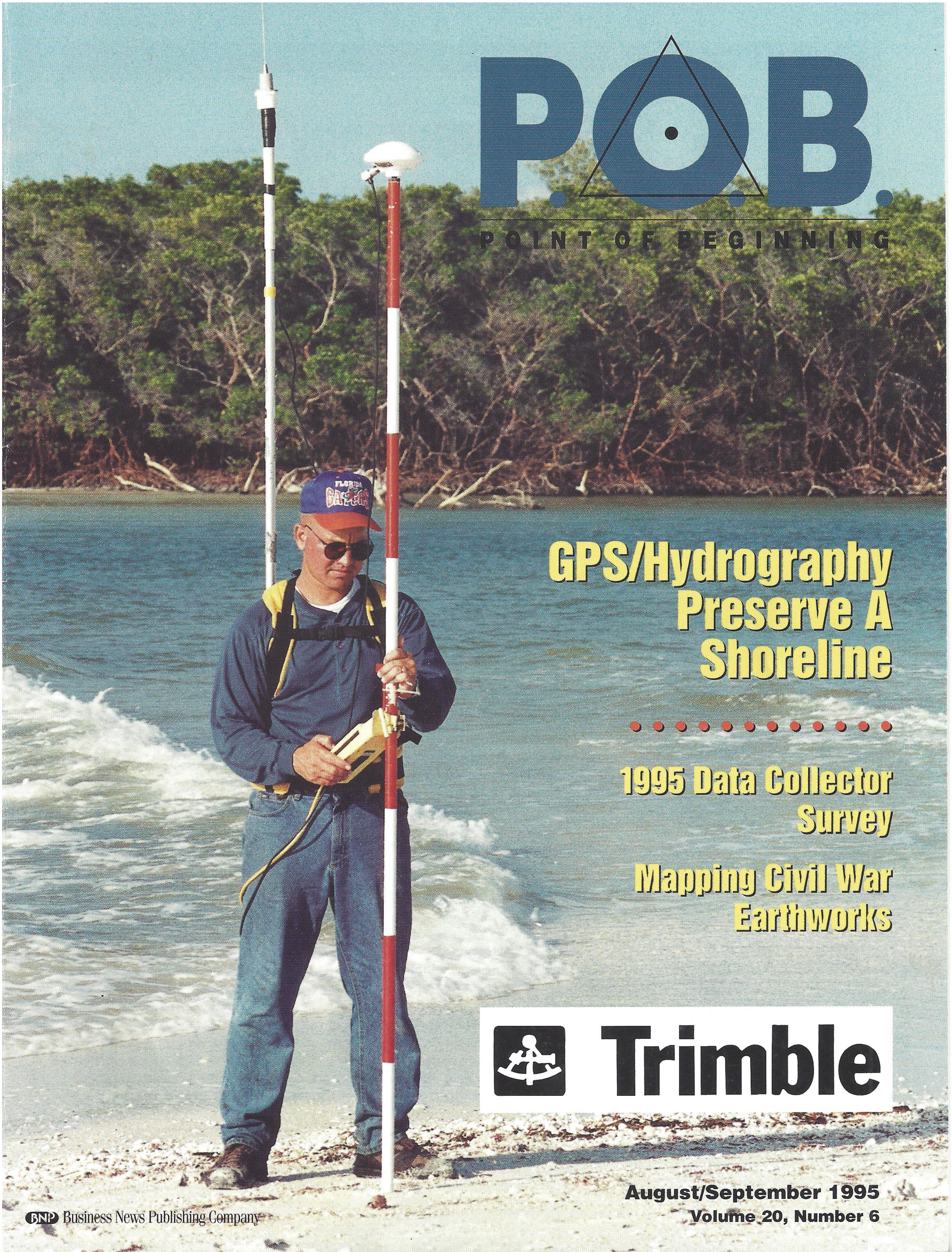
P.O.B.

