Spatial and Temporal Assessment of Ecological Risks at a Gold Mine Pit Lake

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Abstract An ecological risk assessment (ERA) was conducted to evaluate a proposed expansion of the Twin Creeks Mine in the arid Great Basin ecosystem of northern Nevada. This ERA incorporated a detailed spatial analysis of the mine activities, mine geochemistry, habitat formation, habitat access, and contributions of the pit lake water quality, sediment quality, and wall rock concentrations in evaluating ecological risk. The results of this risk assessment showed that consideration of temporal variations at the mine provided more realistic assessments of wildlife exposure and allowed for targeted mitigation of this exposure.

Keywords Pit lake, ecological risk assessment, Nevada, arid environment

Introduction

Typically, ecological risk assessments use toxicological, ecological, and geochemical information to evaluate risk of impacts to wildlife and habitats from human activities such as chemical spills, resource extraction, and land conversion. If ecological risks are unavoidable, the ERA process can help identify opportunities to minimize or mitigate these risks.

State and federal permitting requires an evaluation of ecological risk associated with mining activities. In the case of proposed pit mine expansion, several spatial and temporal issues complicate the ERA approach. The assessment must be conducted for an ecosystem (a pit lake) that does not yet exist, using predictions of what hydrologic, chemical, and biological conditions are likely to be present several decades into the future as the lake infills The ecological risk assessment needs to account for spatial heterogeneity of chemicals to evaluate chemicals that animals will be exposed to once the pit lake exists. The risk assessment also needs to incorporate site geochemistry, which influences the bioavailability of metals and other chemicals to which wildlife may be exposed (Flynn *et al.* 2003, Suedel *et al.* 2006). These issues call for spatially and temporally explicit approaches in order to accurately predict risk and, if risks of adverse effects are found, inform the approach to reduce or mitigate these risks.

Methods

A screening-level ecological risk assessment was conducted, consistent with regulatory guidance (USEPA 1997, 1999, and 2001), which uses maximum concentrations of chemicals in the proposed pit vicinity, assumes complete bioavailability, and compares chemical data to conservative toxicological criteria. Unsurprisingly, the conservatism of this approach resulted in a long list of metals that may cause risk, with substantial uncertainty about the realism of these risks under future conditions.

To address these uncertainties, a spatially explicit ecological risk assessment was conducted. This approach incorporated an expanded set of modeled and empirical data over multiple time scenarios to evaluate expected future sediment and surface water conditions, including:

- Spatially explicit data sets were used to evaluate what concentrations of metals might be expected at the pit wall surface to which the ecological community could be exposed (Figures1). This effort included detailed characterization of the vertical extent of concentrations throughout the geologic section (Fig. 2).

- Estimates of pit lake surface water elevation and water quality was modeled over the complete 200 years of lake infill by other workers (Itasca 2010, Geomega 2010)
- A conceptual site model was designed to look at how ecological communities of the lake might be expected to develop after pit closure and infill (Fig. 3).

These data sets and conceptual models were used to inform a site-specific wildlife exposure model. The model creates estimates of exposure to local wildlife that might be expected to colonize or forage in the habitats that develop as the pit lake is created and habitat is formed (Fig. 3). These estimates of exposure were evaluated relative to toxicological criteria for concentrations of metals that have been shown in the scientific literature to cause no or low levels of adverse effects to wildlife exposed to these metals.

Results and Discussion

Results of the wildlife exposure model included:

- No risks were predicted to modeled granivorous birds or ducks from exposure to chemicals at the site (Table 1).
- Low risks were predicted to ungulates, which could be redressed by considering pit wall mitigation. Exposures to antimony and arsenic were greater than the no-effect criteria for these metals if mule deer were conservatively assumed to spend all their time at the site. This risk could be eliminated if overburden (surficial materials removed prior to mining) is applied to the areas of the pit most likely to be frequented by grazing ungulates (Fig. 2).
- A handful of metals were retained as chemicals of potential concern that exceeded low-effect criteria for one or more taxa of invertivorous mammals and birds (Table 1). However, there are important aspects of the model and the site conditions that are likely to reduce these risks:
- Predictions of risk were largely related to necessarily simplifying assumptions in the model of uptake factors from foods to consumers. From what we know of other metal bioaccumulation patterns, these factors overestimate uptake, particularly at higher concentrations.
- The model assumes complete bioavailability of these metals; however, geochemical modeling indicates that at this site, several metals are likely to be in valence states or composite forms that re-

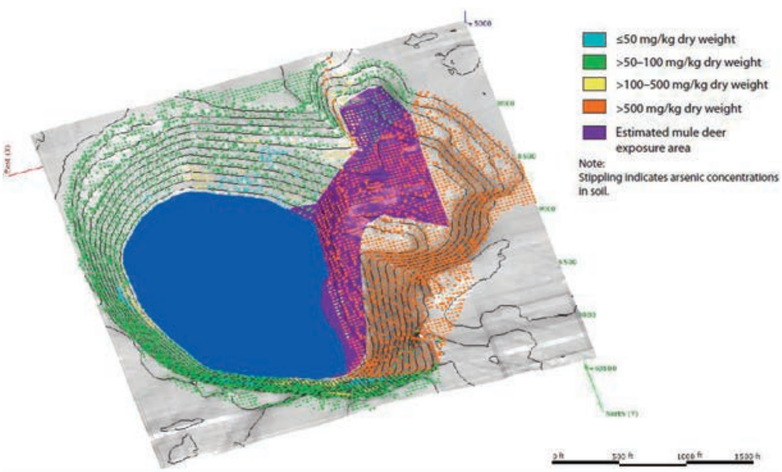

Fig. 1 *Predicted pit-lake geometry and arsenic distribution in the Vista Pit.*

duce their bioavailability. For example, surface water pH greater than 5 is likely for this site, which would maintain aluminum in insoluble form, substantially limiting bioavailability of this chemical.

