Chapter 11

ADJUSTED GRAVITY CONTROL (GRAV ADJU) DATA

INTRODUCTION

This chapter provides detailed specifications and instructions for the coding and keying of adjusted gravity control (GRAV ADJU) data. As explained in Chapter 9, GRAV ADJU data can only be accepted for inclusion into the NGS gravity working file. Since the connecting observations are not available these adjusted values cannot be fully verified and are not appropriate for entry into the NGS gravity data base. GRAV DESC data are not required to accompany GRAV ADJU data, since GRAV ADJU data will not be entered into the NGS gravity data base.

The NGS gravity data base contains values for control points which have been fully verified by NGS and for which NGS has the appropriate descriptions. The gravity working file contains values for survey points that cannot be verified and/or for which NGS does not have the descriptions. The NGS gravity working file is none-the-less an extremely useful file, one on which most geoid modelling and evaluation depend. The NGS gravity data base, however, contains all information about stations and observations and is much more informative when temporal or localized studies are conducted. The rather limited definition of a data base by NGS should not be construed by a potential user that the working file is a substandard file.

The format for the submittal of GRAV ADJU data is significantly different from the formats for the submittal of GRAV OBS and GRAV DESC data. The general format of GRAV ADJU data is the same as that specified by the Department of Defense (DOD) Gravity Services Branch (Gravity Station Data Card Format). A copy of the DoD Gravity Coding Sheet is included in Figure 11-1 at the end of the chapter for reference purposes only. Figure 11-2 should be used when submitting data to NGS, since it reflects the actual format used at NGS.

NGS employs a subset of the strict DoD format. The following is a discussion of those elements of the DoD format which NGS employs. Some of the elements of the strict DoD format are not appropriate for general users and depend on agency policy.

A block diagram illustrating the respective format has been prepared to serve as a model for the Adjusted Gravity Station Data Record. A record is a string of characters containing data coded into a specific format. Every record in a GRAV ADJU data set consists of 80 characters called columns (standard punch card format). Within each record the 80 columns are divided into fixed length "character fields", each field being the space reserved for a specific data item. Accordingly, for every desired data item, there exists a field of appropriate length in which the data items are converted into strings of alphanumeric characters. The set of rules by which specific data items are converted into strings of alphanumeric characters to be entered in the fields of a record is known as the "format" of that record.

ADJUSTED GRAVITY STATION DATA RECORD

The Adjusted Gravity Station Data Record is the only record type allowable for submission of ADJU data for inclusion into the gravity working file. The entries on this record are for the most part self-explanatory. Those which are either Department of Defense specific or require elaboration will be explained in greater detail.

SECURITY CLASSIFICATION
This code identifies proprietary or sensitive data. The following codes should be used:

U or blank = Unclassified material
F = Material classified FOR OFFICIAL USE ONLY

The following codes should be used where DoD classified data are involved:

C = Material classified CONFIDENTIAL
S = Material classified SECRET

As a general policy, NGS will only accept classified data on a case by case basis.

SECURITY CONTROL
The security control code identifies the appropriateness of data dissemination to the public. The general submission of data to NGS requires that this data field be either left blank or the code 4 used. The remaining codes are DoD specific and should not be used by other agencies. The following are the codes:

0 or Blank = No Security Control
1 = (DoD specific) Limited Dissemination, to full-time employees of Department of Defense, Central Intelligence Agency, and Department of Energy
2 = (DoD specific) Not releasable to foreign nationals
3 = (DoD specific) Limited dissemination, not releasable to foreign nationals
4 = Special release from originating agency required for dissemination to any third party
5 = (DoD specific) Modified Handling authorized (includes Foreign "restricted," NATO, CENTO, SEATO, etc.)

