Chapter 3 - Construction Staking

Policy Statement

Any survey which involves construction staking shall conform to the specifications as defined in this document.

General Note

These procedures are to be used in conjunction with the ***OC Survey Construction Staking Guide.***

Preparation and Organization

Before construction activities commence, a thorough search of the site shall be performed in order to identify any existing monumentation (other than project specific construction control) which may be destroyed during construction. All provisions of Section 8771 of the Business and Professions Code (Land Surveyors' Act) shall be followed with regard to preservation of this existing monumentation.

Horizontal and vertical control used for construction staking should be based upon the control scheme used in gathering topographic data for design. In the event that this control scheme is not available, considerable effort shall be expended to ensure that new control set is of the same horizontal and vertical datum as the design data. Where identified on the construction plans, hard-surface conforms (joins) to existing infrastructure shall be verified well before staking operations begin.

As construction activities commence and continue, original project control points often are destroyed and new points will need to be set. Some distinction needs to be made to identify the pedigree of the control so that degradation of integrity can be predicted. A point naming convention shall be established which clearly groups control points by their expected accuracy. Following is a list of typical control pedigrees, in order of decreasing integrity:

- First generation (original) control points
- Second generation control points, those set from first generation control
- Third generation control points, those set from second generation control, and so on
- Control points set by two-point resection**: These points should not be used to set additional control, and under no circumstances are points set by resection to be used to perform subsequent resections.
- Temporary points set for one specific, minor purpose, using weaker geometric principles: These points shall not to be used in any subsequent staking or control operations.

  **Note: Establishing control by two-point resection is permitted, provided a third control point is immediately checked to confirm the mathematical solution. The weakness of the two-point resection lies in the fact that error within the control used to establish the resection is greatly magnified and projected onto the resultant solution. The point to be established should be positioned so that the resultant horizontal angle

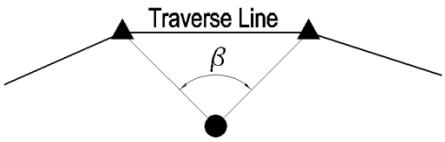
between the fixed control points measures between 45 and 135 degrees (see ***Figure 1***). Keep in mind that as control integrity naturally degrades from generation to generation, the two-point resection becomes a less desirable option.

Figure 1 – Two-Point Resection

▲ **= Existing Control Point**

● **= New Control Point**

β **= Angle between 45° and 135°**



Upon completion of the project, memorialization of project control and the setting of final monumentation and resetting of any destroyed monumentation should be based upon the earliest generation control which remains.

Vertical Control Procedures

Original control shall be elevated using differential leveling procedures and be in conformance with ***Chapter 4 – Differential Leveling.*** Elevations of subsequent control may be derived by trigonometric principles, provided the points are traversed through, double determined, or set by two-point resection, with acceptable mathematical vertical closures observed.

Staking Procedures – Conventional Instruments (total stations)

Whether or not stakeout activities are performed robotically, a tripod/tribrach target should be used for backsight orientation. After the instrument is oriented and the measurement to the backsight is recorded, a third control point is staked out, read, and recorded using the layout rod that will be used for setting of stakes. This provides assurance that the prism offset and rod HI measurement are correct. Check shots should be coded with a unique numbering system which makes them easy to sort and verify. For example, a check shot on point #207 could be named "CHK207".

Before proceeding with setting of stakes, check into stakes set previously, if any exist within a reasonable radius. Where applicable, conforms (joins) to existing infrastructure shall be checked.

In order to prevent degradation of the horizontal and vertical accuracy of stakes, stakeout distances should be limited as follows:

- Limit distances to a maximum of 400 feet when setting stakes for curb, walls, and other features generally requiring horizontal and vertical tolerances of 0.03 feet and 0.02 feet respectively.

- Limit distances to a maximum of 800 feet when setting stakes for rough grade and other features generally requiring horizontal and vertical tolerances of 0.1 feet or greater.

After completion of staking, a check shot to a control point or a previously set stake shall be read and recorded.

Note regarding staking of features with very low rates of flow: Gravity flow pipelines, concrete curb, and the lowest flow line feature of concrete channels, which have a design flow rate of **≤1.0%**, shall be elevated using differential leveling procedures.

