SECTION 22

# MULTIPLE REGRESSION EQUATIONS
# FOR
# DMA-DEVELOPED LOCAL GEODETIC SYSTEM GEOID HEIGHTS
# - MAJOR DATUMS -

Table 22.1

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- North American Datum 1927 (NAD 27)* -

$$N_m = 5.068 - 11.570\,U - 8.574\,V + 27.839\,U^2 - 51.911\,UV + 29.496\,V^2 + 28.343\,U^3 + 24.481\,UV^2$$
$$+ 11.424\,V^3 + 132.550\,U^3V - 110.232\,U^2V^2 + 41.018\,UV^3 - 64.953\,V^4 - 128.293\,U^3V^2$$
$$+ 51.241\,UV^4 - 4.326\,V^5 + 104.097\,U^4V^2 - 128.031\,U^3V^3 + 110.694\,U^2V^4 + 36.330\,V^6$$
$$+ 243.149\,U^6V - 15.790\,U^2V^5 - 38.043\,UV^6 - 40.277\,U^2V^6 + 2.746\,UV^7 - 7.321\,V^8 - 394.404\,U^9$$
$$- 927.540\,U^8V + 63.390\,U^4V^5 + 10.626\,UV^8 - 0.520\,UV^9 - 117.207\,U^8V^4 + 16.352\,U^5V^8$$

In the preceding equation:

$U = K\,(\,\phi - 37\,)$
$V = K\,(\,\lambda - 265\,)$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.3 meters; 444 sites involved in the comparison.

Test Case:

Input data for NAD 27 test point:

$\phi$ = 34°47'08.833"N

$\lambda$ = 273°25'07.825"E

N = 8.63 m (Clarke 1866 Ellipsoid)

* Contiguous United States (CONUS); Clarke 1866 Ellipsoid

Table 22.2

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- South American Datum 1969 (SAD 69)* -

$$N_m = 15.895 - 53.992\ V - 66.142\ U^2 - 43.870\ UV - 9.190\ V^2 + 2.500\ U^3 + 52.410\ U^2V + 47.049\ UV^2 + 102.468\ V^3 + 63.393\ U^4 + 119.668\ U^3V + 73.935\ U^2V^2 - 30.577\ UV^3 - 56.235\ V^4 - 130.660\ U^3V^2 - 126.489\ U^2V^3 + 61.258\ UV^4 - 27.268\ U^6 - 139.477\ U^5V + 34.550\ U^5V^2 + 57.270\ U^4V^3 + 4.265\ U^8 + 51.993\ U^7V - 12.634\ UV^7 - 0.422\ U^9 - 0.838\ U^8V + 1.812\ U^5V^4 - 6.048\ U^9V + 37.272\ U^3V^7 - 8.841\ U^4V^8 - 10.368\ U^6V^9$$

In the preceding equation:

$U = K ( \phi + 20 )$
$V = K ( \lambda - 300 )$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed SAD 69 geoid height (in meters) referenced to the South American 1969 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±2.0 meters; 140 sites involved in the comparison.

Test Case:

Input data for SAD 69 test point:

$\phi$ = -31°56'33.954"S
$\lambda$ = 294°53'41.342"E

N = 3.29 m (South American 1969 Ellipsoid)

* South American 1969 Ellipsoid

Table 22.3

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- European Datum 1950 (ED 50)* -

$$N_m = 6.243 - 7.665\ U + 12.177\ V + 12.886\ U^2 - 15.822\ UV - 28.812\ V^2 + 276.220\ U^3 - 26.228\ U^2V$$
$$- 29.689\ V^3 - 77.289\ U^4 - 64.583\ UV^3 + 40.908\ V^4 - 971.154\ U^5 + 136.704\ UV^4 + 169.545\ U^3V^3$$
$$+ 14.103\ V^6 + 1495.212\ U^7 - 585.474\ U^3V^4 + 78.974\ U^8 - 83.519\ U^2V^6 - 805.496\ U^9 + 435.717\ U^4V^5$$
$$+ 496.171\ U^7V^4 - 13.104\ U^6V^5 - 493.747\ U^6V^6 - 211.226\ U^9V^5 + 675.597\ U^7V^7$$
$$- 255.127\ U^9V^6 - 193.052\ U^9V^8$$

In the preceding equation:

$U = K ( \phi - 52 )$
$V = K ( \lambda - 10 )$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed ED 50 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 116 sites involved in the comparison.

Test Case:

Input data for ED 50 test point: $\phi$ = 46°41'42.893"N, $\lambda$ = 13°54'54.088"E — N = 6.08 m (International Ellipsoid)

* Western Europe Only; International Ellipsoid



[Revised: 30 September 1988]

Table 22.4

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- European Datum 1950 (ED 50)* -

$$N_m = 0.695 + 13.023\ U - 7.961\ V - 12.715\ UV + 15.997\ V^2 + 42.321\ V^3 + 19.513\ V^4 - 102.636\ U^3V^2 - 75.046\ U^4V^2 - 512.671\ U^5V^3 - 0.996\ V^9$$

In the preceding equation:

$U = K ( \phi - 54 )$
$V = K ( \lambda - 0 )$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed ED 50 geoid height (in meters) referenced to International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.4 meter; 66 sites involved in the comparison.

Test Case:

Input data for ED 50 test point: $\phi$ = 49°42'40.562"N, $\lambda$ = 357°48'11.987"E

N = -4.03 m (International Ellipsoid)

* United Kingdom (UK)/Ireland; International Ellipsoid; ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates.



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Table 22.5

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- European Datum 1950 (ED 50)* -

$$N_m = 1.115 + 12.154\ U - 8.575\ V - 3.183\ U^2 - 17.908\ UV + 41.262\ U^3V + 27.707\ V^5 + 81.058\ U^9 - 30.843\ V^9$$

In the preceding equation:

$U = K\ (\ \phi - 54\ )$
$V = K\ (\ \lambda - 0\ )$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed ED 50 geoid height (in meters) referenced to International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 55 sites involved in the comparison.

Test Case:

Input data for ED 50 test point: $\phi$ = 49°42'40.562"N, $\lambda$ = 357°48'11.987"E

N = - 4.08 m (International Ellipsoid)

* United Kingdom (UK) Only; International Ellipsoid; ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates. The equations in Table 22.4 are recommended for geoid heights computations for United Kingdom (UK)/Ireland. Datum transformation equations in Table 19.4 are also recommended for compatibility.



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Table 22.6

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Tokyo Datum (TD)* -

$$N_m = 19.004 - 37.468\,U + 31.786\,V + 3.470\,UV - 4.018\,U^3 + 1.326\,UV^2 - 8.480\,V^3 - 3.724\,U^3V + 7.243\,U^2V^2 - 4.923\,V^4 + 0.293\,U^9V^2 - 0.225\,U^5V^6 + 0.200\,U^2V^9$$

In the preceding equation:

$U = K ( \phi - 35 )$
$V = K ( \lambda - 135 )$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed TD geoid height (in meters) referenced to the Bessel 1841 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.5 meters; 51 sites involved in the comparison.

Test Case:

Input data for TD test point: $\phi$ = 40°42'38.260"N, $\lambda$ = 141°22'23.979"E  N = 8.46 m (Bessel 1841 Ellipsoid)

* Bessel 1841 Ellipsoid

Table 22.7

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Australian Geodetic Datum 1966 (AGD 66)* -

$$N_m = - 4.258 + 2.740\ U + 70.479\ U^2 - 34.946\ UV + 12.676\ V^2 + 24.680\ U^2V - 348.586\ U^4$$
$$- 14.488\ U^2V^2 + 122.302\ UV^3 + 37.035\ U^5 - 17.307\ UV^4 - 6.704\ V^5 + 645.556\ U^6$$
$$- 80.304\ U^3V^3 - 108.866\ UV^5 - 19.475\ U^7 - 271.301\ U^4V^3 - 430.089\ U^8$$
$$- 5.561\ V^8 + 97.772\ U^8V^2 + 449.462\ U^6V^4 - 69.354\ U^2V^8 - 692.991\ U^7V^4$$
$$+ 265.504\ U^3V^9 + 1311.842\ U^9V^5$$

In the preceding equation:

$U = K ( \phi + 27 )$
$V = K ( \lambda - 134 )$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed AGD 66 geoid height (in meters) referenced to the Australian National Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.4 meters; 134 sites involved in the comparison.

Test Case:

Input data for AGD 66 test point: $\phi$ = -17°00'32.776"S, $\lambda$ = 144°11'37.245"E  N = 0.58 m (Australian National Ellipsoid)

* Australian National Ellipsoid

Table 22.8

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Australian Geodetic Datum 1984 (AGD 84)* -

$$N_m = -4.155 + 3.939\,U + 14.693\,V + 65.144\,U^2 - 18.651\,UV + 10.460\,V^2 - 120.684\,V^3 - 267.125\,U^4 + 39.025\,UV^3 - 74.039\,U^4V - 26.446\,UV^4 + 301.719\,V^5 + 445.176\,U^6 - 33.732\,UV^5 + 16.358\,V^6 + 384.399\,U^4V^3 - 312.773\,V^7 - 257.076\,U^8 - 122.384\,U^5V^3 - 117.856\,U^2V^6 - 18.365\,V^8 - 502.439\,U^4V^5 + 9.820\,UV^8 + 110.502\,V^9 + 54.807\,U^9V + 915.970\,U^5V^7 - 3661.876\,U^7V^8 + 3579.951\,U^9V^9$$

In the preceding equation:

$U = K ( \phi + 27 )$
$V = K ( \lambda - 134 )$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed AGD 84 geoid height (in meters) referenced to the Australian National Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 109 sites involved in the comparison.

