VI. A Rock and a Hard Place

● A Rock and a Hard Place

Mining is generally recognized as the dirtiest of the resource extraction industries. Whether it's for metals, fossil fuels, or what have you, mining makes a mess. The annual Toxics Release Inventories required by EPA pursuant to the *Emergency Planning and Community Right ot Know Act* of 1986 (EPCRA) document that mining accounts for by far the largest discharges of pollutants to all media—air, water and soil.

Being one of the most basic resource suppliers, upon which all sectors of society depend, the mining industry is also one of the most intractable (not to say obstinate, hardheaded) of toxics industries, and one of the heaviest lobbying interests. Of all the industries I've dealt with, it still seems to me that mining has moved least toward any sense of environmental and public health protection, let alone pollution prevention, and it has fought every step of the way toward what improvements have been made.

Like towns dependent on any major industry, mining towns tend to be company towns, communities dominated by the company, which in the case of mining is usually a multi-national corporation with its head office in the state capitol or another state or country. Local attitudes about the company and mining in general vary according to stages at any given time in the bust-and-boom economic cycles endemic to the industry and also along labor-management lines. Union struggles to organize western mines are legendary for the brutality of company opposition, one of the most infamous examples being the 1917 "Deportation" in which Phelps Dodge Corporation with the assistance of local police broke a strike by early one June morning rousting out of bed at gunpoint (with pre-approval of President Wilson, the Arizona governor and the sheriff of Cochise Co.) more than a thousand miners (strikers and alleged sympathizers), marching them to the railroad heading, putting them in cattlecars, shipping them into the New Mexico desert and leaving them there in the summer heat several miles from the nearest town.

Until very recently, regulation of mining has been sparse at best, whether surface mining (coal and other "soft" materials), hard rock (metals), oil and gas, or other materials. Until 1977, the main US law for mining was the *General Mining Act* of 1872, which governs prospecting and extraction of hard rock minerals on federal land and is principally concerned with leasing of public lands, with little reference to environmental concerns *per se*.

Environmental and worker protection in mining became major focuses of citizen groups in the 70s. Concerns with occupational hazards resulted in passage of the 1977 *Federal Mine Safety and Health Act*, which updated earlier mine safety laws and established the Mine Safety and Health Administration (MSHA) within the Department of Labor. The first federal mining law with significant environmental provisions was SMCRA (the *Surface Mining Control and Reclamation Act* of 1977), which addressed coal mining and required some restoration of mined lands.

Throughout much of the 70s and 80s, the focus of environmental organizations in regard to hard rock mining was the 1872 law, because reform of the law would potentially allow some protection of public lands, traditionally the principal concern of mainstream environmental organizations, and because (largely due to the efforts of those organizations) the 60s and 70s had seen major gains in environmental protection of public lands and public participation in their management. However, reform of the 1872 law proved politically impossible, and environmentalists turned to regulatory rather than legislative efforts at the federal level, and to both regulatory and legislative efforts at the state level.

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While the DC-based Mineral Policy Center (MPC), closely aligned with the Sierra Club and other national NGOs largely concerned with public lands, led efforts at reform of the 1872 Act, efforts to bring mining into the environmental arena through other means were led largely by two grassroots organizations: first, the Citizens Mining Information Network (CMIN), and then the Environmental Mining Network (EMN). Having been intensely engaged with mining issues since the mid-70s through my involvement with the Phelps Dodge smelter in Douglas and its Copper Queen mine in Bisbee, and in other mines through my role as a member of the Sierra Club's National Hazardous Materials Committee, I came to work closely with MPS, CMIN and EMN, including work with EPA, the USDI-BLM, the USDI Bureau of Mines and other federal and state regulatory agencies,

Unfortunately, though successful in organizing and providing significant training to mining activists, on the federal level CMIN and EMN suffered the same fate as MPC. Particularly disappointing was our failure, despite several years of determined efforts, to get mining regulation written into Article D (the non-hazardous waste section) of RCRA (the *Resource Conservation and Recovery Act* of 1976).

In Arizona, we were more successful. Although we didn't manage to achieve legislation to directly reform mining (as other states, notably New Mexico, did), we were able to pass the *Environmental Quality Act* of 1986. Primarily authored by David Baron of the Arizona Center for Law in the Public Interest, in association with the Sierra Club, Southwest Environmental Services and other organizations, and modeled after an existing California law, the EQA established the Arizona Department of Environmental Quality (ADEQ, the state's EPA), and required pollution controls of all facilities, including mines, that discharged contaminants to aquifers in the state.

Although like many mines, the Copper Queen was on patented land (having originated in the 19th C before Arizona achieved statehood or Bisbee official cityhood, and so was exempt from public lands rules like those of the 1972 Act, it was not exempt from the EQA. Under pressure from ATI and Border Ecology Project, ADEQ chose PD's Copper Queen mine in Bisbee as the first mine in the state to go through the EQA permitting process.

Underground operations at the mine had closed in 1976, so the applicable EQA regs were those dealing with facility closure. PD had long said that there were still rich deposits of ore under its properties in the Bisbee area and that someday, when world copper prices warranted it, they would extract those deposits. One important stipulation of the EQA closure permit was that PD would not be allowed to resume mining before it had first met all permit requirements for closure of the old operation. Among several other requirements, resulting in several extensive clean-up and pollution prevention actions, PD was required to cap tailings piles from the old mine to prevent percolation of contaminated water to the underlying aquifer).

A few years ago, PD sold the CQ to world mining giant Freeport McMoran which also acquired clean-up responsibilities stipulated in the EQA permit and the potentialities for liability connected to the seven-mile long plume of contaminated groundwater stemming from the old tailings piles.

Let's do something exciting tonight.
Let's waste something or ruin something
or make some acid rain or something.

Walking through the acid wastes of Bisbee improper
picking up on all the semi-precious stones--
St. Elmo preserve us, these tailings are hot, the air's on fire--
drop your eyes in the Lavender Pit to fall and fall like spit
from that Turista Kid hanging on the hurricane fence
behind the Chamber of Commerce viewpoint

Once there was a Queen who sold her soul
until all she had left was a big hole.
What did she do then? She sold the hole.

from "Eating Brown Rice and Tamari by
Light of an Ill-adjusted Aladdin Lamp in
Just Deserts, Arizona"
Mr America Drives His Car

On Aquifer Protection Permitting of Phelps-Dodge Copper Queen Branch (1987)

Michael Gregory, for the Sierra Club Grand Canyon Chapter, presented to Arizona Department of Environmental Quality (29 December 1987)

Dear Ron,

In response to your letter of 16 November 87 to me and Dick Kamp. There are several aspects of the letter that give us cause for concern, some of which are touched on in the enclosed letter to Norm Weiss concerning Aquifer Protection Permits (APPs).

Insofar as the Copper Queen facility is to be permitted before the APP rules are adopted, it serves as a model for how the department will be handling other such cases. In that regard, we could use a good deal of clarification about some of the points in your letter.

For instance, in paragraph 2, you state that the department will require PD "to seek a Groundwater Quality Protection Permit (soon to be Aquifer Protection Permit under our new program)." But this implies an equivalence between APPs and GPPs which is just not there. BADCT, contingency plans and other aspects of the APP program are lacking in the old GPP program. Will PD in fact be applying for a GPP or an APP, and when will the application be submitted? Will it be submitted too late to qualify for an APP?

Another question arises from your statement in paragraph 2 that a permit will be required for "all their operations in the Bisbee areas." Does this mean that a single permit will cover all operations, or will different permits be required for different parts of the complex (e.g., tailings ponds, existing leaching, proposed solvent extraction)? If different permits will be required, which will be APPs and which GPPs?

In response to your numbered items:

> 2) Exactly how will the department consider the impact of underground workings, etc. on private wells in Old Bisbee"? Will there be monitoring of those wells, as we have requested?
>
> 4) We disagree with your statement that "the USGS and DEQ studies define the plume quite well." Monitoring has been done primarily only to the south of the tailings ponds. But there is no very goo reason to assume that the plume lies entirely within the USGS study area, nor that the ponds are the source.
>
> 5) Similarly, we disagree with the conclusion that "contaminant movement eastward is unlikely. In fact, no one knows what the groundwater flow is like in the area, reegardless of what groundwater contours indicate. Fissures and cracks in the bedrock or other subsurface conditions may well allow groundwater movement to the east and north. Monitoring should be done in those directions, especially around the mining area itself. The "undetermined subsurface recharge" mentioned in the USGS report may basin and the Sulphur Springs from some hydrologic connection between the Naco/Bisbee subbasin to the east. As the USGS study also states, "no data are available on the hydraulic characteristics of the sedimentary, igneous, and metamorphic rocks" that comprise the basin fill.
>
> 6) We cannot agree with your assumption that the mine discharges onto the tailings

> ponds is "the reason for water quality degradation beneath and downgradient from the tailings pile." This may be the case, but we have seen no evidence to prove it. We cannot agree, either, with your statement that "the USGS report indicates that discharge of water to the tailings pile is responsible for rising groundwater levels in the Bisbee Junction area." The USGS report says simply that this "rise in water level is compatible with the development of a ground-water mound resulting from recharge at the mine-tailings pond northeast of Naco." No conclusion is drawn by USGS, since other factors might also account for the rise of water, and no definitive conclusion should be made until more is known about long-term water-levels in the area. Certainly the drop in levels in some area wells would indicate that a better characterization of the subbasin's hydraulics muse be made before such conclusions can be drawn.

Similarly, without a better understanding of groundwater flows and fill characteristics, we cannot see now you can assume "that cessation of pumping will return hydrologic conditions ot their pre-mining status." We would hope so, and would urge that this be one of the goals in any permit issued.

Even if cessation of pumping does mitigate the tailings pond problem, we cannot assume thst it will mitigate other problems. The parallel situation at Anaconda's Berkeley Pit in Butte gives us cause for concern hee. In Butte, the abandoned pit is filling with contaminated water, not water of good "ambient quality" as you anticipate.

We are particularly concerned by your apparent decision to exclude further public participation until the "public comment stage of the permit process." As I said at the APP working group meeting, the public should be included at every stage of the process in order to avoid difficulties later. The permit process should not be a closed-door confab between the department and the industry. The department needs public input, especially at the front end.

