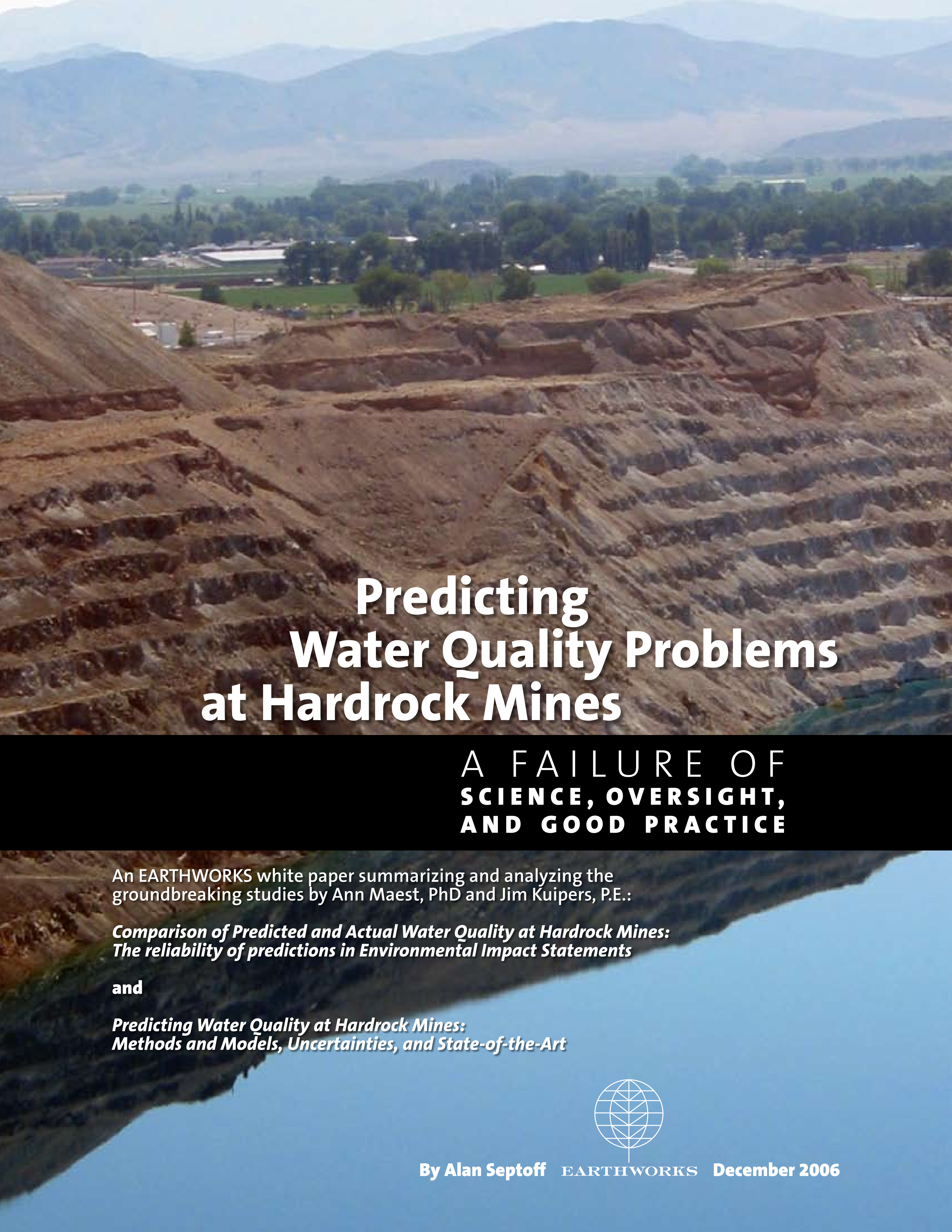

Predicting Water Quality Problems at Hardrock Mines

A FAILURE OF SCIENCE, OVERSIGHT, AND GOOD PRACTICE

An EARTHWORKS white paper summarizing and analyzing the groundbreaking studies by Ann Maest, PhD and Jim Kuipers, P.E.:

Comparison of Predicted and Actual Water Quality at Hardrock Mines: The reliability of predictions in Environmental Impact Statements

and

Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State-of-the-Art

By Alan Septoff EARTHWORKS **December 2006**

Introduction

A failure of science, oversight and good practice

This paper is a summary, written for the layperson, of the findings of a two-year research study on the accuracy of water quality predictions at hardrock mines. The study, conducted by Jim Kuipers and Ann Maest[1], brings to light a decades-long failure by government regulators, industry, and consultants to recognize and correct deficient procedures and methods for predicting contamination of water at hardrock mines.