Test Case:

Input data for AGD 84 test point: $\phi$ = -20°38'00.673"S, $\lambda$ = 144°24'29.288"E

N = 1.06 m (Australian National Ellipsoid)

* Australian National Ellipsoid

Table 22.9

RMS Difference With Which Geoid Height Multiple Regression Equations
Reproduce DMA-Developed Local Geodetic System Geoid Heights

| Local Geodetic System | - RMS Difference - Original Minus Computed ( ΔN ) | Number of Comparison Points |
|---|---|---|
| NAD 27* | ± 1.3 m | 444 |
| SAD 69 | 2.0 | 140 |
| ED 50 (Western Europe)** | 1.0 | 116 |
| ED 50 (UK/Ireland)*** | 0.4 | 66 |
| ED 50 (UK Only)*** | 0.5 | 55 |
| TD | 1.5 | 51 |
| AGD 66 | 1.4 | 134 |
| AGD 84 | 1.2 | 109 |

* Contiguous United States (CONUS)

** Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland

*** European Datum 1950 coordinates developed from Ordnance Survey of Great Britain (OSGB) Scientific Network 1980 (SN 80) coordinates



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SECTION 23

MULTIPLE REGRESSION EQUATIONS

FOR DMA-DEVELOPED LOCAL GEODETIC SYSTEM GEOID HEIGHTS

- REMAINDER OF 83 LOCAL GEODETIC SYSTEMS* -

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* EQUATION NOT INCLUDED FOR EUROPEAN DATUM 1979 (SINCE IT DOES NOT REPLACE ED 50). GEOID HEIGHTS ARE APPROXIMATELY CONSTANT FOR SMALL ISLAND DATUMS AND/OR DATUMS REPRESENTING SMALL GEOGRAPHICAL AREAS. TABLE 23.43 CONTAINS GEOID HEIGHT VALUES FOR SUCH LOCAL GEODETIC SYSTEMS.

Table 23.1

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Adindan Datum* -

$$N_m = -1.412 - 2.891\,U - 13.987\,V + 8.733\,U^2 - 4.984\,V^3 - 4.455\,U^2V^2 - 6.225\,UV^3 - 1.678\,V^4 - 4.948\,U^4V + 15.649\,U^3V^3 - 2.853\,U^3V^6 - 8.902\,U^9V^3 + 0.096\,U^3V^9 + 1.257\,U^9V^5$$

In the preceding equation:

$U = K\,(\phi - 14)$
$V = K\,(\lambda - 32)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Adindan Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 50 sites involved in the comparison

Test Case:

| | | |
|---|---|---|
| Input data for Adindan Datum test point: | $\phi$ = 9°05'12.250"N<br>$\lambda$ = 36°34'48.852"E | N = -5.27 m (Clarke 1880 Ellipsoid) |

* Ethiopia, Sudan; Clarke 1880 Ellipsoid

Table 23.2

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Arc Datum 1950* -

$$N_m = 0.709 - 3.012\,U - 4.491\,V + 1.982\,U^2 - 1.416\,UV - 5.672\,V^2 + 2.088\,UV^2 - 2.756\,V^3 - 4.227\,U^3V + 2.422\,U^2V^2 + 0.551\,UV^4 + 2.477\,U^5V + 0.672\,V^6 - 0.817\,U^3V^4 - 0.288\,U^7V$$

In the preceding equation:

$U = K\,(\phi + 22)$
$V = K\,(\lambda - 27)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Arc Datum 1950 geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.4 meters; 67 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Arc Datum 1950 test point: | $\phi$ = -21°09'03.500"S<br>$\lambda$ = 27°30'38.724"E | N = -0.07 m (Clarke 1880 Ellipsoid) |

* Botswana, Lesotho, Malawi, Swaziland, Zaire, Zambia, Zimbabwe; Clarke 1880 Ellipsoid



[Revised: 30 September 1988]

Table 23.3

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Arc Datum 1960* -

$$N_m = - 7.950 + 54.394\ U - 30.515\ V + 6.331\ U^2 - 42.433\ V^2 - 9.206\ U^3 - 24.156\ UV^2 + 93.603\ U^2V^2$$
$$+ 75.107\ U^6 + 81.282\ V^7 - 93.656\ U^8 + 447.685\ V^8 + 58.844\ U^8V + 3078.922\ U^4V^5 - 971.193\ UV^9$$
$$- 700.255\ U^8V^3 - 8149.817\ U^4V^7 + 448.607\ U^9V^3 - 1170.336\ U^8V^4$$

In the preceding equation:

$U = K\ (\phi + 3)$
$V = K\ (\lambda - 36)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Arc Datum 1960 geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 36 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Arc Datum 1960 test point: | $\phi$ = -6°03'32.760"S<br>$\lambda$ = 35°55'19.249"E | N = -24.10 m (Clarke 1880 Ellipsoid) |

* Kenya, Tanzania; Clarke 1880 Ellipsoid

Table 23.4

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Bogota Observatory Datum* -

$$N_m = 1.218 + 16.490\,U - 45.270\,V - 11.867\,U^2 + 4.754\,UV - 31.201\,V^2 - 38.149\,UV^2 + 73.546\,U^2V^2 + 17.376\,V^4 - 250.666\,U^2V^3 + 148.291\,UV^4 - 67.631\,U^4V^2 - 132.899\,UV^5 + 8.365\,U^6V + 136.574\,U^4V^3 + 554.970\,U^4V^5 + 677.533\,U^6V^8 + 2372.651\,U^7V^9$$

In the preceding equation:

$U = K\,(\phi - 6)$
$V = K\,(\lambda - 286)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Bogota Observatory Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 26 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Bogota Observatory Datum test point: | $\phi$ = 2°34'26.221"N<br>$\lambda$ = 287°21'36.733"E | N = -21.72 m (International Ellipsoid) |

* Colombia; International Ellipsoid

Table 23.5

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Campo Inchauspe Datum* -

$$N_m = 0.785 + 0.892\,U - 4.421\,V + 1.539\,U^2 - 10.975\,UV + 8.042\,V^2 - 3.630\,UV^2 + 4.344\,V^3 + 9.418\,UV^3 - 6.460\,V^4 - 2.356\,U^2V^4 - 0.016\,U^8 - 0.006\,U^9 + 0.047\,U^7V^5 + 0.016\,U^8V^5$$

In the preceding equation:

$U = K\,(\phi + 35)$
$V = K\,(\lambda - 296)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Campo Inchauspe Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.6 meters; 46 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Campo Inchauspe Datum test point: | $\phi$ = | -29°47'45.682"S | N = -1.85 m (International Ellipsoid) |
| | $\lambda$ = | 301°52'21.803"E | |

* Argentina; International Ellipsoid

Table 23.6

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Canton Astro Datum 1966* -

$N_m = 3.255 + 3.851\ U - 4.266\ V$

In the preceding equation:

$U = K\ (\phi + 3)$
$V = K\ (\lambda - 188)$
$K = 1.57079631$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Canton Astro Datum 1966 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.1 meter; 4 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Canton Astro Datum 1966 test point: | $\phi$ = | -4°29'08.524"S | N = -4.57 m (International Ellipsoid) |
| | $\lambda$ = | 187°49'32.444"E | |

* Phoenix Islands; International Ellipsoid

Table 23.7

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Cape Datum* -

$$N_m = 7.444 - 3.534\ U - 22.388\ U^2 - 8.247\ V^2 - 8.640\ V^3 - 9.225\ V^6 + 58.758\ U^8$$

In the preceding equation:

$U = K\ (\phi + 28)$
$V = K\ (\lambda - 26)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Cape Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.1 meters; 32 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Cape Datum test point: | $\phi$ = | -22°15'13.678"S | N = -3.01 m (Clarke 1880 Ellipsoid) |
| | $\lambda$ = | 29°09'47.488"E | |

* South Africa; Clarke 1880 Ellipsoid

Table 23.8

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Cape Canaveral Datum* -

$$N_m = 2.189 - 18.460\ U - 20.413\ V - 37.345\ V^2 - 458.888\ U^3V$$

In the preceding equation:

$U = K\ (\phi - 27)$
$V = K\ (\lambda - 280)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Cape Canaveral Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 26 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Cape Canaveral Datum test point: | $\phi$ = | 26°03'36.424"N | N = 4.28 m (Clarke 1866 Ellipsoid) |
| | $\lambda$ = | 279°51'51.267"E | |

* Florida and the Bahama Islands; Clarke 1866 Ellipsoid

Table 23.9

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Carthage Datum* -

$$N_m = 3.276 + 2.125\ U - 3.665\ V - 9.202\ UV - 7.095\ U^3$$

In the preceding equation:

$U = K\ (\phi - 35)$
$V = K\ (\lambda - 9)$
$K = 0.20943951$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Carthage Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 21 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Carthage Datum test point: | $\phi$ = | 36°49'21.208"N | N = 1.03 m (Clarke 1880 Ellipsoid) |
| | $\lambda$ = | 10°46'08.814"E | |

* Tunisia; Clarke 1880 Ellipsoid

Table 23.10

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Chua Astro Datum* -

$$N_m = 5.854 + 7.619\ U - 14.749\ V - 5.111\ V^2 - 1.730\ U^9$$

In the preceding equation:

$U = K\ (\phi + 25)$
$V = K\ (\lambda - 302)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Chua Astro Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 19 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Chua Astro Datum test point: | $\phi$ = -25°19'23.270"S<br>$\lambda$ = 305°24'47.315"E | N = -3.91 m (International Ellipsoid) |

* Paraguay; International Ellipsoid

Table 23.11

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Corrego Alegre Datum* -

$$N_m = - 3.024 - 22.248\ U - 5.045\ U^2 + 18.091\ UV + 55.880\ V^2 + 22.239\ U^3 + 19.927\ UV^2 - 64.427\ V^3$$
$$- 377.616\ U^4V^2 + 180.395\ U^3V^3 + 242.541\ U^2V^5 - 8.698\ U^9 + 8122.948\ U^8V^4 - 141269.020\ U^9V^9$$

In the preceding equation:

$U = K\ (\phi + 15)$
$V = K\ (\lambda - 310)$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Corrego Alegre Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.1 meters; 47 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Corrego Alegre Datum test point: | $\phi$ = | -20°29'01.019"S | N = 7.78 m (International Ellipsoid) |
| | $\lambda$ = | 305°12'46.829"E | |

* Brazil; International Ellipsoid

Table 23.12

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Djakarta Datum* -

$$N_m = -4.076 + 6.557\,U - 6.697\,U^2 + 7.434\,U^3 + 25.293\,V^3 - 16.419\,U^3V - 16.539\,V^5 - 7.800\,U^6$$

In the preceding equation:

$U = K\,(\phi - 0)$
$V = K\,(\lambda - 100)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Djakarta Datum geoid height (in meters) referenced to the Bessel 1841 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.8 meter; 17 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Djakarta Datum test point: | $\phi$ = | 5°25'51.475"N | N = -0.51 m (Bessel 1841 Ellipsoid) |
| | $\lambda$ = | 95°32'32.178"E | |

* Sumatra; Bessel 1841 Ellipsoid

Table 23.13

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- ED 50 (Cyprus)* -

$$N_m = - 0.603 + 12.824\ U + 4.129\ V + 2.610\ UV - 7.982\ V^2 - 7.782\ UV^2 + 5.369\ V^3 + 3.152\ UV^4 - 2.620\ V^7 - 0.525\ UV^7 + 1.311\ V^8$$

In the preceding equation:

$U = K\ (\phi - 35)$
$V = K\ (\lambda - 33)$
$K = 0.78539816$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed ED 50 (Cyprus) geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.1 meter; 10 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for ED 50 (Cyprus) test point: | $\phi$ = | 34°43'23.316"N | N = -6.38 m (International Ellipsoid) |
| | $\lambda$ = | 32°28'06.026"E | |

* International Ellipsoid

Table 23.14

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- ED 50 (Egypt)* -

$$N_m = 3.430 + 25.637\ U - 28.124\ U^2 + 26.119\ UV^2 - 8.527\ V^3 + 62.197\ U^3V + 58.308\ U^2V^3 + 158.076\ U^4V^2 + 311.812\ U^6V - 190.887\ U^9$$

In the preceding equation:

$U = K\ (\phi - 27)$
$V = K\ (\lambda - 30)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed ED 50 (Egypt) geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.8 meter; 30 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for ED 50 (Egypt) test point: | $\phi$ = | 29°50'07.103"N | N = 8.71 m (International Ellipsoid) |
| | $\lambda$ = | 30°36'05.306"E | |

* International Ellipsoid

Table 23.15

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- ED 50 (Iran)* -

$$N_m = 2.542 + 27.445\,U - 4.130\,V - 44.806\,U^2 - 37.257\,UV - 4.420\,U^3 + 7.351\,U^2V + 12.279\,UV^2 + 25.763\,U^4 + 33.240\,U^3V + 42.862\,U^2V^2 + 12.777\,UV^3 - 12.630\,V^4 - 31.975\,U^3V^2 - 28.888\,U^2V^3 - 2.519\,V^5 - 9.664\,U^4V^2 - 3.528\,U^7 - 13.384\,U^6V - 5.561\,UV^6 - 2.412\,U^8 + 2.833\,V^8 + 1.026\,V^9 - 0.241\,U^2V^9$$

In the preceding equation:

$U = K\,(\phi - 32)$
$V = K\,(\lambda - 55)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed ED 50 (Iran) geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 47 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for ED 50 (Iran) test point: | $\phi$ = | 29°28'59.127"N | N = -17.49 m (International Ellipsoid) |
| | $\lambda$ = | 60°52'31.547"E | |

* International Ellipsoid

Table 23.16

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Geodetic Datum 1949* -

$$N_m = 3.741 - 2.600\ U + 18.891\ UV - 16.708\ V^2 - 12.433\ UV^3 + 1.752\ U^7 - 117.099\ UV^6 + 62.388\ V^7 + 50.312\ U^4V^5$$

In the preceding equation:

$U = K\ (\phi + 41)$
$V = K\ (\lambda - 173)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Geodetic Datum 1949 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.3 meters; 30 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Geodetic Datum 1949 test point: | $\phi$ = | -41°17'32.050"S | N = 3.80 m (International Ellipsoid) |
| | $\lambda$ = | 173°15'15.405"E | |

* New Zealand; International Ellipsoid

Table 23.17

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Guam Datum 1963* -

$$N_m = -7.142 + 8.306\,U - 0.567\,V + 7.076\,U^2 - 7.234\,U^3V - 0.141\,V^5 + 0.014\,U^9V + 0.003\,U^3V^9$$

In the preceding equation:

$U = K\,(\phi - 13)$
$V = K\,(\lambda - 144)$
$K = 1.57079631$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Guam Datum 1963 geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.1 meter; 6 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Guam Datum 1963 test point: | $\phi$ = | 13°36'56.376"N | N = -2.63 m (Clarke 1866 Ellipsoid) |
| | $\lambda$ = | 144°51'25.420"E | |

*Clarke 1866 Ellipsoid

Table 23.18

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Hjorsey Datum 1955* -

$$N_m = 2.466 + 11.998\ U - 2.023\ V - 24.189\ U^2 + 2.547\ UV - 2.637\ V^2$$

In the preceding equation:

$U = K\ (\phi - 64)$
$V = K\ (\lambda - 341)$
$K = 0.20943951$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Hjorsey Datum 1955 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.7 meter; 19 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Hjorsey Datum 1955 test point | $\phi$ = 64°31'29.258"N<br>$\lambda$ = 337°37'54.160"E | N = 3.41 m (International Ellipsoid) |

* Iceland; International Ellipsoid

Table 23.19

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Indian Datum* -

$$N_m = 15.683 - 25.498\ U + 46.169\ V + 2.542\ U^2 - 2.917\ UV + 4.895\ V^2 + 1.102\ V^3 + 0.543\ U^4 + 0.376\ U^2V^2 - 0.641\ V^4 - 0.040\ V^9$$

In the preceding equation:

$U = K\ (\phi - 13)$
$V = K\ (\lambda - 103)$
$K = 0.20943951$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Indian Datum geoid height (in meters) referenced to the Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 40 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Indian Datum test point: | $\phi$ = 16°32'45.140"N<br>$\lambda$ = 107°38'49.803"E | N = 46.39 m (Everest Ellipsoid) |

* Thailand and Vietnam only (Everest Ellipsoid). Contact DMA (see PREFACE) if data in this form is needed for Bangladesh, India, and Nepal.

Table 23.20

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Ireland Datum 1965* -

$$N_m = 2.181 - 1.308\ V^3 + 37.000\ U^3V^3$$

In the preceding equation:

$U = K\ (\phi - 53)$
$V = K\ (\lambda - 354)$
$K = 0.20943951$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Ireland Datum 1965 geoid height (in meters) referenced to the Modified Airy Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 22 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Ireland Datum 1965 test point: | $\phi$ = 54°22'26.715"N<br>$\lambda$ = 351°37'44.633"E | N = 2.23 m (Modified Airy Ellipsoid) |

* Ireland; Modified Airy Ellipsoid

Table 23.21

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Kandawala Datum* -

$$N_m = -0.979 + 1.853\,U - 3.443\,U^2 + 2.523\,U^3 - 5.423\,U^2V - 5.278\,V^3 + 3.965\,U^4V^3 - 0.899\,U^7V^2 + 5.225\,U^2V^9 - 0.58513\,U^7$$

In the preceding equation:

$U = K\,(\phi - 7)$
$V = K\,(\lambda - 80)$
$K = 0.52359877$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Kandawala Datum geoid height (in meters) referenced to the Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ± 0.4 meter; 17 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Kandawala Datum test point: | $\phi$ = | 7°37'02.730"N | N = -4.55 m (Everest Ellipsoid) |
| | $\lambda$ = | 81°40'49.750"E | |

* Sri Lanka; Everest Ellipsoid

Table 23.22

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Kertau Datum 1948* -

$$N_m = -3.833 - 2.701\,U + 17.861\,V + 0.386\,U^2 + 0.980\,V^2 - 0.793\,V^3 - 2.390\,UV^3 - 1.455\,U^2V^4$$

In the preceding equation:

$U = K(\phi - 3)$
$V = K(\lambda - 102)$
$K = 0.41887902$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Kertau Datum 1948 geoid height (in meters) referenced to the Modified Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.2 meter; 18 sites involved in the comparison.

