RESOURCE NOTES

NO. 68 DATE 05/17/04

CARTOGRAPHY/ MAPPING SCIENCES

Airborne LIDAR for Remediation of Abandoned Mine Lands

By Russell Jackson, Photogrammetrist, BLM, National Science and Technology Center

Introduction

Acid mine drainage is a known concern in the upper Arkansas River near Leadville, Colorado. The Lake Fork tributary of the Arkansas River is 4 miles west of Leadville. This stream flows south out of Turquoise Lake for about 4 miles to its confluence with the Arkansas River. Below the Sugarloaf Dam on Turquoise Lake, many turn-of-the-20th-century silver mines exist, with tailing piles leaching heavy metals into the Lake Fork tributary. To aid in the restoration of the Lake Fork watershed, high-resolution, highly accurate terrain data must be obtained.

Traditionally, Bureau of Land Management (BLM) crews on the ground perform surveys of the site to capture the terrain data needed for the restoration process. Other technologies need to be evaluated that may provide the same accuracies and point density necessary for the remediation process. Although conventional photogrammetric practices can provide products that meet these requirements, recent advances with airborne Light Detection and Ranging (LIDAR) imaging systems may also satisfy the requirements in a more timely and efficient way than traditional photogrammetry. Products from both systems were evaluated in early 2003, including bare-earth and vegetation models, digital orthoimages utilizing the terrain data during orthorectification, and intensity data generated from the LIDAR sensor in vegetation identification.

Background

Located between Leadville, Turquoise Lake, and the U.S. Fish and Wildlife Service Fish Hatchery, the Sugarloaf Gulch watershed has tremendous potential for public use. The watershed contains several wetland areas that could potentially be restored for valuable wildlife habitat.

A detailed, three-dimensional map of the area would assist various projects that are under way or are planned in the Lake Fork watershed. The Lake Fork tributary and the surrounding wetlands are significantly affected by acidic mine drainage from the Sugarloaf Mining District. To create detailed three-dimensional data, high-resolution, highly accurate elevation (terrain) data have been captured over the project area by LIDAR imaging systems and also from conventional aerial imagery. Although LIDAR technology may still be classified as an emerging technology, it has been used successfully in a variety of natural resource applications.

Benefits

The acquisition of elevation data will enable partnership institutions to evaluate several alternatives for the reduction of acid drainage and to develop plans for engineering local drainage patterns that will alleviate potential recurrence of the problem. The primary benefit of work in this area will be an improvement of water quality in the Lake Fork tributary and the Arkansas River.

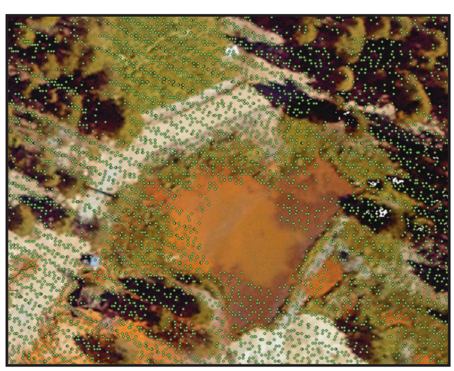

Figure 1. LIDAR bare-earth x,y,z points draped over an orthoimage of the Dinero Dump.

LIDAR imaging can provide multiple spatial data sets, including digital elevation data, as digital elevation models (DEMs), ASCII x,y,z data points, and triangulated irregular networks (TINs), of the bare earth, canopy, and—potentially—the understory. In the present study, two elevation surfaces were acquired, the bare earth and the canopy (Figure 1), in ASCII x,y,z data format. An intensity model of the area was developed, and a digital orthoimage was created by the digital aerial camera located on the same aircraft platform flying the LIDAR system. These products were delivered within 30 days of the acquisition date. In addition to the LIDAR data, conventional aerial imagery was acquired to evaluate the accuracy and image quality (intensity) of the LIDAR. Digital elevation models and digital orthoimages were created for evaluating the LIDAR data. Conventional film of sufficient scale and quality, when combined with the geodetic survey control, provides more accurate products than the LIDAR, allowing BLM National Science and Technology Center scientists to evaluate the accuracy and quality of the LIDAR products. The products generated from the conventional film cannot be created as quickly as the 30-day delivery provided by LIDAR. The timeliness of LIDAR products is one of LIDAR's greatest benefits. For resource management issues, LIDAR technology can provide highly accurate products in a much shorter time than conventional mapping processes.