GEOGRAPHIC UNITS
The geographic units code defines the units of the geographic coordinates of the gravity station in degrees and decimal minutes or degrees, minutes and seconds or decimal degrees. The following codes should be used:

0 or blank = degrees and minutes to .01 minute
1 = degrees, minutes and seconds (The preferred NGS Geographic Units)
2 = degrees to .0001 degree

TYPE of ELEVATION
The type of elevation code indicates where the adjusted value is located. The following codes should be used:

1 = land
2 = subsurface
3 = ocean surface
4 = ocean submerged
5 = ocean bottom
6 = lake surface (above sea level)
7 = lake bottom (above sea level)
8 = lake bottom (below sea level)
9 = lake surface (above sea level) with lake bottom below sea level
A = lake surface (below sea level)
B = lake bottom (surface below sea level)
C = ice cap (bottom below sea level)
D = ice cap (bottom above sea level)
E = helicopter gravity survey over either land or ocean.

ELEVATION UNITS

The elevation unit code defines the units of elevation in meters, feet, or fathoms. The following codes should be used:

0 or blank = meters (the preferred units of measure for NGS)
1 = feet
2 = fathoms

ELEVATION

The elevation is the height of a gravity station above the geoid (approximately sea level), except when the TYPE OF ELEVATION (column 21) is coded as 3, 4, or 5. When the TYPE OF ELEVATION is coded as 3, 4, or 5 the elevation will be the depth of the ocean.

SUPPLEMENTAL ELEVATION

The supplement elevation will be the depth of instrument, lake, or ice, positive downward from the surface. The SUPPLEMENTAL ELEVATION should be used only if the TYPE of ELEVATION (column 21) is coded as a 2, 4, 6 through 9, or A through E (see ANNEX O). In helicopter gravity surveys, the supplemental elevation is the flying height of the helicopter above sea level.

ADJUSTED GRAVITY

Adjusted gravity is the value of gravity, based on IGSN-71 or the U.S. Absolute Gravity Datum, at a specific location. DoD refers to this field as "Observed gravity" on the DoD Gravity Coding sheet (Figure 11-1). The value to be coded in this field is the adjusted gravity value minus 976000.0 milligals.

FREE-AIR ANOMALY

A gravity anomaly is the difference between an adjusted gravity value which has been reduced to an equipotential surface known as the geoid and the corresponding normal gravity value on an ellipsoid. The ellipsoid is chosen so as to be a best fit to the geoid. A free-air anomaly is the difference between an adjusted gravity value which has been reduced to sea level (in an approximation of the geoid surface) and the corresponding normal gravity value on the reference ellipsoid. The correction for the sea level height of the gravity station (+0.3086 milligals/meter) is called the free-air correction. Because the actual

vertical gravity gradient at the gravity station is usually not known, the normal ellipsoidal gravity gradient is used for the free-air correction.

$$A_{fa} = (g_a + f_a) - \gamma$$

where A_{fa} = free-air anomaly
g_a = adjusted gravity value
f_a = free-air correction, which is +0.3086 milligals/meter
γ = gravity on the ellipsoid

The gravity formula of the Geodetic Reference System of 1967 is used for the calculation of gravity on the ellipsoid.

$$\gamma = 978031.85\ (1 + 0.00527\ 8895 \sin^2\phi + 0.00002\ 3462 \sin^4\phi) \text{milligals.}$$

where ϕ is the geodetic latitude of the gravity station.

The computation of free-air anomalies with various types of observations is given in the Anomaly Computation Chart (ANNEX O).

BOUGUER ANOMALY

The Bouguer anomaly is derived from the free-air anomaly by subtracting the gravitational attraction of an infinite plate mass between the gravity station and sea level. With an assumed crustal density of 2.67 g/cm, the Bouguer correction is 0.1119 milligals/meter of station elevation (mean sea level height). A simple Bouguer anomaly assumes that the mass between the gravity station and the geoid is an infinite flat plate with no density variations. It is calculated by:

$$A_b = (g_a + f_a - S) - \gamma$$

where A_b = Simple Bouguer Anomaly
g_a = adjusted gravity
f_a = free-air correction
S = Bouguer plate correction, which is 0.1119 milligals/meter times the elevation for an assumed crustal density of 2.67 g/cm
γ = gravity on the ellipsoid

The computation of Simple Bouguer Anomalies with various types of observations are given in the Anomaly Computation Chart (ANNEX O).

