STATE PLANE COORDINATES
Washington State

Washington State Land Surveyors Association

Larry Signani
13 March 2007
SURVEY TYPES

- Surveys can be grouped into two categories:
- 1. Plane Surveys
- 2. Geodetic Surveys

A survey of a small area in which the area surveyed is considered flat except for topographic variations, is termed a plane survey and this branch of surveying is called Plane Surveying.

When a survey covers a large portion of the earth, the curvature of the earth has to be considered. Surveys of this type cannot be mapped on plane sheets of paper without distortions. These are called Geodetic Surveys, the position of points are indicated either by spherical coordinates, namely Latitude and Longitude, or by Plane Coordinates after projecting onto a plan surface, E.G., State Plane Coordinates.
SURVEY TYPES

- Plane Surveys
  - assume earth’s surface is flat plane
  - use X-Y coordinates
  - easy procedures and computations
  - sufficient for most surveys

- Geodetic Surveys
  - accurately represent earth’s shape
  - use spheroid coordinates (Latitude, Longitude)
  - more complex, expensive, difficult computations
GEOCENTRIC AND GEOGRAPHICAL
LATITUDE & LONGITUDE
THE ELLIPSOID
MATHEMATICAL MODEL OF THE EARTH

\[ a = \text{Semi major axis} \]

\[ b = \text{Semi minor axis} \]

\[ f = \frac{a-b}{a} = \text{Flattening} \]

\[ S \]

\[ N \]
THE ELLIPSOID

THE ELLIPSOID

NORTH GEODETiC POLE

GEODETiC NORMAL

GEODETiC HORIZON

GEODETiC MERIDIAN

GEODETiC PARALLEL

GEODETiC EQUATOR

ROTaTiON AXIS

ZERO GEODETiC MERIDIAN

SOUTH GEODETiC POLE
UNITED STATES
ELLIPSOID DEFINITIONS

BESSEL 1841
a = 6,377,397.155 m 1/f = 299.1528128

CLARKE 1866
a = 6,378,206.4 m 1/f = 294.97869821

GEODETIC REFERENCE SYSTEM 1980 - (GRS 80)
a = 6,378,137 m 1/f = 298.257222101

WORLD GEODETIC SYSTEM 1984 - (WGS 84)
a = 6,378,137 m 1/f = 298.257223563
THE ELLIPSOID

(1738) 6,397,3006,363,806.283191 France Everest
(1830) 6,377,563.3966,356,256.909299.3249646 Britain Bessel
(1866) 6,378,206.46,356,583.8294.9786982 North America Clarke
(1880) 6,378,249.1456,356,514.870293.465 France, Africa Helmert
(1969) 6,378,1606,356,774.719298.25 South America WGS-72
(1972) 6,378,1356,356,750.52298.26 USA/DoD GRS-80
(1979) 6,378,1376,356,752.3141298.257222101 NAD 83
(1982) 6,378,1376,356,752.3298.257024899 N America WGS-84
THE GEOID AND TWO ELLIPSOIDS

GRS80-WGS84

CLARKE 1866

Earth Mass Center
Approximately 236 meters
DATUMS

A set of constants specifying the coordinate system used for geodetic control, i.e., for calculating coordinates of points on the Earth. Specific geodetic datums are usually given distinctive names. (e.g., North American Datum of 1983, European Datum 1950, National Geodetic Vertical Datum of 1929)
DATUM

ANY LEVEL OR CURVED SURFACE (REAL OR IMAGINARY) TO WHICH MARKS ARE REFERENCE TO.

EARTH CRUST

MEAN SEA LEVEL DATUM

VERTICAL LINE OR PLUMB LINE
VERTICAL DATUMS

MEAN SEA LEVEL DATUM OF 1929

NATIONAL GEODE蒂C VERTICAL DATUM OF 1929
(As of July 2, 1973)

NORTH AMERICAN VERTICAL DATUM OF 1988
(As of June 24, 1993)
NGVD 29 and NAVD 88
# COMPARISON OF VERTICAL DATUM ELEMENTS

<table>
<thead>
<tr>
<th></th>
<th><strong>NGVD 29</strong></th>
<th><strong>NAVD 88</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DATUM DEFINITION</strong></td>
<td>26 TIDE GAUGES IN THE U.S. &amp; CANADA</td>
<td>FATHER’S POINT/RIMOUSKI QUEBEC, CANADA</td>
</tr>
<tr>
<td><strong>BENCH MARKS</strong></td>
<td>100,000</td>
<td>450,000</td>
</tr>
<tr>
<td><strong>LEVELING (Km)</strong></td>
<td>102,724</td>
<td>1,001,500</td>
</tr>
<tr>
<td><strong>GEOID FITTING</strong></td>
<td>Distorted to Fit MSL Gauges</td>
<td>Best Continental Model</td>
</tr>
<tr>
<td></td>
<td>NAD 27</td>
<td>NAD 83</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------------------------------------</td>
<td>--------------------------------------------</td>
</tr>
<tr>
<td>ELLIPSOID</td>
<td>CLARKE 1866</td>
<td>GRS80</td>
</tr>
<tr>
<td></td>
<td>(a = 6,378,206.4) m</td>
<td>(a = 6,378,137.) M</td>
</tr>
<tr>
<td></td>
<td>(1/f = 294.9786982)</td>
<td>(1/f = 298.257222101)</td>
</tr>
<tr>
<td>DATUM POINT</td>
<td>Triangulation Station</td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td>MEADES RANCH, KANSAS</td>
<td>EARTH MASS CENTER</td>
</tr>
<tr>
<td>ADJUSTMENT</td>
<td>25k STATIONS</td>
<td>250k STATIONS</td>
</tr>
<tr>
<td></td>
<td>Several Hundred Base Lines</td>
<td>Approx. 30k EDMI Base Lines</td>
</tr>
<tr>
<td></td>
<td>Several Hundred Astro Azimuths</td>
<td>5k Astro Azimuths</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Doppler Point Positions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VLBI Vectors</td>
</tr>
<tr>
<td>BEST FITTING</td>
<td>North America</td>
<td>World-Wide</td>
</tr>
</tbody>
</table>
NAD 27 and NAD 83
HIGH ACCURACY REFERENCE NETWORKS

“GPSABLE”
Clear Horizons for Satellite Signal Acquisition

EASY ACCESSIBILITY
Few Special Vehicle or Property Entrance Requirements

REGULARLY SPACED
Always within 20-100 Km

HIGH HORIZONTAL ACCURACY
A-Order (5 mm + 1:10,000,000)
B-Order (8mm + 1:1,000,000)
HIGH ACCURACY REFERENCE NETWORKS
WASHINGTON
HIGH PRECISION NETWORK
The NGS Data Sheet

See file _data.txt for more information about the datasheet.

DATABASE = .PROGRAM = datasheet, VERSION = 7.5a
1 National Geodetic Survey, Retrieval Date = MARCH 10, 2008
DG9672

**CURRENT SURVEY CONTROL**

DG9672* NAD 83 (1986) - 47 00 36. (N) 122 54 34. (W) SCALED
DG9672* NAVD 88 - 53.014 (meters) 171.93 (feet) ADJUSTED

DG9672 GEOID HEIGHT - -21.36 (meters) GEOID03
DG9672 DYNAMIC HT - 53.024 (meters) 173.96 (feet) COMP
DG9672 MODELED GRAV - 980,809.7 (mGal) NAVD 88

DG9672 VERT ORDER - SECOND CLASS I
DG9672.DThe horizontal coordinates were scaled from a topographic map and have an estimated accuracy of +/- 6 seconds.
DG9672.DThe orthometric height was determined by differential leveling
DG9672.and adjusted in July 2005.
DG9672.DThe geoid height was determined by GEOID03.
DG9672.DThe dynamic height is computed by dividing the NAVD 88
DG9672.geopotential number by the normal gravity value computed on the
DG9672.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
DG9672.degrees latitude (g = 980.6199 gals.).
DG9672.DThe modeled gravity was interpolated from observed gravity values.
DG9672;
DG9672; North East Units Estimated Accuracy
DG9672;SPC WA S - 188,850. 316,810. MT (+/- 188 meters Scaled)
DG9672
DG9672 SUPERSEDED SURVEY CONTROL
DG9672.DNo superseded survey control is available for this station.
DG9672.DG9672.U.S. NATIONAL GRID SPATIAL ADDRESS: 10TET068059(NAD 83)
DG9672.MARKER: F = FLANGE-ENCASED ROD
DG9672;SETTING: 50 = ALUMINUM ALLOY ROD W/O SLEEVE (10 FT.+)
DG9672;STAMPING: ARC 2004
DG9672;MARK LOGO: NADT
DG9672;PROJECTION: RECESSD 16 CENTIMETERS
DG9672;MAGNETIC: O = OTHER; SEE DESCRIPTION
DG9672;STABILITY: S = PROBABLY HOLD POSITION/ELEVATION WELL
DG9672;SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
DG9672;SATELLITE: SATELLITE OBSERVATIONS - October 29, 2004
DG9672;ROD/PIPE-DEPTH: 7.7 meters
DG9672

The NGS Data Sheet
See file _ddata.txt for more information about the datasheet.
DATABASE = , PROGRAM = datasheet, VERSION = 7.58
SY1599 NATIONAL GEOFECTIC SURVEY, Retrieval Date = MARCH 10, 2008
SY1599
SY1599 DESIGNATION - A 461 EAST
SY1599 PID - SY1599
SY1599 STATE/COUNTY - WA/THURSTON
SY1599 USGS QUAD - TIMNARW (1904)
SY1599
SY1599 *CURRENT SURVEY CONTROL
SY1599
SY1599* NAD 83 (1991) = 47 02 05.68216(N) 122 53 12.08665(W) ADJUSTED
SY1599* NAVD 88 = 20.889 (meters) 68.53 (feet) ADJUSTED
SY1599
SY1599 X = -2,364,592.757 (meters) COMP
SY1599 Y = -3,656,966.266 (meters) COMP
SY1599 Z = 4,644,410.470 (meters) COMP
SY1599 LAPLACE CORR = -9.55 (seconds) DEFLEC99
SY1599 ELLIP HEIGHT = -0.560 (meters) (08/17/92) ADJUSTED
SY1599 GEOID HEIGHT = -21.53 (meters) GEOID03
SY1599 DYNAMIC HT = 20.893 (meters) 68.55 (feet) COMP
SY1599 MODELED GRAV = 980,802.9 (mgal) NAVD 88
SY1599
SY1599 HORIZ ORDER = FIRST
SY1599 VERT ORDER = FIRST CLASS II
SY1599 ELLIP ORDER = FOURTH CLASS II
SY1599
SY1599 The horizontal coordinates were established by GPS observations
SY1599 and adjusted by the National Geodetic Survey in August 1992.
SY1599
SY1599 The orthometric height was determined by differential leveling
SY1599 and adjusted in June 1991.
SY1599
SY1599 The X, Y, and Z were computed from the position and the ellipsoidal ht.
SY1599
SY1599 The Laplace correction was computed from DEFLEC99 derived deflections.
SY1599
SY1599 The ellipsoidal height was determined by GPS observations
SY1599 and is referenced to NAD 83.
SY1599
SY1599 The geoid height was determined by GEOID03.
SY1599
SY1599 The dynamic height is computed by dividing the NAVD 88
SY1599 geopotential number by the normal gravity value computed on the
SY1599 Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
SY1599 degrees latitude (g = 980.6199 gals.).
SY1599
SY1599 The modeled gravity was interpolated from observed gravity values.
SY1599
SY1599
SY1599; North East Units Scale Factor Converg.
SY1599 SPC WA S = 191,878.267 316,633.710 MI 0.99994540 -1 44 01.3
SY1599 SPC WA S = -629,520.631 1,045,384.10 FTP 0.99994540 -1 44 01.3
SY1599 UTM 10 = 5,209,049.963 508,608.789 MI 0.99960389 0 04 58.5
SY1599
The NGS Data Sheet

See file _ddata.txt_ for more information about the datasheet.

