OVERVIEW OF WASHINGTON STATE PLANE (GRID VERSUS GROUND)

Donald Wieber

AGENDA

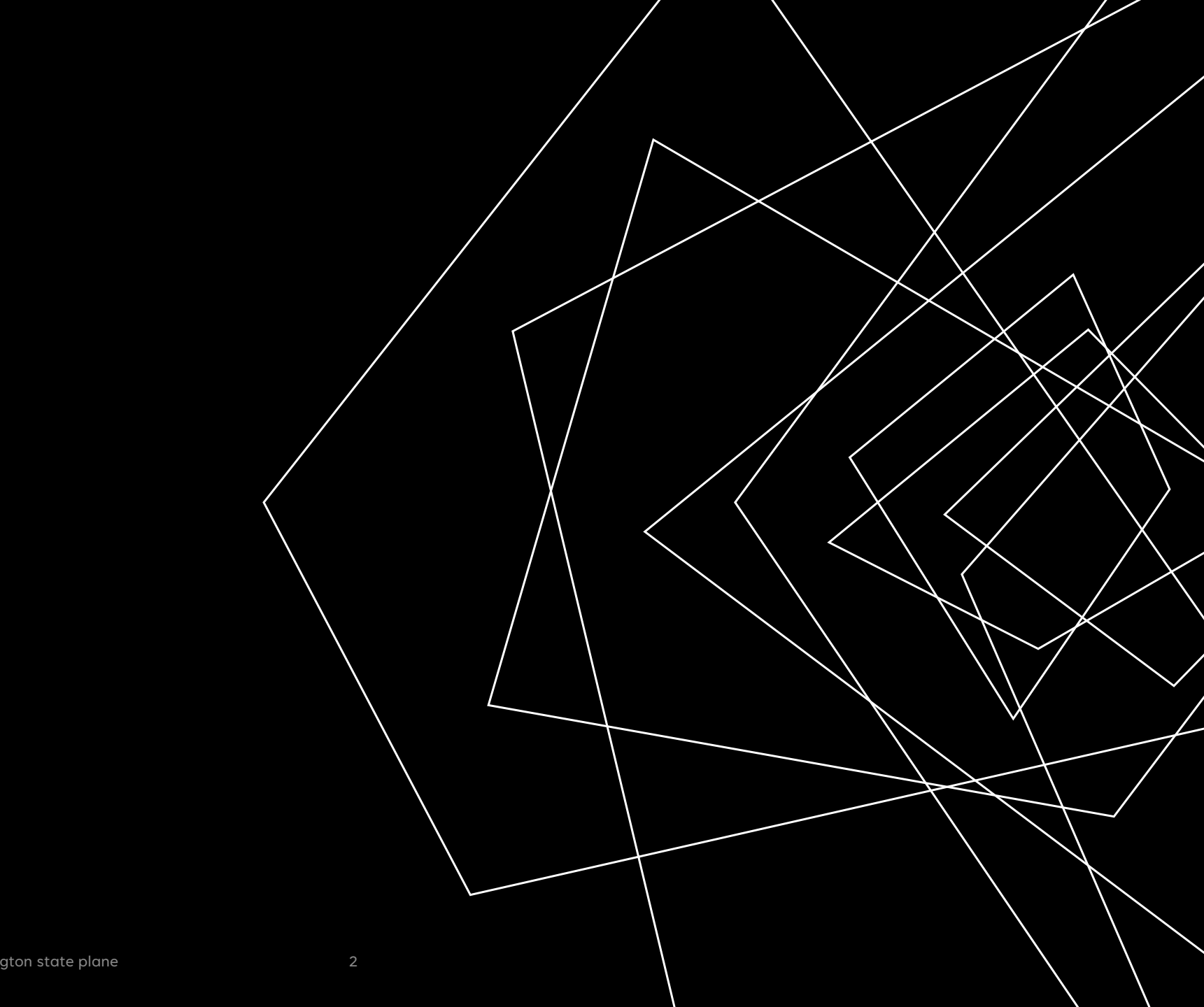
Introduction

Definitions

State Plane Zones

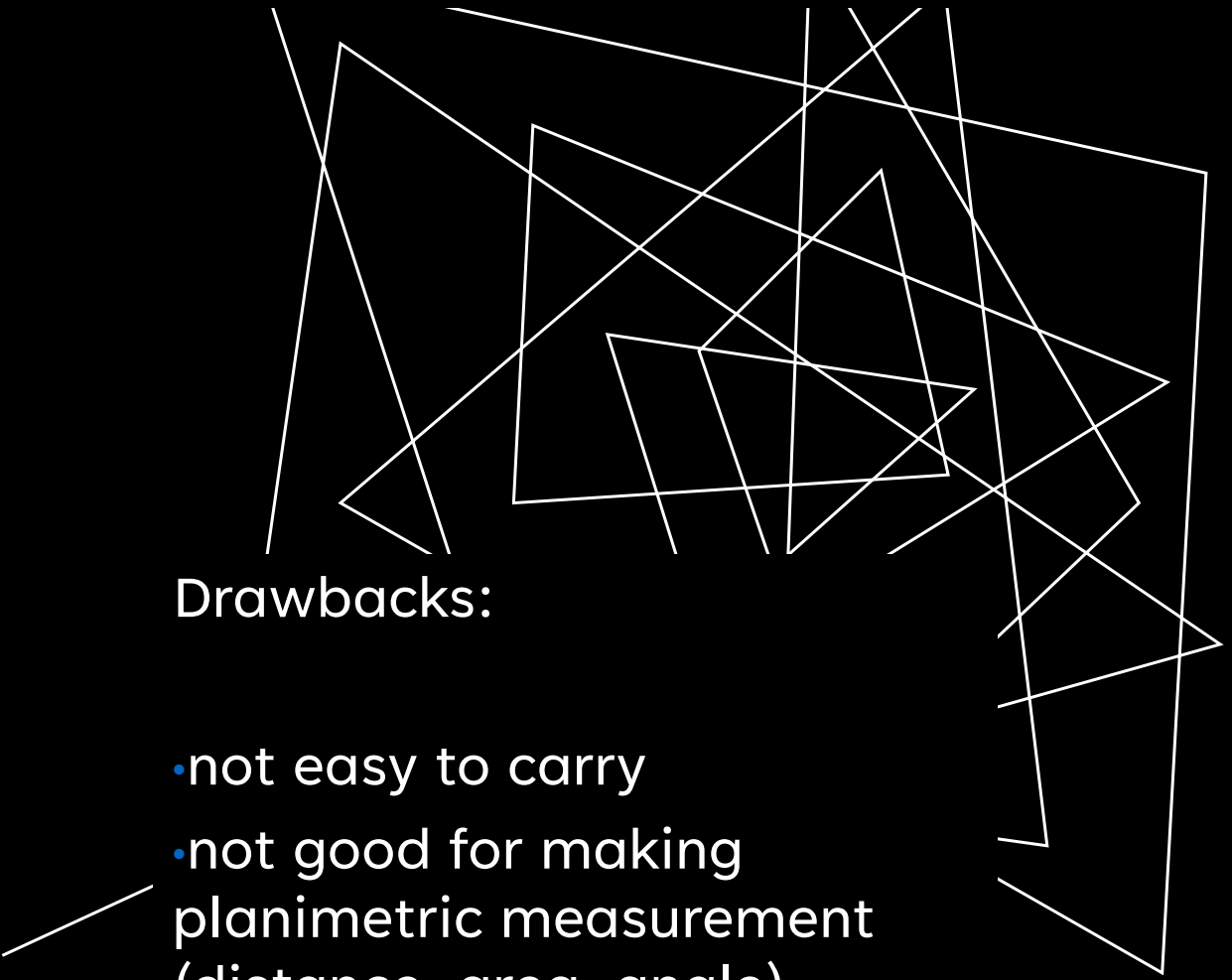
Summary

Questions



THE EARTH IS A SPHEROID

The best model of the earth is a globe



Drawbacks:

- not easy to carry
- not good for making planimetric measurement (distance, area, angle)

MAP PROJECTIONS *ALWAYS* INTRODUCE ERROR AND DISTORTION

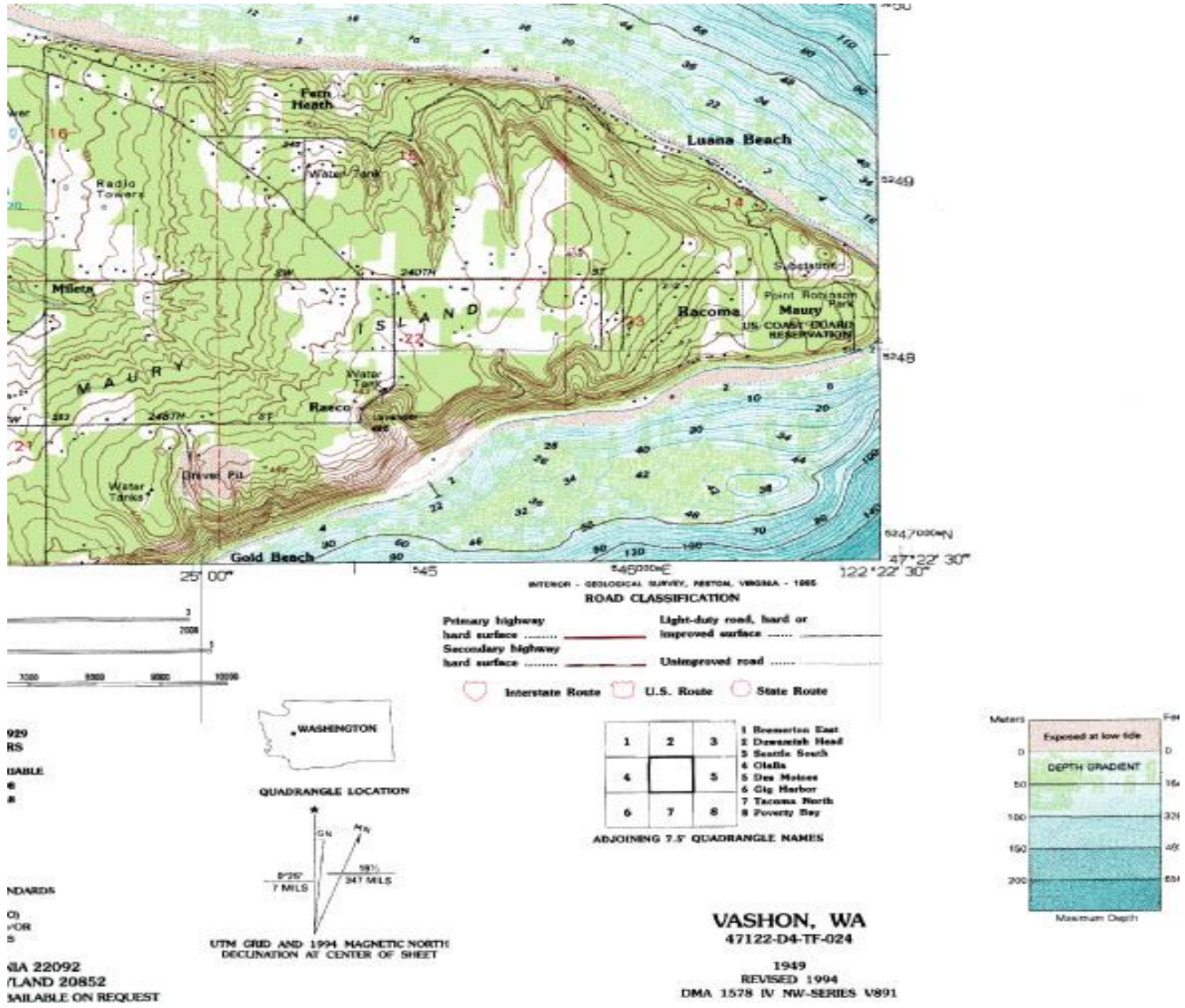
Distortion may be minimized in one or more of the following properties:

- Shape … conformal
- Distance … equidistant
- Direction … true direction
- Area … equal area

MAPS ARE FLAT

GOOD FOR MEASUREMENT

SCALEABLE*



State Plane Coordinates

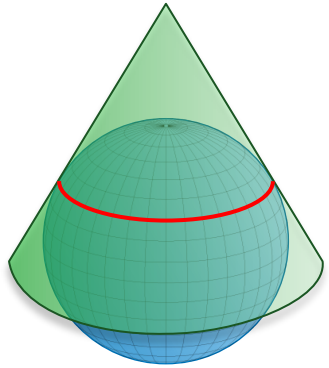
BRIEF HISTORY:

-Originally a U.S. English unit grid system

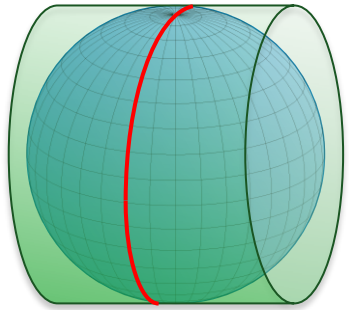
-Developed by land surveyors in the 1930's to simplify surveying computations, cooperative venture between the Coast and Geodetic Survey and the North Carolina state government, and efforts to build a North Carolina spatial coordinate system with minimal distortion was started. In 1933 this cooperative venture produced the North Carolina Coordinate System. In less that 12 months, the North Carolina system had been copied into all of the remaining states, and the State Plane coordinate system was born.

STATE PLANE COORDINATE SYSTEMS (SPS OR SPCS)

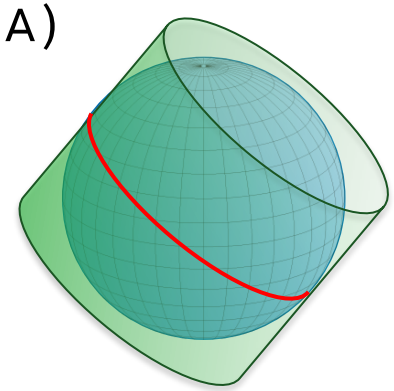
-LAMBERT CONFORMAL CONIC



-TRANSVERSE MERCATOR PROJECTIONS



-OBLIQUE MERCATOR (SOME COAST LINES, AKA ALASKA)

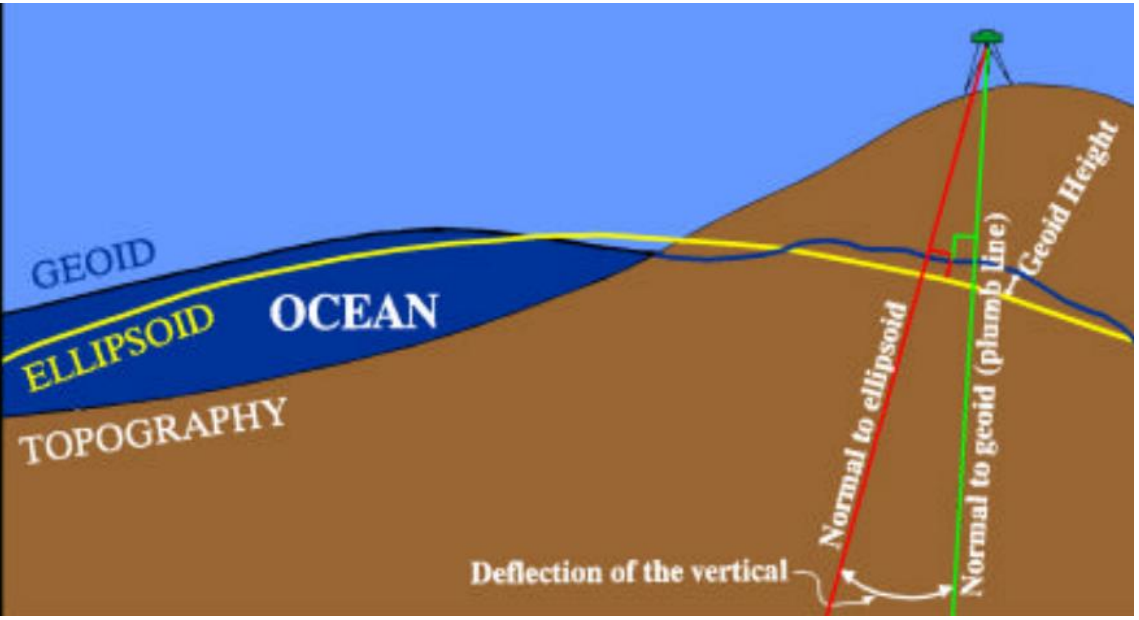


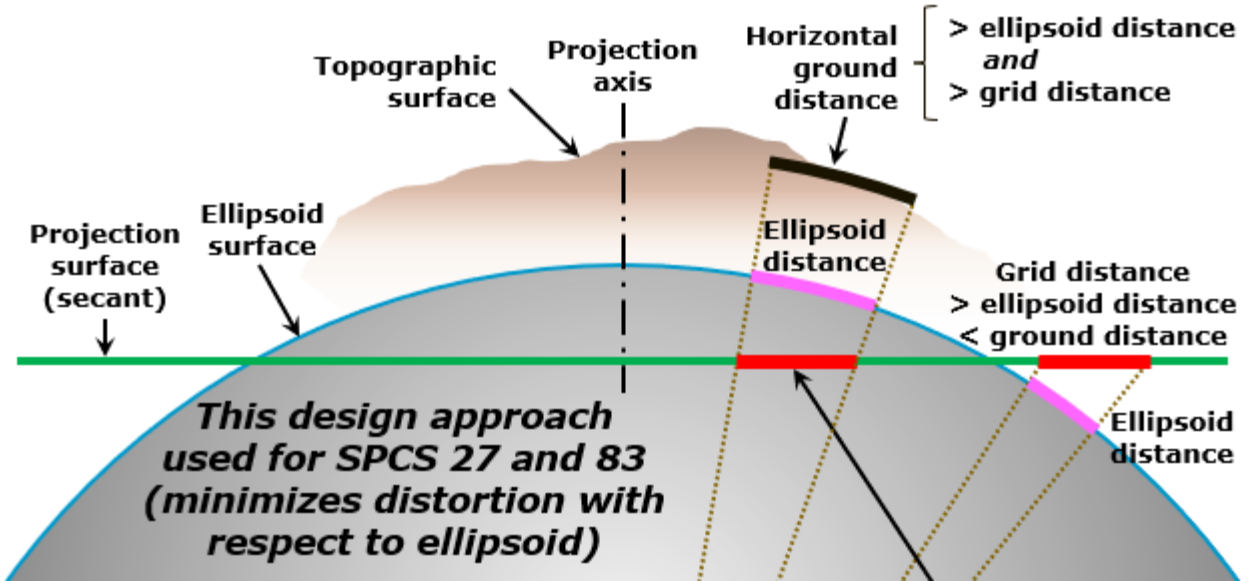
DIFFERENT SURFACES IN GEODESY

- THE **TOPOGRAPHY** – THE PHYSICAL SURFACE OF THE EARTH

- THE **ELLIPSOID** – THE MATHEMATICAL SURFACE WHICH APPROXIMATES THE SHAPE AND SIZE OF THE EARTH, AND IS USED AS A REFERENCE FRAME FOR POSITION COMPUTATIONS.

- THE **GEOID** – THE LEVEL (EQUIPOTENTIAL) SURFACE AT MEAN SEA LEVEL. IN SIMPLE TERMS A LEVEL SURFACE IS A SURFACE ON WHICH WATER WILL STAND STILL. THE GEOID IS A LEVEL SURFACE AT ELEVATION ZERO.





STATE PLANE COORDINATE SYSTEMS (SPS OR SPCS)

THE STATE PLANE SYSTEM WAS CREATED TO MANAGE DATA AT A STATE LEVEL. IT IS ONLY FOR THE UNITED STATES BUT OTHER COUNTRIES HAVE DEVELOPED SIMILAR SYSTEMS FOR THEIR DATA. EACH STATE IS DIVIDED INTO "ZONES" AS NEEDED. THE ZONES ARE DEFINED BY STATE AND COUNTY BOUNDARIES AND WILL RUN NORTH/SOUTH OR EAST/WEST, WHICH EVER IS BETTER TO REDUCE DISTORTION WITHIN THE ZONE. BECAUSE OF THE SIZE OF THE STATES, SOME STATES WILL HAVE ONE ZONE WHILE OTHERS WILL HAVE MORE, ALASKA HAS 10!

UNITS: FEET OR METERS.

