

GPS for machine guidance improves safety at Borax mine



An overview of U.S. Borax's mine, located in the Mojave Desert near Boron, CA. The company developed a Leica global positioning system for machine guidance. This helps shovel operators navigate safely in potentially hazardous areas of the openpit. (Photo courtesy of U.S. Borax).

U.S. Borax's mine in California's Mojave Desert is the source of nearly half the world's supply of refined borates. These minerals are used in hundreds of products, including essential plant nutrients that increase crop yield and quality, and safe building products that protect homes from insects and the elements.

Borax's workforce is also safe. In fact, it is among the safest in the nation. In 2003, the company was recognized by the U.S. Mine, Safety and Health Administration (MSHA) for achieving the best safety record among large U.S. mining operations. It was also recognized by its parent company, Rio Tinto, for achieving the best record among its nearly 80 worldwide mining operations. Borax's safety performance is five times better than the national average. And its workforce recently achieved more than two million hours without a lost-time injury.

Despite these accomplishments, Borax never stops working to improve its safety practices. At its principal mine and refinery operation in Boron, CA, Borax faces unique safety challenges associated with miles of abandoned underground mine works lying beneath its current openpit operation. Men and machines work in close proximity to these underground works. To mitigate the associated risk, Borax has instituted a rigorous safety regime and developed a high-precision global positioning system (GPS) for machine guidance. This helps shovel operators navigate safely in potentially hazardous areas. In addition to protecting people and equipment, the GPS system has also improved the mine's productivity and bench grade control.

In 1927, Borax's began an underground mining operation at its current site — one of two world-class borate deposits on the planet. The company stayed

underground for another 30 years and produced more than 8 Mt (9 million st) of ore from the Baker, the West Baker and the Jennifer mines. In 1957, with the introduction of large-scale mining equipment, the company closed the underground workings and converted the operation to a single openpit mine.

Today, Borax mines ore at a rate of 2.7 Mt/a (3 million stpy). Two 44-m³ (58-cu yd) P&H 4100 electric shovels are used for waste mining. The company's haulage fleet consists of 25 Terex MT4400 218-t (240-st) trucks. Ore is mined using LeTourneau L1350 and L1400 front-end loaders.

Tim Cotton is Borax's manager of mine technical services. He explained the challenges presented by the juxtaposition of old and new. "We have mined safely around our old workings for many years," he said. "But more recently, our operations are intersecting with the underground works of the Baker Mine, the operations' oldest. Previously, only part of the West Baker and Jennifer mines had been intersected," Cotton said. "The Jennifer was developed 25 years after the Baker, using room-and-pillar rather than cut and fill or shrinkage stoping methods. Stope voids in the Baker mine tend to be much larger. To compound the problem, these stopes were not filled — and pillar collapse, water percolation and hanging wall failure have all taken their toll. The end result is that we have unstable ground. It can result in voids opening up more than 90 m (300 ft) above the known workings," he said.

On the ground

Armed with this knowledge, Borax began developing a system to safeguard people and equipment operat-

A P&H 4100A shovel loads a 218-t (240-st) Unit Rig haul truck at U.S. Borax's boron mine. Two of the 44-m³ (58-cu yd) electric shovels are used for waste mining. The operation mines 2.7 Mt/a (3 million stpy) of ore. (Photo courtesy of U.S. Borax.)

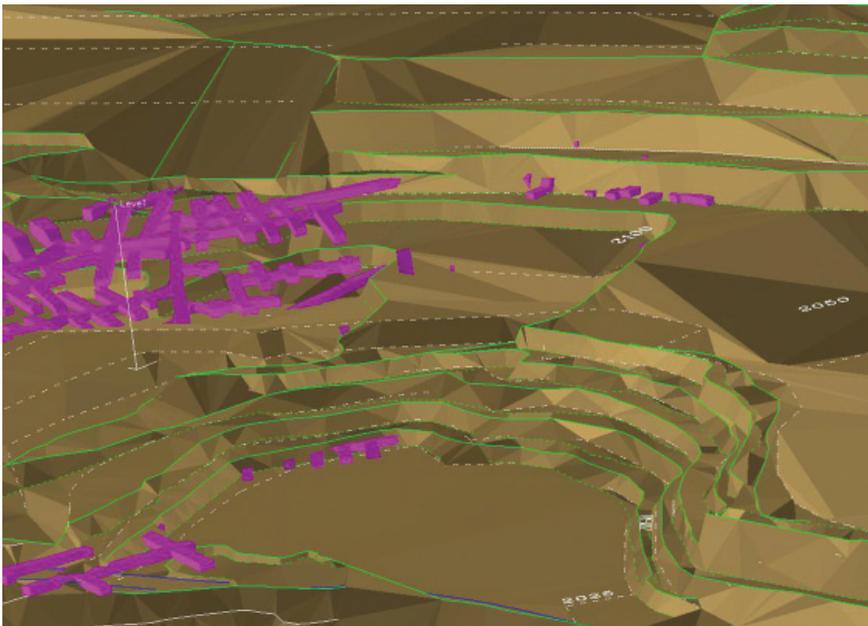


ing around the old Baker Mine. The company worked closely with experts from MSHA and the California Occupational Safety and Health Administration.