Because the mass between the gravity station and the sea level is not flat, the plate correction can be supplemented by a terrain correction. This correction is always positive and accounts for the actual topography surrounding the gravity station. An anomaly derived this way is known as either a terrain corrected Bouguer Anomaly or a complete Bouguer Anomaly and is calculated by:

$$A_c = (g + f - S + T) - \gamma$$

where A_c = complete Bouguer Anomaly
T = Terrain Correction

An Isostatic Anomaly is obtained when corrections for the density variations in the crust and upper mantle are added to the Bouguer Anomaly. If the Bouguer Anomaly included a terrain correction, the derived Isostatic Anomaly is a Terrain Corrected Isostatic Anomaly. These anomalies are calculated by:

$$A_i = (g_a + f_a - S + I) - \gamma$$
$$A_{it} = (g_a + f_a - S + I + T) - \gamma$$

where A_i = Isostatic Anomaly
A_{it} = Terrain corrected Isostatic Anomaly
I = Isostatic Correction

ISOSTATIC ANOMALY OR TERRAIN CORRECTION CODE:
The purpose of this field is to indicate which type of anomaly is in the Bouguer Anomaly field. The following codes should be used:

0 = Bouguer Anomaly.
1 = Terrain corrected Bouguer Anomaly.
2 = Isostatic anomaly.
3 = Terrain corrected Isostatic Anomaly.

SOURCE CODE
The source code is DoD specific and is assigned by DoD. Other submitting agencies should leave this field blank.

BASE REFERENCE STATION CODE
The base reference station code is used to identify the base station location used to determine the adjusted value of the gravity. This field is DoD specific and should be left blank by agencies outside of DoD. Agencies familiar with DoD policy may choose to use this field. Its use, however, is explicitly optional.

BASE REFERENCE SITE
The base reference site identifies the occupied point at the base station location. This field is DoD specific and should be employed only by DoD or agencies familiar with DoD policy.

GRAVITY STATION NUMBER
A gravity station number is assigned to each station within one source code. The gravity station number basically serves the same purpose as the SPSN for a GRAV OBS data set. Its use is agency specific and optional for the purpose of transmitting data to NGS.

FILE MAINTENANCE
This code is inactive and should be left blank.

ESTIMATION STANDARD DEVIATION FREE-AIR ANOMALY AND BOUGUER ANOMALY
This value is an estimation of the standard deviation of the Bouguer Anomaly. Standard Deviation (Error) connotes that there is a 68% probability that the free-air or Bouguer anomalies will fall between the indicated + or - values: e.g., if the free-air anomaly is 10 milligal with a ±2 milligal error or standard deviation, then there is 68% probability that the value lies between 8 and 12 mgals.

FORMAT DIAGRAM

For the Adjusted Gravity Station Data record (see Table 11-2), a block diagram has been prepared to illustrate the format. This 'format diagram' has been designed to fulfill the following objectives:

1. Each record is 80 characters long (standard punched card image).

2. Each record has fixed format, i.e., every data field has a specific length and specific position within the record.

3. Each format diagram is a graphic image of the respective record.

4. Within the limits of available space, information and instructions concerning the data item to be entered in each data field are provided on the format diagrams to render them self-explanatory.

5. When appropriate, sample entities are shown in the data entry line of each format diagram.

6. Each data field is characterized as to its type by a string of lower-case characters which appear immediately below the data entry line.

DATA FIELD TYPES

1. Alpha Field (aa...a) - intended for a data item which is coded as a string of alphabetic, numeric, and special characters, with or without imbedded blanks, to be entered into the respective data field left-justified and blank-filled on the right. See Chapter 9 for a list of special characters which are allowed.

2. Blank Field (bb...b) - to be blank-filled. Data fields which are designated as blank fields must be left blank, i.e., no data items may be entered in these fields.