Test Case:

Input data for Kertau Datum 1948 test point: $\phi$ = 3°27'50.710"N, $\lambda$ = 102°37'24.550"E, N = 0.36 m (Modified Everest Ellipsoid)

* West Malaysia and Singapore; Modified Everest Ellipsoid

Table 23.23

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Liberia Datum 1964* -

$$N_m = 5.209 + 3.083\,U + 1.475\,V - 1.843\,UV + 3.082\,U^2V + 2.535\,UV^2 - 0.808\,U^4 - 6.030\,V^4 + 5.962\,V^6 - 2.337\,V^7 + 0.147\,U^9V$$

In the preceding equation:

$U = K\,(\phi - 7)$
$V = K\,(\lambda - 350)$
$K = 0.52359877$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Liberia Datum 1964 geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.2 meter; 19 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Liberia Datum 1964 test point: | $\phi$ = | 7°31'11.956"N | N = 6.11 m (Clarke 1880 Ellipsoid) |
| | $\lambda$ = | 351°28'54.245"E | |

* Liberia; Clarke 1880 Ellipsoid

Table 23.24

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Luzon Datum* -

$$N_m = -0.695 + 3.074\,V - 10.266\,UV - 14.213\,U^2V - 26.432\,UV^2 - 14.482\,V^3 + 0.637\,U^4 + 25.562\,U^2V^3 + 0.931\,U^4V^2 + 67.489\,U^3V^3 - 55.578\,V^7 + 57.233\,U^4V^4 - 26.880\,U^4V^5 + 37.093\,V^9 + 0.399\,U^9V$$

In the preceding equation:

$U = K\,(\phi - 12)$
$V = K\,(\lambda - 122)$
$K = 0.20943951$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Luzon Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 34 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Luzon Datum test point: | $\phi$ = | 6°06'29.040"N | N = -4.05 m (Clarke 1866 Ellipsoid) |
| | $\lambda$ = | 125°10'44.230"E | |

* The Philippines (Except Mindanao Island); Clarke 1866 Ellipsoid

Table 23.25

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Merchich Datum* -

$$N_m = 2.782 + 18.296\,U - 3.669\,V - 36.995\,U^2 + 16.412\,UV - 8.586\,V^2 + 27.435\,U^4 + 7.039\,UV^3 + 39.471\,U^7 - 34.612\,U^9 - 0.388\,V^9 - 4.892\,U^2V^8 + 1.962\,UV^9$$

In the preceding equation:

$U = K\,(\phi - 32)$
$V = K\,(\lambda - 353)$
$K = 0.20943951$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Merchich Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.9 meter; 28 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Merchich Datum test point: | $\phi$ = | 35°08'39.942"N | N = 7.41 m (Clarke 1880 Ellipsoid) |
| | $\lambda$ = | 357°34'13.307"E | |

* Morocco; Clarke 1880 Ellipsoid

Table 23.26

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Minna Datum* -

$$N_m = 2.267 - 5.296\ U + 5.310\ V - 4.288\ V^2 + 12.235\ U^2V^2 - 16.204\ U^2V^8 - 97.314\ U^4V^8$$

In the preceding equation:

$U = K\ (\phi - 10)$
$V = K\ (\lambda - 8)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Minna Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.7 meter; 23 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Minna Datum test point: | $\phi$ = | 9°19'09.051"N | N = 4.52 m (Clarke 1880 Ellipsoid) |
| | $\lambda$ = | 12°13'50.125"E | |

* Nigeria; Clarke 1880 Ellipsoid

Table 23.27

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Nahrwan Datum* -

$$N_m = 7.464 - 3.286\ U - 3.024\ V - 3.994\ U^2 - 4.720\ V^2 - 2.019\ U^3 - 1.613\ V^3$$

In the preceding equation:

$U = K\ (\phi - 23)$
$V = K\ (\lambda - 57)$
$K = 0.41887902$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Nahrwan Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 19 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Nahrwan Datum test point: | $\phi$ = | 24°58'07.671"N | N = 1.11 m (Clarke 1880 Ellipsoid) |
| | $\lambda$ = | 55°00'07.720"E | |

* Masirah Island (Oman) and United Arab Emirates only (Clarke 1880 Ellipsoid). Contact DMA (see PREFACE) if data in this form is needed for Saudi Arabia.

Table 23.28

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Alaska*) -

$$N_m = 1.341 + 12.556\,U + 8.458\,V + 3.742\,U^2 + 19.896\,UV + 4.249\,V^2 - 12.714\,U^3 - 4.746\,U^2V$$
$$- 4.964\,UV^2 + 0.222\,V^3 - 45.166\,U^3V - 13.051\,U^2V^2 - 6.197\,UV^3 - 4.378\,V^4 + 1.472\,UV^4$$
$$- 45.658\,U^6 + 25.253\,U^5V + 23.419\,U^4V^2 + 9.917\,U^3V^3 + 1.050\,V^6 + 10.540\,U^5V^2 - 0.072\,V^8$$
$$+ 37.757\,U^9 - 10.093\,U^9V^2 - 5.382\,U^7V^4 - 1.081\,U^7V^5 - 1.072\,U^8V^6$$

In the preceding equation:

$U = K\,(\phi - 62)$
$V = K\,(\lambda - 208)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Alaska) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 92 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for NAD 27 (Alaska) test point: | $\phi$ = | 64°31'09.064"N | N = -13.84 m (Clarke 1866 Ellipsoid) |
| | $\lambda$ = | 194°37'28.092"E | |

* Clarke 1866 Ellipsoid

Table 23.29

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Canada*) -

$$N_m = - 15.483 - 12.184\ U - 12.497\ V + 50.396\ U^2 + 19.823\ UV + 2.083\ V^2 + 32.462\ U^2V + 14.999\ UV^2$$
$$+ 4.955\ V^3 - 48.440\ U^2V^2 - 18.312\ UV^3 + 5.671\ V^4 - 98.935\ U^6 + 138.270\ U^4V^2 + 48.225\ U^3V^3$$
$$+ 7.353\ U^2V^4 + 3.978\ UV^5 - 1.770\ V^6 + 189.722\ U^5V^2 + 71.967\ U^4V^3 - 0.050\ V^7 + 13.539\ U^3V^5$$
$$- 0.230\ UV^7 + 0.165\ V^8 - 90.371\ U^9 - 4.118\ U^4V^5 + 56.145\ U^6V^4 - 6.084\ U^3V^7 + 0.023\ UV^9$$
$$- 2.707\ U^4V^8 - 25.209\ U^8V^6 + 4.363\ U^8V^8 - 0.059\ U^9V^9$$

In the preceding equation:

$U = K\ (\phi - 60)$
$V = K\ (\lambda - 260)$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Canada) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.1 meters; 150 sites involved in the comparison.

Test Case:

Input data for NAD 27 (Canada) test point: $\phi$ = 54°26'08.667"N, $\lambda$ = 249°42'57.590"E  N = -1.99 m (Clarke 1866 Ellipsoid)

* Clarke 1866 Ellipsoid

Table 23.30

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Caribbean*) -

$$N_m = 15.540 - 33.562\ U - 29.561\ V + 10.844\ U^2 - 29.206\ V^2 - 12.738\ U^2V + 12.876\ UV^2 + 22.374\ V^3 + 11.968\ UV^3 + 29.126\ V^4 - 20.412\ UV^4 - 23.363\ V^5 + 0.596\ V^9 + 1.696\ UV^9 + 4.409\ U^2V^9 + 4.156\ U^3V^9 - 1.268\ U^9V^9$$

In the preceding equation:

$U = K\ (\phi - 20)$
$V = K\ (\lambda - 283)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Caribbean) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.3 meters; 31 sites involved in the comparison.

Test Case:

Input data for NAD 27 (Caribbean) test point: $\phi$ = 18°13'02.433"N, $\lambda$ = 296°56'03.599"E, N = -10.56 m (Clarke 1866 Ellipsoid)

* Bahama Islands (includes San Salvador Island), Barbados Island, Cuba, Dominican Republic, Grand Cayman Island, Jamaica, Leeward Islands, and Turks and Caicos Islands; Clarke 1866 Ellipsoid



[Revised: 30 September 1988]

Table 23.31

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Mexico, Central America)* -

$$N_m = 103.590 + 447.056\,U + 219.294\,V + 144.208\,U^2 + 1094.743\,UV + 115.742\,V^2 + 643.644\,UV^2 - 68.937\,UV^4 + 5.048\,V^5 + 1942.556\,U^6 - 1357.412\,U^5V - 1064.155\,U^4V^2 - 618.937\,U^5V^2 - 851.672\,U^8 + 2044.548\,U^6V^2 - 57.758\,U^3V^5 + 3132.887\,U^8V - 1147.053\,U^7V^2 + 1.466\,UV^8 - 1303.291\,U^9V - 2.443\,U^2V^8$$

In the preceding equation:

$U = K\,(\phi - 20)$
$V = K\,(\lambda - 290)$
$K = 0.05235988$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Mexico, Central America) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.8 meters; 80 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for NAD 27 (Mexico, Central America) test point: | $\phi$ = | 8°56'12.719"N | N = 37.62 m (Clarke 1866 Ellipsoid) |
| | $\lambda$ = | 280°25'46.382"E | |

* Clarke 1866 Ellipsoid

Table 23.32

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Old Egyptian Datum* -

$$N_m = 8.147 - 21.055\ V - 12.690\ U^2 + 6.005\ UV + 11.487\ U^3 + 9.724\ U^2V + 10.950\ UV^2 - 11.207\ U^3V^2 + 64.862\ U^4V^2 - 102.153\ U^7 - 78.986\ U^6V^2 + 105.675\ U^9$$

In the preceding equation:

$U = K\ (\phi - 27)$
$V = K\ (\lambda - 30)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Old Egyptian Datum geoid height (in meters) referenced to the Helmert 1906 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 30 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Old Egyptian Datum test point: | $\phi$ = 29°50°02.352"N<br>$\lambda$ = 30°35°58.098"E | N = 4.87 m (Helmert 1906 Ellipsoid) |

* Egypt; Helmert 1906 Ellipsoid

Table 23.33

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Old Hawaiian Datum* -

$$N_m = -5.840 + 20.184\,U - 8.681\,V - 22.513\,U^2 - 17.363\,UV - 16.119\,UV^2 - 3.872\,V^3 - 14.717\,UV^3 - 4.638\,V^6 + 62.078\,U^5V^7 + 44.025\,U^6V^9$$

In the preceding equation:

$U = K\,(\phi - 21)$
$V = K\,(\lambda - 202)$
$K = 0.41887902$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Old Hawaiian Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.4 meter; 25 sites involved in the comparison.

