14 GLOBAL NAVIGATION SATELLITE SYSTEMS—STATIC SURVEYS

Asterisks (*) indicate problems that have partial answers given in Appendix G.

14.1 For a 25-km baseline using a dual-frequency receiver, (a) what static surveying method should be used, (b) for what time period should the baseline be observed, and (c) what epoch rate should be used?

(a) Static survey (b) 70 min (c) 15 sec

From Section 14.2.2: Baselines over 20 km should be surveyed using the static survey method. From Table 14.1 the length of the session with a dual-frequency receiver should be 20 + 2(25) = 70 min. From Section 14.2.1, the epoch rate using the static survey method is typically set at 15 sec.

14.2* When using the static surveying method, what is the minimum recommended length of the session required to observe a baseline that is 30-km long with a dual-frequency receiver?

From Table 14.1: **40 min** = 10 min + 1(30) min

14.3 What would be the recommended epoch rate for the survey given in Problem 14.2?

From Section 14.2.2, the typical epoch rate is **5 sec**.

14.4 What defines a GNSS observation session in a static survey?

From Section 14.1: "An observation session denotes the period of time during which all receivers being employed on a project have been setup on designated stations, and are simultaneously engaged in receiving signals from the same satellites. When one session is completed, all receivers except one are generally moved to different stations and another observation session is conducted. The sessions are continued until all planned project observations have been completed."

14.5 What variables affect the accuracy of a static survey?

From Section 14.1: Besides what is mentioned in Section 13.6, other important variables that bear on the accuracy of a static survey include the (1) accuracy of the reference station(s) to which the survey will be tied, (2) number of satellites visible during the survey, (3) geometry of the satellites during the observation sessions, (4) atmospheric conditions during the observations, (5) lengths of observation sessions, (6) number and nature of obstructions at the proposed receiver stations, (7) number of redundant observations taken in the survey, and (8) method of reduction used by the software.

14.6 Why are dual-frequency and GNSS receivers preferred for high-accuracy control stations?

Highest accuracies will be achieved by GNSS and dual-frequency receivers because of their ability to correct for clock bias and refraction. GNSS receivers have the additional advantage of being able to use satellites from 2 or more constellations resulting in increased observational numbers.

14.7 What site conditions are required for a good GNSS session?

From Section 14.3.4: "Once the existing nearby control points and new stations have been located on paper, a reconnaissance trip to the field should be undertaken to check the selected observation sites for (1) overhead obstructions that rise above 10° to 20° from the horizon, (2) reflecting surfaces that can cause multipathing, (3) nearby electrical installations that can interfere with the satellite's signal, and (4) other potential problems."

14.8 Why is it recommended to use a precise ephemeris when processing a static survey?

From 14.5, paragraph 3 and Section 13.6.3: The broadcast ephemeris is a near-future prediction of the location of the satellites whereas a precise ephemeris is their tracked position. Thus orbital errors are removed by processing with a precise ephemeris.

14.9 What are the recommended rates of data collection in a **(a)** static survey, and a **(b)*** rapid static survey?

(a) **<u>15 sec</u>**

(b)* **<u>5 sec</u>**

14.10 List the fundamental steps involved in planning a static survey.

From Section 14.3:

1. Obtain the location of the nearest existing control/reference stations
2. Recon the project area and locate suitable locations for new control
3. Select the appropriate survey method
4. Check satellite availability during observation sessions and space weather forecast.
5. Develop a observational scheme.

***14.11** How many nontrivial baselines will be observed in one session with three receivers?

<u>2</u> By Equation (14.1a): $(3 - 1) = 2$

14.12 What are the requirements of a base receiver in a static survey?

From Section 14.2.1: "The process begins with one receiver (called the *base receiver*) being located on an existing control station, while the remaining receivers (called the *roving receivers*) occupy stations with unknown coordinates."

14.13 A site has some overhead obstructions that are over 10° in altitude. What steps should occur in presurvey planning?

From Section 14.3.1: An obstruction diagram should be overlaid a satellite sky plot to find the best times of day to occupy the station.

14.14 How many trivial baselines will be created if five GNSS receiver simultaneously collect data during a session?

<u>6</u>; By Equation (14.1c): $t = (5 - 1)(5 - 2)/2$

14.15 Describe what a trivial baseline is in a static survey.

From Section 14.3.4 "If more than two receivers are used, both nontrivial and *trivial* (*mathematically dependent*) baselines will result."

