To the last drop

In the mining industry, water is used within a broad range of applications such as product handling, mineral processing, mineral extraction, dust control and amenities. But what happens if there is not a readily available supply? Ailbhe Goodbody investigates.
compounds used to extract target elements from the ore solid phase.

Finley explains: “Some extraction processes require pH conditions that are basic – such as gold heap leaching – and others, such as copper heap leaching, require the opposite pH condition. Thus, the chemistry of the make-up water will have a direct impact on the economics of the overall mining process as a function of how different the make-up water chemistry is compared with the final chemistry of the extraction solution.”

David Walker, technical director, mining and minerals at SLR Consulting, says: “This category of water availability or quality affecting projects or operations can be solved with a combination of technology and cost along with maximising water re-use and recycling. In extreme cases, the cost is prohibitive and may even prevent the project from being developed.”

Human factors also affect mines’ ability to access the appropriate quality and quantity of water. There is frequently competition for local water resources, particularly good-quality water, with environmental or social uses and rights along with municipal, agricultural and industrial demands. Legislative constraints such as riparian rights and water-use licensing recognise the need to conserve water, mitigate against over-abstraction and strategically prioritise water between the competing demands of its users.

It is not uncommon for the challenges of absolute water availability to drive or influence these human factors. Walker notes: “For example, scarce or pressured resources will result in limited water-abstraction permits and the higher the competitive aspects of quantity and quality issues, the tougher the conditions to be met. Competitive elements may include competing commercial practices, as well as communities and environmental drivers. An unfortunate consequence of competing industries comes down to politics, money and vested interests rather than altruistic concern for the environmental and social drivers.”

Such issues can be overcome to some degree by employing more costly water-supply options that might involve transporting water over long distances, or costly treatment such as reverse-osmosis desalination plants. Tony Rex, director and corporate consultant (hydrogeology) at SRK UK, says: “Of course, the viability of implementing such measures, both in terms of capital and operating expenditure, is paramount to such considerations.”

OPTIMISING WATER USE

There are a number of ways to optimise water consumption and conservation at mine sites to reduce their need for water, which can go a long way to reducing water consumption and minimise impacts on water sources that may be under pressure. Some of these are tried-and-tested approaches, while others are more innovative technologies.

For example, specific initiatives such as the use of covers for tailings ponds can reduce evaporative losses of water. Rex adds: “Also important are improvements in management practices at the mine, for example, raising staff awareness of the need to minimise water usage and eliminate waste.”

Louisa Rochford, principal hydrogeologist at WSP | Parsons Brinckerhoff, adds: “A number of underground mines are now using mine voids to store water for reuse. Mine voids conserve water levels, avoiding the evaporative losses that occur when water is stored in on-site dams.”

Another simple and widespread initiative is the separation of clean and affected water within the operation according to current best practices. Walker says: “Simply put, this...”
is the separation of clean and dirty water as far as is practicable. This includes the shedding of unaffected storm-water before it mingles with site water, the capture of otherwise clean water in settlement ponds to reduce stream turbidity before release, and the collection and use of relatively clean, but affected, storm-water within the mine, plant or waste-rock facilities and harvesting as a source of relatively fresh process water. It can also include the capture or interception of dirty storm-water, spills or leaks within the process plant, as well as tailings return water.

In a site-wide water-management system that separates storm-water runoff from disturbed and undisturbed areas, water from undisturbed areas may be relatively clean and of suitable quality to re-use without pre-treating, while water from disturbed areas may be suitable to use where lower-quality water will suffice (for example, for dust suppression).

Recycling can also reduce total water demand at a mine site. Water-recycling systems can be installed in areas such as the processing facilities to reduce consumption. The reuse of water taken from mine dewatering, rather than discharging off site, is another way to reduce total water consumption.

However, while the use of water derived from open-pit dewatering or underground water abstraction is a handy source of reasonably fresh water for mineral processing, dust suppression and other uses, this is not always reliable over the life of a mine, so can only ever be a partial supply solution.