Test Case:

| | | |
|---|---|---|
| Input data for Old Hawaiian Datum test point: | $\phi$ = 21°34'22.580"N<br>$\lambda$ = 201°44'13.631"E | N = -0.91 m (Clarke 1866 Ellipsoid) |

* Hawaii, Kauai, Maui, and Oahu Islands; Clarke 1866 Ellipsoid

Table 23.34

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Oman Datum* -

$$N_m = -1.620 + 0.915\,U - 15.730\,V + 3.532\,U^2 + 5.837\,UV - 2.690\,V^6 - 6.381\,U^4V^3 - 0.511\,U^8V - 2.035\,U^8V^2$$

In the preceding equation:

$U = K\,(\phi - 21)$
$V = K\,(\lambda - 56)$
$K = 0.31415926$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Oman Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 22 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Oman Datum test point: | $\phi$ = | 24°17'39.334"N | N = 1.28 m (Clarke 1880 Ellipsoid) |
| | $\lambda$ = | 56°31'43.374"E | |

* Oman; Clarke 1880 Ellipsoid

Table 23.35

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Ordnance Survey of Great Britain 1936 Datum* -

$$N_m = -1.313 - 4.647\,U - 4.879\,V - 6.705\,UV + 2.492\,V^2 + 5.422\,U^4 - 2.836\,V^4 - 5.209\,U^3V^2$$

In the preceding equation:

$U = K\,(\phi - 54)$
$V = K\,(\lambda - 0)$
$K = 0.15707963$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed Ordnance Survey of Great Britain 1936 geoid height (in meters) referenced to the Airy Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 52 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Ordnance Survey of Great Britain 1936 test point: | $\phi$ = | 52°08'34.745"N | N = 1.21 m (Airy Ellipsoid) |
| | $\lambda$ = | 358°02'00.119"E | |

* United Kingdom (UK); Airy Ellipsoid



[Revised: 30 September 1988

Table 23.36

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Provisional South American Datum 1956* -

$$N_m = - 7.203 + 31.131\ U + 18.762\ V + 15.566\ U^2 - 11.261\ UV - 50.515\ V^2 + 8.936\ U^3 + 10.403\ U^2V + 43.067\ UV^2 - 11.624\ U^4 - 8.754\ U^3V + 84.802\ V^4 - 1.296\ U^5 + 12.535\ U^3V^2 + 1.427\ U^6 - 1.572\ U^5V - 75.550\ V^6 + 2.753\ U^6V - 41.523\ U^4V^3 - 56.983\ U^3V^4 + 11.012\ U^5V^3 + 7.888\ UV^7 + 18.358\ V^8 - 4.118\ U^5V^4 + 60.552\ U^4V^5 + 7.512\ U^5V^6 - 3.866\ U^2V^9 - 12.122\ U^6V^7 - 0.007\ U^9V^5 + 0.073\ U^9V^6 + 0.894\ U^8V^9$$

In the preceding equation:

$U = K\ (\phi + 5)$
$V = K\ (\lambda - 290)$
$K = 0.10471975$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Provisional South American Datum 1956 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.9 meters; 89 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Provisional South American Datum 1956 test point: | $\phi$ = | -16°31'33.903"S | N = -45.39 m (International Ellipsoid) |
| | $\lambda$ = | 291°50'01.014"E | |

* Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, Venezuela; International Ellipsoid

Table 23.37

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Puerto Rico Datum* -

$$N_m = - 0.194 - 2.762\ V - 30.142\ U^2 - 1.474\ V^2 - 0.072\ V^3 + 37.623\ U^9$$

In the preceding equation:

$U = K\ (\phi - 18)$
$V = K\ (\lambda - 295)$
$K = 0.52359877$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Puerto Rico Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 20 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Puerto Rico Datum test point: | $\phi$ = | 18°22'01.523"N | N = 0.01 m (Clarke 1866 Ellipsoid) |
| | $\lambda$ = | 292°44'02.548"E | |

* Puerto Rico and the Virgin Islands; Clarke 1866 Ellipsoid

Table 23.38

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Qatar National Datum* -

$$N_m = 0.224 - 0.395\ U - 0.455\ V + 0.186\ V^2 - 0.124\ U^4 + 1.909\ U^2V^2 + 0.671\ UV^3 - 0.474\ U^2V^3 - 4.852\ U^7V^8$$

In the preceding equation:

$U = K\ (\phi - 25)$
$V = K\ (\lambda - 51)$
$K = 1.04719754$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Qatar National Datum geoid height (in meters) referenced to International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ± 0.0 meter; 7 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Qatar National Datum test point: | $\phi$ = | 24°34'55.061"N | N = 0.40 m (International Ellipsoid) |
| | $\lambda$ = | 50°59'06.940"E | |

* Qatar; International Ellipsoid

Table 23.39

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Southwest Base Datum* -

$N_m = - 2.321 + 5.039\ U$

In the preceding equation:

$U = K\ (\phi - 38)$
$V = K\ (\lambda - 332)$
$K = 0.52359877$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Southwest Base Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 11 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Southwest Base Datum test point: | $\phi$ = | 38°46'51.568"N | N = -0.26 m (International Ellipsoid) |
| | $\lambda$ = | 332°53'52.593"E | |

* Azores (Faial, Graciosa, Pico, São Jorge, and Terceira Islands); International Ellipsoid

Table 23.40

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Timbalai Datum 1948* -

$$N_m = - 1.703 - 6.806\ U - 7.143\ V + 18.663\ U^3 + 23.300\ UV^3 - 13.211\ U^5 - 10.642\ U^4V - 1.909\ V^5 - 36.586\ U^3V^5 - 28.381\ U^3V^7$$

In the preceding equation:

$U = K\ (\phi - 4)$
$V = K\ (\lambda - 114)$
$K = 0.20943951$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Timbalai Datum 1948 geoid height (in meters) referenced to the Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 26 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Timbalai Datum 1948 test point: | $\phi$ = | 5°00'39.333"N | N = -4.49 m (Everest Ellipsoid) |
| | $\lambda$ = | 115°02'46.480"E | |

* Brunei and East Malaysia (Sarawak and Sabah); Everest Ellipsoid



[Revised: 30 September 1988]

Table 23.41

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights
- Wake-Eniwetok Datum 1960* -

$$N_m = -4.879 + 0.201\,U - 0.096\,UV - 0.041\,V^4 - 1.233\,U^6 + 0.017\,U^2V^4 + 0.532\,U^8 + 0.365\,U^6V^3 - 0.009\,U^8V^6$$

In the preceding equation:

$U = K(\phi - 9)$
$V = K(\lambda - 167)$
$K = 2.09439507$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Wake-Eniwetok Datum 1960 geoid height (in meters) referenced to Hough Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ± 0.0 meter; 6 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Wake-Eniwetok Datum 1960 test point: | $\phi$ = | 8°43'12.587"N | N = -5.10 m (Hough Ellipsoid) |
| | $\lambda$ = | 167°44'13.400"E | |

* Kwajalein Atoll Area Only; Hough Ellipsoid

Table 23.42

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Zanderij Datum* -

$$N_m = -0.781 + 7.775\,U + 3.048\,V + 2.838\,U^2 + 2.604\,UV + 3.077\,V^2 + 1.509\,U^3 + 1.997\,UV^2 + 0.833\,V^3 + 1.105\,U^4V + 0.435\,U^5V$$

In the preceding equation:

$U = K\,(\phi - 5)$
$V = K\,(\lambda - 305)$
$K = 0.52359877$
$\phi$ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
$\lambda$ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Zanderij Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 22 sites involved in the comparison.

