# Establishing elevations using GPS:

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The global positioning system (GPS) is a three-dimensional measurement tool being used in many disciplines by novice, technician, and professional alike. At a gross level, it is easy for anyone to determine the 3-D location of a point using an inexpensive hand-held GPS receiver. On the other hand, expensive dual frequency carrier phase receivers and exacting field and office procedures are required to achieve the high accuracies normally associated with control or geodetic surveying.

Many factors need to be considered when attempting to establish elevations using GPS. Since selective availability was disabled on May 2, 2000, it is possible to determine a horizontal position on the ground within about 3-5 meters using a stand-alone code-phase GPS receiver. The tolerance for vertical accuracy is often about 1.5 times that of horizontal. Factors and issues that need to be addressed to improve such accuracy (both horizontal and vertical) will typically include, but are not necessarily limited to:

1. The user must know/decide – accuracy with respect to what. Issues here include:
    A. Which datum is being used on the ground/project and in the GPS receiver?
    B. What control points are being held? CORS, HARN, Benchmarks, other?
2. Geoid height is a consideration. Which is required, elevation or ellipsoid height?
3. Will Geoid03 or other geoid model be used and how?
    A. Is geoid height even necessary or is one value of geoid height sufficient?
    B. How will a geoid model be used to determine an overall “best fit”?
    C. In some applications, additional gravity data may be needed.
4. What GPS equipment is being used; carrier phase, code phase, dual frequency?
5. What GPS data processing technique will be used? Autonomous positions, differential corrections, relative static, kinematic, RTK, OPUS, or other?
6. What network adjustment, if any, will be computed? Will least squares be used? If so, how will the weights be assigned? What end-result criteria are to be met?

Presuming a goal of achieving the “best” elevations reasonably possible using static carrier phase observations and observing a network based upon CORS, HARN, or other proven high-quality control points, the following steps are recommended:

1. Start on 3-D control points with X/Y/Z coordinates and small standard deviations.
2. Collect data (be sure to include HI’s) & build 3-D network with non-trivial vectors.
3. Hold one 3-D point and compute a minimally constrained network.
4. Evaluate and clean up the data. Reject, re-observe, and re-compute as needed.
5. Constrain the network to appropriate control points. Confirm the fact that no observation is unduly distorted by the adjustment. These X/Y/Z’s are held.
6. Compute latitude/longitude/ellipsoid height (derived quantities) for each point.
7. Identify (valid) elevations at known benchmarks. Compare derived geoid heights with values from geoid model. Investigate discrepancies but don’t change the X/Y/Z’s (unless geoid model or gravity data are more precise than the GPS data).
8. Use Geoid03 (or other model) to determine geoid height **differences** between stations. Combine geoid height differences with GPS derived ellipsoid height differences to get orthometric height (elevation) differences between stations.
9. Compute loop misclosures and misclosures between known benchmarks. These misclosures are then used to assess the quality of elevations obtained using GPS. The elevation of known benchmarks may need to be questioned.