How to Evaluate Mining Stocks

by Dr. Mannie Rahn

When evaluating a mining stock, there are several factors that should be considered:

Company Profile: The investor should consider the size, age and history of the company, whether it owns one mine or controls a variety of projects, and whether it specializes in one commodity or has diversified its interests to ameliorate its risk profile. The quality of the various mines, projects under development and exploration prospects are very important. The financial position (including such aspects as hedging policy) will determine whether the company can survive, expand, pay dividends and increase the wealth of the investor.

Management Competence: The strength of the management team and its track record are of cardinal importance. The team's ability to find ore bodies, acquire new ones and expand the company should also be considered.

Type of Deposit: The type of company that is formed to exploit a particular deposit depends on the form in which the mineral deposits occur — from massive formations to narrow, sheetlike bodies.

Quality of the Deposit: The old adage that "a good ore body makes a good mine" remains the most important factor in any mining stock assessment. The deposit must be adequately explored. A bankable feasibility study must be completed (or at least examined) by reputable independent consultants. The study should consider such factors as the availability of basic infrastructure and investment-friendly governments. The return on capital should enhance the value of the controlling company even if it is necessary to bring in partners to lower the risk profile of the investment.

Type of Commodity: The occurrence of commodities is such that, on the whole, the greater number of companies are involved in the exploitation of gold. With the exception of some minor metals, the exploitation of commodities other than gold is dominated by large undertakings.

Valuation Methods: Basically three types of valuation methods are employed in determining the value of a mining stock:

■ The market capitalization per-ounce-in-the-ground method, favored by North Americans and Australians. Using this method, the value of a company, particularly gold, is determined by the exploitable gold remaining to be mined. Applicable to near-surface, low-cost resources, this method implies that a company (in order for its share price to continue rising) must continuously add ounces to its resource base.

■ The traditional price/earnings method, used to derive a historical or future indication of returns. This method is appropriate to the larger, more geographically diverse and commodity-diversified companies.

■ The discounted cash flow method, used where cash flows are determined for the life of a project and then discounted at an appropriate rate to obtain a value. This is the method most favored throughout the world in determining the viability of projects.

Conclusion: No single criterion can provide a complete answer to how a stock should be valued. All the methods are subject to the status and activities of the resource company and the vagaries of the commodity cycle.

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Mining A Wisconsin Tradition

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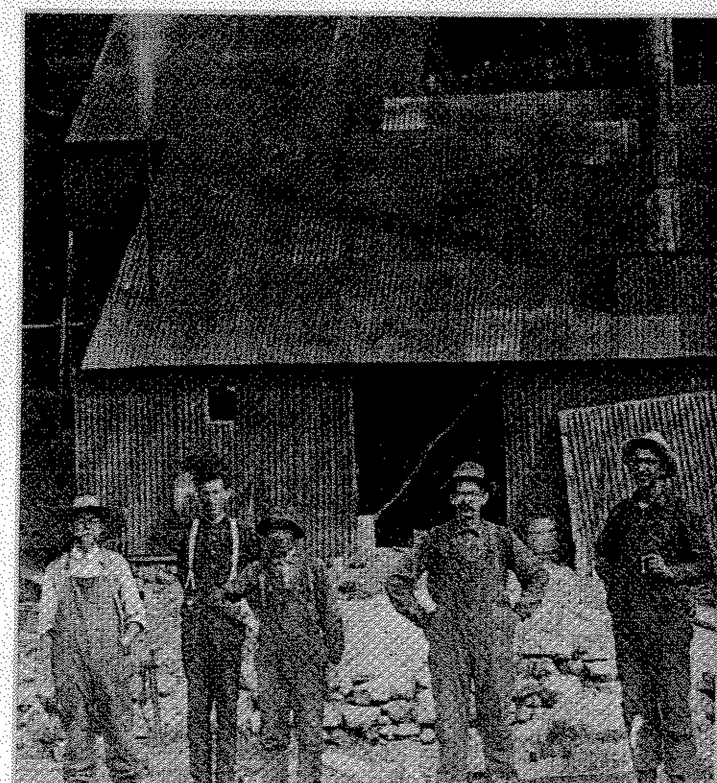


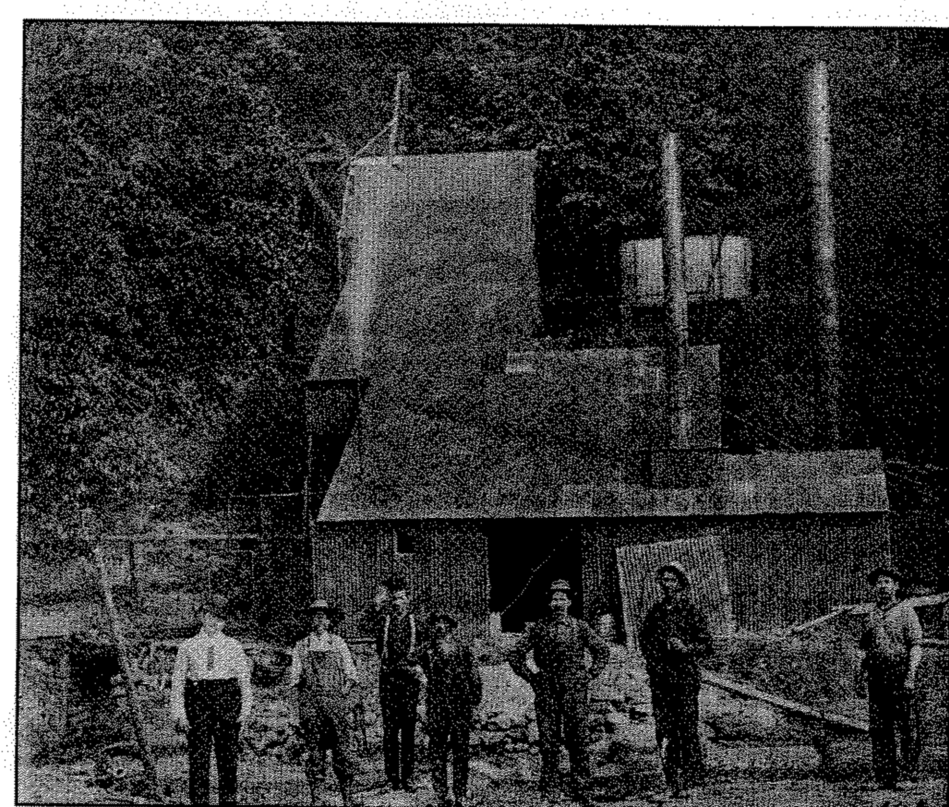
Modern Mining Builds On A Wisconsin Tradition

• The first major influx of settlers to Wisconsin consisted of lead prospectors and miners. In 1836, when the Wisconsin Territory was formed, 5,000 of its 11,000 settlers lived in the southwestern lead region.

• During its history, Wisconsin has been a major producer of lead, zinc and iron. As late as 1968, it was among the nation's top ten zinc producers.

• In 1971, the Wisconsin Legislature passed a bill designating galena – lead sulfide – as the official state mineral.

• To this day, more than 10,000 Wisconsin residents are employed in mining-related jobs.



Early miners, circa 1900, stand outside a small zinc mine near New Diggings, Wisconsin. At this mine, ore was removed by tunneling into the hillside. This operation included a mill that produced zinc concentrates, which were shipped off-site for smelting.

When we think of mining states, we often look west to Nevada, Wyoming and Colorado, or north to Alaska, or east to the Appalachians. But Wisconsin itself has been and remains an important mining state. Driving through the scenic hill country in the state's southwest corner, it is hard to imagine the area as one of the most productive metallic mining regions in the United States. But it was. From small lead mines carved out of hillsides in the 1800s, to large underground zinc mines that operated into the 1970s, Wisconsin contributed greatly to the nation's metal supplies.

Metallic mining in Wisconsin began well before 1700, when Native Americans mined lead in the southwest region. It continued almost without interruption into the 1980s, with lead, zinc and copper production in the southwest, and with iron ore production around Florence, Hurley, Iron Ridge, Baraboo and Black River Falls.

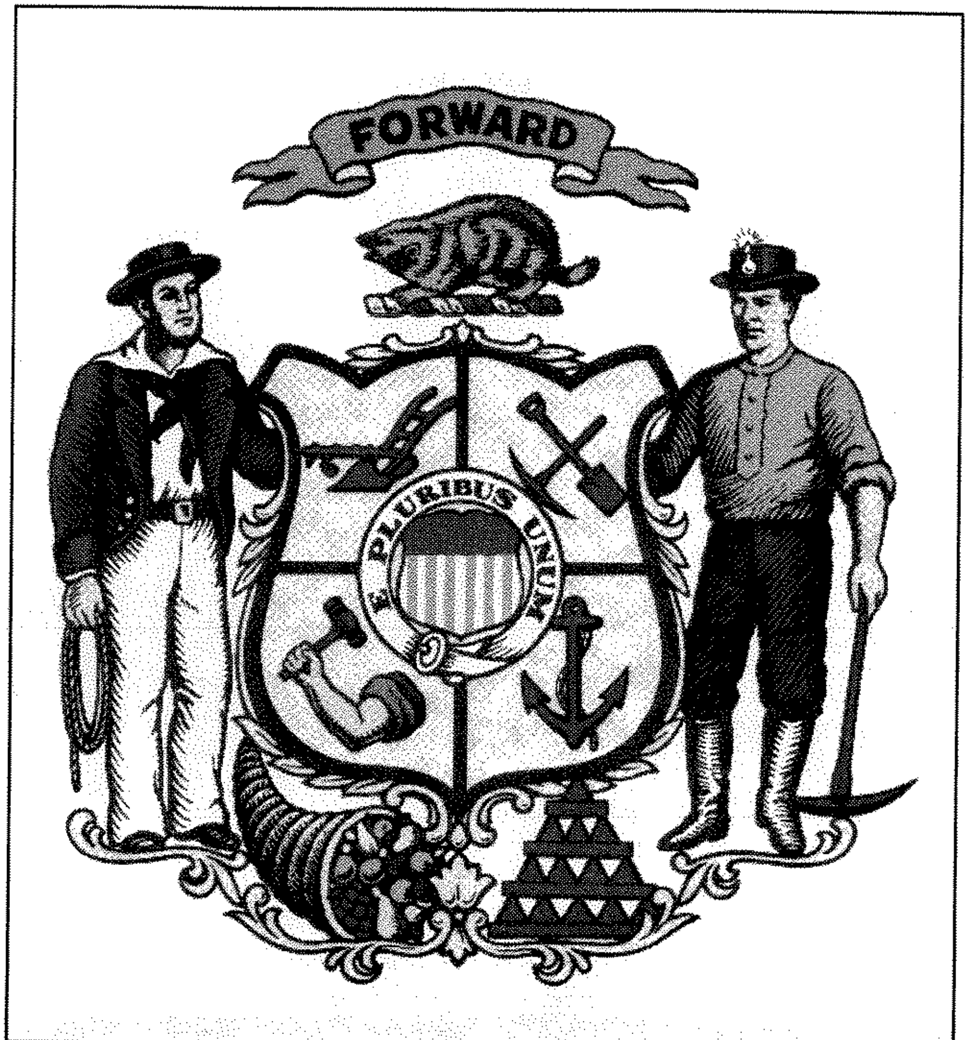
Today, mining is back in the state's economic picture. The open pit Flambeau copper/gold mine in Rusk County is nearing the end of its productive life, and reclamation has begun. Crandon Mining Company is now seeking permits for an underground zinc/copper mine in Forest County. Meanwhile, other mining companies are actively exploring for ore deposits elsewhere in the state.

Far from representing a "new" industry, these projects continue a long-standing tradition – one that has contributed greatly to the state's character and prosperity.

Wisconsin's Mining History:

A Snapshot

One look at Wisconsin's territorial and state seals shows how important mining was to early settlement and economics. But European settlers were not the first miners in the region. Historic records show that Native Americans mined lead ore as early as 1658-59 (and probably long before that) within what is now called the Upper Mississippi Zinc-Lead District. This district covers some 4,000 square miles, most of it in southwest Wisconsin, but including parts of northeast Iowa and northwest Illinois. Over the years, thousands of small lead mines, about 400 zinc mines and several small copper and iron mines were operated within the district. All told, these mines produced some 69 million tons of zinc ore and more than 1 million tons of lead metal. In addition to the lead and zinc mines, Wisconsin was home to several of the nation's most significant iron mines, which operated until as recently as 1983.



The Wisconsin State Seal shows a miner, mining implements, stack of pig lead and the badger, a symbol of early lead miners who burrowed into hillsides. The state seal also appears on the state flag.

Lead Mining

French explorers and resident Native Americans mined lead on a small scale in the Upper Mississippi district throughout the 18th Century. The first lead smelter in what became Wisconsin was built in 1816 at Gratiot, in what is now LaFayette County.

The first major lead strikes in Wisconsin were near New Diggings, Hazel Green (then called Hardscrabble) and Shullsburg in 1825. More large finds were made around Benton, White Oak Springs and Willow Springs in 1826. William S. Hamilton, son of the famous Federalist and the first U.S. Secretary of the Treasury, Alexander Hamilton, found a large lead deposit neat Wiota in 1827. Extensive mining around Platteville began in 1828.

With these and other discoveries, annual lead production grew from 440,000 pounds in 1825 to 13 million pounds in 1829. By that time, 4,253 miners were digging for lead in Wisconsin, and 52 smelters were operating. These early miners gave Wisconsin its nickname, the Badger State. Too busy digging for the "gray gold" to build houses, some miners moved into abandoned mines or, like badgers, lived in burrows in hillsides.

From 1830-71, the Upper Mississippi district was by far the most important lead-producing area in the United States. The metal was used mainly for pewter, weights, printers' type, shot, pipe, roofing and paint.

The lead region furnished many leaders in territorial government and in the attainment of statehood. For six of the twelve territorial years, the region provided the delegate to Congress. It provided the territorial governor for eight years, as well as the state's first governor, Nelson Dewey.

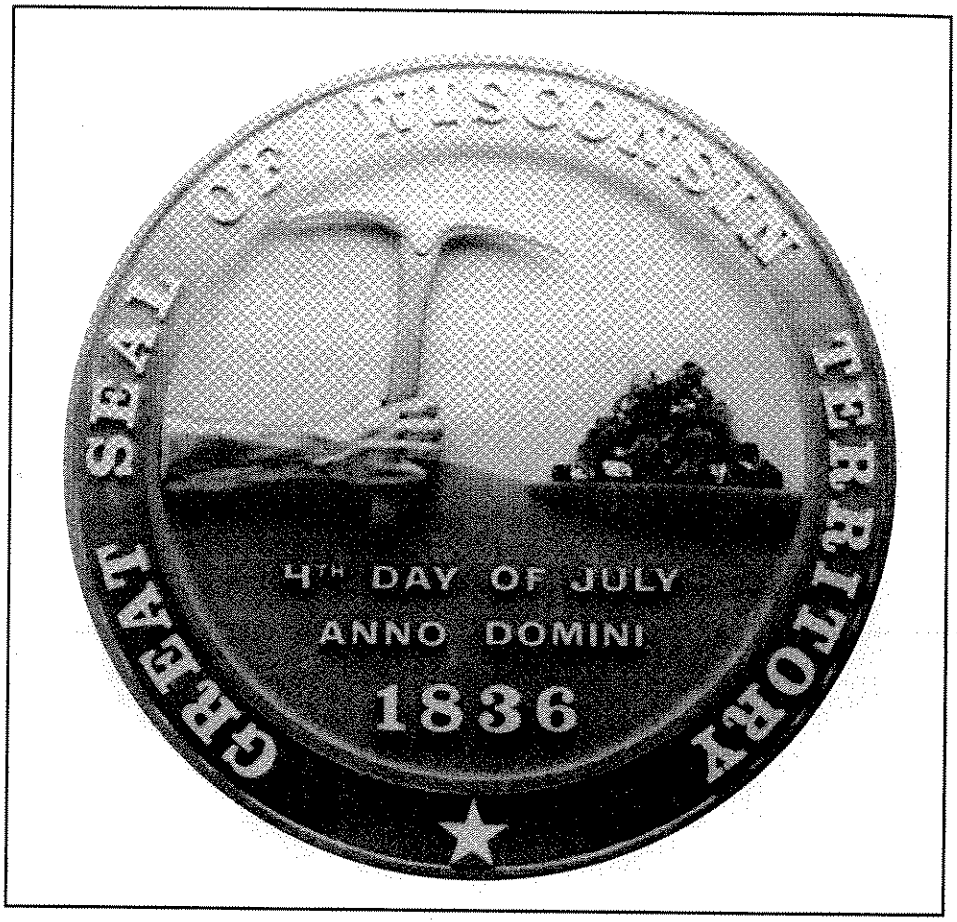
In 1871, the University of Wisconsin created a Department of Mining and Metallurgy. In 1908, the Legislature established The Wisconsin Mining Trade School at Platteville. In 1939, it became The Wisconsin Institute of Technology, and in 1959 it merged with The Wisconsin State College-Platteville, forerunner of what is now The University of Wisconsin-Platteville.

ZINC MINING

Lead mining began to decline in 1848 and, by the late 1800s, zinc had taken over as the primary ore in the district. Lead remained important, however, and the district also produced some copper and iron ore. By 1911, Wisconsin ranked third among zinc-producing states. Production rose steadily, peaking in 1917, when the district produced 64,000 tons of zinc metal. At the onset of World War I, more than 5,000 miners were at work in the district.

Zinc mining was most heavily concentrated in the Shullsburg/Benton area, but the Platteville, Dodgeville and Mineral Point areas also saw major activity. The Mineral Point Zinc Company operated a major zinc oxide processing plant from the late 1800s to 1931. Other important zinc-producing areas were Hazel Green, Cuba City, Linden, Highland and Mifflin.

Zinc production declined sharply during the Great Depression in the 1930s, but rose again during World War II. During the war years, 30 to 40 mines were operating in the Upper Mississippi district. Between 1948 and 1968, Wisconsin remained among the nation's ten largest zinc producers. Most of the zinc was used in galvanizing and for the manufacture of brass and other alloys, batteries, and for zinc oxide, used in making paint, rubber and pharmaceuticals.



The Wisconsin Territorial Seal demonstrates the importance of mining to the region. The first major influx of settlers to what became Wisconsin consisted of lead prospectors and miners. This photograph shows a replica of the Territorial Seal on display at the Mining Museum in Platteville.

IRON MINING

Besides lead and zinc, Wisconsin contained all or parts of six iron ranges in scattered locations. These deposits were mined from the mid-1800s through the early 1980s. The last of Wisconsin's iron mines was the open-pit Jackson County mine, operated from 1969-83 by Jackson County Iron Company, a wholly owned subsidiary of Inland Steel. Its on-site taconite plant had capacity to produce 750,000 tons per year. The Jackson County mine site has been fully reclaimed and is now the 3,200-acre Wazee Lake Recreation Area. Its centerpiece is the reflooded mine pit, now called Wazee Lake. This deep, clear, 146-acre lake is a popular fishing place and a major attraction for scuba divers. Other Wisconsin iron ranges were:

Iron Ridge/Neda. The Iron Ridge open pit and underground mine in Dodge County produced 436,000 tons of ore from 1849-92 and from 1896-1914. The nearby Mayville mine produced 2.1 million tons of ore from 1892-1928. Mayville was also the site of a large iron smelting works.