POINT OF BEGINNING



GPS/Hydrography Preserve A Shoreline

1995 Data Collector Survey

Mapping Civil War Earthworks

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GPS/Hydrography Preserve a Shoreline

From a surveying standpoint, the project proved unique with a sizeable portion of the topographic work being done at night.

Photos and figures courtesy of ARC Surveying and Mapping, Inc.

Hydrographic and GPS surveying methods were necessary to investigate the condition of the northeastern shoreline area of Hilton Head Island, South Carolina.

by **Lou Nash** and **Rick Sawyer**

Background

In October 1994, the town of Hilton Head Island, South Carolina, authorized funding for a detailed investigation of a chronic beach erosion problem along the northeast end of the island. This section of the island is occupied by the Port Royal Plantation, a private development. The erosion problem threatens numerous shorefront properties and a beach club that is central to the area's shorefront recreation. Past attempts to protect these properties and structures have led to the installation of 17 sand-retaining rock groins (small jetties) and two extensive shore-armoring revetments (stone embankments). Although some of these structures have provided limited protection against the erosional forces, most of the shoreline continues to erode.

The erosional forces along this section of shoreline are driven by a very dynamic wave and tidal current climate. The intent of the investigation was to (1) characterize the existing conditions of the beach, protective structures, and offshore bathymetric and shoal features; (2) quantify the magnitude of the erosional forces; and (3) develop an engineering alternative that will provide for the long-term shore protection needs of the property owners. To achieve these goals, a comprehensive survey of the beach, protective structures, and offshore bathymetry was required.

Olsen Associates, Inc. of Jacksonville, Florida, a coastal engineering firm, retained ARC Surveying and Mapping, Inc. (ARC), also of Jacksonville, to provide a controlled, large-scale topographic and hydrographic survey of the Port Royal Plantation area. The survey involved detailed mapping of the beach and dune system, all exposed protective structures, and the offshore bathymetry and shoal features. Deliverables to the engineer included detailed maps of the entire study area and each protective structure.

Survey Specifics

To meet the requirements of Olsen Associates, ARC developed a survey plan to incorporate the following:

1. Hydrographic survey of 50 or more lines, as defined by four survey baselines, at 250-foot intervals along 12,000 feet of shoreline. Bathymetry data would be collected during periods of high tide from as far inshore as possible out to the -20 feet NGVD 29 (National Geodetic Vertical Datum 1929) elevation contour.
2. Topographic surveys would extend the

same 50 or more lines inland and 50 feet beyond the top of berm. The topographic survey lines would also overlap the hydrographic survey lines by approximately 50 feet to provide a measure of quality control/quality assurance.

3. Topographic survey of all man-made coastal control structures along the 12,000 feet of shoreline. This data would include centerline profile data as well as detailed data along the adjacent updrift ambient seabed of each groin at the landwardmost and seawardmost ends.
4. Topographic data of Joiner Bank, a large sandbar located just offshore.

