Mine Water Quality: Predictions Versus Reality

Jim Kuipers – *Kuipers and Associates*

Do predictions of water quality impacts from mines and the effectiveness of environmental mitigation measures bear out once the mines are actually operating?

Mines on land administered by the U.S. Bureau of Land Management, the U.S. Forest Service, and Native American Trust Lands, and those that require certain discharge or wetlands permits are subject to the 1969 National Environmental Policy Act (NEPA). NEPA requires the agencies to evaluate the environmental impacts of the proposed projects. If significant environmental impact may occur, a detailed Environmental Impact Statement (EIS) is required. For hard-rock mines on federal lands, the analysis must include estimating direct impacts to water quality and indirect impacts that occur later but are reasonably foreseeable. How good are the estimates?

Since 1975, 183 major hard-rock metal mines have operated in the United States. Of them, 178 are in the West, with 40 percent in Nevada, and nearly three-fourths are open-pit mines. About two-thirds produce gold and/or silver, and one-fifth produce copper or copper and molybdenum. About half have closed.

Three-fourths of the mines (137) had actions that triggered NEPA analysis, and of these, 71 had EIS documents that could be located. Review of the documents provided information on both *potential* (tending towards worst-case) and *predicted* (considering the benefits of mitigation) water quantity and quality impacts. Estimated impacts were based on factors such as geology, climate, hydrology, field and laboratory analyses, modeling results, mitigation efforts, and discharge information.

A subset of 25 "case-study" mines (see table) for which operational or post-operational water quality data could be obtained was selected to compare predicted and actual water quality. The subset was selected for characteristics with similar distribution as the 183 mines in terms of location, commodity, mining methods, climate, proximity to water resources, and acid drainage and contaminant leaching potentials.

Impacts Underpredicted

Most case-study mines predicted no impacts to surface water or groundwater quality after mitigations were in place, but in the majority of these mines, impacts *have* occurred. Nineteen had mining-related exceedances of water quality standards in surface water or groundwater, but eight of those had predicted low contaminant leaching potential in their EISs. The most common impacts were from metals (63 percent), arsenic and sulfate (58 percent), and cyanide (53 percent).

Actual water-quality impacts more closely matched the potential impacts (without mitigation) forecasted in the EISs. Eleven of 15 mines with surface water exceedances had projected a moderate to high impact without mitigation, and 11 of 13 mines with groundwater exceedances had projected moderate or high impact.

Causes of Failure

Based on analysis of the 25 mines, the lack of adequate geochemical characterization is the single most identifiable root cause of water quality prediction failures. Poor hydrologic characterization and mitigation failure are additional causes. The results also showed that the combination of proximity to water resources and moderate to high acid drainage or contaminant leaching potential increases the risk of water quality impacts and is a good indicator of future adverse impacts.

Improving Future Results

The results of this study could provide the basis for more environmentally conscious mining in the future. For example:

mine	location	primary metals	status
Greens Creek	near Juneau, AK	Ag, Au, Zn, Pb	open
Bagdad	Yavapai County, AZ	Cu	open
Ray	Pinal County, AZ	Cu	open
American Girl	southeast Imperial Valley, CA	Au	closed
Castle Mountain	San Bernardino County, CA	Au	open
Jamestown	western Tuolumne County, CA	Au	closed
McLaughlin	Napa County, CA	Au	closed
Mesquite	Imperial County, CA	Au	open
Royal Mountain King	Calaveras County, CA	Au	closed
Grouse Creek	near Stanley, ID	Au	closed
Thompson Creek	east-central ID	Mo	open
Beal Mountain	near Anaconda, MT	Au	closed
Black Pine	Granite County, MT	Ag, Au	closed
Golden Sunlight	Jefferson County, MT	Au	open
Mineral Hill	Jardine, MT	Au	closed
Stillwater	near Nye, MT	Pt, Pd	open
Zortman and Landusky	north-central MT	Au	closed
Florida Canyon	Pershing County, NV	Au, Ag	open
Jerritt Canyon	Elko County, NV	Au	open
Lone Tree	Humboldt County, NV	Au	open
Rochester	Pershing County, NV	Ag, Au	open
Round Mountain	Nye County, NV	Au	open
Ruby Hill	Eureka County, NV	Au, Ag	open
Twin Creeks	Humboldt County, NV	Au, Ag	open
Flambeau	northern WI	Cu, Ag, Au	closed

These "case-study" mines, listed by state, were selected for detailed pre- and post-operational water quality comparison. Ag=silver, Au=gold, Cu=copper, Mo=molybdenum, Pb=lead, Pd=palladium, Pt=platinum, Zn=zinc.