DISTANCE DISTORTIONS ARE KEPT BELOW 1 PART IN 10,000

NAD 27 - COORDINATES IN U.S. SURVEY FEET

NAD 83 - COORDINATES METRIC W/STATE DEFINED FOOT CONVERSION (WA US FT, OR INTERNATIONAL)

1 METER = 3.280833333 U.S. SURVEY FEET

1 METER = 3.280839895 INTERNATIONAL FEET

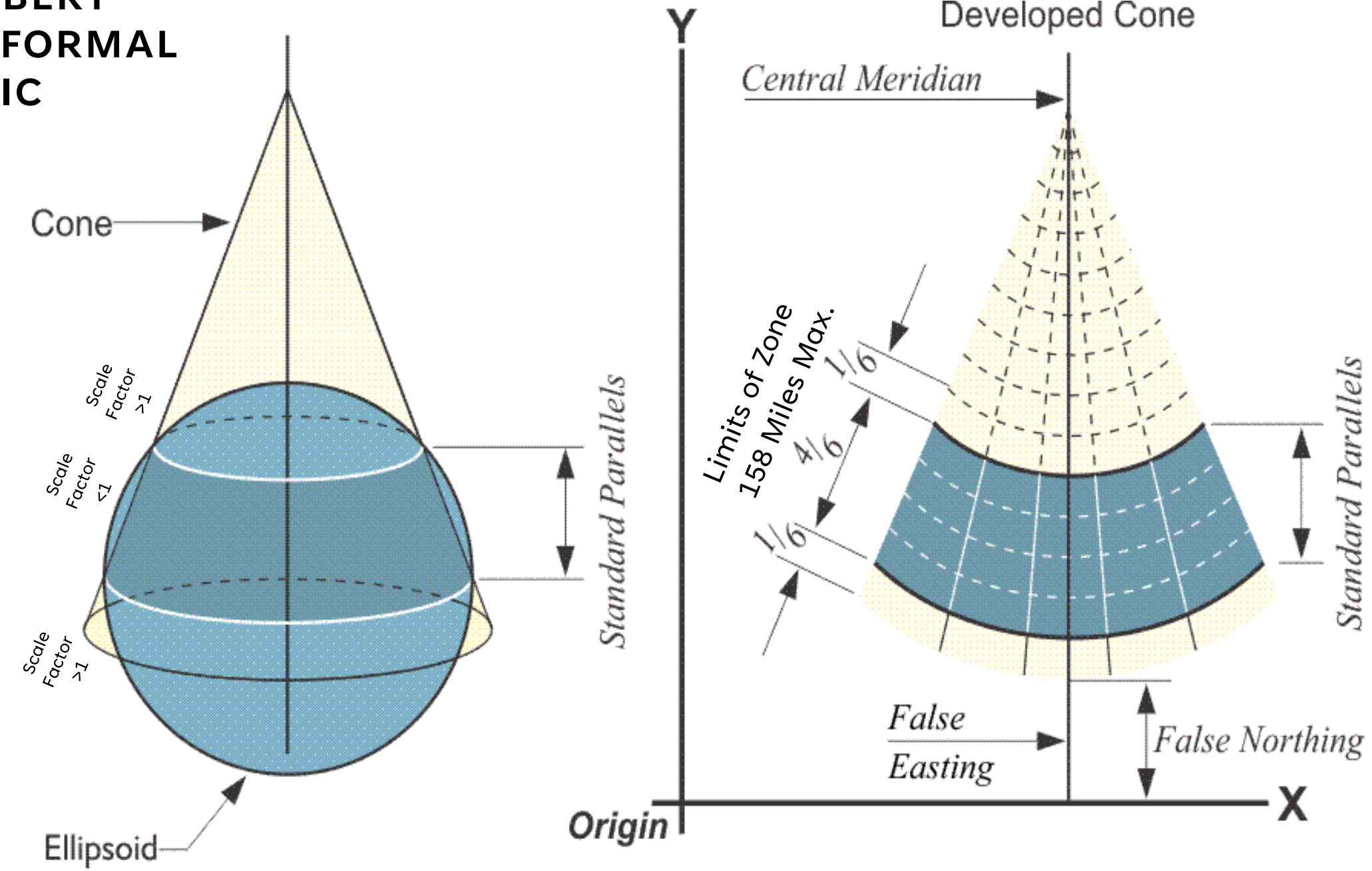
NAD 27 TO NAD 83 VERY LARGE POSITIONAL SHIFTS

CONFORMAL CONIC MAP PROJECTIONS

The Lambert Conformal Conic projection (created in 1772 by Johann Heinrich Lambert), is one of the most commonly used low distortion projections. As the name implies, the Lambert projection is conformal (preserves angles with a unique scale at each point).

This projection superimposes a cone over the sphere of the Earth, with either one reference parallel **tangent** or with two standard parallels **secant** (a straight line that intersects with the globe in two places). Specifying a 'central meridian' orients the cone with respect to the ellipsoid. Scale error (distortion with respect to the ellipsoid) is constant along the parallel(s). Typically, it is best used for covering areas long in the east–west direction, or, for low distortion applications, where topographic height changes more-or-less uniformly in the north-south direction. The Lambert Conformal Conic projection for relatively large regions of the state is designed as a single parallel Lambert projection. The cone of the projection is typically scaled up from the ellipsoid to ‘best fit’ an area and range of topographic height on the Earth’s surface.

LAMBERT CONFORMAL CONIC



LAMBERT CONFORMAL CONIC (CONES)

Spot where the cone cut though the earth is called the standard parallels

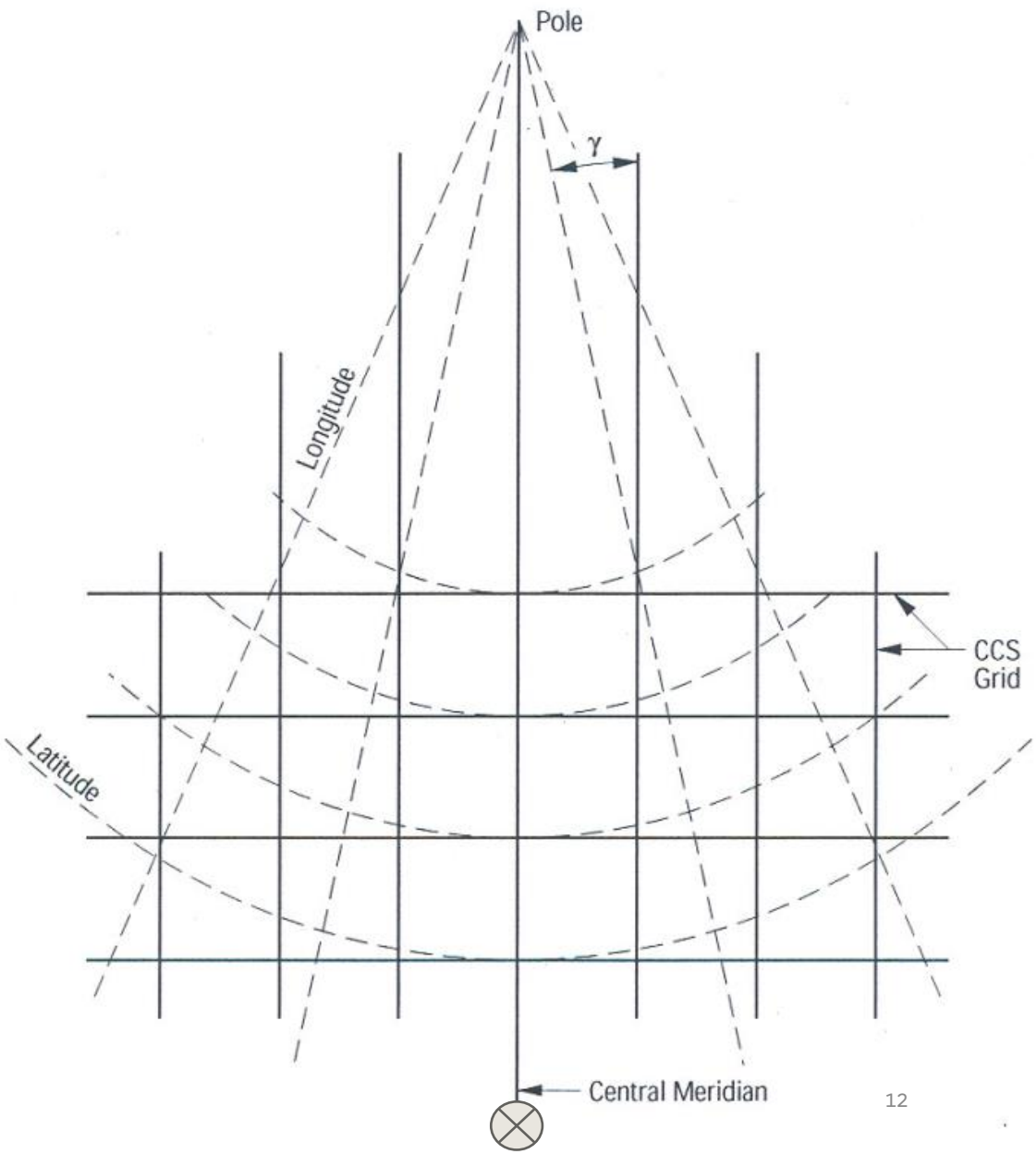
Central Meridian

False Origin (N=0.00,E=500,000.00) in meters

(0,0) in Washington is out in the Pacific

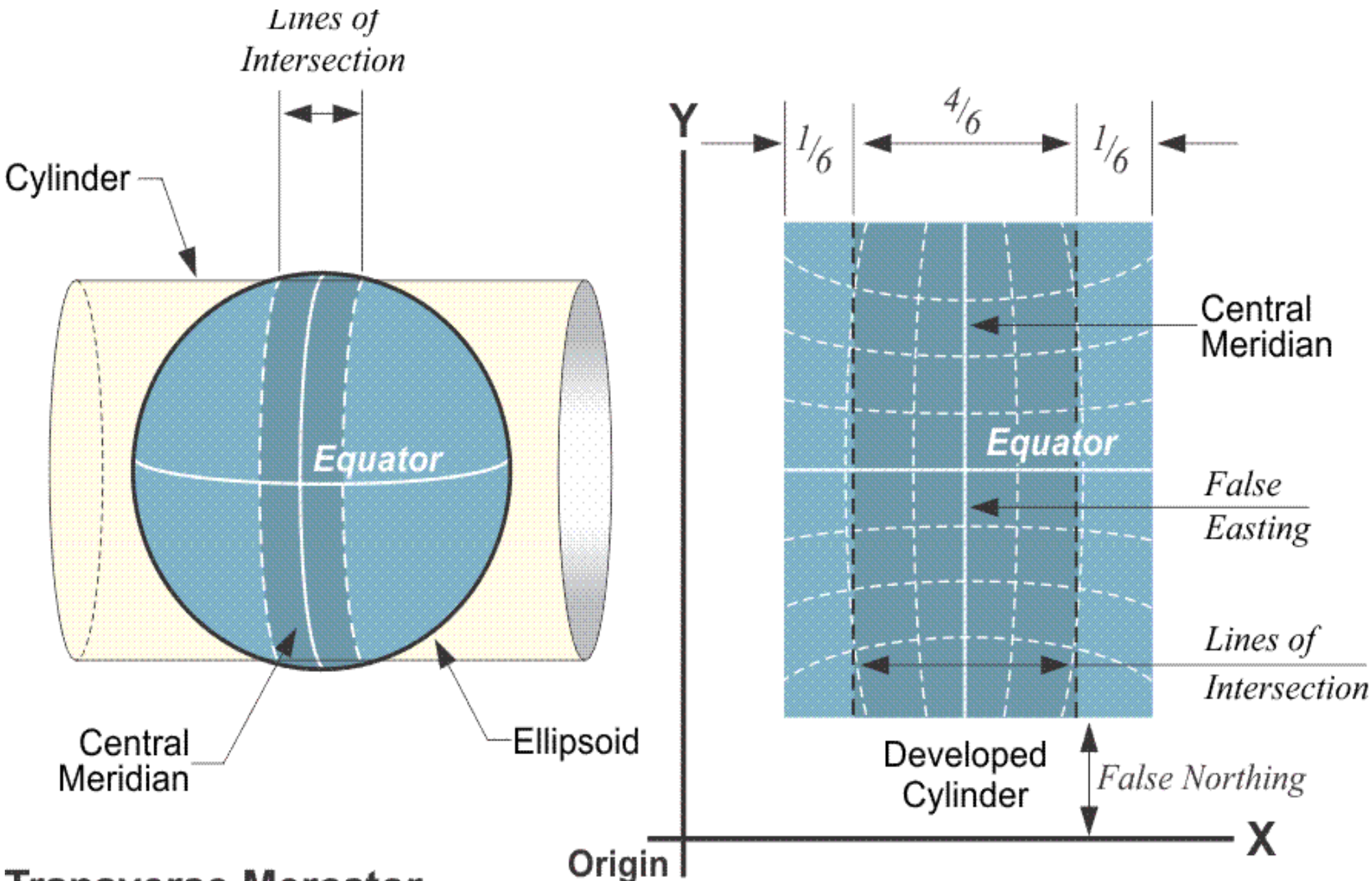
In between the standard parallel the ground distance is longer than the “gird” distance.