Staking Procedures – RTK GPS

Use of RTK GPS when performing construction staking is permissible only under the guidelines defined below:

- **Clearing Limits, Grading Limits, Construction Easements, ESA Fencing:** Provided the project coordinate system and epoch date are the same as that of the base station, stakes of this nature do not require Site Calibration. If a Site Calibration is not performed, known point check shots must be within 0.15 feet horizontally. No elevations will be reported.
- **Slope Stakes, Rough Grade, Top and Toe Stakes, Pressurized Water Lines, Dry Utility Trenches:** Stakes of this nature require a 3D Site Calibration (refer to ***"Appendix A"*** for Site Calibration procedure). Elevations and cuts are recorded to the nearest 0.1 feet. Note that stakes set for fire hydrants which reference top of curb elevations may be staked with RTK but must be elevated with a conventional instrument (a total station or level).
- **Storm Drain Pipelines:** Only the horizontal component of storm drain pipelines may be staked with RTK. Stakes must then be elevated with a conventional instrument. A 2D Site Calibration is required.
- **Sewer Pipelines:** Only the horizontal component of sewer lines may be staked with RTK. Stakes must then be elevated with a conventional instrument. A 2D Site Calibration is required.
- **Concrete Channels:** Stakes for concrete channels shall NOT be set with RTK.
- **Subgrade:** Only the horizontal component of subgrade may be staked with RTK. Stakes must then be elevated with a conventional instrument. A 2D Site Calibration is required.
- **Major Structures, Retaining Walls, Curb and Gutter, Catch Basins:** Stakes for major structures (bridge abutments, piers, or columns), retaining walls, curbs, and catch basins shall NOT be set with RTK.

In all cases, a known point shall be checked before, at multiple times during, and again after staking. Check shots should be coded with a unique numbering system which makes them easy to sort and verify. For example, a check shot on point #207 could be named "CHK207".

Quality Control/Assurance

Before leaving the job site, a stakeout tolerance report shall be generated from the data collector job-file to ensure that all stakes have been set within tolerances defined by the ***OC Survey Construction Staking Guide***.

Archiving of Survey Data

Electronic cut sheets shall be transferred to the Party Chief's workstation along with associated stakeout tolerance reports. Sketches or hand-recorded notes shall be scanned and filed electronically. Data collector Job files shall also be transferred to the Party Chief's workstation and either a master point plot or multiple sub point plots maintained for the duration of the project.

Appendix A - Site Calibration Procedure

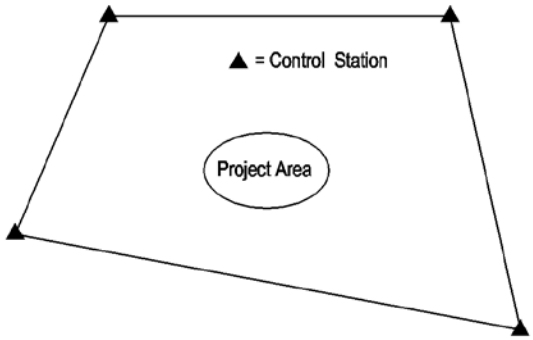
A Site Calibration establishes a relationship between the observed WGS84 coordinates and the local grid coordinates.

The procedures detailed below are specific to construction staking projects. See ***Chapter 2 – RTK GPS*** for more general uses and procedures for Site Calibrations.

General Requirements:

- The control stations shall be selected so as to create a polygon which fully encompasses the project area (see ***Figure 2***). Selected control stations shall be located no more than six miles from the RTN station or base station.
- Conditions which may generate multipath or obstruct view of the satellites, such as overhead power lines, nearby trees, or adjacent buildings, should be avoided.
- Elevation mask shall be set to 15 degrees.
- Each occupation shall consist of either one measurement of 180 epochs, or three sequential measurements of 60 epochs each.
- Upon computation of the Site Calibration, a control station with residual values greater than those defined below shall be discarded and another control station shall be used in place of this outlier.
- All subsequent measurements and staking activities shall use the same RTN base station or base position as was used to generate the Site Calibration.

Figure 2 – Control Station Selection



2D Site Calibration:

- A minimum of 4 horizontal control stations shall be included in a 2D Site Calibration.

- Each horizontal control station shall be measured with 2 independent occupations, with a minimum time differential (time of day) of 2 hours. These time differentials are required in order to ensure significantly different satellite geometry.
- The stations in a 2D Site Calibration shall not exceed a horizontal residual of 0.07 feet

3D Site Calibration:
In addition to the requirements described above for a 2D Site Calibration, the following requirements shall be met for a 3D Site Calibration:

- A minimum of 5 vertical (or 3D) control stations shall be included in a 3D Site Calibration. To avoid creation of a distorted or tipped plane, the stations selected must have been tied together with one common leveling circuit. An alternative to this requirement is to collect data on these 5 vertical control stations but include just one of them in the Site Calibration. Analysis of the data will determine which vertical control station represents a best-fit solution for the project. This may be a better alternative when working with vertical control that has not been recently tied together (OC Survey Benchmarks).
- Each vertical control station shall be measured with 2 independent occupations, with a minimum time differential (time of day) of 4 hours.
- The stations in a 3D Site Calibration shall not exceed a vertical residual of 0.10 feet.