Menominee Range. A small part of this important Upper Michigan range extends into Wisconsin. The Florence County mines produced about 7 million tons of ore through 1955.

Gogebic/Penokee Range. The Wisconsin part of this historic 53-mile-long iron range stretches west from Hurley to Pence. It includes the Montreal mine, the world's deepest underground iron mine, which yielded 44 million tons of exceptional quality ore from 1886-1962. This district supplied U.S. and Canadian steel mills for 80 years. At peak production, the Gogebic's mines in Wisconsin and Michigan employed 6,000 miners. The headframe of the Plummer mine, the last surviving headframe in the state, is the centerpiece of an Iron County Heritage Area.

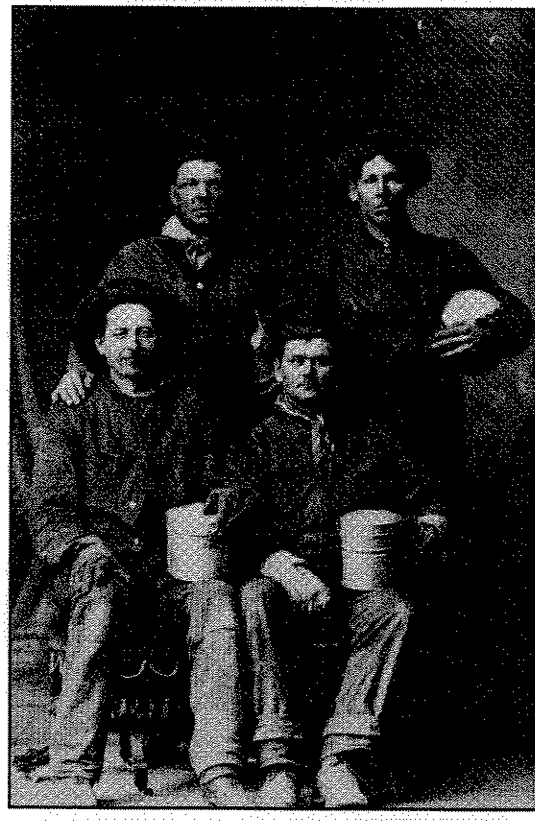
Sauk County. The open pit Ironton mine operated from 1850 to 1880, and the underground Illinois and Cahoon mines near Baraboo produced ore from 1904-25.

The Legacy of Mining in Wisconsin

As pervasive as mining once was in southwestern Wisconsin, its remaining traces are often difficult for any but trained observers to see. Almost all of the mining structures are gone. Many of the waste rock and tailings piles have been removed, or have been covered and vegetated so that they blend in with the landscape. People familiar with mining history can point out remnants of mining operations, and features like "badger holes" left by the small, shallow excavations of early lead miners.

Mining hsitory lives on at the Pendarvis Historic Site in Mineral Point, with its century-old homes built by Cornish miners; at mining museums in Platteville and Shullsburg, where visitors can descend into actual lead mines; at the State Historical Society of Wisconsin museum, which includes a lead-mining exhibit; at Tower Hill State Park near Spring Green, once the site of a lead shot producing operation; and at local heritage museums in Hurley, Benton and Mayville.

But the most significant reminders are the communities that sprang up when mining was thriving and remain prosperous to this day. These communities



Four lead miners from Benton area in the late 1800s show their version of the modern-day lunch bucket. The metal containers, called pie cans, carried meat pies called pasties – still a popular food in Wisconsin and Upper Michigan. Pasties, containing meat, potatoes and a variety of vegetables, were a favorite of Cornish miners because they provided a hearty meal that retained heat for many hours and could be eaten without utensils.

were created by wealth produced in the mines, which extend beneath the streets on which residents and visitors now travel.

When mining wound down, the communities made successful transitions to other industries. For example, Mineral Point and Hazel Green have capitalized on the charms of their Victorian architecture to become centers for tourism, with numerous antique shops and bed-and-breakfast inns. Dodgeville has grown dramatically with the Land's End mail-order clothing business. Platteville is home to a state university campus and a growing industrial base, with the recent addition of a Penda Corporation plastics manufacturing plant.

Historic Mines and the Environment

In contrast to some mining areas in Western southwestern Wisconsin's mining areas experienced few environmental problems. That is partly because of the geology of the historic mining districts.

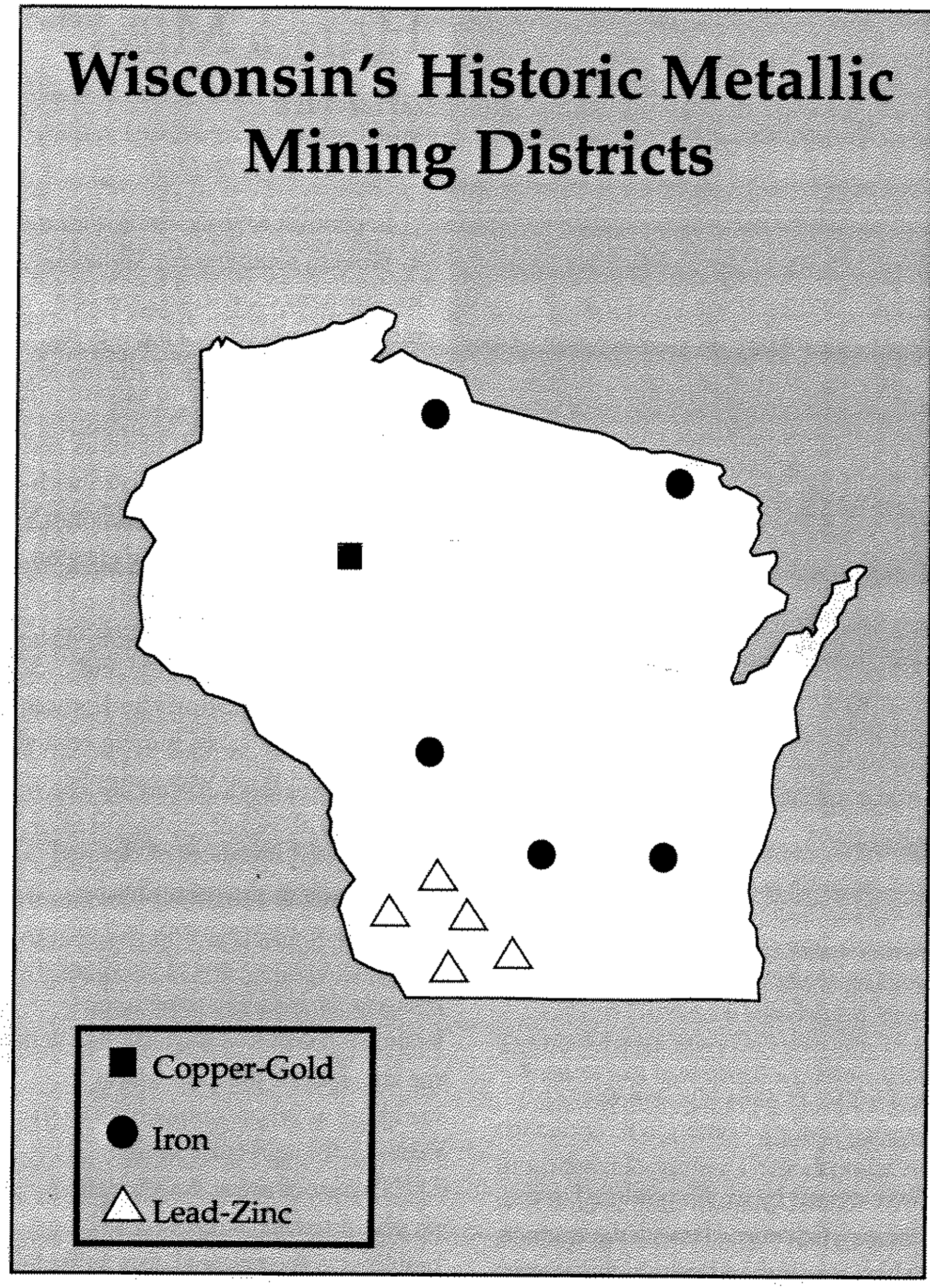
Regardless, hundreds of mines and mills in the district were closed without any reported water pollution. Extensive well tests across the region, conducted by the Wisconsin Department of Natural Resources, the Wisconsin Geological and Natural History Survey and others, show no evidence of mining-related harm to drinking water supplies from heavy metals or acid, and only a few isolated instances of elevated sulfate levels in the groundwater.

While a few waste rock and tailings piles remain from some of the larger mines in the zinc-lead district, the landscape shows few ill effects. Many of the larger waste piles are rapidly vanishing as private companies use the materials for road construction.

This is not to say there have been no mining-related environmental problems in the zinc-lead district. Several water problems have been identified in recent years, although none of those in Wisconsin caused persistent problems on more than a very localized scale.

Shullsburg Mine. A year after this major lead-zinc mine closed in 1979, several private wells in the immediate area showed elevated levels of sulfate. Citizens complained to the DNR, and ultimately a number of neighboring home and agricultural wells were abandoned and replaced.

Brewery Creek. Zinc processing during the first decades of the 20th century left five large piles of roaster



Wisconsin's Historic Metallic Mining Districts

waste near Mineral Point. Over time, leachate from these wastes made its way into Brewery Creek, a small, spring-fed stream that flows into the Mineral Point branch of the Pecatonica River. The leachate colored the stream bright orange, acidified the water for several miles downstream, and depleted fish life. In a clean-up completed in 1993 under DNR supervision, the waste was moved to a new site for containment, the stream was rerouted, and the area was graded and seeded with native grasses and plants. Water quality in the creek has improved markedly and fish populations have rebounded, although the recovery is not yet complete.

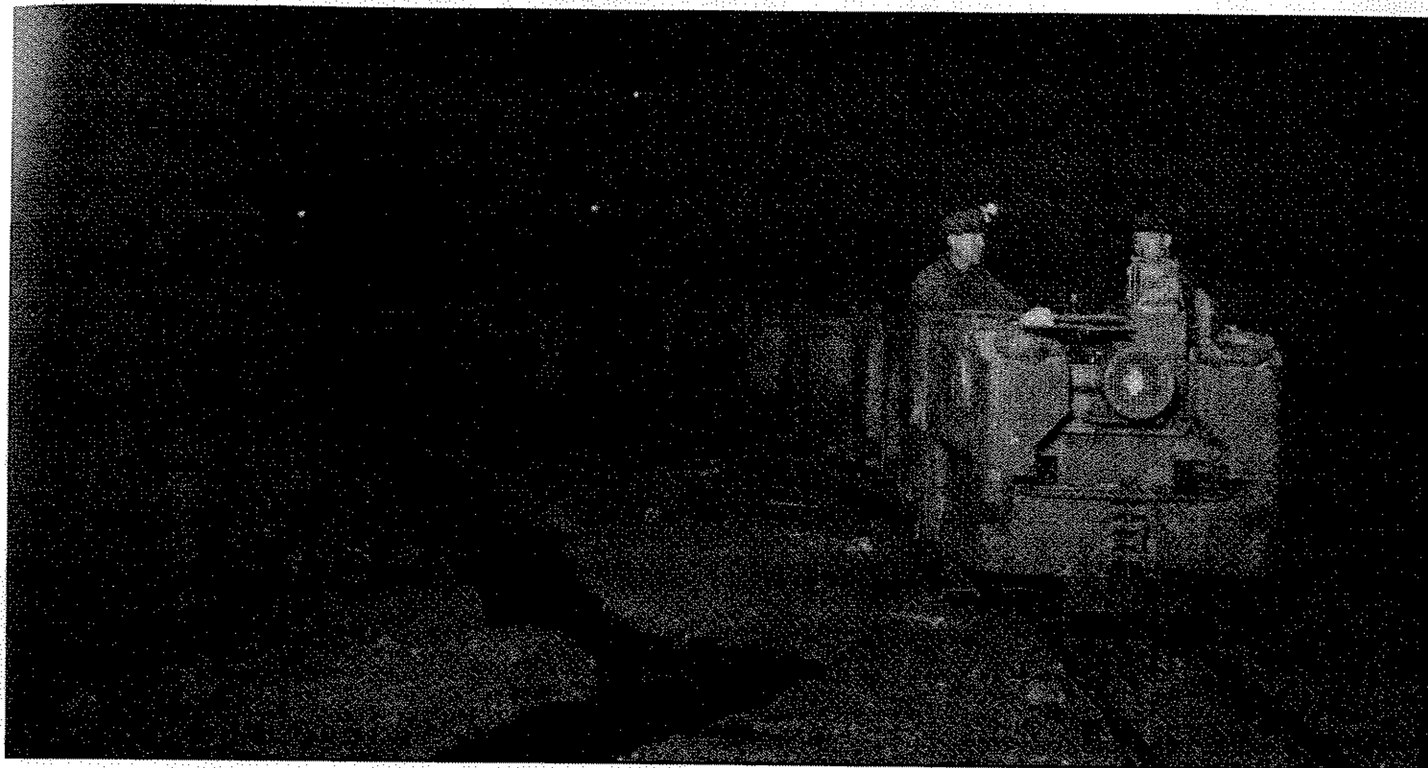
Skinner Roaster, New Diggings. In the early 1900s, processing by the Wisconsin Zinc Company at The Champion Mine near New Diggings left a roaster waste pile in a neighboring wetland. Leachate from the waste pile washed into a small tributary to the Fever River during localized flooding in spring 1993. The roaster waste will soon be removed as part of a DNR supervised cleanup project that started in fall 1996.

Environmental Problems in Modern Perspective

Mining has changed drastically since even the most recent of Wisconsin's lead and zinc mines closed down. The few incidents listed above, and other small-scale problems that may exist elsewhere, resulted from practices that today would be against the law.

Old mines and mills in Wisconsin used low technology and operated when there were few environmental regulations. Waste rock and tailings from these mines were simply placed in piles exposed to the elements. Water pumped out of mine workings was discharged onto the ground or into streams without treatment. Few mines were formally reclaimed.

Problems caused by these practices in Wisconsin and elsewhere led to the comprehensive mining regulations that exist today. New mines cannot open without reclamation plans that ensure long-term environmental safety. Mine water cannot be discharged unless it meets strict quality standards that protect even the most sensitive aquatic life. Groundwater regulations protect drinking water quality. Mine tailings must be placed in engineered facilities that protect ground and surface waters. These facilities must be designed for the specific characteristics of the site and of the tailings material.



By the 1920s and 1930s, mines began installing powered equipment, such as this electric locomotive used to move ore from the working face of the mine to the bottom of the shaft. From there, the ore was hoisted to the surface for milling. This locomotive operated at the Crawford mine near Hazel Green.

If those standards had been in place when Wisconsin's lead-zinc region was active, the handful of past environmental problems would have been even fewer. But, as it stands, given the number and pervasiveness of the mines in southwestern Wisconsin, the industry left behind a remarkably clean legacy.

The Mining Industry in Wisconsin Today

Mining remains important to Wisconsin's economy, with or without the Flambeau mine and the proposed Crandon project. Since it opened in 1993, the Flambeau operation has employed an average of 60 people in well-paid positions. The Crandon mine, if permitted, will employ some 400 during an estimated 28 years of production.

Meanwhile, other Wisconsin companies supply equipment and services to the mining industry in North America and worldwide. These include Falk, Harnischfeger, Nordberg, Rexnord and Bucyrus International in Milwaukee, Applied Power in Butler, Young Radiator in Racine, Telsmith in Mequon, Svedala Industries in Waukesha, Intetractor America Corp. in Elkhorn, Enginaire in Janesville, and Ansul, Inc. in Marinette. The Wisconsin Mining Association estimates that 10,000 state residents hold mining-related jobs.

Mining has been, and remains, a part of Wisconsin's culture, character and economy. Modern mining, with state-of-the-art technology under strict environmental regulations, can return this essential industry to prominence in our state, providing family-wage jobs while protecting the natural resources state residents hold dear.

*** Historic photos unless otherwise noted courtesy of Benton (Wis.) Museum.*

Wisconsin Manufacturers & Commerce

Memo

TO: Assembly Committee on Environment

FROM: Joan M. Hansen, Director Tax & Corporate Policy

DATE: May 12, 1997

RE: Engrossed 1997 Senate Bill 3/1997 Assembly Bill 70

Wisconsin Manufacturers & Commerce (WMC) **strongly opposes** 1997 Senate Bill 3 (and Assembly Bill 70) introduced by Senator Shibilski and Representative Black. Senate Bill 3 in effect places an indefinite moratorium on sulfide metallic mining in Wisconsin.

Senate Bill 3 states that before a mining permit can be issued in Wisconsin there must be proof that a mine has operated in the US or Canada for at least 10 years **without polluting** groundwater or surface water, and that the mine has been closed for 10 years **without polluting** groundwater or surface water.

SENATE BILL 3

Requires Old Technology

Senate Bill 3 is definitely a step in the wrong direction because it ***requires*** that old technology be examined for current or future mining projects in light of today's technology. Mining projects currently operating are using the most state-of-the-art technology of today, and continuously upgrade operations to ensure that the environment is being protected. The focus of SB 3 should be on present day science and technology, not past mining operations.

Neutralizing Geologies

The Senate revised the bill to require that applicants use examples of mines that have operated "in a sulfide ore body which is not capable of neutralizing acid mine drainage." This is extremely vague language and may be interpreted in many ways. Taken literally, virtually all ore bodies are capable of neutralizing acid mine drainage to some extent. The bill, therefore, creates a requirement that cannot be met, thus banning mining permanently.

Ambiguous

Although the Senate included language to define pollution as "degradation that results in any violation of any environmental law," it provides no standards for how an **alleged** violation should be determined. Without requiring an "adjudicated violation", a mining company would have to wait until the DNR clarified and interpreted this language. This opens the door for endless interpretation and potential litigation.

INDUSTRY IMPACT

Furthermore, Senate Bill 3 and Assembly Bill 70 send the message to the business and manufacturing community that industry and their investment in the state are not safe here in Wisconsin. The bill singles out one industry, the metallic mining industry, and basically one company, the Crandon Mining

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Company. It is intended to stop mining in Wisconsin even though Wisconsin's strict laws mandate environmental protection of our pristine natural resources.

Although Senate Bill 3 seems reasonable on its face, it is in fact a ban on mining. As stated earlier, vague language contained in the bill will open the door to litigation for years to come, ultimately putting a halt to any mining project. It is in essence a ban because no mining company will spend millions of dollars in the application and permitting process without knowing what standards must first be met.

A ban on mining undoubtedly goes against the intent of the Wisconsin legislature. The laws are clear. The Wisconsin legislature specifically authorized mining in the state provided it's accomplished in an environmentally sound manner. In Wisconsin environmental protection has always been a priority, should always be a priority and will always be a priority.

As you know, Wisconsin has long been regarded as having one of the most comprehensive and effective environmental regulatory programs in the country. For industry that has often meant having to comply with standards that exceed national norms or those in place in other states. This certainly holds true for mining.

The basic premise of mining opponents seems to be scientists, engineers, and regulatory agencies cannot be trusted to ensure the environment will be protected, and therefore a complete ban on a particular form of industrial activity is warranted. This can only be described as environmental extremism.

Who will be next if we begin to move down this path? Will it be the paper industry that draws heavily on Wisconsin's water resources or the timber industry that necessarily disturbs land in Northern Wisconsin. All industrial activity must comply with current laws and regulations which are based on protecting the environment through scientific methods.