First, Borax cordoned off all the hazardous areas and limited the access to designated personnel with written authorization. Next, exploration holes were drilled to detect any voids and confirm the location of underground stopes and development drives.

When a large void is found, the area is blasted to collapse and close it. It is then re-drilled to confirm that no new voids have opened up. Even if no voids are detected by drilling, once the bench gets within 15 m (50 ft) of stopes or drives, a blast pattern is set out to wreck the pillars and collapse them. Then the area is drilled again to verify that it is safe.

Vulcan Design Package software creates a three-dimensional view of the old Baker underground mine and the current openpit. This has helped U.S. Borax locate the underground workings and avoid hazardous situations involving pit machinery. (Photo courtesy of U.S. Borax.)



Help from above

Two years ago, Borax began investigating GPS-based machine guidance technology to bolster its safety system. The company's goal was to improve the shovel operators' ability to maneuver their machines in and around high-risk areas. To test the system, Borax installed a Leica Geosystems Dozer 2000 system on one of its P&H 4100 waste shovels.

"We had extensive experience with our existing GPS-based surveying and dispatch systems," Cotton said. "So applying the equipment and principles to this challenge was relatively easy. We also had excellent digital maps and good design files for the underground diggings," he said.

The Dozer 2000 system consists of a rugged, high-precision GPS receiver, radio data receiver and touch screen computer running on specialized software supplied by Leica Geosystems. The satellite antenna is mounted on top of the machine, where it has an unobstructed view of orbiting satellites. The GPS receiver calculates its position in three dimensions, 10 times per second.

The GPS position data is corrected for local-area errors using differential data transmitted from a fixed base station. This yields position accuracies of 25 to 50 mm (1 to 2 in.) in real time.

The Dozer 2000 compares the actual GPS position to a computer-generated model of the desired finished terrain and provides visual guidance to the operator. This helps operators move the machine left or right, and cut and fill as needed to match the design surface. Other system elements include Telescope software for data transfer between the machine and the survey office, and Site Manager project design software.

As the name implies, the Dozer 2000 system was originally developed for bulldozers. So modifications were necessary to optimize the system for use on the P&H shovel. A new icon was added to the screen to depict the shovel. And the software was programmed to interpret the GPS data as the shovel swings.

"At the Borax mine, Leica worked with their partners, Carlson Software, to implement an innovative new digital compass solution. This was done to determine the position of the rotating shovel accurately relative to the working face" said Rod Eckels, vice president, south west region, for Leica Geosystems.

Safety on display

Digital terrain files are prepared in the survey office. The files can be generated in any General Mining

Package in a .dxf format. Then it can be converted in the Leica Site Manager to a polyline file for display. Other files used by the system include:

- A grid or triangulation file of the design surface.
- A grid file of current ground surface and centerline alignment of roads or other features.
- A grid file of attributes such as ore grade.
- A local coordinate system information.

Triangulation and grid files are used to calculate excavated volume, which can be reported on a shift-by-shift basis. The grid file can also be used to construct an as-built model of the excavation. "The accuracy of this information is determined by the user's choice of grid size," said Eckels. "Experience has shown that reasonable file sizes can be maintained with grid sizes of around 3.3 m (10 ft)."

Telescope software permits files to be transferred between the machine and survey office by a wireless data link. "This allows the project files to be regularly updated and current face positions to be downloaded at any time," said Cotton.

Safety and productivity benefits

Trials demonstrated that the GPS-based machine guidance system greatly assisted operators. The system provided a detailed plan showing shovel position relative to hazards such as underground voids. "The system gives operators the tools they need to work safely in potentially hazardous areas," said Cotton. "Achieving design grade is also more efficient with this system than with survey stakes."

Eckels said that the system has also helped maintain proper grade in the mining operation. Operators typically keep within 0.3 (1 ft) of design elevation. This has important ramifications on bench road conditions and equipment maintenance. But grade control is secondary to safety for Borax, Eckels said. "This is unusual," he said. "Normally, grade control is the primary concern of our customers."

Cotton said that the Dozer 2000 system, with its intuitive operator interface, was easy for operators to learn with minimal training. "Our operators have adapted well to the system. They have adopted it as an integral part of their safety protocol," he said. "To be safe is to be careful. Working near these hazards, operators must carefully position tracks so that material can be removed by reaching out from all sides. Before we instituted this system, we would have needed a surveyor to be present in the cab at all times to direct the operator."

A Leica Dozer 2000 GPS receiver is mounted on the cab of a P&H 4100A electric shovel. The antenna for the receiver is shown in the upper left corner of the photo. (Photo courtesy of U.S. Borax.)



Other system benefits include the ability to retrieve "as-builts" automatically and calculate remaining muckpile volumes quickly, according to Cotton.

Based on the successful test pilot with the P&H shovel, Borax ordered a second Dozer 2000 system. It has been installed on a new LeTourneau L1350 front-end loader. The loader was being built when the second system was being installed at Borax, Cotton said. So the company was able to set up the proper wiring at the LeTourneau plant in Longview, TX. "LeTourneau's people were a great help in seeing that the installation went smoothly," he said.

Borax has ordered two additional Dozer 2000 systems for installation on another shovel and a Caterpillar D11 bulldozer. This will be a sufficient number of GPS systems for current and future mining operations. But the company will continue to blaze new trails to improve safety for the people who work at and visit California's largest openpit mining operation. ■