Located more than 4,300 meters (14,000 feet) above sea level in the Peruvian Andes, the Compañía Minera Antamina S.A. (Antamina) mine contains one of the largest copper-zinc ore bodies in the world. This world-class mine required a water management planning tool to integrate water use and discharge requirements at the mine site. A dynamic system model (DSM) was developed to enable Antamina to quickly evaluate alternative mill production and water management strategies based on a set of water management objectives. The model allows the user to define initial conditions and a set of operating assumptions to project the performance of the mine system as a function of time. The major performance measures simulated by the model are the volume of water contained in the tailings facility and discharge to the local rivers.

Water Management System

Annual precipitation at Antamina averages 1,150 millimeters (around 45 inches), but varies from as little as 700 mm (28 inches) up to 1,700 mm (67 inches). Wet and dry seasons are pronounced, with less than 20 percent of precipitation occurring from May to September and over 50 percent falling December through March. The mean lake evaporation rate is 700 mm/yr.

Water management objectives at Antamina are to ensure:
• the tailings facility can accommodate a Probable Maximum Flood;
• an adequate supply of water to operate the concentrator even during dry periods;
• an acceptable riparian flow downstream of the tailings facility; and
• sufficient fresh water for the camp and concentrator.

Water must be managed from several major areas: a tailings impoundment, upstream diversion from four subbasins, three mine rock dumps, a low-grade ore stockpile, the concentrator site, and the open pit mine.

The mine site contains a 570-million-metric-ton tailings facility (see photo) consisting of a large rock-fill dam that will ultimately reach a height of 250 meters (820 feet). Tailings from the milling operation are pumped in a slurry into the facility; the rate of production defines the dam-raising schedule. The facility must maintain sufficient capacity to contain both the tailings solids and water in the facility plus the volume of water that would be produced by a Probable Maximum Flood. Under normal conditions, the majority of the water is recycled back to the mill for processing, so the dam-raising schedule is largely determined by the rate new tailings are deposited. However, during an extended period of precipitation with high runoff and precipitation volumes, it may be necessary to discharge some water from the tailings pond to maintain the minimum storage requirement.

Runoff from the four subbasins above the tailings facility is diverted around the facility and stored in several impoundments where it supplies fresh water for the mine. The reservoirs are connected by a series of drainage channels and pipelines.
that allow flows to be directed as needed, such as dry-season releases to meet downstream riparian flow requirements.

**Dynamic System Model**

The DSM was developed by Golder Associates by first breaking down the water management system into subsystems, then partitioning the subsystems into components until all the processes and conditions were identified. This approach helped identify the interactions among the components and between the components and the environment. A conceptual model of the system and subsystems was documented and described graphically in a flow diagram. A mathematical model was then developed and calibrated.

The DSM must account for all precipitation that falls on the mine, including that which passes through the facility as runoff or is diverted around it, is retained in the tailings, recycled within the mill, discharged in the slurry, or seeps through the tailings dam, as well as evaporation and transpiration.

Stage curves were developed for each of the reservoirs and integrated in the model. Periodic bathometric surveys of the tailings facility provide updated storage curve data so the model can account for tailings placed in the facility.

Capacities of the diversion channels, pipelines, and gate valves are also represented in the model. Decision rules based on existing Antamina procedures for operating the system to achieve the water management objectives were incorporated in the model.

A preliminary version of the model was developed in Microsoft Excel for use during the design and construction phase of the mine, then converted to a true dynamic system model using the GoldSim software platform. To simplify its use by site personnel, a customized user interface offers a series of “dashboards” (see example above), which contain intuitive input fields and controls so that users can easily define initial conditions (such as water levels, tailings volume, season) and an operational scenario (ore type, mill production rate). Users can select a randomly generated climate based on local statistics or specify extreme conditions. The interface also provides easy access to model projections.

**Use at the Mine**

The DSM is being used for day-to-day operations and long-range planning at the mine. For the latter, it simulates the behavior of the water management system under different climate conditions and operational rules. Typical climate conditions that are considered include historical precipitation and evaporation conditions (previous five years), and 100-year wet and dry conditions.

Alternative water management approaches being investigated include:

- zero discharge from the tailings facility other than water used in the concentrator;

*see Antamina, page 31*
Utility Planning, continued from page 19

The DSM has provided insights into the appropriateness of some operational rules and a diagnostic understanding of the water management system. It highlights, for example, the need to regularly evaluate existing conditions at the mine to assess possible water deficits during the dry season and whether emergency measures should be instituted. The model is also being used for planning the dam-raising schedule to reduce the likelihood that the freeboard criteria will be violated.

The greatest challenge in developing the model was creating an accurate conceptual model of the water management system and decision rules and assembling and verifying the requisite input data. Considerable time was also required to communicate information about the capabilities of the simulation model and engage clients at the mine who were not directly involved in its development. Because mine conditions are constantly changing, periodic updates to the conceptual model are required to ensure consistency with actual conditions.

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Reference