**DATABASE** - Pgs/Map, PROGRAM - datasheet, VERSION - 7.42

1 National Geodetic Survey, Retrieval Date = FEBRUARY 2, 2007

**SY645** **SY645**

**SY645** PGN - This is a Federal Base Network Control Station.

**SY645** DESIGNATION - FAIR

**SY645** PID - SY645

**SY645** STATE/COUNTY - WA/GRAY'S HARBOR

**SY645** USGS QUAD - ELMA (1981)

**SY645** *CURRENT SURVEY CONTROL*

<table>
<thead>
<tr>
<th>NAD 83 (1998)</th>
<th>47 00 52.55662(N)</th>
<th>123 22 35.28791(W)</th>
<th>ADJUSTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAVD 88</td>
<td>32.316 (meters)</td>
<td>106.02 (feet)</td>
<td>ADJUSTED</td>
</tr>
</tbody>
</table>

**SY645**

**SY645** X   -2,396,675.778 (meters)   COMP

**SY645** Y   -3,638,005.919 (meters)   COMP

**SY645** Z   4,642,875.264 (meters)   COMP

**SY645** LAPLACE CORR 10.40 (seconds) DEFLEC99

**SY645** ELLIP HEIGHT 10.65 (meters) (03/21/00) GPS OBS

**SY645** EROID HEIGHT -21.66 (meters) GEOID03

**SY645** DYNAMIC KT 32.322 (meters) 106.04 (feet) COMP

**SY645** MODELED GRAV 980.791.2 (mgal) NAVD 88

**SY645**

**SY645** HORIZ ORDER A

**SY645** VERT ORDER SECOND CLASS II

**SY645** ELLIP ORDER THIRD CLASS II

**SY645**

The horizontal coordinates were established by GPS observations and adjusted by the National Geodetic Survey in March 2000.

**SY645** This is a SPECIAL STATUS position. See SPECIAL STATUS under the DATUM ITEM on the data sheet items page.

**SY645**

The orthometric height was determined by differential leveling and adjusted by the National Geodetic Survey in April 1995.

**SY645** The X, Y, and Z were computed from the position and the ellipsoidal ht.

**SY645** The Laplace correction was computed from DEFLEC99 derived deflections.

**SY645** The ellipsoidal height was determined by GPS observations and is referenced to NAD 83.

**SY645** The geoid height was determined by GEOID03.

**SY645** The dynamic height is computed by dividing the NAVD 88 by the normal gravity value computed on the Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45 degrees latitude (g = 980.6199 gals.).

**SY645** The modeled gravity was interpolated from observed gravity values.

**SY645**

North East Units Scale Factor Converg.

**SY645**

SY645;SPC WA S 190,863.335 281,347.893 MT 0.999994268 -2 05 22.0

The NGS Data Sheet
See file d3data.txt for more information about the datasheet.

DATABASE = RPROGRAM = datasheet, VERSION = 7.58
1 National Geodetic Survey, Retrieval Date = MARCH 10, 2008
SY3193

SY3193 DESIGNATION - HOSP RM 4 1974
SY3193 PID - SY3193
SY3193 STATE/COUNTY - WA/THURSTON
SY3193 USGS QUAD - LACEY (1994)
SY3193

*CURRENT SURVEY CONTROL

SY3193

SY3193* NAD 83(1991)- 47 02 47.82141(N) 122 51 09.07491(W) ADJUSTED
SY3193* NAVD 88 - 50.4 (meters) 165. (feet) VERTCON
SY3193

SY3193 LAPLACE CORR- -9.04 (seconds) DEFLEC99
SY3193 GEOID HEIGHT- -21.66 (meters) GEOID03
SY3193 HORZ ORDER - SECOND
SY3193

The horizontal coordinates were established by classical geodetic methods and adjusted by the National Geodetic Survey in December 1991.

SY3193

The NAVD 88 height was computed by applying the VERTCON shift value to the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
SY3193

The Laplace correction was computed from DEFLEC99 derived deflections.

SY3193

The geoid height was determined by GEOID03.

SY3193

SY3193;

SY3193;SPC WA S - 193,100.914 321,268.335 MT 0.99994703 -1 42 31.9
SY3193;SPC WA S - 633,531.92 1,054,027.86 sFT 0.99994703 -1 42 31.9
SY3193;UTM 10 - 5,210,355.068 511,202.434 MT 0.99960154 +0 06 28.6
SY3193

SY3193!

- Elev Factor x Scale Factor = Combined Factor
SY3193!SPC WA S - 0.99999549 x 0.99994703 = 0.999994252
SY3193!UTM 10 - 0.99999549 x 0.99960154 = 0.99999703

SY3193

SY3193

SUPERSEDED SURVEY CONTROL

SY3193

SY3193 NAD 83(1986)- 47 02 47.81920(N) 122 51 09.08485(W) AD( ) 2
SY3193 NAD 27 - 47 02 48.46856(N) 122 51 04.58400(W) AD( ) 2
SY3193 NGVD 29 (07/19/86) 49.4 (m) 162. (f) VERT ANG
SY3193

SY3193
**Geographic Services**

**SURVEY INFORMATION SYSTEM**

**GENERAL MONUMENT INFORMATION**

<table>
<thead>
<tr>
<th>Designation:</th>
<th>GP34005-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument ID:</td>
<td>193</td>
</tr>
<tr>
<td>State:</td>
<td>WASHINGTON</td>
</tr>
<tr>
<td>County:</td>
<td>THURSTON</td>
</tr>
<tr>
<td>Region:</td>
<td>OL</td>
</tr>
<tr>
<td>Nearest Town:</td>
<td>OLYMPIA</td>
</tr>
<tr>
<td>Usgs Quad:</td>
<td>LACEY</td>
</tr>
<tr>
<td>T.R.S:</td>
<td>18N, 1W, 18</td>
</tr>
<tr>
<td>Corner Code:</td>
<td></td>
</tr>
<tr>
<td>State Route:</td>
<td>005</td>
</tr>
<tr>
<td>Mile Post:</td>
<td>107.900</td>
</tr>
<tr>
<td>Station:</td>
<td></td>
</tr>
<tr>
<td>Offset:</td>
<td></td>
</tr>
<tr>
<td>Owner:</td>
<td>GS</td>
</tr>
<tr>
<td>Bearing:</td>
<td>M</td>
</tr>
</tbody>
</table>

**ACCOUNTS INFORMATION**

<table>
<thead>
<tr>
<th>BOOK</th>
<th>PROJECT</th>
<th>INVOICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>224</td>
<td>MS5400</td>
<td>23-05032</td>
</tr>
<tr>
<td>233</td>
<td>MS5400</td>
<td>23-05032</td>
</tr>
<tr>
<td>55</td>
<td>OL1550</td>
<td>23-92009</td>
</tr>
</tbody>
</table>

**Description**

THE STATION IS LOCATED IN THE CITY OF OLYMPIA. IT IS LOCATED IN THE NORTHWEST QUADRANT OF THE LILLY ROAD UNDERCROSSING OF SR 005, 8.2 METERS SOUTH OF THE NORTH END OF THE WEST SIDEWALK AND 1.2 METERS WEST OF THE EAST EDGE OF THE SIDEWALK. THE MARK IS A BRASS DISK CEMENTED INTO A DRILL HOLE IN THE CONCRETE SIDEWALK SET LEVEL WITH ITS SURFACE. *NOTE: UPDATED BY G.P.S. CONSTRANDED TO H.P.N.*

**CURRENT SURVEY CONTROL**

<table>
<thead>
<tr>
<th>DATUM</th>
<th>LATITUDE</th>
<th>UNIT LONGITUDE</th>
<th>UNIT NETWORK</th>
<th>METHOD</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAD 83/91</td>
<td>47 02 40.113905 N</td>
<td>122 50 39.990869 W</td>
<td>PRIMARY GPS</td>
<td>2 CM</td>
<td></td>
</tr>
<tr>
<td>NAD 83</td>
<td>44.576</td>
<td>M</td>
<td>GPS</td>
<td>5 CM</td>
<td></td>
</tr>
<tr>
<td>NAVD 88</td>
<td>66.116</td>
<td>M</td>
<td>PRIMARY DIFF LEVELS</td>
<td>1 CM</td>
<td></td>
</tr>
<tr>
<td>SPC ZONE</td>
<td>NORTHING</td>
<td>UNIT EASTING</td>
<td>UNIT SCALE</td>
<td>CONV.ANGLE</td>
<td>COMB.FACTOR</td>
</tr>
<tr>
<td>S</td>
<td>192844.741</td>
<td>M</td>
<td>321874.875</td>
<td>0.99994673</td>
<td>-1.4210.8</td>
</tr>
</tbody>
</table>
**Geographic Services**

**GENERAL MONUMENT INFORMATION**

<table>
<thead>
<tr>
<th>Designation:</th>
<th>GPS4005-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument ID:</td>
<td>192</td>
</tr>
<tr>
<td>State:</td>
<td>WASHINGTON</td>
</tr>
<tr>
<td>County:</td>
<td>THURSTON</td>
</tr>
<tr>
<td>Region:</td>
<td>OL</td>
</tr>
<tr>
<td>Nearest Town:</td>
<td>LACEY</td>
</tr>
<tr>
<td>Usgs Quad:</td>
<td>LACEY</td>
</tr>
</tbody>
</table>

| T.R.S.:           | 18N, 1W, 17 |
| Corner Code:      |            |
| State Route:      | 005        |
| Mile Post:        | 108.400    |
| Station:          |            |
| Offset:           |            |
| Owner:            | GS         |
| Bearing:          | M          |

**ACCOUNTS INFORMATION**

<table>
<thead>
<tr>
<th>BOOK</th>
<th>PROJECT</th>
<th>INVOICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>224</td>
<td>MS5400</td>
<td>23-05032</td>
</tr>
<tr>
<td>233</td>
<td>MS5400</td>
<td>23-05032</td>
</tr>
<tr>
<td>55</td>
<td>0L1550</td>
<td>23-09009</td>
</tr>
</tbody>
</table>

**Description**

The station is located in the city of Lacey. It is located in the bridge deck near the approximate center line of Sleater-Kinney and SR 005. 12.2 meters east of the west traffic barrier wall and 58 meters south of the north expansion joint. The mark is a brass disk cemented into a drill hole in the concrete bridge deck and set level with its surface. *Note: Updated by G.F.S. constrained to H.P.N.*

**CURRENT SURVEY CONTROL**

<table>
<thead>
<tr>
<th>DATUM</th>
<th>LATITUDE</th>
<th>UNIT LONGITUDE</th>
<th>UNIT NETWORK</th>
<th>METHOD</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAD 83/91</td>
<td>47 02 45.168733</td>
<td>N</td>
<td>122 50 01.449477</td>
<td>PRIMARY</td>
<td>GPS</td>
</tr>
<tr>
<td>ELLIP HGT</td>
<td>46.637</td>
<td>M</td>
<td></td>
<td>GPS</td>
<td>5 cm</td>
</tr>
<tr>
<td>ORTHO HGT</td>
<td>68.215</td>
<td>M</td>
<td></td>
<td>PRIMARY</td>
<td>DIFF LEVELS</td>
</tr>
</tbody>
</table>

