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Oregon Coordinate Reference System

Handbook and Map Set

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CONTAINS 39 OCRS ZONE MAPS

Abstract

This document contains the history, development, best practice methods, and technical creation of the Oregon Coordinate Reference System (OCRS) for the State of Oregon. The OCRS is based on a series of 'low distortion' map projections (zones) whose parameters have been defined such that lineal distortion is very minimal for certain geographic areas. Each zone has been optimized by design, to be useful for surveying, engineering, GIS, and cartographic mapping, wherein distances computed between points on the grid coordinate system will closely represent the distances physically measured between the same points on the ground within published zone tolerances. It is important to realize that rectangular grid coordinates for all of the OCRS map projections may now be calculated with formulas through computer programs that would have seemed too complicated in the past, but now are considered to be a routine exercise. These same computer programs may also allow users to complete transformations, moving the coordinates of a point or group of points from one coordinate system referenced to one frame/datum/realization, into coordinates referenced to a different frame/datum/realization for a given epoch. While having numerous state coordinate systems may seem cumbersome at first, actual user application through highly precise GNSS and terrestrial measurement devices provide for a level of measurement accuracy that is beneficial to all mapping professionals.

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Mark L. Armstrong, our NGS Northwest Region Geodetic Advisor who led the development of this manual working countless hours during evenings and weekends with a never waning enthusiasm and sense of urgency that kept the team on track to meet our deadline.

The Technical Development Team, many of whom volunteered their time and expense to travel to meetings to work on the development of the OCRS zones. Their energy, collaboration, and sometimes entertaining moments made the yearlong effort a very memorable one.

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Living document

This OCRS Handbook and User Guide is designed to be a 'living document' and will be updated with information and additional OCRS coordinate systems as new low distortion map projections are developed over time.

The OCRS was created with public money and volunteer effort for the benefit of surveying, engineering, GIS, and mapping professionals in the State of Oregon. Oregon is one of several states that have created new coordinate systems based on 'low distortion' map projections.

Contact information for revision to document

If there are topics that you would like for us to add, cover in more depth, clarify, if you discover an error in the content, or would like to suggest a particular workflow, please contact the ODOT Geometronics Unit:

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Randy Oberg, PLS	Appendix A: Virtual Coordinate computations
Michael Olsen, Ph.D.	GIS topic contributions

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Chapter 1 History and development of the OCRS

1.1 History and development of the Oregon Coordinate Reference System (OCRS)

The utilization of electronic survey data by surveyors and GIS professionals is bringing awareness of the need for higher accuracy when working with measurements on the earth and their representation in electronic databases and on paper. Modern GIS and surveying software now brings the opportunity to create low distortion map projections and coordinate systems that can relate closely to distances measured on the ground. The function of low distortion projections is to minimize the distortions of distances, areas and to a lesser extent azimuths and angles. These distortions are ever present because we live on a semi-round spheroid, and are presented with the impossibility of representing a curved surface on a plane without distortion. We can minimize that distortion by creating a mathematical model (map projection) that will allow us to work in a coordinate grid where calculated positions and distances are represented closely by the same positions and distances we measure on the ground. For mapping and GIS professionals, low distortion projections may dramatically reduce the need to 'rubber-sheet' data sets to make features fit. Now both survey and GIS data can co-exist without either dataset being degraded.

1.1.1 The beginning

For many years the Oregon Department of Transportation had been looking for a better way to deal with map distortion other than the currently used Local Datum Plane Coordinate system (LDPC). Ron Singh, ODOT Chief of Surveys, decided to investigate the use of 'low distortion' projections after attending an ACSM conference session put on by Michael Dennis in 2007. Subsequently, Ron made a presentation at the 2008 ODOT Surveyors Conference to introduce the concept, which was enthusiastically received. Then in April of 2009, the surveying and GIS community were queried to see if there was interest to develop the system as a collaborative effort. The decision followed to move forward with developing test projections which led to the creation of a Technical Development Team made up of interested stakeholders. The term Oregon Coordinate Reference System (OCRS) was suggested and accepted by the group as the name for a new series of coordinate systems for Oregon. This system will be based on optimized 'low distortion' map projections, which when fully developed, will provide movement away from using the (ODOT) Local Datum Plane Coordinate (LDPC) method.

