# Rapid Acquisition of Ground Penetrating Radar Enabled by LIDAR

By David Percy and Curt Peterson

Portland State University
Department of Geology
1721 SW Broadway
Portland, OR 97201
Telephone: (503) 725-3373
Fax: (503) 725-3325
email: percyd@pdx.edu

## ABSTRACT

One of the most time-consuming aspects of collecting a Ground Penetrating Radar (GPR) survey is the acquisition of topographic data. To be useful, GPR data must be corrected for elevation, given that GPR "sees" only the data directly below it. We have developed a new method whereby LIDAR data can be used in conjunction with a Global Positioning System (GPS) for rapid acquisition of the elevation control that corrects GPR data for elevation changes. By collecting real-time GPS data and GPR at the same time, we can post-process these location data against a high resolution LIDAR data set and develop an elevation profile, which can then be used to offset the GPR data. This allows us to see features in the subsurface, such as groundwater surface trends or thickness of surficial deposits.

## BACKGROUND

Ground Penetrating Radar (GPR) is a technique for surveying data in the shallow subsurface of earth materials (up to 40 meters deep, depending on frequency used, and characteristics of material) (Jol and Bristow, 2003). By generating an electromagnetic field and then recording reflections from subsurface materials with different transmissive properties, we are able to calculate the depth to subsurface objects of interest, such as the groundwater surface or the depth of surficial sediments (Peterson and others, in press). Each position along a line is occupied with a transmitter and a receiver at a fixed ground distance apart, depending on the frequency used. For example, a 100Mhz GPR survey will use an antenna spacing of 1m, while a 200 Mhz survey will use antenna separation of 0.5 m.

Every GPR survey that covers an area with varying topography requires a separate elevation survey that will correct for changes in elevation. As seen in Figure 1, this elevation correction can significantly improve the interpretation of GPR data. Here, we see how subsurface groundwater surfaces become horizontal, as expected, once the GPR data are corrected.

When collecting GPR data in the past, we surveyed in the topographic correction data using various methods that take nearly as long to collect as the actual GPR data. In 2004, our department purchased a cart that attached to a vehicle and allowed for transportation of the GPR, and data acquisition at speeds of up to 5 miles per hour. At this point, we needed a more rapid way to collect topographic data. Realizing that high resolution LIDAR data existed for our study area on the coast of Oregon, we decided to develop a methodology for topographic correction based on this.

LIDAR data are acquired via airborne surveys in which laser pulses are sent to the ground and the return times are collected, thus allowing for the collection of a very dense, high resolution elevation surface (Daniels, 2001). In some surveys, multiple return pulses are collected (fourth return) and can thus remove returns from higher elevation objects, such as trees, which results in a "bare earth" elevation surface. Since our collection typically occurs on roads, we can use "first return" data.

## METHODS

A Global Positioning System (GPS) receiver is set in the dashboard of the collection vehicle. This allows for a reasonably good view of the satellites and, given that the GPS can receive through glass, the simultaneous collection of positional and GPR data. A cart is attached to the rear of the vehicle on which the GPR antennas are situated. Fiber optic cables connect the antennas to the interior of the vehicle, where the triggering and acquisition equipment are operated. An odometer wheel located behind the antennas triggers the computer, again via fiber optics, to transmit to the antennas controlling commands that regulate when to send and receive data.

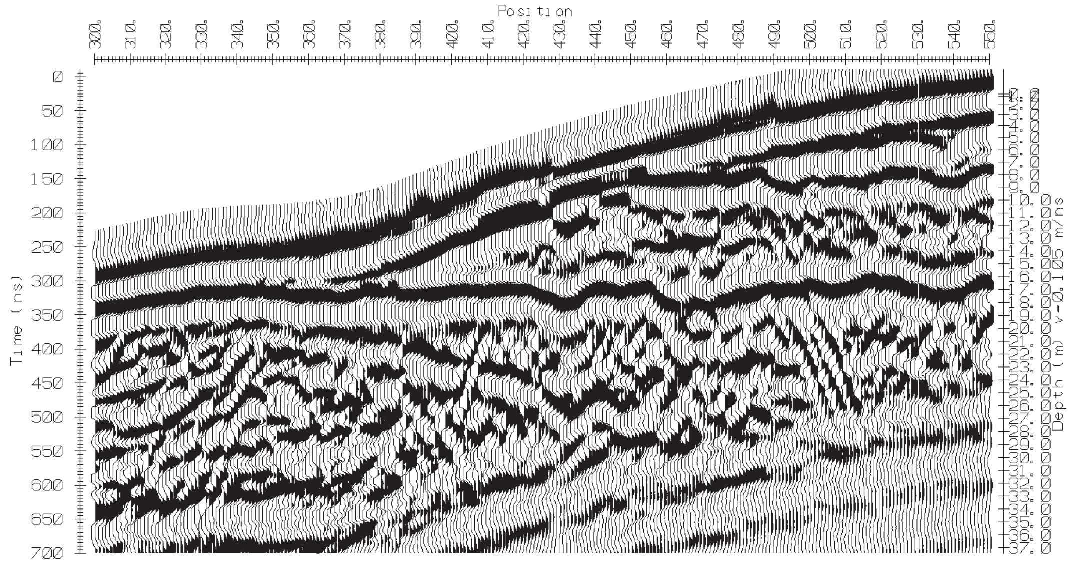


**Figure 1.** Topographically corrected Ground Penetrating Radar profile. Horizontal line at 350 ns time is groundwater surface.