The value of public input in the Copper Queen process is clear. For instance, as of late last month the department personnel handling this situation seemed to be unaware of or ignoring the Notices of Violation EPA had served on PD for exceeding *Clean Water Act* standards. Until Dick brought the NOVs to the department's attention, they seemed likely to completely miss their significance to the permitting process. And the department still seems intent on ignoring the fact that not all of the NOVs were for waters headed south: some related to the waters discharged into Mule Gulch, to the east of the tailings ponds, another reason we recommend monitoring that area.

Rather than exclude the public from the process, we urge the department to include public input at every stage of the process. We hope to be allowed to review and comment on all permit documents submitted by PD and, as soon as possible, to be included in discussions with PD concerning permit requirements, hydrogeologic characteristics of the area, etc.

On Permitting of the Phelps Dodge Copper Queen Branch (1990)

Michael Gregory, submitted to the Arizona Department of Environmental Quality (8 April 1990)

Dear Mr Wood:

Thank you for your letter (undated) in response to ours of 15 January concerning the referenced subject. We have also received correspondence from Ms Abigail Myers, Environmental Program Specialist of the Water Permits Unit.

As you know. it is our opinion that permitting of existing facilities has taken the department far too long since passage of the EQA. Permitting at PD-Bisbee, a priority site, is especially long overdue. The State has never before required the company to get a groundwater protection permit of any kind, and its existing 180 million tons of waste are blamed by the state and federal governments for already polluting the groundwater, so we are glad to see that the department is finally starting to set some deadlines for permit applications at Bisbee. We continue to believe, however, that with the permitting process should already have begun with the new leaching operation the company has started.

As stated ion the interoffice memo of 7 March 90 from Ms Myers to Skip Hellerud, "a decision that does *not* [sic] result in. . .a requirement [that the facility obtain an APP for the pilot operation] has the potential of setting a precedent that may be undesirable. Individuals may find it advantageous to construct discharging facilities on top of existing facilities and thus avoid the permit process." This, of course, is exactly what the department's no-permit decision allows PD to do.

In effect, the department is saying to all minewaste generators that as long as they call their operation a "test" or "pilot" and as long as the facility has accumulated a high enough volume of wastes from previous operations, then it's ok (a) to blast and dig for up to a year in an area never before mined; (b) to create a new pit by taking out as much as 40,000 tons of ore and uncalculated amounts of overburden without consideration of effects on water flows, wildlife, vegetation or other environmental parameters at the pit site; (c) to expose the nearby communities to dust, sonic and concussive impacts of greater magnitude and duration than they have been subjected to for more than a decade; (d) to do so without accurately characterizing the composition and volume of the leach water or the aerial and liquid waste streams, except to say that the acidic wastewater "discharge characteristics may be quite similar" to discharges historically released to the receiving dumps and that the additional volume of waste put on the existing dump will amount to less than 1% of the volume of what is already there; and that (e) to do so without prior notification to and approval by the department.

The department has apparently decided that the degree if significance depends on (a) similarity between characteristics of wastes from the new activities and those of existing waste piles from previous activities, and (b) tonnage ratios between the two. In doing so, the department in effect limits evaluation to thr parameters set by PD's claim of exemption on grounds "that t [the new] operation will not significantly alter the volume or characteristics of pollutants discharged." In effect, the department buys into the company's argument and, unsurprisingly, ends up "taking the company's word for it" that the changes taking place ar insignificant.

Although we agree that these two criteria should weigh heavily in the department's deciding what *significant* means, objective valuation of significance requires that other factors be taken into account. The significance of volume, for instance, depends not just on tonnage ratios of waste stream to waste pile, but on things like the size of the hole blasted and dug out, and the effect of that on area hydrology (water courses, aquifer quality, etc.).

Forty thousands tons of material may represent only "about 1% change in the amount of material on the existing dump," but 40,000 T is not necessarily an insignificant amount when compared to other factors; for instance, the effect on the watershed of removing 40,000 tons of ore and uncalculated tons of overburden from a site that, like this one, hasn't been stripmined before.

In deciding that an Aquifer Protection Permit is not required, the department loses the ability to require BADCT. Consequently, although the memo asserts that the new leaching "process" is essentially the same, if not improved," the department has not sought proof of this nor determined what level of improvement is appropriate for health and environmental protection.

The department's decision raises several questions:

1) Is the department going to assume that any change in volume of less than 1% automatically constitutes an insignificant modification under the EQA?

2) According to a recent newspaper article (enclosed) PD does not intend to use Mule Gulch effluent for the pilot project, but will use "pure" water purchased from the Arizona Water Co. This is presumably the 2000 gpm reported by Mike Schern and is not accounted for in the current NOD and NPDES permit. Will the department or EPA require a revised NOD and/or permit?

3) The Arizona Water Co. wells are located downgradient from the tailings piles in the San Pedro Basin adjacent to wells that the piles have already contaminated. What environmental impacts will the greatly increased drawdown have on the aquifer and movement of contaminants in it?

4) Since "no flow rates to and from the dumps were. . .ever submitted to the file," and there are "unresolved" discrepancies in the volume figures, does the department intend in general to disregard flow rates in determining significance of modifications?

5) Has the department required quantitative data on "the characteristics of water used to leach the piles. . .[and] for water emanating therefrom"? When will the department have that information?

6) How much of the waste generated doesn't get discharged onto the waste piles; how much is dispersed in the air, for instance, and deposited into the surrounding landscape, waters and communities? How much escapes into drainages like Mule Gulch?

We look forward to hearing from you or your staff in response to these questions. Please also send copies of the interim Report of 19 September 1989, updated versions of the APP Guidance Document and copies of the "additional leach test results" cited in Ms Myers' 14 March 1990 letter to Mike Schern, and any future monitoring reports or correspondence with PD concerning the permitting process.

Before the Subcommittee on Mineral Resources Development and Production, Committee on Energy and Natural Resources, United States Senate (1990)

Michael Gregory, presented to the Oversight Hearing on Reclamation and Bonding Practices Associated with Hard Rock Mining on Federal and State Lands, Washington, DC (19 April 1990)

Contents

Background

Mr. Chairman, members of the Subcommittee, I am Michael Gregory, co-director of the Arizona Toxics Information Project, a private non-profit organization working for improved environmental regulation of hazardous and toxic materials, including substances used in and produced by mining.

At the outset, Mr. Chairman, I would like to thank you for holding these hearings and for your persistence in seeking real answers to a problem that is of great concern to the public, especially in states like Arizona that have no mining reclamation law.

Arizona, like the other western states, has a long history of hardrock mineral extraction. In my part of the state, near the Mexican border, there are mining sites that predate the Spanish invasions by hundreds of years. Arizona minerals were one of the commodities carried along the prehistoric trade routes between Central and North America.

The Spaniards came into Arizona and the Southwest in the 17th C largely for the minerals, not just the legendary El Dorado gold and silver, but for the more utilitarian minerals like copper. It was not unusual for the Spanish conquerors to work the same ore bodies that the Native Americans had used, and not infrequently they worked those mines with the forced labor of those same Native Americans.

The third wave of miners, starting shortly after the California gold rush, followed suit and some of the richest Arizona operations since the '49ers have been at ancient sites.

This long tradition of mineral extraction has had significant impacts on the fragile desert environments of the Southwest and is one of the dominant formative elements (along with cowboys and Indians and wide open spaces, etc.) in the Southwestern social and psychological environments. If you live in the Southwest, you're in mining country and mining is going to be a pervasive force in your life. Unfortunately, due to the very nature of mining, that pervasiveness can become invasive, entering not only our minds and institutions, but the most private parts of our bodies, including internal organs, tissue and cells.

Toxic by-products of mining enter the environment primarily through the air and the water. From those media, they migrate out into the food chain. Although when we talk about mining and toxics we usually think of the waste end of the cycle, all phases of a typical hardrock mining operation from exploration through post-closure expose people and our environment to toxic substances. Those substances range in toxicity from very mild to extremely hazardous, depending on the kind of ore and the mine's physical situation. (A list some of the substances likely to be found in a typical hardrock wastedump and some estimates of their toxicity to various plant and animal species are found in Attachment C).

Water Pollution

Hardrock mining has been identified as the source of toxic pollutants in more than a thousand miles of Arizona streams and rivers; 50-75% of all the polluted surface waters in the state are polluted with minewastes (see Attachments A and B).

Underground mines are particularly prone to become sources of water pollution due to their complex network of shafts, stopes and fissures. There are no reliable models for hydrogeologic behavior in these honeycombed subsurface areas but when mining stops and the pumps are turned off, the subterranean chambers fill up with water and may create backpressures that force contaminants through the matrix into groundwater or springs. Contamination of aquifers from such "mine waters" is particularly likely in mines where the natural fabric of fissures and fractures has been interrupted by artificial fractures opened by blasting or by hydraulic pressures applied during in situ leaching.

Two priority sites for State Superfund cleanup are blamed on copper mining. In the Globe-Miami area of central Arizona, three major mining companies have accepted responsibility for a 17-mile long plume of contaminated groundwater. The plume is moving, and the state predicts it may reach Pinal Creek, the major drainage, in 6-25 years (Attachment D). Pinal Creek drains into Roosevelt Lake, a major source of water for Phoenix. Ten miles of Pinal Creek are already contaminated with copper, mercury, manganese and phenols from another mining operation.

In the northwestern part of the state, Phelps Dodge Corp. wastedumps near Jerome, Arizona, are responsible for another State Superfund priority: Bitter Creek, a tributary to the wild and scenic Verde River. The state has not yet determined if groundwater is also contaminated from the

Jerome operations, but in the southeastern corner of the state, Phelps Dodge, while not officially named as a responsible party, has been supplying free bottled water to residents whose wells are contaminated with sulfates downgradient from its tailings ponds. The Bisbee mine is also named by the state and EPA as the source of heavy metal and acid pollution in ten miles of Mule Creek (Attachments A and B).

Since monitoring only began recently, no one knows how long the Globe-Miami and Bisbee aquifers have been contaminated, but groundwater pollution from mines may take 50 years or more to show up even with careful monitoring. The waste tailings ponds at several major mines in Arizona, like the PD sites in Jerome and Bisbee, date back to the late nineteenth century, and none of existing sites has any controls to prevent groundwater contamination. Although some, like Jerome, have been inactive for several years, others, like Bisbee are still being used. Still others are targeted to receive many more millions of tons of wastes as operators begin using new techniques to leach old wastes or, again like PD-Bisbee, open up reserves that were uneconomical with older methods. There are no reclamation plans for any of the above-named sites.