GRID DECLINATION OR MAPPING ANGLE

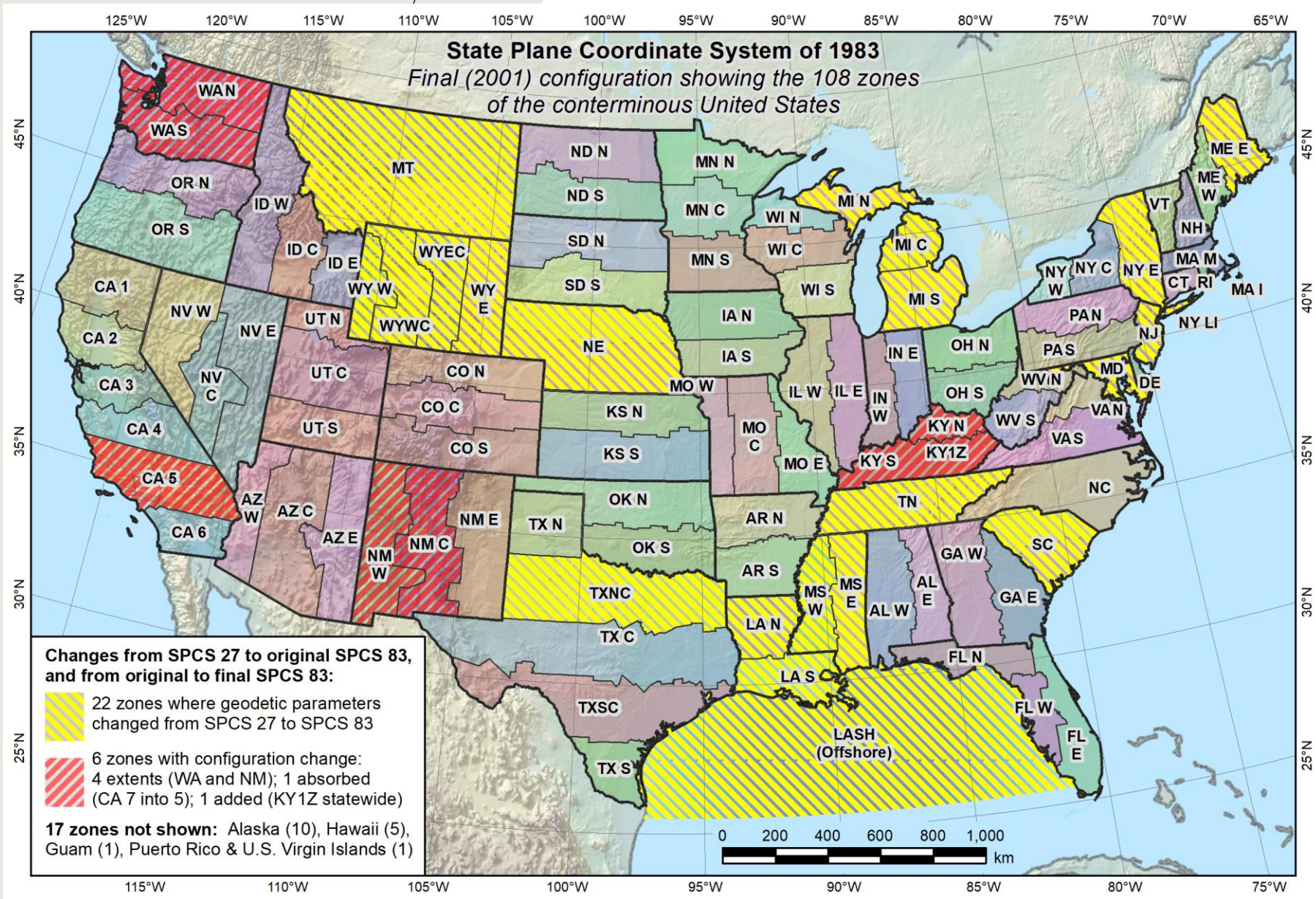


TRANSVERSE MERCATOR

Transverse Mercator projection The Transverse Mercator (ellipsoidal) map projection was originally presented by mathematician Carl Friedrich Gauss in 1822. It is a conformal projection that is characterized by a cylinder superimposed over the ellipsoid of the earth with a straight central meridian. Distances along the meridian have a constant scale. This projection is used for the familiar UTM (Universal Transverse Mercator) map projection series, and it is the most commonly used in geodetic mapping especially for areas of study that are relatively close to the central meridian. This project works particularly well for areas long in the north – south direction, and for low distortion applications where topographic height changes more-or-less uniformly in the east-west direction.

