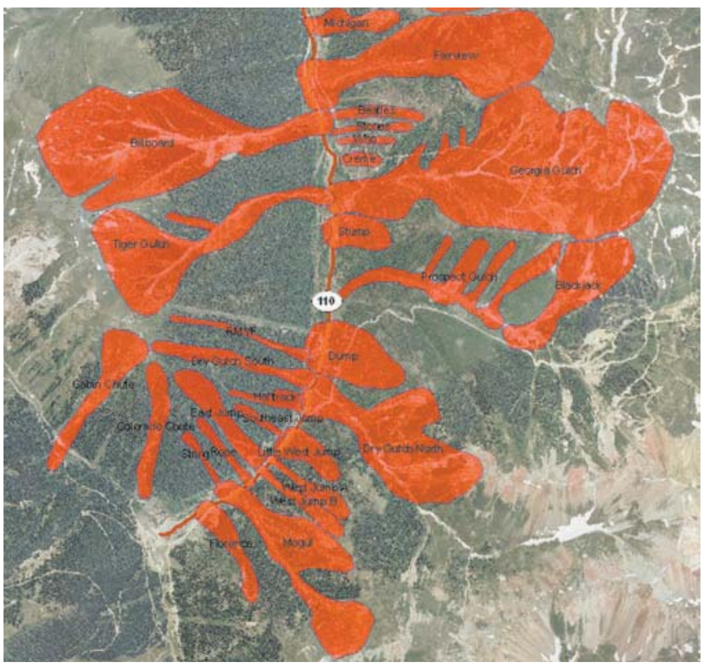
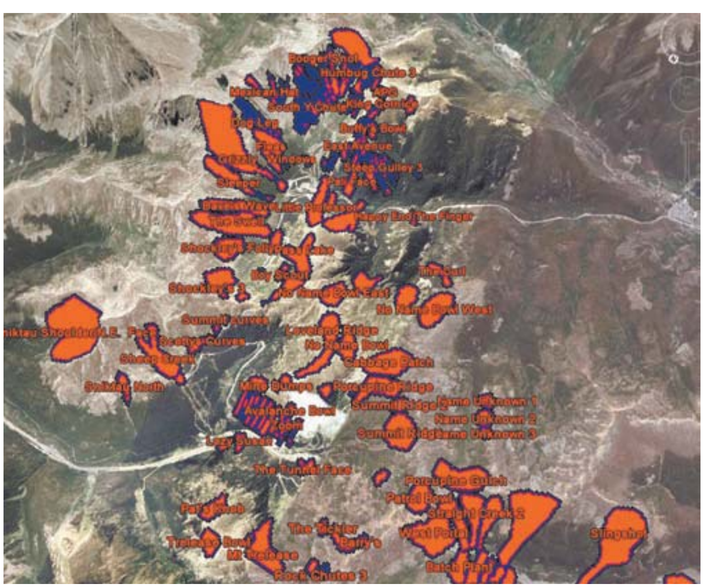
Avalanche-path mapping of the San Juan Mountains along US Highway 550 assist Colorado Department of Transportation (CDOT) road-maintenance workers. Highlighted red areas indicate the slide paths, making it easy to track and identify avalanche activity. Use of the GIS system is also a powerful budgetary tool, allowing CDOT to track avalanche control work by path and facilitating cost analysis on amount of explosives used, man hours and equipment wear and tear. For more about the history of avalanche control efforts along this particular stretch of road, see *Red Mountain Pass – Chief Ouray Highway: A History of Forecasting and Mitigation*, beginning on page 24.



Avalanche paths around Colorado's Silverton Mountain ski area and surrounding peaks.



Loveland Ski Area, Loveland Pass and Arapahoe Basin, Colorado, mapping in Google Earth. This map was created by the author as his capstone project during GIS studies at college. At the time, he also served on the volunteer ski patrol at Arapahoe Basin.

AVALANCHE MAPPING: GIS for Avalanche Studies and Snow Science

Story by Douglas Scott

Swiss, Canadian, and other snow scientists had been using GIS for many years to monitor and document avalanche occurrences, snow profiles, and weather. The United States, however, has had limited GIS use for this discipline. In the past almost all avalanche and snow-profile data observations have been recorded as hard copies with no digital spatial component. Recent technology advances now make it possible to bring observations and data into a GIS for referencing, modeling, and sharing. Historical hand-drawn avalanche path data is converted to digital GIS data, then loaded into a database that can be related to the original hard-copy occurrence, snow profile, and weather data. These data layers can be displayed over other GIS base layers such as DEM, DRG, DOQ, NAIP, soils/geology, and vegetation cover. Then integration of real-time weather and snow-profile data can be added for analysis. Digital data-collection tools can load new data directly into the GIS database. Historical avalanche-path data consists of archived records, photographs, hard-copy mapping of starting zones, and the extent area of danger. High-resolution DEMs allow various terrain analyses: mean slope, minimum slope, maximum slope, mean aspect, and curvature. When the avalanche path data is overlaid on the DEM, it can be analyzed using nearest-neighbor modeling techniques.

