# Chapter 6
# GPS Applications in USACE

## 6-1. General

This chapter outlines some of the varied uses of GPS by USACE surveyors and its contractors. GPS applications apply to all the Corps' civil works, military construction, and environmental missions. These applications include real estate surveys, regulatory enforcement actions, horizontal and vertical control densification, structural deformation studies, airborne photogrammetry, dynamic positioning and navigation for hydrographic survey vessels and dredges, hydraulic study/survey location, river/flood plain cross-section location, core drilling location, environmental studies, emergency operations, levee overbank surveys, and levee profiling. Construction uses of real-time GPS include levee grading and revetment placement, disposal area construction, stakeout, etc. Additionally, GPS has application in developing various levels of Geographic Information System (GIS) spatial data, such as site plan topography, facilities, utilities, etc. In effect, GPS has application for any USACE project requiring georeferenced spatial data. Given the variety of GPS accuracies and operating modes, a particular project application may involve one or more types of equipment and data acquisition methods. Suggested GPS techniques are shown in Table 6-1 for different types of Corps projects.

**Table 6-1. Summary of Typical GPS Applications on USACE Civil and Military Construction Projects**

| USACE Project/Functional Application | Absolute GPS 10 to 30 m | Code Differential GPS 0.5 to 3 m | Carrier DGPS 1 to 10 cm |
|---|---|---|---|
| **General Project Mapping Control (Military & Civil)** | | | |
| Reference benchmark elevations | | | Static PP |
| Reference horizontal positions | | | Static PP |
| **Facility Mapping (Site Plans & GIS)** | | | |
| Building & structure location | | | RTK or PPK |
| Utility location | | | RTK or PPK |
| Roads, streets, airfields, etc. | | | RTK or PPK |
| Grading & Excavation Plans | | | RTK or PPK |
| Recreational Plans | | | RTK or PPK |
| Training Range Plans | | RT | |
| Airfield obstruction mapping | | RT | |
| Training range mapping/location | RT or | RT | |
| Utility Location & As-Builts | | RT or | RTK |
| Environmental Mapping | | RT or | RTK |
| **Flood Control Projects** | | | |
| Floodplain Mapping | RT or | RT | |
| Soil/Geology Classification Maps | RT or | RT | |
| Cultural/Economic Classifications | RT or | RT | |
| Land Utilization Mapping | RT or | RT | |
| Wetland/Vegetation Delineation | RT or | RT | |
| Levee Profiling | | | RTK |

**Table 6-1 (Contd). Summary of Typical GPS Applications on USACE Civil and Military Construction Projects**

| USACE Project/Functional Application | Absolute GPS 10 to 30 m | Code Differential GPS 0.5 to 3 m | Carrier DGPS 1 to 10 cm |
|---|---|---|---|
| **Navigation Projects** | | | |
| Primary Project Control Surveys | | | Static PP |
| Dredge Control: | | | |
| Horizontal position | | RT | |
| Disposal area monitoring | | RT | |
| Vertical reference | | | RTK |
| Hydrographic Survey Control: | | | |
| Project condition | | RT | |
| Measurement & payment | | RT | |
| Accurate tidal monitoring | | | RTK |
| General Vessel Navigation | RT | | |
| Shoreline Mapping | | RT or | RTK |
| MHW line Delineation | | | RTK |
| **Hydraulic & Hydrology Studies** | | | |
| Horizontal reference | RT or | RT | |
| Vertical reference | | | RTK or Static PP |
| **Geotechnical Investigations** | | | |
| Boring location (horizontal) | RT or | RT | |
| Boring reference elevation | | | RTK or Static PP |
| **Structural Deformation Surveys** | | | |
| Network monitoring points | | | Static PP |
| Periodic monitoring surveys | | | Static PP |
| Continuous deformation monitoring | | | RTK or PPK |
| **Construction** | | | |
| Layout and alignment | | | Static PP or RTK |
| Material placement (horizontal) | | RT or | RTK |
| Placement & grading (vertical) | | | RTK |
| **Coastal Engineering** | | | |
| Primary Baseline Control | | | Static PP or RTK |
| Dune/Beach Topo Sections | | | RTK |
| **Photogrammetric Mapping** | | | |
| Camera/LIDAR positioning (ABGPS) | | | PPK |
| Ground control surveys | | | Static PP |
| **Emergency Operations** | | | |
| Personnel location | RT | | |
| Facility location | RT | RT | |
| **Real Estate** | | | |
| Tract, Plat & Parcel Mapping | | | RTK |
| Boundary Monuments | | | Static PP or RTK |
| Condemnation Maps | | | RTK |
| General Location Maps | | RT | |
| **HTRW Site Control & Mapping** | | | |
| Site Plan Control | | | Static PP |
| Geotoxic Data Mapping/Modeling | | RT or | RTK |

