# Establishing Local GPS Base Stations using GrafNet and a Network of Long Baselines

**Waypoint Consulting Inc.**

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## Introduction

The purpose of this report is to demonstrate how to use GrafNet to establish a local base station by using a network of long baselines. This is often necessary when a DGPS survey is being performed in an area with no local control. The four examples provided in this paper use CORS stations from different regions across the United States. The networks are located in: New England, the Mid-West, Alaska, and the Southeastern United States.

## Background

For each of the networks mentioned above, one full day of GPS data was downloaded from the National Geodetic Survey (NGS) for four CORS stations. One station in each network is considered to be the unknown point that we wish to make a local base station, while the other three are considered known. The four networks are shown in Figures 1 through 4. Table 1 on the following page shows the points that make up each network, and whether we consider each point known or unknown.

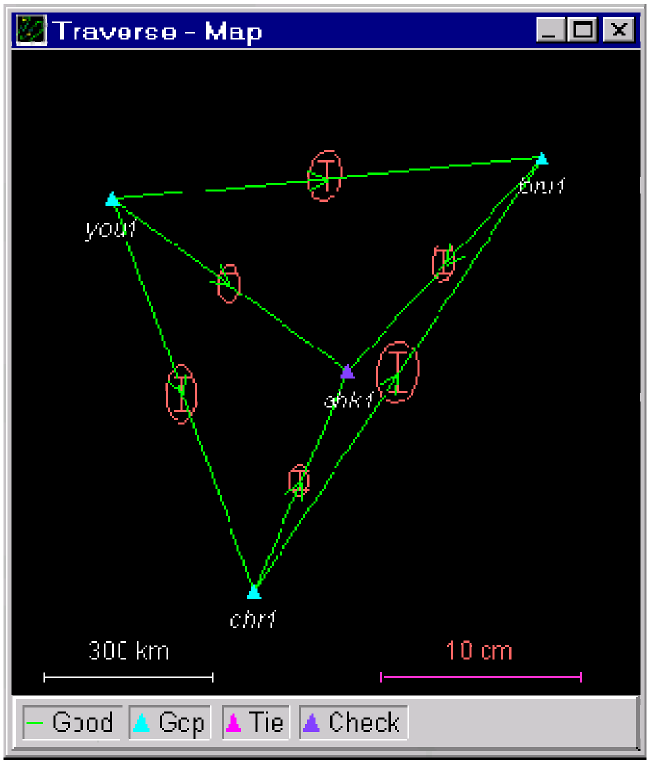

**Figure 1: The New England Network**

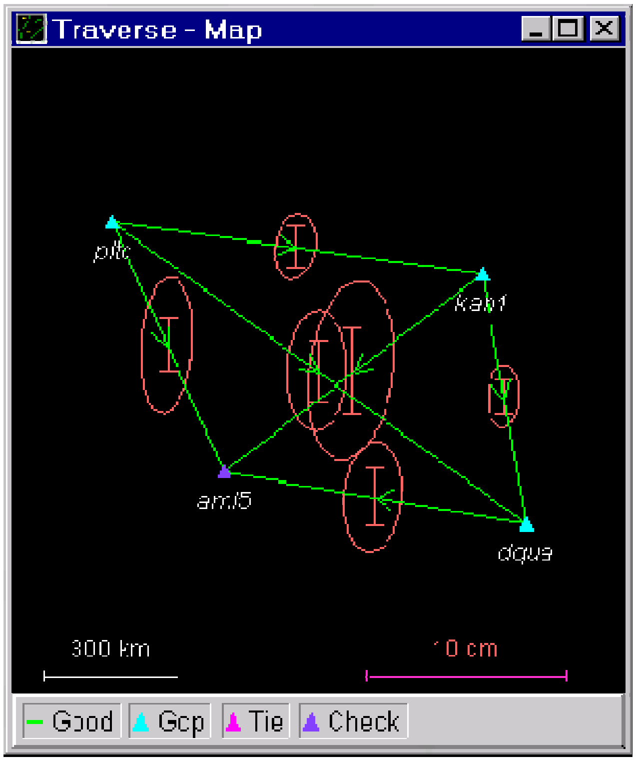

**Figure 2: The Mid-West Network**

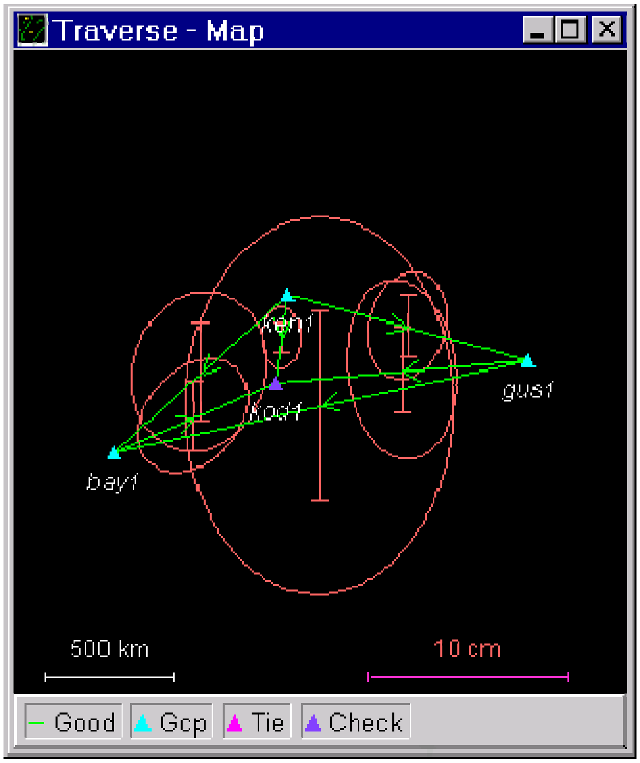

**Figure 3: The Alaska Network**

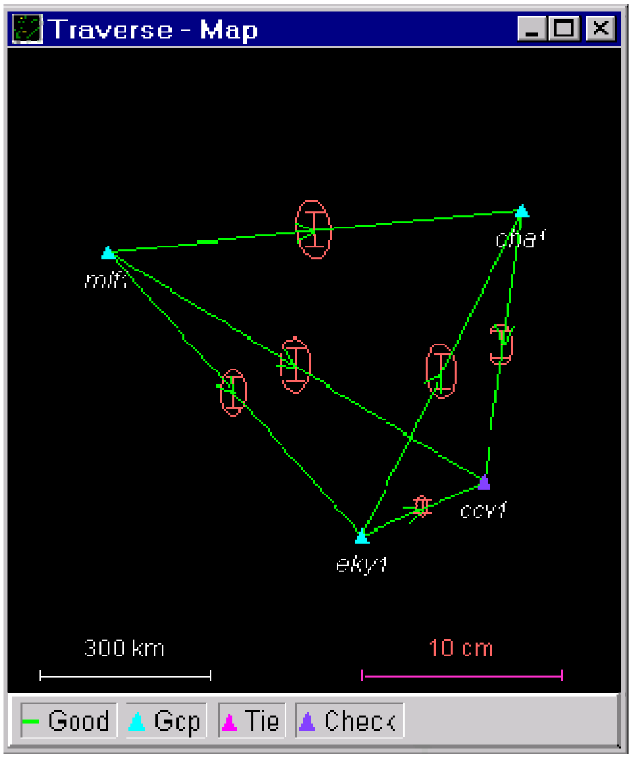

**Figure 4: The South-East Network**

**Table 1: The Four Example Networks**

| Network | Alaska | Mid-West | New England | South-East US |
|---|---|---|---|---|
| Unknown Pt | kod1 | aml5 | shk1 | mlf1 |
| Known Pts | bay1 | pltc | you1 | cha1 |
| | ken1 | kan1 | bru1 | ccv1 |
| | gus1 | dqua | chr1 | eky1 |

## Measurement Errors for Long Baselines

Usually when DGPS data is processed, the measurement errors that occur at each station are very similar, and they cancel each other out when the differences between the observations are taken. This is true for short baselines; however as the length of the baseline increases, the errors affecting the observations made at each station differ more and more. When observations at stations on long baselines are differenced, a larger portion of the measurement errors remains.

It is possible to minimize three kinds of measurement errors prior to taking the differences between observations. These errors include the ionospheric errors, the satellite position errors, and the selective availability errors (SA). Ionospheric errors can be eliminated using the Ionosphere-free processing mode. The GPS data must be dual-frequency data for this to work. The satellite position errors and SA can be eliminated almost completely by using the precise ephemeris.

## Procedure

Two methods were implemented to establish the new base station. The coordinates computed from both methods were checked against the known coordinates of the new base station. In both cases, ionosphere-free processing and the precise ephemeris were used. To assist in the explanation of the two methodologies used, one of the networks, specifically the New England network, will be used as a demonstration.

The first methodology that was used involved fixing the coordinates of only one of the known points in the network and using it as a ground control point (GCP). For the New England network, the point you1 was fixed. The other two known points are used as checkpoints; their known coordinates are compared with the coordinates that are computed in the adjustment. This kind of adjustment is known as a minimum constraint adjustment.

In the second methodology, all three of the known points are fixed and used as GCPs, and only the coordinates for the unknown point shk1 are computed. In this case, we have an over-constrained network. With this procedure, we can only compare the coordinates of shk1 with its known coordinates. An advantage of this procedure over the first one is that the observations between the GCPs and the point of interest are all independent of each other.