Some water pollution problems in Arizona have sources out of state. Over 280 miles of the Rio Puerco, for instance, and 265 miles of its tributaries are contaminated with arsenic, selenium, heavy metals and Radium-226 from spills out of tailing ponds at uranium mines near Gallup, New Mexico. Similarly, some 70-80 miles of the San Pedro River (including the lower 40 that pass through the Bureau of Land Management's showpiece San Pedro Riparian National Conservation Area) are periodically poisoned by tailings spills at Bisbee's sister copper mine at Cananea, 35 miles south of the border in Sonora, Mexico.

Abandoned Sites

Responsible parties are fairly easy to identify for these sites I have mentioned, so reclamation and cleanup are theoretically possible. Other sites are not so lucky. The Harshaw Mining District near Patagonia, Arizona, for instance, is one of those historic areas where miners in the 1880s reopened old Spanish diggings. Between the 1930s and 1970s, the Harshaw District produced over $40 million worth of base and precious metals, primarily zinc, silver and lead.

Today, eleven miles of Harshaw Creek and 15 miles of Sonoita Creek downstream from their confluence are polluted with acidity, copper, magnesium and other toxic metals. Because there are so many mines in the drainage, the state has not been able to pinpoint a particular mine as the source. Many of the waste piles are at abandoned sites and responsible parties will never be found for most of these. If the problem is ever going to be cleaned up, it will have to be by the state and federal governments.

Even if the state had enough resources, it is unlikely they would be allocated to Harshaw Creek in the foreseeable future. Compared with the magnitude of problems at other sites, Harshaw is a pretty low priority. But the Harshaw District is typical of a major aspect of the mining reclamation problem in Arizona and the West. There are thousands, maybe tens of thousands, of old mines on public lands in Arizona where no responsible party can be found.

Federal land managers estimate that the Tonto and Coronado National Forests and BLM's Kingman and Safford District each has thousands of abandoned mines many of which are, for one reason or another, "problem sites." Almost all of them are hardrock sites (though some (abandoned asbestos piles on the Tonto, for instance) present other kinds of hazards.

At unreclaimed sites throughout the state, abandoned tramp metal, trash, wastedumps and inactive mineshafts present physical as well as toxic (and aesthetic) hazards. Several people each year in Arizona are killed or seriously injured from falling into unprotected mineshafts, often in remote areas where search and rescue are difficult. Regulators worry that as Arizona's population continues to explode, more and more people will fall victim to these unreclaimed hazards.

Exactly how many abandoned sites there are is unknown. Every year, pursuant to the state's Abandoned Mine Saftey Act, the State Mine Inspector's office, with part-time seasonal crew of student interns, locates about 200 more mineshafts and, constrained by budget, manage to seal far fewer than that. They do not expect to complete their inventory in our lifetimes.

The Current Boom

Although mining has been going on a long time in Arizona, it is far from slowing down. In the past 20-30 years, the number of mines has grown extraordinarily and, despite the widespread use of "kinder and gentler" practices, the sheer scale of the current boom gives the industry a potential for environmental impacts far greater than those caused by past booms.

From 1980-1989, 45-50,000 new claims were filed on BLM's Arizona Strip District (in northern Arizona above the Colorado River and near Grand Canyon National Park). Most of them were for uranium mines. If the sites are ever developed, they presumably will have to comply with BLM's current rules for reclamation. But there are several weaknesses in the BLM rules, not least of which is the failure to require a look at the potential for cumulative and aggregate impacts on the environment of so many mines clustered in one area. The potential adverse impact is so apparent that several citizens groups have called for a moratorium on any future siting or development until BLM has complied with the National Environmental Policy Act by conducting an analysis of cumulative and aggregate impacts.

Inconsistent Standards

Although the current Forest Service and BLM regulations address reclamation (and, consequently, are, at least in theory, a great improvement over what we had ten or more years ago), the regulations contain no uniform design or performance standards. Quality control is left to the discretion of local managers, many of whom have little or no training in the art and science of reclamation. With no uniform standards, there is no continuity from one manager to the next and no reasonable assurance that requirements will in fact protect human and environmental health.

Under the current situation, what one BLM manager calls "reclamation" another, on a contiguous district, calls overly-strict "rehabilitation"; on the first district, prevention of "undue and unnecessary degradation" requires far less strenuous measures than those required by his fellow manager next door.

On Forest Service lands, reclamation is equally discretionary, based on the requirement to "where practicable, reclaim the surface. . .by taking such measures as will prevent or control on-site and off-site damage. . .including. . .isolation, removal or control of toxic materials" (36 CFR 228.8) In practice, the definition of "practicable measures" varies widely among individual managers, ranging from simple backfilling, bulldozing and contouring to attempts to achieve something like a return to "near natural" conditions. There is no agreement among Forest Service personnel, and even less between Forest Service definitions and BLM's "undue and unnecessary degradation." This lack of consistency presents problems for miners, regulators, the public and the environment.

Recommendations

Standards and Permitting

In light of the foregoing, we offer the following comments and recommendations.

1. Mining will probably never be what we would call a clean industry. Almost by definition, it is bound to cause environmental insults across a whole range of indicator values from aesthetic unpleasantries to toxic assault. But its effects can be mitigated and will be if operators are given sufficient incentives. We strongly recommend strict regulation to assure that the insults are minimized to the greatest extent possible through use of Best Pollution Reduction and Monitoring Technology during all phases of the mining cycle.

2. We recommend that uniform performance standards and definitions for reclamation be established for all federal agencies to follow, including stabilization measures to prevent off-site migration of toxics during the active life of the mine and for at least two hundred years after closure.

3. In some cases, mitigation efforts are bound to be minimally effective and mining should not be allowed at all. There is simply no way, for instance, to successfully restore a large pit mine like those found around the state of Arizona. Even if you could find enough waste rock, tailings and overburden to fill it up, the backfill is likely to cause as much risk or greater risk of water pollution as the piles. And if you could get back to something like natural contours and get something like native vegetation to grow on them (not an easy proposition in arid lands), the plants may well be too contaminated for livestock or wildlife to eat (Attachment C).

Measures can be taken to lessen some impacts, and that should be done; but on the whole, the environmental impact is going to persist for decades or centuries. For sites like these, remediation will not work: prevention is called for. Under such circumstances, FLPMA and NFMA would ordinarily favor a no action alternative.

4. But traditionally, mines have held a privileged position in multiple-use allocations because the 1872 law does not allow regulators to deny or terminate a mining permit. Caught in this dilemma, managers are understandably confused about how to decide what "undue and unnecessary degradation" means. Add to this the ability of miners to patent their claims, and you end up with regulators who have far less authority to protect the environment from mining than from other industries on public lands. We recommend:

(a) that the patent system, which is an invitation to abuse the land, be ended

(b) that a uniform permitting system be adopted for public lands, including frequent review of permit conditions and compliance

(c) that before a mine is permitted, its potential environmental impacts be analyzed, including the cumulative and aggregate impacts of minefields and of mines that cannot be reclaimed

(d) that reclamation be mandatory, not discretionary, except at those sites where concerns of overbearing national significance dictate otherwise

(e) that the value of the proposed mine be weighed against competing multiple-use values

(f) that regulators be given authority to deny a permit when the applicant cannot reasonably be expected to meet strict health and safety standards or when granting it would otherwise result in unacceptable risks.

5. Some minewastes are just too toxic to leave in piles (where they are subject to erosion from wind and surface water) or to put back into the mines (where they may be leach or leak into groundwater). Wastes at such sites should not be re-interred, but should be taken off-site to a permitted facility for treatment as hazardous waste.

Financial Surety

6. Under current rules, federal regulators complain that if a bad actor walks away leaving a mess, there is often nothing the agency can do to force restitution; often the violator is bankrupt or nearly so and could not pay even if successfully prosecuted. In such cases, responsibility falls back on the agency and cleanup is usually dependent on unlikely federal budget increases.

7. It has not been uncommon for mine operators threatened with penalties to escape into bankruptcy. The Contention Mine, for instance, which is the source of cyanide in at least one Tombstone, Arizona well, has been operated by several corporations in the past several years, and although company names have changed, the same faces seem to show up as managers and directors of one after another of the successive companies.

We recommend that financial surety be required at the outset of the permitting process; bonding or some other security should be required adequate to cover costs of continual safe operation, monitoring, and any emergency response or remediation during the life, closure and post-closure phases of the facility.

8. Financial surety standards should be set at the federal level, not left to the discretion of local managers, as at present. Standards should include a prohibition against corporate officers serving at a site where a previous company with which they were associated failed to meet environmental, financial or legal standards.

Funding

9. We recommend that funding be made available from permit fees, royalties or other such operating charges for educational programs so that federal resource managers, the regulated community and the public can talk to each other in the same language. Without such a sharing of common knowledge and terminology, as at present, it is not clear to all managers and permittees that strict compliance with existing state and federal clean water and clear air laws is required.

10. We also recommend that funding be made available for enforcement. One of the most frequent comments of managers in the agencies we have talked to is that they have little enforcement capability. As one federal official said, "if a guy screws up. . .all we can say is, 'Hey, you ought not to do that.'"

This concludes my comments. Mr. Chairman, I want to thank you for holding hearings on this important topic and for the opportunity to make these comments. I will be glad to answer questions.

On Aquifer Protection Permitting of the Phelps-Dodge Copper Queen Branch Tailings Storage Area (1992)

Michael Gregory and Dick Kamp, presented to Arizona Department of Environmental Quality (8 January 1992)

Dear Mr Fox:

We are transmitting herewith comments on the Phelps-Dodge (PD) permit application for the Copper Queen Branch Concentrator Tailings Storage Area. The comments have been prepared by Dr Ann S. Maest at our request and address (1) the three-volume application submitted to the department on 14 August 1990 and (2) the company's response of 3 September 1991 to the department's 29 April 1991 request for additional information.

Dr. Maest's report follows the organization of the PD application and appendices, and concludes with a summary and recommendations on many aspects of the proposed closure of the tailings unit at this site and on the permitting process in general.