RT: Real-time RTK: Real-time Kinematic PP: Post-processed PPK: Post-Processed Kinematic

## 6-2. Project Control Densification

Establishing or densifying primary project control is one of the major uses of GPS technology. GPS is often more cost-effective, faster, accurate, and reliable than conventional (terrestrial) survey methods. The quality control statistics and large number of redundant measurements in GPS networks help to ensure reliable results. Primary horizontal and vertical control monuments are usually set using static GPS survey methods, although some post-processed kinematic methods may also be employed. These primary monuments are typically connected to NGRS horizontal and vertical reference datums. From these primary monuments, supplemental site plan mapping or vessel/aircraft positioning is performed using RTK techniques. Field operations to perform a GPS static control survey are relatively efficient and can generally be performed by one person per receiver. GPS is particularly effective for establishing primary control networks as compared with conventional surveys because intervisibility is not required between adjacent stations. Figure 6-1 below shows a portion of a GPS project planning network for static GPS control surveys along the Mississippi River in Memphis District. Other examples of typical USACE project control surveys are found in the appendices to this manual. These include setting control for a navigation project, a flood control project, and a dam deformation monitoring reference network.

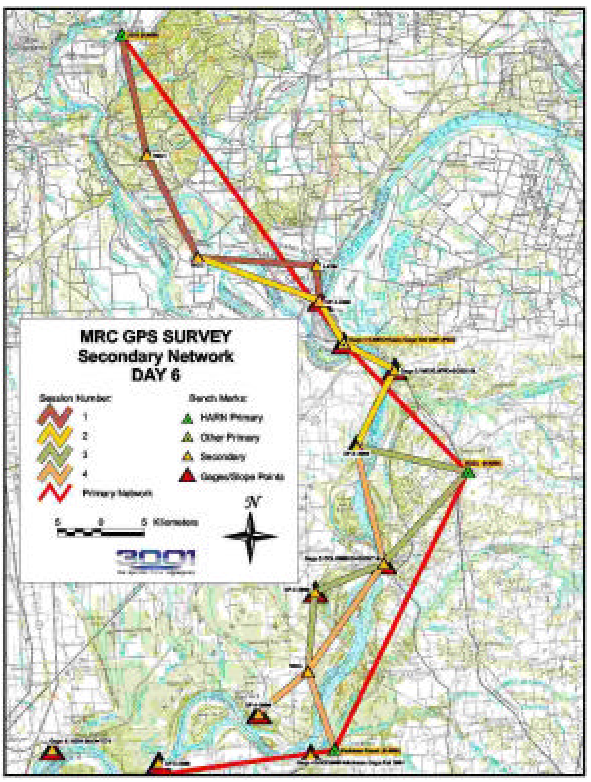



**Figure 6-1. Control survey observing scheme on Mississippi River and control point baseline occupation at Memphis District Ensley Boatyard (Memphis District and 3001, Inc.)**

## 6-3. Facility Site Plan Topographic Mapping and GIS Surveys

Real-time and post-processed techniques can be used to perform topographic mapping surveys and GIS base mapping. Depending on the accuracy, either code or carrier phase techniques may be employed--see Table 6-1. In general, most topographic mapping is performed using real-time kinematic methods using carrier phase accuracy. Post-processed fast-static methods may be used to set temporary mapping control or aerial mapping targets. Figure 6-2 below depicts equipment used on a typical fast-static survey at the Corps' Huntsville, AL training center. Real-time topographic or GIS feature data is usually collected from portable range pole or backpack antenna mounts, as shown in Figure 6-3. Data are logged on standard data collectors similar to those used for terrestrial total stations. Data collector software is designed to assign topographic and GIS mapping features and attributes, and to perform standard construction stakeouts. Code differential techniques may be used for GIS mapping features requiring only meter-level accuracy. If only approximate mapping accuracy in needed, hand-held GPS receivers with absolute (10-30 m) positioning may be used.