**SPC ZONE**

<table>
<thead>
<tr>
<th>NORTHING</th>
<th>UNIT EASTING</th>
<th>UNIT SCALE</th>
<th>CONV ANGLE</th>
<th>COMP.FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>192976.641</td>
<td>M</td>
<td>122632.663</td>
<td>N</td>
<td>0.99994693</td>
</tr>
</tbody>
</table>

**MONUMENTATION HISTORY**

<table>
<thead>
<tr>
<th>DATE</th>
<th>RECOVERED BY</th>
<th>CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/01/1993</td>
<td>GEOGRAPHIC SERVICES</td>
<td>MONUMENTED</td>
</tr>
<tr>
<td>09/09/1997</td>
<td>GEOGRAPHIC SERVICES</td>
<td>GOOD</td>
</tr>
<tr>
<td>05/25/2006</td>
<td>GEOGRAPHIC SERVICES</td>
<td>UPDATED</td>
</tr>
<tr>
<td>09/25/2006</td>
<td>GEOGRAPHIC SERVICES</td>
<td>GOOD</td>
</tr>
</tbody>
</table>

**SUPERSEDED CONTROL**

<table>
<thead>
<tr>
<th>DATUM</th>
<th>LATITUDE</th>
<th>UNIT LONGITUDE</th>
<th>UNIT NETWORK</th>
<th>METHOD</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAD 83/91</td>
<td>47 02 45.168599</td>
<td>N</td>
<td>122 50 01.449824</td>
<td>PRIMARY</td>
<td>GPS</td>
</tr>
<tr>
<td>ELLIP HGT</td>
<td>46.637</td>
<td>M</td>
<td></td>
<td>GPS</td>
<td>5 cm</td>
</tr>
</tbody>
</table>
**Geographic Services**

**Report of Survey Mark**

**GENERAL MONUMENT INFORMATION**

<table>
<thead>
<tr>
<th>Designation</th>
<th>GPS4005-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monument ID</td>
<td>193</td>
</tr>
<tr>
<td>State</td>
<td>WASHINGTON</td>
</tr>
<tr>
<td>County</td>
<td>THURSTON</td>
</tr>
<tr>
<td>Region</td>
<td>O1</td>
</tr>
<tr>
<td>Nearest Town</td>
<td>OLYMPIA</td>
</tr>
<tr>
<td>Usgs Quad</td>
<td>LACEY</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>T.R.S.</th>
<th>18N, 1W, 18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corner Code</td>
<td></td>
</tr>
<tr>
<td>State Route</td>
<td>005</td>
</tr>
<tr>
<td>Mile Post</td>
<td>107,900</td>
</tr>
<tr>
<td>Station</td>
<td></td>
</tr>
<tr>
<td>Offset</td>
<td></td>
</tr>
<tr>
<td>Owner</td>
<td>GS</td>
</tr>
<tr>
<td>Bearing</td>
<td>M</td>
</tr>
</tbody>
</table>

**ACCOUNTS INFORMATION**

<table>
<thead>
<tr>
<th>BOOK PROJECT INVOICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>224 MS5400 23-9032</td>
</tr>
<tr>
<td>233 MS5400 23-9032</td>
</tr>
<tr>
<td>55 0L1550 23-9209</td>
</tr>
</tbody>
</table>

**Description**

The Station is located in the City of Olympia. It is located in the northwest quadrant of the Lilly Road undercrossing of SR 505, 8.2 meters south of the north end of the west sidewalk and 1.2 meters west of the east edge of the sidewalk. The mark is a brass disk cemented into a drill hole in the concrete sidewalk set level with its surface. *Note: Updated by G.P.S., constrained to H.P.N.*

**CURRENT SURVEY CONTROL**

<table>
<thead>
<tr>
<th>DATUM</th>
<th>LATITUDE</th>
<th>UNIT LONGITUDE</th>
<th>UNIT NETWORK</th>
<th>METHOD</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAD 83/61</td>
<td>47 05 40.113905</td>
<td>N 122 50 39.991666</td>
<td>M</td>
<td>GPS</td>
<td>2 CN</td>
</tr>
<tr>
<td>IAD 83</td>
<td>ELLIP HGT</td>
<td>44.576</td>
<td>M</td>
<td>GPS</td>
<td>5 CN</td>
</tr>
<tr>
<td>NAVD 88</td>
<td>ORTHO HGT</td>
<td>66.116</td>
<td>M</td>
<td>PRIMARY</td>
<td>1 CN</td>
</tr>
<tr>
<td>SPC ZONE</td>
<td>NORTING</td>
<td>192644.741</td>
<td>M</td>
<td>121674.875</td>
<td>0.99994673</td>
</tr>
</tbody>
</table>

**MONUMENTATION HISTORY**

<table>
<thead>
<tr>
<th>DATE</th>
<th>RECOVERED BY</th>
<th>CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>07/01/1991</td>
<td>GEOGRAPHIC SERVICES</td>
<td>MONUMENTED</td>
</tr>
<tr>
<td>09/09/1997</td>
<td>GEOGRAPHIC SERVICES</td>
<td>GOOD</td>
</tr>
<tr>
<td>09/25/2005</td>
<td>GEOGRAPHIC SERVICES</td>
<td>GOOD</td>
</tr>
<tr>
<td>06/25/2005</td>
<td>GEOGRAPHIC SERVICES</td>
<td>UPDATED</td>
</tr>
</tbody>
</table>

**SUPERSEDED CONTROL**

<table>
<thead>
<tr>
<th>DATUM</th>
<th>LATITUDE</th>
<th>UNIT LONGITUDE</th>
<th>UNIT NETWORK</th>
<th>METHOD</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAD 83/61</td>
<td>47 05 40.113905</td>
<td>N 122 50 39.991666</td>
<td>M</td>
<td>GPS</td>
<td>2 CN</td>
</tr>
<tr>
<td>IAD 83</td>
<td>ELLIP HGT</td>
<td>44.580</td>
<td>M</td>
<td>GPS</td>
<td>5 CN</td>
</tr>
</tbody>
</table>
## Horizontal Monument Standard Long Report

### Point Designation: 209

<table>
<thead>
<tr>
<th>ID</th>
<th>County/Municipality</th>
<th>Point Designation</th>
<th>Point ID</th>
<th>History Records</th>
<th>Geocode</th>
<th>BLM Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pierce County</td>
<td>GPS209</td>
<td>310</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Horizontal Control

<table>
<thead>
<tr>
<th>EASTING (m)</th>
<th>NORTING (m)</th>
<th>LATTITUDE (m)</th>
<th>Longitude</th>
<th>Scale Factor</th>
<th>Convergence</th>
<th>ZONE 5 NORT</th>
<th>Meridians</th>
<th>Section</th>
<th>SURVEY SPOT</th>
<th>MONUMENT TYPE</th>
<th>VISIT DATE</th>
<th>VISIT BY</th>
<th>MONUMENT SET</th>
<th>CASED MONUMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1174215.75458</td>
<td>198667.39139</td>
<td>47° 00 ' 02 &quot; 3294 N</td>
<td>122° 22 ' 28 &quot; 3748 W</td>
<td>0.999940869057</td>
<td>1.1219799</td>
<td>4602</td>
<td>Willamette</td>
<td>S2671889016</td>
<td></td>
<td></td>
<td></td>
<td>1992-07-22 00:00:00</td>
<td>PCM</td>
<td></td>
</tr>
</tbody>
</table>

### Monument Condition: Existing or Recovered

<table>
<thead>
<tr>
<th>Project/Survey</th>
<th>Field Book</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992 GPS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Reference

- SR 7-26600
- Station is on SR 7 north of 267th St. E. at or on the north line of J. McPhail DLC.

### Add Tone

- No PLS number recorded on view diagram. Possible NE corner for J. McPhail DLC.
THE GEOID

THE GEOID IS THE EQUIPOTENTIAL SURFACE OF THE EARTH'S ATTRACTION AND ROTATION WHICH, ON THE AVERAGE, COINCIDES WITH MEAN SEA LEVEL IN THE OPEN OCEAN.

\[ H = \text{HEIGHT ABOVE SEA LEVEL} \]
\[ N = \text{GEOID HEIGHT} \]
\[ h = h + N = \text{ELLIPSOIDAL HEIGHT} \]

THE GEOID: An ellipsoid is defined as a surface of revolution about the minor axis. The geoid is not. It is defined as the sea level surface and is subject to gravitational anomalies which cause it to have an undulating surface. Sometimes it is above the ellipsoid and sometimes below. The separation between the ellipsoid and the geoid, at a given point, is called geoid height. The NAD27 Datum based on the Clarke ellipsoid of 1866 had small geoid heights but the ellipsoid for NAD83 does not fit North America as well. In the conterminous United States the ellipsoid is above the geoid while in Alaska it is below the geoid. Ellipsoidal height is defined as the height of the surface above the ellipsoid. Geoid height is defined as ellipsoidal height minus elevation. In the midwest, the geoid height is approximately -30 meters which places it below the ellipsoid.
\[ \alpha_g = \alpha_A + \text{Laplace Correction} - \gamma \]
\[ = 253^\circ 26' 14.9'' \quad (\text{Observed Astro Azimuth}) \]
\[ + (-0.1)'' \quad (\text{Laplace Correction}) \]
\[ = 253^\circ 26' 14.8'' \quad (\text{Geodetic Azimuth}) \]
\[-0 36 37.0 \quad (\text{Convergence Angle}) \]
\[ = 252^\circ 49' 37.8'' \]

The convention of the sign of the convergence angle is always from Grid to Geodetic.
UNDULATIONS OF THE GEOID
UNDULATIONS OF THE GEOID
ELLIPSOID - GEOID RELATIONSHIP

H = Orthometric Height (NAVD 88)
h = Ellipsoidal Height (NAD 83)
N = Geoid Height (GEOID 99)

\[ H = h - N \]
State Plane Coordinates

BRIEF HISTORY:

-Originally a U.S. English unit grid system

-Developed by land surveyors in the 1930’s to simplify surveying computations

A cooperative venture between the Coast and Geodetic Survey and the North Carolina state government, and efforts to build a North Carolina spatial coordinate system with minimal distortion was started. In 1933 this cooperative venture produced the North Carolina Coordinate System. In less than 12 months, the North Carolina system had been copied into all of the remaining states, and the State Plane coordinate system was born.