The approach that has been taken with the mining industry is in sharp contrast to the historic approach taken in Wisconsin where the application and enforcement of a comprehensive regulatory program has fostered both a strong economy and clean environment.

Again, WMC urges you to oppose these bills.

Executive Summary

A Survey of Modern Mining Principles and Practice At Mines Throughout North America

A number of mining success stories are compelling evidence that metallic mineral mining can supply the materials we need and protect the environment we value

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A Precambrian volcanogenic massive sulfide mineral belt in Northern Wisconsin has attracted the attention of mining and mineral exploration companies for over 25 years. Two commercially viable deposits have been discovered: the Flambeau deposit in Ladysmith and the Crandon deposit in Crandon.

The Flambeau Mine, an open-pit copper mine, began operations in 1993.[1] It has a spotless environmental record, and final reclamation is set to begin in 1997. Currently, Crandon Mining Company (CMC) is in the permitting process to build, operate and reclaim the Crandon zinc and copper deposit.

Despite the success of the Flambeau project and Wisconsin's comprehensive regulatory structure,[2] mining opponents in Wisconsin have continued to insist that mining is inherently incompatible with environmental protection. In 1995–97, those charges have taken the form of proposed legislation which challenges the mining industry to prove sulfide mining can be done in an environmentally safe and responsible manner.[3] This debate is not unique to Wisconsin. Across North America, mining industry detractors rely on outmoded images of mining to bolster their claims that no mining is safe.

In support of its planning and permitting process and its position that the hard rock mining industry has, can and will continue to operate mines that use proven technology and sound science to comply with comprehensive state and federal laws, CMC commissioned a study to determine the extent and degree of environmental awareness and sensitivity in mining and processing operations and to locate examples of environmentally responsible operations in a sulfide ore environment.

CMC retained the services of two highly respected and experienced mining environmental experts to conduct the survey, Jeffrey Todd and Debra Struhsacker.[4] In addition to identifying mining operations that meet the arbitrary criteria contained in AB 758, introduced in 1996, their survey focused on substantiative documentation and real measurements of how well the mining industry is performing and can perform.

The survey was initiated in the fall of 1995. Hundreds of potential sites were screened to determine which were operating within or had historically operated within a sulfide ore zone. Over the course of several months, more than 150 telephone discussions with the companies, regulatory agencies and industry and environmental organizations were initiated to narrow the field of study. More than two dozen active and closed mines were identified for possible site visits, and 14 visits were conducted in the fall of 1996.

Modern Mining Success Stories: Six Exemplary Mines

- The Henderson Mine and Mill
  Empire, Colorado
- The McLaughlin Mine
  Lower Lake, California
- The Cannon Mine
  Wenatchee, Washington
- The Viburnum Mine No. 27
  Viburnum, Missouri
- The Stillwater Mine
  Nye, Montana
- The Flambeau Mine
  Ladysmith, Wisconsin

The survey reveals four key points:

- There are mines in Southwest Wisconsin that meet both criteria contained in AB 758.
- In addition, several active operations answered part of the challenge set for in AB 758, namely "that a mining operation has operated in a sulfide ore body in the United States and Canada for at least 10 years without polluting groundwater or surface water from acid drainage at the tailings site or at the mine site or from release of heavy metals."
- The bill sets arbitrary standards without scientific or technical basis and thus eliminates many exemplary mines from consideration, including many that use state-of-the-art technology and environmental controls but simply have been closed and reclaimed for less than the 10-year criterion. Mines examined as part of this study include those that have been successfully reclaimed within the last 10 years.
- A more meaningful yardstick for measuring the success of a mining operation must include the following criteria: the existing regulatory framework and the level of enforcement of those laws; the application of sound science and proven technology in all aspects of the mine's design and operations; the attention to reclamation, ongoing monitoring and closure inherent in modern mining; and the commitment of the mine operator to meet, or surpass existing environmental expectations as well as community and public expectations.

The Todd and Struhsacker survey evaluated environmental practices at modern mines and identified active, reclaimed, closed and partially closed mines that employ sound proactive and contemporary environmental management practices. In this manner, the survey focuses on identifying environmentally responsible mines that have been developed under the current regulatory framework and that have used modern pollution prevention and environmental protection technology. Metallic mining under the modern, stringent, environmentally sensitive regulatory climate at the state and federal levels is a completely different enterprise than 100 year ago…or even 20 years ago.

In short, the survey identified mines that meet a higher standard than AB 758 or subsequent bills demand.

Findings of Fact

Today's mines are highly regulated and make extensive use of pollution prevention technology. It is inappropriate to use environmental problems at antiquated mine sites to predict what will happen in the future at modern mines.

Environmentally responsible operations are evident at every active mine site explored by this survey.

There are examples of currently active sulfide mines that have been in operation for more than 10 years and have not caused surface or groundwater pollution.

There are several successfully closed and reclaimed mines that operated for at least 10 years

There are a number of old lead-zinc sulfide mines in southwestern Wisconsin that operated for more than 10 years, were either closed or mined out more than 10 years ago and have caused no known surface or groundwater pollution problems.

A more meaningful measure of compliance with all applicable environmental protection standards would evaluate operating and closed sites that are subject to rigorous and regular monitoring, reporting, and inspection requirements.

For a complete copy of the report, published by the Society for Mining, Metallurgy, and Exploration, Inc. (SME), please contact the Executive Director, Wisconsin Mining Association, P.O. Box 352, Madison, Wisconsin 53701-0352.

Footnotes:

1. For a complete record of the Flambeau Permitting Process, see Decision, Findings of Fact, Conclusions of Law and Permits, State of Wisconsin, Division of Hearings and Appeals.

2. Wisconsin's mining laws are discussed in detail in The Wisconsin Geological and Natural History Survey (WGNHS) of the University of Wisconsin-Extension Special Report 13, Wisconsin's Metallic Mining Regulations.

3. Several versions of the mining ban bill have been introduced: 1995–96, AB 758; 1997, AB 70 and SB 3.

4. Mr. Todd has degrees in wildlife ecology and more than 23 years' experience in environmental and regulatory affairs. Ms. Struhsacker is a geologist with over 20 years of experience in the mining industry, 11 of which have dealt with environmental and regulatory issues.

Regulatory Time Line

Comprehensive Regulations Define Modern Mining

Date	Commencement of Mining Activities	Enactment of Environmental Laws or Regulations Affecting Mining
1825	Upper Mississippi Valley lead mining (Southwestern Wisconsin and adjacent Iowa and Illinois)	
1849	California—gold mining	
1858	Colorado—precious metals mining	
1859	Nevada—Comstock Lode silver and gold mining	
1862	Montana—gold mining	
1863	Utah—copper mining	
late 1860s	Upper Mississippi Valley zinc mining (Southwestern Wisconsin and adjacent Iowa and Illinois)	
1875	South Dakota—Black Hills gold mining	
1877	Colorado—base metal mining, and Arizona—copper mining	
1882	Montana—copper mining	
1917	Colorado—molybdenum mining	
1965	Nevada—Carlin-type gold mining started	
1966		National Historic Preservation Act
1967		Air Quality Act
1969		National Environmental Policy Act (NEPA)
1970		Occupational Safety and Health Act (OSHA), Clean Air Act, and CA Environmental Quality Act (CEQA)
1971		MT Metal Mine Reclamation Act and MT Environmental Policy Act (MEPA)
1972		Federal Water Pollution Control Act/Clean Water Act
1973		Endangered Species Act
1974	Mining begins at Henderson Mine, CO	Safe Drinking Water Act (SDWA) and U.S. Forest Service Mining Regulations
1975		CA Surface Mined Land Reclamation Act (SMARA)
1976		Federal Land Policy and Management Act (FLPMA), Resource Conservation and Recovery Act (RCRA), Clean Water Act Amendments, and CO Mined Land Reclamation Act
1977		Mine Safety and Health Act (MSHA), Surface Mining Control and Reclamation Act (SMCRA), WI Metallic Mining Reclamation Act, and ID Surface Mining Act
1979		Archeological Resources Protection Act
1980	Mining begins at Jerritt Canyon, NV	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as Superfund
1981	Viburnum Mine No. 27 becomes drinking water source for Viburnum, MO	U.S. Bureau of Land Management Mining Regulations
1982		SD Mined Land Reclamation Act, WI Metallic Mineral Mining (Ch. NR 132) and Regulation of Metallic Mining Waste (Ch. NR 182)
1984		Hazardous and Solid Waste Amendments, CA Chapter 15 Discharges of Waste to Land, Article 7, Mine Waste Management
1985	Mining begins at Cannon Mine, WA, McLaughlin Mine, CA, and Sleeper Mine, NV	
1986	Mining begins at Goldstrike Mine, NV and Montana Tunnels, MT	Superfund Amendments and Reauthorization Act, and Emergency Planning and Community Right-to-Know Act
1987	Mining begins at Stillwater Mine, MT	UT Mined Land Reclamation Act (amended)
1988		ID Code §39-118A (statutory provision requiring permits for processing ore by cyanidation)
1989		NV Mined Land Reclamation Act and MT Admin. R. §§26.4.160 to .168, and NV Water Pollution Control Law
1990		Clean Air Act Amendments and CO Mined Land Reclamation Act Amendments
1993	Mining begins at Flambeau Mine, WI	

Over 140 years of mining before these laws and regulations were passed

Davis Creek Reservoir at the McLaughlin Mine in Lower Lake, California. Built as a freshwater reservoir for the mine, it is now an ecological research site for University of California at Davis.

Modern Mining:

Science, Technology and Comprehensive Regulations Make it Possible

Crandon Mining Company Announces Environmentally Responsible Mining Survey Results

Take a Look for Yourself at Modern Mines Across America

Ongoing environmental monitoring at the Flambeau Mine in Ladysmith, Wisconsin

Crandon Mining Company has conducted a year-long intensive survey of modern mining industry environmental practices. This survey included over 150 interviews with mining industry representatives and state and federal regulatory authorities with jurisdiction over mining in the U.S. and Canada, and visits to 14 sulfide mining operations in California, Washington, Montana, Colorado, Nevada, Missouri, New York, and Wisconsin. The survey was conducted by independent environmental consultants who are experts in evaluating environmental issues associated with mining.

What did those experts find? Environmentally responsible sulfide mining is occurring all across the country. Many of the mine sites researched during the survey are located in scenic, high altitude mountainous areas that receive severe winter weather and provide valuable habitat for terrestrial and aquatic wildlife. The many environmentally sensitive settings prove that similar sulfide mining can be done in an environmentally responsible manner in Wisconsin-especially in light of Wisconsin's stringent mining regulations. These regulations require state-of-the-art engineering design, pollution prevention technology, monitoring, and financial guarantees to ensure that Wisconsin mines are built, operated, and reclaimed to the highest environmental standards.

A few examples of environmentally responsible sulfide mines include the following:

The Henderson Mine and Mill

This molybdenum sulfide mine and mill have maintained a spotless environmental compliance record since 1976 when mining and milling operations commenced. Located less than a two-hour drive west of Denver, Colorado, at an elevation of 10,346 feet in the spectacular mountain scenery of the Colorado Front Range; the areas immediately around the mine and mill serve as Denver's back yard and receive intensive year-round recreational use. Denver residents regularly use areas adjacent to the mine and mill sites for fishing, camping, picnicking, hunting, hiking, skiing, and snowmobiling. Treated wastewater from the operation supports a thriving population of Boreal toads, a species that the U.S. Fish and Wildlife Service is considering listing as threatened and endangered. Streams downstream from both the mine and mill facilities are excellent brown and brook trout fisheries. Both the mine and the mill are located in Denver's watershed, and two reservoirs associated with the nearby reclaimed Urad Mine are used as municipal reservoirs for the city of Golden, Colorado.

The Viburnum Mine No. 27

Developed in geology similar to that found in southwestern Wisconsin's lead-zinc mining district, the water from this lead-zinc-copper sulfide mine, which operated from 1960 to 1978, is so clean it has served as the primary domestic water source for the town of Viburnum, Missouri, since 1981.

The McLaughlin Mine

Straddling three counties about 70 miles north of San Francisco in the rugged mountainous terrain of California's Coast Range, this gold mine is acknowledged by regulators, environmentalists, and the mining industry to be a model of effective environmental practice. Proactive mine planning and permitting processes, pollution prevention features, and reclamation and habitat management programs are just some of the mine's successful environmental efforts that have been adapted for use at other mine sites. Comprehensive environmental monitoring of the McLaughlin Mine confirms the ecological effectiveness of these practices. This monitoring demonstrates that

The tailings management area at the active Henderson Mill near Parshall, Colorado

since its development in 1985, the mine has operated without environmental harm, and has not only protected but actually enhanced the quality of both on-site and downstream habitats and improved downstream water quality. Using ecology-based habitat management planning, resource values of the surrounding landscape that were disturbed by historic mining are in the process of being restored and enhanced. Ultimately the entire mine site and attached buffer lands of thousands of acres will become a wildlife preserve and an environmental studies field research station for the University of California.

The Stillwater Mine

Located in southern Montana in the magnificent Beartooth Mountains on the northern edge of the Absaroka-Beartooth Wilderness, about 30 miles north of Yellowstone National Park, this platinum-palladium sulfide mine is an excellent example of environmentally responsible mining in an extremely beautiful and sensitive environment. Operating since 1987, the Stillwater Mine has maintained a clean environmental record. The only domestic source of these strategic minerals, the Stillwater operation includes an off-site smelter in Columbus, Montana, with state-of-the-art pollution control equipment. This underground mine is recognized by regulators, environmental groups, and industry experts for its excellent concurrent reclamation activities, wildlife enhancement projects, community support programs, and responsive environmental management. In addition to its scenic attributes, the area around the mine is also recognized for its recreational opportunities-the mine is adjacent to the Stillwater River, a Montana Blue Ribbon Trout Fishery.

The Cannon Mine

Located at the intersection of South Miller and Circle Streets, this gold mine was developed in 1985, one block south of the Wenatchee, Washington, city limits. This agricultural community of approximately 40,000, known as "the apple capital of the world," is about 150 miles east of Seattle. With residents, parks, churches, schools, hospitals, and an equestrian center as its neighbors, the Cannon Mine is a model of environmentally responsible mining in an established urban environment. The mine, which operated for nine years, is now in the final stages of reclamation, and nearly all traces of this once bustling underground mining and milling project are gone. All of the millsite buildings have been removed, the area regraded, and replanted; the mine portal has been plugged; and the tailings management area has been reclaimed and planted with natural grasses. The local school district has converted the mine buildings into offices and an equipment maintenance facility. As quoted in a July 2, 1996, article entitled "A Promise Kept-Mine Tailing Cleaned Up" in the *Wenatchee World*, a local official states that the mine has done a good job living up to its promises—"The scale of the (reclamation) work is just amazing. It's been a good project."

The Flambeau Mine

Located in northern Wisconsin's Rusk County, practically within the city limits of Ladysmith and immediately adjacent to the Flambeau River, this copper mine has complied with all applicable environmental regulations since opening in 1993. Stormwater runoff from sulfide waste material and the operating open pit, along with groundwater infiltration into the pit, are treated in a state-of-the-art water treatment facility that produces mine discharge water which has proven safe at 100 percent concentration (i.e., without dilution) for the most sensitive aquatic life and meets state drinking water safety standards. Examinations of fish, crayfish, macro-invertebrates, and dragonfly; sediment sampling; and habitat characterization both above and below the mine discharge point prove the mine water has not adversely affected river life. Upon completion of mining in 1997, the open pit will be backfilled and the site will be recontoured and revegetated to pre-mining conditions. City officials credit the mine with creating an economic miracle for the local community of 4,000 people. Tax revenue from the mine has stimulated an economic development boom in Rusk County where the unemployment rate has fallen from 15.3% just prior to the mine opening to 4.0% in October 1996. The Flambeau Mine is one of Rusk County's top tourist attractions, with over 30,000 people per year visiting the mine's information center.

The Henderson Mine and Mill

Location Empire, CO (mine), Parshall, CO (mill)
Type of Mine Underground Molybdenum Mine with Tailings Area
Tons of Ore 130 million tons of ore mined to date
Size of Mine Over 100 miles of underground workings, mill site and tailings disposal area cover approximately 3,500 acres
Contact Ms. Anne Beierle, Environmental Manager
Climax Molybdenum Company

McLaughlin Mine

Location Lower Lake, CA
Type of Mine Open-Pit Gold Mine with Tailings Area
Tons of Ore Approximately 40 million tons of ore and 130 million tons of waste rock mined, and 2.7 million ounces of gold produced to date
Size of Mine The open pit is approximately one mile long, one-half mile wide, 1,000 feet deep, and covers about 210 acres; the total mine area is approximately 1450 acres, 700 of which are now reclaimed
Contact Mr. Raymond E. Krauss, Environmental Manager
McLaughlin Mine, Homestake Mining Company

Cannon Mine

Location Wenatchee, WA
Type of Mine Underground Gold Mine with Tailings Area
Tons of Ore 4.5 million tons of ore mined to produce 1.25 million ounces of gold and 2 million ounces of silver
Size of Mine Total mine area is approximately 200 acres; the site is now reclaimed
Contact Mr. Gary Bates, Vice President
Selland Construction

Viburnum Mine No. 27

Location Viburnum, MO
Type of Mine Underground Lead, Zinc, and Copper with Tailings Area
Tons of Ore 8,593,390 tons of ore to produce 350,703 tons of lead concentrate, 20,956 tons of zinc concentrate, and 22,702 tons of copper concentrate
Size of Mine The No. 27 mine was one of three mines feeding a central mill. The No. 27 underground workings extended for over a mile to the north and west of the shaft and approximately one-half mile to the south of the shaft
Contact Mr. John E. Carter, Manager Mining Properties
The Doe Run Company

Stillwater Mine

Location Nye, MT
Type of Mine Underground Platinum-Palladium Mine with Tailings Area
Tons of Ore 3.3 million tons of ore and 2.7 million tons of waste rock mined to date, with over 2 million ounces of platinum group metals produced to date
Size of Mine Over 27 miles of underground workings
Contact Mr. Bruce E. Gilbert, Environmental Affairs Manager,
Stillwater Mining Company

