MISUSE OF WATER QUALITY PREDICTIONS IN MINING IMPACT STUDIES

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INTRODUCTION

If one is going to commercially mine gold in the western United States, the operation is likely to be, at least partly, on federally-managed land—most often managed by the U.S. Bureau of Land Management (BLM) or the U.S. Forest Service (USFS)*. Such federal lands comprise about 50 percent of the eleven western states and 90 percent of Alaska. Portions of these mines may also be on private lands. Most such operations are huge open pit mines, sometimes more than 1000 feet deep, and may be nearly a mile wide and more than a mile in length. The land management agencies will oversee the permitting and operational processes with the intent of minimizing future impacts to the site and it's resources. However, the construction of such huge structures inevitably involves moving and exposing massive volumes of waste rock, and often mining hundreds of feet below the water table. Once mining ceases and the dewatering pumps are shut off, a lake will form within the excavated hole(if excavated below the water table). Pits of this scale at gold sites were first constructed in the late 1980's. Thus, we have no long-term

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* *This paper focuses on an example of mining on BLM land, but the conclusions pertain generally to mining on any federally-managed lands. Also, it comments specifically on predictions about pit lake water quality, but the same general issues are relevant to predictions about the quality of water from mine workings, waste rock piles, tailings,and heap leach piles.*

information on the chemistry of such pit waters; these pits are still being excavated and, in most cases, the lakes have yet to form.

Mining regulatory agencies like the BLM have a dilemma when faced with permitting such mining activities. On the one hand they are required to prepare environmental documents that are supposed to disclose any anticipated significant damages to the resources of the site and describe appropriate mitigation procedures. On the other hand they are mandated by agency policy to promote mining activities on federal lands. Discussions between myself and numerous BLM staff in Idaho, Nevada, Utah, Montana, and Colorado have confirmed that they operate under such a mandate. Hence it is not surprising that these same BLM employees could not name any sites where a formal request to conduct large-scale hardrock mining on BLM land had ever been denied for environmental reasons. (This observation was corroborated by Roger Flynn, attorney, Western Mining Action Project, Boulder, CO). Thus, environmental documents describing proposed mining activities need to assure the public that impacts to water resources, wildlife, etc., will be acceptable.

How can the BLM assure the general public that site surface and ground water quality will not be degraded as a result of these activities? Obviously they can't in fact! But, it has not been traditionally acceptable for the BLM to tell citizens that they are uncertain about future impacts. Thus, the BLM usually requires the mining company to present **predictions** of future water quality in the environmental documents prepared for public review. Until about ten years ago, such documents would often simply present a qualitative opinion about the likelihood of future water quality problems developing. More often than not, no significant, long-term water quality problems were anticipated or disclosed in the dozens of mining environmental documents I have reviewed. In the intervening years, the public has become more skeptical about such simple, rosy characterizations, especially as actual field observations have often shown that unforeseen problems have frequently developed (see for example, documents for Summitville, CO, Zortman/ Landusky, MT, Gilt Edge, SD, Thompson Creek, ID, Sleeper Mine, NV).

In an attempt to make the predictions appear more scientific and trustworthy, regulators in recent years have usually required that some form of predictive testing and/or geochemical computer modeling be included in the environmental studies. They lend an apparent sense of certainty. Unfortunately, the majority of the dozens of such more recent studies I have reviewed, continue to anticipate few, if any, significant, long-term water quality problems. These documents and predictions were, and generally are, prepared by consultants chosen by and paid by the mining companies being regulated.

Clearly there has been a tendency to predict overly optimistic scenarios in older studies. Most of the scientists and engineers I deal with in both the public and private sectors contend that "better science" would solve the problem. Unfortunately, most of the more detailed mining water quality computer simulations were performed in recent years, and insufficient time has elapsed in which to reasonably judge the success of these predictions. To some extent the water quality predictive technology is still in it's infancy, but in the paper that follows, I wish to present the view that the fault lies more with the economic and political pressures placed on the technical consultants and the government managers, which then leads to the misuse of predictive model results.

