Precious Metals Pit Lakes:
Controls on Eventual Water Quality

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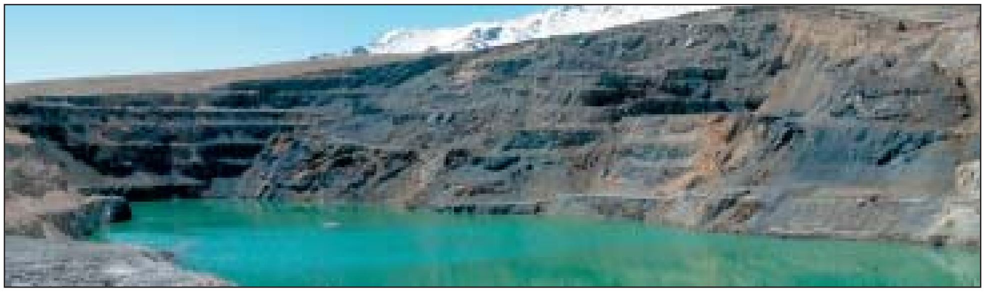

Existing pit lake at a gold mine in Nevada

Gold-mining pit lakes in Nevada, when filled, will contain more water than all of the reservoirs within the borders of this arid state. An estimated 35 pit lakes from all types of hard rock mining are expected to form, containing from less than 100 acre-feet up to about 540,000 acre-feet of water. On a statewide basis, all of the existing reservoirs within the state (excluding Lake Mead) contain approximately 600,000 acre-feet. In contrast, pit lakes in the Humbolt River Basin alone will contain 1,500,000 acre-feet, and evaporation from their surfaces is expected to remove the equivalent of five percent of the flow of the Humboldt River at Winnemucca each year. Thus, from a water resource perspective, pit lakes are important to Nevada, and the quality of the water in them will determine their future use, as well as their effects on the aquifer, wildlife and ecosystems.

The chemistry of a pit lake is, in part, a reflection of the groundwater that existed prior to mining as well as the reactions of the surrounding rock that host the pit lake. Since most pit lakes will not have surface water directly flowing into them, groundwater will make up the vast majority of the influent water. With several exceptions, groundwater surrounding new mine sites is generally good and stands as the appropriate comparison for water quality in the pit lake. In fact, if water in the pit lake is of significantly lower quality than in the surrounding aquifer, the pit lake water represents a potential long-term source of contamination to the regional groundwater.

The Cove Pit Lake south of Battle Mountain, Nevada.

Oxidation Reactions

An important factor of pit lake water quality is the interaction of groundwater with the walls and surrounding host rock of the pit. In an open pit, oxidation reactions on the exposed walls release sulfate, acid, and metals into the lake. Additionally, when a pit is excavated below the regional water table, the aquifer in the host rock is dewatered. The typically sulfide-rich host rock will oxidize when exposed to air that is pulled into the evacuated pore spaces, generating reaction products on the exposed surfaces. As the aquifer recovers following mining, those oxidation products will be flushed into the pit lake by groundwater flowing into the cone of depression. For every acre-foot of water that is replaced with air, sufficient oxygen is introduced to generate 514 mg/L of sulfate, initially as sulfuric acid.

The Cove Pit Lake south of Battle Mountain, Nevada illustrates the potential impact of oxidation reactions in the dewatered aquifer. In 1999, geochemical models predicted that the pit lake water would contain 120 to 260 mg/L of sulfate, primarily from oxidation of the wall rock surface. However, in early 2002, the sulfate concentration in the lake was 1240 mg/L, five to ten times higher than the 1999 prediction (see table). The modeling under-predicted the amount of oxidation by up to one order of magnitude.

An Arizona copper mine pit lake

pH Effects

The pH of the pit lake is the single greatest determinant of the water quality, or toxicity, of a pit lake. As oxidation of the pit wall rock and rubble releases sulfuric acid, calcium carbonate that may be present in the wall rock also dissolves and neutralizes the acid. In many cases where sufficient carbonate is present, the water that enters the pit lake will be near-neutral (see table) while in others, the pit lake will be acidic. Metal solubility, particularly of divalent problematic metals such as cadmium, nickel, zinc, and copper, is much higher at low, acidic pHs and can render poor water quality — a potentially toxic prospect for birds or other wildlife that may attempt to utilize the lake. The Berkeley Pit in western

Montana, for instance, has essentially no neutralizing capacity; as a result the pH is low and metal loadings are high.

A striking example of pH effects on pit lake water quality is provided by the Sleeper Pit Lake northwest of Winnemucca, Nevada. The surrounding rock does not contain sufficient neutralizing ability to limit acid generation, so lime was added for several years to bring the pH to neutrality. This treatment was remarkably successful; although sulfate concentrations remain elevated, the metal loading is very low. In early 1997, a portion of the pit wall failed, sending large amounts of acidic rock into the pit lake. The pH immediately dropped, and metal loadings rose dramatically. However, additional lime brought the pH back to neutrality and the Sleeper Pit Lake has remained low in metals.

Pit Filling

Once water has covered the reactive surfaces, oxidation rates become very slow due to slower rates of oxygen transfer through water. Thus, aggressive refilling of a pit lake by both groundwater inflow as well as additional pumping (as was done with the Sleeper Pit Lake) appears to be useful for limiting the amount of continued oxidation that will occur. However, the acidic water created in the surrounding host rock during the dewatering phase will ultimately flush into the lake, and long-term management may be required. The successful modification of the Sleeper Pit Lake chemistry indicates that long-term management of the toxicity of a pit lake is indeed possible.

Backfilling with waste or other rock may be a beneficial - if costly - management option. If the infill material is calcareous, as is the case with many desert soils, pit water may be neutralized. However, if no neutralization capacity is available in the backfill material, acidic water could replace the former cone of depression, and management of the groundwater in the former pit area will be much more difficult.

Technologies for large-scale, open-pit mining and dewatering have existed for only the past several decades, and the problems of pit lakes have become recognized in the United States for only 20 years. Pit lakes represent an in-perpetuity commitment of groundwater resources and their management needs further study, particularly in arid climates where water is the limiting resource for agricultural and municipal development.

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Water Quality in Existing Pit Lakes (surface samples) (units in mg/L except for pH)

Pit Lake	pH	sulfate	TDS	As	Se	Cd	Zn	Cu
Cove (predicted, 1999)	8.06	120-260	–	0.00068	0.003	0.00039	3.4	0.040
Cove (measured, 2002)	7.7	1240	1940	0.01	<0.010	0.017	7.29	0.007
Yerington (1995)	8.25	270	630	0.004	0.11	–	–	0.114
Aurora (1996)	7.31	265	491	<0.005	–	<0.05	<0.05	<0.05
Berkeley (1993)	2.85	7600	13040	0.8	<0.4	2.14	550	172
Sleeper (post-lime, 1997)	6.9	1520	2660	0.001	0.002	0.0009	0.1	<0.1

Table References: ....

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