Chapter 2
Control Surveying Applications

2-1. General

Control surveys are used to support a variety of USACE project applications. These include project boundary control densification, structural deformation studies, photogrammetric mapping, dynamic positioning and navigation for hydrographic survey vessels and dredges, hydraulic study/survey location, river/floodplain cross-section location, core drilling location, environmental studies, levee overbank surveys, levee profiling, levee grading and revetment placement, disposal area construction, grade control, real property surveys, and regulatory enforcement actions. Some of these applications are described below.

2-2. Project Control Densification

a. Conventional surveying. Conventional geodetic control surveys are those performed using traditional precise surveying techniques and instruments--i.e., theodolites, total stations, and levels. Conventional control surveys can be used to economically and accurately establish or densify project control in a timely fashion. Quality control statistics and redundant measurements in networks established by these methods help to ensure reliable results. However, conventional survey methods do have the requirement for intervisibility between adjacent stations.

b. GPS surveying. GPS satellite surveying techniques can often be used to establish or densify project control more efficiently (and accurately) than conventional control surveying techniques--especially over large projects. As with conventional methods, quality control statistics and redundant measurements in GPS networks help to ensure reliable results. Field operations to perform a GPS survey are relatively easy and can generally be performed by one person per receiver, with two or more receivers required to transfer control. GPS does not require intervisibility between adjacent stations. However, GPS must have visibility of at least four satellites during surveying. This requirement may make GPS inappropriate in areas of dense vegetation. For GPS control survey techniques refer to EM 1110-1-1003, NAVSTAR GPS Surveying.

2-3. Geodetic Control Densification

Conventional control and GPS surveying methods can be used for wide-area, high-order geodetic control densification. First-, Second- or Third-Order work can be achieved using conventional or GPS surveying techniques. GPS techniques are now generally used for most horizontal control surveys performed for mapping frameworks. Conventional instruments and procedures are generally preferred for site plan topographic mapping and critical construction control. Topographic mapping procedures used in detailed site plan surveys are contained in EM 1110-1-1005, Topographic Surveying.

2-4. Vertical Control Densification

Conventional leveling methods are used to determine orthometric height elevations of benchmarks established for vertical control densification. The setup and operation for conventional control surveying for vertical control densification offers economies of scale in the same manner as that offered by the setup for horizontal project control densification--i.e., smaller projects require less setups, while larger projects require more. For large mapping projects, differential GPS may prove more cost effective for densifying vertical control. However, for small project sites or construction projects, conventional spirit leveling is generally preferred.

2-5. Structural Deformation Studies

a. Conventional control surveying can be used to monitor the motion of points on a structure relative to stable monuments. This is usually done using an Electronic Distance Measuring (EDM) instrument located on various stable reference monuments away from the structure, and measuring precise distances to calibrated reflectors positioned at selected points on the structure. When only distances are measured, trilateration techniques may be employed to compute absolute movements. If angular observations are added, such as with a theodolite or electronic total station, then triangulation methods may be added to a position solution. These precise techniques can provide a direct measure of the displacement of a structure as a function of time. If procedures are strictly adhered to, it is possible to achieve a $\pm$0.5 mm + 4 ppm (4 mm/km) baseline accuracy using conventional surveying instruments. Personnel requirements generally are two, once the initial test network of reference and object points are set up--one person to monitor the EDM or total station and another to aid in reflector placement.

b. GPS can also be used to monitor the motion of points on a structure relative to stable monuments. With GPS, an array of antennae are positioned at selected points on the structure and on remote stable monuments--as opposed to using reflectors and EDMs as previously described. The baselines between the antennae are formulated to monitor differential movement. The relative precision of the measurements is on the order of $\pm$5 mm over distances averaging between 5 and 10 km, and near the 1-mm level for short baselines. GPS observations can be determined continuously 24 hours a day. Once a deformation monitoring system has been set up using GPS, it can be operated unattended and is relatively easy to maintain.

2-6. Photogrammetry

Geodetic control surveys are used in the support of photogrammetric mapping applications. These control surveys are performed to provide rigid horizontal and vertical alignment of the photographs. Since photogrammetric mapping projects typically are large in extent, GPS methods have largely replaced conventional control survey techniques. In many cases, photogrammetric mapping control surveys have been largely eliminated through the use of differential GPS-controlled airborne cameras. More specific guidance on the use of control surveying in support of photogrammetry is included in EM 1110-1-1000, Photogrammetric Mapping.

2-7. Dynamic Positioning and Navigation

a. Conventional control surveying can be used to establish the primary project control for the dynamic positioning and navigation of construction and surveying platforms used for design, construction, and environmental regulatory efforts. These efforts include dredge control systems, site investigation studies/surveys, horizontal and vertical construction placement, hydraulic studies, or any other waterborne activity requiring two- or three-dimensional control. Second Order or Third Order leveling is required for these efforts.

b. GPS has reduced (or even eliminated in many cases) the time and effort required to establish control for dynamic positioning and navigation systems. In addition to this capability, GPS equipment can provide dynamic, real-time GPS code and carrier phase positioning of construction and surveying platforms. GPS code phase differential techniques can provide real-time meter-level horizontal positioning and navigation, while GPS carrier phase differential techniques can provide real-time, centimeter-level, three-dimensional positioning and navigation. These GPS methods can be used for any type of construction or survey platform (e.g., dredges, graders, survey vessels, etc.). More specific guidance on the use of GPS for dynamic positioning and navigation is included in EM 1110-2-1003, Hydrographic Surveying.

2-8. GIS Integration

A Geographic Information System (GIS) can be used to correlate and store diverse information on natural or man-made characteristics of geographic positions. To effectively establish and use a GIS, it must be based on accurate geographic coordinates. A GIS with an accurate foundation of geographic coordinates enables the user to readily exchange information between databases. Conventional control surveying and GPS surveying can be used to establish the geographic coordinates used as the foundation for a GIS. Refer to EM 1110-1-2909, Geospatial Data and Systems, for detailed guidance on GIS development.