Feasibility

The LIDAR systems provide terrain data at the accuracies needed for this study (15–20 cm RMSEz vertical accuracy over the mine dump areas and 30–45 cm RMSEz accuracy over the rest of the watershed). LIDAR systems can produce accurate terrain data in areas of heavy vegetation cover faster and at a lower cost than traditional photogrammetric methods, which is significant in this study area because the overall site is covered with a fairly dense canopy of lodgepole pine and heavily vegetated riparian areas. In addition, a significant enhancement capability of LIDAR systems is the ability to generate surface models of the vegetation canopy from the same data sets that produce the bare-earth surface models. This additional surface model will provide information on the type and density of vegetation in the site for remediation and in support of other resource management issues such as wildfire management.

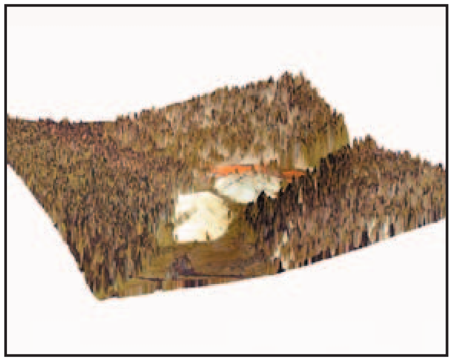

Figure 2. Oblique view of the Dinero Dump showing an orthoimage draped over a surface model composed of bare-earth and canopy points.

To understand the capabilities and accuracies associated with the LIDAR data, bare-earth surface models were created from the airborne imagery through photogrammetric methods and evaluated against the LIDAR bare-earth surface models. Costs associated with generating similar products have been evaluated and compared and are available on request.

Although the overall cost of acquiring the LIDAR products is presently higher than the cost of products obtained from conventional photogrammetry, the future cost of photogrammetric work will exceed that of LIDAR. Total photogrammetric costs are presently 94% of the total LIDAR costs. Costs of the LIDAR products were $6.40 per acre. Photogrammetric costs are $6.00 per acre. It should be noted that these costs are for this study only and should not be used to project costs of other studies. The photogrammetric products cover only the Dinero Dump (Figure 2; two stereo models), whereas the LIDAR products cover the entire project area. In addition to the costs for photogrammetric products, costs associated with reclaiming the dumps, producing volume calculations and cut–fill estimates, and additional survey costs for each dump must be considered.

Conclusions

The results of this project met the following objectives:

- All the LIDAR data sets provided complete coverage in the project area. Only minor artifacts were noticeable in the digital orthoimage.
- All the products met the spatial requirements for the project. Horizontal accuracies according to the National Standard for Spatial Data Accuracy (NSSDA) 95% confidence level were equal to 1.11 meters at ground scale. Vertical accuracies at the NSSDA 95% confidence level were equal to 0.325 meters at ground scale.
- All the data were delivered according to the specifications of the statement of work and delivered to the field office staff in the specified time.
- Costs associated with acquiring the LIDAR data sets were competitive with costs of products from conventional photogrammetric methods.

Partnership institutions presently involved with research projects in the Lake Fork, Colorado, drainage are the University of Colorado, Colorado State University, Mesa State University (Colorado), Colorado Mountain College, Colorado School of Mines, U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, Colorado Division of Wildlife, and Lake County, Colorado.

Contact

Russell Jackson, Photogrammetrist
National Science and
Technology Center
Denver Federal Center,
Building 50
Denver, CO 80225-0047
Phone: 303-236-1614
Fax: 303-236-6564
Email: Russell_Jackson@blm.gov