Why is the appropriate use of such models important? The predictions are presently being used to justify federal and state approval of massive mining projects, implying that we truly know what the future water quality impacts will be. They present a false sense of certainty to the public. Where unforeseen problems develop many years after mine closure, the taxpayers may have to bear the remediation costs and/or the environmental consequences, as they often have in the past.

NEVADA CASE HISTORY

Description of an actual example of hardrock mining on federal land will best illustrate how predictions have typically been used. The present example is an open pit gold site in north-central Nevada. As the announcer on 1950's radio and television mysteries would say, " The names have been changed to protect the innocent." This site will be referred to as the Aguirre mine. The technical details come from draft and final environmental impact statement (EIS) documents released in 1994 and 1996, and supporting documents. I participated in the preparation of the final EIS.

A large Canadian- based company had proposed to construct the open pit Aguirre gold mine to a depth of nearly 1000 feet, approximately 800 feet below the local water table, mostly on BLM land. While most of this part of Nevada is harsh desert, it is frequently underlain by highly-permeable alluvial and carbonate aquifers that yield tremendous amounts of ground water. As such, it was clear that an extensive system of extraction wells and pumps would have to be constructed around the perimeter of the proposed pit to dewater the rock, so that it could be mined. Once all of the economically-suitable ore had been removed—in an estimated 12 years—the pumps would be shut off, and water would begin to flood the pit forming a lake with a depth between 700 and 800 feet. While there have been more than 30 previous open-pit gold mines permitted in Nevada, most have resulted in relatively shallow lakes. None of the other deep pits had been flooded at the time the Aguirre EIS was being prepared. Thus, no examples of directly comparable gold pit water quality were available in the literature. (At least one moderately-deep comparable pit, the Sleeper Pit, has filled and begun to react chemically since the preparation of this paper. It is discussed briefly below). An operation involving the pumping of tens of thousands of gallons per minute of ground water always generates considerable concern on the part of neighboring landowners and frequently with local and national environmental groups. The proposed Aguirre mine also aroused the concerns of several native American groups. In general, some were worried that the mine dewatering might dry up existing springs or wells that are used for livestock watering and domestic purposes. Also, some stakeholders worried that the water in the pit lake would become contaminated, and that it might contaminate surrounding ground water and springs. Hence various federal and state regulatory agencies became involved.

In Nevada, the actual enforcement of water yield and water quality regulations at mining sites falls to the State agencies. However, since most of the operations are on federal lands, the federal agencies (the BLM and the Forest Service) make the decisions about appropriate land use. Theoretically, they can approve, deny or modify any proposed activity such as mining, logging or grazing. In fact, I have been told by many federal land management staff that they do not have the legal authority to oppose a mining operation; they can only attempt to minimize the negative impacts. Many resource experts disagree with this opinion, feeling that it is simply a comfortable political position the agencies have chosen to take (Wilkinson, Charles,1992). I will not pursue the legal details of this issue further, other than to say that the controlling legislation, the Mining Law of 1872, clearly instructs the agencies to promote mining on federal lands (Leshy, J.D.,1987).

This leaves the regulators in a touchy position. They feel obligated to allow mining to occur, but they must ensure the public that negative impacts will be minimal. Hence, they encourage the use of predictions of future water quality conditions and impacts---and other impacts. Obviously, there is a conflict of interest here, along with indirect pressure to predict a largely benign future.

The situation at the Aguirre mine was typical in that the company hired their own consultants to collect data, perform studies, and predict future conditions. In essence, these studies stated that there would be no negative consequences to any nearby water resources. That is, nearby wells and springs would not have their yields reduced, and the chemical quality of these waters would not be degraded.

The post-mining pit water quality was predicted by the company's consultant using two computer models coupled together, which are known as PHREEQE and MINTEQA2. Both are well known within the modeling community, and are often used to gain a better understanding of which chemical species may be stable and what reactions may be occurring in a specific environment. It is, however, only within the consulting community that these models are routinely used to predict specific concentrations of minor and trace constituents far in the future. Since this paper is intended for a broad, non-specialized audience, I will not go into the details of the modeling and the myriad of assumptions and simplifications required. A few such assumptions will be mentioned later.