**Figure 6-2. Fast-Static control survey of topographic reference monument at Huntsville Bevill Center**

**Figure 6-3. GPS real-time kinematic topographic surveys using backpack and range pole antenna mount**

## 6-4. Shallow Wetland Mapping

Carrier and code differential GPS can be employed for surveys of shallow wetland areas. These GPS techniques are significantly more effective and accurate than terrestrial methods in these inaccessible areas. Real-time kinematic methods can provide decimeter-level (or better) elevation accuracies, which are critical in flat, low-flow areas. GPS topographic shot points can be observed in clear areas to minimize vegetation clearing in environmentally sensitive areas. These data points can then be input into a terrain model of the area. GPS equipment can be mounted on airboats, swamp tractors, or other platforms, as shown in Figure 6-4 below. Higher antenna pole mounts may be needed to reach over taller grass.

**Figure 6-4. GPS RTK surveys from airboat operating in shallow wetland areas (Jacksonville District)**

## 6-5. Flood Control Projects--Levee Assessments

Post-processed or real-time kinematic methods may be used to rapidly measure levee profile elevations, using platforms such as those shown in Figure 6-5. Similar RTK methods may be used to run levee cross-sections at selected intervals along the levee baseline--eliminating the need to stakeout individual hubs on the baseline. These "overbank" sections can also be extended into the water for hydrographic depth measurement, with the RTK system providing the reference elevation.

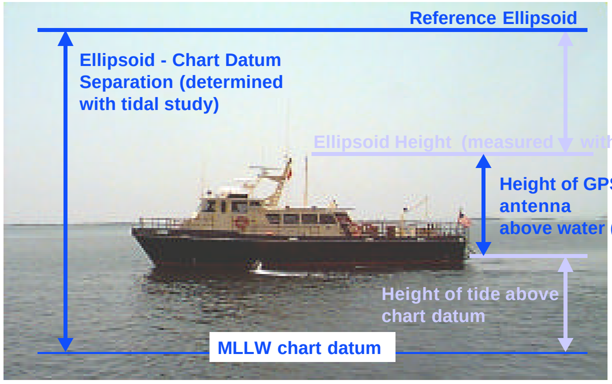
**Figure 6-5. New Orleans District levee profiling using real-time kinematic GPS methods (New Orleans District and 3001, Inc.)**

## 6-6. Navigation Project Survey Vessel and Dredge Control

Both code and carrier phase DGPS methods are used to control most in-house and contracted dredging and surveying operations on Corps navigation projects. Code-phase differential GPS is typically used for dynamic, meter-level accuracy positioning of survey boats and dredges. Centimeter-level accuracy carrier phase differential GPS is used for real-time tidal or river stage modeling during hydrographic surveys. The following figures (6-6 through 6-8) are representative of Corps platforms utilizing code and carrier phase GPS navigation and positioning. For details on marine platform positioning, refer to EM 1110-2-1003 (Hydrographic Surveying).


**Figure 6-6. Typical USCG Maritime DGPS controlled Corps hopper dredge at Southwest Pass, LA (New Orleans District)**


**Figure 6-7. Typical Corps hydrographic survey vessel equipped with carrier phase DGPS and IMU for measuring vessel position, roll, pitch, and heave parameters during real-time surveys (New York District)**




**SB Florida, Jacksonville District**

**Figure 6-8. Use of carrier phase DGPS for real-time modeling offshore tides at Kings Bay FBM Entrance Channel (Jacksonville District and ERDC Topographic Engineering Center)**

## 6-7. Hydraulic and Hydrology Studies

River hydraulic measurements and studies can be positioned using meter-level code phase techniques. RTK methods can be used if accurate cross-sections are required. Overbank and flood plain topography can be obtained from a variety of terrestrial and airborne survey methods--all controlled using DGPS. A typical Corps survey boat designed to obtain river hydraulic and hydrologic data is shown in Figure 6-9 below. This vessel is capable of obtaining acoustic topographic elevation models of the riverbed, Doppler current data, and sub-bottom material classification. These datasets are georeferenced using either real-time code or kinematic GPS observations aboard the boat.


**Figure 6-9. St. Louis District hydraulics and hydrology survey boat**

## 6-8. Structural Deformation Surveys

GPS survey techniques can be used to monitor the motion of points on a structure relative to stable reference monuments. This can be done with an array of antennae positioned at selected points on the structure and on the reference monuments. Baselines are formulated between the occupied points to monitor differential movement. Given the typically short baselines (< 500 m), the relative precision of the measurements is on the order of 2 to 5 mm. Measurements can be made on a continuous basis. A GPS structural deformation system can operate unattended and is relatively easily installed and maintained. Alternatively, periodic monitoring observations are taken using RTK or post-processed kinematic techniques, as illustrated in Figure 6-10. Prior to performing structural monitoring surveys, the stable reference network must be accurately positioned. Long-term static GPS observations are typically used to perform this task. Detailed procedures on these surveys are covered in EM 1110-2-1009 (Structural Deformation Surveying).


