8. WGS 84-TO-LOCAL GEODETIC SYSTEM DATUM TRANSFORMATIONS

As explained in Chapter 1, it is advantageous for many reasons to have a single, accurate, earth-centered geodetic system which can be used worldwide for all MC&G applications and activities. Therefore, a key WGS 84 development task has been the development of techniques or procedures for referencing local geodetic systems to WGS 84. The success of this endeavor is evident from Chapter 7, which discusses the availability of approaches for transforming 83 local geodetic systems to WGS 84. This is heartening, indicating that, for the first time, the potential exists for replacing the use of 83 local geodetic systems in MC&G applications and activities with a single geocentric system, WGS 84. Since such a major objective has been achieved, why should a WGS 84-to-Local Geodetic System Datum Transformation, a reverse process which appears to be counter to one of the main objectives of the WGS 84 development, warrant attention?

The answer to the preceding question rests with NAVSTAR GPS User Equipment and the continued availability (at this time) of mapping, charting, and geodetic products referenced to local geodetic systems. The standard output of NAVSTAR GPS User Equipment consists of WGS 84 geodetic latitude, geodetic longitude, and geodetic heights, and WGS 84-related elevations above mean sea level. Since many local geodetic systems are currently still in use, an approach is needed for converting GPS-derived WGS 84 coordinates to local geodetic system coordinates. The relevant formulas, a rearrangement of Equations (7-6) and (7-5) from Chapter 7, respectively, are:

$$\begin{aligned} \phi_{LGS} &= \phi_{WGS\ 84} - \Delta\phi \\ \lambda_{LGS} &= \lambda_{WGS\ 84} - \Delta\lambda \\ H_{LGS} &= H_{WGS\ 84} - \Delta H \end{aligned} \qquad (8\text{-}1)$$

or

$$\begin{aligned} X_{LGS} &= X_{WGS\ 84} - \Delta X \\ Y_{LGS} &= Y_{WGS\ 84} - \Delta Y \\ Z_{LGS} &= Z_{WGS\ 84} - \Delta Z\ . \end{aligned} \qquad (8\text{-}2)$$

Values of $\Delta\phi$, $\Delta\lambda$, ΔH from the Local Geodetic System-to-WGS 84 Datum Transformation techniques discussed in Chapter 7 may also be used to obtain the $\Delta\phi$, $\Delta\lambda$, ΔH data needed in Equation (8-1). In the case of the $\Delta\phi$, $\Delta\lambda$, ΔH Multiple Regression Equations, simply evaluate the equations using the WGS 84 ϕ, λ, H coordinates of the site being converted, and insert the derived $\Delta\phi$, $\Delta\lambda$, ΔH values in Equation (8-1) to obtain the site's local geodetic system coordinates. The Molodensky Formulas may also be similarly used if WGS 84 Ellipsoid parameters (a, f) and station coordinates replace their local geodetic system counterparts in the formulas (Table 7.8), and Local Geodetic System-to-WGS 84 Datum Transformation parameters (ΔX, ΔY, ΔZ, Δa, Δf) are used as listed (Table 7.21), or Table 10.1 of [8.1], without sign change.

The accuracy of the conversion process providing local geodetic system coordinates via the above approach is discernible from the reverse procedure where local geodetic system coordinates are transformed to WGS 84 coordinates using Multiple Regression Equations or Molodensky Formulas and then compared with known WGS 84 coordinates. Such coordinate comparisons were made at 433 and 405 NAD 27 sites, respectively, in the Contiguous United States. The RMS and maximum coordinate differences listed in Table 8.1 are also applicable for WGS 84-to-NAD 27 Datum Transformations accomplished using Multiple Regression Equations or Molodensky Formulas (ignoring the error contributed by the GPS system error). (Although not a topic for further discussion here, GPS system error must be taken into account when determining the accuracy of GPS-derived local geodetic coordinates.) Additional information is contained in Tables 7.12 and 7.18 for other major local geodetic systems.