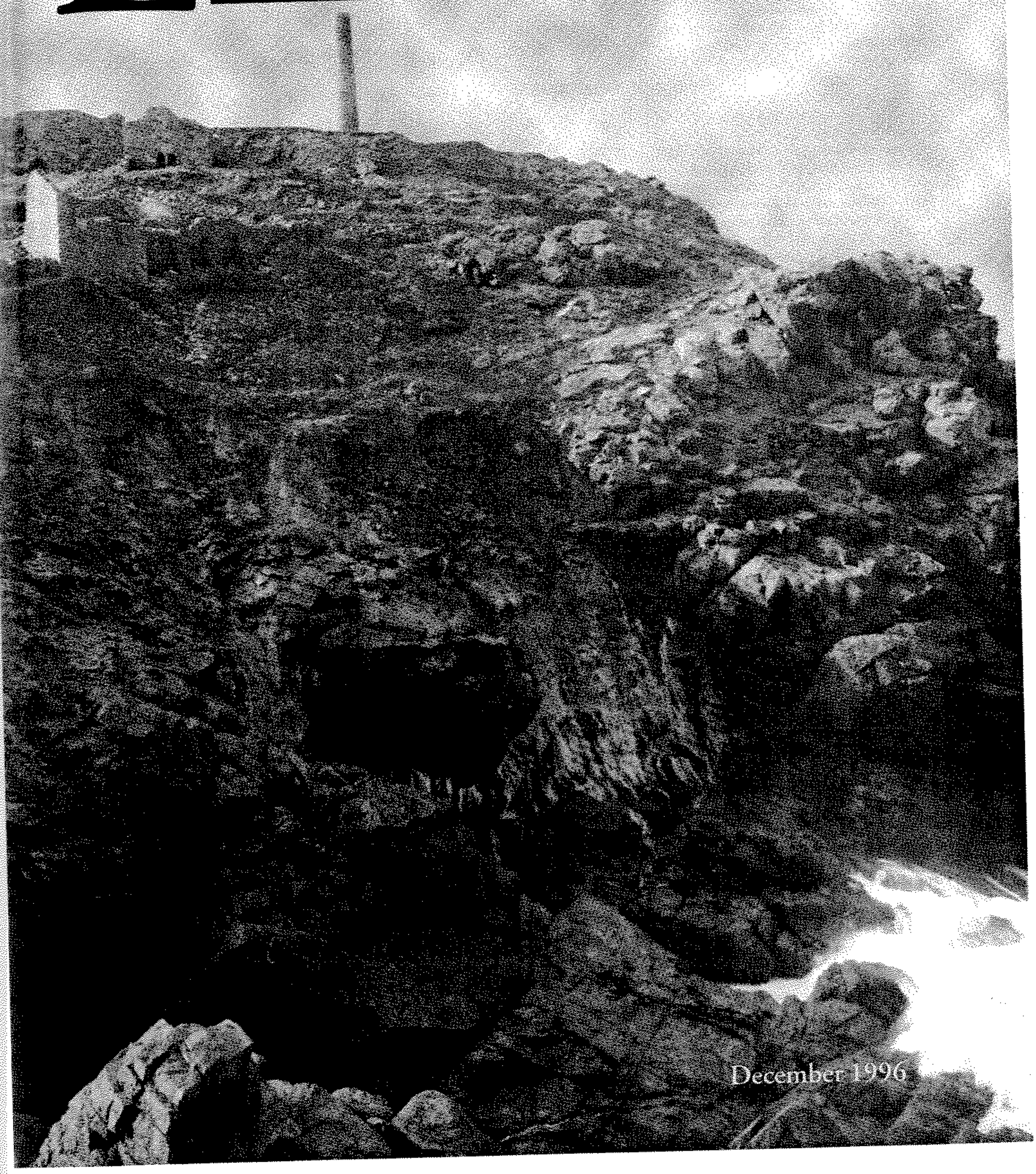
Flambeau Mine

Location Ladysmith, WI
Type of Mine Open-Pit Copper Mine
Tons of Ore Just under 2 million tons of ore, and 10 million tons of waste rock
Size of Mine The pit is about 550 feet wide, 2,600 feet long, and 225 feet deep, and covers about 35 acres
Contact Tom Myatt, General Manager

For more information about
environmentally responsible mining and the technology, people, science
and regulations that make it possible, please contact:

Executive Director
The Wisconsin Mining Association
P.O. Box 352
Madison, Wisconsin 53701-0352

MINING Environmental MANAGEMENT



December 1996

Control technologies for ARD

Acid rock drainage (ARD) is one of the most significant environmental challenges facing the mining industry today. ARD is produced by the exposure of rock, rich in pyrite and other sulphide minerals, to oxygen and water. It causes a number of serious water quality impacts due to its typically low pH and unacceptable concentrations of metals. While ARD can form naturally, it occurs at a number of mining operations throughout the world. When ARD develops at a mine, its control can be difficult and costly.

Mining operations can increase the rate of ARD generation compared to the natural environment because rock is moved from its original place in the earth and crushed, ground, or otherwise treated in ways that increase the exposure of pyrite to oxygen and water. Sulphide-enriched waste rock can have significant ARD potential and is usually stored on the surface, where it is subjected to abundant oxygen, weathering, and leaching. Sulphide-rich tailings are generally slower to produce ARD than waste rock because they are finer-grained (hence less permeable) and are typically stored in near-saturated conditions. Historically, many tailings have been deposited or stored in ponds along valley bottoms, where they are subject to active erosion by streams and high precipitation events.

Three broad categories of ARD control measures exist: source control, migration control and treatment. Source control refers to measures that can be employed to prevent acid generation before it develops. Migration control restricts the amount of water moving through potentially acid generating mining waste, thereby preventing the movement of acid. Collection and treatment of ARD is the control option of last resort because it is typically the most expensive and may be required for many years after mining has ceased.

One of the best means of eliminating the risk of ARD at new mine sites is through the engineering design of the mine and facilities. Geochemical characterisation is important in determining if there is a potential ARD risk. It is necessary to know which rock types pose a concern, what their potential volumes are, where and how they can be stored and if their storage poses a short- or long-term threat to surface- or groundwater quality. The mine facilities can then be designed and constructed to eliminate or significantly reduce the potential for ARD.

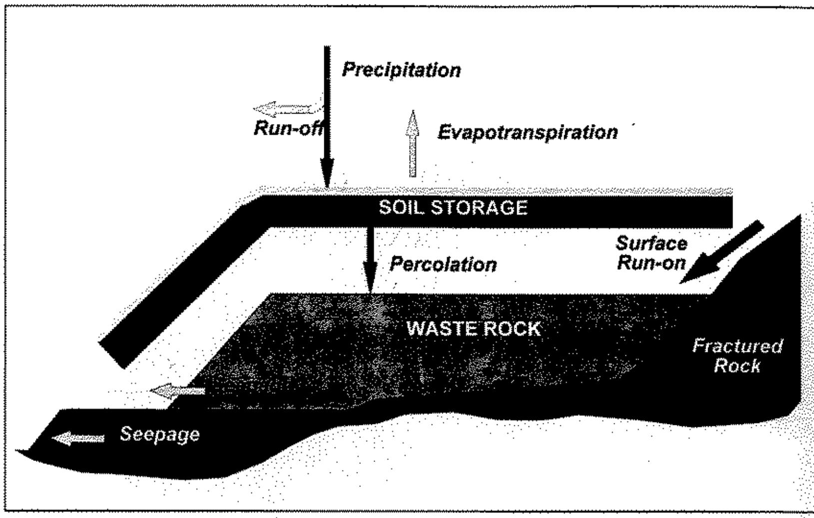


Figure 1. Conceptual water balance of a mine waste rock pile.

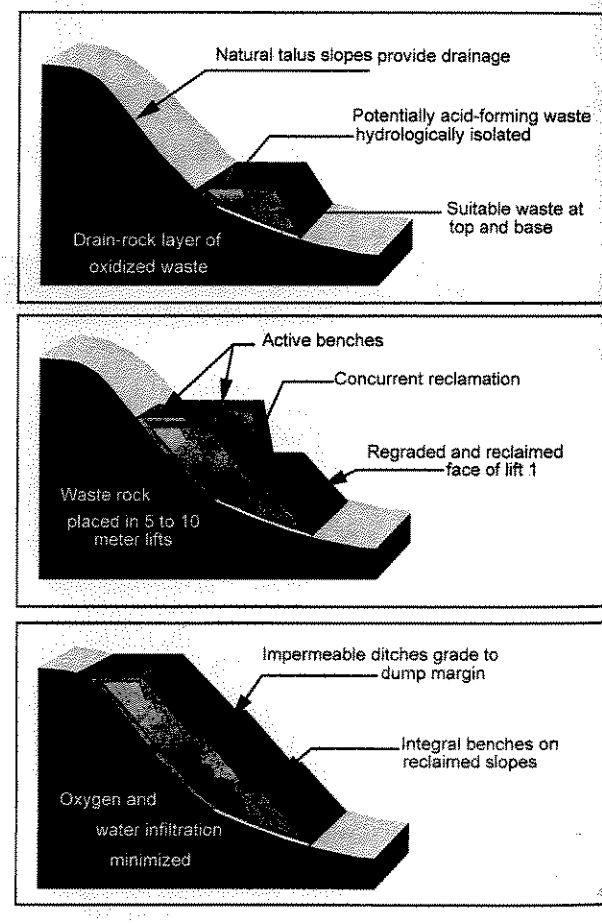


Figure 2. Waste rock piles built in lifts have less potential for air and water movement.

CONTROL TECHNIQUES

Control techniques are much less costly than the collection or treatment of ARD. Reliable testing techniques have been developed in recent years, allowing ARD risk to be predicted before it occurs. As the potential impact of ARD has been recognised, mines have increasingly employed up-front ARD testing and prediction. A mining company will have many more ARD control options if measures are taken before mining begins. When the risk of ARD is confirmed, facilities that store potentially acid generating rock material can be situated, designed, operated and reclaimed in a manner that prevents or controls ARD.

Mine operators need to plan ahead to use source control measures. Depending on the climate and the nature of the waste, these measures may include segregation and/or encapsulation of potentially acid generating mining wastes, their disposal under water where they

Reprinted from Mining Environmental Management, December 1996.

will not be in contact with oxygen, the addition of limestone to neutralise the acid at source and the removal of sulphides from the tailings during mineral processing followed by special placement of these sulphides. Covers, caps and seals can be used to isolate or encapsulate sulphide-bearing waste and limit the access of either water or oxygen, or both, to these materials. Excluding oxygen from waste materials is very effective as a means of preventing sulphide oxidation, but may be more difficult than excluding water. Capping materials that have a low coefficient of oxygen diffusion include water, amended and compacted soils and geofabrics or membranes.

If there is no seepage or movement of acid out of a waste storage facility, there can be no ARD even when pyrite oxidises and forms acid *in-situ*. Thus, migration control measures seek to minimise the amount of water entering the facility and contacting the rock. To do this effectively requires an understanding of the water balance of the site. The methods used in managing the water balance are aimed at reducing infiltration into mined materials, surface-water control and diversion, and groundwater interception (Figure 1).

Proper siting of the facility, diversion of surface water, regrading of slopes and use of engineered covers are the most commonly used tools for preventing ARD migration. In humid climates, with more than 50 cm of rainfall, an effective cover usually employs a low permeability layer such as clay or a synthetic geomembrane. In drier climates, a soil layer on which vegetation is established can be just as effective in preventing water movement as more costly and complex covers.

If possible, it is best to choose sites for waste rock disposal that are high and dry, because waste rock piles need to be protected from surface-water run-on and groundwater seepage prior to, during and after, closure. Valley bottoms and tributary stream channels should be avoided to minimise surface run-on and the need for long-term, high maintenance diversion systems. Likewise, low-lying wet areas and hillsides, with numerous seeps and springs, should also be avoided to minimise groundwater inflow or seepage. Waste rock piles built with multiple 5 to 10 m lifts are a better design for minimising ARD than single-lift dumps (Figure 2).

Tailings impoundments are often sited in valley bottoms or low areas for various engineering reasons. Large volumes of tailings can be contained in natural topographic 'bowls' with minimum embankment construction. However, in these areas, long-term stream diversions and liner systems are likely to be necessary to protect the dams and materials from erosion and from infiltration by oxidising surface- and groundwaters, even if sub-aqueous tailings closure plans are being considered.

An understanding of the site water balance is critical to the control of surface water and the diversion of flows away from waste rock and tailings facilities. Diversions are used to prevent the flow of otherwise clean water across materials with the potential to form ARD and release trace metals. Diversion ditches may be lined to prevent infiltration into the underlying materials and may be armoured to minimise erosion.

> Collection and treatment of ARD is the control option of last resort

Diversions are also used to concentrate or collect water from the waste rock or tailings storage sites so that it can be monitored, and stored and treated, if necessary. To avoid standing water on the storage site, the top is typically sloped slightly into the hillside, where a lined diversion ditch collects and channels run-off away. This type of diversion system helps to minimise the amount of water that needs to be treated, should treatment become necessary. During reclamation, the side of the site is regraded to at least a slope of two units in the horizontal to one unit in the vertical (2H:1V). This regrading allows for placement of soil, if necessary, and reduces the potential for erosion (Case Study No.1).

Groundwater migration is usually controlled using some type of interceptor structure. Grout curtains and slurry walls are both effective constructed diversions. Also, diversion ditches can be used to intercept and divert groundwater flow. Occasionally, the natural setting contains geologically and hydrologically favourable containment structures. Elsewhere, the slow movement of groundwater through natural materials can be used to attenuate low levels of metal concentrations.

DRY COVERS AND LINERS

Dry covers and liners of soil or geofabric are used to restrict the entry of water or oxygen into rock or tailings materials. They can be effective in preventing rainfall infiltration, particularly when combined with a vegetative cap. However, if clay or other low-permeability soil is used, it must be kept saturated with water to limit oxygen penetration and prevent cracking. To be effective, dry covers need to be used in conjunction with a surface water run-on control plan.

Geofabrics such as polyvinyl chloride (PVC) and high density polyethylene (HDPE) are currently used for both top and bottom liners for mining wastes and tailings. Because of their very low permeability, they are excellent at excluding both air and water if properly installed. This requires caution to prevent punctures and careful preparation of bedding and upper surface protection layers. Most geofabrics have not been in use long enough to be able to predict accurately how long they will last. However, they are expected to last for at least 100 years if properly installed and protected from differential settlement, puncturing, root penetration and weathering.

Covers or top liners are typically protected with thick multiple layers of material designed to provide lateral drainage, liner protection and a substrate for revegetation. Bottom liners are frequently constructed with a compacted clay bedding layer that effectively duplicates the low-porosity and permeability of the geofabric, thereby duplicating protection. They may or may not have an under-drain system and are typically covered with a layer of protective material prior to the placement of wastes or tailings.

In semi-arid climates, simple single-layer soil covers can be a remarkably effective means of controlling percolation of water into mining waste. A satisfactory thickness of soil material and an appropriately regraded slope that will induce some run-off, resist erosion and retain water is an ideal dry cover. Establishment of a dynamic vegetative community will maximise the evapo-transpiration of water, thus decreasing potential infiltration. Studies have shown that percolation rates can be reduced to 1-2% of total rainfall, in zones with less than 50 cm of rainfall. The efficiency of revegetated soil covers can be increased by placing a layer of coarse rock beneath the cover, which forms a capillary break, further minimising any percolation.

Multi-layer covers, often used in higher rainfall areas, employ various layers for specific purposes. The layers may include, from top to bottom: a revegetated soil layer to retain moisture; a coarse layer to provide lateral drainage of infiltrating water; a compacted, low-permeability clay layer to prevent infiltration; and a prepared, compacted base layer with added neutralising material to facilitate cap construction and minimise reaction of water in the waste with the clay layer.

SUB-AQUEOUS DEPOSITION

Sub-aqueous or wet covers appear to be the most promising means of controlling the generation of acid, especially in higher rainfall areas. Oxygen has a very low solubility and a diffusion rate through water almost four orders of magnitude less than in air. Therefore, placing potentially acid generating materials beneath a cover of water or in water-saturated material reduces the rate of oxidation to such a slow rate that ARD does not occur.

Sub-aqueous deposition of tailings or waste rock can encompass many forms, including back-filling of mine pits and allowing the pit to flood, placement in man-made lakes or impoundments, or placement in flooded underground workings.

Disposal in lakes and marine environments, although effective in controlling acid production, may increase turbidity and cause the release of metals into the water. Back-filling requires double handling of materials; frequently not all of the material mined will fit back into the mine openings. Sub-aqueous deposition in man-made impoundments is probably the most common application of this technology.

SEPARATION AND BLENDING

Sulphide-bearing waste and tailings materials should be examined for their acid-producing characteristics, trace element contents and mobility, prior to mining. Once potentially problematic materials have been delineated, the potentially acid generating waste or tailings can be segregated for storage. These 'reactive wastes' should be placed where they are isolated hydrologically or where they are not in contact with oxygen. Isolation from water is typically accomplished in waste rock piles by placing the potentially acid generating waste above an under-drain layer of coarse unreactive rock. The potentially acid generating waste is then covered with compacted clay or low-permeability unreactive waste rock (Figure 2).

If materials can be segregated and separated based on their acid generation potential, then the blending of potentially acid generating rock with local or off-site neutralising materials may also mitigate ARD risk. The neutralising products most frequently used are limestone ($CaCO_3$), lime (CaO), hydrated lime ($Ca(OH)_2$), soda ash (Na_2CO_3) and caustic soda ($NaOH$). Adding neutralising minerals is a very effective means of controlling acid-drainage from waste or tailings materials and is also used extensively to amend acidic soils prior to revegetation.

Research has shown that alkaline materials must be intimately blended with sulphide waste, not merely layered. Also, the amount of limestone required for long-term neutralisation may be greater than that necessary to equally balance the acid generation potential, as indicated by static acid-base accounting tests. Typically, the final ratio of acid neutralising potential to acid generating potential in the amended material is between 1.25 and 3, depending on the relative rates of dissolution of the neutralising and acid generating materials (Case Study No.2).

Blending neutralising materials with potentially acid generating waste does not stop pyrite oxidation. Rather it neutralises the acid produced at the source. If no steps are taken to minimise water infiltration into the blended waste, through an appropriate cover or revegetation, then a neutral drainage may develop with unacceptably high total dissolved solids and sulphate content. Some metals, especially zinc and cadmium, may also be soluble at neutral pH. Thus, blending of potentially acid generating waste must usually be combined with migration control measures.

BACTERICIDES

Bactericides made of surfactant chemicals have been added to potentially acid generating materials to temporarily suppress the growth of acidophilic bacteria, particularly *Thiobacillus ferrooxidans*, which can accelerate the rate of sulphide oxidation. This technique is only effective after acid production has begun,

Right: The dozer is creating basins to minimise sheet run-off during the earliest stage of revegetation.

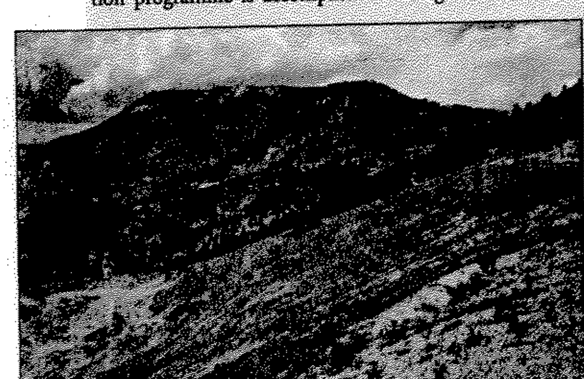
Left: Initial reclamation involved regrading to a 2V:1H slope with diversion ditches every 200 vertical feet.

Case Study No.1: Golden Sunlight mine

The Golden Sunlight mine (Placer Dome) is a large precious metal complex in Whitehall, Montana U.S., where waste rock contains an abundance of unoxidised, sulphide-rich material. The climate is semi-arid temperate and sulphide oxidation has led to heating of the rock mass and evolution of steam from the dump surface, but acid rock drainage has not occurred. Regulatory agencies have expressed concern that water movement through reclaimed dumps could cause ARD to migrate from the facilities. A waste rock reclamation hydrology study was conducted by Schafer and Associates in response to these concerns.