1.2 The OCRS technical development team

The Technical Development Team was formed by soliciting participants from meetings and workshops held to explore the interest in the OCRS, through April of 2009. The Team was later expanded to include anyone who was interested in actively participating in the development of an OCRS zone in a particular geographic region. For the names of the individuals that participated on the Technical Development Team see the acknowledgement inside the front cover. The Technical Development Team worked closely with Michael Dennis (Geodetic Analysis) over multi-day sessions to construct projections through a refined iterative process leading to a final optimized solution for each new low distortion projection. Over time new projections were added until finally, in 2016, the entire State of Oregon was covered with 39 low distortion zones.

1.3 OCRS 'best practice' goals

During the spring and summer of 2009 several meetings were held and the following 'best practices' were developed by the Technical Development Team in an effort to focus on the critical elements that would lead to the creation of these new map projection zones. These 'best practices' continued to evolve during the process and are currently listed by number below.

1. The goal was initially established to use 1:100 000 ratio = ±10 ppm statewide [as big as zones as possible and still meet these criteria. No criteria difference between urban (local) and rural (regional) areas]. While actually creating the optimized zones a more realistic goal of ±20 ppm proved to more achievable.
2. Use common and easy to implement map projections: Lambert; Transverse Mercator; with the Oblique Mercator (Rectified Skew Orthomorphic) added for special cases.
   Vendor software needs to support these projections. ODOT sent a letter to vendors letting them know that new coordinate systems for Oregon were under development.
3. The OCRS system would not require a site calibration (localization) by a surveyor for horizontal positioning in each projection zone coordinate system.
4. Each zone would have a positive NE coordinate system.
5. The false Northing's and Easting's for each zone would be designed to not conflict with one another and be markedly different than Oregon State Plane coordinates.
6. Units: (meters) - Considered dual units with international feet, but decided to move ahead with metric units for map projection parameters. Individuals may project into desired units.
7. The OCRS zones will be referenced to the National Spatial Reference System (NSRS). This is currently defined geometrically as NAD 83 (GRS-80 ellipsoid) and it will follow the NGS path (new global frame realization definitions) in the future. The projection parameters will not be affected by a specific realization of NAD 83, since all of these realizations reference the GRS 80 ellipsoid; however, coordinates ARE affected by change in a realization.
8. Projections created should be referenced to NAD 83 'generically' or International Terrestrial Reference Frame (ITRF) ECEF global frame when adopted in the future as the NSRS. The specific realization of NAD 83 (such as HARN, CORS96, NSRS2007, 2011, etc.) or ITRF global frame (such as 2000, 2008 etc.) should be stated in the metadata associated with the survey project.
9. The method used to create each zone will not involve scaling the ellipsoid. Scaling modifies GRS-80, making the resulting projection not compatible with NAD 83.
10. If an existing low distortion projection already exists it will be reviewed by the Technical Development Team to see if it meets these 'best practices' and also provides for the greatest available ±10ppm coverage for the area under consideration.
11. The vertical datum will be the current NAVD 88, but will also follow the NGS lead adopting the future NAVD based on a pure gravimetric geoid (via the GRAV-D Project). The geoid model used is part of the metadata belonging to a full coordinate system; however the geoid is independent of the OCRS projection zone parameters.
12. The development of the OCRS system will include parameters for each zone that will be included in a future published Handbook and User Guide.
    The OCRS has its own web page separate from the Oregon Real-time GNSS Network (ORGN) web page.
13. No artificial political boundaries will define the limits of a particular zone. Each zone will be defined by latitude and longitude limits, but may include the option to modify the zone limits to match key areas or include political boundaries (will try not to break populated areas into two zones).
14. Interact with NGS in the future to develop:
    a. Standard methodology for low distortion project zone development.
    b. In the future suggest the NGS develop an automated software tool for creating low distortion projection coordinate systems.
    c. Document/register/catalog zones on the NGS website
    d. Discuss the possibility of OCRS and other state legislated zones being included on NGS datasheet output files, including OPUS output results.
15. Involve stakeholders in the review of the OCRS development by giving presentations etc. (include OCRS users: PLSO, OACES, OGUG, GIS groups, OSU, OIT, etc.)
16. Involve software vendors so they can include the OCRS zones when they update their software.