3. Floating-Point Field (ff...fdd...d) - intended for a data item that is coded as a decimal number, i.e., as a string of numeric characters (prefixed with a minus sign if the number is negative) which may not contain any imbedded blanks. If the decimal point is present, the character string representing the integer digits, the decimal point, and the decimal fraction digits may be positioned anywhere within the respective field (generally left-justified), and the unused columns of the data field are blank-filled.

When the decimal point is not coded, the "f" portion of the floating-point field is to contain the integer part of the decimal number, and the "d" portion the corresponding decimal fraction part, the decimal point being implied between the rightmost "f" column and the leftmost "d" column of the field.

Accordingly, a string of numeric characters representing m integer digits followed by n decimal fraction digits with the decimal point absent must be positioned in the floating-point field in such a manner that its integer part falls into the m rightmost "f" columns, and its decimal fraction part into the n leftmost "d" columns, with any unused "d" columns filled with zeros and any unused "f" columns filled with blanks. When a negative number is entered, code the minus sign immediately preceding the leading digit.

4. Integer Field (ii...i) - intended for a data item which is coded as a string of numeric characters representing a positive or negative integer number, to be entered into the respective data field right-justified. In the case of a positive integer number, blank-fill any unused columns on the left. In the case of negative integer number, code the minus sign immediately preceding the leftmost non-zero digit, and blank-fill any unused columns to the left of the minus sign.

Required Data: In general, only those records which are applicable to the data at hand should be included in a GRAV ADJU data set. The character fields intended for data items which are essential have been shaded on the format diagram: if applicable to the data being coded, these character fields must be in accordance with the instructions given on the respective format diagrams or in the text of this chapter.

ADJUSTED GRAVITY STATION DATA RECORD. Submit this record for each adjusted gravity station, for which connecting observations are not available, for inclusion into the NGS gravity working file.

Columns	Description	Example	Format
1	Security Classification (See Chapter 11)		a
2	Security Control (See Chapter 11)		i
3	Geographic Units (See Chapter 11)	1	i
4–10	Latitude - Sign of Latitude in Column 4 (- for South) Decimal Point is implied: after Column 6 for Decimal Degrees after Column 8 for Degrees and Minutes after Column 10 for Degrees, Minutes and Seconds	555959	iiiiiii
11			b
12–19	Longitude - Sign of Longitude in Column 12 (- for West) Decimal Point is implied: after Column 15 for Decimal Degrees after Column 17 for Degrees and Minutes after Column 19 for Degrees, Minutes and Seconds	-1620231	iiiiiiii
20			b
21	Type of Elevation (See Chapter 11)	1	a
22	Elevation Units - 0=meters, 1=feet, 2=fathoms	0	i
23–29	Elevation Decimal Point is implied after Column 28 This field will contain Depth of Ocean (Positive Downward) if Column 21 contains 3, 4 or 5	5505	ffffffd
30			b
31–35	Supplemental Elevation Depth of Instrument, Lake or Ice. Positive Downward from Surface		iiiii
36			b
37–42	Adjusted Gravity Adjusted Gravity Value - 976000.00 milligals Decimal Point is implied after Column 40	561320	ffffdd
43			b
44–48	Free-Air Anomaly in milligals Decimal Point is implied after Column 47	221	ffffd
49			b
50–54	Bouguer Anomaly in milligals Decimal Point is implied after Column 53	258	ffffd
55			b
56	Isostatic Anomaly or Terrain Correction (See Chapter 11)	0	a
57			b
58–61	Source Code - DoD Specific (Optional) A Source Code Assigned by the Submitting Agency		aaaa
62			b
63–67	Base Reference Station DoD Specific (Optional)		aaaaa
68	Base Reference Site DoD Specific (Optional)		b
69–72	Gravity Station Number - (Optional) The Sequence Number of Each Station within a Survey	0932	iiii
73			b
74	File Maintenance DoD Specific (Optional)		a
75			b
76–77	Standard Deviation Free-Air Anomaly - Estimate of the standard deviation of the free-air anomaly in milligals	02	ii
78			b
79–80	Standard Deviation Bouguer Anomaly - Estimate of the standard deviation of the bouguer anomaly in milligals	02	ii