The original predicted pit water quality concentrations, as shown in the Aguirre mine consultant's report and the Draft EIS are presented in Table 1. Using these modeled results, the mining company's consultant stated that the pit water was expected to have near-neutral pH, a total dissolved solids (TDS) concentration less than 500 mg/L, and low dissolved metals concentrations. This description is essentially what one would expect for water suitable for human consumption. In fact, mining company representatives, their consultants, and BLM staff stated that the post-mining pit water would be of drinking water quality while speaking at several public meetings with local citizens during and after preparation of the Draft EIS.

Most of us might not be too surprised to find that the water quality predictions made by consultants employed almost solely by the mining industry tend to be overly optimistic. Would they continue to be employed if this were not so? Surprisingly, I know of no detailed studies that have ever been done to compare the predicted versus the observed long-term water quality at such mining sites. Nevertheless, my own, admittedly non-random and biased observations at numerous hard rock sites confirms this tendency towards being overly optimistic. It is, however, interesting to observe how these consultant's reports are incorporated into EIS documents to "inform the public".

Under the National Environmental Policy Act (NEPA, 1969), which became effective in 1970, all federal agencies must prepare a "detailed statement" for all " major federal actions significantly affecting the quality of the human environment." Thus the need for EIS's, or similar reports, when large-scale mining is proposed on federal lands. Given the cutbacks in federal budgets and staffs, seldom would the land management staff be able to prepare such an EIS, especially not on the schedule the mining company desires. Also, agencies like the BLM often do not have staff suitable to perform the more technical analyses, such as geochemists. As a result, another consultant is usually hired to advise and assist the BLM--- the third-party consultant. One would assume that the third-party consultant is hired to give an independent perspective to the management agency, to balance the biases inherent in the industry consultant's viewpoints. But here is where the process becomes convoluted and conflicted. The mining company generally has considerable influence on the BLM staff's decision as to which third-party consultant is selected. More importantly, it is the mining company that ultimately pays all the invoices of the third-party consultant.

Clearly the third-party consultant has a conflict of interest. They work for both the federal management agency and the company being regulated—who is providing the funding! Both "masters" may review and approve estimated costs, cost modifications, and schedules. The company also supplies critical environmental baseline data, project design information, and results of *their* alternatives analyses. The lead federal agency is supposed to direct the technical effort of the third-party consultant and decide upon the final language of the EIS. Depending on the individual personalities involved, their technical background, and the work load of the BLM staff, much of the EIS preparation may actually be directed by a representative of the mining company.

The Draft EIS prepared for the Aguirre mine contained general water quality predictions and impacts assessments based on the industry consultant's modeling. The actual predicted pit water quality data (see table 1) were never shown in the Draft EIS, only the consultant's report was cited. Since the industry-consultant's conclusions were quoted in the Draft EIS with no substantive changes or additions, it is obvious that the third-party consultant accepted these model results without any significant independent scrutiny. When the Aguirre Draft EIS went to the public in the summer of 1994, it received much criticism. Most centered on the unreasonableness of the pit chemistry predictions. How was it possible that a lake formed in the scorching Nevada desert sun would still have dilute waters suitable for drinking decades or even hundreds of years after mining ceased? Why hadn't the EIS discussed the future concentrations of many other toxic metals not shown on Table 1?

In this instance the modeling had been too simplistic. It considered only conditions of chemical equilibrium and did not allow the pH to vary as theoretical chemical conditions changed; it did not account for evapoconcentration through time, or the differing speeds of chemical reactions; it made no allowance for changes in reaction rates or solubilities due to having water temperatures above standard conditions (25 degrees C, and 1 atm. pressure)—the deep site water was of geothermal origin; it did not realistically deal with the fate of metals once they became trapped on solid particles of clays or iron hydroxide. For example, this model assumed that once a copper ion was attached to iron hydroxide particles, the suspended iron-copper mass would settle to the bottom of the pit lake, and that there were no conditions under which the copper, and other sorbed metals might be released back into the lake waters. The pit lake was simulated as a one-way sink for metals, hence the concentrations were guaranteed to decline.