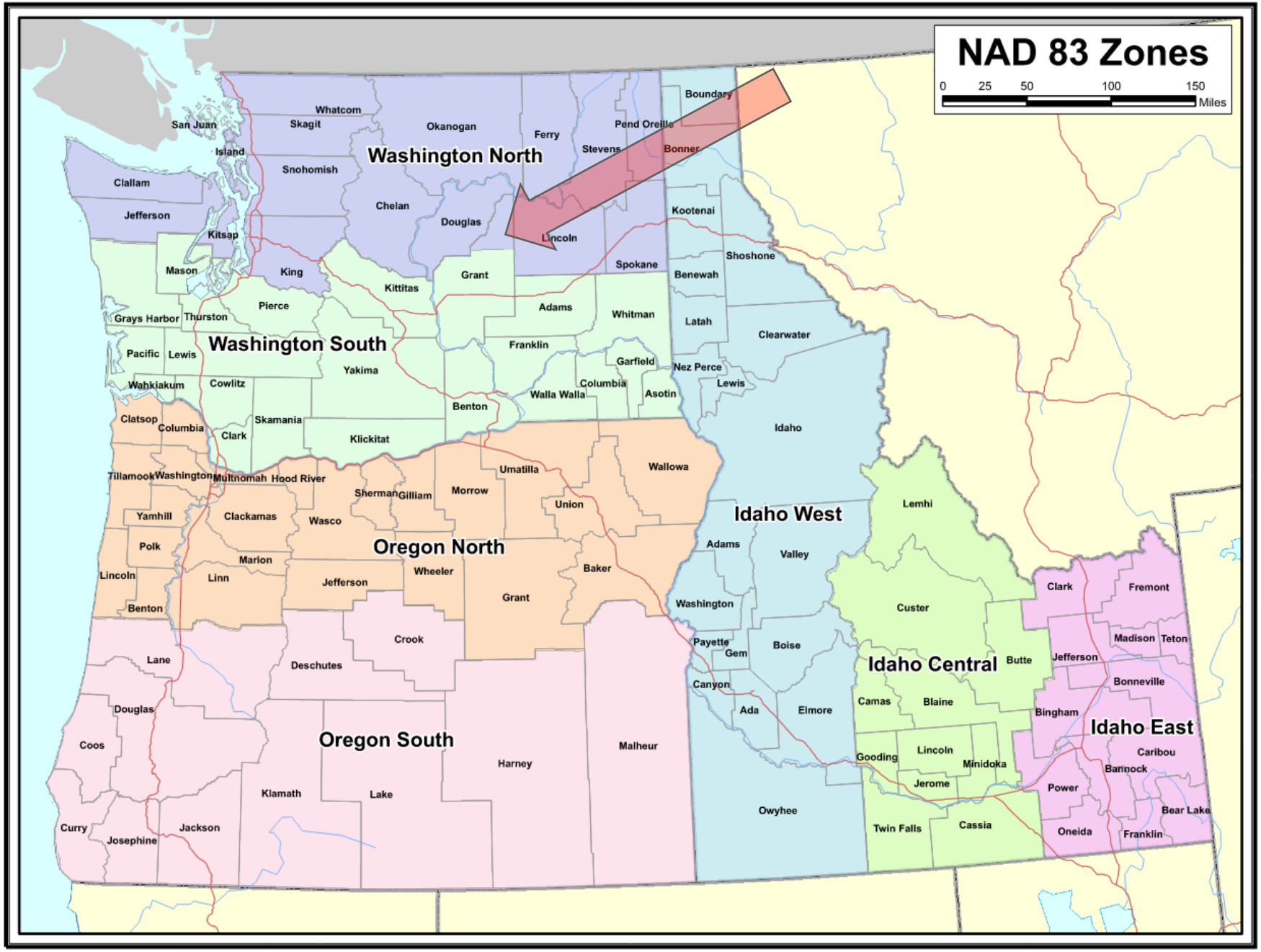


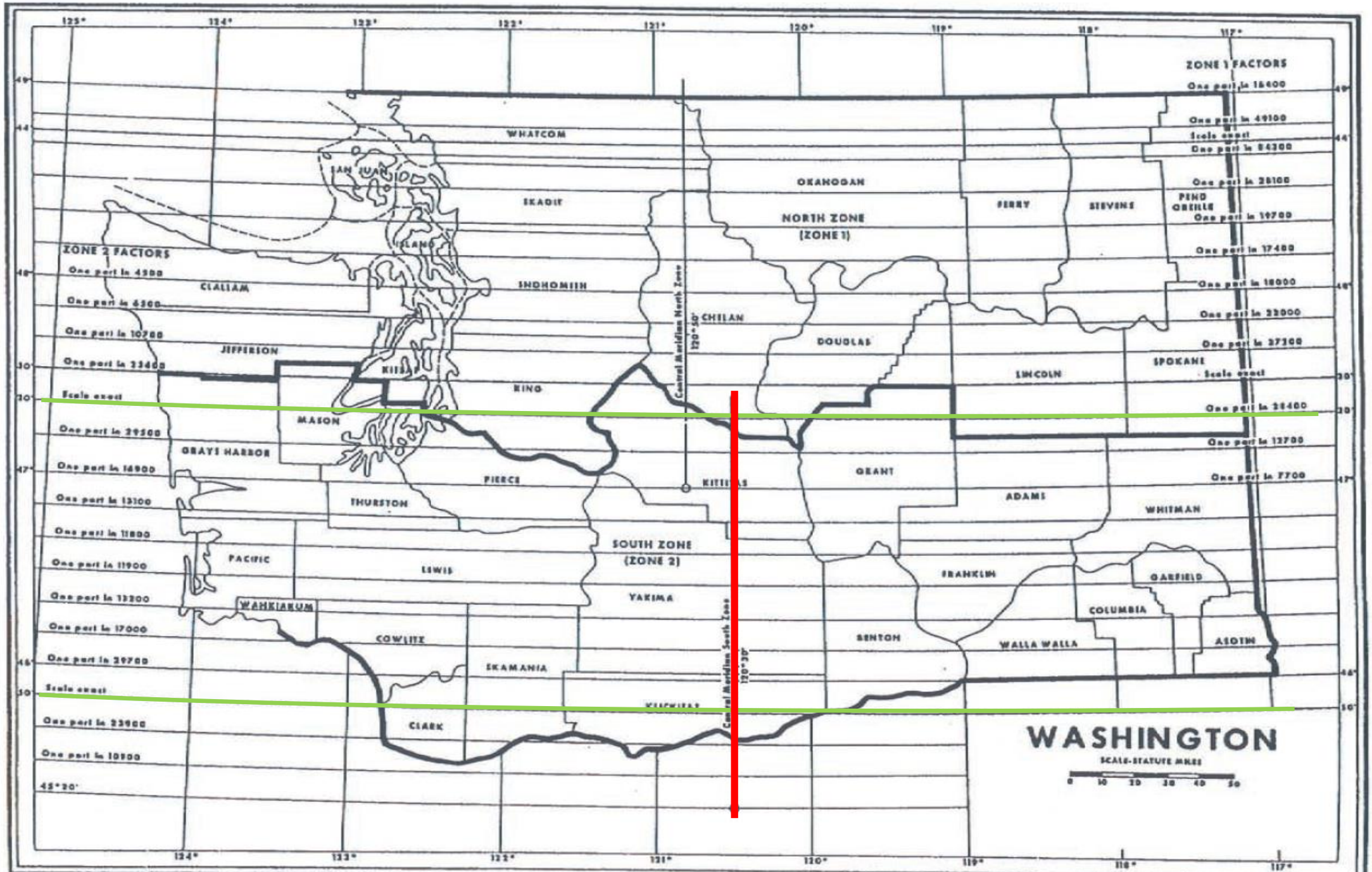
Transverse Mercator Projection


State Plane Coordinate System of 1983
Final (2001) configuration showing the 108 zones
of the conterminous United States
Changes from SPCS 27 to original SPCS 83, and from original to final SPCS 83:
22 zones where geodetic parameters changed from SPCS 27 to SPCS 83
6 zones with configuration change: 4 extents (WA and NM); 1 absorbed (CA 7 into 5); 1 added (KY1Z statewide)
17 zones not shown: Alaska (10), Hawaii (5), Guam (1), Puerto Rico & U.S. Virgin Islands (1)
0 200 400 600 800 1,000
km

