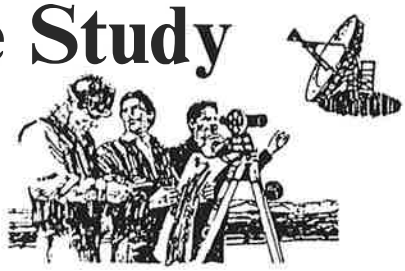
The Global Positioning System: A Case Study



Kenneth M. Slaugenhoupt

How GPS was used for a "Corridor" type survey and why it was so advantageous.

During the winter of 1986–87, the New York State Department of Transportation (NYSDOT) moved forward with plans to replace 19 aged bridges spanning the historic Erie Canal in Niagara County New York. These bridges were spread out between the City of Lockport and Village of Middleport in Niagara County and included both urban and rural settings. As with most such projects, aerial mapping of the sites and their approaches were the first steps needed.

One of the aftermaths of the tragic New York Thruway bridge collapse, which happened in early 1987, was naturally an increased sense of urgency in completing such rehabilitation projects. Early in the review of the survey needs for this work, it was known that although there was substantial control monumentation available in the City of Lockport, once outside the City limits both vertical and horizontal control became scarce. Alternatives were sought to speed the completion of the design phase.

The horizontal ground control for photogrammetry was required to meet a 1:25,000 closure, and the control needed to be secure for future use through the design and build phases of the projects as well as for supporting long-term survey needs in the area. Early in the process, it was determined that normal terrestial surveying between existing monuments (NGS) would involve traverses running between 11 and 15 miles to include three existing first-order control marks that had been recovered. In order to meet the closure specifications it was estimated that up to five crew weeks would be needed, together with supporting office time and administration to complete the effort. The price tag for that work was placed at around $19,000.

The New York State Department of Transportation hired our firm, Frank T. Tripi and Associates, P.C. (FTA), under a Term Agreement for Surveying Services to perform the surveys. We had twice earlier worked together with NYSDOT to perform Global Positioning System surveys for geodetic monument densification in the southern tier of western New York. GPS became available to the private sector of this country's surveying community in 1983, and has been blossoming ever since. Currently, there are several manufacturers of GPS equipment as well as service companies who will come and observe the data from your control points and provide a detailed report to you listing the locations in whichever format you prefer (latitude/longitude, state plane, etc.).

During the initial planning meeting, which was held on February 11, 1987, NYSDOT directed FTA to determine the feasibility and cost of, first, establishing new geodetic control monuments in the project areas using GPS, and then completing the photo control work using the resulting densified control scheme.

I was selected as the Project Manager for FTA and began by making a thorough review of current literature and contacting as many GPS firms as possible to gather data to establish a Scope of Services for that portion of the work and determine costs for the effort. Ultimately, five firms were identified for discussions and were sent Requests For Proposals based upon the developed Scope.

Initially, three NGS Control Marks were identified and recovered to supply the necessary references for the GPS work. They were "Upper," "Gasport," and "Medina," all first-order NGS points. NYSDOT had used monument Medina in the past and considered it suspect because of the difficulties previously encountered with it. These three monuments form a rough east-west line, in the middle of which were the various project sites. It was decided to set 10 "Monument Pairs" along the Erie Canal to maximize the advantage of the GPS. The advantage was defined as the amount of time and money that could be saved in the residual work needed after the GPS was complete to place all the control traverses where needed.

The high precision capabilities are not available through any other technique.

The Monument Pair concept results from the GPS technology and differs from the previous method of setting a primary mark and azimuth mark. With the pairs, both monuments are considered primary, both were set with subsurface marks and multiple references, and both were observed with equal care to establish New York State Plane Coordinate System, West Zone coordinates. That way, any surveyor could occupy either end of the line formed by the intervisable pairs, sight the other, and begin with reliable coordinates and grid azimuth. This concept is applicable to most "Corridor" type surveys where it would be advantageous to establish known baseline references at road crossings, river crossings, railroads, etc. Depending upon the specific GPS chosen for the work, reliable azimuths can be established between points as close together as a quarter mile.