Avalanche Mapping has been developing a US-wide GIS database (also know as geodatabase) since 2000. When I went back to school in 1999 to enter the GIS industry, I found there had been almost no US GIS work done with avalanches, although much had been done in Europe. There had been some use of the GIS technology at the La Sal Forest Service Avalanche Center in Utah, but some of the efforts they were proposing went too far into forecasting on DEM terrain models, so was abandoned for being too rough and inaccurate. In addition, the software at the time was expensive, cumbersome, and required special training.

With that history in mind, my capstone project became the creation of a digital avalanche atlas for Arapahoe Basin ski area, where I was part of the volunteer ski patrol. After that project was finished and after graduation, I acquired the URLs for Avalanche Mapping and created a Web site with the goal of building avalanche atlas maps and collecting snow and avalanche observations using digital GIS and GPS technology.

While working on the 2002 Olympics in Salt Lake City, I came upon the GIS data sets for the Cottonwood Canyons and Provo Canyon, which I believe was developed by Utah's AGRC and UDOT. A grant from Backcountry Access and a copy of the Arapahoe Basin Atlas resulted in the construction of a map for Little Cottonwood Canyon. Around that time I had given one of the atlas maps to long-time friend Gary Neptune, owner of Neptune Mountaineering, who told me, "If you start producing these, I will sell them for you." So that became the start of the client base.

I began tracking down different sources of historical data in earnest. For Colorado, there was an existing highway avalanche atlas built by the Colorado Avalanche Information Center (CAIC) in pdf format. This was one of the main sources for the Colorado data. In other areas, I tracked down old hard-copy atlases and land-use planning reports. I also contacted long-time locals for their help in delineating the paths they knew by hand, drawing on top of hard-copy topographic maps which were then digitized.

Data is acquired from a number of places: it is purchased from Digital Data Services or the Geocommunity GIS data warehouse, or it is downloaded from the NRCS data gateway, university data warehouses, and the USGS. The most common base dataset setup for the mapping projects is a 10m DEM hillshade to show the surface terrain, digital topographic maps that we stitch together using GIS software to make them continuous. Grayscale aerial photography shot between 1999-2000 and some color satellite imagery shot between 2005-06 is also available from government Web sites.

Topo maps allow us to correlate to the old avalanche atlases since almost all of them were done with topo backgrounds. The other data provides more detail so we can see ridge break lines from the terrain model. The aerial imagery allows us to see the avalanche tracks more clearly than on topo maps, and the different years show changes over time. We sometimes use the DEM data to derive slope and aspect data to populate the attributes of a path.

It should be noted that the 10m DEM is a resampled 30m DEM. According to remote sensing experts, DEMs can have anywhere from 70-100' of error. These errors create inaccuracies in modeling and forecasting avalanches. There have been some projects done around the country using very expensive high-resolution Lidar data, and this is better but by no means perfect.

Using the above techniques, Avalanche Mapping has developed a GIS database of over 2500 historically observed avalanche paths in Alaska, Arizona, Colorado, Utah, Washington, and Wyoming. We are currently collecting information for California and Montana.

So how has this data been used?

One of the primary ideas of the digital avalanche atlases was to produce mapping of the historically observed paths around popular backcountry ski and riding areas. A map may help give people a heads-up when out-of-bounds travel has potentially high consequences.

In addition, clear mapping leads to consistency in path and area names. The majority of the users of these maps have been winter backcountry users; other groups include search-and-rescue and law-enforcement departments. Some avalanche-instruction schools have been utilizing the maps as training tools, helping students visualize the terrain they are about to enter as an aid to determine proper avalanche-safety protocol.

The Colorado Department of Transportation (CDOT) maintenance group that works in the San Juan Mountains utilizes the data to help plow drivers identify the names of the avalanche paths they are plowing and report what ran. In addition, use of the GIS system allows CDOT to track the avalanche control work by path, allowing for cost analysis on the amount of explosives used, control work results, number of man-hours, and equipment wear and tear. This may be one of the best applications of GIS technology for the avalanche-control community.

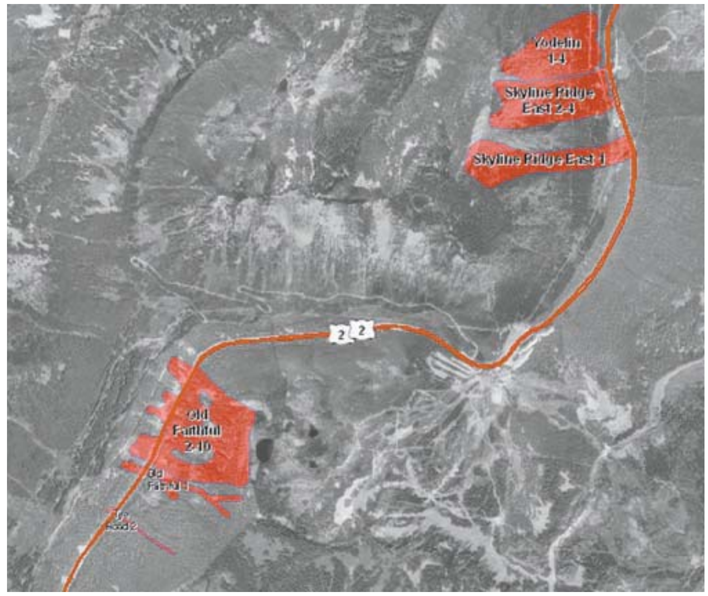
The CAIC will be using the statewide avalanche path database to track occurrence information and tie the historic occurrence/accident records to the avalanche-path polygon. The CAIC is also interested in tracking information for mitigation and explosives use.