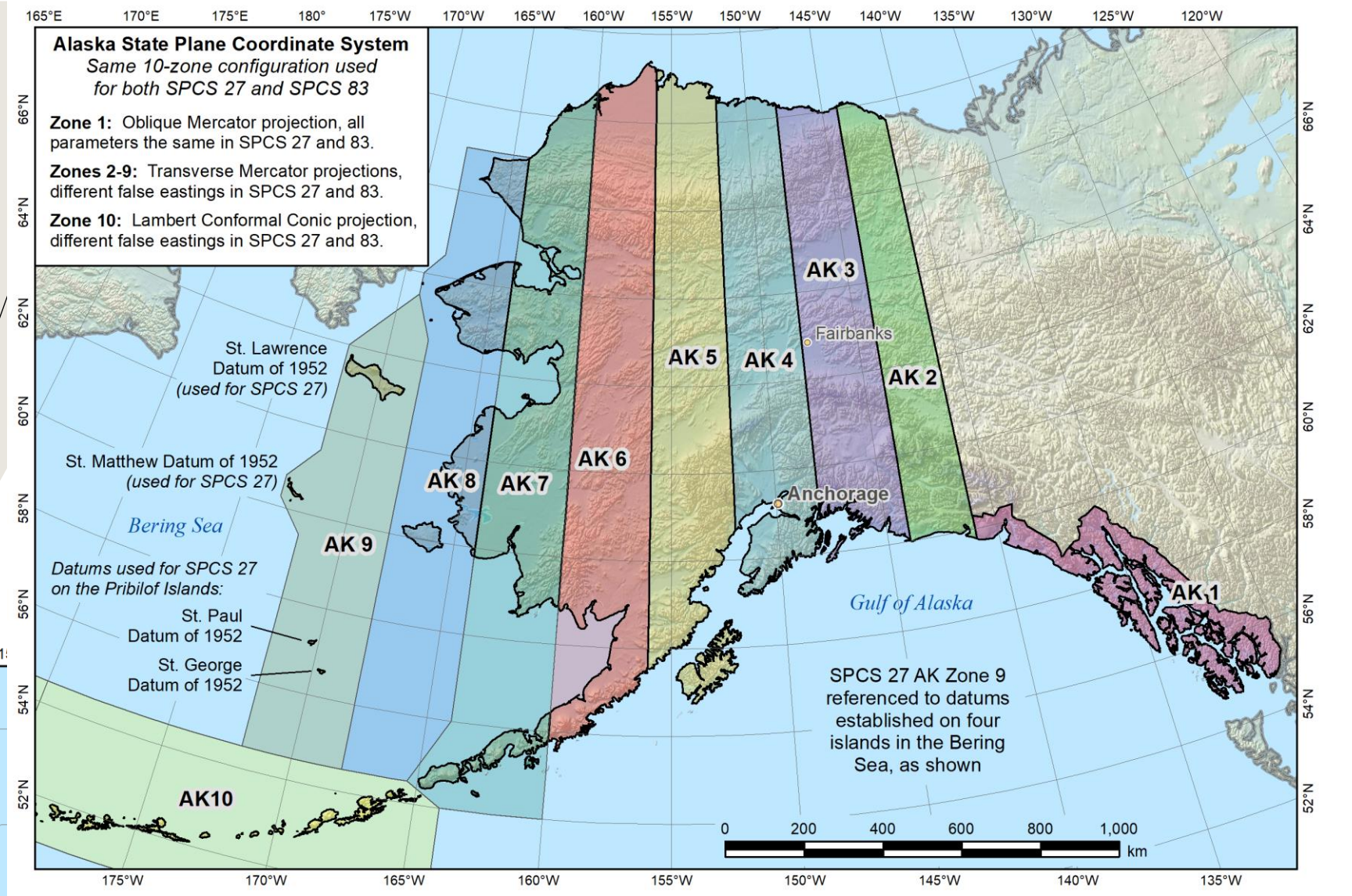
IKE
:R

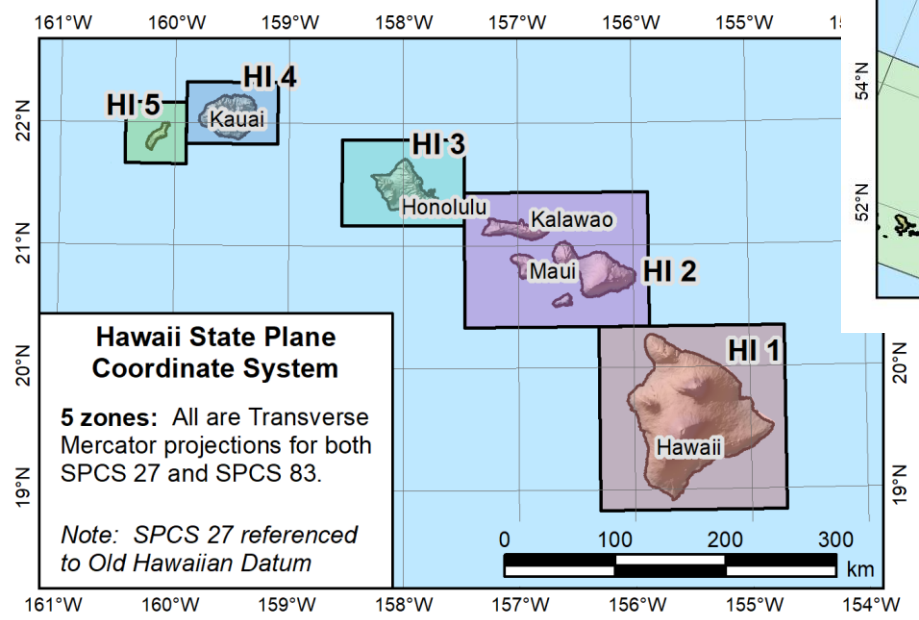
SPC Zones - 2004

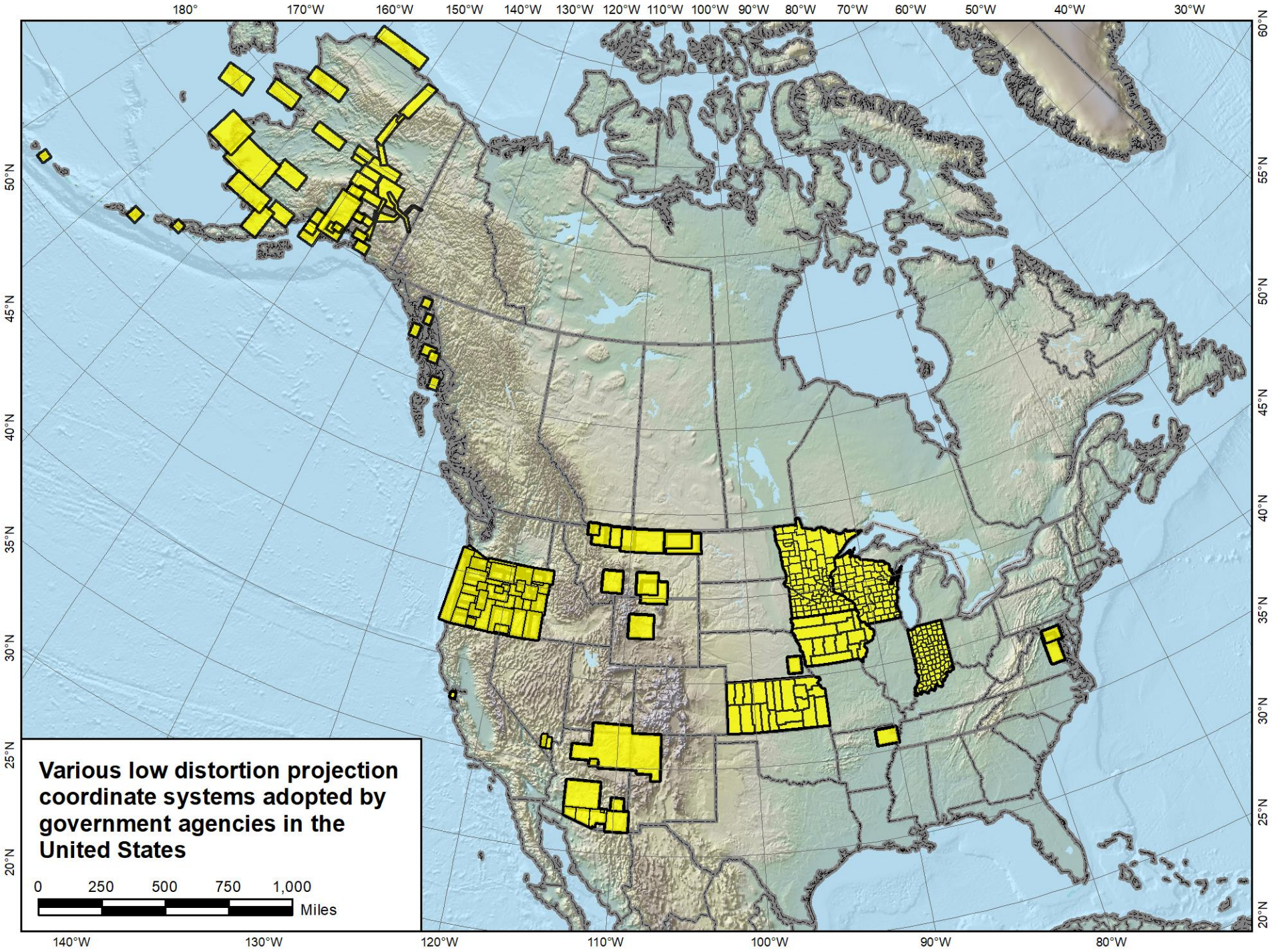

NAD 83 Zones
0 25 50 100 150
Miles
Washington North
Washington South
Oregon North
Oregon South
Idaho West
Idaho Central
Idaho East
Whatcom
Skagit
San Juan
Island
Snohomish
Clallam
Jefferson
Kitsap
Mason
King
Pierce
Grays Harbor
Thurston
Pacific
Lewis
Wahkiakum
Cowlitz
Clatsop
Columbia
Clark
Skamania
Klickitat
Yakima
Kittitas
Chelan
Okanogan
Douglas
Grant
Adams
Franklin
Benton
Ferry
Stevens
Pend Oreille
Boundary
Bonner
Lincoln
Spokane
Whitman
Garfield
Columbia
Walla Walla
Asotin
Kootenai
Shoshone
Benewah
Latah
Clearwater
Nez Perce
Lewis
Idaho
Wallowa
Umatilla
Morrow
Union
Gilliam
Sherman
Wasco
Hood River
Multnomah
Washington
Tillamook
Yamhill
Clackamas
Polk
Marion
Linn
Lincoln
Benton
Jefferson
Wheeler
Grant
Baker
Crook
Deschutes
Lane
Douglas
Coos
Curry
Josephine
Jackson
Klamath
Lake
Harney
Malheur
Owyhee
Adams
Valley
Washington
Payette
Gem
Boise
Canyon
Ada
Elmore
Lemhi
Custer
Butte
Camas
Blaine
Lincoln
Gooding
Minidoka
Jerome
Twin Falls
Cassia
Clark
Fremont
Madison
Teton
Jefferson
Bonneville
Bingham
Caribou
Bannock
Power
Oneida
Bear Lake
Franklin


ZONE 1 FACTORS
One part in 15400
One part in 49100
Scale exact
One part in 84300
One part in 28100
One part in 19700
One part in 17400
One part in 18000
One part in 23000
One part in 27300
Scale exact
One part in 28400
One part in 12700
One part in 7700
ZONE 2 FACTORS
One part in 4300
One part in 4300
One part in 10700
One part in 33400
Scale exact
One part in 29500
One part in 14900
One part in 13100
One part in 11800
One part in 11900
One part in 13200
One part in 17000
One part in 29700
Scale exact
One part in 23900
One part in 10100
WHATCOM
SAN JUAN
ISLAND
SKAGIT
SNOHOMISH
CLALLAM
JEFFERSON
KITSAP
KING
MASON
GRAYS HARBOR
PIERCE
THURSTON
PACIFIC
LEWIS
WAHKIAKUM
COWLITZ
SKAMANIA
CLARK
OKANOGAN
NORTH ZONE
(ZONE 1)
FERRY
STEVENS
PEND OREILLE
CHELAN
DOUGLAS
LINCOLN
SPOKANE
Scale exact
GRANT
ADAMS
WHITMAN
SOUTH ZONE
(ZONE 2)
YAKIMA
FRANKLIN
GARFIELD
COLUMBIA
BENTON
WALLA WALLA
ASOTIN
KLICKITAT
Central Meridian North Zone
120°30'
Central Meridian South Zone
120°30'
WASHINGTON
SCALE-STATUTE MILES
0 10 20 30 40 50

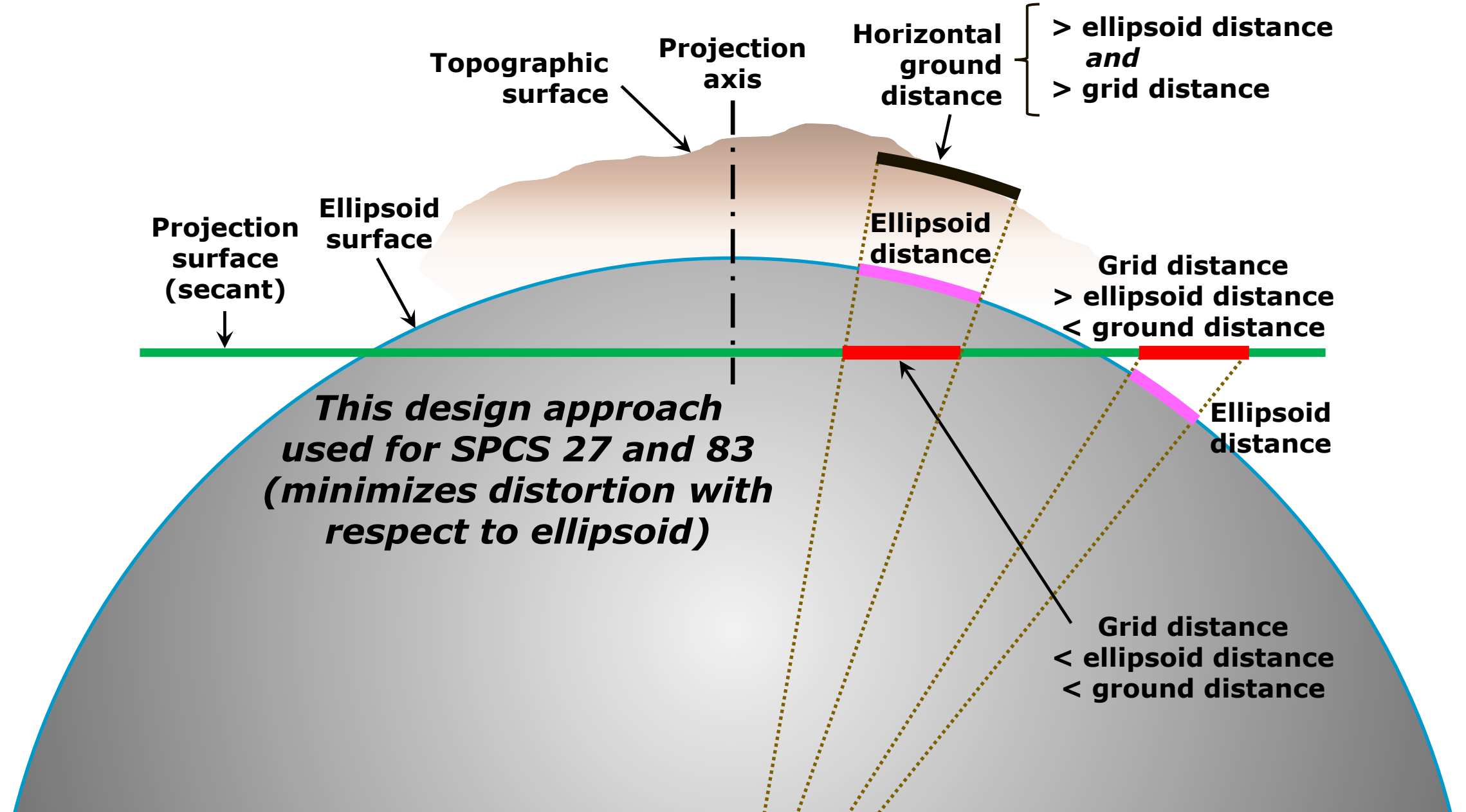
Alaska uses all 3 types of projections



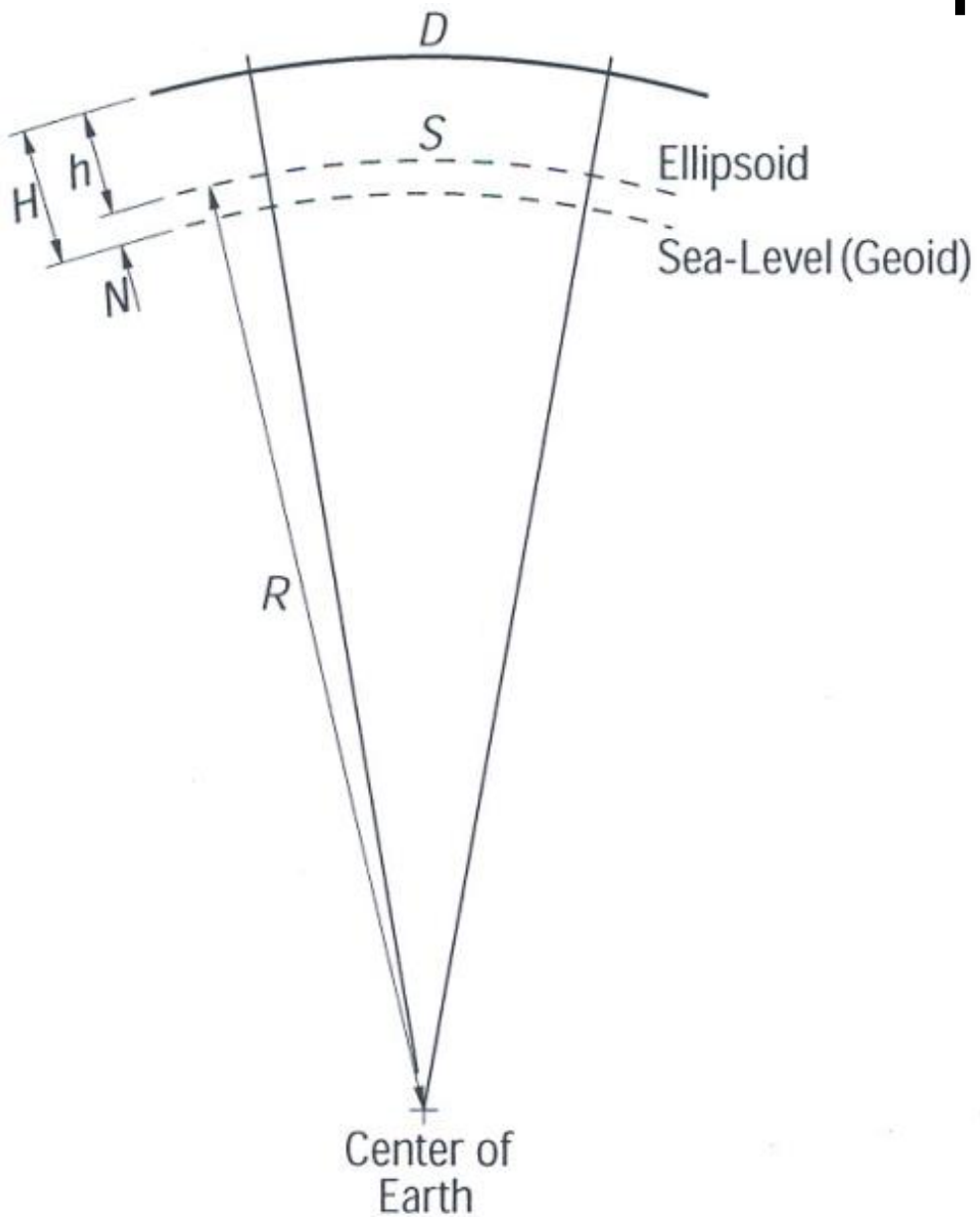



180°
170°W
160°W
150°W
140°W
130°W
120°W
110°W
100°W
90°W
80°W
70°W
60°W
50°W
40°W
30°W
60°N
55°N
50°N
45°N
40°N
35°N
30°N
25°N
20°N
Various low distortion projection coordinate systems adopted by government agencies in the United States
0
250
500
750
1,000
Miles
140°W
130°W
120°W
110°W
100°W
90°W
80°W