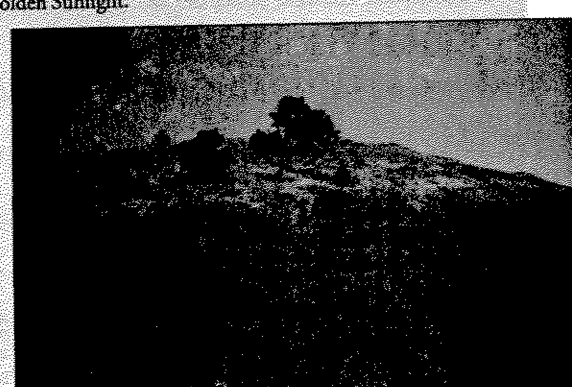
The focus of the West Dump study has been to evaluate the effectiveness of various reclamation strategies, including surface water diversion, slope regrading (3H:1V vs. 2H:1V), soil covers and revegetation, in promoting slope stability and preventing acid seepage by limiting infiltration into the dump. Evaluation of the reclamation demonstration programme is accomplished through the use of neutron probe equipment to measure water content in the waste rock, thermistors to measure temperature, gas ports to measure oxygen and carbon dioxide concentrations and lysimeters for collection of water quality samples. Erosion monitoring troughs have also been constructed on waste dump slopes to compare sediment yield and runoff volumes on sites with varying styles and degrees of reclamation.

Results from the first five years of study indicate that the concurrent use of surface water diversions, grade control (2H:1V), cap construction using oxide cap covered with soil, and revegetation is successful in virtually eliminating infiltration under average precipitation conditions of 340 mm/y. Reclaimed sites stay significantly drier and exhibit far less pyrite oxidation than unreclaimed control sites. Erosion is minimal, and revegetation is successful, indicating that the 2H:1V slopes are stable. These results indicate that the waste rock reclamation programme will prevent the migration of significant ARD from the waste rock facilities at Golden Sunlight.



Left: Revegetation after one year.

Right: Revegetation after two years. The line just beneath the trees is the uppermost diversion ditch separating reclaimed waste rock below from the natural slope and vegetation above.



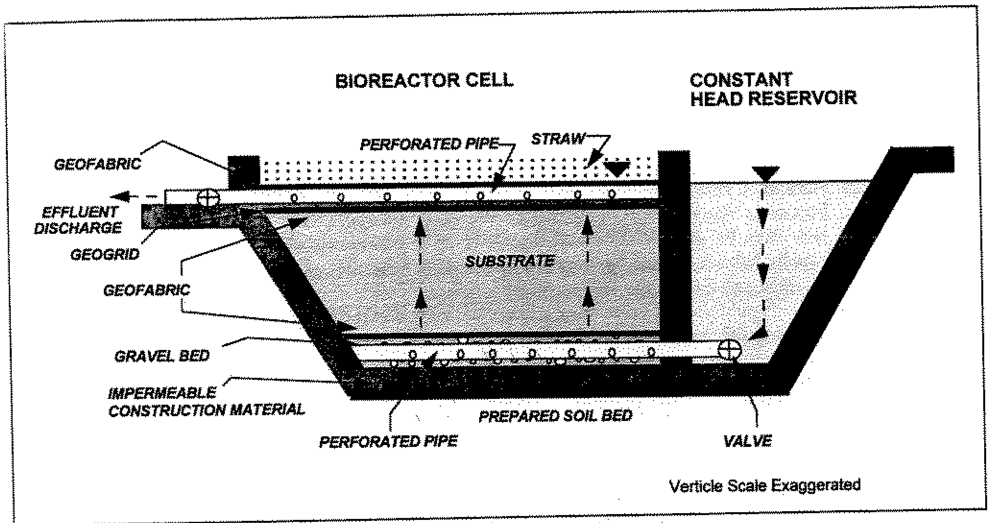


Figure 3. Schematic of a typical upflow anaerobic bioreactor. The arrows show the flow.

because bacterially catalysed oxidation only becomes important when the pH of the system is less than 3.5.

Bactericides only work well for limited periods of time, unless a time-release formulation is applied. They do, however, work more effectively when combined with the addition of neutralising material and natural organic fertilisers which stimulate the growth of vegetation and benign microbes.

COLLECTION AND TREATMENT

Many mines, especially in humid or tropical climates, produce excess water that needs to be discharged into the environment. Some of these discharges may require a water treatment system to achieve regulatory standards prior to release.

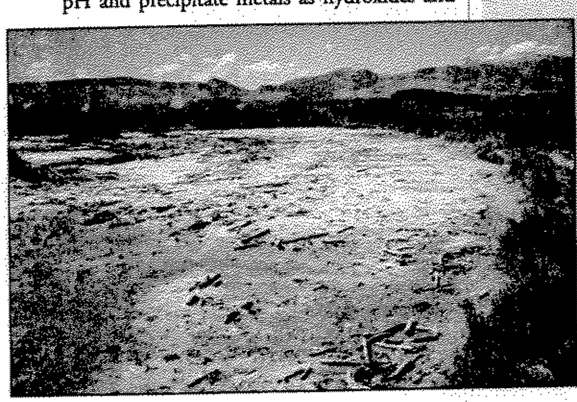
Water treatment systems are commonly used to treat both process and decant water from tailings ponds, and also can be used to treat contaminated water from ARD. However, traditional active water treatment can be capital and labour intensive and may need to continue for many years after mine closure. Treatment of ARD using passive (or low-maintenance) treatment options such as constructed wetlands or bioreactors, lagoons and anoxic limestone drains has recently offered hope of reducing costs. Traditional active water treatment methods for ARD use lime, caustic soda, or soda ash. The most common method is the use of lime to increase the pH and precipitate metals as hydroxides and some of the sulphate as gypsum. To bring metal levels down to permitted levels, a second-stage treatment at a different pH or by sulphide precipitation may also be required. Collection systems may be a series of ditches and holding or collection ponds for surface flows. Trenches, pump-back wells and cut-off walls are used when necessary to collect or bring groundwater to the surface for treatment. Active treatment methods are quite effective in controlling ARD and related mine drainage problems. However, they typically require continuous operation, a constant power supply, back-up systems or contingencies for excess water storage, and a means of disposing of large volumes of sometimes hazardous sludges.

Wetlands have been used to improve water quality in settings where acidic drainage has already developed. Two main types of constructed wetland or passive bioreactor approaches are currently in use to treat mine drainage. They are surface-flow aerobic wetlands and subsurface-flow anaerobic bioreactors. (The term 'bioreactor' is used with anaerobic systems because they typically function better without vegetation and are often covered.) The chemistry of the water to be treated and the final water quality determine which type of treatment, or series of treatments, is appropriate. Drainages of constant, low flow rates are most amenable to passive treatment. The climate can also affect treatment efficiency because the geochemical and microbial reactions decrease substantially in cold weather.

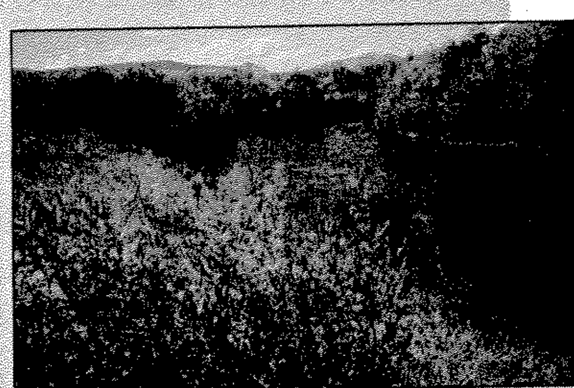
Case Study No.2: Historic tailings

Nineteenth and early twentieth-century mining and smelting in and near Butte, Montana U.S., placed millions of tonnes of metal-laden, acid-producing mine tailings and waste rock along 130 km of the Clark Fork River and its tributaries. As late as 1989, rains washed toxic levels of soluble metals into the river from the tailings, resulting in fish kills. Traditional contaminant removal was impractical and cost-prohibitive due to the size of the site, the tonnage of contaminated materials and habitat sensitivity. The climate of the area is semi-arid temperate, with an annual precipitation of about 400 mm. Therefore, it was decided to try a simple amendment addition to treat the tailings in-place.

Schafer and Associates developed and tested alternative amendment methods to restore the stream corridor to beneficial use without disruption. Lime and limestone were added to the tailings in an amount about 25% greater than that needed to neutralise the acidity, so that a slightly alkaline soil was formed. The amended tailings were deep-tilled to a depth of about one metre. They were then seeded to restore wildlife habitat, minimise infiltration into the tailings, and retard stream bank erosion. The amendments and revegetation have reduced soil acidity and made metals insoluble, improving water quality and encouraging the growth of vegetation. Additional damaged riparian areas are presently being revegetated to improve forage and habitat for livestock and wildlife.



Left: Historic tailings deposited along the Clark Fork River.



Right: Amended and revegetated tailings after about three years.

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Aerobic Wetlands: The dominant processes treating mine drainage in aerobic wetlands are oxidation of iron (II) to iron (III) by aeration spillways, precipitation of iron (III) hydroxides, and settling of the hydroxides in ponds. Vegetation is typically used within the system because it helps trap suspended matter and provides additional oxygen. Aerobic wetland treatment works best on coal mine drainages with low concentrations of other metals because these generally require a pH above 9 to precipitate as oxides or hydroxides. Aerobic treatment requires sufficient alkalinity in the water to keep the pH from falling as a result of the hydrolysis of iron:

$Fe^{3+} + 3\,H_2O \longrightarrow Fe(OH)_3 + 3\,H^+$

Anoxic Limestone Drains: An anoxic limestone drain can sometimes be installed before a wetland to add alkalinity and raise pH. These provide 'up-front' alkalinity, and are usually used to help remediate poor water quality in situations where acidic drainage has already developed. The alkalinity is provided by caches of limestone buried in the hillside or waste facility immediately up-gradient of the point where an acidic seepage surfaces.

Dissolution of limestone can be effective in reducing acidity by buffering and neutralising the pH of downstream waters only under very specific conditions. The seepage water must be 'anoxic', containing no dissolved oxygen which may oxidise iron (II) in the drainage to iron (III). No measurable iron (III) or aluminium can be present in the initial drainage because either of these species will precipitate on the limestone and coat, or 'armour', the limestone, making it unreactive. Anoxic limestone drains are most effective when used in conjunction with settling ponds and wetland treatment systems.

Manganese Wetlands: Treatment of manganese requires a special type of aerobic wetland that is highly oxidising and contains populations of micro-organisms that help catalyse the precipitation reaction. Without catalysis, manganese requires a pH greater than 9 to precipitate. Manganese wetlands are usually shallow rock wetlands, colonised with green algae and cyanobacteria, to locally raise pH and redox potential (Eh). They are usually preceded by an aeration spillway to ensure the water is highly oxidised.

Anaerobic Bioreactors: Metal sulphides are much less soluble than their corresponding hydroxides and will precipitate at acid to neutral pH. Therefore, a recent emphasis has been placed on methods to remove metals from ARD as sulphides. Anaerobic bioreactors use bacterial reduction of sulphate and iron to accomplish metal sulphide precipitation.

The reduction reactions occur only in the subsurface of the bioreactor because the bacteria cannot tolerate the presence of oxygen. Therefore, uniform rates and even distribution of flow through the bioreactor substrate are critical to effective treatment. The ideal flow is vertical, either 'downflow' or 'upflow'. Figure 3 shows a typical upflow cell.

An exciting new approach to anaerobic ARD treatment is co-treatment with sewage and recovery of potentially economic metal sulphides. This treats two water quality problems at once and combines the advantage of metal sulphide precipitation and recovery with the advantage of a constant source of 'fresh' organic matter.

Many environmental issues that the public associates with mining are based on inaccurate perceptions stemming from mining practices used early in the century, and which are no longer in use today. Some environmental problems, however, remain challenges even today. One of these issues is ARD. In the last decade, the mining industry has demonstrated that ARD can be prevented through proper mine planning, design, implementation, and monitoring.

By Dr Lorraine Filipek[1], Mr Allan Kirk[2] and Dr William Schafer[1]

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[2] *President, Brimstone Mining Co.*

This article is based on Section 5 of a white paper entitled "A Review of Acid Mine Drainage: Chemical Evolution, Prediction, and Control" by Allan Kirk, which was submitted to the State of Wisconsin (USA), Department of Natural Resources, in 1995 while Allan was with Schafer and Associates.

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Crandon Mining Company

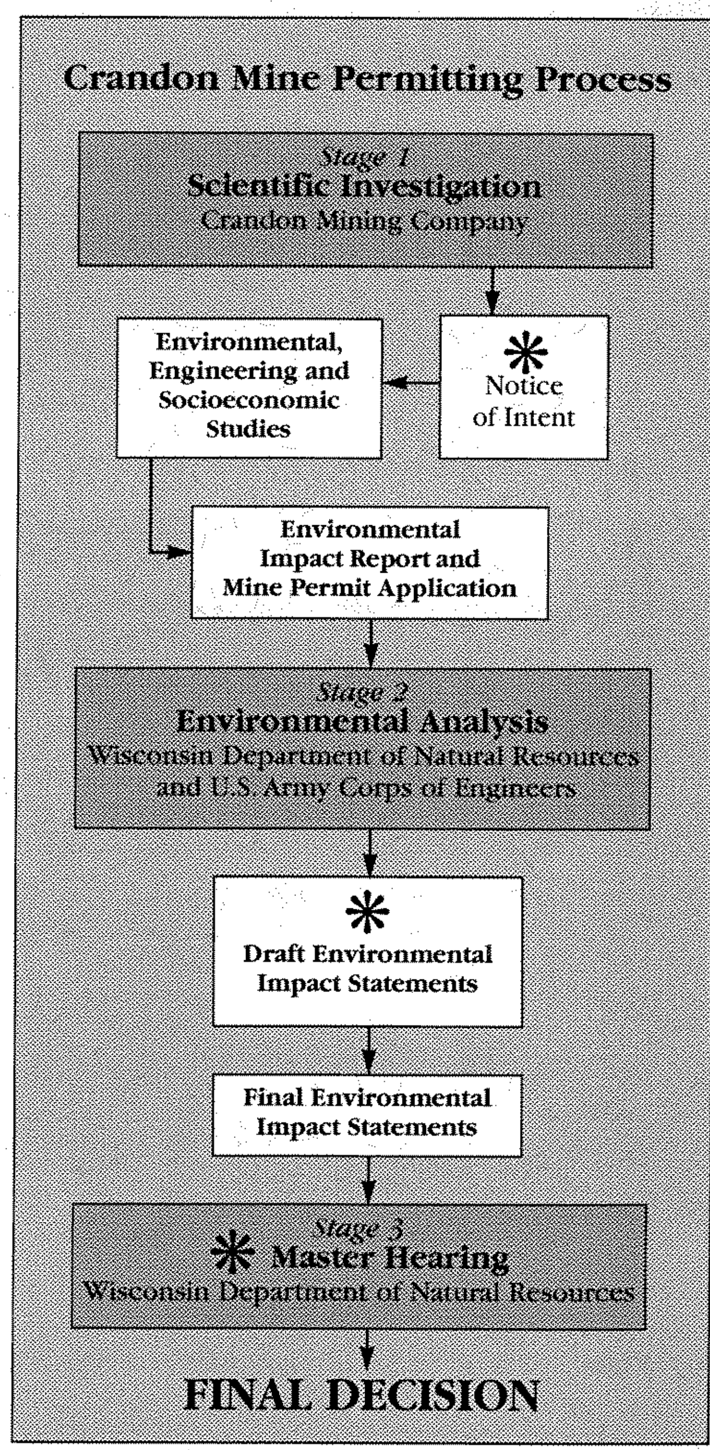
Mine Permitting Process

Wisconsin's Mine Permitting Process Encourages Public Involvement

Plans for the Crandon mine are now receiving a thorough environmental analysis conducted by the Wisconsin Department of Natural Resources and the U.S. Army Corps of Engineers under federal and state laws. In addition, the mine requires zoning approval from six local jurisdictions: Forest and Oneida counties, the towns of Lincoln, Nashville and Crescent, and the City of Crandon.

The accompanying diagram shows how the state mine permitting process will proceed. Complete copies of CMC's Mine Permit Application, Environmental Impact Report and other official documents related to the mine project have been placed on file at local libraries and at town, city, county and tribal offices. All Wisconsin residents are welcome to review the documents and become actively involved in the process.

The DNR expects to issue an Environmental Impact Statement in summer of 1997 for public review and comment.



* **Public Hearings**

Crandon Mining Company

Local Agreements

Crandon Mining Company Reaches Local Agreements with Area Communities

*I*n December 1996, the Forest County Board voted 18 to 3 and the Town of Nashville Board voted 3 to 0 in support of local agreements negotiated with Crandon Mining Company. The local agreements outline key provisions that are of interest to taxpayers and residents living near the proposed Crandon Mine.

The conditions that were agreed upon by local boards are legally binding and are designed to protect area residents and their property. The local agreements include:

THE FOREST REPUBLICAN

Crandon, Wisconsin — Wednesday, December 18, 1996

County Votes 18-3 to Sign Local Agreement with CMC

Nashville Board Approves Signing Local Agreement

- *A guarantee that local residents will be given preference in hiring and training and an open invitation for children of local residents to return home to live and work in the area.*

- *A guarantee that Crandon Mining Company can be held responsible for any mine-related damage done to water wells anywhere.*

- *A Citizens Oversight Committee that will monitor compliance with the local agreements and ensure that Crandon Mining Company keeps its commitments.*

- *A guarantee that Forest County will receive tax revenues based on $110 million in mine value, whether or not the state Department of Revenue assesses the value that high.*

- *A guarantee of $1.9 million in mining payments to Forest County over six years.*

- *Payments to the Town of Nashville equal to its tax levy for town expenses for three years of mine construction and for the first three years of mine operation.*

These are a few of the many detailed terms agreed upon by local governments and Crandon Mining Company. Town and county officials negotiated these agreements in the interests of the local citizens who elected them.

CMC is still discussing local agreements with the City of Crandon and the Town of Lincoln.

The Crandon Project

Mine Plan and Environmental Impact Report

Crandon Mining Company

• Environmentally Responsible •

Crandon Mining Company

October, 1996

This summary is an update of the publication that was initially produced in December, 1995. The need for such an update is another demonstration that the permitting process in Wisconsin is indeed very rigorous, demanding, and effective in protecting the state's natural resources. As we continue with the permitting process, meeting with the Department of Natural Resources and the U.S. Army Corps of Engineers, additional refinements and adjustments are being made in our applications as a result of those discussions. Thus you'll note that this publication reflects updates and changes in the figures as additional studies are completed.

We are pleased to provide this update summary of the mine's operations, environmental impacts and economic benefits. As outlined herein, we are committed to building a mine that will:

- Meet or exceed all federal and state environmental regulations, protect or enhance all local resources, and operate in harmony with Northwoods life.
- Provide hundreds of long-term jobs and new tax revenue to support a higher standard of living and help local communities build a strong, prosperous future.

We encourage you to review our plans and to bring any questions or concerns to our attention.

Sincerely,

Rodney Harrill, President
Crandon Mining Company

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THE CRANDON PROJECT - FACTS AND FIGURES

PROJECT DATA

Project location Forest County, 5 miles south of Crandon.

Project site 550 acres including mine, mill and all related facilities.

Orebody 55 million tons of recoverable ore, primarily zinc and copper, smaller amounts of lead, silver and gold.

Production rate 5,500 tons of ore per day, extracted by underground methods.