In both procedures, the GCPs' coordinates were assigned a standard deviation of 0.005m. This allowed them to move a bit, but not much considering the lengths of the baselines in the networks.

## Results

When comparisons between computed coordinates and known coordinates were made (see Tables 2 and 3 below), for both methods, we found that the computed coordinates for an unknown base station were considerably better when three GCPs were used as opposed to when one GCP was used.

**Table 2: Discrepancies between Computed Coordinates and True Coordinates using Three GCPs**

| Network | Point | RE (m) | RN (m) | RH (m) |
|---|---|---|---|---|
| New England | shk1 | 0.0149 | 0.0123 | -0.0878 |

| | | | | |
|---|---|---|---|---|
| Mid-West | aml5 | -0.0208 | 0.0313 | -0.0333 |
| Alaska | kod1 | -0.0228 | 0.0328 | 0.0277 |
| South-East | ccv1 | 0.0135 | 0.0015 | 0.0038 |
| | RMS | 0.0184 | 0.0235 | 0.0490 |

**Table 3: Discrepancies between Computed Coordinates and True Coordinates using One GCP**

| Network | Point | Point Type | RE (m) | RN (m) | RH(m) |
|---|---|---|---|---|---|
| New England | shk1 | New Base | 0.0083 | 0.0297 | -0.1438 |
| | bru1 | Check Point | -0.0463 | 0.0190 | -0.0600 |
| | chr1 | Check Point | 0.0170 | 0.0321 | -0.0998 |
| | | | | | |
| Mid-West | aml5 | New Base | -0.0186 | 0.0379 | -0.1845 |
| | dqua | Check Point | 0.0256 | 0.0246 | -0.2069 |
| | pltc | Check Point | 0.1020 | 0.0125 | -0.1886 |
| | | | | | |
| Alaska | ko1 | New Base | -0.0321 | 0.0503 | -0.0067 |
| | bay1 | Check Point | 0.0043 | -0.0503 | -0.0067 |
| | gus1 | Check Point | 0.0173 | 0.1719 | -0.1981 |
| | | | | | |
| South-East | ccv1 | New Base | -0.0338 | -0.0017 | 0.0921 |
| | cha1 | Check Point | -0.1383 | -0.0186 | 0.2315 |
| | mlf1 | Check Point | 0.0005 | -0.0331 | -0.0502 |
| | | | | | |
| | | RMS | 0.0544 | 0.0582 | 0.1467 |

Since the results presented above were derived from networks of six baselines each, it is not possible to give an exact value for the relative accuracy obtained. Tables 4 and 5 below present the best and worst relative errors found in each of the networks. It should be noted that even though all of the networks were designed so that most of the baselines were between 500km and 750km in length, the Alaska-network's shortest baseline is 344km long, and the South-East-network's shortest baseline is 238km. These two baselines are the reason for the slightly higher than expected worst-case relative errors found in Tables 4 and 5.

**Table 4: Best and Worst Relative Errors using Three GCPs**

| Network | Best Relative Horizontal Error (ppm) | Worst Relative Horizontal Error (ppm) | Best Relative Vertical Error (ppm) | Worst Relative Vertical Error(ppm) |
|---|---|---|---|---|
| New England | 0.06 | 0.07 | 0.17 | 0.20 |
| Mid-West | 0.05 | 0.06 | 0.05 | 0.06 |
| Alaska | 0.06 | 0.12 | 0.04 | 0.08 |
| South-East | 0.02 | 0.06 | 0.01 | 0.02 |

**Table 5: Best and Worst Relative Errors using One GCP**

| Network | Best Relative Horizontal Error (ppm) | Worst Relative Horizontal Error (ppm) | Best Relative Vertical Error (ppm) | Worst Relative Vertical Error(ppm) |
|---|---|---|---|---|
| New England | 0.06 | 0.12 | 0.12 | 0.33 |
| Mid-West | 0.05 | 0.17 | 0.26 | 0.34 |
| Alaska | 0.05 | 0.50 | 0.01 | 0.5 |
| South-East | 0.04 | 0.58 | 0.07 | 0.97 |

## Conclusions

The results obtained from the two procedures were not entirely expected. When adjusting a network of long baselines using a minimum constraint adjustment in general, about 6cm of accuracy can be expected horizontally and about 15cm vertically. When three points other than the point of interest are held fixed, 3cm of accuracy horizontally and 5cm vertically can be expected.

These results seem counter intuitive at first, since an over-constrained adjustment will generally result in distortions in a network. However, by fixing three GCPs, the baselines going the point of interest (i.e. the new base station) become independent of each other. When all of these baselines become independent measurements, the redundancy in the network rises dramatically, and as a result, increases the accuracy of the network. An important prerequisite for using multiple GCPs is that the coordinates for all of the GCPs must be known very accurately. If this is not the case, the results from a network with multiple GCPs will yield results that are greatly distorted.