The biggest consumer of water on any mine site is the mineral-processing plant and the single biggest opportunity for minimising water loss is the tailings management facility. Walker cautions: “However, it is a lot more complex than the simple recycling of tailings return water or dewatering (partially or otherwise) tailings before depositing. In any closed or partially closed process circuit there is a build-up of chemicals and mineral constituents that are deleterious to the process, impinge on operational efficiency and/or affect longevity of mechanical equipment.”

Such chemicals and mineral constituents can have serious cost implications on several fronts, and despite the cost aspect of treatment, they can have diminishing returns before fresh make-up water is essential. Unintended consequences can include additional waste streams or sludge to handle and manage, which could include waste streams with potentially high toxicity due to concentration of minerals and chemicals.

“For years, many mines did not have a formal method to evaluate the mine water balance,” says Finley. “Most water balances in the 1990s were created in computer spreadsheets, which for a large complicated mine resulted in a complicated and often unusable water-balance model. The complications associated with the functionality of computer spreadsheets (i.e., cells linked to cells linked to other worksheets linked to databases) imposed large uncertainties in the validity of the water balance.

“Additionally, the complexity of the spreadsheet model made it almost impossible to change the computer code to reflect changes in the mine water-management systems that naturally accompany the evolution of the mine. Then, in the late 1990s, the field of dynamic systems modelling was introduced to the mining industry through products such as GoldSim. Previously, dynamic systems modelling were confined principally to the fields of economics and ecology, but the significant time-dependencies of mining operations are an excellent fit for simulating mine water-management systems using dynamic systems modelling methods.”

With the arrival of dynamic systems modelling, most mines have now implemented water-balance modelling as an important tool in optimising water-management systems. Well-developed water-balance models are able to identify low-functioning parts of a water-management system as well as being able to identify and assess potential water-savings methods before investing large sums of money in something that might not provide a good return on investment.

Many mining companies are now thinking increasingly strategically about their water footprint and committing to water-stewardship strategies that take a more holistic approach to global water management across their mining assets.

Rex explains: “This typically involves undertaking water audits, understanding baseline conditions, improving monitoring, formulating detailed water balances to fully understand the mine-wide water situation, and development of water-management plans.”

In addition, associated stakeholder engagement and disclosure reporting can act as real drivers to the strategy being effectively implemented.

Walker says: “Innovation in mineral processing, water-treatment technologies coupled with environmental water management is where the path to innovation lies. In other words, while there may be further technological answers, the true path to conserving resource and minimising water related impacts lies in the integration of engineering and technology with hydrological and environmental sciences.”
Recent projects

Mining Magazine spoke to some industry experts about recent mining projects that have required support with their water-sourcing needs

MWH GLOBAL (PART OF STANTEC)

A recent project that MWH was involved with was the Cerro Verde copper and molybdenum mine in Arequipa, an arid region in southern Peru.

Water was a critical component of the mine’s expansion project, and it was estimated that an additional allocation of 1m³/s would be required.

To evaluate options to provide additional water resources for the expansion, a sophisticated watershed analysis was developed that simulated stream flows, existing reservoirs, and current user allocations over a 40-year period.

By incorporating the influence of droughts, the effects of mine expansion, and potential water-allocation changes, the analysis assessed possible effects on watershed performance.

A decision-support model helped to evaluate various potential water sources – including new reservoirs, reservoir expansion, downstream pumping and groundwater – none of which proved viable at that time.

With no conventional alternatives available to meet water-resource needs, the project team ultimately developed a solution that consisted of constructing a water-recovery facility to treat domestic waste from the city, improving the water quality in the river, and then using a portion of the treated effluent from the treatment plant as a water source for the expansion. The sewage-treatment system is more reliable than surface water, as it remains largely unaffected by seasonal drought and produces a 100% firm yield of the necessary water volume required for the mine expansion.

Two reservoirs (Bamputañe and Pillones), a potable water-treatment plant and the sewage-treatment plant were designed by MWH and built by Cerro Verde to secure the water required to supply the mine-expansion project.

Finley notes: “The reservoirs balance the highly seasonal flow, and the treatment plants give the city of Arequipa first use, with the mine using recycled water for its operations.”

SLR CONSULTING

SLR has been recently involved in several mining projects in one or more aspects of sourcing water, conserving water resources, meeting the challenges of conflicting resources demands, minimising impacts on water sources or addressing legacy issues to reduce existing impacts or clean up damage already incurred, all the while adhering to the principles of social responsibility.