Kuipers and Maest have discovered that, in practice, there is a failure to compare predictions made before the mines are permitted with the actual results. The predictive modeling results are not adjusted to account for real-life failures—this, despite the fact that at the vast majority of mines, problems were worse than predicted. Establishment of credibility in modeling requires that the predictions be tested, and then the models adjusted based on the results. This process appears broken when it comes to predicting the impact of mines on water quality for mine permits.

To permit mines, federal law[2] requires regulators to apply scientific approaches to predict the environmental impacts of the mine proposal – including surface water and groundwater quality impacts. The accuracy of these water quality predictions is of significant public concern. Mining's impacts on water quality may affect municipal, agricultural, and rural water supplies; important commercial, subsistence and sports fisheries; wildlife populations; tourism; and recreation. One of the reports from the study, *Comparison of Predicted and Actual Water Quality at Hardrock Mines (Comparison Report)*, asks a basic question that government regulators, industry officials and consultants should have asked long ago:

Do predicted water quality impacts match reality?

The answer, in short, is **no**. The *Comparison Report* reveals:

- 100 percent of mines predicted compliance with water quality standards before operations began (assuming pre-operations water quality was in compliance).
- 76 percent of mines studied in detail exceeded water quality standards due to mining activity.
- Mitigation[3] measures predicted to prevent water quality exceedances[4] failed at 64 percent of the mines studied in detail.

Along with more analysis of this question, the *Comparison Report* and the companion report on methods and models used to predict water quality (*Methods and Models Report*), also seek to answer the necessary follow-up questions:

- In cases where predicted water quality impacts fail to match reality, why do they fail?
- Do certain types of mines fail more often than others?
- What can be done to address current failures and prevent future failures?

The Kuipers-Maest reports were prepared for a professional audience The purpose of this paper is to translate and summarize the main findings of their research (for the layperson and the interested public), and to offer common sense recommendations based on those findings with an eye toward protecting natural resources and public health.

The Context

Why this research was necessary

The Environmental and Public Costs of Faulty Predictions

The failure to accurately predict and manage water quality impacts can result in significant negative impacts on clean water and steep taxpayer liabilities for the costs of cleanup. Consider one often-cited example — the Summitville gold mine in Colorado. Water pollution at this mine has cost American taxpayers more than $200 million in cleanup costs. The majority of that money has been spent mitigating acid drainage and cyanide releases that were not predicted during the permitting process. When pollution spilled from a containment pond, 18 miles of the Alamosa River were effectively killed – impacting not only the aquatic life in the river, but also the adjacent farms and ranches that relied upon the Alamosa for irrigation and livestock watering.

While it may be argued that Summitville is one of the worst-case examples, problems abound. According to the U.S. EPA's Abandoned Mine Land Team, the cost of mine cleanup at sites on the National Priorities List (i.e., Superfund sites, like Summitville) in the United States is $20 billion – almost 3 times the EPA's FY 2007 budget request. Long term water treatment and management is often the single most significant cost associated with mine cleanup.

In fact, there is an increasing number of mine sites throughout the U.S. that will require water treatment in *perpetuity*. In the arid west, these types of long-term impacts place a tremendous burden on downstream communities who must deal with the consequences of failed predictions. For example, government regulators have determined that the Zortman Landusky mine, located near the Fort Belknap Reservation in Montana, will continue to generate acid mine drainage for thousands of years. As a result, the Fort Belknap Tribes are faced with a continual threat to important tribal water resources, and the state of Montana will be spending tens of millions in public funds for long-term water treatment.[5]

In order to ensure clean water and protect taxpayers from liability for cleanup costs it is important to understand the frequency and magnitude of failures in predicting water quality impacts. Consider that at most major mines, operators are required to post financial assurances prior to operating. This is the good news. These assurances are supposed to guarantee that, should the mine operator go bankrupt, the mine site will be reclaimed at no cost to the taxpayer. However, the bad news is that these financial assurances are based upon expected reclamation costs and expected reclamation costs are based in large part upon water quality predictions.