17. The size of each zone to be determined when created. Zones will cover as large an area as possible and still meet the distortion criteria, so as to minimize the total number of zones.
19. For Lambert Conformal Conic (LCC) zones, the Latitude of grid origin shall be the same as the standard parallel chosen to facilitate zone parameter entry into software.
20. Each zone must have unique coordinate system origins that differ from one another by a significant amount so that the north and east coordinates will not to be confused with one another.

1.4 Why the Oregon State Plane Coordinate System is deficient for certain modern day uses

The State Plane Coordinate system was first studied in 1933 by the U.S. Dept. of Commerce, Coast and Geodetic Survey and eventually adopted for Oregon law (legal status) in 1945. Oregon is based on the Lambert Conformal Conic Projection with two zones (North-3601 and South-3602). By keeping the width of the zones under 158 miles (with the scale exact along the standard parallels), the maximum distortion (with respect to the ellipsoid) was kept to approximately one part in 9,500 (105 ppm) (5). This distortion error occurs when these zones are constructed for mapping purposes and it is because of this that the state plane system presents the following issues for the surveying and GIS community:

- Does not represent ground distances except near sea level elevations (along the coast and major river systems) and near the standard parallels.
- Does not minimize distortion over large areas and varying elevations
- Does not reduce convergence angles
- Does not support modern datum and geoid grid reference frames