The model made no allowance for the roles of microorganisms in the chemical reactions. This is a common shortcoming of geochemical models, and can render such simulations all but useless quantitatively, since microorganisms can drastically change the rates at which many reactions occur (Chapelle, F.H., 1993). The model did not consider variations in chemistry with depth in a deep lake. Also, the model assumed that the quality of waters entering the pit from the weathering and oxidation of the pit walls would be represented by data from extremely simplistic, short-term leaching tests (meteoric water mobility tests). A related shortcoming is the assumption that only the rocks/ minerals exposed on the two-dimensional faces of the pit walls are oxidized when a pit is dewatered. This seems unreasonable since the dewatering wells would lower the water table to below the level of the pit bottom, allowing much of the three-dimensional rock mass within the dewatered zone to become oxidized during the many years of mining. Most important from a practical point of view, the baseline water quality and rock geochemistry data needed for input to the model were inadequate, especially with regards to the deeper zones.

Nevertheless, the computer-generated results could appear to be quite formidable to the lay audience—and to the local BLM staff. The data were calculated to several significant figures, i.e. predicted calcium was 54.83 mg/L. There was no discussion of the possible uncertainty in these predictions. The implication was, this is TRUTH. Such predictions generate a sense of confidence in the minds of the audience, which allows the regulators to move the regulatory/decision- making process forward. Often it is clear that the BLM staff do not appreciate the degree to which these apparently precise, numerical predictions are actually subject to considerable uncertainty. In other instances, they have a sense of this uncertainty, but feel compelled to “present the numbers”, usually without explaining to the public the range of reasonable interpretations for these results.

The Aguirre mine site is located on federal land involving ownership disputes between the BLM and native Americans of the Western Shoshone tribe. These disputes tended to polarize the discussions regarding potential environmental impacts, making the ordinarily routine review process contentious and visible. The public criticism, together with significant newspaper and TV coverage forced the BLM/ third-party consultant's team to enlist more experienced folk and to re-examine the predictions more seriously. As the new water quality/ geochemistry expert for the third-party team, I attempted to make obvious the model shortcomings, but most importantly, tried to shift the focus towards highlighting the uncertainty of such predictions—even when performed at the state-of-the-art. None of us, in any discipline, seem to be able to predict the future very well, consistently. If one accepts that, then the only way to move forward is to look clearly at the uncertainty and to attempt to minimize the risk—as insurance companies do.

Uncertainty is often a threatening concept to regulators and public officials in general. The public is usually reluctant to accept and fund a project for which the outcomes are not well understood. However, similar projects have usually been completed numerous times before, and the regulators may have a data base compiled from the population of such projects from which interpretations based on statistics can be drawn. It is common for a technical manager to consult historical data on, for example, predicted maximum flood heights or average dam construction cost overruns, in order to anticipate the range of expected outcomes. These data are routinely presented in statistical terms, means, medians, along with error bars or confidence intervals. Public officials often, however, are not comfortable presenting such complex and uncertain scenarios to the public, especially before the project has been formally approved.

Hence, one might expect that the BLM would have data bases showing actual and predicted water quality data from, for example, a population of waste rock piles at hardrock gold mining sites throughout the West where predominantly oxidized or reduced ores were mined. Certainly it would be necessary to consider other factors such as similar climate, etc., but in this way a land manager could get a statistical sense of the risk of future water quality problems based on the frequency of recorded developments in similar settings. Because deep pit lakes are a relatively new phenomenon, data on such sites would be quite limited. Such compilations apparently do not exist within the BLM. Instead they prefer to have consultants generate site-specific, apparently accurate predictions of future water quality like those for the Aguirre pit lake.

Neither the BLM, nor the Aguirre company representatives wanted the revised EIS to discuss the uncertainty of predictions, probably because of all the reasons already mentioned. Also, if the uncertainty was obvious, the BLM might be obligated to increase the dollar amounts of financial bonding required from the mining company. Such a situation might even cause the land managers to consider the need for environmental liability insurance. Bonding and/or environmental liability insurance for long-term water quality problems are very sensitive subjects in the mining business---especially since they have so seldom been required. Better, from the industry and BLM points of view, to attempt to refine the predictive models to maintain the impression of predictability.