Project Schedule

Construction	3 years
Operations	28 years
Reclamation	4 years
Long-term care	40+ years

ENVIRONMENTAL PROTECTION

Surface water Sophisticated water treatment plant releasing high-quality treated water to Wisconsin River at Hat Rapids Dam, south of Rhinelander.

Groundwater Engineered tailings ponds with top and bottom liner systems, drain system, monitoring wells and other safeguards.

Other control Project design minimizes air emissions, noise, erosion and runoff.

Permits More than 40 federal, state and local permits required.

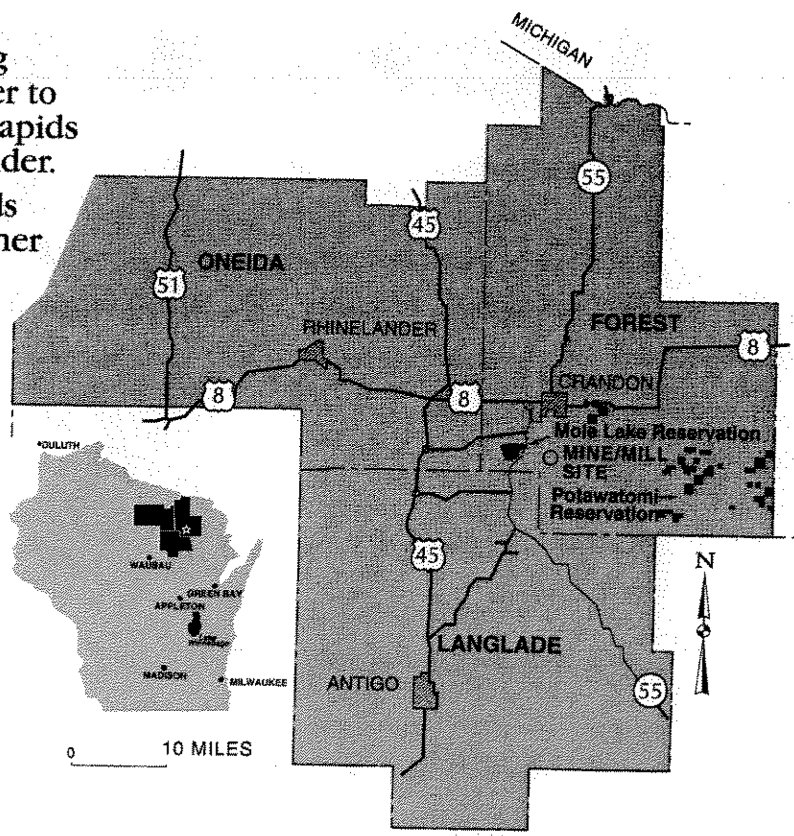
ECONOMIC BENEFITS

Employment 550 construction employees at peak (30% local hires); 402 full-time operations employees for 28 years (70% local hires); 341 jobs in related businesses.

Local purchases $43 million total during 3 years of construction; $1.2 million annually during 28 years of operations.

Tax revenue $119 million in Net Proceeds Taxes over project life.

$110 million increase in local tax base, benefiting towns of Lincoln and Nashville, Forest County, Crandon School District.



MINE PROFILE

The Crandon mine will use modern technology to protect the surrounding environment, maximize worker safety, and remove ore and metals efficiently.

THE OREBODY

The Crandon orebody, discovered in 1975, lies in Forest County, five miles south of the city of Crandon and two miles east of State Highway 55. It contains 55 million tons of ore, mainly zinc and copper with smaller amounts of lead, silver and gold. The orebody is about 4,900 feet long from east to west and about 100 feet wide from north to south. It begins about 200 feet below the surface and extends to a depth of about 2,200 feet.

THE MINE SITE

Mine facilities will occupy about 550 acres, including mainly forest and also smaller tracts of wetlands and open land. Major facilities on the surface include the headframe housing the opening to the main shaft, a mill for ore processing, a tailings management area, a water management and treatment system, offices, maintenance shops, storage buildings, and parking.

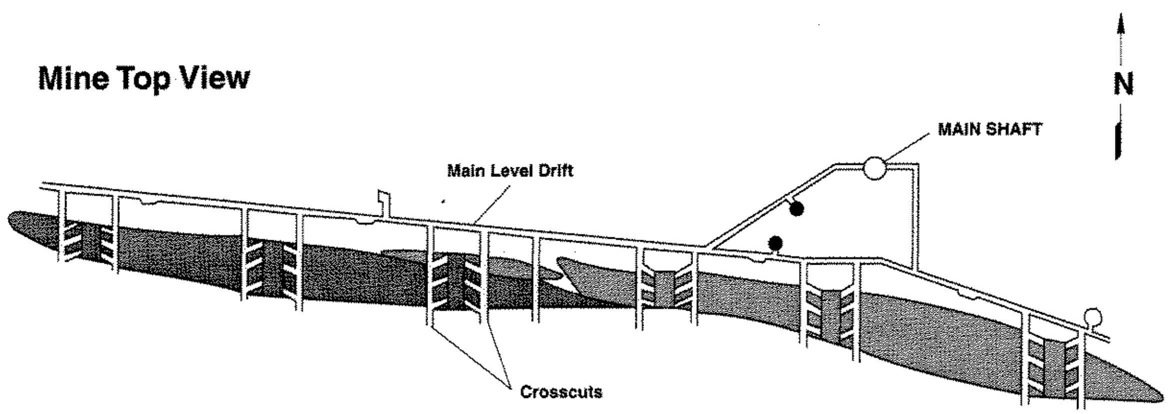
TRANSPORTATION AND UTILITIES

Cars and trucks will reach the mine using a 3-mile service road running southeast from Highway 55. A 2.7-mile railroad spur will connect the mine to the Wisconsin Central Limited tracks northeast of the site. A 115-kilovolt power line will connect the mine with an electric power substation near Monico, about 14 miles to the northwest. To supply natural gas, a pipeline will connect the mine with an existing gas main one-half mile north of Crandon.

MINING THE ORE

The mine will produce about 5,500 tons of ore per day. Ore will be mined underground by blasthole open stoping, a method proven both safe and efficient. To reach the ore, miners will construct three vertical shafts and a series of horizontal tunnels called drifts. Ore will be blasted loose from chambers called stopes, each 100 feet wide, 75 feet long and upwards to 300 feet high. The ore will be hauled to an underground crusher, then hoisted to the surface for processing. Mined-out stopes will be backfilled with waste rock from the mine, coarse tailings from the mill and, if needed, cement.

Mine Top View



SEPARATING THE METALS

In the mill, ore will be combined with water and ground to a consistency of fine sand. This mixture will go through a series of steps that separate metal particles from the rock and float them to the surface. The mill will produce separate concentrates of zinc, copper and lead. These will be shipped by rail to smelters outside the state. Small amounts of silver and gold will be recovered during smelting.

MANAGING MINE TAILINGS

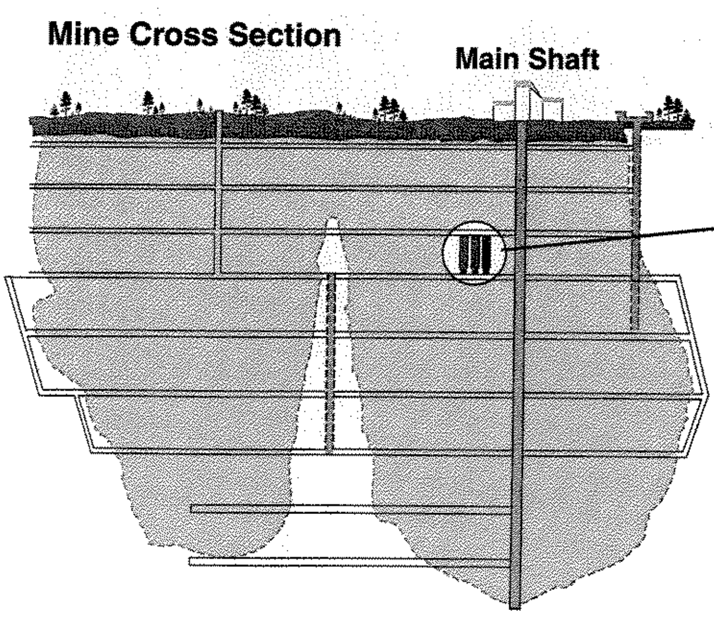
Tailings - rock particles left after ore minerals have been removed - will be used to backfill the mine. Approximately 50 percent of the tailings not needed for backfill will be placed in four engineered basins designed to permanently protect the groundwater. As each basin is filled, it will be closed and reclaimed.

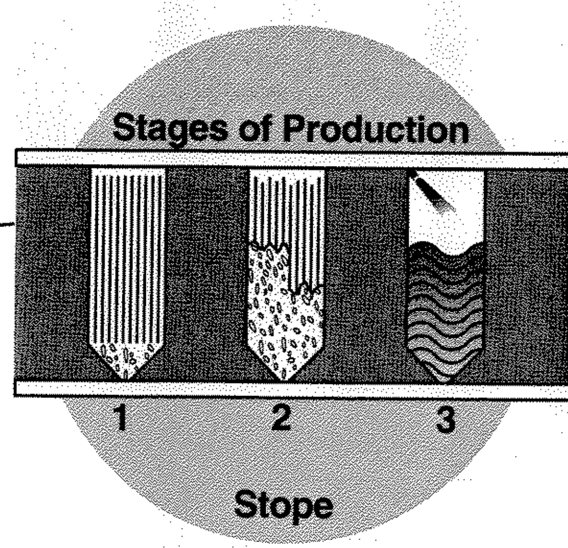
KEEPING WATER CLEAN

Groundwater that seeps into the mine will be collected and used in mine and mill operations. Water in excess of these needs will be treated in a sophisticated water treatment plant to meet strict quality standards set by the Wisconsin Department of Natural Resources. After treatment, the water will be discharged by way of a buried pipeline to the Wisconsin River.

RECLAIMING THE LAND

Site reclamation will be a continuous process: as soon as work is completed on a given part of the site, reclamation in that area will begin. When the entire project is completed, final reclamation will start. Under state law, Crandon Mining Company must provide financial guarantees that the site will be reclaimed to a long-term, environmentally stable condition.





1. New stope just starting production
2. Active stope in full production
3. Stope being backfilled

ENVIRONMENTAL STUDIES

Exhaustive scientific studies show that the Crandon mine will protect lakes, streams, groundwater, wetlands, wildlife and other natural resources, while providing substantial economic benefits.

As required by state and federal laws, Crandon Mining Company has prepared a complete Environmental Impact Report for the Crandon project. The following pages explain how the mine will affect local natural resources and the economy.

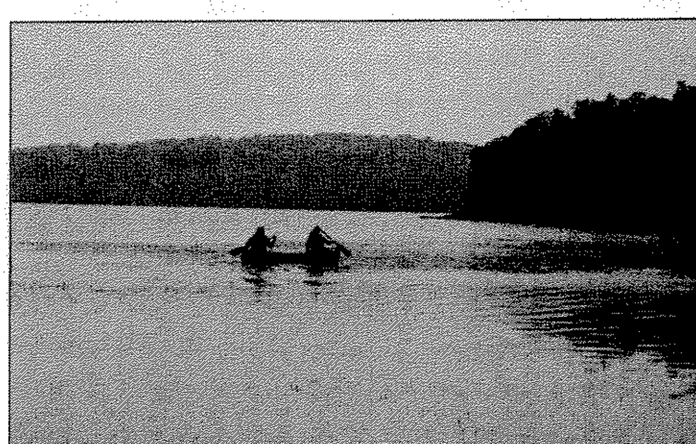
These findings are based on a series of scientific studies believed to be the most thorough ever conducted for an industrial project in Wisconsin. The studies, conducted by Foth & Van Dyke, an environmental engineering firm based in Green Bay, involved more than 165,000 hours of work by over 150 engineers, scientists and technical personnel. For added assurance that these studies are accurate, Crandon Mining Company asked independent experts to review and critique critical study methods and findings.

Preparing stream water samples for testing.

Measuring stream flow rates.

All of this work built upon, updated and refined previous studies of the local environment conducted in the 1970s and 1980s. Volumes of data have been collected, including soil and rock samples, well surveys, groundwater and surface water testing and flow analyses, lake studies, water and sediment samples, fish samples, bird and mammal studies, air monitoring, recreational resource inventories, wetlands assessments, socioeconomic studies, archaeological surveys and traditional cultural property inventories.

Taken together, the studies provided a comprehensive body of knowledge that CMC used to design the mine for the lowest possible impact on the environment, in full compliance with all relevant environmental standards.



Studying aquatic life in local lakes.

WISCONSIN'S MINING REGULATIONS

Under Wisconsin's mining regulations, the Crandon mine will proceed only if it is scientifically proven environmentally safe.

All of CMC's environmental studies are required to show that the Crandon mine will comply with Wisconsin's mining regulations, which are among the strictest in the nation.

All told, the mine needs more than 40 federal, state and local permits before construction can start.

Under the state's mine permitting process, the Crandon mine will receive a thorough, scientific review conducted by the Wisconsin Department of Natural Resources. In addition, the U.S. Army Corps of Engineers will conduct its own review.

The two agencies will prepare separate Environmental Impact Statements, first a draft for public review, then a final document. The Final Environmental Impact Statements will be the subject of a formal Master Hearing, leading to a final decision on whether permits are issued.

During the process, DNR's and COE's own scientific experts will review CMC's environmental studies and mine plans. Any individual or group in the state has the right to do the same. In the end, before receiving a permit, the Crandon mine must meet six criteria specified in state law and listed at the right.

The Crandon mine will receive a permit only when it is proven to:

1. **Comply with all state and federal environmental regulations.**
2. **Protect public health, safety and welfare.**
3. **Safeguard lands with unique features, critical ecological importance or historical value.**
4. **Have a net positive socioeconomic impact.**
5. **Comply with local zoning laws.**
6. **Include suitable plans for reclamation.**

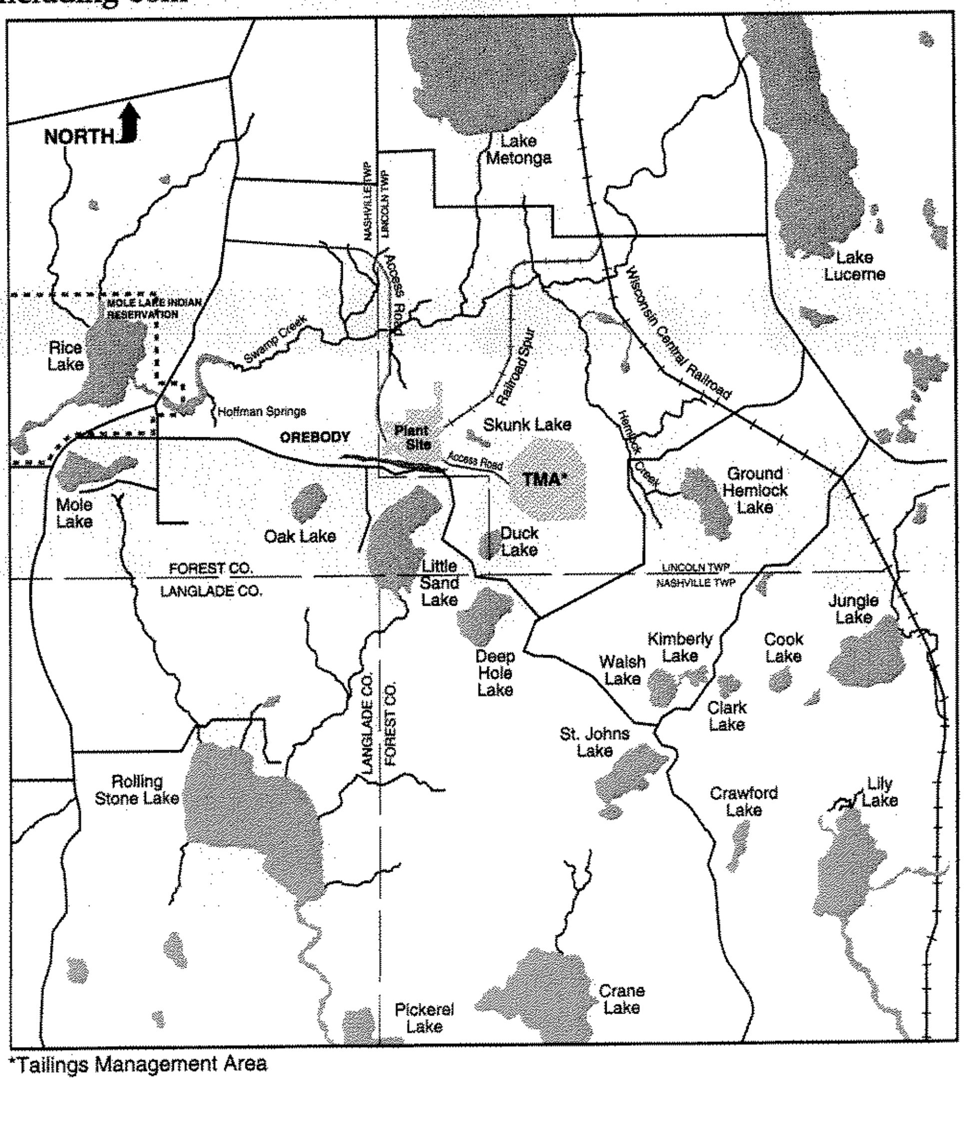
SUSTAINING WATER LEVELS

Mining at Crandon will have minimal effects on lake and stream levels, and only in the immediate area of the orebody. All private water supplies will be fully protected.

As the Crandon mine is built and operated, water will seep into the mine from the overlying groundwater at the rate of about 700 gallons per minute. Over several years, this will gradually lower groundwater levels in the immediate area of the mine.

To learn about the effects of lower groundwater levels, Crandon Mining Company conducted extensive environmental studies, including computer simulations of the effects on lakes and streams. These studies show that the effects on surface waters will be small. All lakes and streams will be sustained at levels that protect fishing, boating, swimming, wild rice gathering and other public uses, as required by state law. Among the findings:

- Only 12 private wells in the immediate area of the mine that are not owned by CMC will be potentially affected. CMC will monitor groundwater and will deepen or replace, at its expense, any wells that monitoring shows are likely to be affected by the mine.
- Water levels will not change on Lucerne, Metonga, Ground Hemlock, Mole, St. Johns, Oak, Crane, Pickerel, Post, Kimberly, Walsh and other lakes more than two miles from the mine.
- Effects on Rolling Stone and Rice lakes will be too small to measure.
- Among lakes closest to the mine, there will be minor effects – less than one inch – on Little Sand, Duck and Deep Hole lakes.



*Tailings Management Area

- There will be minor effects to Skunk Lake, a shallow, 6-acre lake on the mine property with no fish population and no cottages.
- For the expected mine impacts there will be no measurable change in the flow rate of the Wolf River. Swamp, Hemlock, 12-9, 11-4, Hoffman and Upper Pickerel creeks will see some reductions in flow.
- Effects of lowered water levels on wetlands will be limited to changes in the mix of plant life around the edges of some wetlands near the mine site. These wetlands will retain their value for wildlife habitat, stormwater storage and other environmental functions.

The decline in groundwater levels will be temporary. Within a few years after the mine is closed and reclaimed, groundwater and local lakes and streams will return to their previous levels, and wetlands affected by groundwater levels will revert back to their present conditions.