We recognize that it is unusual for such detailed public scrutiny to be given to the application stage of a permit, but such attention is amply justified by (1) the existing groundwater contamination at this site, which is a probable precursor of more serious contamination in the future and which already has led to PD' supplying bottled water to residents whose wells have been contaminated; and by (2) the precedent-setting nature of this permit for a major mining operation granted under the 1986 *Environmental Quality Act*, and which is generally regarded as a prelude to permitting of a major new mine expected to be opened at the Copper Queen Branch.

In addition, we feel that our attention to this process is more than justified by the potentially serious implications for public health and the environment of discrepancies in the application materials and other inadequacies discovered by Dr. Maest's study.

In short, the study shows that the PD application is seriously flawed due to inaccurate or otherwise unwarranted assumptions, missing data (including data specifically requested by the department), misapplication of formulas and other inappropriate deviations from standard analysis methodology.

The application certainly does not comply with department rules requiring "a *demonstration* [emphasis added] that the facility will not cause or contribute to a violation of Aquifer Water Quality Standards" (R18-9-108), which standards, as you know, require that "a discharge shall not cause a pollutant to be present in. . .a concentration which endangers human health [or in any amount] which impairs existing or reasonably foreseeable uses of water in an aquifer" (R18-11-405).

Nor does the application show how PD will comply with the statutory requirement (ARS 49-243) that the facility be "so designed, constructed and operated as to ensure the greatest degree of discharge reduction achievable through application of best available demonstrated control technology, processes, operating methods or other alternatives, including, where practicable, a technology permitting no discharge of pollutants."

In particular, thr report draws into question PD's assertions to the effect (1) that the tailings piles are not the source of current groundwater contamination; (2) that the piles cannot become a source of future contamination; (3) that the company's proposed permit area boundaries appropriately define the potential Discharge Impact Area (DIA); (4) that the application adequately characterized existing hydrological and geochemical conditions at the site and the potential future physical and chemical behavior of the tailings piles; and (5) that the company's proposed design and management (including monitoring) of the waste unit will provide adequate protection in the future.

Without detracting from the importance of other issues raised in the report, we draw your attention in particular to concerns in regard to the following three topics: site characterization, Contamination Potential, and Permit Conditions.

Inadequate Site Characterization

1. *Missing Data*

A.C.C. R18-9-108 requires that all known structures, wells, and borings be located on the application site plan and described, but three monitoring wells which were identified in PD's interim application report ae not located on the application' Site Plan, and no sampling data has been presented for these wells in the application.

Persistent local rumors have insisted that these wells and/or other assessment wells or borings which have been abandoned and for which no data has been presented, are associated with high levels of radioactivity, a concern that is heightened by the high uranium content (2-7 ppm) of low grade leach solutions from the Lavender Pit. The uranium content of the mine rock is high enough that a few years ago PD was seriously considering adding a yellowcake process to its leaching operations. The geologic assessment wells in question allegedly have been plugged and abandoned and covered with several tons of rock during PD's recent capping of the tailing piles.

PD has reported testing only two wells for radioactivity (despite the department's specific request for radioactivity sampling results from these and all other wells. If the company cannot supply the well data the wells should be reopened (or, if necessary, redrilled) and new samples taken.

2. *Proposed Permit Area Too Small*

The Discharge Impact Area (DIA) that PD has proposed for permitting excludes highly populated areas where spills rom rock dumps (e.g., the 1980 spill onto the Greenway School grounds in the Bakerville area) and dust fallout (e.g., the San Jose and South Bisbee areas) have occurred, as well as high potential sources of contamination, such as the Lavender Pit. In addition, several wells that have excessive levels of contaminants are excluded. These wells, the mine itself, all waste rock dumps and the dump run-off ditch thorough Warren should be included in the permit area and monitoring of air and water should be required to prevent exposure.

Understating of Contamination Potential

1. *Limited Sampling of Waters*

The department's rules (R18-9-108) require the applicant to provide "documentation of the existing quality of the aquifer underlying the site. . . . [and] assessment of the discharge to cause the leaching of pollutants," but PD has taken too few tests or has inadequately analyzed the tests of waters at the site to determine the potential for further groundwater contamination by acid drainage, heavy metals or other pollution. For instance, only one analysis of mine water is reported, and that single sample (done not by PD and prior to the PD application) cannot be representative of the mine water now filling the Lavender Pit and posing a potential threat to ground and surface waters as pressures build up in the abandoned diggings.

Furthermore, and contrary to PD's assertions, the few pH tests that have been done indicate that it is the tailings pond waters (which contain high levels of cadmium, chromium, lead, selenium, silver and copper), *not* the waters historically put on the irrigated area below the tailings, are the most likely source of low pH and low acid neutralizing potential in soils of the permit area. More testing and analysis should be required in order to make a final determination on this important issue.

2. *Incomplete Testing of Waste Materials*

PD reports tailings leach tests for only composite sampling of the Warren tailings. This cannot be considered an adequate representation of the North and South tailings piles. More testing should be done, and should include tests of the coarse materials as well as the fines.

In addition, a number of hazardous materials that PD has put, is putting or will put on the tailings have the potential to leach into groundwater but have not been characterized by leaching tests. These include the Crawford Mill tailings (which contain high levels of copper and lead); the SACs LOGS dump material from South Bisbee (which contain high concentrations of arsenic , copper, lead and zinc); the evaporation pond residues (which contain high concentrations of of cadmium, chromium, copper, lead, manganese and zinc); and the irrigation area soils (which have elevated concentrations of cadmium, chromium, copper, lead, manganese and zinc).

All of these waste materials should be subjected to leach tests and acid generation potential tests.

3. *Failure to Test for Constituents of Concern*

PD has denied "that hazardous constituents are being managed at this facility," has identified only sulfates and total dissolved solids (TDS) as constituents of concern, and has failed to analyze leach test samples (or report test results) for certain constituents of concern specifically required by the department.

Besides radioactivity, these include volatile organic compounds (some of which were found in core borings at the South tailings impoundment), reagents used in the mining process, and highly toxic reagent breakdown products, like carbon disulfide. All of these constituents should be determined in existing groundwater samples and in future well monitoring and leach tests.

4. *Failure to Test Water under the Tailings*

PD hass not conducted any tewsts of the groundwater below the tailings piles, in effect claiming that since the company's model says that the geochemistry of the area precludes the possibility of leaching, there is no need to test. But the tailings contain a great deal of water, soil under the piles is at least six times more permeable than clay liners normally required in leaching operations, so there is good reason to suspect that the groundwater will be affected in time.

5. *PD's Argument thsat the Tailings Cannot Leach is Flawed*

PD argues that "the tailings are not active sources of sulfates or TDS, or any other constituents to the subsurface." However, the calculations presented to defend this assertion (1) are based on invalid assumptions, (2) do not take into account some important variables, (3) are not based on state-of-the-art testing methodology, and (4) as stated above, are not backed up with sufficient sampling to prove the argument.

More specifically, the argument that the tailings will not leach into groundwater is based on two points: (1) that sampling of the unsaturated zone below the tailings found no contamination; and (2) that the extent and chemistry of the soils below the tailings traps metals during the neutralization process and so precludes migration to the groundwater.

But, (1) lack of contamination in the permeable unsaturated zone certainly does not prove that contamination of the lower saturated zone has not occurred or may not occur in the future as the piles generate mor leachable constituents; and (2) even if the caliche soils were an effective chemical barrier, the caliche layers are almost certain to contain cracks and fissures that can allow leaching to the groundwater below. Furthermore, (3) PD has failed to perform the necessary analysis of the soils themselves, a serious oversight sine these soils, to which toxic metals may adsorb in the short term, may release the metals to percolating water in the future; and (4) the mobility pf metals and soil chemistry are not adequately characterized by the less-than-state-of-the-art testing and analysis PD has done.

6. *Failure to Use State-of-the-Art Test Methods*

According to the department BADCT Guidance document, the purpose of leach tests is to "evaluate which of the specified constituents could leach from the tailings material at a concentration exceeding primary drinking water standards." Not only has PD failed to test for some of those specified constituents of concern (as noted above), but the methodology chosen by PD is not adequate to achieve the stated purpose.

a. *Improper Choice of Detection Limits*

For instance, PD claims that it is unable to detect some constituents (arsenic, cadmium, chromium, copper, lead, mercury, etc.) except at concentrations as high or almost as high as the legal limits (Maximum Contaminant Levels, of MCLs). In at least one case (lead), PD claims that the detection limit is actually higher than the standard. This claim, if accepted, would make it nearly impossible to tell if a violation had occurred.

But PD's claimed detection limits directly contradict best laboratory practices and EPA's officially established standards for detection limits, which generally run about ten times lower than the MCLs they are meant to detect.

b. *Improper Reliance on ANP Tests*

In addition, PD rests its arguments for non-leachability and for limiting the size of the permit area almost entirely on tests for the Acid Neutralizing Potential (ANP) of the tailings piles and associated soils. But such static, short-term tests cannot predict the long-tern mobilization of pollutants. All ANP shows is the ability of soils to neutralize acidity.

State-of-the-art testing requires determination not only of the acid neutralizing ability of contaminated materials, but the Acid *Generating* Potential (AGP) of the piles themselves. AGP tests characterize long-term constituent behavior much more accurately than ANP tests alone.

c. *Improper Use of Soil/Water Coefficient*

Furthermore, PD has inaccurately characterized the potential for migration of pollutants and therefore improperly delimited the extent of the soil/water distribution coefficient (K_4). In fact, the conclusions PD draws about the improbability of contaminant transport from using K_4 improperly in its model, are contradicted by PD's own tests.

d. *Failure to Use Most Accurate Tests*

PD's analysis of leach potential apparently relies on short-term tests with de-ionized water. The results of such a procedure are not easily verifiable and are, therefore, unreliable for characterizing conditions at the site. State-of-the-art methods include use of buffered water in a test that takes place over an 8-12 week period, during which the test materials are brought to a state of equilibrium which more accurately simulates actual conditions in the tailings piles over time.

e. *Failure to Describe Procedures*

Throughout the application, PD generally fails to describe its test procedures, a breach of standard scientific protocol which makes it very difficult to replicate the tests, critique the analyses or verify the claimed results.