**Figure 6-10. Real-time kinematic structural deformation surveys of locks and dams--St. Lucie Lock (Jacksonville District and Arc Surveying & Mapping, Inc.)**

## 6-9. Construction Stakeout and Grading

Survey-grade GPS receivers are now designed to perform all traditional construction stakeouts--e.g., lots, roads, curves, grades, etc. Typical Corps applications include staking out baselines for beach renourishment projects, levee baselines, boring rig placement, and facility or utility construction alignment. An example stakeout survey for a beach renourishment construction baseline is found in an appendix to this manual. GPS can also be used to control and monitor earth-moving operations, such as grading levees or beach construction--Figure 6-11. For further information on typical construction stakeout and laser alignment techniques with GPS, see *Trimble Survey Controller Reference Manual/Field Guide* (Trimble 2001a).

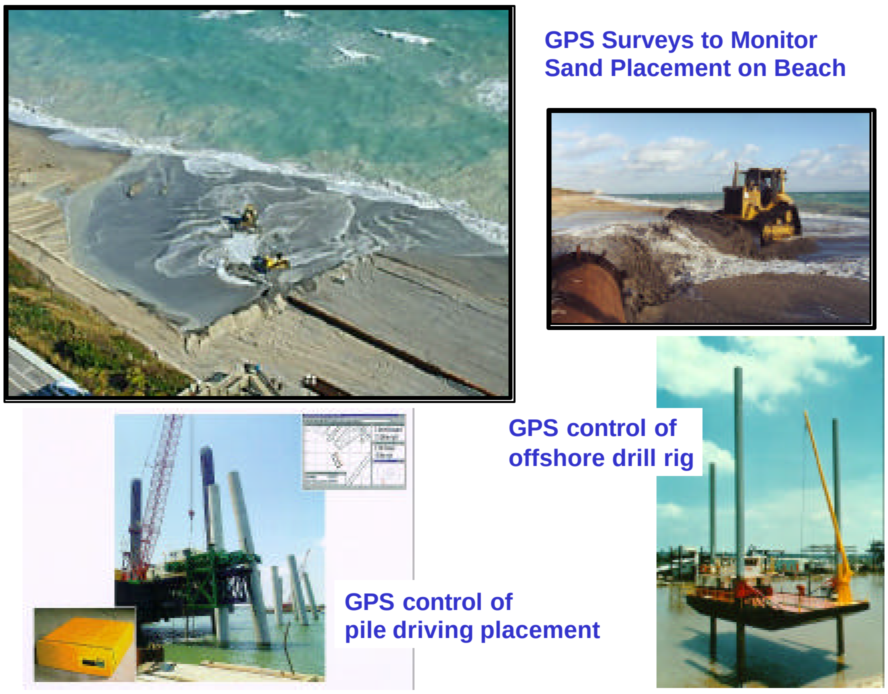



**Figure 6-11. Construction grading and core drill location GPS applications**

## 6-10. Coastal Engineering Surveys

Differential GPS positioning and elevation measurement techniques have almost replaced conventional survey methods in performing beach surveys and studies. Depth measurement sensors (physical or acoustical) are typically positioned with RTK methods. DGPS is used to control the "sounding rod" attached to the "CRAB," "LARC," and sled platforms shown in Figure 6-12. Vessels and other platforms usually merge RTK observations with inertial measurement units in order to reduce out surf heave. Land sections of beach profile surveys are usually controlled using RTK topographic methods, as shown in Figure 6-12 where beach profiles are merged with offshore hydrographic profiles. See also EM 1110-2-1003 (Hydrographic Surveying) for more details on coastal engineering surveys.


**Figure 6-12. Differential GPS controlled beach survey platforms--for coastal engineering surveys (ERDC/Coastal & Hydraulics Lab, Jacksonville District, Arc Surveying & Mapping, Inc.)**

## 6-11. Photogrammetric Mapping Control

The use of an airborne GPS (ABGPS) receiver, combined with specialized inertial navigation, LIDAR, and photogrammetric data processing procedures, can significantly reduce the amount of ground control for typical photogrammetric projects. In effect, each camera image or LIDAR scan is accurately positioned and oriented relative to a base reference station on the ground, as shown in Figure 6-13. In the past, the position and orientation of the camera was back-computed from ground control imagery. Traditionally, these mapping projects required a significant amount of manpower and monetary resources for the establishment of the ground control points. Therefore, the use of ABGPS technology significantly lessens the production costs associated with wide-area mapping projects. Tests have shown that ground control coordinates can be developed from an airborne platform using adapted GPS kinematic techniques to centimeter-level precision in all three axes if system related errors are minimized and care is taken in conducting the ABGPS and photogrammetric portions of the procedures. ABGPS has been used extensively in St. Louis and Jacksonville Districts for photo and LIDAR mapping projects. ABGPS is also used to control the Mobile District's airborne LIDAR hydrographic survey system--Figure 6-14. Detailed coverage of ABGPS is given in EM 1110-1-1000 (Photogrammetric Mapping).