-Used only in the US
STATE PLANE COORDINATE SYSTEMS

Lambert Conformal Conic and Transverse Mercator Projections
  International, State and County Boundaries
  NAD 27 - Coordinates in U.S. Survey Feet

NAD 83 - Coordinates Metric w/State Defined Foot Conversion
  1 Meter = 3.280833333 U.S. Survey Feet
  1 Meter = 3.280839895 International Feet
  NAD 27 to NAD 83 VERY large Positional Shifts
Types of Plane Systems

- Plane
- Ellipsoid
- Tangent Plane
- Local Plane
- Point of Origin
- Axis of Ellipsoid
- Ellipsoid
- Apex of Cone
- Axis of Cone & Ellipsoid
- Standard Parallels
- Ellipsoid
- Intersecting Cone
- 2 Parallel Lambert
- Intersecting Cylinder
- Transverse Mercator
- Axis of Cylinder
- Ellipsoid
LAMBERT CONFORMAL CONIC WITH 2 STANDARD PARALLELS

Approximately 158 miles

STANDARD PARALLELS

CENTRAL MERIDIAN
GEODETIC vs. GRID DISTANCE

ab > a'b'

cd < c'd'

Earth Center
LAMBERT CONFOMAL CONIC WITH 2 STANDARD PARALLELS

Grid Scale Factor

- **SCALE > 1**
- **SCALE < 1**
- **SCALE EXACT**

CENTRAL MERIDIAN

STANDARD PARALLELS

\[ \text{\( \theta_0 \)} \]
Standard Parallels

Figure 6-2
TRANSVERSE MERCATOR

CENTRAL MERIDIAN

SCALE > 1

SCALE EXACT

SCALE < 1

SCALE > 1

$\hat{0}$

SCALE EXACT
STATE PLANE COORDINATE SYSTEMS
North and South Zones

N. Zone Origin 47-00/120-50
N=0m, E=500,000m

S. Zone Origin 45-20/120-30
N=0m, E=500,000m
WASHINGTON ZONES
### Parameters of a Lambert Projection

#### Washington North Zone

<table>
<thead>
<tr>
<th>1. Projection</th>
<th>NAD 27</th>
<th>NAD 83</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambert</td>
<td>Lambert</td>
<td></td>
</tr>
<tr>
<td>2. Latitude of Origin</td>
<td>47° 03'</td>
<td>47° 00'</td>
</tr>
<tr>
<td>3. Central Meridian</td>
<td>120° 50'</td>
<td>120° 50'</td>
</tr>
<tr>
<td>4. Standard Parallel 1</td>
<td>47° 30'</td>
<td>47° 30'</td>
</tr>
<tr>
<td>5. Standard Parallel 2</td>
<td>48° 44'</td>
<td>48° 44'</td>
</tr>
<tr>
<td>6. False Easting</td>
<td>2,000,000.00 FT.</td>
<td>306,000.00 M.</td>
</tr>
<tr>
<td>7. False Northing</td>
<td>0.00 FT.</td>
<td>0.00 M.</td>
</tr>
</tbody>
</table>

#### Washington South Zone

<table>
<thead>
<tr>
<th>1. Projection</th>
<th>NAD 27</th>
<th>NAD 83</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lambert</td>
<td>Lambert</td>
<td></td>
</tr>
<tr>
<td>2. Latitude of Origin</td>
<td>45° 20'</td>
<td>45° 20'</td>
</tr>
<tr>
<td>3. Central Meridian</td>
<td>130° 30'</td>
<td>130° 30'</td>
</tr>
<tr>
<td>4. Standard Parallel 1</td>
<td>45° 50'</td>
<td>45° 50'</td>
</tr>
<tr>
<td>5. Standard Parallel 2</td>
<td>47° 20'</td>
<td>47° 20'</td>
</tr>
<tr>
<td>6. False Easting</td>
<td>2,000,000.00 FT.</td>
<td>306,000.00 M.</td>
</tr>
<tr>
<td>7. False Northing</td>
<td>0.00 FT.</td>
<td>0.00 M.</td>
</tr>
</tbody>
</table>

### Notes:
- Projection: Lambert conformal
- Zones: North and South
- Coordinates: Feet and Meters
- North/South orientation: 'N' = South, 'N' = North
- Foot (US or Int): US Survey
- Mean Radius 'R': 29,869,852 ft
- Elevation Factor: To sea level or to ellipsoid
RCW 58.20

- **RCW 58.20.110**
- **Definitions.**
- Unless the context clearly requires otherwise, the definitions in this section apply throughout RCW 58.20.110 through 58.20.220 and 58.20.901:

  1. "Committee" means the interagency federal geodetic control committee or its successor;

  2. "GRS 80" means the geodetic reference system of 1980 as adopted in 1979 by the international union of geodesy and geophysics defined on an equipotential ellipsoid;

  3. "National geodetic survey" means the national ocean service's national geodetic survey of the national oceanic and atmospheric administration, United States department of commerce, or its successor;

  4. "Washington coordinate system of 1927" means the system of plane coordinates in effect under this chapter until July 1, 1990, which is based on the North American datum of 1927 as determined by the national geodetic survey of the United States department of commerce;

  5. "Washington coordinate system of 1983" means the system of plane coordinates under this chapter based on the North American datum of 1983 as determined by the national geodetic survey of the United States department of commerce.

- [1989 c 54 § 9.]
RCW 58.20

- **RCW 58.20.120**

- **System designation — Permitted uses.**

- Until July 1, 1990, the Washington coordinate system of 1927, or its successor, the Washington coordinate system of 1983, may be used in Washington for expressing positions or locations of points on the surface of the earth. On and after that date, the Washington coordinate system of 1983 shall be the designated coordinate system in Washington. The Washington coordinate system of 1927 may be used only for purposes of reference after June 30, 1990.
RCW 58.20

- **RCW 58.20.130**
- **Plane coordinates adopted — Zones.**
- The system of plane coordinates which has been established by the national geodetic survey for defining and stating the positions or locations of points on the surface of the earth within the state of Washington is designated as the "Washington coordinate system of 1983."

  For the purposes of this system the state is divided into a "north zone" and a "south zone."

  The area now included in the following counties shall constitute the north zone: Chelan, Clallam, Douglas, Ferry, Island, Jefferson, King, Kitsap, Lincoln, Okanogan, Pend Oreille, San Juan, Skagit, Snohomish, Spokane, Stevens, Whatcom, and that part of Grant lying north of parallel 47° 30' north latitude.

  The area now included in the following counties shall constitute the south zone: Adams, Asotin, Benton, Clark, Columbia, Cowlitz, Franklin, Garfield, that part of Grant lying south of parallel 47° 30' north latitude, Grays Harbor, Kittitas, Klickitat, Lewis, Mason, Pacific, Pierce, Skamania, Thurston, Wahkiakum, Walla Walla, Whitman and Yakima.
RCW 58.20

- **RCW 58.20.150**
- **Designation of coordinates — "N" and "E."**
- "N" and "E" shall be used in labeling coordinates of a point on the earth's surface and in expressing the position or location of such point relative to the origin of the appropriate zone of this system, expressed in meters and decimals of a meter. These coordinates shall be made to depend upon and conform to the coordinates, on the Washington coordinate system of 1983, of the horizontal control stations of the national geodetic survey within the state of Washington, as those coordinates have been determined, accepted, or adjusted by the survey.
RCW 58.20

- RCW 58.20.160
- Tract in both zones — Description.
- When any tract of land to be defined by a single description extends from one into the other of the coordinate zones under RCW 58.20.130, the positions of all points on its boundaries may be referred to either of the zones, the zone which is used being specifically named in the description.
For purposes of more precisely defining the Washington coordinate system of 1983, the following definition by the national geodetic survey is adopted:

The Washington coordinate system of 1983, north zone, is a Lambert conformal conic projection of the GRS 80 spheroid, having standard parallels at north latitudes 47° 30' and 48° 44', along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 120° 50' west of Greenwich and the parallel 47° 00' north latitude. This origin is given the coordinates: E = 500,000 meters and N = 0 meters.

The Washington coordinate system of 1983, south zone, is a Lambert conformal conic projection of the GRS 80 spheroid, having standard parallels at north latitudes 45° 50' and 47° 20', along which parallels the scale shall be exact. The origin of coordinates is at the intersection of the meridian 120° 30' west of Greenwich and the parallel 45° 20' north latitude. This origin is given the coordinates: E = 500,000 meters and N = 0 meters.
RCW 58.20

- RCW 58.20.180
- Recording coordinates — Control stations.
- Coordinates based on the Washington coordinate system of 1983, purporting to define the position of a point on a land boundary, may be presented to be recorded in any public land records or deed records if the survey method used for the determination of these coordinates is established in conformity with standards and specifications prescribed by the interagency federal geodetic control committee, or its successor. These surveys shall be connected to monumented control stations that are adjusted to and published in the national network of geodetic control by the national geodetic survey and such connected horizontal control stations shall be described in the land or deed record. Standards and specifications of the committee in force on the date of the survey shall apply. In all instances where reference has been made to such coordinates in land surveys or deeds, the scale and sea level factors shall be stated for the survey lines used in computing ground distances and areas.
The position of the Washington coordinate system of 1983 shall be marked on the ground by horizontal geodetic control stations which have been established in conformity with the survey standards adopted by the committee and whose geodetic positions have been rigorously adjusted on the North American datum of 1983, and whose coordinates have been computed and published on the system defined in RCW 58.20.110 through 58.20.220 and 58.20.901. Any such control station may be used to establish a survey connection with the Washington coordinate system of 1983.

**RCW 58.20.190**

**Conversion of coordinates — Metric.**

Any conversion of coordinates between the meter and the United States survey foot shall be based upon the length of the meter being equal to exactly 39.37 inches.
RCW 58.20

- **RCW 58.20.200**
- **Term — Limited use.**
- The use of the term "Washington coordinate system of 1983" on any map, report of survey, or other document, shall be limited to coordinates based on the Washington coordinate system of 1983 as defined in this chapter.

- **RCW 58.20.210**
- **United States survey prevails — Conflict.**
- Whenever coordinates based on the Washington coordinate system of 1983 are used to describe any tract of land which in the same document is also described by reference to any subdivision, line or corner of the United States public land surveys, the description by coordinates shall be construed as supplemental to the basic description of such subdivision, line, or corner contained in the official plats and field notes filed of record, and in the event of any conflict the description by reference to the subdivision, line, or corner of the United States public land surveys shall prevail over the description by coordinates.
RCW 58.20

- **RCW 58.20.220**
  - Real estate transactions — Exemption.
  - Nothing contained in this chapter shall require any purchaser or mortgagee to rely on a description, any part of which depends exclusively upon the Washington coordinate system of 1927 or 1983.

- **RCW 58.20.901**
  - Severability — 1989 c 54.
  - If any provision of this act or its application to any person or circumstance is held invalid, the remainder of the act or the application of the provision to other persons or circumstances is not affected.

- **58.09.070**
  - Coordinates — Map showing control scheme required.
  - When coordinates in the Washington coordinate system are shown for points on a record of survey map, the map may not be recorded unless it also shows, or is accompanied by a map showing, the control scheme through which the coordinates were determined from points of known coordinates.
The following standards shall apply to local geodetic control surveys:

The datum for the horizontal control network in Washington shall be NAD83 as officially adjusted and published by the National Geodetic Survey of the United States Department of Commerce or as established in accordance with chapter 58.20 RCW. The datum tag and coordinate epoch date (if pertinent) shall be reported on all documents prepared, which show local geodetic control; e.g., NAD83 (1991), NAD83 (CORS) (2002.00), NAD83 (NSRS) (2005.50) and other future [standards].
58.09.070
 Coordinates — Map showing control scheme required.

When coordinates in the Washington coordinate system are shown for points on a record of survey map, the map may not be recorded unless it also shows, or is accompanied by a map showing, the control scheme through which the coordinates were determined from points of known coordinates.

