By Landon Blake, LS

Landon Blake is currently project manager and project surveyor for a small civil engineering and land surveying company in California's Central Valley. Licensed in California and Nevada, his many activities include speaking and teaching at group conferences around the state.

Best Practices for Very Large Boundary Surveys

Dealing With Distortions in Distance

When it comes to very large boundary surveys, distances can become distorted over large areas. Because effective boundary surveying requires accurate measurements, anyone doing very large boundary surveys should therefore consider using a bit of geodesy.

Let's say you've been tasked with a boundary survey for property in PLSS Sections 2, 3, and 4 along an area known as Three Meadows Creek. After completing your research and project set-up you perform a set of initial field surveys to search for evidence of PLSS monuments along the south line of the sections.

The south line in question runs parallel to Three Meadows Creek. The creek drains an east-west valley high in the mountains. Near the boundary common to Section 3 and 4 the valley makes a steep decline out of the mountains onto the flatlands. **Figure 1** shows the results of your field survey. Regular flooding of Three Meadows Creek has destroyed all evidence of the original PLSS corners along most of the south line of Sections 2 and 3.

The topography of your survey area results in a major elevation change along your surveyed line. The segment between PC 106 and PC 110 is at approximately elevation 6,500.00. The segment between PC 110 and PC 112 is at approximately elevation 4,500.

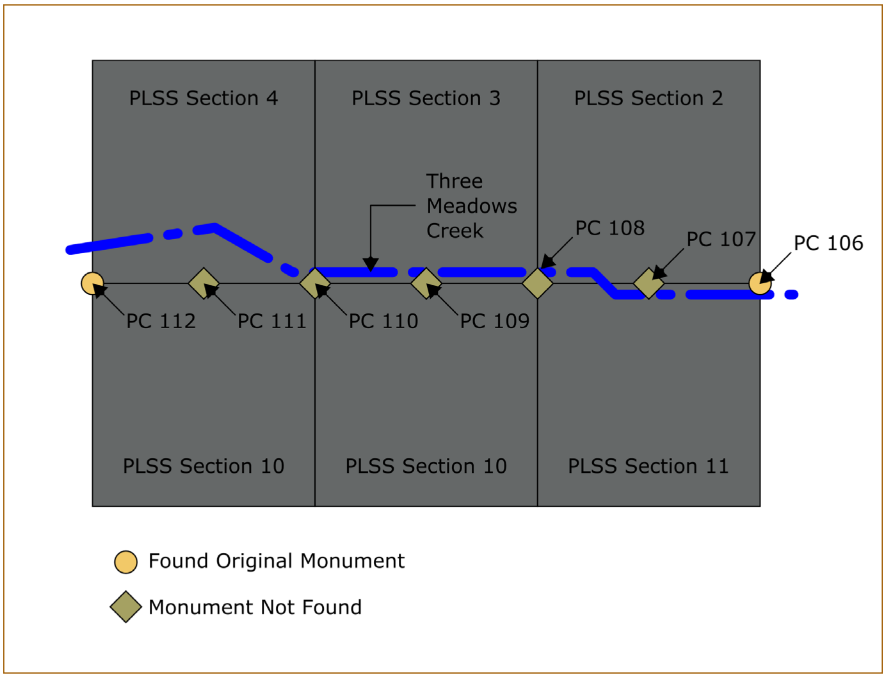

Figure 1

After your field survey is complete, you decide to calculate the position of PC 110 based on proportioning. You want to determine how close the proportioned position is to an old fence corner found in your search area for PC 110.

If you performed a total station survey, can you just calculate your proportion using your measured ground distances? What if you used RTK GPS for your survey and you're already on the State Plane Coordinate System? Can you just use your grid distances to do the proportioning calculations?

You could, but you'll be introducing some error because of the significant surveyed elevation change on this project. How much error? Is this error significant?

A bit of simple math will help to answer those questions.