Test Case:

| | | | |
|---|---|---|---|
| Input data for Zanderij Datum test point: | $\phi$ = | 5°27'09.451"N | N = 0.89 m (International Ellipsoid) |
| | $\lambda$ = | 304°47'47.486"E | |

* Surinam; International Ellipsoid



[Revised: 30 September 1988]

Table 23.43

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights* - Remaining Local Geodetic Systems

| Local Geodetic System | Geoid Height (Meters) | Reference Ellipsoid |
|---|---|---|
| ADINDAN | | |
| Mali | ** | Clarke 1880 |
| Senegal | ** | Clarke 1880 |
| AFGOOYE | | |
| Somalia | ** | Krassovsky |
| AIN EL ABD 1970 | | |
| Bahrain Island | 1 | International |
| ANNA 1 ASTRO 1965 | | |
| Cocos Islands | -3 | Australian National |
| ASCENSION ISLAND 1958 | | |
| Ascension Island | -2 | International |
| ASTRO BEACON "E" | | |
| Iwo Jima Island | -8 | International |
| ASTRO B4 SOROL ATOLL | | |
| Tern Island | -7 | International |
| ASTRO DOS 71/4 | | |
| St. Helena Island | -3 | International |
| ASTRONOMIC STATION 1952 | | |
| Marcus Island | -3 | International |
| BELLEVUE (IGN) | | |
| Efate and Erromango Islands (New Hebrides Islands) | -4 | International |
| BERMUDA 1957 | | |
| Bermuda Islands | -4 | Clarke 1866 |
| CHATHAM 1971 | | |
| Chatham Island | 3 | International |
| DOS 1968 | | |
| Gizo Island (New Georgia Islands) | 0 | International |
| EASTER ISLAND 1967 | | |
| Easter Island | 0 | International |
| EUROPEAN DATUM 1950 | | |
| Sardinia | -2 | International |
| Sicily | -1 | International |
| GANDAJIKA BASE | | |
| Republic of Maldives | 1 | International |

* For use throughout the areal extent of the local geodetic system and/or geographical area listed; supplements Table 23.1 through Table 23.42

** Time constraints prevented inclusion of DMA-developed local geodetic system geoid heights in this form for these datums or areas. If such data is required, contact DMA (see PREFACE).



[Revised: 30 September 1988]

Table 23.43 (Cont'd)

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights* - Remaining Local Geodetic Systems

| Local Geodetic System | Geoid Height (Meters) | Reference Ellipsoid | Local Geodetic System | Geoid Height (Meters) | Reference Ellipsoid |
|---|---|---|---|---|---|
| GUX 1 ASTRO<br>Guadalcanal Island | -1 | International | MAHE 1971<br>Mahe Island | -1 | Clarke 1880 |
| HONG KONG 1963<br>Hong Kong | 1 | International | MARCO ASTRO<br>Salvage Islands | -4 | International |
| INDIAN<br>Bangladesh, India, and Nepal | ** | Everest | MASSAWA<br>Eritrea (Ethiopia) | ** | Bessel 1841 |
| ISTS 073 ASTRO 1969<br>Diego Garcia | -2 | International | MIDWAY ASTRO 1961<br>Midway Island | -6 | International |
| JOHNSTON ISLAND 1961<br>Johnston Island | -4 | International | NAHRWAN<br>Saudi Arabia | ** | Clarke 1880 |
| KERGUELEN ISLAND<br>Kerguelen Island | 0 | International | NAPARIMA, BWI<br>Trinidad and Tobago | 3 | International |
| L.C.5 ASTRO<br>Cayman Brac Island | -2 | Clarke 1866 | NAD 27<br>Greenland (Hayes Peninsula) | ** | Clarke 1866 |
| LUZON<br>Mindanao Island | ** | Clarke 1866 | OBSERVATORIO 1966<br>Corvo and Flores Islands (Azores) | 2 | International |

* For use throughout the areal extent of the local geodetic system and/or geographical area listed; supplements Table 23.1 through Table 23.42.

** Time constraints prevented inclusion of DMA-developed local geodetic system geoid heights in this form for these datums or areas. If such data is required, contact DMA (see PREFACE).

Table 23.43 (Cont'd)

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights* - Remaining Local Geodetic Systems

| Local Geodetic System | Geoid Height (Meters) | Reference Ellipsoid | Local Geodetic System | Geoid Height (Meters) | Reference Ellipsoid |
|---|---|---|---|---|---|
| PICO DE LAS NIEVES<br>Canary Islands | -6 | International | SÃO BRAZ<br>São Miguel, Santa Maria Islands (Azores) | -1 | International |
| PITCAIRN ASTRO 1967<br>Pitcairn Island | -3 | International | SAPPER HILL 1943<br>East Falkland Island | 1 | International |
| PROVISIONAL SOUTH CHILEAN 1963<br>South Chile (Near 53°S) | 0 | International | SCHWARZECK<br>Namibia | ** | Bessel 1841 |
| QORNOQ<br>South Greenland | 6***<br>23**** | International | SOUTH ASIA<br>Singapore | 0 | Modified Fischer 1960 |
| REUNION<br>Mascarene Island | -6 | International | SOUTHEAST BASE<br>Porto Santo and Madeira Islands | -3 | International |
| ROME 1940<br>Sardinia Island | 3 | International | TRISTAN ASTRO 1968<br>Tristan da Cunha | 2 | International |
| SANTO (DOS)<br>Espirito Santo Island | -4 | International | VITI LEVU 1916<br>Viti Levu Island (Fiji Islands) | 0 | Clarke 1880 |

* For use throughout the areal extent of the local geodetic system and/or geographical area listed; supplements Table 23.1 through Table 23.42

** Time constraints prevented inclusion of DMA-developed local geodetic system geoid heights in this form for these datums or areas. If such data is required, contact DMA (see PREFACE).

*** Vicinity of 61°30'N, 318°E

**** Vicinity of 67°N, 309°E

SECTION 24

# SOLVING DIRECTLY FOR WGS 84 COORDINATES

Table 24.1

Procedure for Solving Directly for WGS 84 Coordinates*

1. Acquire Doppler Data (35 or More Passes) from Each Site to be Positioned.

2. Acquire Precise Ephemerides for "Tracked" Navy Navigation Satellite System (NNSS) Satellites from DMA. The Precise Ephemerides are Based on:

   a. Defining Parameters of WGS 84 Ellipsoid

   b. WGS 84 EGM (n=m=41)

   c. WGS 84 Coordinates for Doppler Tracking Network (TRANET) Stations Used in the Generation of the Precise Ephemerides. (These Station Coordinates, Determined When Placing the NNSS on WGS 84, are Held Fixed.)

3. Perform Satellite Point Positioning Solution (Using Data From 1, Above), Holding Precise Ephemerides (From 2, Above) Fixed Within Estimated Error Bounds, to Directly Obtain Doppler-Derived WGS 84 Coordinates for Site of Interest.

* It is anticipated that current usage of NNSS Satellites will give way to NAVSTAR GPS Satellites and associated tracking data as the latter System nears full operational capability.

Table 24.2

WGS 84 Coordinates
Solved for Directly in WGS 84
- Comments -

1. The accuracy (one sigma) of WGS 84 coordinates directly determined in WGS 84 by Doppler Satellite Point Positioning utilizing NNSS Satellites, their respective precise ephemerides, and ground-based Doppler Satellite tracking data acquired in the static mode [2; Sections 7.2.1 and 9.2] is in geodetic latitude, geodetic longitude, and geodetic height:

$$\sigma_{\phi} \text{ (WGS 84)} = \pm 1 \text{ m}$$
$$\sigma_{\lambda} \text{ (WGS 84)} = \pm 1 \text{ m}$$
$$\sigma_{H} \text{ (WGS 84)} = \pm 1 \text{ to } \pm 2 \text{ m.}$$

A similar Satellite Point Positioning capability utilizing NAVSTAR GPS Satellites is currently under development by DMA.

2. Organizations desiring directly solved for WGS 84 coordinates at special locations such as test range sensor sites, etc., for reasons of accuracy and/or confidence, should make their requirements known through appropriate Service channels to the address provided in the PREFACE.

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SECTION 25

# CONVERSION OF WGS 72 COORDINATES
# TO
# WGS 84 COORDINATES

Table 25.1

Conversion of WGS 72 Coordinates
to WGS 84 Coordinates
- Comments -

1. Formulas (General Form)

$$\phi_{WGS\ 84} = \phi_{WGS\ 72} + \Delta\phi$$

$$\lambda_{WGS\ 84} = \lambda_{WGS\ 72} + \Delta\lambda$$

$$H_{WGS\ 84} = H_{WGS\ 72} + \Delta H$$

[$\phi$ = Geodetic Latitude, $\lambda$ = Geodetic Longitude, H = Geodetic Height]

2. WGS 84 Coordinates Will Differ From WGS 72 Coordinates Due To:

- Shift in Coordinate System Origin
- Change in Longitude Reference
- Change in Scale
- Changes in Ellipsoid Size (a) and Shape (f)
  (a = Semimajor Axis, f = Flattening)

[See Figures 25.1, 25.2, 25.3, 25.4, and 25.5]

3. NOTE:

At non-Doppler sites, this method of obtaining WGS 84 coordinates (Table 25.1) should generally only be used if localized Local Geodetic System-to-WGS 84 Datum Shifts are not available or if WGS 84 Coordinates cannot be solved for directly in WGS 84 using Satellite Point Positioning and ground-based satellite tracking data. [Also, see Section 11, Section 24, Section 26 (Figures 26.1 - 26.30), and Section 27 (Table 27.1, Figures 27.1 - 27.21) of this report and Sections 7.2.3 and 9.3 of Reference 2.]