Previous research by Jim Kuipers demonstrates that taxpayers are potentially liable for up to $20.4 billion[6] in financial assurance shortfalls at existing mine sites (in addition to the $20 billion for Superfund sites) – due in large part to inaccurate water quality predictions.

A Growing Problem

Without correction, the environmental and financial impacts of faulty predictions could grow. Recent increases in metals prices have triggered an increase in the number of new mines being proposed in the United States. According to the Bureau of Land Management, new mining claims filed in 2006 are on track to more than quadruple since metals prices began their precipitous rise in 2002.

In the United States alone there are approximately 180 large hardrock mines – in nearly all regions of the country – that are in various stages of permitting, development, operation or reclamation and closure. In order to better protect important water resources and reduce future economic liability, improvements must be made in the prediction and prevention of impacts to water quality at these sites. On the positive side, the increase in metals prices has resulted in fewer bankruptcies in the sector—and it is bankruptcies that trigger the use of reclamation bonds for mine site reclamation and water treatment. This may provide regulators and industry officials with a window of opportunity to solve the underlying problems with water quality prediction.

Unprecedented Research: the absence of previous studies and the data gap

When they began their research, the authors expected to incorporate data from some mines where government officials had already completed a comparison of predicted and actual water quality impacts. However, they were unable to find comparisons of water quality predictions and actual water quality impacts of mines.

The authors found that no single repository exists for the Environmental Impact Statements (EISs) currently mandated under federal law. EISs contain the water quality predictions analyzed in the study. In some cases, local federal offices that processed the studies did not have copies of them. Furthermore, in many cases, the authors were forced to submit Freedom of Information Act requests and pay fees to obtain copies of these studies. Similarly, water quality from mines was inordinately difficult to obtain and in most cases required personal visits to agencies and long hours sorting through paper files.

Taken together, the absence of previously published research and the difficulty in gathering information is evidence of a data gap that surprised the authors and may help explain the previous lack of a comprehensive study of this nature.

It is important to note that the predictions data were available – no matter how difficult to obtain – only because the National Environmental Policy Act (NEPA) requires it. Without NEPA, this study would have been impossible to conduct.

A Tool for Many Audiences

While the research focuses on the underlying scientific and engineering processes that form the basis of water quality predictions, its recommendations are intended for use by many audiences to increase the effectiveness of future mine water quality predictions – directly and indirectly:

- This study should be useful to the scientific and engineering communities for suggesting ways to better characterize risks to water quality and to better apply mitigation methods to minimize or prevent potential impacts.
- The regulatory community can look to these reports, especially *Methods and Models*, for recommendations on how to fundamentally improve the permitting process to ensure a more accurate analysis of potential mining impacts. The inherent uncertainty in water quality predictions and mitigation failures should be conservatively viewed in order to ensure mine permitting decisions that are more protective of human health and the environment. The integrity of the mine permitting process is dependent on the use of accurate methods and models.
- This report can be utilized by the mining industry to improve current practices and more accurately predict consequences and ameliorate potential effects.
- It can be utilized by the insurance and investment industry as a tool to better understand the potential risks and costs associated with mining, and as a basis to re-assess risks at current mines.
- And finally, it can be utilized by the interested public to more effectively advocate for water quality protections in the permitting process and to advocate in the public arena for legislative and regulatory changes that better protect water resources.

Do Predicted Water Quality Impacts Match Reality?

As indicated above, the answer is usually no — particularly when high risk mines, such as those with close proximity to water resources, are considered.

