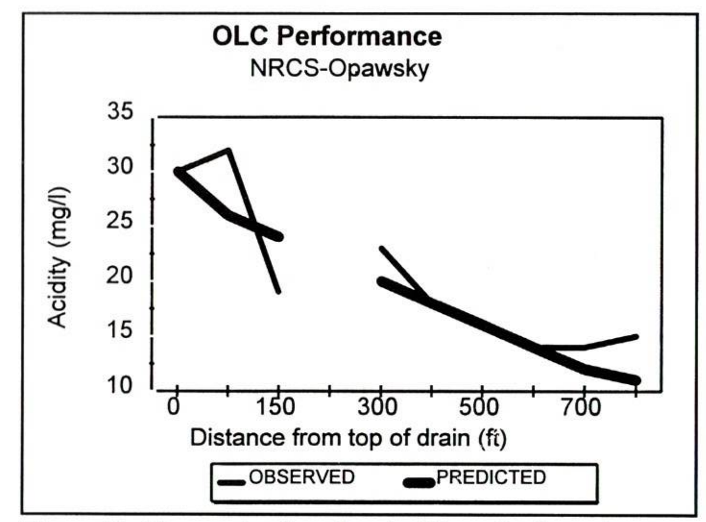


Figure 16. Observed and predicted acidity reductions of an open limestone channel at the NRCS Opawsky site in Armstrong County,PA.

The results confirmed the logarithmic acidity decay curve with ALS reported by Pearson and McDonnell (1974). Thus acidity removal by ALS is proportional to the increment of channel length and cross sectional area, regardless of initial acidity. In other words, a fixed proportion of acidity is removed by ALS per ft of channel (width and depth included). Acidity loss is rapid at first then gradually slows down.

OLC's work best on steep slopes. The key factor in designing OLCs is to prevent iron and aluminum flocs from settling out and plugging the LS pores in the channel. One LS channel not reported here was found on a nearly flat slope (1 to 3%). It was filled with floc and was ineffective in treating acidity. The successful channels generally had slopes above 10% and used coarse LS (15- to 30-cm sized material or 6- to 12-in sized material). Both slope and size of LS can maximize void space and water velocity thereby inhibiting floc settling. Evidence of the effect of slope on ALS dissolution is seen on the Pennsylvania Game Commission and PaDER sites that had LS channels constructed on slopes > 40%. Each of the passive treatment systems (aerobic wetlands, anaerobic wetlands, ALDs, APS, and OLCs) have an area of application (see Faulkner and Skousen 1995 for descriptions and applications of each). It will be difficult to achieve effluent limits by passive water treatment in most cases by using any one method alone. However, coupling these systems could allow some acidity reduction and metal precipitation with one system, then routing the water into another system for additional acidity and metal removal. The primary application of most passive treatment systems will be on watershed restoration projects, AML sites, and perhaps for pretreatments for active treatment systems using chemicals. OLCs are particularly useful in steep terrain where long (300 to 1000 m) channels are possible, and they offer a unique treatment where no other passive system is likely to be appropriate. OLCs will produce metal flocs, so settlement basins should be incorporated in the design. Larger OLCs should have settling ponds or wetlands placed at intermediate points (flat channel segments) to remove the precipitates and help prevent plugging.

The age of the channels studied varied from 2 to 8 yrs and none of these channels had required maintenance. If constructed correctly, OLCs should be nearly maintenance free and less expensive to construct than other systems.

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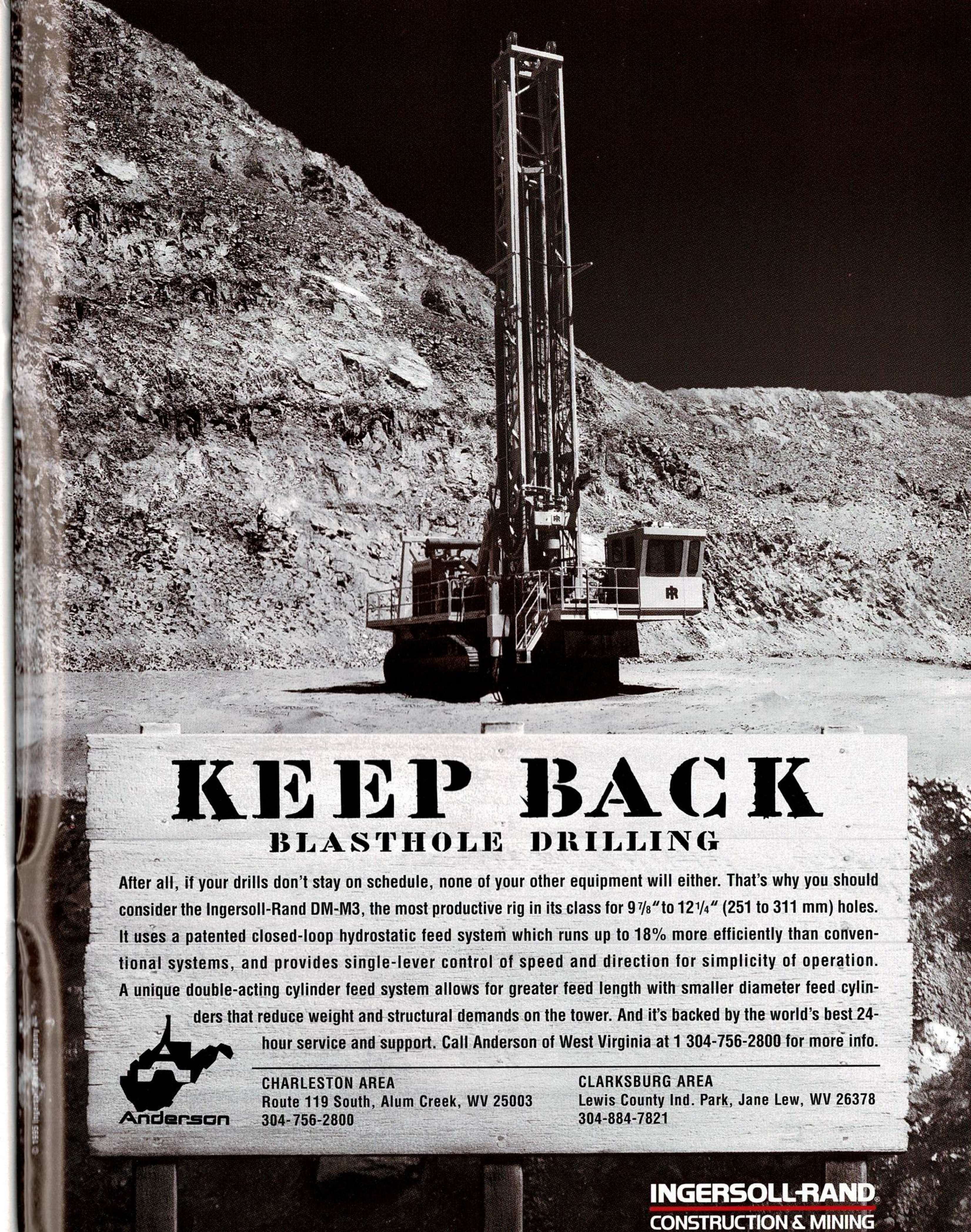

