Chapter 6 - Topographic Surveys

Policy Statement

Any survey performed for the purpose of collecting topographic data shall conform to the specifications as defined in this document.

Preparation

Before planning the survey, a meeting between the Party Chief and the Requestor shall be conducted on the job site. During this meeting, the Requestor will explain specific project requirements. It is the responsibility of the Party Chief to listen attentively and take notes, and to bring up any questions or concerns. Any changes to the scope of the project agreed upon during this meeting must be documented by the Requestor in the form of an amended ***"Request for Survey."***

Accuracy Requirements

Topographic data points should be located within the following tolerances, relative to project control ("local accuracy"):

- Data points representing hardscape features (concrete, asphalt, underground vaults) should be located within +/- 0.03 feet horizontally and +/- 0.02 feet vertically
- Data points representing utility appurtenances (pull boxes, manholes, fire hydrants) should be located within +/- 0.15 feet horizontally and +/- 0.02 feet vertically; note that utility appurtenances may be collected with RTK GPS, provided they are *omitted* from the DTM (see section below entitled ***"RTK GPS"*** for more details)
- Data points representing original ground features (dirt breaklines, spot elevations) should be located within +/- 0.15 feet horizontally and +/- 0.1 feet vertically
- Data points representing landscaping features (trees, shrubs) should be located within +/- 0.5 feet horizontally and +/- 0.1 feet vertically

Field Methodology

This document establishes acceptable methodology for topographic surveys incorporating conventional instruments (total stations) and RTK GPS. See ***Chapter 7 - LiDAR Surveys*** and ***Chapter 10 – Small Unmanned Aerial Vehicle (sUAV) Surveys*** for alternate methods of data collection.

See sections below related to **establishing the control network** for details on the horizontal and vertical control network upon which the topographic survey is based.

General Methodology:

The following general notes relate to data collected from any source:

- Instrument set-up information, point ranges used, edits needed, etc. shall be logged on a ***"Data Collection Set-Up Sheet"*****.**
- Data points shall include proper topo codes and attribute data from OC Survey's ***"Topo Code List"*****.**

- Spacing of data points shall be such as is necessary to capture an accurate representation of the horizontal and vertical geometry of all linear features and establish an accurate Digital Terrain Model (DTM) inclusive of all features and surfaces. Determination of point spacing is made by the Party Chief on a project by project basis.
- Care must be taken to ensure that individual data points do not misrepresent or corrupt the DTM - for example a tree may lift the ground elevation in the area of the trunk. Shots of this nature should be omitted from the DTM.
- When capturing data points within any soft surface, e.g. sand or mud, the layout rod shall be equipped with a "shoe" or other blunt object designed to keep the rod from sinking beneath the surface.

Conventional Instruments:
The following notes are specific to data collected with a conventional instrument:

- 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 collection of data points. 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*".
- In order to prevent degradation of the horizontal and vertical accuracy of data points, measurement distances should be limited to a maximum of **400 feet** when collecting hardscape features and **800 feet** when collecting original ground or landscaping features.
- When collecting hardscape features, the prism rod HI should be limited to **10 feet**.
- Some features, such as traffic signal poles and trees, cannot be precisely occupied by the prism rod. It is at the discretion of the Party Chief as to when these features will be collected using an "offset routine", which computes an approximate position of the center of the feature. Typically, signal poles and other features having a direct impact on curb-ramps and sidewalk widths are collected in this manner. Trees and similar features can often be collected by simply placing the prism rod next to the feature.

RTK GPS:
The following notes are specific to data collected with RTK GPS (RTK):

- Refer to ***Chapter 2 - RTK GPS*** for detailed policy on the use of RTK.
- A known point shall be checked at the beginning and end of each session. Prudent practice would indicate additional checks, particularly after initialization is lost. 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".
- Only data points representing original ground features (dirt breaklines, spot elevations), utility appurtenances, and landscape features (trees, shrubs) may be collected with RTK (note that utility appurtenances collected with RTK shall be *omitted* from the DTM). Hardscape features shall be collected with a conventional instrument.