[1973 c 50 § 7.]
WAC 332-130-090

- **WAC 332-130-090**
- No Washington State Register filings since 2003
- **Field traverse standards for land boundary surveys.**
  - The following standards shall apply to field traverses used in land boundary surveys. Such standards should be considered minimum standards only. Higher levels of precision are expected to be utilized in areas with higher property values or in other situations necessitating higher accuracy.

  1. Linear closures after azimuth adjustment.
     
     a. City - central and local business and industrial areas ............. 1:10,000

     b. City - residential and subdivision lots ................. 1:5,000

     c. Section subdivision, new subdivision boundaries for residential lots and interior monument control ................. 1:5,000

     d. Suburban - residential and subdivision lots ............. 1:5,000

     e. Rural - forest land and cultivated areas ............... 1:5,000

     f. Lambert grid traverses .................. 1:10,000

  2. Angular closure.

     a. Where 1:10,000 minimum linear closure is required, the maximum angular error in seconds shall be determined by the formula of $10 \sqrt{n}$, where "n" equals the number of angles in the closed traverse.

     b. Where 1:5,000 minimum linear closure is required, the maximum angular error in seconds shall be determined by the formula of $30 \sqrt{n}$ where "n" equals the number of angles in the closed traverse.
SYMBOLS USED IN TEXT

\( \phi \) = PHI = LATITUDE
\( \lambda \) = LAMBDA = LONGITUDE
\( \alpha \) = ALPHA = AZIMUTH OF LINE, USUALLY REFERRING TO GEOGRAPHIC VALUES.
GRID OR PLANE AZIMUTHS ARE USUALLY DENOTED AS \( \alpha \)
OCCASIONALLY USED TO INDICATE AN ANGLE.
\( \Delta \) = DELTA = DIFFERENCE
\( \Delta \phi \) = DELTA PHI = DIFFERENCE IN LATITUDE
\( \Delta \lambda \) = DELTA LAMBDA = DIFFERENCE IN LONGITUDE
\( \Delta \alpha \) = DELTA ALPHA = DIFFERENCE IN AZIMUTH

\( \rho \) = RHO = RADIUS OF CURVATURE OF THE REFERENCE SPHEROID. THIS ONLY
USE MADE OF THIS QUANTITY IN THIS PAPER IS IN THE
REDUCTION OF HORIZONTAL DISTANCES TO ELLIPSOID VALUES.
FOR THIS PURPOSE, A MEAN VALUE EQUAL TO 20,905,000 FT.
AND DESIGNATED AS "R" HAS BEEN UTILIZED. THIS "R" VALUE
SHOULD NOT BE CONFUSED WITH THE "R" OR "\rho" QUANTITIES
USED IN THE COMPUTATIONS INVOLVING THE CONVERSION OF
GEOGRAPHIC POSITIONS TO LAMBERT PLANE COORDINATES AND
THE INVERSE OF THE PROBLEMS.

\( h \) = ELEVATION AND ON RARE OCCASIONS MAY INDICATE A
DIFFERENCE IN ELEVATION.
\( l \) = SLOPE OR INCLINED DISTANCE
\( D \) = HORIZONTAL DISTANCE
\( S \) = GEOGRAPHIC DISTANCE = DISTANCE AT THE ELLIPSOID SURFACE.
\( S_g \) = GRID DISTANCE = GEOGRAPHIC DISTANCE MULTIPLIED BY SCALE
GRID FACTOR.

\( CM \) = CENTRAL MERIDIAN = THE MERIDIAN (LONGITUDE) OR AXIS USUALLY
SITUATED NEAR THE CENTER OF A PLANE COORDINATE ZONE WHICH
SEPARATES THE POSITIVE AND NEGATIVE X' VALUES (SEE DEFINITION
OF X').

\( X' \) = THE DISTANCE (IN METERS FOR THE STATE GRID SYSTEMS) EAST
AND WEST OF THE CENTRAL MERIDIAN. EAST OF THE CENTRAL
MERIDIAN THE VALUES ARE POSITIVE, WEST OF THIS MERIDIAN
THEY ARE NEGATIVE. THESE QUANTITIES CAN BE DESCRIBED IN
PLANE SURVEYING TERMINOLOGY AS THE DEPARTURES MEASURED
FROM THE Y AXIS.
SYMBOLS USED IN TEXT

\( E \) = THE PLANE COORDINATE VALUES WHICH ARE PERPENDICULAR TO THE \( N \) AXIS. THESE VALUES USUALLY CONSIST OF A CONSTANT \( C \). THE CONSTANT "\( C \)" IS GENERALLY OF SUFFICIENT SIZE TO ASSURE THAT THE \( X \) QUANTITIES WILL BE POSITIVE.

\( \gamma \) = GAMMA = THE MAPPING ANGLE IN THE LAMBERT PROJECTION USUALLY REFERRED TO AS THE "GAMMA" ANGLE. THIS ANGLE IS APPLIED TO GEODETIC AZIMUTHS TO OBTAIN PLANE (GRID) AZIMUTHS AND VICE VERSA.

NOTE: ALTHOUGH THESE REDUCTIONS ARE NOT EXACT, THE ERROR IN NEGLECTING ANOTHER CORRECTION WHICH IS KNOWN AS THE "SECOND TERM" (\( T \) CORRECTION) IS QUITE SMALL FOR THE STATE SYSTEMS AND CAN BE IGNORED EXCEPT FOR THOSE OCCASIONS WHERE THE MOST PRECISE COMPUTATIONS ARE DESIRED.

\( H \) = THE PLANE COORDINATE VALUES (GIVEN IN METERS FOR THE STATE GRID SYSTEMS) WHICH CORRESPOND TO THE DISTANCES NORTH OF THE ORIGIN TO THEIR INTERSECTION WITH THE \( E \) COORDINATES OF THE POINTS. THESE QUANTITIES CAN BE DESCRIBED IN PLANE SURVEYING TERMINOLOGY AS THE LATITUDES MEASURED FROM THE ORIGIN.

\( R \) = IN THE STATE LAMBERT GRID SYSTEMS, THE DISTANCES IN METERS FROM THE VERTEX OF THE CONE TO THE LATITUDES OF THE POINTS.

\( R_e \) = IN THE STATE LAMBERT GRID SYSTEMS, THE DISTANCE IN METERS FROM THE VERTEX OF THE CONE TO THE ORIGIN.

\( \lambda \) = A CONSTANT DETERMINED FOR EACH ZONE OR BAND OF A LAMBERT PROJECTION AND IS EQUAL TO THE SINE OF \( \theta \) WHICH IS THE LATITUDE ABOUT MIDWAY BETWEEN THE STANDARD PARALLELS. A MULTIPLIED BY THE DIFFERENCE IN SECONDS BETWEEN THE LONGITUDE OF A POINT AND THE CENTRAL MERIDIAN EQUALS \( \gamma \) (\( \text{GAMMA} \)) ANGLE IN SECONDS FOR THE POINT.
DEFINITIONS

DEFINITIONS OF GEODETIC AND OTHER TERMS

ASTRONOMIC AZIMUTH
At the point of observation, the angle measured from the vertical plane through the celestial pole to the vertical plane through the observed object. Astronomic azimuth is the azimuth which results directly from observations on a celestial body, and is usually reckoned from south = 0 degrees. It is affected by the local deflection of the vertical (station error), which, in the US, produces differences between astronomic and geodetic azimuths of as much as 28° in the mountain regions of the west.

CARTESIAN COORDINATES
For this discussion, not to be confused with state plane coordinates. The X, Y, Z values expressed on the NGS data sheets beginning at the earth's center of mass are reckoned from the mean value of the earth's axis of rotation, more technically referred to as geocentric coordinates. The Z value is the vertical position on the ellipsoid from the earth's center of mass.

DATUM
A datum is a reference system from which survey measurements are made and are expressed in quantities or set of quantities that serve as a reference or basis for calculation of other quantities. The values or coordinates expressed originate from a specified point of origin. The datum may be a local system, a statewide system, a system that represents North America only or could be a worldwide system.

ELLIPSOID
A mathematical model of a surface generated by rotation of an ellipse about one of its axes and is defined by a semi-major axis and a semi-minor axis. The ellipsoid of the earth is the ellipsoid which most closely approximates the geoid.

EQUIPOTENTIAL SURFACE
A surface with the same potential, usually of gravity or of gravitation, at every point. An equipotential surface is also referred to as a level surface.

GEODETIC AZIMUTH
The angle measured on the horizon between the meridian and the plane of the vertical circle through a celestial body corrected by the lefence correction.

GEODETIC COORDINATES
A set of coordinates designating the location of a point with respect to the reference ellipsoid and with respect to the planes of the geodetic equator and a selected geodetic meridian. The coordinate system consists of an ellipsoid, the equatorial plane of the ellipsoid, and a meridional plane through the polar axis and is expressed in latitude and longitude.

GEOID
The equipotential surface of the earth's gravity field which best fits, in the least squares sense, mean sea level.

GEOID HEIGHT
The value indicating the separation between the geoid (sea level) and the ellipsoid. In the contiguous US the ellipsoid is above the geoid. The ellipsoidal height (h) = height above sea level (H) + geoid height (N).
DEFINITIONS

GRID AZIMUTH
The angle in the plane of projection between a straight line and the
central meridian of a plane-rectangular coordinate system.

LAPLACE AZIMUTH OR CORRECTION
The Laplace azimuth is a geodetic azimuth derived from an astronomic
azimuth by means of the Laplace equation. The Laplace condition arises
from the fact that a deflection of the vertical in the plane of the
prism vertical will give a difference between astronomic and geometric
longitude and between astronomic and geodetic azimuth.

MAPPING ANGLE OR CONVERGENCE ANGLE
The angular difference between grid north and geodetic north, which
includes the correction for the "second term" or arc-to-chord
correction. The symbol 'γ' is gamma.

MAP PROJECTIONS
A system of lines on a plane representing a corresponding system of
imaginary lines on an adopted terrestrial or celestial datum surface.
The lambert conformal conic projection is one of many such projections.

PLANE COORDINATES
A cartesian coordinate system in the plane, with the axes intersecting
at right angles. In the Washington Coordinate System the values are
identified as: "N" for the longitudinal (north-south) position and "E" as
the longitudinal (east-west) position.