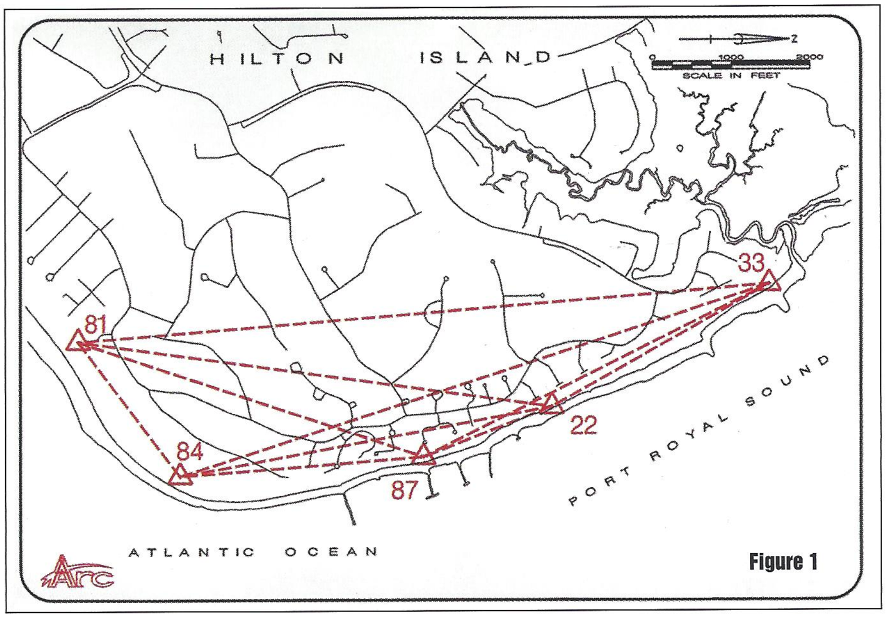


Figure 1

Survey Methodology

ARC office personnel gathered nautical charts and tidal information to develop a survey plan before mobilizing to Hilton Head Island. Analysis of this information led to the conclusion that hydrographic data could be collected when tides were in excess of four feet and topographic data could be collected when tides were less than two feet. The semidiurnal tides would allow for less than four hours of uninterrupted topographic data collection at a time. Coupled with short winter days, this promised to spell trouble for conventional topographic data collection methods. The company decided to test Trimble Navigation's (Sunnyvale, California) Real Time Kinematic (RTK) system, which consists of 4000SE single-frequency GPS receivers; TRIMVEC, TRIMNET, and TRIMMAP software; and TDC1 Survey Controller data logger. Pacific Crest Corporation's (Santa Clara, California), RDDR-96 radios were used for the RTK's radio telemetry. Consequently ARC enlisted the aid of its sister company, SUNBELT Surveyors, Inc. of Largo, Florida, to provide assistance in the RTK surveys.

Static GPS Network

The four-person crew, made up of employees from SUNBELT and ARC, arrived on Hilton Head Island on the morning of December 8, 1994. The initial plan was to locate five South Carolina Coastal Council (SCCC) control monuments, as identified by earlier office research, which would define the beach monitoring baseline. "To-Reach" descriptions provided North American Datum 1983 (NAD 83) Northing and Easting values as well as NGVD 29 elevations for each of the points. Job site reconnaissance began immediately, and well-written descriptions provided easy recovery of each monument.

As is often the case however, the initial plan, as arranged from the comfort of the office, was soon voided when the crew discovered that two stations were inadequate for their intended use. One monument was destroyed; ocean surf washed away its base, allowing it to topple over. The view to the sky at the other monument was heavily obstructed by large oak trees. Although it would be possible to successfully occupy the station in a properly planned GPS (Global Positioning System) session, obstructions would inevitably render the point useless as a Differential GPS (DGPS) and RTK base station or calibration checkpoint. Two new monuments were established, their locations chosen so that they would serve as survey baseline points and be unobstructed to the sky.

The crew then designed a GPS network that incorporated the two new points and the remaining three SCCC monuments (see Figure 1). Each station was evaluated in the field by means of mission planning software on a laptop PC. Using four 4000SE GPS receivers, the crew completed the network by early afternoon.

The majority of the crew remained at the job site while the GPS receivers were taken back to the motel for downloading and data processing. The beach crew, using WILD NA2 levels (Leica Inc., Norcross, Georgia), then set a tide gage and ran a line of conventional levels, looping up and down the beach, to establish vertical "checkpoints." These checkpoints would be used later during the RTK surveys. As good survey practice dictates, the crew also ran differential levels through the newly set GPS monuments.

It should be noted that the level runs were the only use of "traditional" surveying techniques exercised in this project. Furthermore, it will be shown later in this article that this survey could have been *totally* completed using only GPS technology without any support from traditional surveying techniques. However, the authors note that the prudent surveyor, adhering to sound surveying practices, checks and rechecks his or her work in any and every manner available.