A procedure was established to ensure efficiency during the GPS portion of the project. It was my responsibility to select the initial 20 monument sites, considering the parameters required for GPS observa-

Kenneth M. Slaugenhoupt, PLS/SRWA, Ch. 18, is a principal in the firm of Frank T. Tripi and Associates, P.C., Lewiston, New York. Over the past 8 years he has supervised surveys for boundary, topography, right of way, aerial photogrammetric control, and geodetic control.

tions and those required by NYSDOT to ensure long-term stability and safety of the points. From the GPS standpoint, primary concern is visibility by clear line of sight to those portions of the sky in which the usable Navstar Satellites will appear. This is accomplished by using "Visibility Diagrams," which are prepared from computer printouts listing azimuth and elevation of each satellite for various times during the observation window. Unfortunately, at this time there are only six or seven satellites (depending on the receiver used) available for such service. The Navstar satellites were being placed in orbit on a regular schedule by NASA's Shuttle Program. When the Challenger disaster occurred, this schedule of deployment was severely curtailed, and it appears it will now be 1990 or later before additional vehicles are placed into use.

For this specific project site and on the dates planned for observation, the observation window began at about 6:45 p.m. EDst and ran to almost midnight. During that period, the satellites rise above the horizon and traverse across the sky in various locations and then begin to set. Planning and scheduling of observations is the most critical element in performing a successful GPS project.

One advantage of GPS is that measurements can be obtained in practically any weather condition.

After I had staked the 20 proposed sites, I held a review trip with Mr. Norb Pleban and Mr. Larry Graziano of NYSDOT Region Five Survey Department. The purpose of this review was to assure security of placement from the NYSDOT's point of view. During that daylong effort, several of the points were relocated to provide safer locations. Then, on May 6th, a final review was made between a representative of Aero Service Corp. of Houston, Texas, the consultant selected for the GPS portion of the work, and Mssrs. Graziano and Baldwin of NYSDOT, and myself. Aero Services' responsibilities included the actual construction of the monuments and the observation of data, processing, analysis, and reporting of the new monument locations. Before having the monuments built at some expense, we wanted to make absolutely certain that the sites were both observable and secure. During this review, Mr. Steve Bell of Aero Service verified the observability of each site, and NYSDOT gave final approval for safety and security.

During the day, we discussed the fact that another control mark, Monument "Thirty," was available and quite observable by GPS. It was located on the southerly shore of Lake Ontario, about 12 miles from the project site. Because GPS can reach out many more miles than that, there was little reason not to include it in the control scheme. This provided a better check on the GPS traversing and a backup control point, unless Medina proved to be a problem.

Planning and scheduling of observations is the most critical element in performing a successful GPS project.

Once all three parties were satisfied that the locations selected for the permanent markers were acceptable, Aero Service was instructed to begin the monumentation. Because the monuments were to reach down 52 inches to be stabilized against potential frost heave, there existed an additional concern that the excavation could endanger any underground utilities in the area. Therefore, we called the local underground utility stakeout service, provided the specific location of each of the proposed excavations, and asked them to clear each site before the placement of the monument. Two companies called our office for details and were provided maps showing the locations.

The monuments were installed between May 14th and May 20th without incident—well, almost. In preparation for this work, I wrote letters to the various political leaders of the municipalities involved and the Niagara County Sheriff's Department, explaining what we would be doing and when. Although there was no need nor plans to enter private property, experience shows that landowners can be upset quickly by what they don't know or understand, and we were trying to have all parties prepared for those instances. One night, however, I received a call at home from the Sheriff's Deputies asking me to verify the story being given them by the monument installation crew. They had been spotted one evening working to install monuments and drawing water from the Erie Canal to make concrete. A worried landowner had called the Sheriff, who investigated by checking with me. Once I explained the situation, all seemed well and work progressed without further delay. It just goes to show that no matter how well you think you have planned everything, something always pops up.

Primary concern is visibility by clear line of sight to those portions of the sky in which the usable Navstar Satellites will appear.

Once the monuments were installed, our firm moved forward with the traversing between the GPS points that would be needed to complete the control schemes. This was well used time that allowed us to make good progress while we awaited arrival of the GPS observation crew who were finishing up a project in Ohio.