Inadequate Permit Conditions

1. *Points of Compliance*

In general, PD has not (as required by the department) *demonstrated* that compliance with BADCT will be achieved, but has merely identified points of compliance where it will test for non-hazardous constituents (sulfates and TDS). PD has proposed only three point-of-compliance wells, one of which is too far from the tailings (the probable source of contamination). All three are designed to test only the uppermost aquifers, which the company has claimed is all that the law requires.

However, ARS 49-244 requires that the points of compliance shall be on a vertical plane extending through the uppermost aquifers under a facility, not terminating in those aquifers. And the statute further requires that the points of compliance shall ensue protection of all current and reasonably foreseeable future uses of those aquifers.

Consequently, the department should require that more compliance wells be chosen that are close to the tailings, and that additional compliance wells be designated to assure that contamination (including all constituents of concern, especially heavy metals, carbon disulfide and radioactivity) does not each the lower aquifers that will be used for drinking water in the future.

2. *Alert Levels*

PD has objected to permit conditions requiring early warning of contamination before concentrations reach violation status. But ARS 49.243.F.7 makes it clear that the director shall prescribe such alert levels, which trigger corrective action that *prevents* violative levels from occurring and that prevents the more costly clean-ups required by massive unchecked leakages into the groundwater. Alert levels should be set well below MCLs (not at a statistical average of levels found in groundwater) for all constituents of concern, including hazardous metals, VOCs, carbon disulfide and other breakdown products.

3. *Contingency Plan*

The PD proposal essentially says that a contingency plan for response to contamination will be developed if and when monitoring shows that a violation has occurred. But the department's rules (R18-9-108.C.2) and common sense require that a detailed proposal for contingency actions be part of the permit to prevent further exceedances once alert levels are reached.

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In addition to these points, Dr. Maest's report discloses a great many more inadequacies in the PD application. These include problems with (1) Unit Design (e.g., failure to specify revegetation or slope stability standards, to set effective control measures, or—in direct contradiction of the Guidance document—to direct drainage away from the center of the tailings); (2) Monitoring Plan (e.g., failure to require monitoring for dust—especially in populous areas—and failure to propose adequate monitoring locations and frequencies; and (3) the enforcement discrepancies in the permitting process itself (e.g., removal of SACs LOGS and evaporation pond residues to the south slope of the tailings without prior departmental approval, and failure to consider alternatives as required by R18-9-108.

Rather than discuss these and other points here, we direct your attention to the report itself with the request that you consider these concerns and recommendations and respond to them quickly and effectively.

In closing, we would note that although this report illustrates the value to the department snd to the environment of having environmental groups involved in early stages of the permitting process; and although we are glad to have been able to provide this service, and look forward to continuing to work closely with the department on this and other matters; nonetheless, the expense and effort required to perform such analyses on a regular basis are clearly a strain on the resources of non-profit organizations like ours, and fall well within the scope of the department's mission.

We would hope that under your direction the department will make the kind of in-depth scrutiny represented by Dr. Maest's report a standard operating procedure for review of permit applications in order to overcome the historically typical situation in which corporate figures have been accepted by the department without the close analysis they require.

Environmental and Social Impacts of Mining: Notes for a Workshop (1998)

Michael Gregory, for Sierra Club Grand Canyon Chapter, Phoenix, Arizona (10 April 1998)

Contents

I. Introduction: Environmental and Social Impacts from Mining

Every stage in the life of a mine presents potential environmental impacts; consequently, public input is essential at every stage. The kinds of impacts that can occur include physical, chemical and biological effects on the natural environment as well as economic and cultural effects on the social environment. Although a century or two ago mining was sometimes considered the highest use of many public lands, ***mineral values are now considered only one of a variety of competing land-use values***, including

- plant and animal diversity
- ecosystem integrity
- water quality and quantity
- air quality

- recreation
- agriculture
- community stability/integrity
- economic stability/diversity

The decision to mine or not to mine, to choose one or another development technique, one or another waste management method, and one or another closure option, will depend on the balance of values decided upon.

Impacts from mining may occur in the immediate vicinity of the mine site, but may also affect people and environment in distant areas due to transport of materials (including waste materials) by air, water and man-made conveyances. Economic and social effects may also be significant in distant communities that are in the supply-stream for goods and personnel above or below the site. Potential impacts include:

Natural environment

- disturbance of the natural landscape and subsurface conditions
- disturbance of wildlife habitat
- diminishing of biodiversity, including loss of rare and endangered species
- diversion, impeding, impounding or consumption of surface and groundwaters
- contamination of surface water, groundwater, air, soil or biological resources
- contamination of air with particulates as well as toxic gases and metals

Social environment

- displacement and relocation of communities
- disturbance of cultural resources such as sacred or historically significant sites
- disturbance of community integrity from noise, heavy traffic and outside workforce
- disturbance of community economic diversity by single-company dominance
- disturbance of community economic stability by " boom and bust" patterns
- disruption or stressing of community infrastructure and services
- public and occupational health problems

- **Physical, chemical and biological impacts** can occur from primary activities (such as drilling and blasting or other methods of moving and earth, rock and ore), as well as from secondary activities (such as processing of ore or generation and management of waste products) and ancillary infrastructure development activities (such as road and building construction).

    • ***Biological Resources*** The entire biotic support capacity of an area affected by mining is disrupted by the mining process. All vegetation and the habitat it comprises, all of the geologic strata from the root zone to the ore body, must necessarily be removed for surface mines to develop. More land must be covered with the crushers and beneficiation facilities and the wastes they create. Tailings ponds and minewaters have killed thousands of migratory birds in the past few years, as well as poisoning other wildlife and livestock. The net result of all mining projects is a loss of biological diversity and wildlife populations.

    • ***Water Resources*** Mining operations interrupt natural watercourses on the surface and underground. Water quantity and water quality are both impacted. Tailings and waste piles may block natural drainage patterns so that waters saturate the piles periodically, then inevitably emerge carrying varying levels of contamination. Stormwater moving through a mine site picks up fine particles sediment or silt, which clouds the receiving waters downstream and degrades the quality of the aquatic habitat. Sediment loading is sometimes so severe that the stream bed becomes coated with sediment, impairing the health of small organisms that are the foundation of the aquatic food chain. Thousands of miles of dead streams have resulted from mining activities.

• ***Air Quality*** Mining also affects air quality, emitting a wide variety of toxic particles and gases. Fine particulate matter not only causes or contributes to a wide variety of diseases by coating the lungs of people and animals, but also coats the leaves of plants, making it difficult for them to breathe as well. Air pollution from mining activities has completely wiped out some plant communities, reduces the nutritional value of many food plants and. in some cases, makes normally edible plants toxic to wildlife.

• ***Noise and Activity*** An often overlooked impact of mining operations is the sheer noise and activity which occurs at the site, often twenty to twenty-four hours a day. The degree of impact on wildlife will vary species to species, depending on their sensitivities to the blasting, haul truck traffic, nighttime lighting and other disturbances which go along with modern mining operations. The area of impact may be quite large, extending far offsite, depending on the severity of the blasting and other noise, and on the topography in the vicinity. The increased noise and activity a mine brings can also significantly impact the sense of well-being in nearby human communities.

● **Social impacts** can occur from a variety of disturbances in community stability, including changes in population numbers, employment patterns, income distribution, service needs, and a wide range of concerns that may be grouped under the heading “quality of life.” Disturbances in the social fabric can range from minor increases in traffic to physical removal and relocation of whole communities. Religious, historical or other cultural heritage sites may be disturbed. Public and occupational health or safety may be adversely impacted from the presence of toxic chemicals and explosives, increased dust and noise, or increased disease vectors. Effects on indigenous communities may be particularly severe.

It is sometimes argued that ecological balance can be maintained by creating an equivalent ecological feature elsewhere to compensate for features lost at the mine site or because of the mine. For instance, if the mine will destroy a particular riparian area and its associated biodiversity, it may be argued that the loss can be compensated for by construction or enhancement of a similar riparian system nearby.

Furthermore, it is sometimes argued that loss of one feature can be compensated with a feature not at all similar to the original. For instance, an agricultural area or public park or improvements to community infrastructure (such as a hospital, improved schools, sewage systems, paved roads) may be offered in compensation for loss of a natural wetland or archaeological resource. Comparing such features — even less alike than apples and oranges — is difficult to impossible.

Attempts to justify such trade-offs (sometimes incorrectly referred to as “mitigation”) often invoke the slippery accounting concept known as “Net Environmental Benefit.” But with such simplistic, bottom-line thinking it is difficult at best to take into account the unique qualities of a site, which cannot be reproduced in all their complexity and variety, and may not be easily be approximated.

The decision to build or not build a mine requires consideration of a complex assortment of site-specific information and often non-monetary or otherwise intangible issues. It requires information-sharing and in-depth discussion among a broad spectrum of interested parties, especially those who live or work in the area proposed for mining.

In the past few years, developing and newly-industrialized nations, including those in Latin America, have been experiencing an unprecedented boom in mining. During that period, some seventy countries have rewritten their national mining codes in order to attract foreign investment. It has been estimated that ***in the next twenty years over half the gold produced worldwide will come from mines opened on the lands of indigenous peoples***, as will significant percentages of other metals.

This guide is intended to help focus attention on some of the many socio-ecological issues that must be considered if decisions are to be made equitably and democratically, and if mining is to be carried out in accordance with ***the principles of pollution prevention and sustainable development***.

II. Minewastes

Minewastes are one of the greatest environmental problems with mining, and a modern mine generates an enormous amount of waste. For instance, about 2.8 tons of gold ore must be removed from a modern gold mine to produce enough refined gold for just one wedding band. Or, to put it another way, refined gold represents only about 0.00015% of the raw materials used and disturbed in the gold-mining process. Refined copper, though it may represent as much as 0.06% of the raw materials, generates the greatest amount of waste by weight of all metal mining due to the huge volumes of copper that are mined.

Besides industrial wastes similar to those of other industries, mines generate three others kinds—***waste rock, tailings and minewaters***. Minewaste problems come both from the toxicity of constituents and from the sheer volume of materials. Waste rock and tailings of a single mine typically cover hundreds of acres of habitat and may contaminate miles of water above and below the surface.