The availability of littoral habitat is likely to play a major role in shaping the ecological community of the site. Rapid infill rates over the first 20 years or so (Fig. 4) is likely to preclude the development of littoral habitat and will lead to the formation of a deep, mesotrophic pit lake. As lake infill slows, littoral habitat development will be regulated by the spatial proximity of shallow lake waters to horizontal pit wall benches that could allow for the development of a shallow vegetated photic zone. Low organic matter content in this arid ecosystem is likely to slow and limit shoreline soil capable of supporting substantial vegetation, further limiting habitat development.

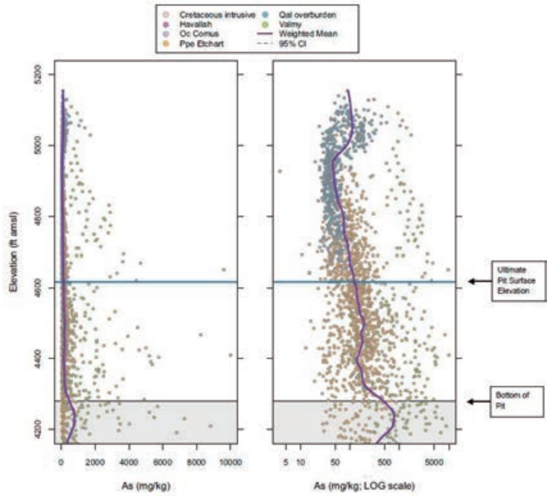

Fig. 2.*Arsenic concentrations as a function of depth in the proposed Vista Pit.*

Conclusions

The use of spatially and temporally explicit geochemical and ecological modeling to inform risk assessment has substantively improved our understanding of the ecological trajectory and potential for risk at the future Vista Pit lake. Following closure and infill from groundwater, Vista Pit is likely to function as a deep, mesotrophic pit lake. The development of shallow littoral habitat capable of supporting wildlife will depend on the intersection of pit geometry and final surface level equilib-

Receptor:	Chukar	Mule Deer	Myotis	Barn Swallow	Mallard	Spotted Sandpiper
Feeding guild:	Granivore	Browsing Ungulate	Aerial Invertivore	Aerial Invertivore	Omnivore	Shoreline Invertivore
Aluminum	—	—	X	X[b]	—	X
Antimony	—	X[b]	X[c]	No criteria	No criteria	No criteria
Arsenic	—	X[b]	[b,c]	— X	—	X[c]
Barium	—	—	—	—	—	—
Beryllium	—	—	—	No criteria	No criteria	No criteria
Cadmium	—	—	—	—	—	—
Chromium	—	—	X[b,c]	X[b,c]	—	X[b,c]
Copper	—	—	X[b,c]	X[b]	—	X [b]
Iron	—	—	—	—	—	—
Lead	—	—	—	X[b,c]	—	X [b]
Manganese	—	—	—	—	—	—
Mercury	—	—	—	X	—	X
Nickel	—	—	—	—	—	—
Selenium	—	—	X[b]	X[b]	—	X[b,c]
Silver	—	—	—	—	—	—
Zinc	—	—	—	—	—	—

Notes:
— = Criteria not exceeded.
X = Criterion exceeded
[a]Exposures at three time scenarios: 50 years of lake infill, 100, and 200 years were run and all results are summarized here.
[b] Criterion for lowest observed adverse effect is not exceeded, indicating risk is low
[c]For one or more time scenarios, concentration does not exceed criterion.

Table 1. Summary of toxicological criteria exceedences[a] using the wildlife ingestion model.

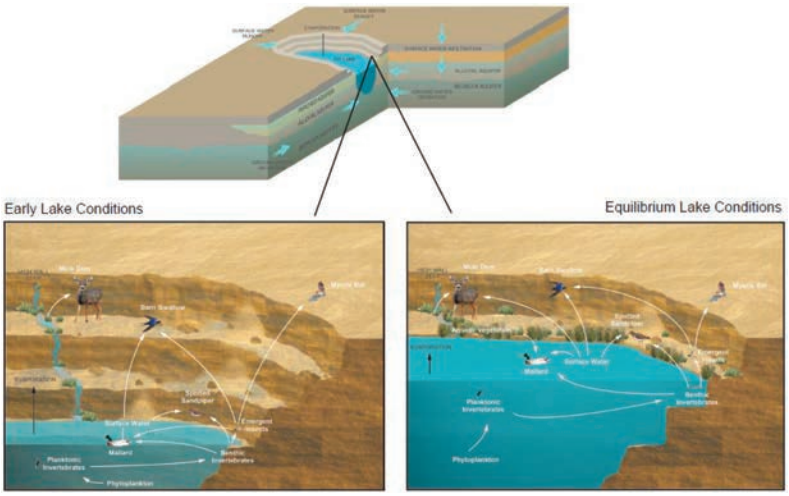

Fig. 3.*Ecological conceptual model of pit infilling and habitat development.*

rium, is likely to be prevented during initial rapid infill rates, and will be limited in the long term by low rates of organic matter accumulation in this arid ecosystem. Most chemicals that were evaluated were not found to be present at concentrations that suggest the potential for adverse effects on wildlife. A handful of metals were retained as chemicals of concern, though these risks may be mitigated by considering the conservatism of the exposure model and the likely reductions of bioavailability given predicted site geochemistry. Steps such as the use of overburden to cover pit wall surfaces that present a high likelihood of exposure may also be helpful in mitigating risk.

Acknowledgements

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