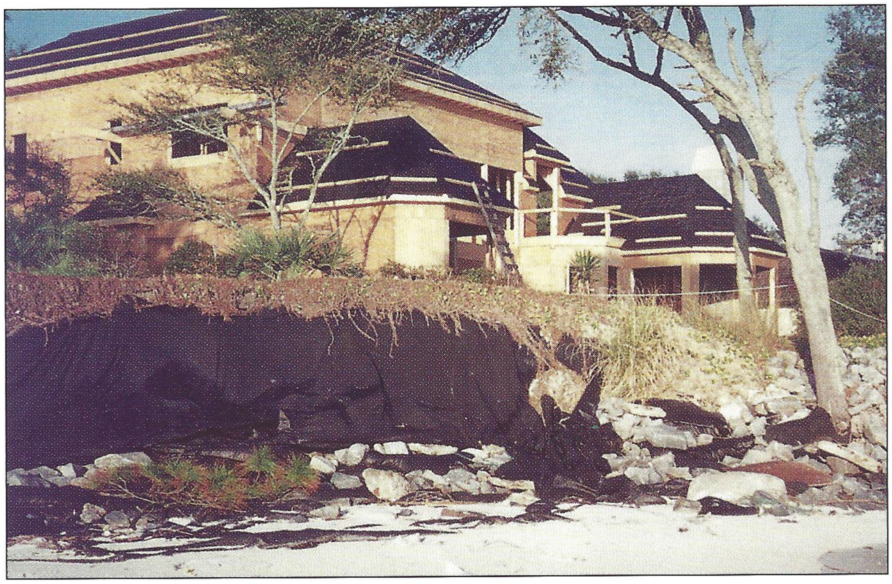
Processing the GPS static data was fairly straightforward. NAD 83 latitudes and longitudes of the known control points were used to "seed" the least squares GPS

Table 1. Comparison of Redundant Vector Components

From	To	Delta X	Delta Y	Delta Z
33	81	+0.0056	+0.0006	-0.0096
33	87	-0.0014	-0.0039	-0.0003
81	87	-0.0072	-0.0041	+0.0092

Table 2. Comparison of Differential Leveling and Static GPS

Station 22		Station 33		Station 84	
Levels	GPS	Levels	GPS	Levels	GPS
9.49	9.47	8.45	8.47	10.19	10.19



Beach erosion of this section of Hilton Head Island is caused by dynamic wave and tidal current action.

vector computation algorithms. The vectors obtained were then evaluated in an unconstrained network.

Analysis of the unconstrained network showed that the average horizontal misclosure in the network was 1:920,000. This factor is indicative of quality GPS vectors in a network that contains relatively short (500 meters) vectors. Another indication of network quality was found in the evaluation of redundant vectors as outlined in Table 1 (all units in meters).

A third indicator of GPS vector quality was found in utilizing Trimble's loop closure utility program. In essence, the program uses GPS vectors as input to traverse around or throughout a GPS network. When applied to this particular network in traversing its outer bounds (approximately 5800 meters), the loop misclosure equated to a horizontal precision of 0.89 parts per million.

Fully constrained and properly weighted, the network had an average horizontal misclosure of 1:550,000. This evaluation factor is indicative of the high quality and precision of the SCCC monuments themselves. It also demonstrated that the monumentation established was more than adequate to meet the requirements of this particular survey.

Computation of Orthometric Heights

A prerequisite of properly calibrating the RTK system is that the relationship between the ellipsoid and the geoid be established in a "localized" sense. To accomplish this, geodetic coordinates (NAD 83) for GPS points 81 and 87, as determined by the GPS network adjustment, were used as input to National Geodetic Survey's GEOID90 Program, Version 1.00, to obtain geoid heights for both points. The geoid heights were then combined with their corresponding orthometric heights and a "localized" ellipsoid height obtained. The two points, being fairly well separated in both the north/south and east/west directions, were chosen for ultimately defining a model of the ellipsoid throughout the job site.