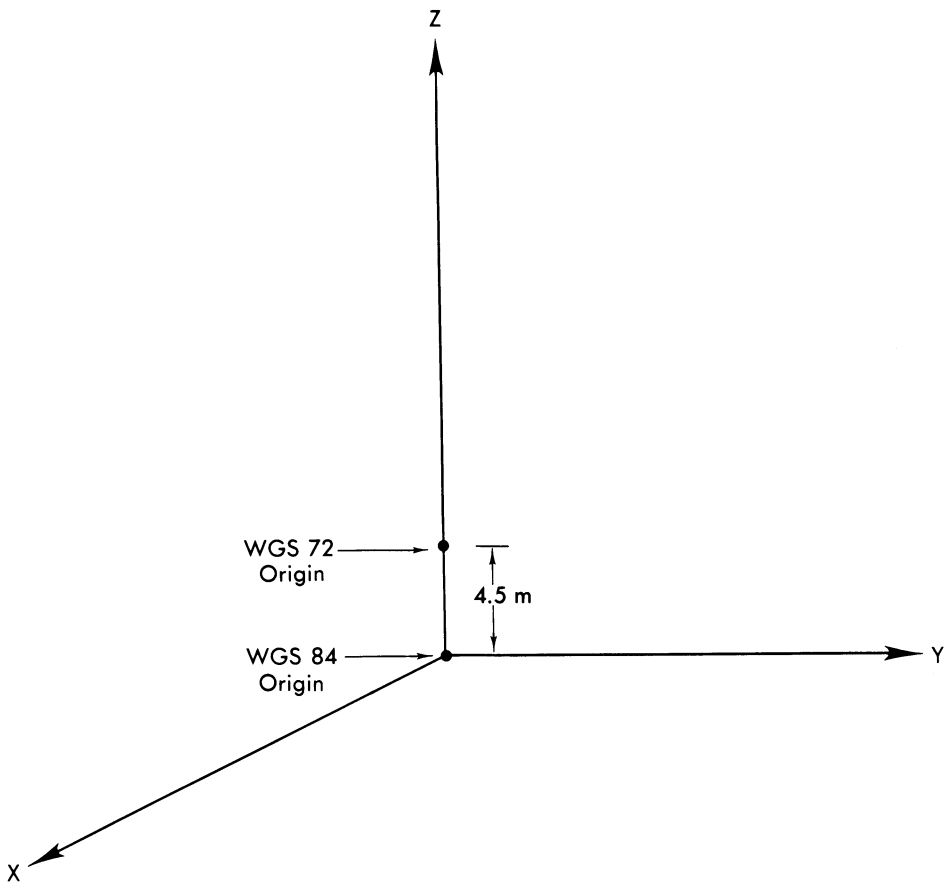



Figure 25.1. Difference Between WGS 72 and WGS 84 Reference Frame Origins

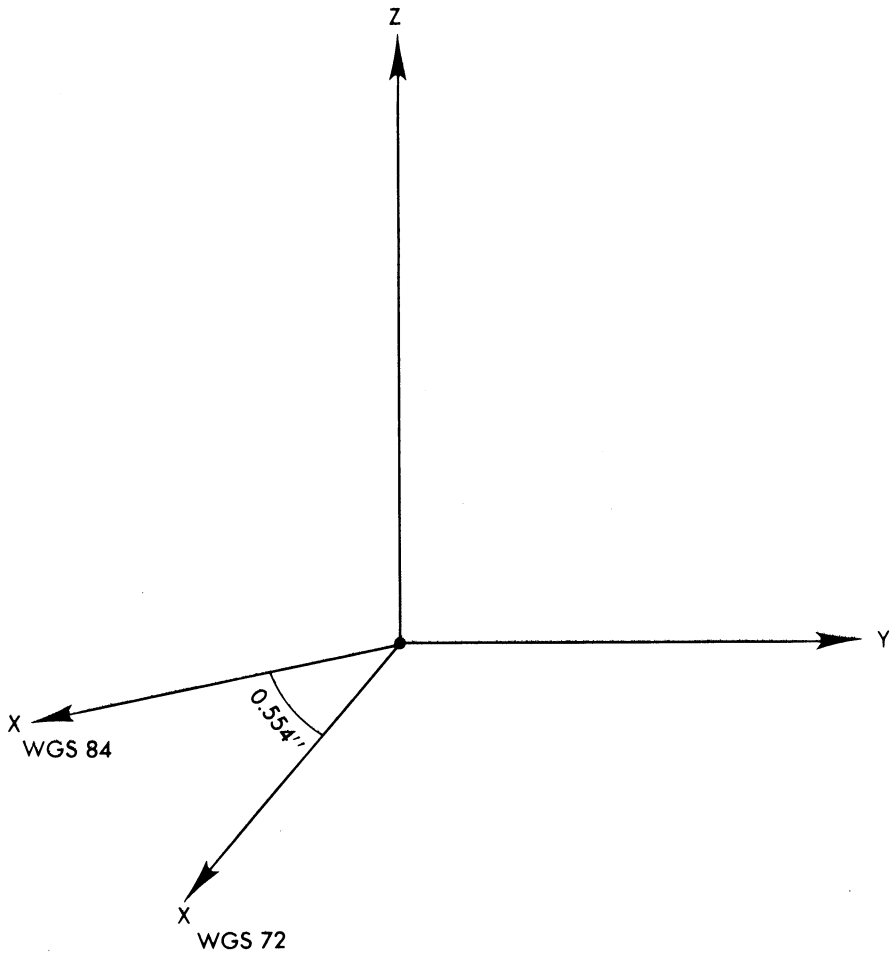



Figure 25.2. Difference Between WGS 72 and WGS 84 Longitude References (X-Axes)

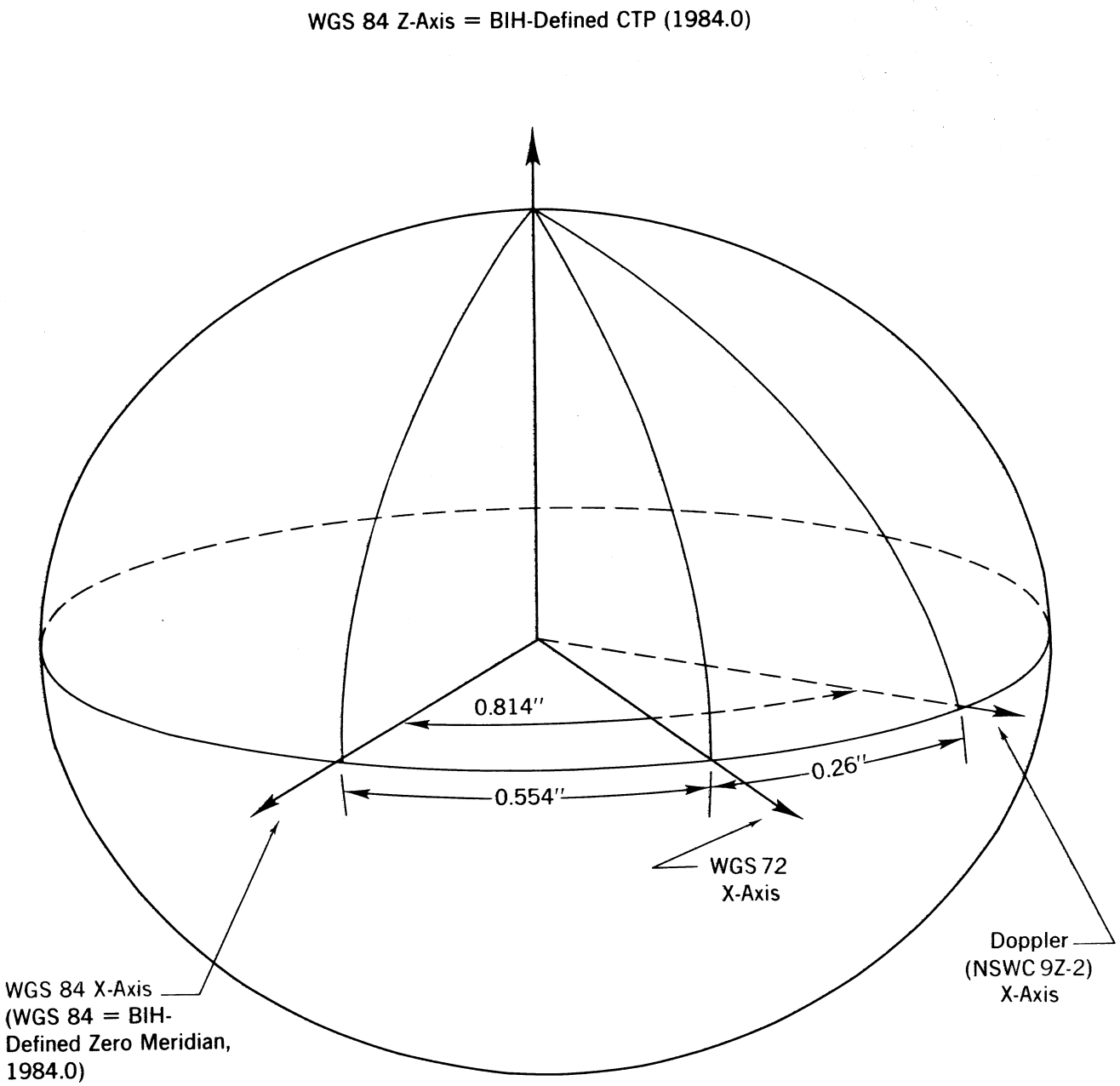
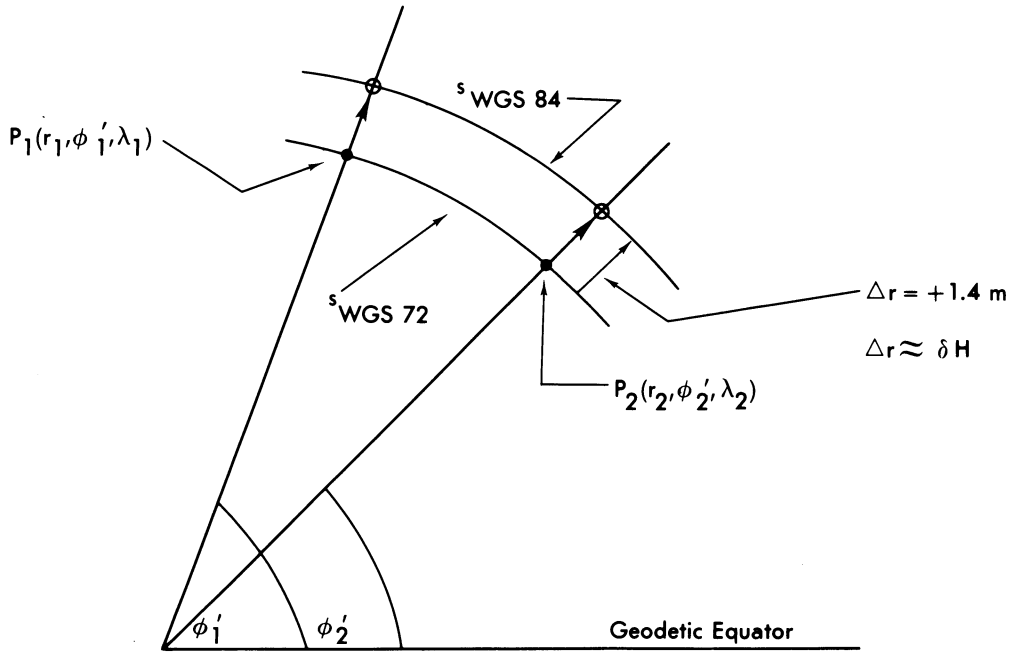