● ***Waste rock*** Surface mining generates massive amounts of waste because most of the rock and soil encountered is of no economic value and must be removed to expose the "paydirt." ***Waste rock*** is the general term to describe rock that must be removed but which is not ***ore*** (i.e., the heavily mineralized rock that can be extracted at a profit). Waste rock is taken away (usually as short a distance possible, in order reduce transport costs) and deposited in ***waste piles*** (sometime called ***waste dumps***). Waste dumps may also contain ***overburden*** (the overlying, generally less-mineralized rock, that must be removed to reach ore. It is not uncommon for waste rock from surfacing mining to cover more land area than the mine itself.

Waste dumps are usually composed of coarse material that easily accepts water from precipitation or other sources and which, because it is mineralized (though perhaps to a currently uneconomic degree), may generate acidic discharges. Most existing waste dumps are not lined underneath with impermeable materials, so they contaminants may seep into the soil and groundwater below. Not only uranium mines generate wastes that contain radioactive materials; many other ores are embedded in a matrix that includes uranium and related substances, which become exposed to air and water during mining and may be deposited with the waste rock and tailings or discharged with minewaters.

As global economics and technological developments have increasingly made mining of low-grade ores more feasible in recent years, some companies have begun to consider dumps as stockpiled resources for future mining, rather than wastes. The change in name and intention, however, does not change the need to manage the piles in a manner that protects human health and the environment.

● ***Tailings*** are the residues left over after target minerals have been removed during milling processes (see the section on *Ore Processing*, below). Their management can be one of the most significant environmental aspects of mining. The failure of tailings containments has been the cause of many of the worst water pollution from mines, and continues to be one of greatest concerns in the design, siting and post-closure care of mines.

Tailings can be dry, with no water used in the processing, as in simple screening, but usually contain water along with crushed waste rock and chemicals (reagents) used in the milling process. Tailings are often removed from the mill in a semi-liquid slurry state, sometimes through pipelines, and deposited in an impoundment behind a dam which has been constructed to hold them .

Unlike waste rock, tailings are likely to be composed of fine silt-like materials which may be relatively impervious to water. Consequently, the tailings stored behind the tailings dam will often to form a shallow lake, which lasts as long as new slurries are added to the pile and precipitation falls on it. Once the mine or pile become inactive, the lake may dry out from evaporation and slow seepage. If not covered, the "fines" on the surface of the tailing (which contain varying amounts of heavy metals and process chemicals) may be easily lifted by winds to present a respiratory hazard to humans, livestock and wildlife, or may be carried down the slopes in runoff water.

In addition, depending on the composition of the piles, their location in relation to water courses and the amount of moisture they contain, and whether or not the impoundments are built on an impermeable liner, toxic metals and other hazardous materials may leach through the tailings and be discharged to surface waters or percolate into groundwater beneath the piles.

Besides other concerns mentioned in this section, specific issues to consider in evaluating tailings management options include:

- The potential for leachate migration from the tailings
- The geochemical characteristics of the area to be impounded/inundated by tailings
- Seismic potential of the area and other natural hazards that might affect the suitability of potential treatment/disposal areas or engineering design
- Conflict with sites of ecological, cultural, agricultural, or other importance
- Chemical characteristics of sands, slimes and pond water, and requirement for treatment
- The water management regime, the effects of discharging effluents and the degree of treatment required
- The reclamation potential of the site, based of these and other factors
- Risks associated with impoundment failure

Pollution prevention and control of tailings during operational and post-operational life of the mine should address, among other concerns expressed in this section:

- Prevention of seepage

• Prevention of runoff
• Treatment and return of decant waters
• Prevention of wind erosion
• Potential effects on wildlife

● ***Minewaters A significant concern with all forms of minewaste is water contamination***. Waters that are discharged from or impounded on a mine site are known as minewaters. These may include runoff from or percolation through dumps or tailings; precipitation or seepage waters pumped out from pits ("pit water" or underground workings during "dewatering"; escaped or otherwise released process waters from leaching or milling operations (see *Kinds of Processing*, below); or other sources. Minewaters inevitably contain contaminants such as nitrates, sulfates, and metals, some of which are highly toxic.

Because waste dumps and tailings are open to precipitation and may be in the path of springs and streams and other surface water sources, they are particularly prone to absorb large quantities which then come in contact with the metallic contents of the waste materials.

Exposure and mixing of subsurface materials creates unnatural conditions which may result in air and water contamination that was unlikely to occur as long as the site was left undisturbed. For example, mining may release to the surface environment higher levels of radioactive radon gas or uranium.

One of the most common results of mixing materials is an increase of Acid Generating Potential (AGP) as certain elements and chemical compounds react to each other in the presence of moisture to generate acidic compounds that have greater potential than natural materials to leach into water resources. Such discharges are known as ***Acid Mine Drainage (AMD).***

For instance, when high-sulfide pyritic rock (and other sulfide minerals such as chalcopyrite) is exposed to oxygen and water, the pH value of the water is lowered substantially (as low as 2.0 and below). When this acidic drainage contacts rock containing arsenic or heavy metals (such as are often found in waste rock piles and tailings), the metals are dissolved and carried down with the drainage, which may poison vegetation and fisheries as well as community water supplies.

Ground and surface water around mines is also commonly contaminated with nitrates from use of ammonium nitrate explosives and from the oxidation of cyanide used in leaching processes.

Early characterization and prevention are essential, since otherwise an AMD problem may not become apparent until many years after mining operations have ceased and the mining company has left the site or the country. In addition, acid mine drainage is extremely difficult and expensive to reverse or contain once it begins. A typical remedy, for instance, is construction and operation of one or more treatment facilities at the sources of pollution, in conjunction with extensive regrading, recontouring, and capping of waste rock piles to prevent ingress of water; perpetual monitoring and maintenance of the facilities; and treatment and disposal of the toxic sludge removed from the contaminated water by the treatment process.

Another after-the-fact mitigation procedure is neutralization of dumps and tailings with lime or carbonate. But neutralization, like other active treatment methods, provides only temporary improvement rather than the perpetual care that is needed. Furthermore, addition of lime and carbonate disrupts the chemistry in monitoring wells, masking real conditions.

● ***Preventative Waste Management*** In some situations a more satisfactory solution may be achieved through application of pollution prevention techniques. For instance, AGP can be calculated during before mining and waste accumulation begins and precautionary procedures written into the Mine Plan. Under such a preventative plan, reactive materials would be identified during exploration and then segregated into separate piles during the operational phases to prevent or minimize their contact with incompatible wastes or water.

Alternatively, in situations where a mine is not below the water table it might be designed for phased backfill as well as for ore production. The reactive wastes would then be isolated and encapsulated within the backfill with clays to reduce contact with water. Compacted clay layers would be used within the backfilled pit to seal leaking aquifers and reconstructed drain segments truncated by the pit would also be sealed by a clay subgrade layer to reduce water infiltration.

Similarly, the soil removed with the overburden could be segregated and put back in place with any needed supplemental growth media during reclamation, then seeding and planted to prevent runoff, erosion and percolation.

In any case, prevention depends on early characterization and planning for the waste materials to be generated at the mine.

III. The Life of a Mine

The productive life of a mine is relatively short compared to the environmental and social impacts it may cause. In deciding whether or not to allow a mine to be built, the community needs to consider not just the productive period of exploitation, but the full life cycle from exploration and site selection, through operational stage, to closure and post-closure.The stages in the life of a mine include:

- Exploration, Characterization and Site Selection
- Application, Permitting and the Mine Plan
- Development/Operation
    - Ore extraction, processing and other plantsite operations
    - Waste rock removal, containment, treatment and disposal
    - Infrastructure, access and energy
    - Construction workcamps and operational townsites
- Closure
- Post Closure

The life of a typical hardrock mine begins with a pre-mine stage of ***exploration, characterization and site selection***; then continues through several ***operational phases of mine development***; to ***closure*** (when the operation is being closed down); to ***post-closure care*** (after the site is non-operational, but still requires oversight to ensure that contamination of water resources or other adverse effects do not occur or are properly mitigated).

● *Exploration, Characterization and Site Selection*

Before mining begins, a process known as exploration ***drilling*** (i.e., taking core samples from above, within, and below the target ore body) usually takes place to define the size and extent of a targeted ore body in such detail that the entire life of the mine and anticipated revenues may be calculated in advance.

The extensive cutting exploration roads, constructing drill pads and drilling required to provide this level of detail can have a transformational impact on wildlife habitat, surface waters, groundwater and recreational opportunities, converting the exploration site into a heavily-roaded and fragmented industrial area.

Potential impacts from exploration include increased sedimentation in surface waters from road and cleared site runoff; chemical contamination from drilling fluids, waste water, fuels and oils; disruption of wildlife; and loss of agricultural, cultural or historical features; as well as various intrusions upon existing communities, including exposure of habitants to diseases carried by exploration workers.

Furthermore, once exploration work is done, it may be easier for regulators to justify permitting of the actual mine, because the site has been significantly degraded by the exploration process and no longer qualifies for the same level of protection as a pristine or special area.

Consequently, ***it is important that consultation with communities and other concerned parties take place before any exploration work is begun*** and that particular weight is given to local concerns. Impacts are likely to be particularly significant in areas near indigenous communities.

If analysis of the core samples indicates probable economic feasibility, the project moves into the site characterization stage, during which mine interests attempt to factor other considerations besides mineral values into a draft Mine Plan.

Community input at this stage is essential to ensure that values important to the community are weighed into the decision of whether or not a mine will be built at the explored site. Not only mineral potential, but socio-ecological characterization of the site must be made.

Pre-selection site characterization is critical; it may occur before, during or after exploration, but the sooner the better. Whether or not the company decides to select the site, and whether or not regulators agree to permit the mine, may be determined by the kind and quality of citizen input at this early stage of the process. Actually stopping a mine is much more difficult after the company has selected the site and invested in post-exploration development.

Input regarding community concerns about wildlife, water supply, contamination, social and economic impacts and other matters are appropriate and needed. The community may also contribute valuable information on technical matters which would otherwise go unnoticed by the mining company and regulators. For example, local citizens may be aware of past seismic activity in the area which s not recorded in official records but may pose significant potential threat to future mine structures. Additionally, local citizens may know of cultural sites or protected wildlife or vegetation species in the area, unknown to government and industry officials.