Sampled Mines

To arrive at this answer the authors initially reviewed 104 Environmental Impact Statements (EISs) and Environmental Assessments (EAs) for 71 major hardrock mines in the United States.[7] The mines covered all important mineral sectors (gold, silver, copper, platinum group metals, molybdenum, lead, and zinc) and ten mining states (Alaska, Arizona, California, Idaho, Montana, New Mexico, Nevada, South Dakota, Utah, and Wisconsin).

A representative subset of 25 case study mines was then selected to evaluate the accuracy of the water quality predictions. Environmental impact reports for these mines were evaluated for predictions related to surface water, groundwater, and mine drainage quality during and after mining. These predictions were then compared with actual water quality conditions during and after mining.

Potential & Predicted Water Quality

The authors discovered a two-tiered system for water quality predictions, one-tier of which was based not on sound science, but on unsupported "good faith" projections.

The two tiers of "predictions" made about water quality in environmental assessments are referred to by the authors as "potential" and "predicted" water quality:

- **Potential** water quality is the expected water quality conditions in the absence of mitigation efforts by the operator.
- **Predicted** water quality takes the effect of mitigating measures into account. It is what mine operators forecast actual water quality will be during and after operations.

All the environmental reviews analyzed in the *Comparison Report* predict acceptable water quality after mitigation at mines where water quality standards were met before mining began. If this prediction were not made, the regulatory agency would not be able to approve the mine.

However, inadequate information was provided to demonstrate how the mitigation measures would actually prevent water quality impacts. Therefore, regulators were generally accepting the final water quality predictions on "faith."

Major Findings: Chronic Underestimates of Water Quality Problems

Prediction vs. Reality: Overall Water Quality Impacts to Ground and Surface Water

Of the 25 mines sampled:

- 76% of mines polluted groundwater or surface water severely enough to exceed water quality standards.
- 60% of mines polluted surface water severely enough to exceed water quality standards.
- At least 13 mines (52%) polluted groundwater severely enough to exceed water quality standards.

Predictions vs. Reality: the Failure of Mitigation

In the cases where water quality standards were exceeded, in some cases the mine proponent anticipated the potential for pollution and prepared mitigation strategies (e.g. a mine waste dump lined with plastic to prevent acid drainage leaching into groundwater). Predictions of the efficacy of mitigation were no more reliable than overall predictions of water quality:

- 73% of mines exceeded surface water quality standards despite predicting that mitigation would result in compliance. The other 4 mines didn't predict the need for mitigation.
- 77% of mines that exceeded groundwater quality standards predicted that mitigation would result in compliance. The other 3 mines didn't predict the need for mitigation.

Predictions vs. Reality: Mines near Water with Elevated Acid Drainage or Contaminant Leaching Potential are High Risk

Some mine projects are so high risk that water quality exceedances are a near certainty: those mines that are both near groundwater or surface water resources, and possess an elevated potential for acid drainage or contaminant leaching.

- 85% of the mines near surface water with elevated potential for acid drainage or contaminant leaching exceeded water quality standards
- 93% of the mines near groundwater with elevated potential for acid drainage or contaminant leaching exceeded water quality standards.
- Of the sites that did develop acid drainage, 89% predicted that they would not.

Water Quality Pollutants

Of the 19 mines that exceeeded water quality standards, the pollutants that exceeded standards were as follows

- Toxic heavy metals such as lead, mercury, cadmium, copper, nickel or zinc exceeded standards at 63% of mines.

- Arsenic and sulfate exceeded standards at 58% of mines.
- Cyanide exceeded standards at 53% of mines.

Why Do Predictions Fail?

In order to evaluate water quality impacts during the permitting process, government regulators rely on water quality predictions created by hydrologists and geochemists and mining engineers using computer models and other types of field or laboratory studies. Those predictions are only as good as the science upon which the models/tools are based, and the site characterization information supplied to those models. So when water quality predictions fail to predict water quality for mining operations, they fail for two general reasons:

1. the science of mine water quality prediction is imperfect
2. the science of mine water quality prediction is imperfectly applied at mine sites

The Imperfect Science of Mine Water Quality Prediction

The complexity of pollutants' interaction and movement in groundwater and surface water systems at mines is difficult to recreate in a model. This is addressed in detail in the companion report by Maest & Kuipers titled *Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State-of-the-Art*.