Given this political reality, the new third-party consultants suggested that whatever predictions were made, even if simplistic, they ought to reflect common sense. Anyone could go to the desert geochemical literature and find frequent references to the fact that most natural desert lakes evolve towards being highly alkaline. Such a condition would increase the dissolved concentrations of many metals and metalloids (i.e. arsenic, mercury, selenium, molybdenum, uranium, nickel, etc.) under the right circumstances. This alkaline scenario was largely ignored by the mining regulatory community prior to the mid-1990's. They tend to be focused only on the dangers of developing acid leachates. It was suggested that the revised impacts analysis ought to indicate that the pit lake would likely be strongly alkaline after many decades, and that predictions of metal concentrations would be subject to a wide margin of error.

Most of a year passed while the company hired an additional geochemical consultant, and all parties gave direction to the original company consultant on how to improve the predictions. Numerous different assumptions and input data were incorporated into a revised model which yielded, not surprisingly, totally different results. After many runs of the new model, and much tinkering to try to correct for internal inconsistencies, the data shown in Table 2 were generated. These predictions ultimately appeared in the Final EIS. Unlike the tapwater-quality liquid of the Draft document, this pit fluid would be highly alkaline, with high dissolved solids content, and significantly-elevated concentrations of several metals and other constituents. Such water might prove to be toxic to fish, birds, livestock, and would probably not be fit for humans to drink.

The new model results were more realistic, but still quite simplistic, possessing most of the shortcomings previously mentioned. One of the more severe weaknesses was presenting a uniform water chemistry for the entire lake for each time period. As most competent limnologists and oceanographers would attest, it is extremely unlikely that the chemistry of such a deep lake would be uniform throughout its depth, at all seasons of the year. (Kuhn, A. and others,1994; Miller and others,1996). (Almost a year after publication of the Final EIS, I received data for the Sleeper Pit, corroborating that pit lake stratification can occur. This Nevada gold site had ceased mining, and a lake approximately 300 feet deep had begun to form. Pit lake waters at a depth of 120 ft. had a pH of 3.75(Water Management Consultants, 1996)). While comparable pit lakes in this setting are expected to be alkaline, the acid conditions at depth within the Sleeper pit lake reflect the high sulfide content of the host rock. Again, the important point is not the technical details, but how the predictive modeling was used.

In preparing the last revision of the Final EIS for review by the BLM, text was added warning readers that the latest predicted pit concentrations (see Table 2) should not be taken as "gospel". One important EIS paragraph read: "It should be noted that hydrogeochemical models are most useful as tools to better understand, qualitatively, how a complex interactive system will behave. Such models are less successful at making accurate or precise quantitative predictions of future metals concentrations (Nordstrom and Munoz 1994,pp 397-417; Bredehoeft and Konikow 1993, pp 178-179; Oreskes et al 1994, pp 641-646). Therefore, the predicted pit metals concentrations should be interpreted as general approximations having considerable potential for error, both positive and negative. Only through future monitoring will the actual concentrations be known."

This one paragraph was the only portion of the revised EIS noted for revision by the BLM water quality specialist. He wanted it removed! To discuss uncertainty in modeling was heresy. Fortunately one of the senior staff of the BLM in Nevada agreed to leave the offending paragraph in the Final EIS.

CONCLUSIONS/RECOMMENDATIONS

The Aguirre mine example elucidates several problems inherent in the use of predictions where public policy is involved.

- the regulatory agency encourages the use of numerical models to lend a sense of certainty to the predictions, and to promote the agency's perceived charter.
- the BLM staff feel obligated to promote mining on public lands. Hence, political pressures can cause the impacts analysis to be redone until it indicates a generally favorable outcome. In the example cited, the NEPA review process did succeed in revising the predictions such that they were less optimistic and more reasonable, but this result seems to be an exception.
- consultants in the present system are often not sufficiently independent financially or politically. Overly optimistic predictions are the result. Some means must be found to allow both the regulators and their consultants to feel free to give more independent evaluations.
- the recent cut-backs in federal staffs and budgets make it unlikely that the BLM (and similar management agencies) can adequately oversee this complex process. The BLM modeling expert involved with the Aguirre EIS stated that he had been advising on approximately 16 to 18 different mine projects at the same time.
- the reliance on modeled predictions lends a false sense of certainty about the future. That, coupled with the tendency to report optimistic predictions means that the agencies will often underestimate the dollar amount of bonds collected to cover future

cleanup operations. If an unforeseen environmental problem surfaces years after mining has ceased and the bond has been released, the taxpayers may be stuck with the bill—or the impacts. This is especially true where small, foreign-owned companies are involved. There may be no practical means for attaching their overseas assets to pay for later cleanup.