SLR was recently hired to determine the water needs for a new 500Mt gold mine in northern Ontario, Canada. SLR performed the overall mine water-balance analyses to determine the amount of water that could be recycled from the tailings storage facility and how much would need to be drawn from local lakes.

Walker says: “In order to ensure that withdrawal from the local lakes would not result in any environmental damage, SLR established a regional hydrologic and lake water-balance model that simulated the effect of the withdrawals on half-a-dozen lake levels during average, wet and dry periods as well as projecting levels 50 years in the future under climate-change conditions. This model was then used to establish a lake-withdrawal system and withdrawal schedules that prevented any significant changes to lake water levels and would not cause any environmental harm.”

SLR recently assisted a mining company in Mexico in developing concepts for a water-exchange programme under which ranchers, located close to the coast, would receive seawater treated with reverse osmosis, in exchange for the mine increasing groundwater withdrawals in the mountain surrounding the groundwater basin within which the farmers are located.

SLR is also currently working on over a dozen abandoned mine sites

“Water was a critical component of the mine’s expansion project, and it was estimated that an additional 1m³/s would be required”
in the Yukon and Northwest Territories in Canada and in California, US. Senior SLR staff members are involved in the closure planning and design for these mines, where a major thrust is to restore the ground and surface water quality of future beneficial uses.

Walker states: “Some of the conventional and innovative approaches being applied and considered include in-situ treatment of waters in underground and open-pit mines, ex-situ treatment and discharge of pit lake waters, reverse-osmosis treatment of leachate form mine waste-management units, and the collection and storage of mine waste leachate with discharge controlled to occur during high flood flows when there is minimal impact on the receiving surface water.”

Sometimes excess water is a greater problem than a lack of water to meet demands. This was the case in the western coalfields of New South Wales, Australia, where SLR was involved in dealing with the surplus water produced in underground mine operations. Walker says: “Off-site discharge of untreated water to streams was not an option, so water was dispersed using a sophisticated irrigation-management scheme. This was achieved through a combination of a 500ML storage dam and irrigation scheme. The water was used to water perennial pastures, using land management and monitored beef cattle rotation techniques. This innovative approach solved water-disposal needs, while preserving the integrity of the agricultural lands and creating a unique salinity-offset programme.”

SLR has also been providing expert review for a diamond mine in Namibia where water supplies were becoming a critical issue. Over time, in conjunction with the mining company, SLR was able to establish tailings-deposition procedures that halved the amount of water lost in the tailings facility. Walker explains: “This has been accomplished by changing the tailings-depositional scheme to discharging into several smaller constructed tailings cells, instead of the entire tailings facility, as originally operated.”

The company also has a brand-new project under development for a client in Tanzania. SLR is involved in the development of the project, using the latest best practice in responsible resource development.

Walker says: “Apart from the tailings disposal facility, SLR has undertaken determination of groundwater inflows into the open-pit mine as well as the establishment of a wellfield to deliver water supply to processing plant; the latter could be considered part of a social responsibility programme to supply water to local communities after the mine’s mineral reserves are depleted.”

**SRK CONSULTING**

SRK has worked on several projects in the Middle East where water scarcity has been a major challenge. Rex comments: “Accessing groundwater from deep aquifers via wellfields requires a long-term programme of exploration to identify potentially productive settings, followed by comprehensive drilling and test work to evaluate the yield and quality characteristics.”

Similarly, in permafrost regions, such as at a project in Siberia, a 200m thickness of permafrost required deep groundwater to be explored for its water-supply potential for a new mining project. Rex says: “Such groundwater is brackish in quality and is not replenished by recharge. As a result, there is the likelihood of deterioration of water quality with time, requiring a flexible approach to water treatment.”

Another solution adopted by some mining operations in the Middle East has been the use of grey water discharge from municipal sewage-treatment plants as a water supply. For example, SRK was one of a team of consultants that advised Ma’aden in Saudi Arabia on water-supply options for its gold mines in the Arabian Shield, and this culminated in the selection of a piped grey water supply between the city of Taif and its gold projects located over 400km to the east.