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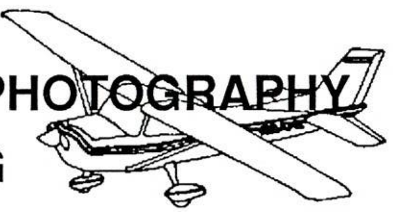

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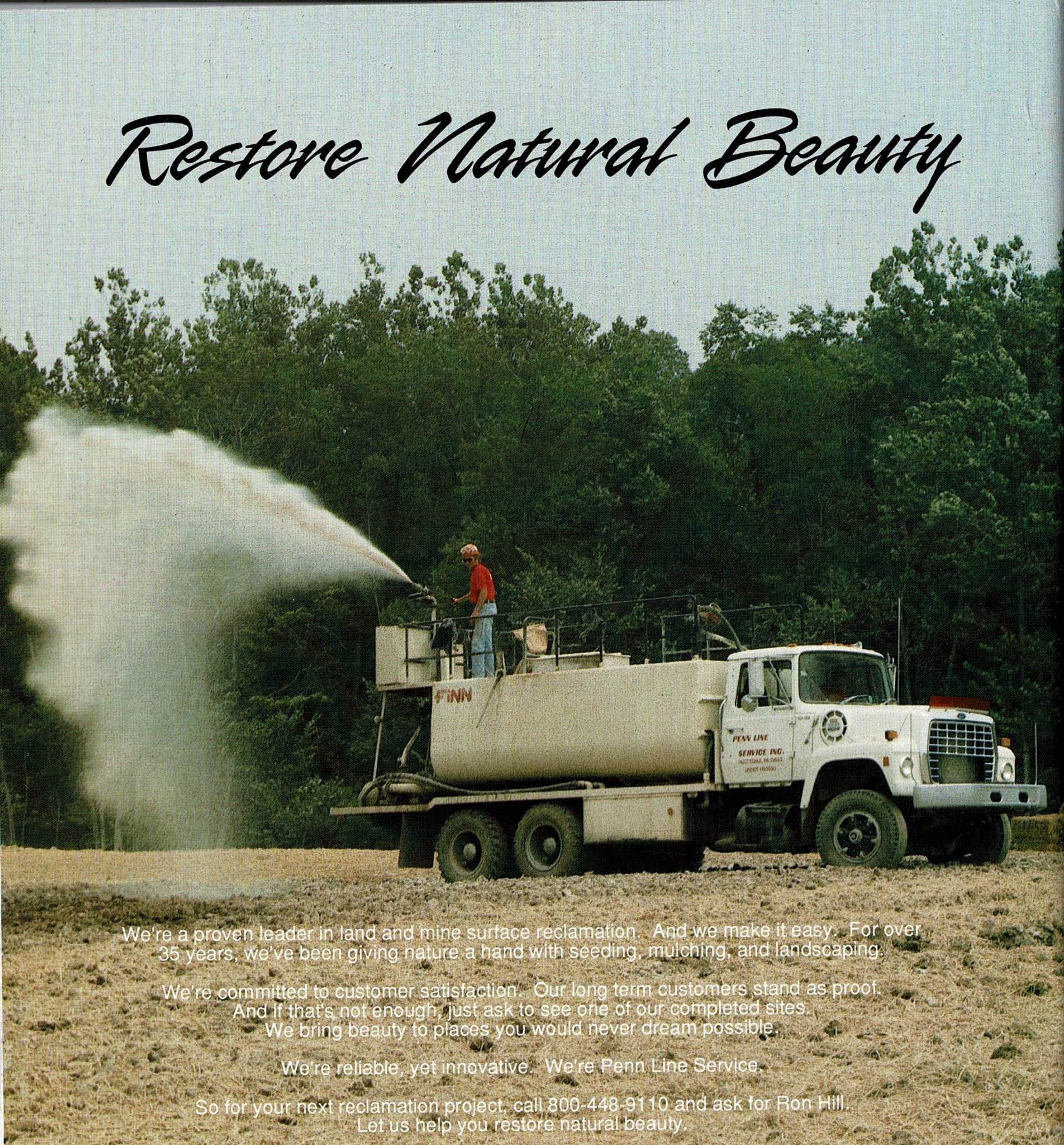

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