- existing complicated, duplicative regulations encourage a "command and control" style of oversight by both the State and Federal governments. Lots of paper is generated, but detailed oversight is often actually meager. If instead, a simplified method of calculating environmental liability bonds was implemented, much of the regulatory nit-picking could be relaxed. If, for example, a $50 million bond was held by the BLM to specifically cover potential long-term water quality problems, the mining company would willingly do whatever was necessary to get back their money. Another alternative might be requiring the company to purchase some form of environmental liability insurance---adequate to cover unforeseen water quality problems. A branch of the World Bank Group—MIGA, the Multilateral Investment Guarantee Agency—has for years sold currency and political risk insurance to mining and other companies overseas. Obviously the international lending agencies believe the concept has some merit. This approach, however, is clearly subsidized by the taxpayers of the cooperating countries.
- fundamental research needs to be conducted on the reasonableness of using data from short-term leaching or kinetic tests as input to such models. The existing tests have been largely developed within the mining industry. There is considerable reason to believe such short-term tests do not give reasonable predictions of future leachate

chemistry (Li, 1997; Lawrence, and others, 1997; Robertson and Ferguson,1997). Independent, long-term testing is warranted.

- predictive models should be used to improve the **conceptual** understanding of how the rock-water-chemistry systems work--not to generate apparently precise predictions of, for example, the arsenic concentration, to the nearest 5 micrograms/L, in the surface layer of a pit lake 100 years in the future. Instead, most scientists knowledgeable about the overall uncertainty would likely state that the metal concentration was predicted to be between 5 and 50, or 5 and 500 micrograms/ L, for example. Studies by the U.S. Geological Survey (Plumlee, G. S. and others, 1993) report approaches where only broad ranges of expected metal concentrations are "predicted" using graphical techniques. This level of certainty seems more appropriate for use in mining environmental report predictions, as opposed to the approaches used in preparation of the Aguirre EIS.

In his always entertaining and enlightening book—Money, Whence It Came, Where It Went —John Kenneth Galbraith (1975) makes some comments on predictions that seem entirely relevant to our subject. He notes the serious flaws economists were beginning to discover, in hindsight, in the " New Economics"—Keynesian economics—after the second world war.

"The first was the reliance on prediction and foresight –on taking action before need. Foresight is an imperfect thing—all provision in economics is imperfect. And, even more serious, the economist in high office is under a strong personal and political compulsion to predict wrongly. That is partly because of the temptation to predict what is wanted, and it is better, not worse, economic performance that is always wanted. It is partly because prediction in economics is thought by many to be self-fulfilling. A gloomy prediction on employment and output will, it is imagined, make businessmen gloomy and pessimistic and cause them to retrench. A prediction of higher prices will cause corporations to look again at their own prices and to raise them. And unions will base their wage claims on what the government says is going to happen to prices and living costs—a forecast of higher prices will immediately be an argument at the bargaining table. It follows that *all* official prediction in economics is suspect; everyone reading it should assume a heavy component of wishful thought. In the decade from the mid sixties to the mid seventies economic policy was to be extensively guided by prediction that was deeply subordinate to hope."

Sounds familiar.

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Table 1.0 Predicted Post-Mining Pit Water Quality—Draft EIS
All concentrations in mg/L, unless noted.