According to *Methods and Models*, factors that complicate the prediction of water quality at mine sites range in scale from small to large. On a small scale, for example, it is not well known how minerals react in complex systems. On a large scale, geology, climate, methods of mining and mineral processing, and mine waste management approaches vary among and within mine operations. These large scale variations limit the degree to which information from one site can be applied to another.

Also, extrapolation from the laboratory to the mine must address complicating factors such as environmental conditions, water and gas transport, differences in particle size, and how these variables affect drainage quality over periods of decades or centuries. However, there is virtually no available field information describing the effect of these variables over extended periods of time. The lack of this field information introduces significant additional uncertainty into predictions.

Just as weather cannot be accurately predicted beyond a certain point because weather models and their inputs are not perfect, the transport of pollutants through complex geological and hydrological systems over the longer term, which can range from five years to tens of thousands of years is similarly difficult to predict.

One of the study's most significant findings, however, is where the practice of predicting weather and the practice of predicting water quality at mining operations part ways. Weather models are consistently reevaluated based on a comparison of predictions with actual weather conditions that occur subsequently.

Not so with the models used for predicting water quality at mining operations. The very fact that the study is unprecedented shows that *professionals who predict mine water quality do not revisit their predictions, and neither do the regulators responsible for ensuring the accuracy of those prediction*. The models used for the predictions cannot be improved if their failures and successes are not evaluated. Where predictions of water quality at mining sites are concerned, the scientific process is broken.

Imperfect Science, Imperfectly Applied

A mine water quality prediction model can only reach its potential at any individual mine site if that site is correctly characterized (in terms of its hydrology and geochemistry) to the extent possible. According to Maest and Kuipers, that potential is not being reached.

There are two types of characterization failures described in the *Comparison Report*: hydrologic (related to water flow at a mine site) and geochemical (the chemistry, geology and mineralogy of the materials/minerals that comprise the mine site).

The *Comparison Report* documents that six of the 25 case study mines were inadequately characterized hydrologically, and that eleven of the case study sites were inadequately characterized geochemically.

Another example of "imperfect science, imperfectly applied" is the bias of mine water quality predictions made by consultants hired by the prospective mine operator. This problem is implied by the number of site characterization failures, and by the failure to check the results of past mine water quality predictions.

Regulatory agencies, both federal and state, allow the mining company to select and directly pay consultants to predict mine water quality impacts, and to review and comment on (or even reject) those predictions, prior to release to the agency. It is an understatement to say that consultants heavily influence mine water quality predictions.

Unfortunately, given the client/customer relationship between prospective mine operators and their consultants, consultants are rewarded for having favorable predictions. On the other hand a prediction of poor water quality will usually delay a permit, which increases the permitting costs. While exceptions exist, consultants that predict poor water quality often are not rehired. This perverse incentive is contrary to the spirit of unbiased science, and contrary to the public interest.

Preventing Future Failures (and Addressing Current Failures)

Recommendations

Both the *Comparisons* and the *Methods and Models Reports* reveal that the prediction of future mine water quality is an uncertain business. And given the difficulty in modeling natural systems, even if the all the recommendations included here and in the Kuipers-Maest research are implemented, mine water quality prediction will always be an uncertain business. However, there is considerable room for improvement.

Just as weather prediction has improved over time, so can mine water quality prediction — if regulators and professionals in the sector learn from past predictions and improve characterization efforts.

With that in mind, the following recommendations are intended to help improve mine water quality predictions today and in the future.

Addressing the Consequences of the Existing Prediction Process

Assess existing mines. If the results of the *Comparison Report* are extrapolated to all operating major mines, water quality standards would be exceeded at roughly 75% of all mines in the United States. Regulators should, in a public process, canvass all permitted mines to:

- determine which mines are exceeding water quality standards,
- evaluate how surrounding communities and the environment are being affected, and what cleanup steps are necessary,
- revisit the original predictions, and
- reassess the adequacy of the financial assurances provided by mine operators to guarantee mine cleanup and long-term water treatment.

Incorporate uncertainty into permitting process. Regulators should take a suitably precautionary approach to the mine permitting process, and require that mine design, mitigation and financial assurance calculations prepare for reasonable worst-case rather than best-case scenarios.

