Restoring Erosional Features in the Desert

New Landform Design Software and Automated Machine Guidance Combine in Award-Winning Reclamation Project

Using specially developed software and GPS guidance systems on dozers, BHP Billiton's La Plata mine restored mined desert lands efficiently and cost-effectively.

The focus of any mining operation is recovery of the mineral reserve, whether coal or other deposit, but often the greatest cost of mining is associated with moving, storing and replacing overburden – functions that produce no revenue for the mine. When that material is replaced during reclamation, it will have to meet many stringent performance criteria all aimed at providing a landform that will sustain a specified post-mining land use, and which is intended to be stable against erosion essentially forever (as 'proven' by a bond liability period), and which will generate runoff water quality that meets applicable water quality standards.

To ensure the reclamation program will meet these regulatory requirements, the mine operator normally posts a bond, which could amount to $50 million to $150 million for a large operation for a minimum five- to 10-year liability period.

Mine operators are looking for practices that can minimize the rehandling of overburden, improve the performance of the regraded landform to meet the required regulatory criteria and minimize this financial liability. The following case history shows how BHP Billiton adopted newly developed technologies for topographic (modeling) design and automated machine control to achieve dramatic results in productivity in its award-winning reclamation project at La Plata, N.M.

RECLAMATION CHALLENGE AT LA PLATA

The La Plata mine was a short-term operation necessary to continue the coal supply to a mouth-of-mine power plant at the BHP Billiton San Juan mine 20 miles to the west. The San Juan mine was completing surface dragline operations and converting to an underground longwall operation. The steep dip of the coal from the outcrop at the La Plata mine made contemporaneous backfilling behind active mining a safety issue because of concerns that a spoil pile failure could bury miners. Because of this concern, the mine was operated as an open pit mine. The entire 2,018 acres of mine disturbance would have to be reclaimed in a continuous operation beginning just before the cessation of reserve recovery.

The La Plata mine ceased operation in early 2003, and the reclamation phase began immediately thereafter. The reclamation work was initially estimated to require seven to eight years, using the conventional methods available at the time, and BHP Billiton began looking for ways to speed up the work to minimize this liability period.

The La Plata reclamation program faced a number of challenges. The swell factor of the material dictated an additional out-of-pit waste dump because the swelled material could not fit back into the mine pits.

Because of the unique topography, the company was not satisfied with the gradient terrace and down-drain design for slope reclamation that was the conventional practice. The terraces and down-drains were expensive to build, and expensive to maintain because sediment accumulation on the terraces or animals burrowing through them could cause slope washouts. If the slope damage required major repair work, the bond liability period could be restarted from the repair date.

Also, the constant-gradient slope faces associated with the then-conventional design led to great slope areas facing the same direction (aspect) and very uniform water retention across the slope faces. These factors combined to create ideal habitat for only some plant types which frustrated efforts to meet vegetation species composition and diversity criteria for bond release. Those criteria require that not only does something have to grow on the reclamation, but the vegetation has to belong to an integrated vegetation community consistent with the 'sustainable development' concept. If slopes have uniform aspect and water-holding properties, an operator can seed them repeatedly with a variety of seeds, but find that only the plants that like those conditions grow.

The designated post-mining land use for the mine was wildlife habitat. Wild animals require habitat diversity just as plants do. Varied topography provides opportunities for different plants to grow, some of which will provide food, some security cover, and others perhaps a home. The then-conventional uniform grading practices did not satisfy these needs very well.

Additionally, the mine had to meet state water quality standards for runoff from the reclaimed lands under the authority of the federal Clean Water Act. Excessive erosion could frustrate meeting those criteria. The mine is in an extremely erosive environment, a fact which is not intuitively obvious to some because it is in a semi-arid climate. But consider that perhaps the greatest erosional feature in North America, the Grand Canyon, is in the same region, only about 200 miles (320 km) to the west. The combination of erodible earth materials, minimal vegetation cover, steep gradients, thin soils and infrequent but high-intensity short-duration storms make for very erosive conditions, and an extreme reclamation challenge.