ELEMENT	VALLEY CENTER	VALLEY MARGIN	MIXTURE	AT EQUILIB. w/ CALCITE QUARTZ &ILLITE	AT EQUILIB. W/ 0.002 MOLES/L (250 MG/L) PYRITE
Ca	72.45	57.01	62.18	54.83	increase
Mg	12.07	17.03	15.57	15.58	no change
Na	69.17	97.25	87.95	88.00	no change
K	9.06	14.92	12.98	12.98	no change
Fe	0.561	0.085	0.244	0.244	increase
Mn	0.028	0.039	0.035	0.035	no change
Al	<0.05	0.091	0.061	0.061	no change
Ba	0.053	0.045	0.048	0.048	no change
Sr	0.361	0.847	0.686	0.686	no change
Si as SiO2	14.40	12.17	13.28	5.99	no change
Cl	57.25	26.57	35.14	35.16	no change
C			167.4	160.75	increase
S as SO4	88.48	128.84	115.50	115.52	increase
N as NO3	1.525	1.19	1.302	1.303	no change
F	0.639	2.36	1.788	1.788	no change
Li	0.016	0.260	0.179	0.179	no change
pH	7.78	8.01	7.95	7.48	7.19
pE	-0.80	-0.70	-0.9256	0.4801	-3.6926
Temp	16.15	27.2	23.52	23.52	23.52
Total Alk	167.33	263.32	232.21	209.79	404.45

pH in std. Units
pE in millivolts
temperature in degrees centigrade

Table 2.0 Predicted Post-Mining Pit Water Quality—Final EIS

Constits.	5 yrs	50 yrs	100 yrs	150 yrs	200 yrs	250 yrs	Nev Stds*
pH	**8.57**	**8.81**	**9.05**	**9.24**	**9.37**	**9.46**	**6.8—8.5**
Alkalinity	**198**	**351**	**648**	**1083**	**1580**	**2060**	
Chloride	**30**	**40**	**52**	**66**	**80**	**95**	**250**
Fluoride	**1.4**	**1.9**	**2.5**	**3.0**	**3.5**	**3.9**	**2.0**
Nitrate	**0.8**	**1.1**	**1.4**	**1.7**	**2.1**	**2.5**	**10**
Sulfate	**100**	**133**	**171**	**214**	**258**	**301**	**250**
Arsenic	**0.02**	**0.02**	**0.03**	**0.04**	**0.04**	**0.04**	**0.05**
Barium	**0.06**	**0.09**	**0.12**	**0.13**	**0.15**	**0.16**	**2.0**
Cadmium	**0.003**	**0.004**	**0.005**	**0.006**	**0.007**	**0.008**	**0.005**
Calcium	**7.2**	**2.7**	**1.1**	**0.6**	**0.4**	**0.4**	
Chrom.	**0.005**	**0.007**	**0.009**	**0.011**	**0.013**	**0.015**	**0.1**
Copper	**0.004**	**0.006**	**0.007**	**0.008**	**0.009**	**0.01**	**1.3**
Iron	**0.0006**	**0.0009**	**0.0015**	**0.0023**	**0.0031**	**0.0038**	**0.3**
Lead	**0.001**	**0.001**	**0.002**	**0.002**	**0.003**	**0.004**	**0.015**
Magnes.	**12**	**16**	**21**	**26**	**32**	**38**	**150**
Mangan.	**0.03**	**0.03**	**0.04**	**0.05**	**0.06**	**0.06**	**0.05**
Mercury	**0.001**	**0.001**	**0.002**	**0.002**	**0.003**	**0.003**	**0.002**
Potass.	**10**	**14**	**18**	**22**	**26**	**30**	
Selenium	**0.006**	**0.008**	**0.01**	**0.012**	**0.014**	**0.016**	**0.05**
Silver	**0.3**	**0.3**	**0.4**	**0.6**	**0.7**	**0.8**	**0.1**
Sodium	**84**	**110**	**142**	**182**	**223**	**264**	
Zinc	**0.09**	**0.12**	**0.16**	**0.22**	**0.21**	**0.21**	**5.0**
TDS	**444**	**671**	**1058**	**1610**	**2206**	**2795**	**500**

(All concentrations in mg/L,unless noted)

- **Nevada Drinking Water Stds.**
- **pH in std. Units**
- **Alkalinity as CaCO3**
- **Charge imbalance increases from 2%, 8%, 19%, 29%, 37%, to 41% from year 5 through year 250.**

KEYWORDS

predictions

mining

pit lakes

acid rock drainage

geochemistry

Bureau of Land Management

metals

computer models

environmental impact studies

federal lands

bonding

environmental liability insurance

water quality

Aguirre Mine

open pit mines

uncertainty

consultants