Local Geodetic System-to-WGS 84 Datum Shifts (localized, regional, or mean values), Table 10.1 of [8.1], may be taken directly from the table and inserted in Equation (8-2) to obtain local geodetic system X, Y, Z coordinates for a site with known WGS 84 X, Y, Z coordinates. If this WGS 84-to-Local Geodetic System Transformation approach is used, but the local geodetic system coordinates are needed in ϕ, λ, H form, Equations (7-15), (7-16), and (7-17) may be used to accomplish the (X, Y, Z) - to - (ϕ, λ, H) conversion. The accuracy of the process providing local geodetic system coordinates via this approach is also discernible from Table 8.1 if mean datum shifts were used in

the conversion process. As stated earlier, the RMS and maximum coordinate differences listed in the Table for a comparison involving 405 sites are also applicable for a WGS 84-to-NAD 27 Datum Transformation accomplished using the Abridged Molodensky Datum Transformation Formulas and mean datum shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$). (As earlier, the error contributed by the GPS system error is not reflected in the tabular results.) Additional information is contained in Table 7.12 for other major local geodetic systems.

The use in GPS receivers of a WGS 84-to-Local Geodetic System Datum Transformation technique capable of providing better results than those achievable through the use of mean datum shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) will improve the accuracy of GPS-derived local geodetic system coordinates. Although the large NAVSTAR GPS "system" error of ±10 meters (one sigma, linear) in the dynamic mode [8.2] - [8.4] currently limits to a large extent the improvement that a more accurate WGS 84-to-Local Geodetic System Datum Transformation technique can make in GPS-derived local geodetic system coordinates, this "system" error will undoubtedly be reduced in the next few years. Various investigations have already identified the differential operating mode and other approaches that might be used to effect a "system" error reduction [8.2] - [8.17]. As a result, NAVSTAR GPS receivers will soon require geodetic data and implementing equations of the best possible accuracy.

This brief Chapter on WGS 84-to-Local Geodetic System Datum Transformations has been included in deference to those involved in GPS User Equipment (UE) development and applications. To ensure extraction of geodetic data of the best possible accuracy from GPS receivers and commonality of output data from receivers used by various DoD elements, developers should contact DMA prior to proceeding with receiver development. This is necessary to ensure that the UE-related WGS 84 data available for utilization is current, in the most appropriate form, and of the best accuracy possible. Geodetically-related actions that need to be taken with respect to future NAVSTAR GPS receiver development efforts include:

- The improved determination of GPS-derived local geodetic system coordinates. This involves updating the UE in-use list of local geodetic

systems and replacing the currently used datum transformation formulas with a more accurate datum transformation technique.

- The improved determination of GPS-derived height-above-mean sea level values. This involves replacement of the UE in-use 10°x10° grid of geoid heights and interpolation scheme with a higher resolution 1°x1° (or 2°x2°) equal-area grid of geoid heights and a slightly improved geoid height interpolation scheme.

The WGS 84-related geodetic/gravimetric products necessary to effect the above UE-related improvements are available at DMA. The DMA point of contact for discussions on such GPS UE-related topics is the:

Director
Defense Mapping Agency Systems Center
ATTN: SGS
Suite 800
8301 Greensboro Drive
McLean, Virginia 22102

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Table 8.1

WGS 84 "True"* Coordinates Minus WGS 84 Coordinates
Calculated Using Different Local Geodetic System-to-WGS 84 Datum Transformations
- NAD 27 (CONUS) -

	Coordinate Differences From Using					
	Multiple Regression Equations			Abridged Molodensky Formulas and Mean Datum Shifts ($\overline{\Delta X}, \overline{\Delta Y}, \overline{\Delta Z}$)		
	$\Delta\phi$	$\Delta\lambda$	ΔH	$\Delta\phi$	$\Delta\lambda$	ΔH
RMS Differences [Tables 7.12, 7.18]	±1	±1	±1	±4	±3	±2
Maximum Differences**	4	4	4	10	10	6

Units = Meters

* Determined using the NSWC 9Z-2 to WGS 84 Transformation (Table 2.4)

** Without regard to sign