Down to the Ellipsoid

Because map projections will only complicate our calculations, we will instead

Distance ID	Ground Distance	Radius of NAD83	Average Elevation	Radius + Elevation	Scale Factor	Ellipsoid Distance
PC 106 to PC 110	10560.00	20885603.00	4500.00	20890103.00	0.999784587	10557.73
PC 106 to PC 110	10560.00	20885603.00	6500.00	20892103.00	0.999688878	10556.71
					Error	1.01

Scale facor table

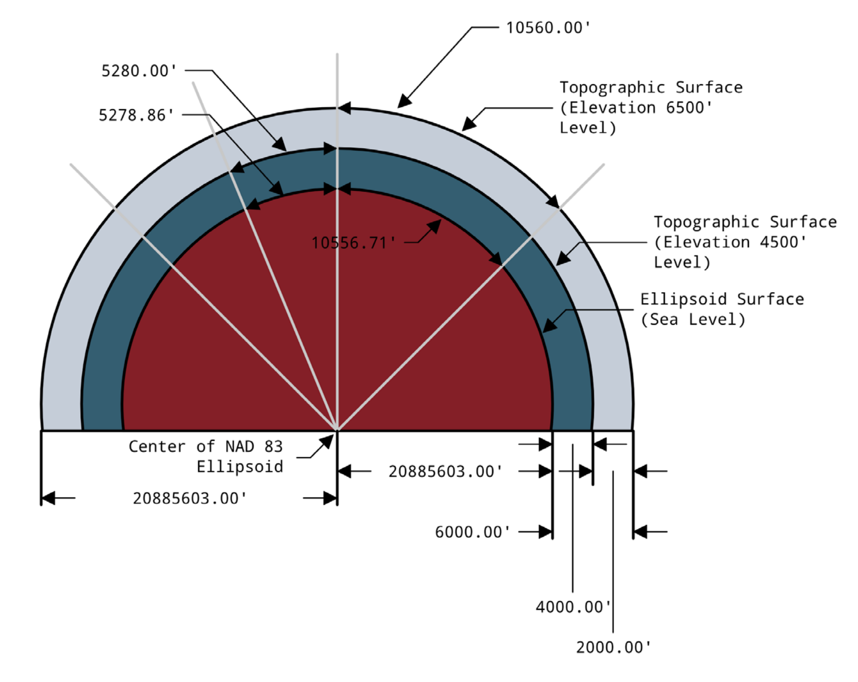

Figure 2

reduce our distances to an (approximately) sea level ellipsoid. Now let's compare the right and wrong ways of going about it.

The Wrong Way Down

We can calculate a scale factor to convert our measured ground distances to distances on the sea level ellipsoid. For illustration purposes, we will use an approximation of the NAD83 ellipsoid and pretend the earth is a sphere and not an ellipse, only because it makes the math easier. (Before the geodesy purists cry foul, it should be noted that this simplification won't make a huge difference in our calculations.)

The scale factor we compute for the "wrong" way is shown in the first row of the scale factor table. This scale factor is 0.999784587. It is calculated using an elevation of 4,500 feet for the whole survey area. The table shows the result of using this scale factor to convert our distances to the ellipsoid surface. Our scale factor makes the ellipsoid distances slightly smaller than the measured ground distances. Hopefully when you look at **Figure 2**, which is a side view of the earth showing our survey area, you will understand why.

The Correct Way Down

Now take a look at the second row of the scale factor table. This time we've used the correct average elevation of 6,500 feet to scale our distance. The error when applying a single scale factor (using an elevation of 4,500 feet) to both distances is 1.01 feet.

For many purposes that isn't very big, and can be ignored, since it probably isn't going to change how we evaluate that fence corner. However, in other scenarios, with modern surveying equipment, an error like that is much bigger than the random error in our measurements; in many cases, several times bigger. It is important for boundary surveyors to understand such a source of error in measurements and calculations.

Understanding the source and magnitude of an error and choosing to ignore it is not the same as ignoring an error because you're ignorant of its cause.

If you just turn on your GPS and start surveying, and then run your calculations with the default State Plane coordinates determined by your processing software, more than likely your software applied a single scale factor using one average elevation across the project site.

Best Practices

1. Understand how significant changes of elevation over a survey area may distort distances.
2. Evaluate the distortion and determine if it is significant for your purposes. If necessary, run some calculations to determine at what magnitude of elevation change the error is small enough to be ignored.
3. If the distortion to distances caused by significant changes of elevation is important in your survey, break your project into zones based on average elevation and use unique scale factors for each zone.
4. If you are working on a very large boundary survey, consider the best way to reduce your distances to a common working surface (like a sea level ellipsoid surface).

Come Back Up

Depending on the final results of your survey, you may need to lay out points in the field (for example, to set property corner monuments at calculated positions). If you are going to do this, don't forget to scale your sea-level ellipsoid distances back up to ground before the layout is performed.

Spreadsheets to assist with these types of calculations are available for download at the Footsteps Boundary Surveying Blog, where you'll also find a more detailed explanation on the calculation of scale factors.