Some helicopter skiing companies also want a full GIS to manage their lease areas – tracking runs, avalanche, wildlife, other backcountry users – plus more information too diverse to list. These companies have found this a very useful method to manage information, especially for permitting processes with the Forest Service and other agencies.

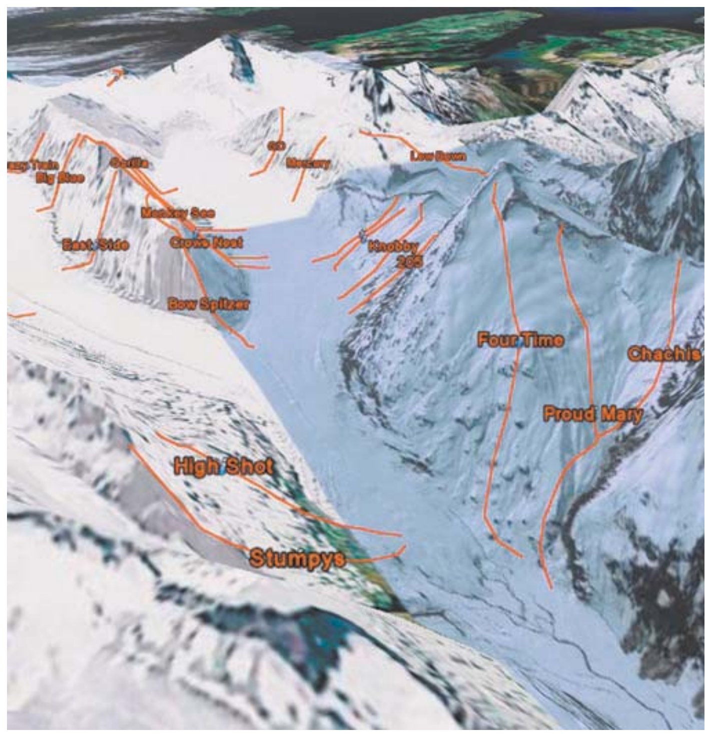
There are possibilities for forecasting, but without the high accuracy (-2ft) DEM data and high-frequency weather data that is very close to the site of interest, there is still a lot of variability as to its accuracy. We have had many promising discussions on the use of GIS as a tool for regions that have well-documented historic data, such as ski areas and small mountain communities. But as a large forecast tool for the avalanche centers, the US areas are just too vast. In Colorado the San Juan Mountains are about the same size as Switzerland, and that is just one of our 10 mountain ranges that have avalanches. The Swiss model would be extremely expensive to implement here in the US, so please let me know if anyone would like to contribute the appropriate technology.

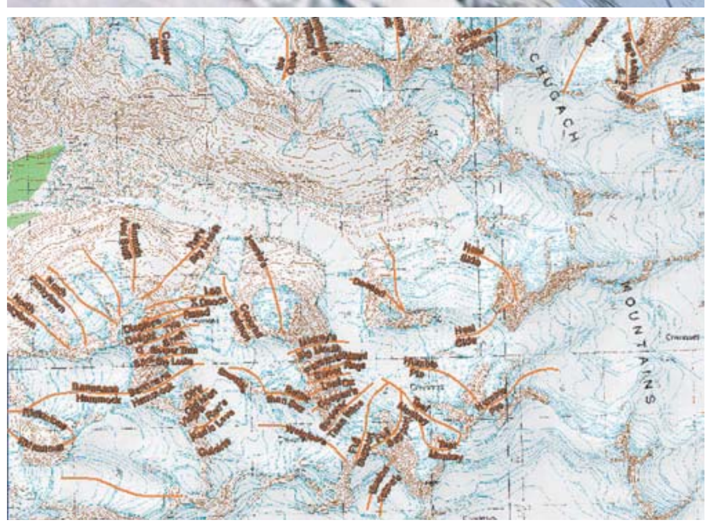
Douglas Scott is the owner/director of Avalanche Mapping which can be found at www.avalanchemapping.org. He is also the geospatial data manager for the US Geological Survey in Lakewood, Colorado, and resides with his family in Lafayette, Colorado. ❄

Doug enjoys a ski day with daughters Gabi and Cheyenne at Loveland Ski Area.



above and left: Avalanche mapping around Stevens Pass ski area in Washington. Scott highlights slide paths in red overlays over topographical maps as well as grayscale photography available from government Web sites.





Both maps above are examples of helicopter skiing runs mapped for Points North Heliski in Cordova, Alaska. The maps were developed on GIS topographic backgrounds and then brought into Google Earth.