Monumentation

Monuments set as control points during the course of a topographic survey shall meet the following criteria:

- Monuments which fall on concrete curbs or in the surface of concrete paving shall consist of a tag secured in a lead plug or set in epoxy.
- Monuments which fall on asphalt dikes or in the surface of asphalt paving shall consist of a spike or "MAG" nail with a washer.
- Monuments which fall in non-paved areas shall consist of an iron pipe with a tag or disk, or a rebar with an aluminum cap. Rebar must be set a minimum of 3 inches below the ground surface.
- All tags/washers/disks/caps referenced above shall be stamped with the agency name or the license number of the surveyor in responsible charge, and shall also be stamped "CP" or "CONTROL POINT".
- Tags set in iron pipes shall be of a diameter less than that of the inside diameter of the pipe. Disks affixed to iron pipes shall be of a diameter equal to that of the outside diameter of the pipe.
- Under no circumstances are plastic plugs to be used with iron pipe or rebar.

Office Workflow

The following office workflow is to take place as the fieldwork progresses:

- Field data should be downloaded at the end of each day. Data shall be reviewed and edited by or under the supervision of the Party Chief. Care must be taken to resolve crossing breaklines, errors in the surface, or miscoded points.
- This edited data shall be delivered to the Mapping Unit (placed on the Field Survey Server) in blocks of no larger than three days of fieldwork.
- Note that the files themselves are not delivered by email. Files shall be copied to the Field Survey Server and organized as described in ***Chapter 13 – Preparation of the Field Note Package***. A link to the file location is emailed to the Mapping Unit.
- Data is delivered in Starnet **DAT** format (see Adjustment of the Network below for more details on generating the **DAT file**). The Starnet project file (**.SNPROJ**) containing all project settings is also delivered, and as new field data is collected, the Mapping Unit and the Party Chief will each maintain a running amended adjustment as an additional layer of QA/QC.
- Along with the Starnet data, the Party Chief shall deliver data collector job files (.JOB), copies of the Data Collection Set-Up Sheets, and Attribute Reports. The attribute reports are exported from the data collector by applying the "***Attribute"*** style sheet.
- The Mapping Unit will process the data, run surface modeling, and add the data to the master project.
- After completion of the fieldwork and topo processing, the Mapping Unit will provide the field crew with a plot of the entire project. The Party Chief shall walk the jobsite with the plot in hand, searching for errors or omissions, making corrections as needed.
- After final edits have been made, a plot is provided for the Senior Land Surveyor to review.

Establishing the Horizontal Control Network

Horizontal control for topographic surveys shall conform to a minimum combined (relative) positional accuracy of **1:10,000** (at a 95% confidence level, or 2 sigma), or a combined distance error of **≤ 0.033 feet** for connection distances shorter than **330 feet**. Relative positional accuracy is a measure of the accuracy of point positions in relation to each other, and is not to be confused with the measure of traverse closure expressed as a ratio.

This **1:10,000** standard shall be met whether the survey is conducted by GPS (static or RTK), conventional traverse (total station), or any combination thereof.

The following are guidelines for GPS and conventional traverse methodology:

Static GPS:

Control for a topographic survey project may be established by static (or fast-static) GPS procedures. While a network adjustment may be performed using only GPS vectors (stand-alone), combining conventional traverse data with GPS vectors will sometimes result in a network with higher relative positional accuracy.

Design of the network and occupation scheme will be determined by the Party Chief in conformance with ***Chapter 1 – Static GPS*** When selecting points to be included in the static network, consideration must be given as to strength of figure and adequate spacing. The minimum allowable spacing for points in stand-alone networks shall be dictated by the following criteria:

- Trimble R10 receivers, rated for static surveys at 3mm + 0.5 ppm at 68% confidence level (1 sigma): a minimum spacing of **500 feet** when tied to CGPS stations at an average distance of 32,000 feet, and a minimum spacing of **300 feet** when tied to primary project control or legacy control at an average distance of 4,000 feet
- Minimum spacing for GPS receivers with static survey ratings different from those listed above can be computed using the formula shown in "***Appendix A, Section 1***"

RTK GPS:

RTK is generally not to be used as a stand-alone measurement tool when performing a control survey. RTK is best used to bolster the control network, not define it. In order to ensure realization of the **1:10,000** criteria, the network shall be adjusted using RTK measurements together with conventional traverse data.