14.16 Why should buildings be avoided for station locations in a GNSS survey?

From Section 14.3.3: "Once the existing nearby control points and new stations have been located on paper, a reconnaissance trip to the field should be undertaken to check the selected observation sites for (1) overhead obstructions that rise 10° to 15° from the horizon, (2) reflecting surfaces that can cause multipathing, (3) nearby electrical installations that can interfere with the satellite's signal, and (4) other potential problems."

From Section 14.6.2: "Thus, the best approach to reducing this problem is to avoid setups near reflective surfaces. Reflective surfaces include flat surfaces such as the sides of building, vehicles, water, chain link fences, and so on."

14.17 What is National Spatial Reference System?

From Section 14.3.: "The HARN and CORS stations make up what is known as the *National Spatial Reference Frame*."

14.18* When using three receivers, how many sessions will it take to independently observe all the baselines of a hexagon?

<u>5 sessions</u>; Using Equations (14.1): 2 nontrivial lines per session with a total of 10 lines.

14.19 Plot the following ground obstructions on a obstruction diagram.

(a) From an azimuth of 65° to 73° there is a building with an elevation of 20°.

Student graphic

(b) From an azimuth of 355° to 356° there is a pole with an elevation of 35°.

Student graphic

(c) From an azimuth of 125° to 128° there is a tree with an elevation of 26°.

Student graphic

14.20* In Problem 14.19, which obstruction is unlikely interfere with GPS satellite visibility in the northern hemisphere?

(b) because the obstruction is in near pole and GPS' inclination angle prevents satellites near the polar region.

14.21 In preplanning it is noticed that for 20 min there is only one satellite in the NW quadrant of the sky plot. An obstruction will block this satellite for five min during this time.

(a) What concerns should this raise about the survey at this site?

The obstruction will cause a loss of lock on the satellite in the NW quadrant and will likely cause high PDOP during this time.

(b) What can be done to ensure a successful survey at this site?

The easiest solution is to avoid occupation of this station during this time period. The other possibility is to use the static survey method, which can often survive poor observation conditions due to the length of the session and the changes in geometry over the session.

14.22 Why should the height of the antenna be listed on the site log sheet?

From Section 14.5: "As the observation files are downloaded, special attention should be given to checking station information that is read directly from the file with the site log sheets. Catching incorrectly entered items such as station identification, antenna heights, and antenna offsets at this point can greatly reduce later problems during processing."

14.23 What is a satellite availability chart and how is it used?

From Section 14.3.1, paragraph 5: "To aid in selecting suitable observation windows, a satellite availability plot, as shown in Figure 14.7, can be applied." It also shows the PDOP, HDOP, and VDOP, which allows the user to pick the optimal time to collect observations.

14.24* What order of accuracy does a survey with a standard deviation in the geodetic height difference of 15 mm between two control stations that are 5 km apart meet?

Fourth order, Class II; $\frac{15}{\sqrt{5}} = 6.71$, which is under 4th order, class II of 15.0.

14.25 Do Problem 14.24 when the standard deviation in the geodetic height difference is 8.3 mm for two control points 15 km apart?

Third order, Class II; $\frac{8.3}{\sqrt{15}} = 2.14$, which is under 3rd order, class II of 3.0.

14.26 Use the NGS web site to download the station coordinates for the nearest CORS station.

Answers will vary.

14.27 What are CORS and HARN stations?

From Section 14.3.5, paragraph 2: "In recent years, the NGS with cooperation from other public and private agencies has created a national system of ***C****ontinuously* ***O****perating* ***R****eference* ***S****tations*, also called the *National CORS Network*. The location of stations in the CORS network as of 2003 is shown in Figure 14.12. As of January 2007 there are 1221 CORS stations. These stations not only have their positions known to high accuracy,[4] but they also are occupied by a receiver that continuously collects satellite data. The collected data is then downloaded and posted on the NGS Internet site at http://www.ngs.noaa.gov/CORS/."