Considering all of these criteria, a reclamation grading design using a fluvial geomorphic approach was proposed. Instead of the then-conventional approach that sought to make water flow sideways on slope terraces and retard erosive forces of water with rock rip-rap, gabions and other structures, the design took the lead from natural stable landforms in the area.

THE FLUVIAL GEOMORPHIC APPROACH

Fluvial geomorphology is the branch of earth sciences that studies landforms shaped by the processes of flowing water (fluvial – flowing water, geo – earth, morph – form). The La Plata reclamation project presented an ideal opportunity to apply fluvial geomorphology in a practical real-world problem.

During the last 30 or 40 years, hydrologists working with perennial streams have identified the dimensional characteristics of stable streams, and developed mathematical relationships that describe their geometries. During extreme storm events, when water was flowing overland and coalescing into ephemeral streams and flowing into perennial streams, the flow made one continuous system. The ephemeral streams in the upland areas had similar characteristics to the downstream perennial channels. From these observations, it was reasoned that the upland divides between these channels had geometry related to the channel geometry. Measurements were taken from stable landforms in an area of interest to define the morphology or shape of the stable landform that will develop in that area over time, given local earth materials, climate and vegetation.

These principles were incoporated into a solution called GeoFluv. Essentially, the GeoFluv approach asks, "What stable landform would naturally evolve at this site given these earth materials, this climate and this vegetation?" It then designs that landform. The GeoFluv technology is being marketed by Carlson Software as part of its patent-pending Natural Regrade design module, which includes material cut/fill balance calculations, and a material centroids calculator that locates the centers of mass of material needed to make a design, can determine associated haul distances, and outputs its design in the file formats used by machine guidance systems.

GPS MACHINE GUIDANCE

As the production department at the La Plata mine studied ways to improve the efficiency of the earthmoving and construction work associated with the reclamation project, it was quickly recognized that automated machine guidance could play an important role in improving productivity and accuracy of earthmoving operations.

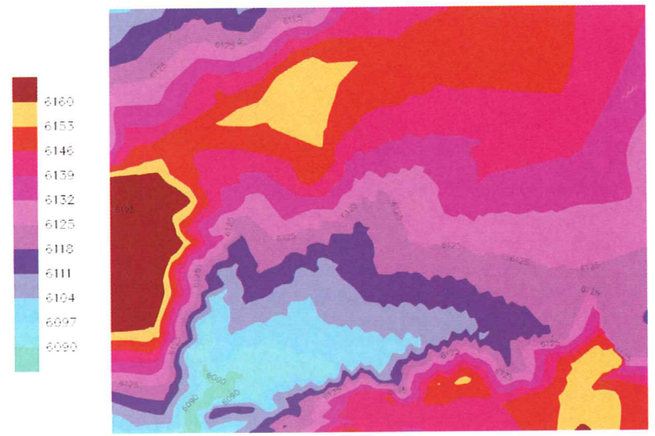
Accordingly, Leica Geosystems Dozer 2000 machine guidance systems were installed on four bulldozers (one D10 and three D11s) working on the reclamation site. In addition, two Dozer 2000 systems were installed on pickup trucks for the foremen and engineers to verify work.

The Dozer 2000 uses high-precision GPS to compute the dozer's position in real-time. The machine's operator can see the vehicle's actual position relative to the desired design grade on a large computer screen in the cab. The computer gives the operator cut and fill instructions with easy-to-follow arrows on the screen.

To achieve the necessary levels of accuracy, a GPS base station was established on site. The base station calculates errors in the GPS signals and transmits correction factors to the machines via a radio data link.

Today, the design surface model, which is produced by the Natural Regrade software, is transmitted to the bulldozers via a radio data modem, or alternatively (then) by loading the data on a PCMCIA card, which is hand-carried to the machines.

The dozer operators can quickly and easily accomplish the desired grade matching by following the computer model's on-screen instructions. They can move from one display screen to another to view graphic representations of the long-section (in front or behind), cross-section (to the left or right) and plan view (bird's eye), as well as the cut and fill values required to reach the design surface. In addition to this basic functionality, the operators can create



GeoFluv design made into a bench plan to build the complex topographic surface up in a series of lifts using precision GPS-guided dumping. Dozers guided by machine control efficiently smoothed the edges of the lifts to complete construction of the design.