PHOTO: Lighthawk and Earthworks

The Golden Sunlight open-pit gold mine near Whitehall, Montana, shown here on Sept. 22, 2004, was one of the mines for which predicted and actual water quality impacts were evaluated.

- Base the threshold for requiring an EIS analysis on potential (pre-mitigation) rather than predicted water quality impacts.
- Standardize federal and state geochemical testing frequency and parameters.
- Require permitting agencies to more closely scrutinize mines near water resources or with moderate to high acid drainage or contaminant leaching potential.
- Require multiple mitigation measures in recognition of their relatively high failure frequency.
- Given the difficulty of simply obtaining the data needed to evaluate EIS effectiveness, improve public access to water quality data.

This article summarizes the report, "Comparison of Predicted and Actual Water Quality at Hardrock Mines," by James R. Kuipers and Ann S. Maest, available at www.earthworksaction.org/pubs/ComparisonsReportFinal.pdf. Contact Jim Kuipers at jkuipers@kuipersassoc.com.

Is Your Model Right for the Job?

John Winchester *– Hydrosphere Resource Consultants*

Extreme drought. Climate change. New standards. Any of these could reduce available water supplies far below levels historically experienced. To quantify the sensitivity of a system to uncertainty and determine the most beneficial action, water resource managers are increasingly turning to models to simulate scenarios. To help them select an appropriate model, Hydrosphere Resource Consultants compared raw water supply models commonly used in Colorado for the 2007 Colorado Water Congress annual convention.

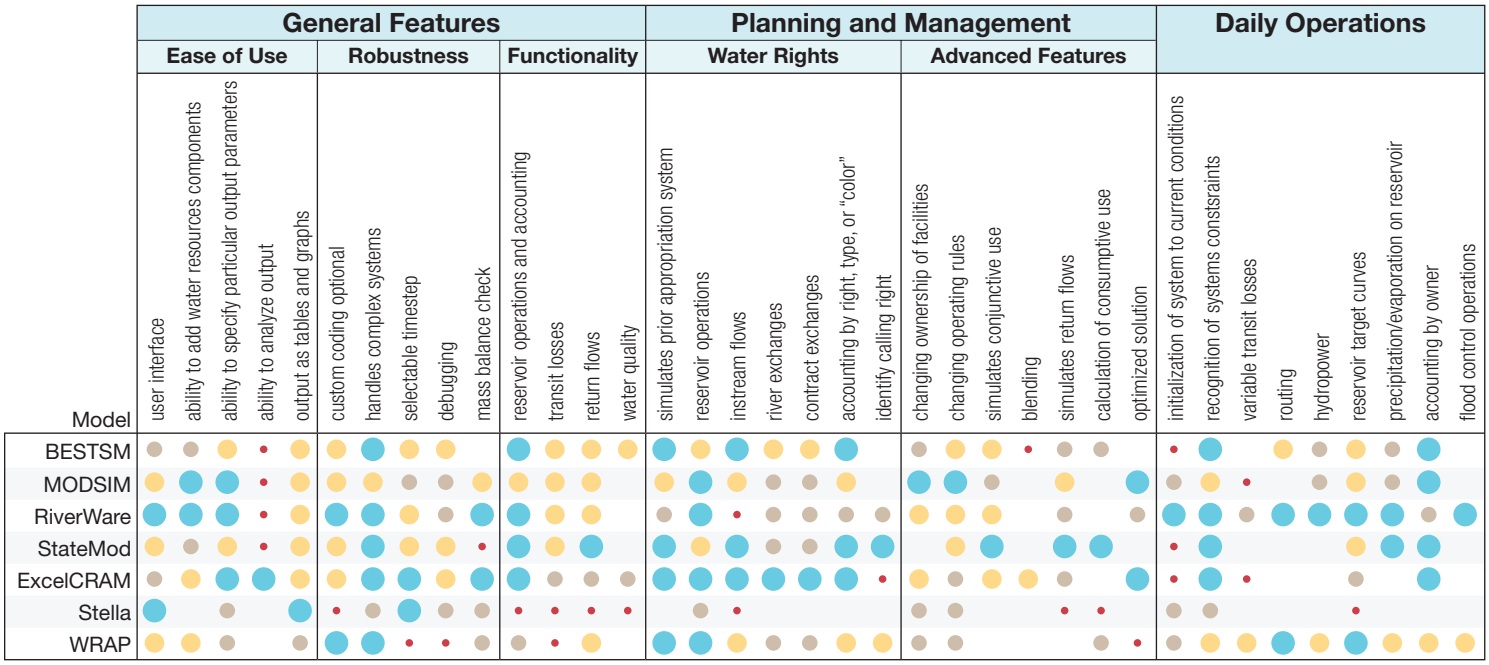
Water planning models typically are used to quantify how complex systems will respond to change, with the goal of cost-effectively maximizing yield. Models are increasingly being used to study the uncertainty associated with long-term droughts identified in tree-ring reconstructions, with potential changes in hydrology due to climate change, and with new environmental or legal mandates. A variety of water resources planning models is available, each designed for a particular purpose and user group, and often with capabilities that overlap.