From Section 14.3.5, paragraph 1: "To meet this need, individual states, in cooperation with the NGS, have developed ***H****igh* ***A****ccuracy* ***R****eference* ***N****etworks* (HARNs). The HARN is a network of control points that were precisely observed using GPS under the direction of the National Geodetic Survey (NGS)."

14.28 Why should repeat baselines be performed in a static survey?

From Section 14.5.3: "Another procedure employed in evaluating the consistency of the observed data and in weeding out blunders is to make repeat observations of certain baselines. These repeat measurements are taken in different observing sessions and the results compared. Significant differences in repeat baselines indicate problems with field procedures or hardware."

14.29 What is typically listed on a site log sheet?

From Section 14.4: "While the data is being logged, other ancillary information at the site can be collected and recorded. Typical ancillary data obtained during a survey includes (1) project and station names, (2) ties to the station, (3) a rubbing or photo of the monument cap, (4) panoramic photos of the setup showing identifying background features, (5) potential obstructive or reflective surfaces, (6) date and session number, (7) start and stop times, (8) name of observer, (9) receiver and antenna serial number, (10) meteorological data, (11) PDOP value at the start and end of the session, (12) antenna height, (13) orientation of antenna, (14) rate of data collection (epoch rate), and (15) notations on any problems experienced."

14.30 Using loop *ACDFA* from Figure 14.6, and the data from Table 14.6, what is the

(a) Misclosure in the X component? **15.1 mm**

(b) Misclosure in the Y component? **17.6 mm**

(c) Misclosure in the Z component? **14.0 mm**

(d) Length of the loop misclosure? **24,267.5 m**

(e)* Derived ppm for the loop? **1.12 ppm**

14.31 Do Problem 14.30 with loop *ABDEA*.

(a) Misclosure in the X component? **51.2 mm**

(b) Misclosure in the Y component? **5.8 mm**

(c) Misclosure in the Z component? **6.6 mm**

(d) Length of the loop misclosure? **23,282.9 m**

(e) Derived ppm for the loop? **2.23 ppm**

14.32 Do Problem 14.30 with loop *BFDB*.

Note: Answers may vary slightly if students use baseline *FB*.

(a) Misclosure in the X component? **−2.1 mm**

(b) Misclosure in the Y component? **−4.4 mm**

(c) Misclosure in the Z component? **9.7 mm**

(d) Length of the loop misclosure? **17,877.7 m**

(e) Derived ppm for the loop? **0.61 ppm**

14.33 A survey list the standard deviation in geodetic height of ±6.5 mm, which was derived from a baseline that is 5 km long. What NGS geodetic height order and class does this meet?

3rd Order, Class II, since b is less than 3.0; $b = \frac{6.5}{\sqrt{5}} = 2.91$

14.34 The observed baseline vector components in meters between two control stations is (1120.1968, −6953.0053, 328.9602). The geocentric coordinates of the control stations are (1,162,247.650, −4,882,012.315, 4,182,563.098) and (1,163,367.854, −4,888,965.343, 4,182,892.034). What are:

(a)* ΔX ppm? **1.02 ppm**

(b) ΔY ppm? **3.22 ppm**

(c) ΔZ ppm? **3.43 ppm**

14.35 Same as Problem 14.34 except the two control station have coordinates in meters of (1,130,295.165, −5,498,572.893, 3,018,271.182) and (1,130,898.370, −5,497,676.648, 3,019,382.416), and the baseline vector between them was (603.2066, 896.2442, 1111.2325).

(a) ΔX ppm? **<u>1.03 ppm</u>**

(b) ΔY ppm? **<u>0.52 ppm</u>**

(c) ΔZ ppm? **<u>0.97 ppm</u>**

14.36 Baseline *EA* for Figure 14.6 is resurveyed at a later time as (5321.7122, −3634.0702, −3173,6614). What is

(a)* ΔX ppm? <u>0.58 ppm</u>

(b) ΔY ppm? <u>0.72 ppm</u>

(c) ΔZ ppm? <u>0.53 ppm</u>

14.37 Repeat Problem 14.36 for baseline *CF* of Figure 14.6, which was as (−10,527.7798, 994.9434, 956.6185).

(a) ΔX ppm? **<u>0.51 ppm</u>**

(b) ΔY ppm? **<u>0.54 ppm</u>**

(c) ΔZ ppm? **<u>0.57 ppm</u>**