Besides the above concerns, issues to consider during Exploration, Site Characterization and Site Selection include:

- Options for minimizing disturbances at and around the site
- Social and ecological impacts from construction of new access routes
- Proximity of surface waters to drill sites
- Ecological significance of affected habitat and extent of increased access
- Proximity to and intrusion upon existing communities and community resources

- Extent of affected community isolation or exposure to diseases prevalent among exploration workers
- Feasibility of rehabilitating exploration sites

● ***Application, Permitting and the Mine Plan***

Before mine development and operations can begin, and before a permit is issued, companies are typically required to submit and gain approval of a ***Mine Plan***.This is another critical period for public input.

Permitting requirements vary from state to state and country to country, but plans typically must address a range of issues in sufficient detail to assure regulators and the public that the mine will be operated responsibly throughout its life in a manner that protects environmental and social values.

At a minimum, such responsibility requires that the Mine Plan demonstrate financial and technical capability for all routine operations as well as for response to potential catastrophic events like tailings spills or groundwater contamination. ***Not only proposed and most likely courses of operation, but credible worst-case scenarios and alternative actions for preventing or mitigating them should be integral parts of the initial Mine Plan. The Plan should present in detail an integrated view of all the stages through which the life of the mine will proceed***, from initial surface preparation to closure and post-closure, including successive phases of build-out during the operational period.

Mine Plans are typically submitted in conjunction with ***environmental impact analyses*** (EIAs) that provide in-depth assessment of (1) pre-mining baseline conditions at the site and other potentially affected sites; (2) the proposed mine's potential impacts on the natural and social environments; as well as (3) comparative potential impacts of a range of alternatives to the proposed action (including, for instance, no mine or different methods of constructing the mine or managing its wastes).

Establishing a baseline of pre-mine conditions is essential for understanding impacts that may occur during operations and for designing and implementing closure and post-closure procedures (the last of which may require re-establishing of resources removed during the active life of the mine).

Baseline documentation of the community of life at and around the mine site, including the human community, should include maps and photographs of vegetative communities; characterization of the type and volume of the soil resource (which is often scarce in mineralized areas); identification of the full microbiotic community within the soil resource (in order to re-inoculate the stockpiled soils during reclamation.

The ability to develop a credible EIA is one measure of the company's technical capability. Another measure is the company's past ***record of compliance*** with regulations and maintenance of good relations in other communities where it has operated. At a minimum, the applicant company should be able to demonstrate that the firm and its individual officers have a history of compliance with environmental, occupational health and corporate accounting regulations in whatever jurisdiction the company (or its parent or any of its subsidiaries) has operated previously.

Financial assurance may be demonstrated in a number of ways, such as bonding, formation of a public trust account. For instance, reclamation bonds should be of sufficient size and held long enough to ensure that any partial or complete failures in the restorative effort would be quickly and completely repaired.

The decision of regulators on whether to approve or deny a permit should rest not only on the regulators' own review and analysis of the Mine Plan, but on consideration of comments made by the public after the public has been given ample opportunity for its own review. ***Public review and comment*** should include widespread effective notification of the proposed mine and the permitting process, as well as public hearings and a post-hearing period long enough to allow adequate time for reasoned written public comment.

Due to the large number of technical details to be considered, and the enormity of potential impacts, ***it is not unusual for review of a Mine Plan and EIA to take several years and several thousands of dollars***. The ability of the company to proceed through the public review process in a forthright and transparent manner, and to cover the costs the regulatory body incurs during the process, are further demonstrations of the firm's technical and financial capability.

● ***Developmental/Operational Phases (Build-out)***

The developmental or operational processes of mining (also known as the period of "build-out") may last for decades or only a few months. Development tends to occur in distinct phases, and the more a mine is planned before operations begin, the more likely it is to proceed in a phased manner. Phased development is particularly important for integrating ore extraction with pollution prevention, waste management and community involvement. For instance, advance planning may allow waste rock from one phase of build-out to be used as backfill for the previous phase, thereby minimizing waste treatment and disposal problems.

Activities will differ according to the kind and location of the mine as well as other factors, but developmental/operational processes in general can be categorized as follows:

- Ore extraction, and disposal of overburden and waste rock
- Ore processing and plantsite operations
- Tailings containment, treatment and disposal
- Infrastructure, access and energy
- Construction of workcamps and operational townsites

Overburden and waste rock are discussed above in the section on *Minewastes*, and Ore processing and plantsite operations are discussed in the following section. The remaining activities associated with developmental/operational processes are discussed below.

● ***Ore extraction, and disposal of overburden and waste rock***

Potential environmental adverse effects from these activities include impacts on water quantity and quality; air quality; plant and animal diversity, health or life; and loss of natural habitats. Social impacts may include removal and relocation of individuals, families and dwellings; loss or cultural heritage sites; disturbances of visual amenities; loud and extended noise; and loss of agricultural, forestry or recreational lands or waters.

Depending on the kind of mine and other factors, in addition to concerns discussed above un the section on *Minewastes*, considerations related to ore extraction and disposal of overburden may include:

- The extent and depth of the mineralized zone
- The quantities of material to be mined and disposed of
- The effects of disposal on dump locations and designs
- The toxicity or other hazards of the wastes
- The potential for acid mine drainage and requisite controls
- Health and safety issues related to transportation, storage and use of explosives and other hazardous materials
- Suitability of materials and engineering feasibility for landscaping, road fill, tailings dam or other containment structures, disposal areas or settlement ponds
- Containment, control and disposal of slurries from dredging and placer operations)
- Surface damage and subsidence resulting from underground mining

● ***Infrastructure, access and energy***

Gaining access to mines, operating mines and associated facilities, accommodating workers, obtaining power (during construction and operation) and exporting finished products all require specific infrastructure and sources of energy. So do exporting of finished products, materials handling within the mining area (conveyors, railroads, pipelines, crushers, etc.), and construction of railhead or port facilities.

The impacts of these activities can be significant and require consideration of such factors as:

- Proximity of the mine to suitable access infrastructure and energy sources
- Number of construction and operational staff required, and level of in-migration
- Proximity of mine to and influence on protected areas and natural habitats, potable water sources, and lands used by indigenous peoples
- The relative extent to which existing communities and mine workers are affected by communicable diseases (e.g., malaria or AIDS)

● ***Construction workcamps and operational townsites***

The demand for workers and qualifications required at industrial mining operations often exceed local supply. But the impacts of recruiting , importing and providing necessary infrastructure for large numbers of migrant workers can be significant.

Large numbers of workers can have particularly significant adverse affects in areas where human settlement has been naturally constrained by availability of natural resources or other environmental factors. Impacts may include degradation of forests; contamination and reduction of water supplies; local extinction of wildlife and trade in endangered species; and transmission of communicable diseases. In addition, increased populations of workers can put considerable strain on existing solid and sanitary waste infrastructure.

● ***Closure***

Planning for closure of a mine requires thorough analysis of potential socio-economic effects on the associated community, including review and upgrade of a detailed ***Post-Closure Plan***, which should be required as part of the initial application.

● ***Post-Closure***

- Remediation/Reclamation
- Contingency Planning and Response including pre-closure bonding to assure adequate funds for any needed mitigation
- Monitoring for as long as post-closure conditions may present a risk

Reclamation is intended to restore a measure of lost integrity to natural systems after a mine is closed. The goal of reclamation is typically to return the site as nearly as possible to pre-mine conditions, including return of a full range of species and habitat types and a blending of the restored property with the surrounding topography and drainage patterns.

IV. Kinds of Mines

Mine configurations will differ according to mineral type, geographical setting, and other factors, but in general there are two major kinds of hardrock mines, surface and underground, each with several methods of development:

- Surface
  - Open Pit
  - Open Cast
  - Quarry
  - Strip
  - Dredging
  - Placer (Hydraulic)

- Underground
  - Cut-and-fill
  - Pillar-and-stope
  - Shrinkage stope
  - Block caving
  - Longwall
  - In-situ

● ***Surface mining***

All surface mines (dredging and placer to a lesser degree) share impacts from:

- Initial roadwork
- Scraping and pushing to strip the mine area of vegetation and soils, which are pushed just out of the way of the pit
- Selection and building of storage and processing sites for waste materials
- Construction of infrastructure (water systems, buildings, etc.)

For open-pit, open cast and strip mines, an area of a square mile or more may be sacrificed in order to expose the ore body. Because vehicular access for huge ore-hauling trucks must be provided, the area disturbed by a surface mine a much larger area than the ore “footprint”. To this is added the surface area required for waste rock disposal, processing and beneficiation waste (tailings) disposal, as well as roads to and from the mine, ancillary facilities, etc.

● ***Open Pit Mining***.

Open pit mining involves the gradual development of a large-scale conical depression (the pit) which usually consists of benches up to about 15 feet wide blasted into the earth in a spiral fashion with each downward leg of the spiral (40 to 60 feet below the previous one) smaller and deeper than the previous one until the depth of the target ore body is reached. These "benches" also serve as roads that ore-hauling vehicles can traverse, bringing raw ore to the crusher and waste rock to the waste dumps. As each new level of depth is required, the benches above normally have to be moved back, so the mouth of the pit grows wider throughout the active life of the mine. Some large copper mines, for instance, are more than one-half mile deep and more than 2.5 miles wide.

As an open pit develops, very often water-bearing strata are encountered. These waters, and storm or snowmelt runoff, begin to accumulate in the closed basin of the pit. This impounded water is an impediment to mine development and must be removed using pumps. The process of removing this water is referred to as dewatering the pit (see *Minewaters*, above).

● ***Placer (Hydraulic) Mining***

Placer mineral deposits are formed by secondary deposition after transport by water from their places of origin. Gold, for instance, often forms in small veins in solid rock in mountains or uplands. Over time, stream erosion carries away small particles of gold along with its host rock to downstream areas. The gold or other target minerals within stream sediments and terrace deposits is the placer resource.

Placer mining can occur at a wide variety of scales but, regardless of the size of the operation, the basic requirements are the same. The mineral-bearing gravels must be moved (commonly with huge dredges) through a series of step-down "sluice" traps that allow the lighter minerals to wash over, while the heavier material, like gold, works its way into the bottom of the sluicing operation. Water is usually employed to move the sediments through the system (hence the name, "hydraulic mining," or simply "hydraulicking"), although in the early part of this century a dry sluice process was sometimes used successfully.

Placer mining on a large scale can literally turn a stream valley upside down and disrupt everything in its path. A variant form of large-scale placer mining used where rivers empty into oceans or lakes is similarly disruptive of the coastal environment. In some cases, placer mining is combined with open pit or underground mining.