Effect* of Mining on Lake Levels

Lake	Change in Water Level (Inches)		
	Expected Case	Practical Worst Case	Natural Variation
Duck	0.1	1.3	31.7
Deep Hole	0.2	4.7	26.8
Little Sand	0.8	5.8	31.9
Skunk	6.4	7.0	56.0

Effect* of Mining on Stream Flows

Stream	Change in Flow Rate (Cubic Feet per Second)		
	Expected Case	Practical Worst Case	Natural Variation
Swamp Creek (STH 55)	0.91	1.49	8 to 228
Hemlock Creek	0.31	0.52	2.4 to 53
Hoffman Creek	0.15	0.26	Up to 5
Creek 12-9	0.36	0.62	1.1 to 42
Upper Pickerel Creek	0.16	0.28	Up to 23

* Effects under average conditions.

PROTECTING SURFACE WATERS

The Crandon mine's sophisticated water treatment plant and a comprehensive water management system will protect all lakes and streams in the project area.

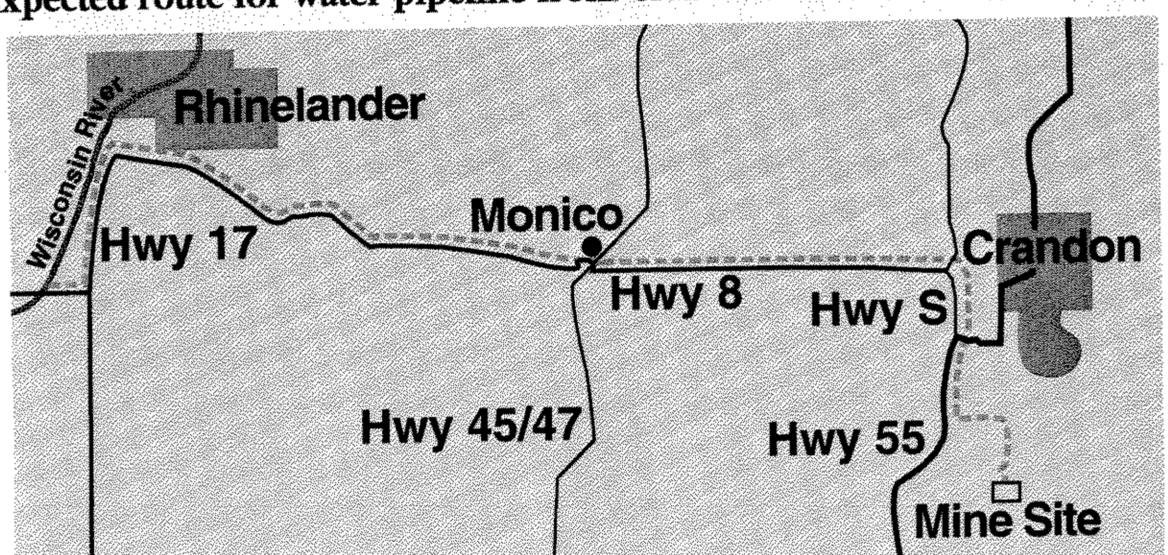
The Crandon mine will discharge treated water through a 38-mile buried pipeline to the Wisconsin River at the Hat Rapids Dam, south of Rhinelander. All water discharged will meet strict standards set by the Wisconsin Department of Natural Resources to protect water quality, fish and wildlife in the river. CMC studies show that the treated water will be consistently better than DNR standards.

The treatment plant will be built according to plans approved by the DNR and will use a lime/sulfide treatment process that has been tested to prove that it is effective. The plant will be staffed by state-certified operators with thorough knowledge of modern industrial water treatment systems.

The treatment plant will process both groundwater that seeps into the mine and surface runoff water from production and storage areas. After treatment, the water will be held in storage basins, where it will be tested. If at any time the water does not meet DNR standards, it will be recycled and re-treated. Water will be discharged to the Wisconsin River at about 570 gallons per minute, less than half of one percent of the river's flow at the Hat Rapids Dam measured at times of low water. This discharge will have no adverse effects on the river.

Throughout its life, the mine and mill will recycle and reuse water extensively to keep discharges as low as possible. During mine construction, runoff basins and erosion controls will keep soil and sediment out of local lakes and streams.

Expected route for water pipeline from Crandon mine to Wisconsin River



The mine's buried water pipeline, which will be installed within highway rights-of-way already disturbed by road work, will have minor, temporary effects on the environment.

MANAGING MINE TAILINGS

Mine tailings will be placed in engineered basins designed for long-term environmental safety. The tailings basins will provide permanent protection for groundwater.

Mine tailings consist of finely ground rock that remains after ore has been processed to remove valuable metals. The Crandon mine will use the latest, widely accepted technologies to manage these tailings for long-term environmental safety.

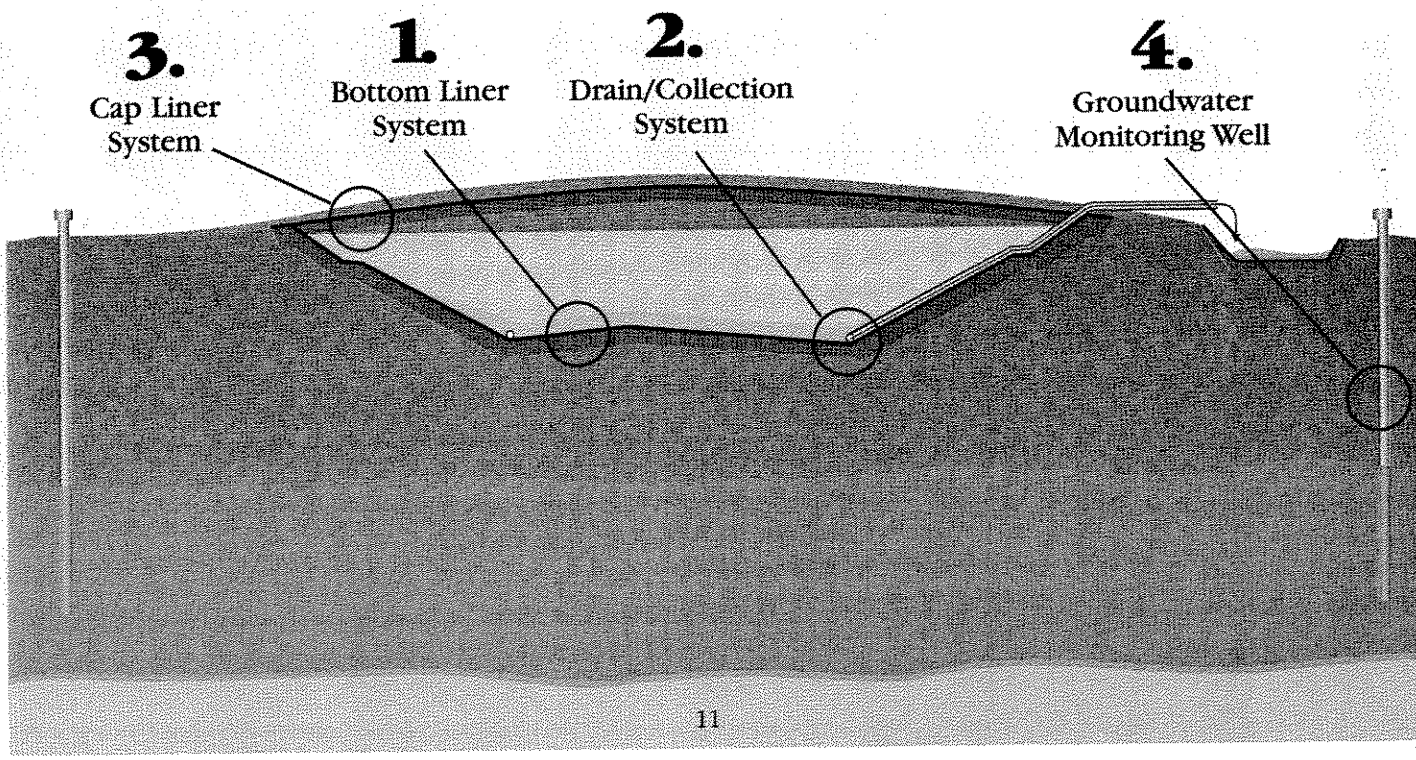
Engineered tailings basins will be built with multiple safeguards to prevent the condition known as acid rock drainage that has occurred at some old, unregulated mines. The basins will permanently protect groundwater to meet strict quality standards set by the Wisconsin Department of Natural Resources.

Each of the four tailings basins will be designed from the start to be reclaimed to an environmentally safe and stable condition. Each basin will include:

1. A bottom liner system that holds water within the basin.
2. A drain system that collects water at the bottom of the basin and above the liner system so that it can be pumped out and recycled or treated.
3. A cover liner system - called a cap - that limits the entry of water and oxygen and keeps tailings in a neutral condition.
4. Monitoring wells to detect changes in groundwater quality so that corrective action can be taken at an early stage, if that should be required.

Both the top and bottom liner systems will have multiple layers that include a heavy-duty plastic membrane, an engineered clay liner, and a 12-inch-thick layer of low permeable soil.

The basins will effectively isolate the tailings from the surrounding environment and surface waters. They will be constructed to withstand even major natural disasters such as earthquakes, tornadoes and floods.



PROTECTING WETLANDS AND WILDLIFE

The Crandon mine poses no threat to the survival of any species of plant or animal. It will protect wetlands and wildlife habitat to the maximum extent possible.

ENDANGERED SPECIES

During 1994 and 1995, CMC conducted an extensive search for threatened and endangered species around the proposed mine site. The search involved some 8,000 hours of study performed by more than 30 biologists and technicians. It covered 30 square miles, including nine lakes, 20 miles of streams and 1,700 acres of wetlands.

Among all the endangered species targeted in the search, only the goblin fern was found on land that would be disturbed by the mine. The goblin fern, listed by the state as endangered, lives on the site of the proposed tailings management area. However, in follow-up work, CMC biologists found the plant in more than 40 other places in six counties. Goblin fern habitat is common in Wisconsin, and the plant is also known to live in Minnesota and Michigan. Therefore, the construction of the mine will not endanger the survival of the goblin fern.

CMC studies have added greatly to scientific knowledge of the goblin fern and of the plant and wildlife communities of the Northwoods.

WETLAND PRESERVATION

CMC designed the mine facilities to keep effects on wetlands to a minimum. The project will result in a net gain of high-quality wetlands in the Fox-Wolf River watershed.

Mine facilities will directly affect less than 30 acres of wetlands, a tiny fraction of the wetland acreage in the surrounding area and Forest County. CMC will replace this acreage with 57 acres of high-quality wetlands, a ratio of nearly 2 to 1. The new wetlands will be created by reflooding land in Shawano and Oconto counties that was drained for farmland years ago. The land has natural wetland soils and will revert to a high-quality wetland within a few years. Ultimately, CMC plans to turn the property over to a public agency for permanent use as a conservancy area.

The goblin fern is a tiny plant newly discovered as a species in 1981. Wisconsin listed it as endangered in 1985 mainly because very little was known about it. CMC studies show this plant is far more abundant than previously thought.

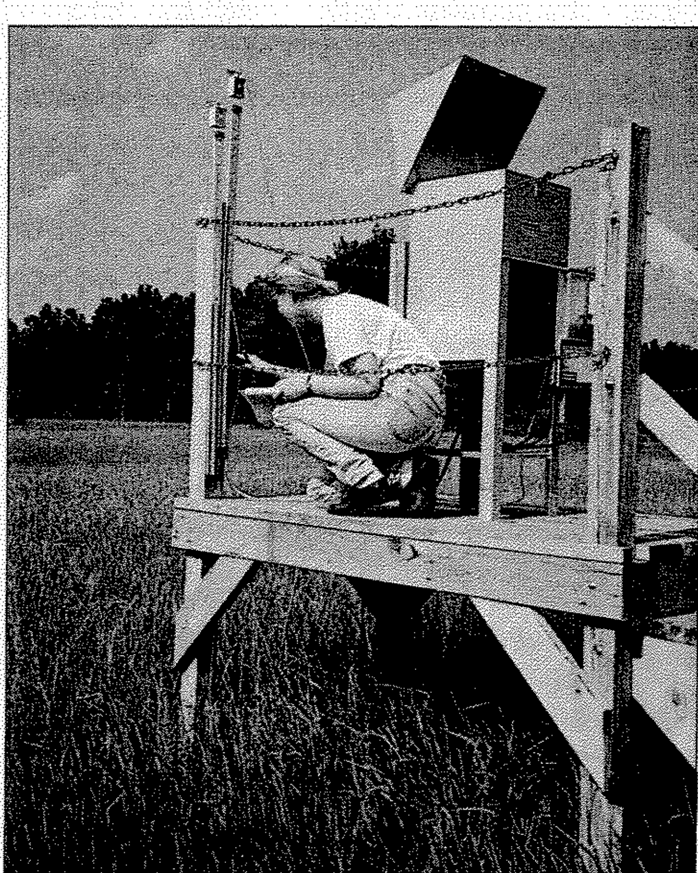
PROTECTING AIR, SCENERY AND QUIET

The Crandon mine will meet all federal and state air-quality standards. The mine will operate quietly, and mine facilities will be hidden by surrounding forests.

AIR QUALITY

The Crandon mine will be designed, built and operated with controls to keep the release of dust and other air pollutants as low as possible. As a result, mine emissions will have a minimal effect on local air resources and will be well within federal and state air standards.

Effective dust control devices will be used on underground mine equipment used for drilling, blasting, hauling and conveying of ore and rock.



Air monitoring stations will continuously measure air quality in the area to make sure the mine meets all air standards.

Mobile diesel-fueled machines will have exhaust scrubbers similar to catalytic converters.

The mine's air-heating system and the standby electric generators will be fueled with clean-burning natural gas. CMC will monitor air quality around the mine during construction and operations to make sure the mine complies with all air standards.

NOISE AND VIBRATION

As an underground operation, the Crandon mine will operate quietly. CMC will minimize construction noise by limiting work to daylight hours and selecting low-noise equipment. Mine ventilation fans will be designed and built for low-noise operation. Fan intakes and exhausts will be equipped with silencers, as will the emergency electric power generators. Vibration from underground mine operations will not be noticeable outside the mine property.

SCENIC RESOURCES

The mine will be compatible with local scenery. Even its tallest structure, the headframe over the main shaft, will be effectively screened by surrounding forests and will be visible from only a few locations. CMC will use low-intensity, downward-directed lighting outside mine buildings, on interior roads and in the parking area.

PRESERVING LOCAL HISTORY AND CULTURE

The Crandon mine affects no major historical features. It will protect Native American reservation resources, off-reservation activities and cultural sites.

In surveys covering more than 5,000 acres around the mine site, CMC researchers found a small number of pre-historic and historic archaeological sites, all but one outside the immediate area of the project. The most significant historic site was the former Keith's Siding railcamp settlement northeast of the mine along the route of the proposed rail spur. This site may qualify for the National Register of Historic Places. If so, artifacts will be recovered using techniques approved by state and federal agencies.

CMC studies show that the mine is compatible with the protection of Native American reservation resources, off-reservation activities and economies. CMC has commissioned extra studies of Native American cultural resources in the vicinity of the mine including traditional cultural properties. CMC continues to seek assistance from the Tribes in evaluating these matters and resolving any concerns.

CMC is committed to building a productive dialogue with the Mole Lake Sokaogon Chippewa Community, the Forest County Potawatomi Community and the Menominee Indian Tribe of Wisconsin on matters of environmental, economic and cultural concern. In line with this commitment the company has pledged to:

- Respect the separate sovereignty, culture, traditions, heritage and diversity of each of the Tribes.
- Comply with the letter and spirit of all applicable laws governing Native American rights.
- Make active efforts to evaluate, understand, avoid and minimize any potential adverse effects of the mine on Native American Tribes, their members and the cultural resources they use.
- Explore possible service, supplier and other business relationships that could mutually benefit the Tribes and the company.

MONITORING AND CONTINGENCIES

CMC's monitoring and contingency plans will ensure the environment is protected throughout mine construction and operation.

CMC will monitor the environment throughout the life of the mine to verify compliance with state and federal laws. CMC will regularly monitor groundwater levels and quality, surface water quality, water levels in lakes and streams, water levels and plant life in wetlands, water seepage into the mine, air quality, and more.

If the monitoring program should detect any unexpected conditions, contingency plans would help CMC find the cause and take prompt, effective action, if needed. CMC also has contingency plans to ensure effective response to such events as storms, floods or fires.

To keep the chance of unexpected events as small as possible, CMC has designed its environmental controls with back-up safety systems. For example, the water treatment plant includes two separate treatment units, each able to treat all the mine water if the other should need repairs. Mine buildings and the tailings management area are designed to withstand even major natural disasters.

RECLAIMING THE LAND

CMC must guarantee that the mine site will be reclaimed to a long-term, environmentally stable condition. Environmental monitoring will continue for at least 40 years after the mine closes; environmental liability will last forever.

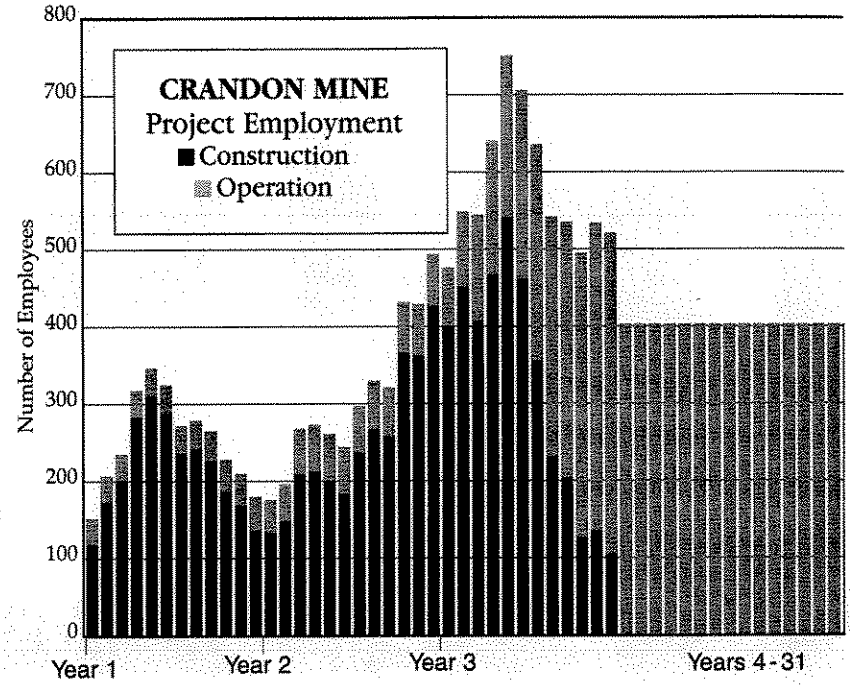
After the mine closes, CMC will reclaim the land so that it can return to productive uses, and so that the environment is protected for the long term. State law requires that CMC provide extensive guarantees that the site will be properly reclaimed and that the mining company covers all costs. Before receiving a mining permit, CMC must:

- File an environmental monitoring plan and prove financial responsibility for long-term care and monitoring on the site for 40 years after the mine closes - or longer if the state Department of Natural Resources determines it is necessary.
- File a financial guarantee large enough to pay for full reclamation of the site at any point in the life of the project.
- Assume perpetual environmental liability for the site. (Wisconsin Statutes 144.441 (2) (c) says: "... the owners' responsibility for the long-term care of an approved facility does not terminate.")