The GPS network was then readjusted with the same horizontal constraints as before but with vertical constraints to the "localized ellipsoid" at points 81 and 87. This provided "localized" ellipsoid heights for all five monuments. The procedure outlined above was then used in reverse order to determine orthometric heights (from ellipsoid and geoid heights) for the remaining stations. A comparison between orthometric heights determined by the beach

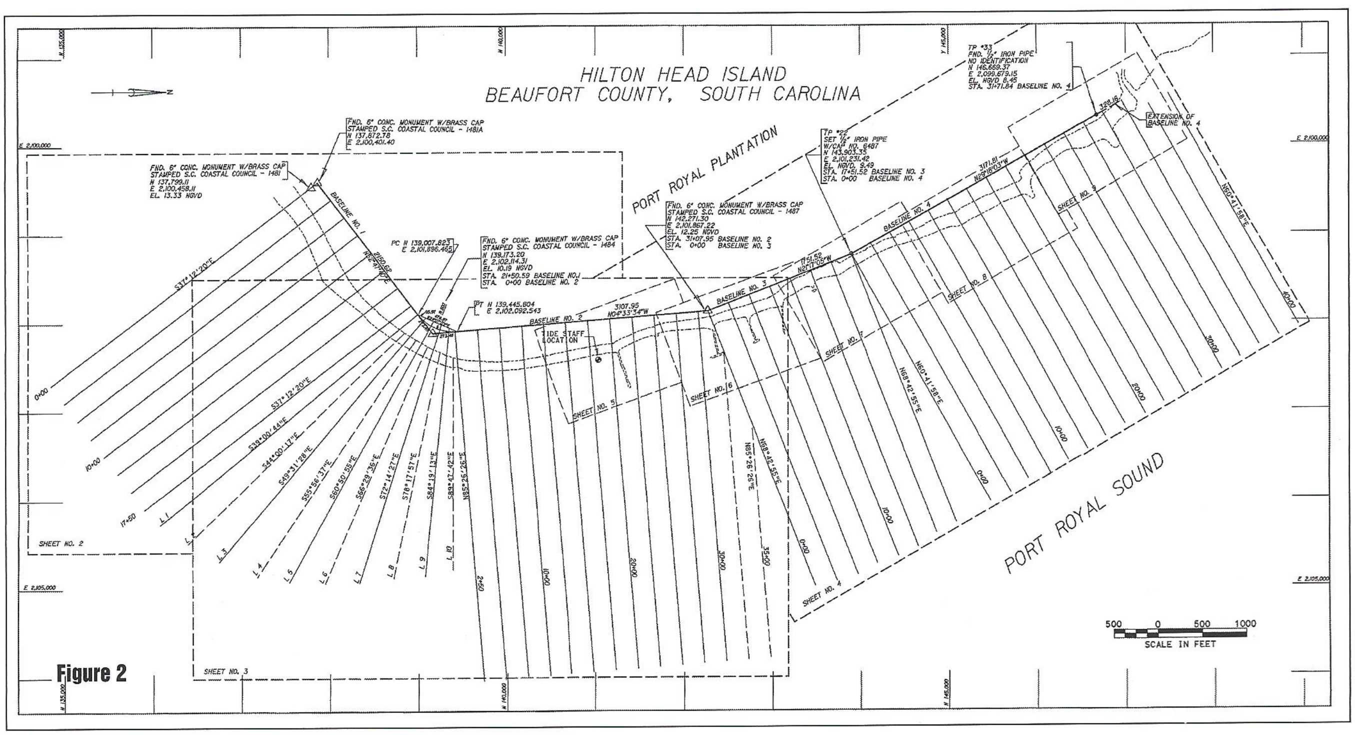


Figure 2

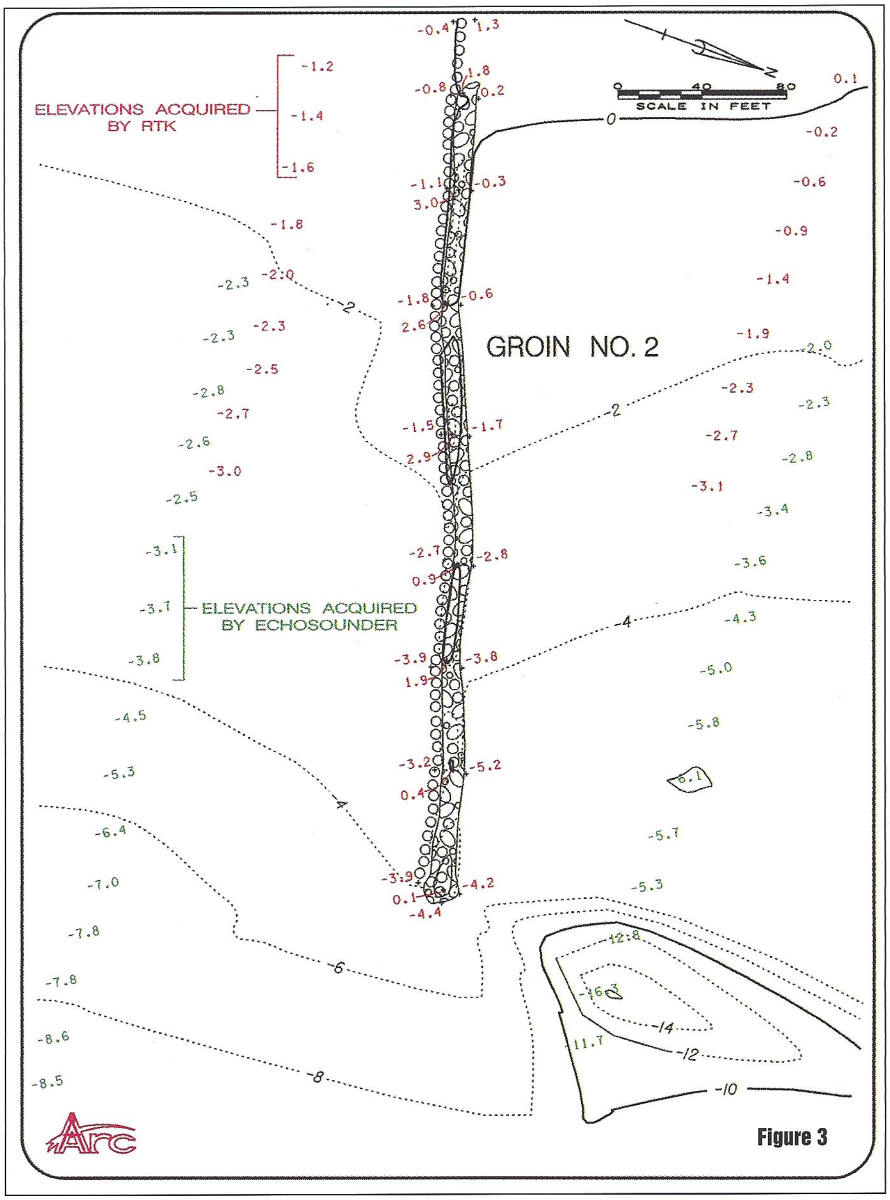


Figure 3

crew by differential leveling and static GPS observations is given below in Table 2 (all elevations in feet).

Survey Line Files

Coordinate values of the five controlling monuments were used in establishing the four baselines from which the survey would originate. A total of 56 survey lines were developed. These lines would later serve as input to both the RTK and automated hydro data collection system (see Figure 2).

Determination of RTK Calibration Parameters

In a very basic sense, the Real-Time-Kinematic (RTK) system is a fairly direct application of datum transformations, computing power, and radio telemetry, all incorporated into a single compact system.