TRANSFORMATION
The process of projecting a datum or points on it, from its plane onto
another plane by translation, rotation, and/or scale change.
STEPS TO CALCULATE TRAVERSE ON WASHINGTON COORDINATE SYSTEM

1. Obtain starting NGS or other acceptable control point with NAD 83 coordinates.
2. Find acceptable NGS backsight control point with NAD 83 coordinates.
3. Calculate inverse directly from published coordinates to derive starting azimuth.
4. Obtain closing NGS or other acceptable control point with NAD 83 coordinates.
5. Find acceptable NGS foresight control point with NAD 83 coordinates.
6. Calculate inverse directly from published coordinates to derive closing azimuth.
7. Determine the appropriate scale (latitude) factor for the project or for each traverse line, depending on the size of the project and accuracy required.
8. Determine the appropriate elevation factor for the project or for each traverse line, depending on the topography of the project and accuracy required.
9. Combine the scale and elevation factors for a project combined factor or compute a factor for each line, depending on the size of the project and accuracy required.
10. Reduce the horizontal distances to grid by multiplying by the combined project factor or the factor for each line.
11. If the project is small and the traverse lines are shorter than 5 miles long, skip to step 15.
12. Use preliminary azimuths derived from mean field angles and using grid distances compute approximate state plane coordinates.
13. Compute the second term, t-T corrections, using the approximate coordinates for each point.
14. Apply t-T corrections to the measured angles to obtain grid angles.
15. Determine the angular closure and adjust the angles.
16. Determine the closing error and adjust the traverse.
17. The computed inverses between the adjusted final coordinates will be the adjusted grid azimuths and distances.
18. To obtain the ground distances, divide the adjusted grid distances by the combined project grid factor or the combined factor for each line.
PARAMETERS OF A LAMBERT PROJECTION

(With Scale Factor $k_0$)
## Parameters of a Lambert Projection

### Washington North

#### Defining Constants
- \( R_n = 47.13 \)
- \( R_b = 48.44 \)
- \( L_0 = 180.50 \)
- \( N_0 = 500000.0000 \)

#### Computed Constants
- \( M_0 = 49.179151437 \)
- \( S_n = 0.746520326851 \)
- \( R_b = 5859778.6038 \)
- \( W_n = 124292.3669 \)
- \( K = 11570409.5959 \)
- \( K_b = 0.999942253481 \)
- \( M_0 = 6370495.7054 \)
- \( r_0 = 6380060. \)

### Washington South

#### Defining Constants
- \( R_n = 45.50 \)
- \( R_b = 47.20 \)
- \( L_0 = 120.30 \)
- \( N_0 = 0.0000 \)
- \( E_0 = 500000.0000 \)

#### Computed Constants
- \( M_0 = 46.5850847865 \)
- \( S_n = 0.726395784020 \)
- \( R_b = 6139352.7355 \)
- \( W_n = 6044820.3637 \)
- \( K = 11380393.9643 \)
- \( K_b = 0.99991597644 \)
- \( M_0 = 6358612.1773 \)
- \( r_0 = 6378742. \)

### Coefficients

#### Coefficients for GP to PC
- \( L(1) = 111386.1944 \)
- \( L(2) = 9.72145 \)
- \( L(3) = 5.61785 \)
- \( L(4) = 0.027630 \)

#### Coefficients for PC to GP
- \( G(1) = 8.993922319E-06 \)
- \( G(2) = -7.07270E-15 \)
- \( G(3) = -3.67384E-20 \)
- \( G(4) = -1.4705E-27 \)

#### Coefficients for Grid Scale Factor
- \( F(1) = 0.999942253481 \)
- \( F(2) = 1.22844E-14 \)
- \( F(3) = 7.08E-22 \)
## CONSTANTS FOR THE LAMBERT PROJECTION

### Description

- **B_s**: Southern standard parallel
- **B_n**: Northern standard parallel
- **B_b**: Latitude of grid origin
- **L_o**: Longitude of the true and grid origin, the "central meridian"
- **N_b**: Northing value at grid origin "B_b"
- **E_o**: Easting value at the origin "L_o"
- **B_o**: Latitude of the true projection origin, the "central parallel"
- **SinB_o**: Sine of B_o
- **R_b**: Mapping radius at B_b
- **R_o**: Mapping radius at B_o
- **K**: Mapping radius at the equator
- **N_o**: Northing value at the true projection origin "B_o"
- **K_o**: Central parallel grid scale factor
- **M_o**: Scaled radius of curvature in the meridian at "B_o"
- **R_o**: Geometric mean radius of curvature at B_o scaled to the grid

### Notes

- B_s, B_n, B_b, and L_o in degrees: minutes
- B_o in decimal degrees
- Linear units in meters
Lambert conformal conic projection with two standard parallels
Plane coordinate projection tables

DATUM: NAD 83
The projection is WASHINGTON NORTH

Ellipsoidal constants

\(a = 6378137 \text{ m}\)
\(f = 1/298.257223563\)

Defining constants

\(\gamma_0 = 47^\circ 00'\) (latitude of grid origin)
\(\lambda_0 = 120^\circ 50'\) (longitude of origin and Central Meridian, CH)
\(\phi_1 = 47^\circ 30'\) (southern standard parallel)
\(\phi_2 = 48^\circ 44'\) (northern standard parallel)
\(N_1 = 500000.0000 \text{ m}\) (northing coordinate of origin)
\(N_0 = 0.0000 \text{ m}\) (northing coordinate of origin)

Derived constants

\(\zeta = 0.744320328553 = \sin(\phi)\)
\(K = 10670909.3589 \text{ m}\) (mapping radius at the equator)
\(K_0 = 965578.6438 \text{ m}\) (mapping radius at grid origin)

Lambert coordinates \((N, E)\) from geodetic positions \((\lambda, \phi)\)

\[\gamma = (\lambda - \lambda_0) \sin(\phi)\]
\[E = R \sin(\gamma) + E\]
\[N = R_0 - R \cos(\gamma) + N_0\]

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude</th>
<th>(\gamma)</th>
<th>(E)</th>
<th>(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48 7</td>
<td>0.000000</td>
<td>5729625.030 m</td>
<td>462773.940 m</td>
</tr>
<tr>
<td>2</td>
<td>121 20</td>
<td>0.000000</td>
<td>-0.12 20.13859 m</td>
<td>124274.306 m</td>
</tr>
</tbody>
</table>

Geodetic positions from Lambert coordinates

\(\tan(\gamma) = (E - E_0)/(R_0 - (N - N_0))\)
\(R = (R_0 - (N - N_0))/\cos(\gamma)\)
\(\lambda = \lambda_0 - \gamma/\zeta\)

\(\phi\) from table using \(R\)

<table>
<thead>
<tr>
<th>Station</th>
<th>(E)</th>
<th>(E - E_0)</th>
<th>(R)</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40000.000 m</td>
<td>5729625.030 m</td>
<td>48 10</td>
<td>4.7701</td>
</tr>
<tr>
<td>2</td>
<td>110000.000 m</td>
<td>5723778.604 m</td>
<td>90 24</td>
<td>1.49555 120 17 43.9406</td>
</tr>
</tbody>
</table>

WARNING: Use sufficient significant digits for trig functions
Lambert conformal conic projection with two standard parallels
Plane coordinate projection tables

Datum: NAD 83
The projection is WASHINGTON SOUTH

Ellipsoidal constants

\( a = 6378137 \) m
\( f = \frac{1}{298.25722210} \)

Defining constants

\( \lambda_0 = 45^\circ 20' \) (latitude of grid origin)
\( \lambda_W = 120^\circ 30' \) (longitude of origin and Central Meridian, CM)
\( \phi_s = 45^\circ 50' \) (southern standard parallel)
\( \phi_n = 47^\circ 20' \) (northern standard parallel)
\( E_s = 500000.0000 \) m (east coordinate of origin)
\( N_s = 0.0000 \) m (northing coordinate of origin)

Derived constants

\( \xi = \frac{0.726395784620}{\sin(\phi)} \)
\( X = 11750332.9644 \) m (mapping radius at the equator)
\( R = 643985.274 \) m (mapping radius at grid origin)

Lambert coordinates (\( N, E \)) from geodetic positions (\( \phi, \lambda \))

\( \gamma = (\lambda - \lambda_0) \sin(\phi) \) (\( \gamma \) is the meridional convergence)
\( E = R \sin(\gamma) + E_s \) (\( R \) from table)
\( N = R_0 - R \cos(\gamma) + N_s \)

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude (( \phi ))</th>
<th>Longitude (( \lambda ))</th>
<th>R</th>
<th>( \sin(\gamma) )</th>
<th>( \cos(\gamma) )</th>
<th>E</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>sample 1</td>
<td>46 15 0.00000</td>
<td>121 0 0.00000</td>
<td>6045015.043 m</td>
<td>-0.0063382566</td>
<td>461680.982</td>
<td>6045015.043 m</td>
<td></td>
</tr>
</tbody>
</table>

Geodetic positions from Lambert coordinates

\( \tan(\gamma) = (E - E_s)/(R - (N - N_s)) \)
\( R = (R_0 - (N - N_s))/\cos(\gamma) \)
\( \lambda = \lambda_0 - \gamma/\xi \)
\( \phi \) from table using R

<table>
<thead>
<tr>
<th>Station</th>
<th>E</th>
<th>E - E_s</th>
<th>R</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>sample 2</td>
<td>540000.000 m</td>
<td>40000.000 m</td>
<td>6044084.6377 m</td>
<td>46 35 30.1237</td>
<td></td>
</tr>
<tr>
<td></td>
<td>140000.000 m</td>
<td>6043952.275 m</td>
<td>0 22 45.07891</td>
<td>119 58 40.7535</td>
<td></td>
</tr>
</tbody>
</table>

WARNING: Use sufficient significant digits for trig. functions
WHAT YOU NEED TO USE THE STATE PLANE COORDINATE SYSTEMS

- N & E STATE PLANE COORDINATES FOR CONTROL POINTS

AZIMUTHS
- Conversion from Astronomic to Geodetic
- Conversion from Geodetic to Grid (Mapping Angle)

DISTANCES
- Reduction from Horizontal to Ellipsoidal
  “Sea-Level Reduction Factor”
- Correction for Grid Scale Factor
- Combined Factor
SYMBOLS USED IN TEXT

\( \phi = \text{PHI = LATITUDE} \)

\( \lambda = \text{LAMBDa = LONGITUDE} \)

\( \alpha = \text{ALPHA = AZIMUTH OF LINE, USUALLY REFERRING TO GEODEtic VALUES. GRID OR PLANE AZIMUTHS ARE USUALLY DENOTED AS } \alpha \text{. OCCASIONALLY USED TO INDICATE AN ANGLE.} \)

\( \Delta = \text{DELTA = DIFFERENCE} \)

\( \Delta \phi = \text{DELTA PHI = DIFFERENCE IN LATITUDE} \)

\( \Delta \lambda = \text{DELTA LAMBDa = DIFFERENCE IN LONGITUDE} \)

\( \Delta \alpha = \text{DELTA ALPHA = DIFFERENCE IN AZIMUTH} \)

\( \rho = \text{RHO = RADIUS OF CURVATURE OF THE REFERENCE SPHEROID. THE ONLY USE MADE OF THIS QUANTITY IN THIS PAPER IS IN THE REDUCTION OF HORIZONTAL DISTANCES TO ELLIPSOID VALUES. FOR THIS PURPOSE, A MEAN VALUE EQUAL TO 20,906,000 FT. AND DESIGNATED AS "R" HAS BEEN UTILIZED. THIS "R" VALUE SHOULD NOT BE CONFUSED WITH THE "R" OR "R" QUANTITIES USED IN THE COMPUTATIONS INVOLVING THE CONVERSION OF GEOGRAPHIC POSITIONS TO LAMBERT PLANE COORDINATES AND THE INVERSE OF THE PROBLEMS.} \)

\( h = \text{ELEVATION AND ON RARE OCCASIONS MAY INDICATE A DIFFERENCE IN ELEVATION.} \)

\( L = \text{SLOPE OR INCLINED DISTANCE} \)

\( D = \text{HORIZONTAL DISTANCE} \)

\( S = \text{GEODEtic DISTANCE = DISTANCE AT THE ELLIPSOID SURFACE.} \)

\( S_g = \text{GRID DISTANCE = GEODEtic DISTANCE MULTIPLIED BY SCALE (GRID) FACTOR.} \)

\( CM = \text{CENTRAL MERIDIAN = THE MERIDIAN (LONGITUDE) OR AXIS USUALLY SITUATED NEAR THE CENTER OF A PLANE COORDINATE ZONE WHICH SEPARATES THE POSITIVE AND NEGATIVE X' VALUES (SEE DEFINITION OF X').} \)

\( X' = \text{THE DISTANCE (IN METERS FOR THE STATE GRID SYSTEMS) EAST AND WEST OF THE CENTRAL MERIDIAN. EAST OF THE CENTRAL MERIDIAN THE VALUES ARE POSITIVE, WEST OF THIS MERIDIAN THEY ARE NEGATIVE. THESE QUANTITIES CAN BE DESCRIBED IN PLANE SURVEYING TERMINOLOGY AS THE DEPARTURES MEASURED FROM THE Y AXIS.} \)
\( E \) = The plane coordinate values which are perpendicular to the \( X \) axis. These values usually consist of a constant \( C \) \( \pm \) \( X \). The constant "C" is generally of sufficient size to assure that the \( X \) quantities will be positive.