Mine reclamation will be an ongoing process. When work is completed on any part of the site, reclamation in that area will start promptly. When the entire project is completed, mine shafts will be plugged with concrete and surface facilities will be removed or converted to other uses. The land will be regraded, planted with trees or other vegetation, and converted to forestry or recreational uses.

ENHANCING THE LOCAL ECONOMY

The Crandon mine will add about 740 long-term mining and mine-related jobs in the three-county area, while adding just 1.2 percent to the area population.



The Crandon mine will provide a major increase in jobs, tax base and tax revenue in Forest, Oneida and Langlade counties while having minor effects on population. That is the conclusion of a study forecasting the mine's socioeconomic effects over a 40-year period, starting with the onset of mine construction. Here is a summary of the major findings:

EMPLOYMENT

The mine construction work force will start at about 175 in the first year, then gradually increase to a peak of about 550 during the third year. CMC will encourage contractors to give hiring preference to qualified tri-county area residents.

During 28 years of mine operations, CMC plans to employ about 402 people full-time. CMC will give hiring preference to tri-county area residents and will provide job training so as many local people as possible have the opportunity to work at the mine.

People employed at the mine will spend money throughout the tri-county area, stimulating the economy and helping create more new jobs. For every 10 jobs at the mine, approximately eight jobs will be created in related businesses. CMC estimates that 402 mining jobs will lead to an additional 341 jobs in local communities.

CRANDON MINE
ESTIMATED NET PROCEEDS TAX PAYMENTS

Jurisdiction	Total Payments Over Project Life
Town of Lincoln	$ 4.0 million
Town of Nashville	$ 4.0 million
Forest County Potawatomi Community	$ 2.4 million
Sokaogon Chippewa Community	$ 2.4 million
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Reserve Fund	$ 8.6 million
Discretionary Grants for Local Impacts	$ 42.6 million
Total Local Share	**$ 71.9 million**
State of Wisconsin Badger Fund	$ 47.2 million
GRAND TOTAL	**$119.1 million**

Crandon Mine Employment Projection

Type of jobs	Number of jobs	Duration	Local hires
Construction	175 to 550	3 years	30%
Operations	402	28 years	70%
Local mine-related	341	28 years	

LOCAL SPENDING
The mine will spend about $43 million for goods and services in the tri-county area during three years of construction. During 28 years of operations, the mine's local spending will total about $1.2 million per year, or about $33.6 million over the project's life.

POPULATION
Because a large majority of mine workers will be hired locally, the mine will have a minor effect on population in the tri-county area. During operations, the mine will add about 713 more people (1.2 percent more population) than if the mine were not built. About 34 percent of the new residents will live in Forest County, 38 percent in Oneida County and 28 percent in Langlade County. During the peak of mine construction, the population of the tri-county area will be about 1,174 people (2.2 percent) higher than if there were no mine.

HOUSING
The housing supply in the tri-county area can support the small population growth created by the mine. Long-term mine operations workers will need a maximum of 1.1 percent of the available homes in the tri-county area. During the peak of construction, mine workers will require about 2.7 percent of the area housing supply.

LOCAL GOVERNMENT EXPENSES
Because of the modest growth in population, the mine project will not require any major expenses for additional fire and police protection, social services, highways, water supply, wastewater treatment or other government services.

SCHOOL DISTRICT ENROLLMENT
The area's eight school districts will have ample space for the children of new families. The mine will bring about 150 more students than if the mine were not built, but those students will be spread across the Antigo, Crandon, Elcho, Laona, Rhinelander, Three Lakes, Wabeno and White Lake districts. No schools will have to be built or expanded because of the mine.

TAX REVENUE
CMC will pay federal and state income taxes totaling an estimated $175 million over the life of the mine. In its first year of operation, the mine will add an estimated $110 million to the local property tax base, to the benefit of taxpayers in Forest County, the Crandon School District, and the towns of Lincoln and Nashville. Local governments will be able to use this increased tax base to provide property tax relief, to improve local facilities and services, or both.

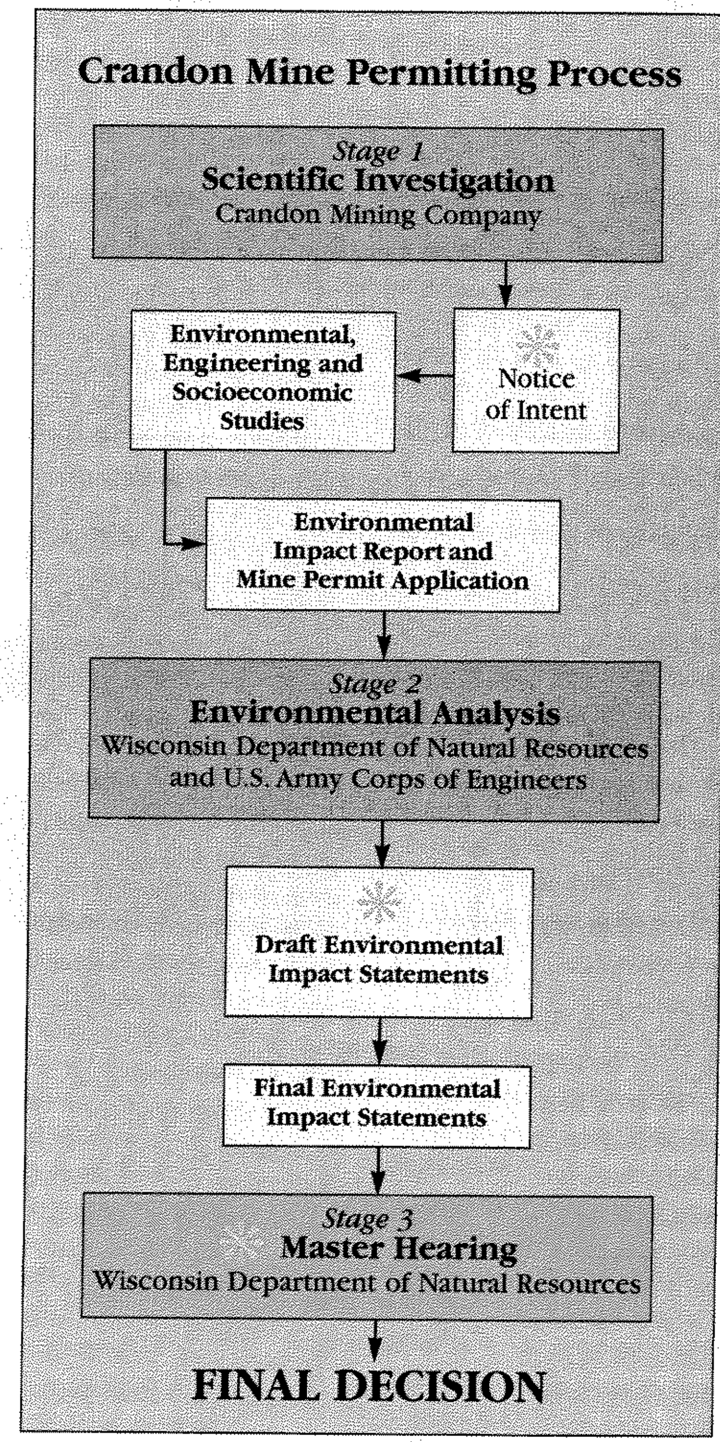
Over its life, the mine will pay an estimated $119 million in Net Proceeds Taxes to the state. Of this amount, $71 million (60 percent) will go into the Mining Investment and Local Impact Fund available to local communities as direct payments and discretionary grants.

STAYING INVOLVED

Wisconsin's mine permitting process encourages public involvement.

Plans for the Crandon mine will receive a thorough review conducted by the Wisconsin Department of Natural Resources and the U.S. Army Corps of Engineers under federal and state laws. In addition, the mine requires zoning approval from six local jurisdictions: Forest and Oneida counties, the towns of Lincoln, Nashville and Crescent, and the City of Crandon.

The accompanying diagram shows how the state mine permitting process will proceed. Complete copies of CMC's Mine Permit Application, Environmental Impact Report and other official documents related to the mine project have been placed on file at local libraries and at town, city, county and tribal offices. All tri-county area and Wisconsin residents are welcome to review the documents and become actively involved in the process.



✳ Public Hearing

About Crandon Mining Company
Crandon Mining Company is a partnership between subsidiaries of Exxon Coal and Minerals Company of Houston, Texas, and Rio Algom Limited of Toronto, Ontario. Staff members are:

Rodney Harrill	President
Bob Abel	Controller
Don Moe	Technical/Permitting Manager
Ken Black	Senior Environmental Engineer
Dick Diotte	Director of Community Relations
Doug Kincaid	Site Manager
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Lynn Smith	Administrative Assistant
Barb Newlun	Administrative Assistant

Crandon Mining Company

• Environmentally Responsible •

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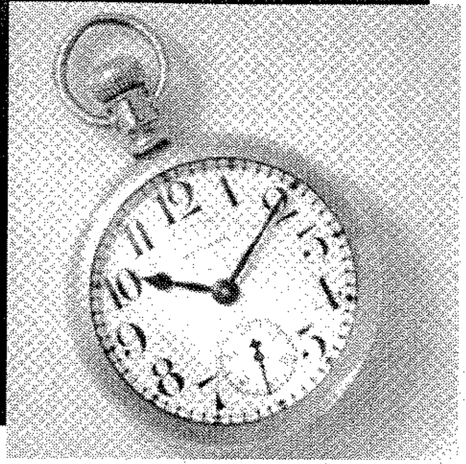


It's Time You Had the Facts About Modern Mining in Wisconsin!

Mining is not a new industry here in Wisconsin ... from the earliest settlers in the southwestern part of our state to the iron ore operations in Black River Falls during the 1970s to the Flambeau mine currently operating in Ladysmith, the mining industry has, like many industries in Wisconsin, abided by our State's laws and regulations, created jobs and produced tax revenue.

And, just like any other industry, the mining industry has undergone changes: modern technology, advances in engineering, and increased regulatory oversight, differentiate mining in the 1990s from mining in years past.

Industry experts, regulators and scientists agree on the key points about modern mining. The Wisconsin Mining Association hopes that by providing the facts about the industry, we can help focus the discussion about mining in Wisconsin on the facts, the evidence and the reality of mining today.

From exploration to reclamation, Wisconsin ensures the protection of every aspect of the environment — groundwater and surface water, air and wetlands, wildlife and scenic value — with stringent laws, public involvement and proven technology.

This informational packet was prepared by the Wisconsin Mining Association and printed on recycled paper.

1 The Water Treatment Plant

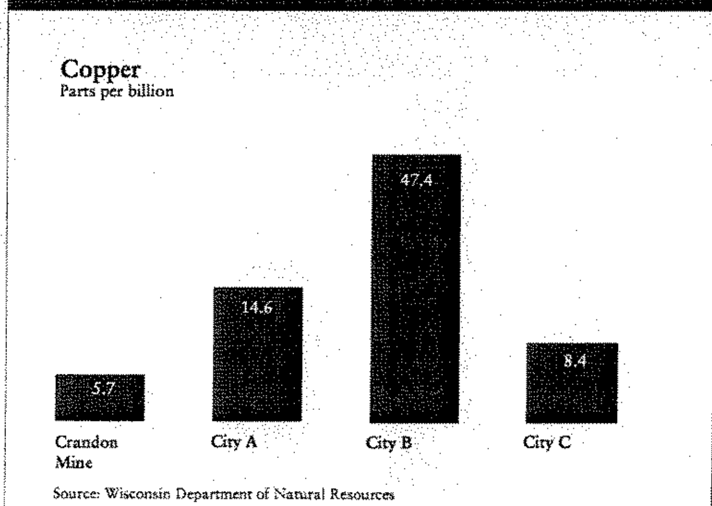
There are 599 industrial and 678 municipal water treatment plants in the State of Wisconsin. Every one of them is regulated and monitored by the DNR just like the proposed Crandon plant will be.

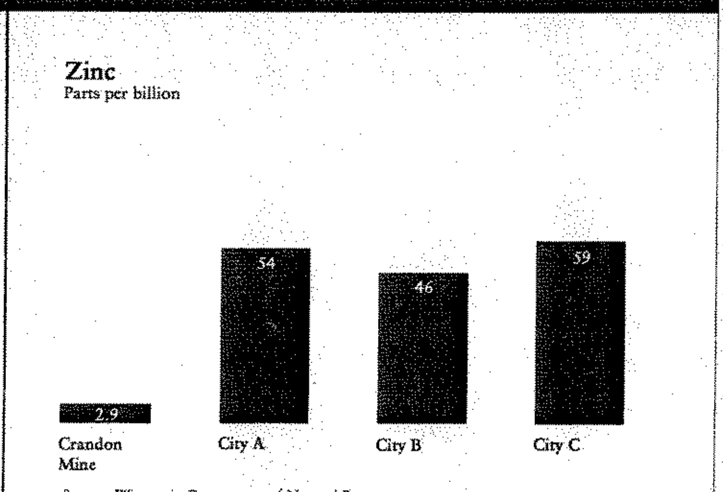
Before it can acquire permits, Crandon Mining must prove its treated water will meet permit standards.

The proposed Crandon mine will have a state-of-the-art water treatment facility which will use technology that is widely acknowledged to be reliable and effective. For example, using similar technology, the Flambeau mine's water-treatment plant has consistently produced water that is better than its permit requires.

- ✔ **All water that makes contact with any aspect of the mine operation will be collected and treated at a state-of-the-art water treatment facility that will be operated by a state-licensed technician.**
- ✔ **The Crandon mine will make use of the same technology and engineering that has been PROVEN to be effective in treating water at the Flambeau mine. The Flambeau project has been operating for more than three years and has consistently produced water far better than the permit standards which protect the most sensitive of aquatic species.**
- ✔ **The DNR has studied the Crandon mine's water treatment system and has concluded treated water from the mine will be of far better quality than other dischargers currently permitted to discharge treated water into the Wisconsin River (see charts below).**
- ✔ **Currently, more than 24 industries and municipalities discharge carefully treated water into the Wisconsin River. All told, more than 1,200 Wisconsin communities and industrial operations are currently permitted to discharge water into the State's lakes and streams. These discharges must meet water quality standards that protect human health and the most sensitive of aquatic species.**
- ✔ **The flow of treated water into the Wisconsin River represents one tablespoon of treated water per gallon of River water at the River's low flow. At the River's high flow, Crandon's treated water will represent an average of one teaspoon per gallon.**

DNR Test Results: Crandon Discharge Compares Favorably to Other Wisconsin River Dischargers





DNR tests (results shown above are for copper and zinc, two prevalent components of the Crandon deposit) show the Crandon mine's treated water will be better than other area dischargers and better than expected permit standards. All of the discharges shown in these charts meet state regulations. Crandon Mining proposes to transport treated water from the mine through a 38-mile buried pipeline to the Wisconsin River. Water would be discharged into the Wisconsin River at the Hat Rapids Dam. The plan must be approved by the DNR as part of Wisconsin's permitting process.

Crandon Mining Company

Six Tests

Six Tests

Under Wisconsin Law, no mine can receive a permit from the Wisconsin Department of Natural Resources unless it:

1. *Complies with all pertinent environmental regulations.*
2. *Safeguards lands with critical ecological importance or historic value.*
3. *Protects public health, safety and welfare.*
4. *Benefits the local community and economy.*
5. *Complies with local zoning laws.*
6. *Includes suitable plans for reclamation.*

Wisconsin Statutes 144.85

Crandon Mining Company

Wisconsin's Mining Heritage

Wisconsin has a long history as a mining state. The first major influx of settlers consisted of prospectors and miners flocking to the southwestern lead region. All told, this area produced some 69 million tons of zinc ore and more than one million tons of lead metal from the early 1800s through 1968. Wisconsin also contained all or parts of six iron ranges, mined from the mid-1800s through the early 1980s. Many signs of mining heritage still remain:

- "The Badger State" is named for early lead miners who, like badgers, lived in burrows in hillsides.

- Galena -- lead sulfide -- is the official state mineral, designated by the Legislature in 1971.

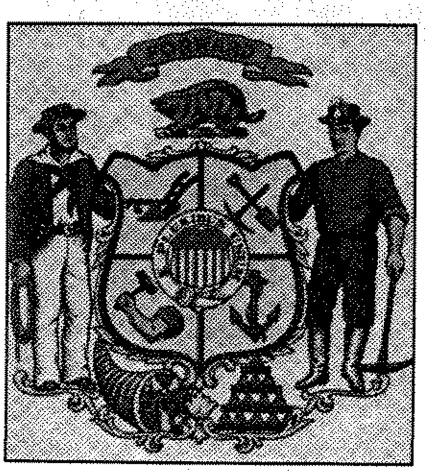
- Mining is evident in the names of Wisconsin places: New Diggings, Mineral Point, Lead Mine, Ironton, Iron Ridge, Iron Belt, Platteville (named for flat sheets of lead produced by crude log-fired lead smelters).

- The University of Wisconsin-Platteville evolved in part from the Wisconsin Mining Trade School, established in 1908. The large letter M on a hillside northeast of Platteville stands for mining.

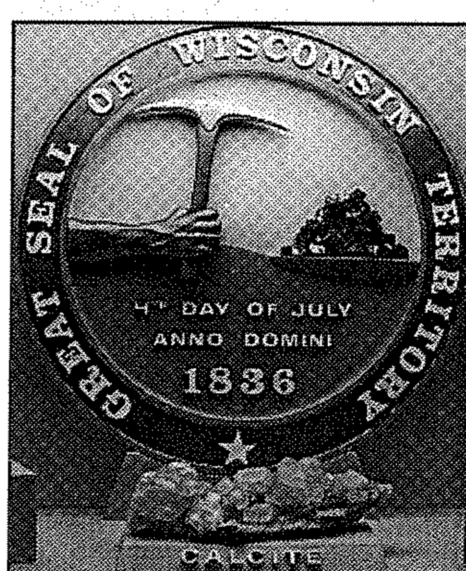
- The weekly newspaper in Hurley is the *Iron County Miner*; the Florence weekly is the *Florence Mining News*.

- Shullsburg High School sports teams are called the Miners; Ashland High School teams are called the Oredockers.

More than 10,000 Wisconsin residents now earn their living in mining, or in companies that supply the mining industry. Meanwhile, mining history lives on at the Pendarvis Historic Site in Mineral Point, at mining museums in Platteville and Shullsburg, at the State Historical Society of Wisconsin museum, at Tower Hill State Park near Spring Green, and at local heritage museums in Hurley, Benton and Mayville.



The Wisconsin State Seal shows a miner, mining implements, and the badger, a symbol of early lead miners who burrowed into hillsides. The state seal also appears on the stateflag.



This replica of the Wisconsin Territorial Seal is on display at the Mining Museum in Platteville.

Crandon Mining Company

SOCIOECONOMIC IMPACTS

Socioeconomic Impacts

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Local & State Revenue Benefits

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Over the life of the project, the Crandon Mine is expected to contribute about $1.5 billion to the Wisconsin economy in the forms of wages, taxes, royalty payments, materials, supplies and services.

Population

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Tourism

Many of the services used by the mine will be supportive of tourist-oriented businesses, such as restaurants, hotels, convenience stores and service stations. The experience of the Flambeau mine shows that mining is supportive of tourism and, in fact, serves as its own tourist attraction, with over 100,000 people having visited the Flambeau mine over the past five years.

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