The observation crew arrived on Saturday, June 6th. I met with them at the motel that evening. We reviewed maps showing the location of all of the points to be occupied as well as the proposed observation schedule. The schedule was designed to allow three observations per evening. This meant that, with four units in use, three baselines per observation (traverse method), or nine per night, were measured. In order to complete the assignment, three nights would be required.

One of the many advantages of GPS is the fact that measurements can be obtained in practically any weather condition. Cloud cover, rain, snow, etc. do not affect the reception of the radio waves from the satellites. In this case, however, weather was fine on all three nights and everything went off without a hitch.

This concept is applicable to most "Corridor" type surveys. . .

The data collected during the three evenings was sent to Aero Service's Houston office for processing. At our request, the first observation to be reduced was the one that covered all four of the primary control points mentioned above. We wanted an opportunity to see how the GPS measurements would compare with the data published by the NGS. It must be noted here that all prior NYSDOT records were related to NAD 27 in the New York State Plane Coordinate System, West Zone. The more recent adjustment, NAD 83 has con-

Table 1. Comparison of GPS Measurements to NAD 27 and NAD 83 State Plane Coordinate Data: Lockport/Eastern Niagara County Canal Study

Course	NAD 27 Inverse	NAD 27 Relative Error	Indicated NAD 27 error	NAD 83 Inverse	NAD 83 Relative Error	Indicated NAD 83 Error
Gasport-Upper	57,510.40	1:88,000	0.654 foot	57,510.72	1:566,000	0.102 foot
Gasport-Medina	49,122.61	1:101,000	0.486 foot	49,122.90	1:267,000	0.184 foot
Gasport-Thirty	65,576.20	1:88,000	0.745 foot	65,576.87	1:425,000	0.154 foot
Upper-Thirty	102,198.95	1:119,000	0.859 foot	102,199.60	1:622,000	0.164 foot
Thirty-Medina	70,125.60	1:104,000	0.674 foot	70,125.94	1:308,000	0.228 foot
Upper-Medina	106,492.10	1:92,000	1.158 feet	106,492.75	1:288,000	0.370 foot

sistently shown a better relationship to GPS results where state plane data was needed. The NAD 83 adjustment is in fact more accurate, perhaps because of the availability of powerful computers. Anyway, we requested the comparisons be made to both NAD 27 and NAD 83 in terms of relative error of closures.

I received the information over the telephone so a quick decision could be made. The results were as shown in Table 1. It can be quickly seen that much better closures were obtained using NAD 83 coordinates; however, for the purposes of this work, very satisfactory results were obtained in the NAD 27 as well. It is interesting to note that closures were relatively worse when the monument Medina was included in the course. Also, when the GPS-measured vectors from Medina to the other control monuments were reviewed, there is considerable evidence that the published location of Medina may be significantly south of its real position. When vectored from Medina, monument Thirty was found 43 mm south, monument Upper was found 94 mm south, and Gasport was 56 mm south. I believe there is some credence to the prior concern as to the location of Medina; however, in terms of practical survey precision it was not substantial enough to warrant abandonment of NGS control. Therefore the decision was made by NYSDOT to balance all of the new monuments, giving even weight to Upper, Gasport, and Medina.

Although the cost of GPS equipment is still high, this application was very cost-effective.

In comparison to the estimated cost to perform this work traditionally, the cost for the GPS element of the project was $14,600. In addition, $7,200 was spent to construct monumentation, and an additional $2,300 was spent to compute all monument locations in the NAD 83 basis for future use.

With the GPS monuments in place, the individual sites were easy to control horizontally, saving probably one third of the time that would have been needed otherwise.

Although the cost of GPS equipment is still high, this application was very cost-effective. In the future, those costs will continue to drop, making GPS the clear choice for large scale control projects. The high precision capabilities are not available through any other technique, so for deformation studies and geodetic control, it is far and away the best option even now. Everyone in the survey and engineering field needs to become aware of GPS and comfortable with its use. Our firm has chosen to move forward immediately with in-house capabilities for our clients. This is clearly a technology for today. (IRWA)