Linear distortion *with respect to topographic surface*



THE MATH



$$\frac{S}{D} = \frac{R}{R+h}$$

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

or:

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

Where:

- S = Distance on ellipsoid
- D = Distance on ground
- R = Radius of ellipsoid for zone
- N = Geoidal height
- H = Elevation
- h = Ellipsoid height

NGS POINTS

SEVERAL WAYS TO ACHIEVE STATE PLANE COORDINATES. NGS DATA SHEET, NEAR OR WITHIN THE PROJECT.

```
The NGS Data Sheet
See file dsdata.pdf for more information about the datasheet.
PROGRAM = datasheet95, VERSION = 8.12.5.16
Starting Datasheet Retrieval...
1       National Geodetic Survey,   Retrieval Date = SEPTEMBER 11, 2023
 DR8948 ***********************************************************************
 DR8948  HT_MOD      -  This is a Height Modernization Survey Station.
 DR8948  PACS        -  This is a Primary Airport Control Station.
 DR8948  DESIGNATION -  PSC E
 DR8948  PID         -  DR8948
 DR8948  STATE/COUNTY-  WA/FRANKLIN
 DR8948  COUNTRY     -  US
 DR8948  USGS QUAD   -  GLADE (2017)
 DR8948
 DR8948                        *CURRENT SURVEY CONTROL
 DR8948
 DR8948  ______________________________________________________________________
 DR8948* NAD 83(2011) POSITION- 46 16 07.89749(N) 119 07 05.03001(W)   ADJUSTED
 DR8948* NAD 83(2011) ELLIP HT-   100.093 (meters)        (04/18/23)   ADJUSTED
 DR8948* NAD 83(2011) EPOCH    -  2010.00
 DR8948* NAVD 88 ORTHO HEIGHT -   121.87  (meters)      399.8   (feet) GPS OBS
 DR8948  ______________________________________________________________________
 DR8948  GEOID HEIGHT    -        -21.750 (meters)                    GEOID18
 DR8948  NAD 83(2011) X  - -2,149,283.790 (meters)                    COMP
 DR8948  NAD 83(2011) Y  - -3,858,637.544 (meters)                    COMP
 DR8948  NAD 83(2011) Z  -  4,586,029.145 (meters)                    COMP
 DR8948  LAPLACE CORR    -         -0.57  (seconds)                   DEFLEC18
 DR8948
 DR8948  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 DR8948  Standards:
 DR8948         FGDC (95% conf, cm)     Standard deviation (cm)     CorrNE
 DR8948           Horiz  Ellip           SD_N   SD_E   SD_h      (unitless)
 DR8948  ------------------------------------------------------------------
 DR8948  NETWORK    0.74   2.29           0.34   0.25   1.17     -0.00907930
 DR8948  ------------------------------------------------------------------
 DR8948  Click here for local accuracies and other accuracy information.
 DR8948
 DR8948.This mark is at Tri-Cities Airport (PSC)
 DR8948
 DR8948.The horizontal coordinates were established by GPS observations
 DR8948.and adjusted by the GEOPRO CONSULTANTS LLC in April 2023.
 DR8948
 DR8948.NAD 83(2011) refers to NAD 83 coordinates where the reference frame has
 DR8948.been affixed to the stable North American tectonic plate. See
 DR8948.NA2011 for more information.
 DR8948
 DR8948.The horizontal coordinates are valid at the epoch date displayed above
 DR8948.which is a decimal equivalence of Year/Month/Day.
 DR8948
 DR8948.The orthometric height was determined by GPS observations and a
 DR8948.high-resolution geoid model.
 DR8948
 DR8948.Significant digits in the geoid height do not necessarily reflect accuracy.
 DR8948.GEOID18 height accuracy estimate available here.
 DR8948
 DR8948.Click photographs - Photos may exist for this station.
 DR8948
 DR8948.The X, Y, and Z were computed from the position and the ellipsoidal ht.
 DR8948
 DR8948.The Laplace correction was computed from DEFLEC18 derived deflections.
 DR8948
 DR8948.The ellipsoidal height was determined by GPS observations
 DR8948.and is referenced to NAD 83.
 DR8948
 DR8948. The following values were computed from the NAD 83(2011) position.
 DR8948
 DR8948;                  North         East      Units Scale Factor Converg.
 DR8948;SPC WA S     -   104,916.464   606,516.721   MT  0.99992975   +1 00 13.8
 DR8948;SPC WA S     -   344,213.43  1,989,880.28    sFT  0.99992975   +1 00 13.8
 DR8948;UTM  11      - 5,126,100.753   336,791.186   MT  0.99992745   -1 31 51.0
 DR8948
 DR8948!             -  Elev Factor  x  Scale Factor =   Combined Factor
 DR8948!SPC WA S     -   0.99998431  x   0.99992975  =   0.99991406
 DR8948!UTM  11      -   0.99998431  x   0.99992745  =   0.99991176
```


```
DR8948;                  North         East      Units Scale Factor Converg.
DR8948;SPC WA S     -   104,916.464   606,516.721   MT  0.99992975   +1 00 13.8
DR8948;SPC WA S     -   344,213.43  1,989,880.28    sFT  0.99992975   +1 00 13.8
DR8948;UTM  11      - 5,126,100.753   336,791.186   MT  0.99992745   -1 31 51.0
DR8948
DR8948!             -  Elev Factor  x  Scale Factor =   Combined Factor
DR8948!SPC WA S     -   0.99998431  x   0.99992975  =   0.99991406
DR8948!UTM  11      -   0.99998431  x   0.99992745  =   0.99991176
```

OPUS SOLUTION

FILE: 01602480.23o OP1694468322941

NGS OPUS SOLUTION REPORT
==========

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: https://www.ngs.noaa.gov/OPUS/about.jsp#accuracy

USER: ghouser@mackaysposito.com DATE: September 11, 2023
RINEX FILE: 0160248p.23o TIME: 21:39:58 UTC

UTM COORDINATES	STATE PLANE COORDINATES	
	UTM (Zone 11)	SPC (4602 WA S)
Northing (Y) [meters]	5124953.534	103761.600
Easting (X) [meters]	336592.999	606369.459
Convergence [degrees]	-1.53213611	1.00225556
Point Scale	0.99992824	0.99993076
Combined Factor	0.99991217	0.99991469

UTM COORDINATES	STATE PLANE COORDINATES	
	UTM (Zone 11)	SPC (4602 WA S)
Northing (Y) [meters]	5124953.534	103761.600
Easting (X) [meters]	336592.999	606369.459
Convergence [degrees]	-1.53213611	1.00225556
Point Scale	0.99992824	0.99993076
Combined Factor	0.99991217	0.99991469

US NATIONAL GRID DESIGNATOR: 11TLM3659324954(NAD 83)