Figure 25.3. Reference Longitude Relationships: Doppler (NSWC 9Z-2), WGS 72, and WGS 84 = BIH-Defined Zero Meridians

$(s_{WGS\ 72} < s_{WGS\ 84})$

s = distance
r = radius vector
$\phi'$ = geocentric latitude
$\lambda$ = geocentric (geodetic) longitude
H = geodetic height




(See Table 25.2.)

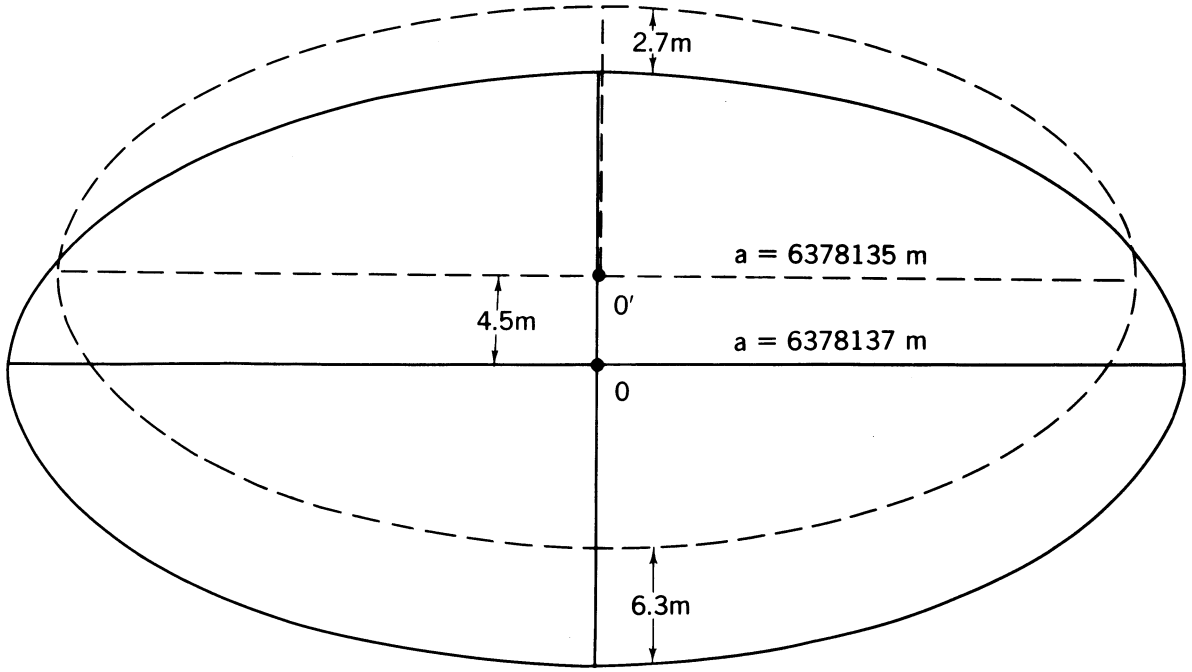
Figure 25.4. Differences Between WGS 84 and WGS 72 Distances and Geodetic Heights (Effect of Scale Change)

WGS 84

a = 6378137m
b = 6356752.3142m
f = 1/298.257223563
(0.00335281066474)

WGS 72

a = 6378135m
b = 6356750.5m
f = 1/298.26
(0.00335277945417)




0 = Origin of WGS 84 Ellipsoid = Earth's Center of Mass

0' = Origin of WGS 72 Ellipsoid = Earth's Center of Mass (as Known in 1972)

Figure 25.5. WGS 84 and WGS 72 Ellipsoid Differences (Size, Shape)

Table 25.2

Formulas and Parameters
to Transform WGS 72 Coordinates
to WGS 84 Coordinates

| | |
|---|---|
| Formulas | $\Delta\phi'' = (4.5 \cos \phi) / (a \sin 1'') + (\Delta f \sin 2\phi) / (\sin 1'')$<br>$\Delta\lambda'' = 0.554$<br>$\Delta H_m = 4.5 \sin \phi + a\, \Delta f \sin^2 \phi - \Delta a + \Delta r$ |
| Parameters | $\Delta f = 0.3121057 \times 10^{-7}$<br>$a = 6378135$ m<br>$\Delta a = 2.0$ m<br>$\Delta r = 1.4$ m (See Figure 25.4.) |
| Instructions | To Obtain WGS 84 Coordinates, Add the $\Delta\phi$, $\Delta\lambda$, $\Delta H$ Changes Calculated Using WGS 72 Coordinates to the WGS 72 Coordinates ( $\phi$, $\lambda$, and H, Respectively). (Table 25.3 Entries May be Used as Test Points.)<br><br>Latitude is Positive North and Longitude is Positive East (0° to 360°). |

Table 25.3

Difference Between WGS 84
and WGS 72 Geodetic Coordinates*

| Degrees | Difference (Meters) | | |
|---|---|---|---|
| | Latitude | Longitude | Height |
| 90 N | 0.0 | 0.0 | 4.1 |
| 85 | 0.4 | 1.5 | 4.1 |
| 80 | 0.8 | 3.0 | 4.0 |
| 75 | 1.3 | 4.4 | 3.9 |
| 70 | 1.7 | 5.9 | 3.8 |
| 65 | 2.1 | 7.2 | 3.6 |
| 60 | 2.4 | 8.6 | 3.4 |
| 55 | 2.8 | 9.8 | 3.2 |
| 50 | 3.1 | 11.0 | 3.0 |
| 45 | 3.4 | 12.1 | 2.7 |
| 40 | 3.6 | 13.1 | 2.4 |
| 35 | 3.9 | 14.0 | 2.0 |
| 30 | 4.1 | 14.8 | 1.7 |
| 25 | 4.2 | 15.5 | 1.3 |
| 20 | 4.4 | 16.1 | 1.0 |
| 15 | 4.4 | 16.5 | 0.6 |
| 10 | 4.5 | 16.9 | 0.2 |
| 5 N | 4.5 | 17.1 | -0.2 |
| 0 | 4.5 | 17.1 | -0.6 |
| 5 S | 4.4 | 17.1 | -1.0 |
| 10 | 4.4 | 16.9 | -1.4 |
| 15 | 4.2 | 16.5 | -1.8 |
| 20 | 4.1 | 16.1 | -2.1 |
| 25 | 3.9 | 15.5 | -2.5 |
| 30 | 3.7 | 14.8 | -2.8 |
| 35 | 3.5 | 14.0 | -3.1 |
| 40 | 3.3 | 13.1 | -3.4 |
| 45 | 3.0 | 12.1 | -3.7 |
| 50 | 2.7 | 11.0 | -3.9 |
| 55 | 2.4 | 9.8 | -4.2 |
| 60 | 2.1 | 8.6 | -4.3 |
| 65 | 1.7 | 7.2 | -4.5 |
| 70 | 1.4 | 5.9 | -4.7 |
| 75 | 1.1 | 4.4 | -4.8 |
| 80 | 0.7 | 3.0 | -4.8 |
| 85 | 0.4 | 1.5 | -4.9 |
| 90 S | 0.0 | 0.0 | -4.9 |

*Applies only when proceeding directly from WGS 72 Coordinates to WGS 84 Coordinates; does not contain the effect of the WGS 84 Earth Gravitational Model and Geoid, nor the effect of Local Geodetic System-to-WGS 84 Datum Shifts being better than Local Geodetic System-to-WGS 72 Datum Shifts. Results in this Table are based on formulas and input data from Table 25.2. (Also, see Table 6.1.)

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