July 10, 2003 - The image is taken from a higher lift against the endwall looking southeast toward part of the highwall. Precision dumping, guided by global positioning system (GPS), is following the GeoFluv design. The irregular shapes of the outslope piles forming the edges of each lift are visible in the foreground, center right, and upper left. Spot dumping to supplement fill for ridges against the highwall has begun.

August 1, 2003 – As precision GPS-guided dumping continues, the general shape of the GeoFluvTM -designed landform begins to emerge. Valleys will be cut between the fill against the highwall and the cut material will supplement the ridges.

June 4, 2004 – After the material was placed by precision GPS-guided dumping, dozers equipped with Leica's Dozer 2000 knocked off the edges of the lifts and completed shaping of the complex slopes and valley bottom channels.

May 5, 2005 – After grading was completed to final design using Dozer 2000-guided equipment, the topdressing was added and seed was applied. Vegetation is beginning to sprout. Note the absence of any rills or gullies despite the landform having endured winter snowmelts and spring rainstorms.

December 13, 2005 –A half-year after plants began to sprout and the stable and functional GeoFluvTM -designed landform already harmonizes with the surrounding landforms. The highwall is gone, replaced by a stable and functional north-facing special landscape enhancement feature that will promote tree growth. This feature, about 1,200 feet (366 m) long, enhances the post-mining land use and eliminated the need to move huge volumes of material against the former highwall.

basic design surfaces on the fly (flat elevations), design ramps, log points of interest and carry out a range of other functions.

Dozer operators describe it as "having a surveyor in the cab." They know where they are digging at all times, day or night, in sunshine or in snow, without the need for grade stakes.

Downtime is minimized, since work can continue with confidence after dark or when a surveyor may not be available. The equipment operators are empowered with instant feedback on their design performance and are enabled to achieve final grade on the first pass, eliminating the need for re-staking and excessive, non-productive site-to-site equipment movement to make grade corrections. This reduced equipment movement reduces maintenance and fuel costs. All these efficiency gains combine to shorten the project time to completion, which affects other associated production costs. Importantly, shortened project construction time can also reduce the bond liability period.

PRACTICAL SOLUTIONS

The 38-acre 170 Arroyo headwaters area provides a good demonstration of how the GeoFluv and Dozer 2000 combination worked to good effect. The 170 Arroyo terrain drained southwest to a corner of the highwall. Conventional reclamation methods would have dictated moving millions of cubic volumes of material to backfill up to the top of the highwall. In contrast, the GeoFluv design called for cutting several channels into the highwall and endwall, making them into special landscape enhancement features and eliminating the need for moving huge volumes of material.

Likewise, the valley floor had three main channels separated by low divides. Under conventional practices, bulk volumes of material would be hauled to their approximate final location, and the site would be staked out to a constant-gradient slope design before turning the dozers loose to push the material into place. At La Plata, however, the complex GeoFluv design was translated into a truck dump plan that would build up the land surface in a series of lifts, layer-cake fashion. The trucks, precision guided using GPS, dumped the material according to this plan. Then the dozers, using Dozer 2000, knocked off the edges of the lifts to complete the project as designed without the need for surveying, grade checks and minimal work hours.

The La Plata mine reclamation project provides a convincing demonstration of the results that can be achieved by combining a thorough hydrological approach to reclamation and implementing it with GPS-guided earth movers.

Success has been great on many fronts. The mine's reclamation had been scheduled to take seven to eight years after cessation of reserve recovery. That estimate has now been reduced to three to four years. This means bond liability can end sooner and total construction costs will be less. Rather than arbitrarily moving millions of tons of material great distances at great expense, the terrain has been shaped into functional and stable landforms according to fluvial geomorphic principles. These landforms have survived extreme storm events, without erosion or requiring maintenance during the last five years.

In September 2004, the Department of the Interior recognized BHP Billiton's San Juan Coal Company with two reclamation awards for its work, a "National" and the "Best of the Best".

This article was provided by Leica Geosystems and Carlson Software with the approval of BHP Billiton.