RTK occupation points are selected in such a way as to maximize strength of figure, while leaving the bulk of the data to be captured by conventional traverse. The occupation scheme will be determined by the Party Chief in conformance with ***Chapter 2 – RTK GPS.***

The minimum recommended spacing for points in RTK surveys shall be dictated by the following criteria:

- Trimble R10 receivers, rated for RTK surveys at 8mm + 1 ppm at 68% confidence level (1 sigma): a minimum spacing of **1200 feet** when tied to OCRTN stations at an average

distance of 32,000 feet; a minimum spacing of **700 feet** when tied to local project control in a base-rover configuration at an average distance of 4,000 feet

- Minimum spacing for GPS receivers with static survey ratings different from those listed above can be computed using the formula shown in *"Appendix A, Section 1"*

Conventional Traverse (Total Station):
Conventional traversing may be used either as a stand-alone method or in combination with GPS vectors when establishing control networks for topographic surveys.

Field measurements shall meet the following specifications:

- Horizontal Angles: Minimum of two direct (face 1) and two reverse (face 2) with a maximum residual of 5 seconds; exception granted for sights closer than 300 feet.
- Distances: Measured to backsight and foresight; minimum of two direct and two reverse with a maximum residual of 0.007 feet.

Establishing Vertical Control

For topographic surveys representing hardscape features (concrete, asphalt), elevations of points within the primary control network shall be established using differential leveling procedures. Leveling shall be referenced to a minimum of two vertical control points (benchmarks) and be in conformance with ***Chapter 4 – Differential Leveling.***

Elevations of subsequent supplemental 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.

Adjustment of the Network

Control Network:
All GPS and conventional data shall be adjusted by least squares adjustment software in conformance with ***Chapter 12 – Network Processing.***

Statistical analysis of the adjustment shall be performed to ensure that a minimum combined (relative) positional accuracy of **1:10,000** has been achieved for all connected monument pairs. Although this computation is automatically performed in most network adjustment software, the formula for this computation is shown in *"Appendix A, Section 2."*

Connections of very short distances often will not meet this **1:10,000** standard. An alternative standard for distances of less than **330 feet** is shown in *"Appendix A, Section 3."*

In the event one or more pairs of monuments fail to pass these relative positional accuracy criteria, the network adjustment shall be reviewed and a determination made by the Senior Land Surveyor (or Project Manager) as to whether or not additional observations will made in order to improve geometry, increase redundancy, or further isolate errors.

Topo Sideshots:
After the control network has been satisfactorily adjusted, topographic data points are added. Unique **DAT files** for each block of data (data representing 1 to 3 days of fieldwork) are created

from the data collector files. Be sure to export data points in **sideshot** format. All necessary edits are made within the **DAT files**.

All topo sideshot **DAT files -** original and edited **-** are delivered to the Mapping Unit, along with **DAT file/s** representing the project horizontal and vertical control network, and the Starnet project file **(.SNPROJ)**.

Important Note:
Once a network has been adjusted and coordinates are reported to another entity (e.g.: Mapping Unit), these coordinates shall be deemed final. Should supplemental control or boundary ties be needed, the primary coordinates shall be fixed in subsequent adjustments. Only in the event that erroneous data is discovered will previously reported coordinate values be changed.

Appendix A – Formulas

1. Minimum spacing for new control points to be positioned using GPS can be computed using the following formula:

   $D = 10{,}000 \times \sqrt{(2 \times \{ [(1.96)(a)]^2 + [(1.96)(b)]^2 + c^2 \})}$
   where:

   - D = minimum spacing (in feet) between static or RTK occupation stations
   - a = manufacturer's millimeter rating at a 68% confidence level, (converted to feet)
   - b = manufacturer's ppm rating at a 68% confidence level, times the average distance (in feet) from legacy control stations, and divided by 1,000,000
   - c = estimated receiver positioning error (rod plumb or tribrach errors), commonly estimated to be 0.007 feet
   - 1.96 = the multiplier from a 68% confidence level (1 sigma) to a 95% confidence level (2 sigma)

2. All connected monument pairs shall pass the following mathematical test:

   $D \div \sqrt{(x^2 + y^2)} \geq 10{,}000$ (or $\geq$ 20,000 where required above)
   where:
   - D = distance (in feet) between the pair of monuments being examined
   - x = error ellipse semi-major axis for monument #1 (at 95% confidence)
   - y = error ellipse semi-major axis for monument #2 (at 95% confidence)

3. Connections of very short distances often will not meet the **1:10,000** standard defined by the formula in Section 2 above. An alternative standard for distances of less than 330 feet follows:

   $\sqrt{(x^2 + y^2)} \leq 0.033$ feet
   where:
   - x = error ellipse semi-major axis for monument #1 (at 95% confidence)
   - y = error ellipse semi-major axis for monument #2 (at 95% confidence)