A particularly poisonous practice common in the past and still employed in some places is ***mercury amalgamation***. Other than mercury, chemical reagents are not a common feature of placer mining.

● ***Underground Mining***.

This mining practice involves accessing a target ore body through one or more types of underground shafts and tunnels (technically, tunnels are open at both ends, drifts are open at none, and adits at one). Most modern underground mining complexes access the various working levels of the mine through a vertical service shaft within which a heavy-duty elevator hauls miners and equipment to the working levels of the ore body. The horizontal tunnels that lead into the ore body are called drifts. In some mines, the ore produced from the working levels is hauled to the surface for processing through a long sloping tunnel called either a decline or an incline depending on which way traffic within it moves.

Usually some sort of conveyor is installed within a decline to move ore and wastes to the surface for processing or disposal. The working levels of an underground mine often become very complex due to the development of open stopes, which are large, sometimes irregular voids created by the removal of high-grade ore pockets above or on the same level as working drifts. The configuration of large underground mines becomes more complex with the addition of shafts driven between working levels (winzes, which are driven down and raises, which are driven up), ventilation shafts, which reach all the way to the surface, and a variety of other features that support ore removal and mine maintenance.

Underground mining is much more expensive per ton of material mined than surface mining, which is one of the reasons that more care is taken to minimize waste generation at underground mines, and also one of the reasons that lead and zinc are the only major metals extracted today primarily by underground mining. However, significant amounts of gold, silver and copper are still mined underground.

Smaller scale underground mines are usually less complex, but this does not automatically equate with less environmental impact. Many smaller mines are inactive part of the year and, during this time of non-management, conditions may change that lead to pollution and habitat loss. Also, some of the smaller mines are located in high-quality or fragile environments where even a small release of pollutants can produce severe and lasting damage. The amount of waste produced from underground mines is significantly less than that generated by open pits, but can still lead to water quality and habitat loss problems. All underground mines have the potential to affect to varying degrees the same range of resources as open pit mines.

- ***In Situ Mining***

In situ mining (the term is Latin for "*in place*") is different from surface mining and other forms of underground mining in that it does not removed from the ground and processed. Rather, the ore is left in place and chemical extractants (known as "lixiviants"), usually strong acids, are forced into the earth through an injection well where they dissolve targeted ore-bearing strata. The impregnated liquids are pumped back to the surface through a production/recovery well, to undergo a reverse chemical reaction that precipitates the desired product out of the solution.

In-situ mining is increasingly being used to extract copper, uranium and some non-metals such as potash and soda ash. Besides being used for primary mining, it is also sometimes used to recover low-grade or otherwise difficult-to-extract deposits in played-out underground or pit mines.

While in-situ mining has the advantage of greatly reducing the amount of solid wastes produced by non-chemical mining methods, it presents significant danger of groundwater contamination. Since the underground environment (especially the hydrogeology) in mineralized areas is very difficult to predict even with extensive exploration, there is always a good chance that the injected acid will be lost in an unexpected fissure of the underground strata (as has happened, for instance, at a mine in Arizona) and end up in the groundwater or drinking water wells.

V. Ore Processing and Refining

Once ore has been extracted, it must undergo a series of processing techniques to remove the target minerals from the host rock and prepare them for market. These somewhat overlapping processes include milling (crushing and/or grinding), beneficiation (which concentrates the ore for further processing or grades it for sale), and various chemical processing and refining activities such as dump and heap leaching.

Regardless of which beneficiation method is used, the principal output (besides refined ore) is waste materials in the form of tailings and fugitive dust emissions. Some of the chemicals used in processing, various concentrations of which end up in the tailings, are inherently hazardous and their transportation, storage, use and disposal require careful planning, handling and oversight. Chemicals of concern include cyanide, mercury and strong acids.

● ***Beneficiation*** typically consists of concentration by gravity or magnetic separation or by flotation, followed by dewatering and filtration.

● ***Processing/refining*** typically involves the isolation of metal substances from ore concentrates by pyrometallurgical, hydrometallurgical or electrometallurgical methods, singly or in combination. In order to avoid hauling costs, these processes usually are carried out at or near the mine. Processing facilities generally are constructed before ore production begins.

- ***Pyrometallurgical methods such as roasting and smelting*** result in air pollution (e.g., sulfur dioxide, particulates, arsenic and heavy metals) as well as slags containing these and other materials.

- ***Hydrometallurgical methods*** typically retain pollutants in the aqueous phase and those which are not recycled are usually discharged to tailings ponds.

- ***Electrometallurgical methods*** involve extraction of the target metals as electrolytes after they have been dissolved in acid baths.

● ***Flotation***

There are many types of flotation milling processes (typically used for copper, lead, molybdenum), some quite complex, but this general description applies to most situations.

After crushing and grinding, the powdered ore is mixed with water to form a slurry that is pumped into a series of open troughs called flotation cells. One or more chemical reagents known as collectors and depressants are added which, when the solution is agitated, cause the target minerals to separate from non-target material ("gangue"), with one or the other sinking to the bottom while the other floats to the top in a foam or froth which can be skimmed off.

Chemicals used in flotation methods include cyanide, formates, fuel oil, kerosene, amines, sodium sulfide, sodium carbonate, ammonia, and lime, some of which are highly toxic. In some flotation schemes, no chemicals are used and separation of the target mineral from the gangue is achieved by differences in density. Water used in flotation can often be recycled or used elsewhere, such as to transport the gangue and other wastes to a tailings pond.

- ***Chemical Leaching***

One of the best ways to cut production costs at a mine is to minimize handling of ore. One way to do this is to treat the ores without having to crush and grind them (or, as with in situ leaching, not to dig them out of the ground). Sophisticated methods of old techniques known as "chemical" or "solution" mining are increasingly being used to replace expensive conventional crushing and refining processes like flotation and smelting. In addition, the new methods are making it profitable for companies to mine large amounts of low-grade ore that would have been uneconomical with old methods. The principal methods of solution mining (used primarily for gold, silver and copper production) are dump, heap and vat leaching.

• ***Heap Leaching***.

Heap leaching is increasingly used for extraction of gold, silver and copper. For all three metals, crushed ores are placed on a liner (usually of plastic or asphalt over clay), which facilitates collection of the metal-laden ("pregnant") solution (cyanide for gold, sulfuric acid for copper) that has been introduced (usually through sprinklers) to the top of the piles, which are often hundreds of feet high and cover hundreds of acres. Heap leaches are constructed in "lifts" or layers: after one lift has been leached (a process which may take three months), another is added to the top of it and leached, then another, and so on.

Pregnant solution from the heap is collected in a pond, then pumped to a processing facility for recovery. Gold is recovered by first running the pregnant solution over activated carbon materials which pick up the gold-cyanide complex. The carbon is then washed with a highly alkaline cyanide solution to release the gold, which is then recovered by washing it with a zinc solution that causes the gold to precipitate out. The gold is then sent to a smelter or electrowinning facility for further purification. Copper goes through a similar process, but is leached with sulfuric acid rather than cyanide.

Copper heaps may yield base metal for decades, but gold leaching heaps are soon depleted and the spent ore, along with residual cyanide, must be treated as a waste. Untreated cyanide-laden piles care highly toxic and if left untreated can easily become a source of air and water pollution, as well as being a direct threat to wildlife that is attracted to the salty flavor of the cyanide.

• ***Dump Leaching***

Dump leaching is a common method of extracting copper. This method requires large areas of land onto which crushed ores are dumped, and then configured to facilitate their saturation with sulfuric acid, commonly using a sprinkler system. The copper-laden acidic solutions percolate through the dumps and are gathered in ditches or pipes at the bottom for transportation to a mill or electrowinning facility for processing. Unlike heap leaching, dump leaching does not use protective liners underneath the piles, so dump leaching often results in release of metal-laden solutions to soils and natural waters.

• ***Vat Leaching***

Gold and silver are sometimes leached in vats, rather than from heaps.The chemical process is similar, but more contained and more expensive. The decision of which method to use is made on a truckload-by-truckload basis, determined by whether or not there is a high enough concentration of gold in the ore to justify the higher cost of vat leaching.

● ***Electrowinning***

Modern copper and gold leaching is increasingly combined with a refining technique known as solvent extraction/electrowinning ("SX/EW") to produce a highly purified product. The process is similar for both metals except that, as in leaching, cyanide is used for gold and sulfuric acid for copper.

After the pregnant solution is collected from the leach piles, it is sent to a solvent extraction tank.

For copper, the tank contains an organic extractant *usually composed of aldoxime or ketoxime compounds dissolved in a kerosene base). The organic agent selectively bonds with the copper, leaving impurities in the solution, which is drained off. Sulfuric acid is added to the extracted copper forming an electrlytic solution which is then sent to electrowinning cells or tanks. An electric current is sent through the electrolytic solution, causing the dissolved copper to deposit on metallic plates called cathodes. The deposits are 99.9% pure copper, so require no further refining, making the SX/EW process highly economic (and far less polluting than smelting).

VI. Sample Protective Measures

Seismic activity/Karst zones	Prohibition mining at site: cf State of _______________
Unique/sensitive areas (for ecological, scientific, cultural, historical purposes, etc.)	Prohibition mining at site: cf State of __________________
Ecosystem integrity	Prohibit mining in designated wilderness areas: State of __________________
	Require protection of riparian zones: State of _______________________
	Require compensatory enhancement of equivalent systems: State of ____________
Water conservation	Limit size of mine: State of ____________
	Set pumpage limits: State of ____________
	Require conservation measures: State of ____________________
Groundwater quality	State of Arizona requires applicants for permits to demonstrate before a permit will be issued that certain substances will not enter groundwater in any amount
Surface water quality	Require proper slope construction: State of ____________________
	Require tailings containment: State of ____________________
Plant and animal biodiversity	Require wildlife exclosures (nets over cyanide ponds, fences around heaps, etc). Cf State of ___________________
Reclamation	USFS requires that mine site on federal land be restored to “near natural” conditions,

	including slope angles, vegetation, etc.
	USDI requires that mine site be restored to________________
Revegetation	State of ___________________
	State of New Mexico requires that______
Waste management	Segregate materials to prevent Acid Generating Potential: cf State of ______
	Neutralize piles to prevent Acid Mine Drainage: cf State of _______________
	Isolate materials from moisture: cf State of _____________________

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