After the data acquisition, post-processing begins. The GPS data are differentially corrected for standard errors in GPS, such as atmospheric, ephemeris (satellite positional error), and other errors that can be corrected by differential correction. These data are then converted into GIS coverages and named according to the GPR line. We refer to each set of data as a line. Each line then needs to be corrected by using heads up digitizing in the GIS software. Even though it has been differentially corrected, the GPS traverse will have "wiggles" in it due to errors in collection. These errors will make the GPS line greater in length than the GPR line and result in errors. Each line is smoothed by the GIS operator such that it matches the notes collected from the field and runs clearly down the road on which the GPR was collected. An overlay of aerial photography assists greatly in this process.

Next, a set of "addresses" is generated. Each GPR line is treated as if it were a street in the GIS software. Thus, it has a beginning "address" of 0 and an ending address of the length of the line. For example, a 1.5Km line would have a beginning address of 0 and an ending address of 1500. GIS software has a method for geocoding addresses against linear features based on the beginning and ending addresses of streets. This is often used for delivering pizzas, for example. In our case, we use this technique to determine positions along a line of data acquisition. We generate a set of addresses every 10 meters to retrieve elevation data at this interval from the LIDAR (Figure 2 shows addresses and corresponding points).

These addresses are then geocoded against the GPS lines, which generates a set of points that are 10 meters apart on the GPS line. Next, we convert these points to three-dimensional points, taking the Z-value from the LIDAR. After extracting these Z-values into a new field in the database, these values are reduced to an array of x-offset and z value (Table 1), which can be used to correct the GPR data, as seen previously in Figure 1.

## CONCLUSION

This methodology has enabled us to collect data more rapidly than in the past. There are obviously some fundamental requirements that LIDAR data and aerial photography exist for the study area. With these data in place, however, we can now collect many kilometers of data per day without the expensive field collection of surveying elevation points. This has allowed us to collect and process voluminous data on groundwater surfaces in the coastal plains of Oregon. As more LIDAR data become available, we anticipate using this method to acquire better surficial deposit data for many areas.

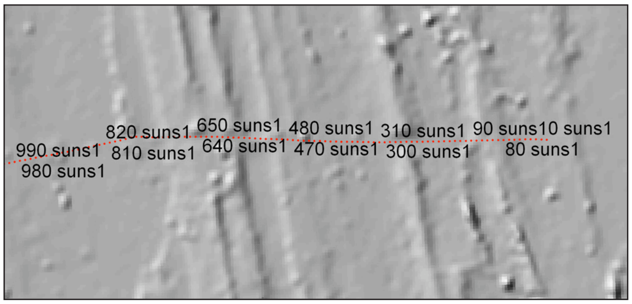


**Figure 2.** GPR "addresses" overlaid on a hillshade of LIDAR. Addresses are meters of offset from beginning of lines, concatenated with the name of the GPR line. North-trending linear features are shore parallel dune ridges.

**Table 1.** Sample elevation offsets calculated from LIDAR and geocoded GPR "addresses".

| X location (m) | Z elevation (m) |
|---|---|
| 0 | 6.8 |
| 10 | 7 |
| 20 | 7.1 |
| 30 | 6.3 |
| 40 | 5.6 |
| 50 | 5.1 |
| 60 | 5.3 |
| 70 | 5.4 |
| 80 | 5.2 |
| 90 | 4.9 |
| 100 | 4.8 |
| 110 | 4.8 |
| 120 | 4.7 |
| 130 | 4.8 |

## REFERENCES

Daniels, R.C., 2001, Datum conversion issues with LIDAR spot elevation data: Photogrammetric Engineering and Remote Sensing, v.67, p.735-740.

Jol, H.M., and Bristow, C.S., 2003, GPR in sediments: advice on data collection, basic processing and interpretation, a good practice guide, *in* Bristow, C.S., and Jol, H.M., eds., GPR in Sediments: Geological Society of London, Special Publication 211, p.9-27.

Peterson, C.D., Jol, H.M., Percy, David, and Nielsen, E.L., in press, Groundwater surface trends from ground penetrating radar (GPR) profiles taken across late-Holocene barriers and beach plains of the Columbia River littoral system, Pacific Northwest coast, USA: Geological Society of America Special Publication.