Better screen high-risk mines. Regulators must demonstrate concrete improvement in the accuracy of mine water quality predictions and mitigation efforts. For example, additional regulatory scrutiny should be given to the highest risk proposals such as those mines near water resources **and** with elevated acid drainage or contaminant leaching potential. In cases where the risks are too high, regulators should not permit mines. It should be noted that this recommendation is supported by the *Comparison Report* which demonstrates that 93 % of such mines near groundwater, and 85% near surface water, exceeded water quality standards.

Some major mining companies are realizing that the life-cycle costs need to be clearly evaluated, including the costs of *perpetual maintenance and water treatment after mine closure*. While some leaders in the industry are using life-cycle cost estimates, this is still not a uniform industry standard, and regulators ultimately must make the determination for many mine proposals.

Inform the public about the uncertainty of water quality prediction. As part of the mine permitting process, regulators should inform the public of the history of the accuracy of mine water quality predictions so they can better determine the risk involved in a mine proposal.

Improving Future Mine Water Quality Predictions

Ease access to predictions and results. Information regarding pre-mining, mining and post-mining water quality should be publicly available online, along with the associated mine water quality predictions made during the permitting process. This will facilitate a more informed mine permit process for regulators and the public.

Review original predictions as water quality develops during mining. Mine operations should be regularly assessed to determine if they are departing from mine water quality predictions. This will allow regulators and mine operators to take early action when mine water quality begins to depart from the predicted.

Consult past predictions at other mines. When permitting a mine, regulators should be required to seek similar mines, or similar aspects of different mines, and determine what predictions were made and what water quality actually occurred. These mine analogs should be publicly disclosed.

Require improved characterization of mine sites. This recommendation is covered in much greater detail in the *Methods and Models Report*. In summary, regulators should require better information about the mine site — before, during and after operations.

Require more research on the effectiveness of mine water quality mitigation. The *Comparison Report* found that where predictions of good mine water quality were predicated upon the mine operator using mitigation strategies, mine water quality usually exceeded water quality standards. More research is needed to determine how and why these mitigation efforts fail, and how to improve them.

Change the procedure for selecting consultants to avoid the present conflict of interests. Agencies should independently select and pay the consultants to conduct the studies. This will limit the ability of a mining proponent to influence the outcome of the predictions. The mine proponent can comment on the study, similar to public interest organizations, but they should not be able to exert sufficient influence to bias the outcome.

Increase government expertise. Many state and federal agencies are not sufficiently funded to employ staff with the technical expertise to provide appropriate analysis and oversight of the mine permitting process. Increased funding should be incorporated into agency budgets to ensure that technical expertise is available for permit review.

Endnotes

1. Jim Kuipers, PE, is a mining engineer with Kuipers & Associates in Butte, Montana, and Ann Maest, PhD, is an environmental geochemist with Buka Environmental in Boulder, Colorado.

2. The National Environmental Policy Act requires a science-based review of mine proposals when federally-owned land is affected, or when a federal permit is required (e.g. the Clean Water Act requires a permit when a mine discharges into waters of the United States). Many states have similar laws, based on NEPA, that apply to mine proposals even when federal land is not involved.

3. Mitigation is the effort by a mine operator to prevent or reduce pollution. For example, some mine waste (e.g., tailings impoundments) is underlain by thick plastic to prevent contaminants from moving into nearby water resources.

4. In this paper, an "exceedance" is the presence of a pollutant in concentrations higher than a water quality standard. This is different from a water quality "violation," which is a breach in the terms of a water quality permit. A water quality permit, although based on standards, may allow exceedances under some conditions. A mine operator is legally liable for a water quality violation.

5. Mitchell, Larry D., a staff paper prepared for the Environmental Quality Council, "Zortman and Landusky Mines: HJ 43 Water Quality Impacts, October 2004.

6. Kuipers, J, 2003, Putting a Price on Pollution: Financial Assurance for Mine Reclamation and Closure. This report was funded by Mineral Policy Center.

7. Many mines have multiple EISs or EIAs for different eras of mining.