\( \gamma \) = Gamma = The mapping angle in the Lambert projection usually referred to as the "gamma" angle. This angle is applied to geodetic azimuths to obtain plane (grid) azimuths and vice versa.

**Note:** Although these reductions are not exact, the error in neglecting another correction which is known as the "second term" \((T-t)\) correction is quite small for the state systems and can be ignored except for those occasions where the most precise computations are desired.

\( N \) = The plane coordinate values (given in meters for the state grid systems) which correspond to the distances north of the origin to their intersection with the \( E \) coordinates of the points. These quantities can be described in plane surveying terminology as the latitudes measured from the origin.

\( R \) = In the state Lambert grid systems, the distances in meters from the vertex of the cone to the latitudes of the points.

\( R_b \) = In the state Lambert grid systems, the distance in meters from the vertex of the cone to the origin.

\( \lambda \) = A constant determined for each zone or band of a Lambert projection and is equal to the sine of \( \phi \) which is the latitude about midway between the standard parallels. \( \lambda \) multiplied by the difference in seconds between the longitude of a point and the central meridian equals \( \gamma \) (gamma) angle in seconds for the point.
SOLUTION EQUATIONS

\[ \gamma = \pi (\Delta \lambda)'' \]
\[ \Delta \lambda = \text{central meridian} \]

\[ R = (R_n - N) / \cos \gamma \]
STEPS TO CONVERT

GEODETIC POSITIONS TO LAMBERT COORDINATES

WARNING: Use sufficient significant digits for trig functions

STEP 1: COMPUTE $\alpha$ VALUES FOR LATITUDE OF POINT

\[ \alpha = 48^\circ 07' 00.0000' \text{ latitude of point} \]

Lambert conformal conic projection table:

<table>
<thead>
<tr>
<th>Lat</th>
<th>R (meters)</th>
<th>tab diff.</th>
<th>k</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 5</td>
<td>5733331.125</td>
<td>30.88492</td>
<td>0.99994244</td>
</tr>
<tr>
<td>48 6</td>
<td>5731478.131</td>
<td>30.88300</td>
<td>0.99994230</td>
</tr>
<tr>
<td>48 7</td>
<td>5729625.938</td>
<td>30.88109</td>
<td>0.99994225</td>
</tr>
<tr>
<td>48 8</td>
<td>5727771.925</td>
<td>30.87919</td>
<td>0.99994229</td>
</tr>
<tr>
<td>48 9</td>
<td>5725918.814</td>
<td>30.87728</td>
<td>0.99994224</td>
</tr>
</tbody>
</table>

\[ R = 5729625.938 \]

STEP 2: COMPUTE $\gamma$ VALUE FOR LONGITUDE OF POINT

\[ \gamma = (\lambda - \lambda_0) \sin(\phi) \] \[ \gamma \text{ is the meridional convergence} \]

GIVEN: \[ 121^\circ 20' 00.0000' = (\lambda) \text{ longitude of point} \]

\[ \lambda_0 = 120.50 \text{ (longitude of origin and Central Meridian, cm)} \]

\[ \phi = 0.744520326553 = \sin(\phi) \]

\[ \gamma = \left(121-120.50-0.0000\right) \times 0.744520326553 \]

\[ \gamma = -0.27-0.0326553 \]

\[ \gamma = -0.27-0.326553 \]

\[ \gamma = -0.27-0.326553 \]
### SOLUTIONS

**STEP 3. Compute Easting of Point**

\[ E = R \sin(\gamma) + E \]  
(easting coordinate of origin)

\[
E = 5729625.030 \times \sin(\gamma) - 0.22 \times 26.5657 + 500000.000m
\]
\[
= 5729625.030 \times 0.606477120 + 500000.000m
\]
\[
= 37286.06636 + 500000.000m
\]
\[
= 462773.946 m
\]

**STEP 4. Compute Northing of Point**

\[ N = R_0 - R \cos(\gamma) + H_0 \]

- \( R_0 = 5853778.6038 \) m (mapping radius at grid origin)
- \( H_0 = 0.0000 \) m (northing coordinate of origin)

\[
N = 5853778.6038 - \frac{5729625.030 \times \cos(\gamma) - 0.22 \times 26.5657 + 500000.000m}{R_0}
\]
\[
= 5853778.6038 - 5729625.030 \times 0.999977084 + 462773.946 m
\]
\[
= 5853778.6038 - 5729384.878 + 462773.946 m
\]
\[
= 1242774.506 m
\]

<table>
<thead>
<tr>
<th>Station</th>
<th>Latitude</th>
<th>Longitude</th>
<th>R</th>
<th>( \sin(\gamma) )</th>
<th>E</th>
<th>( \cos(\gamma) )</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>sample 1</td>
<td>43.7</td>
<td>0.00000</td>
<td>5729625.030 m</td>
<td>-0.0064971198</td>
<td>462773.946 m</td>
<td>0.999977084</td>
<td>1242774.506 m</td>
</tr>
</tbody>
</table>
SCALE FACTORS

Grid Distance $A'$ to $B'$ is Smaller Than Geodetic Distance $A$ to $B$

Grid Distance $C'$ to $D'$ is Larger Than Geodetic Distance $C$ to $D$

Figure 4.2.—Geodetic vs. grid distances.
REDUCTION TO GRID

(Geodetic Distance) \times k \ (\text{Grid Scale Factor})
The scale factor for the State of Washington south zone at 47° 15' 06.14

K = 0.99998200
K = 0.99998543

0.000000343

60" = 0.0000006

0.99998200 \times 06.14 = 0.00000035

0.99998235 = K_{47-15-06.14}
### SCALE FACTORS

#### Traverse Computation Sheet

<table>
<thead>
<tr>
<th>Station</th>
<th>Deflection Angle</th>
<th>Azimuth (or Bearing)</th>
<th>Distance</th>
<th>Cosine</th>
<th>Sine</th>
<th>N.</th>
<th>E.</th>
<th>W.</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-17</td>
<td></td>
<td>NORTH</td>
<td>3160.00</td>
<td>316100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3160.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Convergence

- **56 N 675 W**: 2116311.24300 E 120° 02’ 03’ 54579 W
- **618 627 675 816 31 209**

- **656 307 675 816 32 209**

#### Scale Factor

- Convergence: 00 20 17.76929
- Scale Factor: 0.999933975

- Convergence: 00 20 19.73056
- Scale Factor: 0.999944576

- Convergence: 00 20 21.69964
- Scale Factor: 0.999957482

---

Scale factor is a function of latitude and can be obtained from the appropriate projection table. Depending on accuracy requirements and the extent of the project area in a north-south direction, the average latitude as obtained from a quad sheet is sufficient. When working on the 83 system in Washington, a very conservative rule of thumb is use an average latitude for a township. For "real picky" surveys a weighted average of scale factor for each line can be used. But there are usually more important things to worry about - optical plumets, ppm correction, baseline calibration, etc.
ELEVATION FACTORS

\[ S = D \left( \frac{R}{R + N + H} \right) \]

Where:
- \( S \) = Geodetic Distance
- \( D \) = Horizontal Distance
- \( H \) = Mean Elevation
- \( N \) = Mean Geoid Height
- \( R \) = Mean Radius of Earth

REDUCTION TO THE ELLIPSOID

ALASKA
ELEVATION FACTORS

\[ \frac{S}{D} = \frac{R}{R + h} \]

\[ S = D \left( \frac{R}{R + h} \right) \]

\[ h = N + H \text{ by definition} \]

\[ S = D \left( \frac{R}{R + N + H} \right) \]

REDUCTION TO THE ELLIPSOID

LOWER STATES
GEOID MODELS

U.S. NATIONAL MODEL -- GEOID99
(http://www.ngs.noaa.gov/cgi-bin/GEOID_STUFF/geoid99_prompt1.prl)

CANADIAN NATIONAL MODEL -- CGG2000

GLOBAL MODEL -- EGM 96
(http://www.nima.mil/GandG/wgs-84/egm96.html)
USGG2003 and GEOID03

USGG = U.S. Gravimetric Geoid
GEOID03 = U.S. Hybrid Geoid

In excess of 11,000 GPS on BMs
(A, B, and 1<sup>st</sup>- Order GPS on 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> – Order NAVD 88 BMs)

Possibly overall misfit will be about 2.9 cm.
REDUCTION TO THE ELLIPSOID

Earth Radius
6,372,161 m
20,906,000 ft.

Earth Center

S = D \times \left( \frac{R}{R + h} \right)

h = H + N

S = D \times \left( \frac{R}{R + H + N} \right)
The Elevation factor for a mean elevation of 1941.8 ft. and a Mean Geoid Height of -19.65 ft is

0.9999023

Mean \( H = 1941.8 \) ft.
Mean \( N = -19.65 \) ft. = 64.5 ft

Elevation factor = \( \frac{20,906,000}{20,906,000 + H + N} \) = \( \frac{20,906,000}{20,907,877} \) = 0.9999023
### ELEVATION FACTORS

<table>
<thead>
<tr>
<th>ELEVATION FEET</th>
<th>FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.000000</td>
</tr>
<tr>
<td>300</td>
<td>.9999761</td>
</tr>
<tr>
<td>1000</td>
<td>.9999522</td>
</tr>
<tr>
<td>1500</td>
<td>.9999283</td>
</tr>
<tr>
<td>2000</td>
<td>.9999043</td>
</tr>
<tr>
<td>2500</td>
<td>.9998804</td>
</tr>
<tr>
<td>3000</td>
<td>.9998565</td>
</tr>
<tr>
<td>3500</td>
<td>.9998326</td>
</tr>
<tr>
<td>4000</td>
<td>.9998087</td>
</tr>
<tr>
<td>4500</td>
<td>.9997848</td>
</tr>
<tr>
<td>5000</td>
<td>.9997609</td>
</tr>
<tr>
<td>5500</td>
<td>.9997370</td>
</tr>
<tr>
<td>6000</td>
<td>.9997131</td>
</tr>
<tr>
<td>6500</td>
<td>.9996892</td>
</tr>
<tr>
<td>7000</td>
<td>.9996653</td>
</tr>
<tr>
<td>7500</td>
<td>.9996414</td>
</tr>
<tr>
<td>8000</td>
<td>.9996175</td>
</tr>
</tbody>
</table>

**NOTE:** Where difference in elevation does not exceed 500' along any traverse, mean traverse elevation can be used and one factor may be interpolated for entire traverse. When violent difference in elevation occurs, individual factors must be interpolated.
COMBINED FACTOR

CF = Ellipsoidal Reduction Factor x Grid Scale Factor (k)
**CONVERGENCE**

Lambert Polyconic Projection
Washington, South Zone

**Scale Increases**
North Pole

**Scale Decreases**

Surface
Spheroid

Meridians

West

EQUATOR

Central Meridian

**Scale Increases**

Point of Origin
E.