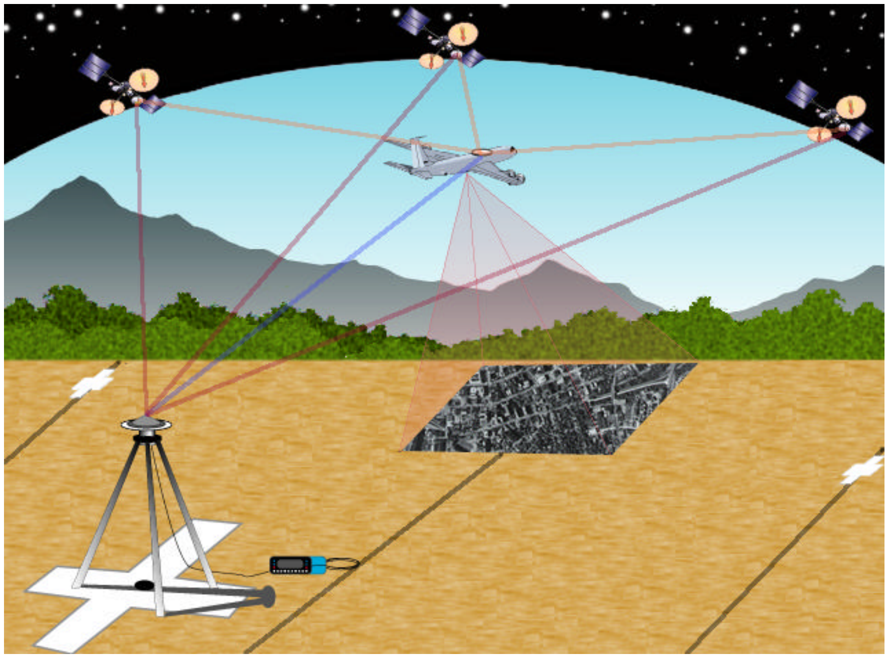


Figure 6-13. Airborne GPS control for photogrammetric mapping projects

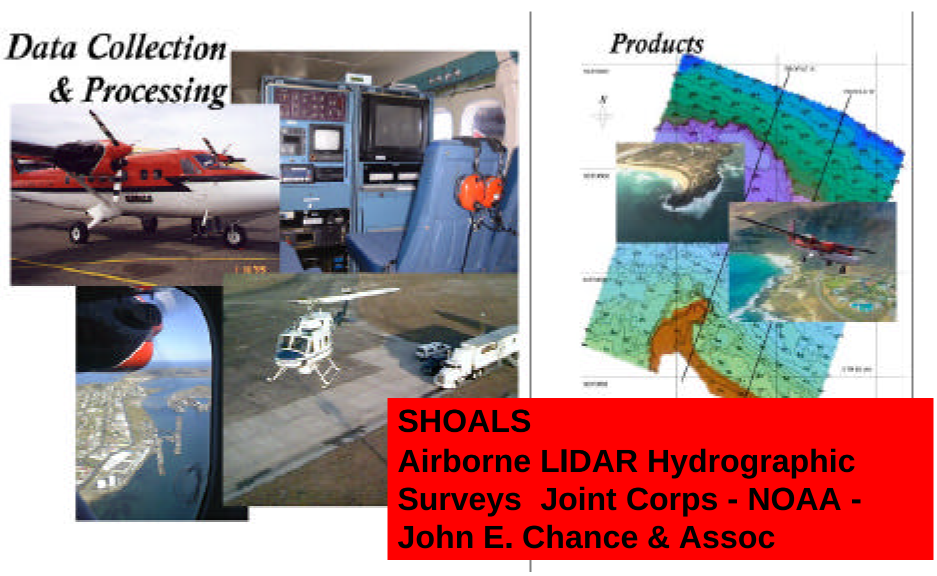



Figure 6-14. USACE GPS-controlled SHOALS hydrographic surveying system (Mobile District)