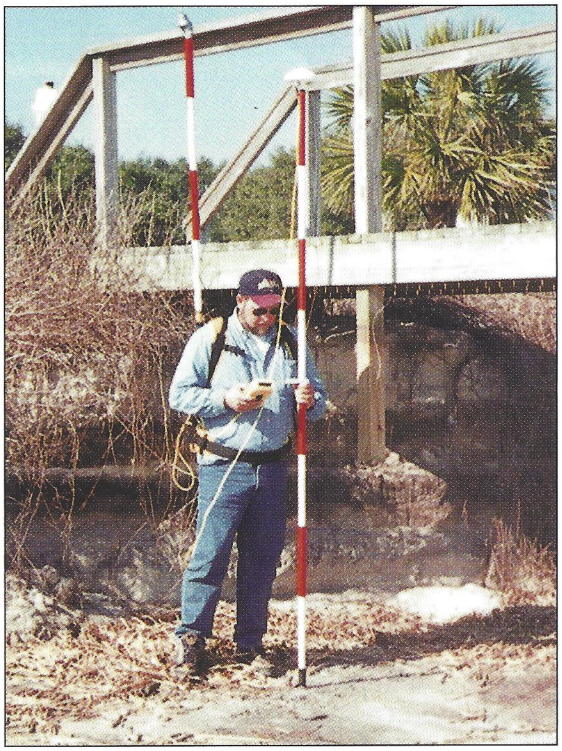
Calibration of the RTK system requires that a localized datum transformation be performed. In this survey, latitudes, longitudes, ellipsoid heights, northings, eastings, and orthometric heights (along with an average convergence angle value) of the five control monuments were used as input to the manufacturer's software package. The software calculated the datum transformation parameters as well as several statistical parameters for evaluating the quality of the transformation itself. The transformation parameters were then downloaded to the Trimble TDC1 handheld data collectors that interface with the GPS receiver. As a final check of the transformation (before going to the field!) we entered the geodetic coordinates of a centrally located control point into the data collector and toggled the display to read the transformed grid coordinates, ensuring the adequacy of the mathematics involved in the RTK calibration for the local job site.

Computing power becomes a key factor when initializing the RTK system at the job site. A control point is occupied as a base station and its coordinates input to the data collector as the radio telemetry system is started. Attaching the manufacturer's initialization plate provides a "portable baseline" from which to initialize the system. A second control point near the site could also serve as an initialization point but we prefer to initialize at the base (with the truck, the spare cables, the duct tape, etc.). Control coordinates are then calculated for the initialization plate, or input for a secondary control point. With coordinate values for both the base station and rover and sharing data through the 9600-baud telemetry link, the data collector firmware solves for the cycle ambiguity of each satellite in view. The cycle ambiguity is the number of full cycle wavelengths (integers) of the GPS satellite signal as measured at the base station. The remaining phase value is measured by the receiver, added to the number of full cycles, and scaled by the speed of light to determine a range from each satellite in view.

Once the cycle ambiguity has been resolved at the base station, the information is shared, via the telemetry link, with any number of properly initialized roving units in the area. Essentially, the base/rover pair then "carry around" a three-dimensional GPS vector. As a measurement or "shot" is taken with the data collector, this vector is accurately measured, the integer ambiguity having been already resolved. The coordinates of the "rover end" of this vector are, in turn, transformed (by the parameters as determined earlier) to the local survey grid. Northings, eastings, and orthometric heights may then be viewed in real time.

Nighttime Surveying

The second day of the job started early with the crew arriving at the job site under cover of darkness. As the sun came up, the RTK base station was set up, including its radio telemetry transmitting antenna that reached 30 feet into the South Carolina sky. Cross-sectional lines were laid out relative to the survey baselines utilizing the data collector's stakeout module, after



Rick Sawyer, vice president of ARC Surveying & Mapping, Inc., Jacksonville, Florida, uses a real-time kinematic (RTK) survey system to collect topographic data on cross-sectional lines along the shore.

which two rover units were soon collecting data. As the morning progressed, northeasterly winds intensified. By about 9 a.m., the rising tides and the wind-driven waves ended the collection of topographic data. Sea conditions also prohibited launching the survey boat.