Scale Factor

Point of Origin
W.

Scale Factor

**When position is East of Central Meridian, \( \Gamma \) is plus (p); when West of C.M., \( \Gamma \) is minus (m).**

\( \text{GAMMA (}\gamma\text{) angle is the amount of correction between Grid Az. and Geodetic Az.} \)

**Example:**

- Grid Az. 53°30'00.0"
- \( \gamma = 1°15'46.1" \)
- True Az. 54°45'46.7"
CONVERGENCE

IN NAD83
ALL AZIMUTHS
ARE FROM NORTH

Lambert Conformal Projection
Washington, South Zone

Grid Azimuths

IF YOU ARE USING
GRID AZIMUTHS YOU CAN
JUST ADD OR SUBTRACT
AS THE GRID REFERENCE
YOU ARE USING TO
GRID AZIMUTHS

SCALE DECREASES

Meridians

WGS84

SINMA (t) Correction is the amount of correction between grid A.Z. and Geodetic A.Z.

Also you can compute:

East Correlation (t) = sin(t) - cos(t)

North Correlation (t) = cos(t) - sin(t)

When position is East of Central Meridian, convert(t) - 90°

When position is West of Central Meridian, convert(t) + 90°
LAMBERT CONFORMAL CONIC WITH 2 STANDARD PARALLELS

The Convention of the Sign of the Convergence Angle is Always From Grid To Geodetic

Convergence angles ($\alpha$) always positive East

Convergence angles ($\alpha$) always negative West

CENTRAL MERIDIAN

$\alpha_0$
GROUND LEVEL COORDINATES

“I WANT STATE PLANE COORDINATES RAISED TO GROUND LEVEL”

GROUND LEVEL COORDINATES ARE NOT
STATE PLANE COORDINATES!!!!!
PROJECT COORDINATES

PROJECT LENGTHS FROM STATE COORDINATES

Engineering projects require the field location of construction lines and survey points. Since most large projects will be established with reference to control points on the state coordinate system, the construction plans and drawings will contain state coordinates and grid lines. If the state coordinates of two ends of a construction line are used to inverse the line, the grid length and grid bearing or azimuth will result. The proper length to be laid off, however, is the actual ground length. The difference between the grid length and the ground length can be taken into account by one of two methods. The first method, which is quite practical, is to ignore the difference. This method assumes that the errors in layout measurements are larger than the errors introduced by neglecting the difference between the grid and the ground distance. For example, in an area whose elevation is 2500 ft, the sea-level reduction factor is 0.9998804. Suppose the grid scale factor is 0.9999000 or one part in 10,000. The combination factor is then 0.9997804. This means that the difference between the ground length and the grid length is only 0.02 ft/100 ft or 0.22 ft/1000 ft. This small discrepancy, amounting to about one part in 5000, could be ignored on most construction projects. In high country the sea-level reduction factor becomes significant, particularly if the project lies in an area of the state projection where the grid scale factor is less than unity.

The second method is to compute the combination sea-level grid factor, and then to divide all grid distances indicated on, or derived from, the plans in order to obtain the correct ground or project lengths. In order to accomplish this without misunderstanding between the surveyor, engineer, and contractor, a note should accompany each construction drawing giving explicit instructions to the user. The note could possibly read, “All distances shown on this set of plans (drawing) or derived from plane coordinates shown on the plans (drawing) are grid distances on the — Coordinate System, Zone—. To obtain ground distances for laying out construction lines, divide grid distances by 0.9998940.”
PROJECT DATUM COORDINATES

THE NAD 83 PLANE COORDINATE DATA ISSUED BY THE NATIONAL GEODETIC SURVEY IS AT THE ELLIPSOID REFERENCE. TO PROPERLY USE THIS DATA, GROUND DISTANCES SHOULD BE CORRECTED BY A SCALE FACTOR AND REDUCED TO THE ELLIPSOID. THIS COMPUTATION IS USUALLY MADE USING A COMBINED FACTOR. IT HAS BEEN SHOWN THAT TO OBTAIN ADJUSTED GROUND LEVEL DISTANCES THE ADJUSTED GRID DISTANCES ARE DIVIDED BY THE COMBINED FACTOR. TO OBTAIN GROUND LEVEL OR PROJECT DATUM COORDINATES, ALL THAT NEEDS TO BE DONE IS TO DIVIDE THE ELLIPSOID COORDINATES BY THE COMBINED FACTOR. THE DISTANCES COMPUTED FROM THESE COORDINATES WILL BE AT GROUND LEVEL.

THERE IS ANOTHER APPROACH THAT MAY BE TAKEN WHEN PROJECT DATUM COORDINATES ARE DESIRED. FIRST, THE PLANE COORDINATES FOR THE FIXED CONTROL POINTS ARE DIVIDED BY THE COMBINED FACTOR, WHICH REPRESENTS THE MEAN ELEVATION AND THE MEAN SCALE FACTOR FOR THE AREA TO PLACE THE FIXED CONTROL AT GROUND LEVEL. HORIZONTAL GROUND LEVEL DISTANCES ARE USED IN THE COMPUTATIONS WITH PROJECT DATUM COORDINATES THE END RESULT.

EXTREME CAUTION MUST BE EXERCISED WHEN SHOWING PROJECT DATUM COORDINATES ON A PLAT OR DOCUMENT. IN ADDITION TO A CLEAR EXPLANATION OF THE COORDINATES, THE COMBINED FACTOR SHOULD BE SHOWN, AND THE COORDINATES SHOULD BE CHANGED BY ADDING OR SUBTRACTING CONSTANTS OF SUFFICIENT SIZE SO THAT THEY WOULD NEVER BE TAKEN AS STATE PLANE COORDINATES.
PROJECT COORDINATES

1. Determine combined ellipsoid and scale factor for project area.

2. Divide coordinates for control points by combined factor or multiply by 1/Cf.

3. Use horizontal ground level distances.

4. Balance traverse - results are ground level coordinates. Distances computed from these coordinates are adjusted ground level values.

5. In order that the ground level coordinates will not be mistaken as specs values, do the following:

   a. Make coordinates unique by dropping some figures on left or add large constants.

   b. Document all computations, plats, maps, etc., with pertinent details including combined factor used. Note mean latitude and mean elevation of project in documentation.
Ground Level Coordinates

Project Datum coordinates are based on state plane, but.....

Are NOT state plane coordinates!!!!
GROUND LEVEL COORDINATES

TRUNCATE COORDINATE VALUES
SUCH AS:

N = 13,750,260.07 ft becomes 50,260.07
E = 2,099,440.89 ft becomes 99,440.89

AND
LEGAL DESCRIPTIONS

BASIS OF BEARINGS FOR THIS SURVEY IS NO2°00'54"E BETWEEN THE CASED MONUMENTS AT THE SOUTHEAST CORNER AND THE EAST QUARTER CORNER OF SECTION 28, TOWNSHIP 31 NORTH, RANGE 5 EAST, WILLAMETTE MERIDIAN, ORIENTED ON THE WASHINGTON COORDINATE SYSTEM NAD 83 (1991), NORTH ZONE.

SECTION SUBDIVISION INFORMATION SHOWN HEREON WAS ESTABLISHED BY GPS, AND IS SCALED TO GROUND DISTANCES WITH A GRID SCALE FACTOR OF 0.9999423 AND AN ELEVATION FACTOR OF 0.9999970 BEING APPLIED, FOR A COMBINED FACTOR OF 0.9999393, YIELDING HORIZONTAL GROUND DISTANCES FOR THE SECTION SUBDIVISION AND THROUGHOUT THIS MAP.

FIELD MEASUREMENTS FOR THIS MAP PERFORMED WITH TRIMBLE 4000 SSE GPS, WILD 1610 AND SOKKIA SET 2 TOTAL STATIONS, AND MEET OR EXCEED A LINEAR CLOSURE OF 1:15,000 AND THE LEAST SQUARES ADJUSTMENTS YIELDS A RELATIVE ACCURACY NO GREATER THAN 0.08 FEET AT A 95% CONFIDENCE LEVEL, RELATIVE TO THE CONTROLLING MONUMENTS (SNOHOMISH COUNTY GPS CONTROL POINTS #516 AND #438).

ALL PRIMARY MEASUREMENT EQUIPMENT UTILIZED HAS BEEN COMPARED AND ADJUSTED TO A NATIONAL GEODETIC SURVEY CALIBRATED BASELINE, WITHIN THE LAST YEAR.

THIS SURVEY UTILIZED CHICAGO TITLE REPORT NOS. 363284 & 363066.
LEGAL DESCRIPTION USING WASHINGTON COORDINATES

That portion of the southwest one-quarter of the northwest one-quarter of Section 16, Township 12 North, Range 19 East, Willamette Meridian, situated in county of Yakima, State of Washington, described as follows:

Commencing at the northwest corner of said Section 16, having grid coordinates of N 438 136.45 and E 1650729.03, South Zone, Washington Coordinate System NAD 83/91; thence South 0°21′01″ West, a grid distance of 1,388.13 feet along the West line of said Section 16; thence South 89°38′59″ East, a grid distance of 173.54 feet to the True Point of Beginning having grid coordinates of N 438747.29 and E 1650884.07; thence North 79°55′36″ East, a grid distance of 149.97 feet; thence South 10°04′24″ East, a grid distance of 149.97 feet; thence South 79°55′36″ West, a grid distance of 149.97 feet; thence North 10°04′24″ West, a grid distance of 149.97 feet to the True Point of Beginning.

All bearings and distances shown are on the Washington Coordinate System NAD 83/91, South Zone and the combined grid factor is 0.9998308

SAMPLE CONVERSIONS OF PLANE COORDINATE VALUES FROM METRIC TO ENGLISH UNITS

EXAMPLE 1: Convert NAD 83 State Plane Coordinate Value in Meters to Value

Expressed in U.S. Survey Feet (1200/3937 meter)

1 meter = 39.37 inches exactly = 3937/1200 feet

Northing (meters) \times (3937/1200) \text{ U.S. Survey Feet/meter} = \text{ Northing (U.S Survey Feet)}

98.923.927 m \times (3937/1200) \text{ U.S. Survey Feet/meter} = 324,552.917 \text{ U.S. Survey Feet}

Easting (meters) \times (3937/1200) \text{ U.S. Survey Feet/meter} = \text{ Easting (U.S. Survey Feet)}

602,242.230 m \times (3937/1200) \text{ U.S. Survey Feet/meter} = 1,975,856.353 \text{ U.S. Survey Feet}

EXAMPLE 2: Convert NAD 83 State Plane Coordinate Value in Meters to Value

Expressed in International Feet (1250/381 meter)

1 inch = 2.54 centimeters exactly
1 foot = (12 in/ft \times 2.54 \text{ cm/ft}) \times (1 m/100 \text{ cm}) = 0.3048 \times 381/1250 =

Northing (meters) \times (1250/381) \text{ International Feet/meter} = \text{ Northing (International Feet)}

98.923.927 m \times (1250/381) \text{ International Feet/meter} = 324,553.686 \text{ International Feet}

Easting (meters) \times (1250/381) \text{ International Feet/meter} = \text{ Easting (International Feet)}

602,242.230 m \times (1250/381) \text{ International Feet/meter} = 1,975,860.335 \text{ International Feet}
CORPSCON