Rex tells MM: “Interestingly, Anglo American, at some of their sites in South Africa, has treated the mine’s wastewater effluent to augment the local municipal drinking-water supply. The use of reverse-osmosis technology to treat waste water streams to meet stringent environmental-discharge standards means that such water can relatively easily be redirected for use as a drinking-water supply.”

**VEOLIA WATER TECHNOLOGIES**

Veolia recently implemented a zero liquid discharge system at a rare earth mineral mine, where the client was reviving, expanding and modernising its operations in order to produce higher volumes of rare earths in an environmentally responsible manner.

As part of the expansion, it
contracted Veolia to design and build a water-treatment plant for its state-of-the-art rare earth facility. The plant needed to treat a combination of well water and process wastewater, with the clean water produced being reused for rare earth processing and power generation.

The concentrated reject stream would then be further treated and processed in the rare earth facility’s chlor-alkali plant to be put into the principal chemical reagents needed to conduct rare-earth separation; this production would assist in achieving a goal of zero wastewater discharge at the facility.

The wastewater-treatment plant designed and built by Veolia incorporates its OPUS technology, which uses a reverse-osmosis process operated at an elevated pH to maximise water recovery. By combining Veolia’s MULTIFLO high-rate chemical softening process with filtration, ion exchange and reverse osmosis, this technology generates high-quality water with a low waste volume.

The system was designed to treat 1,000gpm (63L/s) of well water and wastewater, which would enable the client to increase production to approximately 20,000t/y.

This project’s sustainability aspects include reuse of constituents in the water for reduction of chemical costs. After removing salts through the OPUS technology, the reject stream is sent to salt recovery units and used as feed for the onsite chlor-alkali facility.

Veolia provided a long-term performance guarantee to ensure that water quality, system availability and water-treatment production rates at the plant would meet the needs of the client.

Veolia also implemented a zero liquid waste (ZLW) system at a coal mine in West Virginia, US. The project was undertaken to meet a new regulatory limitation imposed by the West Virginia Department of Environmental Protection for chlorides discharged to surface waters.

Veolia designed and built a 3,500gpm (221L/s) centralised ZLW system to generate clean water for reuse in various energy endeavours or for discharge to the environment, with no residual waste from the treatment process leaving the site.

The system is designed to treat a maximum flow of approximately 5 million gallons per day of mine water from six remote sites to comply with a monthly average discharge limit for chlorides. Veolia uses a combination of water softening, chemical precipitation and multimedia filtration with reverse osmosis and evaporation/crystallisation to treat 1.83 billion gallons (6.96 billion litres) per year. Solid waste from the operations is non-hazardous and is disposed in an on-site landfill.

The process utilises state-of-the-art membrane treatment to achieve the discharge criteria, and evaporation and crystallisation technology to manage the brine from the water-treatment process. As a result, the system creates clean water for discharge while generating zero liquid waste. The desalinated water can be used for energy endeavours or discharged back to the receiving stream.

The residuals from the treatment process, including softening sludge and mixed salts, are concentrated into a solid waste that is disposed of in landfill on site. As a result, no residual solid waste from the water-treatment operations leaves the property.

WSP | PARSONS BRINCKERHOFF

WSP | Parsons Brinckerhoff recently provided water-management services for augmenting the supply to a mine site in northwestern New South Wales. Rochford says: “The mine proposed sourcing groundwater from an alluvium aquifer located on a valley plain near a major river and within an agricultural area, which proved challenging given the regulatory requirements associated with licensing and environmental considerations.”

The approvals process required an assessment of drawdown impacts on the aquifer and sensitive receptors, such as nearby groundwater users; baseflow into the major river and groundwater-dependent ecosystems.

Rochford explains: “Groundwater numerical modelling was undertaken to optimise take from a series of bores across the region, with consideration given to minimising impacts to sensitive receptors and adhering to state government instrumentalities, Water Aquifer Interference Policy and regional water-sharing plans. Modelling also considered worst-case scenarios of extended dry conditions and maximising take from the borefield.”

“...the system creates clean water for discharge while generating zero liquid waste. The desalinated water can be used for energy endeavours or discharged...”