Models can be classified by the type of solver used. *Linear* models add and subtract inflows and depletions in a predetermined order. *Network flow* models, an efficient form of linear programming, allocate water to provide the greatest value for the system as a whole based on user-specified priorities within a single timestep. *Optimization* models allocate water to maximize the delivery of water to defined needs over multiple timesteps. All types typically have a daily, weekly, or monthly timestep and impose potential operations or facilities on historical or virgin hydrology.

BESTSM, a proprietary model from Boyle Engineering Company, is designed to allocate water to demands based on the prior appropriation system. BESTSM is capable of modeling water quality for conservative constituents. Based on linear programming, the model uses simplified physical processes (e.g., return flow calculations), does not optimize, and does not calculate channel hydraulics. (See Boyle Engineering website at *www.boyleengineering.com/Services/WR.asp*.)

MODSIM, available from Colorado State University, is a network flow model in which the priority-based solver mimics water rights allocations. MODSIM is linked to MODFLOW and QUAL2E to calculate groundwater/surface water interactions and water quality. MODSIM has a friendly user interface, but it has a few shortcomings: it is unable to split a water right between multiple owners, implementing rule-based operations is sometimes difficult, and the data storage format can make it difficult to ensure quality assurance and quality control of input data for large networks. (See *ftp://ftp.engr.colostate.edu/people/labadie/modsim/Documentation/NewManual.pdf*.)

RiverWare, a product of CADSWES at the University of Colorado, is based on linear programming and has three simulation modes: pure simulation, rule-based simulation, and optimization. In pure simulation, all but one operations parameter is specified by the user, and the model calculates the unknown. In rule-based simulation, the user prioritizes rules for operations and the model allocates inflows to meet the rules. In optimization mode, the model allocates water to meet demands in a priority order. RiverWare is expensive, the extensive user interface can be difficult to master, and the optimization solver is not well-suited for complex water rights. (See *cadswes.colorado.edu/riverware/*.)



Comparison of various features of the models described. ● excels, ● does well, ● neutral; does okay, • does poorly, does not do, or does very poorly

StateMod is a publicly available version of BESTSM, available from the Colorado Department of Natural Resources. StateMod differs from BESTSM in that it is equipped with enhanced surface water/groundwater routines for agricultural operations. Also, StateMod cannot model water quality and does not perform routing calculations. (See *ftp://dwrftp.state.co.us/cdss/swm/sw/StatemodUser_20041029.pdf*.)

ExcelCRAM, a proprietary model available from Hydrosphere Resource Consultants, is a network flow model based in Microsoft Excel. ExcelCRAM can repeatedly simulate the same timestep, which allows the model to accurately simulate extremely complex systems and to track water quantity and quality from different sources. Designed for the advanced modeler, ExcelCRAM has a robust interface that can be daunting to novices. (See Hydrosphere website at *www.hydrosphere.com/services/cram.htm*.)

WRAP, publicly available from Texas A&M University, is a linear accounting model with an exceptionally good reliability and frequency functionality. WRAP calculates the natural hydrology of a basin and then allocates water based on the water rights priorities specified by the user. The user interface is primarily a file manager; all file creation and editing is done through other spreadsheet, text, and word processing programs. It is the only model described here without a graphical user interface. (See *twri.tamu.edu/reports/2005/tr256.pdf*.)

Stella, a proprietary model developed by ISEE Systems, is a systems dynamics model based on linear programming. It can be applied to any problem by inexperienced users. Stella has a friendly graphical user interface with very good graphical output. But because it was not designed as a water-resources planning tool, it has no predefined water-related facilities, such as reservoirs. All water-resources constructs—reservoirs accounting, losses, routing, etc.—must be developed from scratch. (See *www.iseesystems.com/resources/Articles/STELLA_productsheet.pdf*.)

The accompanying chart compares the model attributes. It is most useful for comparing general trends between models. For example, daily operations are generally best performed by RiverWare and WRAP, advanced agricultural operations are modeled well by StateMod, and water rights are addressed well by BESTSM, MODSIM and ExcelCRAM.

Contact John Winchester at jnw@hydrosphere.com. Also visit www.cowatercongress.org.

Reference

Wurbs, R.A., 2005. Comparative evaluation of generalized river/reservoir system models. Texas Water Research Institute Technical Report 282. twri.tamu.edu/reports/2005/tr282.pdf