To salvage the rest of the work day, the crew devised yet another plan of attack. Reviewing available tidal data revealed that topographic data could be collected that evening just before sunset and into the night. Having already developed a feel for the topography during the morning's low tide period, the crew staked out survey lines by placing tall lathes on line above the berm as well as just above the high tide mark in areas devoid of major breaklines. The crew then returned to the motel for an early supper.

Returning to the job site later that evening, the crew stopped at a local sporting goods store to purchase battery-powered head lamps and chemical glow lights. As the sun was setting, the base station was established a second time and chemical glow lights attached to the lathes set earlier in the day. These illuminated lathes gave the roving RTK unit operators alignment guidance. Working in pairs with head lamps and flashlights, the two roving units worked well into the night collecting data from above the berm into the surf.

The next few days brought more high winds and cold weather. The crew continued in its early morning/late night RTK survey routine, completing the cross-sectional lines as well as the perimeter survey of the shore protection structures. To acquire RTK data alongside the groins, RTK teams again worked in pairs. One man wore the backpack that holds the GPS receiver, batteries, and radio gear and operated the data collector while walking atop the rock groins. The second man donned a wet suit and waded through the surf around the groin. A 100-foot-long antenna cable allowed the GPS antenna to be positioned alongside the groins while keeping the electronics in the backpack high and dry.

Hydro Data Collection

As the final RTK data was collected, the bad weather persisted and showed no signs of letting up. Unable to even launch the survey boat, the crew was forced to return to Jacksonville to wait out the weather.

In early January, the crew returned to Hilton Head Island with the sun shining and the sea laying flat. As the boat was being launched, a DGPS base station was set up at the monument that served as the RTK base station. One 4000SE GPS receiver occupied the base station while another was on the boat. An RTCM radio link sent corrections to the boat's receiver. The receivers provided DGPS horizontal positioning data accurate to about 1.5 feet.

The automated hydro survey boat was fully equipped with the GPS receiver, radio receiver, Innerspace Technology, Inc. (Waldwick, New Jersey) Model 449 200 kHz portable depth sounder, and an Austin Direct (Austin, Texas) 486 66 MHz PC loaded with Coastal Oceanographics, Inc.'s (Durham, Connecticut) HYPACK hydrographic data collection package. The survey boat began collecting data the minute it reached the survey area. The data collection software package provided graphical guidance to the helmsman, enabling him to travel along the preprogrammed survey lines. A sounding acquisition rate of approximately five soundings per second was chosen while positioning data was collected at a rate of two positions per second. The boat made quick work of the survey lines and the crew returned to the RTK surveying portion of the project.

The crew made good use of the excellent weather and sea conditions and backpacked across the entire exposed portion of the offshore sandbar, Joiner Bank. The cross-sectional lines were also extended well into the surf.

Upon returning to the room that evening, the hydro data was edited and tidal corrections applied. As a further quality assurance/quality control check, RTK-acquired elevations were compared to the elevations derived by echo soundings. Figure 3 illustrates the agreement between the two data sets.

The field portion of the survey being completed, the crew returned to the office to generate the final deliverables.

Summary

From a surveying standpoint, the project proved unique in that it was a nearly total GPS survey with a sizable portion of the topographic work being done at night. Static GPS observations were used to establish control monuments above the berm of the beach. Orthometric heights were determined for newly established points, based on the static network results. The network also provided the coordinate data needed to perform a datum transformation for "calibrating" the RTK system to the local area. Additionally, the network provided coordinate data for DGPS and RTK base and calibration check stations.

The authors would like to express their appreciation to Christopher Creed of Olsen Associates for providing project background information for this work. ▲

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