NEAREST NGS PUBLISHED CONTROL POINT
SA2212 PASCO AIRPORT BEACON N461526.527 W1190651.443 475.3

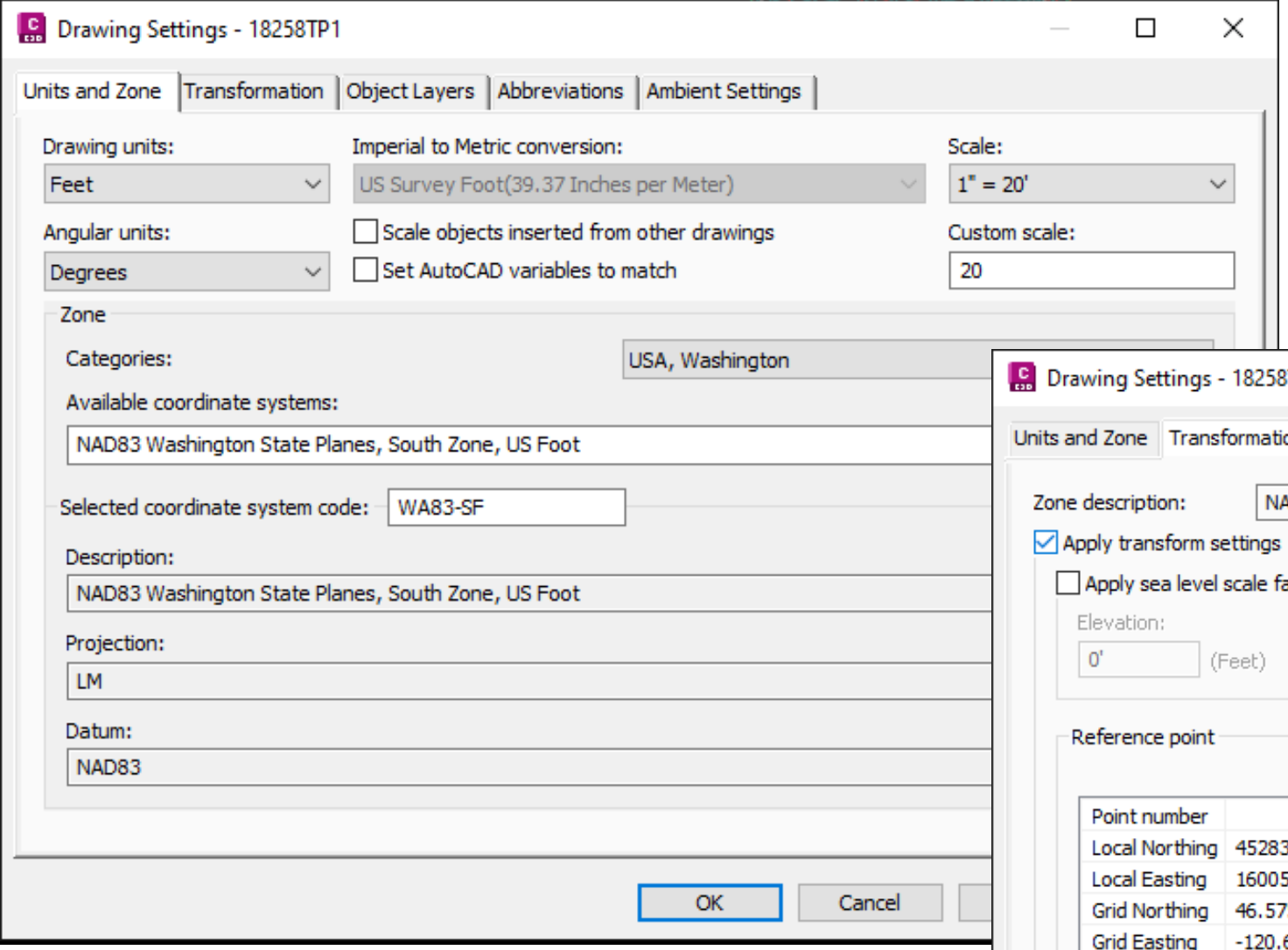
BASE STATION INFORMATION

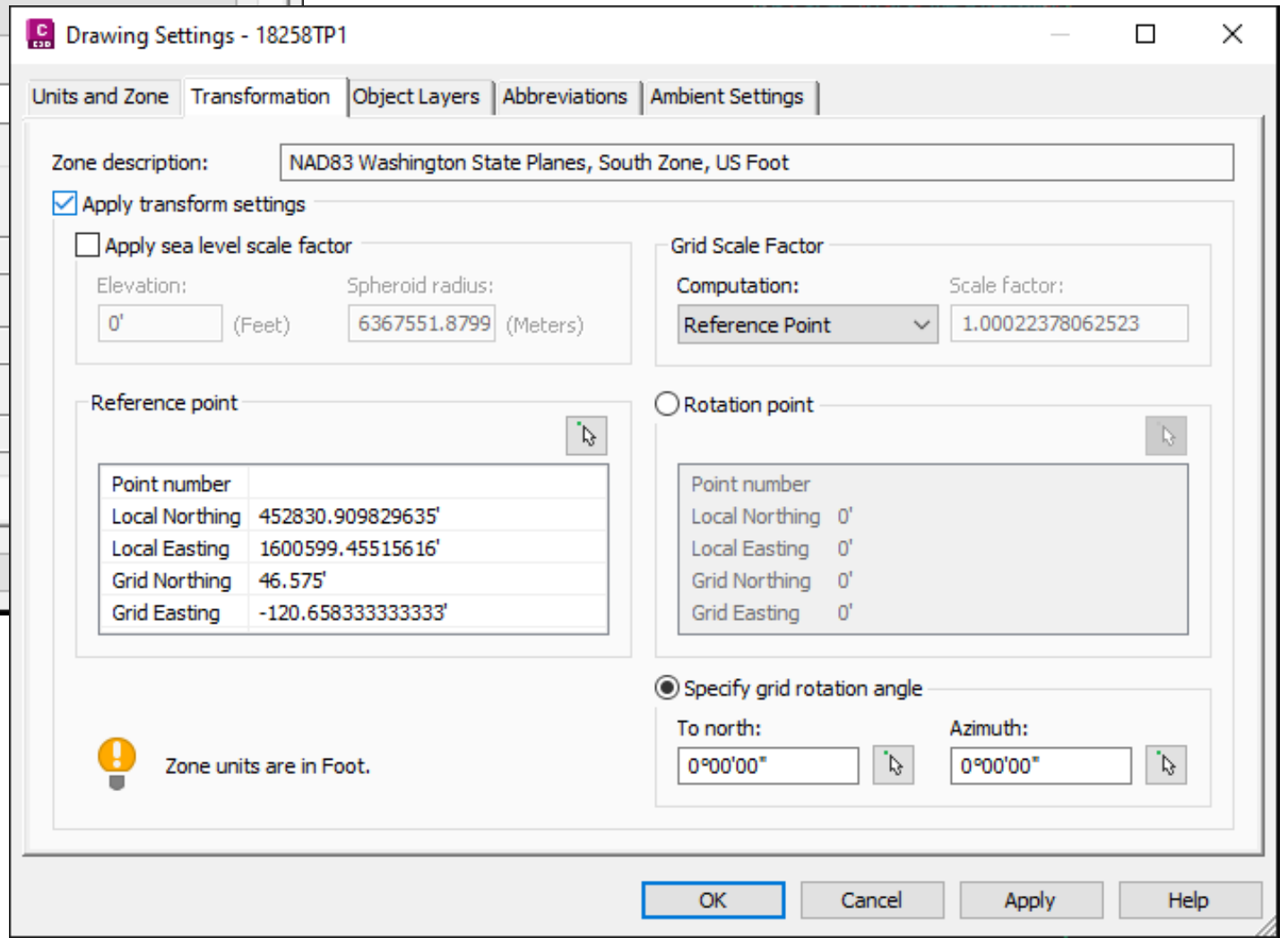
STATION NAME: pdtn a 5 (PENDLETON; Pendleton, Oregon USA)
MONUMENT: NO DOMES NUMBER

STATE PLANE COORDINATES - U.S. Survey Foot

	SPC (4602 WA S)
Northing (Y) [feet]	340424.516
Easting (X) [feet]	1989397.133
Convergence [degrees]	1.00225556
Point Scale	0.99993076
Combined Factor	0.99991469

CIVIL 3D
“DRAWING SETTINGS”





HOW DO WE WORK WITH THIS DATA?

Grid factors will differ from point to point because of change in elevation and latitude, as a general rule, a mean grid factor is selected for **each project.**

Large projects or **projects with elevations that very significantly**, **more than one grid factor** may be required.

The purpose of using project datum is so that a foot will equal a foot on the ground for location and construction surveying

- To use state plane coordinates you have to use GPS (Lat and Long) or a know state plane coordinate.
- Don’t mix apples and oranges.
  - One method is to add 100,000 meters to both northing and easting to easily see the difference. This works well but will disassociate geo-referenced photos and GIS data…

At the beginning of a project, a CF (combination factor) needs to be calculated, well documented, and used throughout the project.

When using a combination factor, it is always Project Specific.

It is mandatory to provide a clear, well-documented explanation of the combination factor and how it derived to establish the project datum coordinates. The following questions must be answered in documenting the creation of the combined factor:

• What published control points were used for the **minimum and maximum latitudes to determine the mean latitude**?

• What published control points were used to derive the **minimum and maximum orthometric** and **geoid heights** to determine the **mean elevation** and **mean geoid height**?

• Were ellipsoid heights used in lieu of orthometric elevations and geoid heights?

• If scale factors were used instead of latitudes, what are the scale factors that were used (scale factors are published on the monument data sheets)?

• Were the numbers and calculations checked independently?

It is also necessary to clearly state the combined factor (CF) and add a constant of sufficient size to make it impossible to mistakenly believe the Project Datum coordinates to be State Plane Coordinates.

One method of clearly defining a Project Specific from State Plane is the WSDOT method; add 100 000.000 meters to both the northing and easting coordinates The following are items to consider in determining the projection for the project:

If possible, try not to exceed 6 miles of total project length when developing the “Project Datum Combination Factor”. If the project exceeds 6 miles and/or there is a large difference in elevation within the project, separate combination factors within the project area may need to be used. Generally, this is not recommended due to the potential confusion and errors it can create. It is always best to only have one combination factor per project whenever possible.

DETERMINING THE COMBINED FACTOR

Determining a Combined Factor is a two-step process.

First you determine the project Scale Factor (SF) and the project Elevation Factor (EF).

The SF is determined based on the mean scale factors of the project control that has been established surrounding the project. See appendix A for a worksheet to help you calculate the SF.

The EF is determined based on the mean elevation of the project. See appendix A for a worksheet to help you calculate the EF.

Then you calculate a Combined Factor (CF). Multiplying the SF by the EF does this. See appendix A for a worksheet to help you calculate the CF.

APPLYING THE COMBINED FACTOR TO YOUR CONTROL POINTS

First, state plane grid coordinates values (in metric) on ALL of your initial control points are divided by your combined factor (CF). See appendix A for a worksheet to help you apply the CF.

Now add 100,000 meters to the northing and easting values of all of your control points to make their appearance very different from WSPC. We do not want State Plane coordinates and Project Datum coordinates to be confused. See appendix A for a worksheet to help you apply the 100,000 meters.

For the conversion of coordinates from metric to english units, 1 meter is equal to 39.37 inches (RCW 58.20.190). Therefore, since WSDOT typically works in english units; a conversion from metric to english is necessary. See appendix A for a worksheet to help you convert from metric to english units.

Apply these steps to any project control. The process of projecting state plane coordinates to a project datum needs to only be done once at the start of a survey project and ALL data gathered on the project will use the original CF.

After applying the CF to the control points, the surveyor will gather all of the data for the project with a scale factor of 1.0000000 in their data collectors, designers will design the project with no scale factors, construction will be accomplished with no scale factors.

When the project is completed and ready for archiving, the conversion from project datum coordinates to Washington State Plane Coordinates are calculated in the reverse order. So, English units are converted to metric, subtract 100,000 meters from each coordinate, then multiply the coordinate values by the combined factor. The result is the entire project is then based on the Washington State Plane Coordinates system and ready for archiving, GIS, transfer to others, etc.

Computer spreadsheets have been developed for ease of these calculations.

Check with the Regional Survey Coordinator or the State CAE Survey Coordinator for help with the computer conversion spreadsheets.

EXAMPLE

WORK SHEET FOR CONVERTING STATE PLANE COORDINATES TO PROJECT DATUM

Project Name	Zone (North or South)	Minimum Latitude	Maximum Latitude	Mean Latitude	Mean Elevation	Mean Geoid Height

(SF)	(EF)	(CF)	(N) and (E) Project Datum	Conversion to US Survey Foot
Obtained by using the mean latitude from the table k value	$E.F. = \frac{R}{R+N+H}$ R = assumed radius of earth of 6,372,000 (meters) H = mean elevation from sea level for project (meters) N = mean Geoid height for project (meters)	SF × EF = CF	$N = \frac{Y}{CF} + 100{,}000$ $E = \frac{X}{CF} + 100{,}000$	$N \times \frac{39.37}{12}$ $E \times \frac{39.37}{12}$

Point ID	(Y) State Plane Northing (meters)	(X) State Plane Easting (meters)	(SF) Mean Scale factor (8 significant digits)	(EF) Mean Elevation factor (8 significant digits)	(CF) Combined Factor (8 significant digits)	(N) Project Datum Northing (meters)	(E) Project Datum Easting (meters)	Project Datum Northing (feet)	Project Datum Easting (feet)

Calculated By:	Checked By:

MAKE IT OBVIOUS

In the base drawing use large text (50 feet tall)

Write a narrative.
example) Scaled about control point #### Scaled factor .99983765 give the inverse to get back to ground....

Don’t assume you will remember what you did...

RESOURCES

WSDOT – HIGHWAY SURVEY MANUAL

NGS (NATIONAL GEODETIC SURVEY)

QUESTIONS

THANK YOU

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