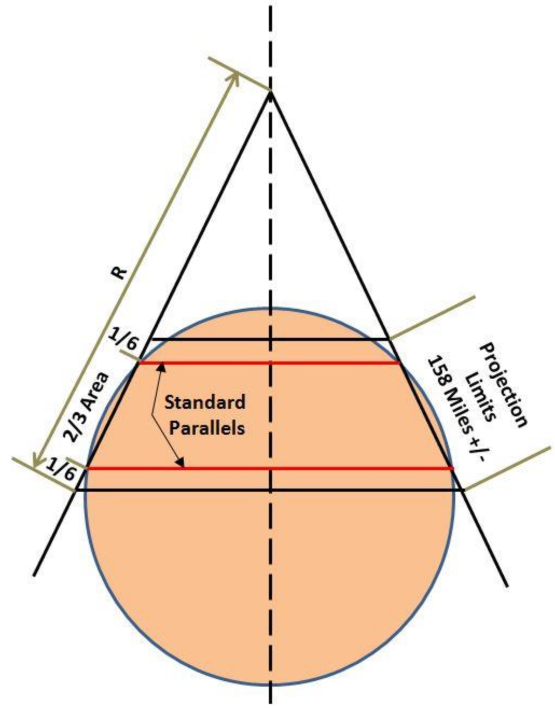
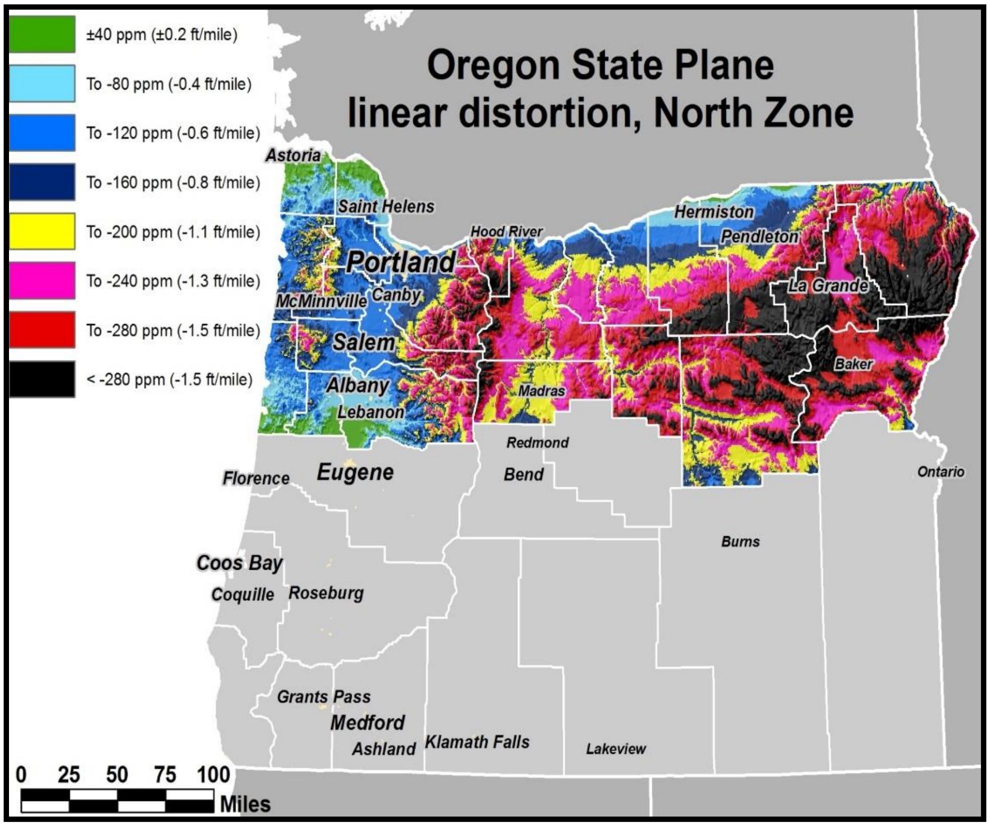
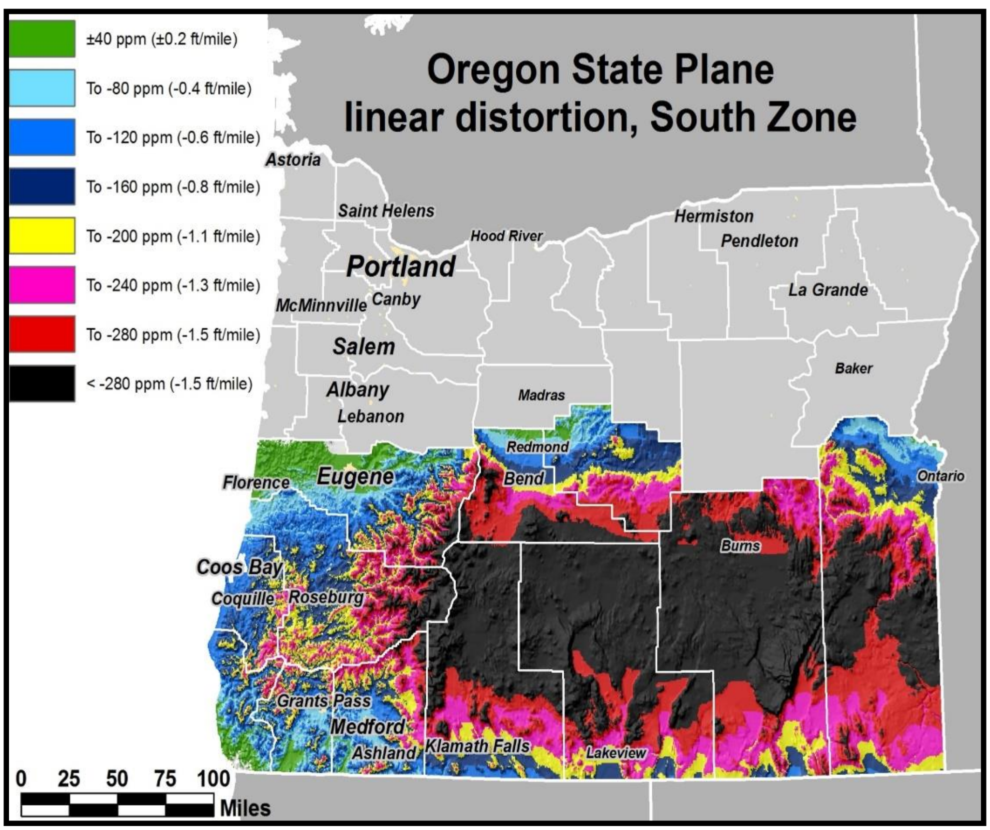


Figure 1.4: Oregon State Plane Two parallel Lambert Conformal Conic Projection [mla]

Currently State Plane coordinates are available for all Oregon's horizontal control points that reside in the National Geodetic Survey (NGS) Integrated Database (datasheets) and are also generated for all points submitted to the NGS Online Positioning User Service (OPUS). The Oregon State Plane Coordinate System still maintains some limited advantages for general surveying and mapping (GIS) at a statewide level, such as depicting physical, cultural, and human geography over large areas of the state. It also works fair for mapping long linear facility lines such as highways, electrical transmission, and pipelines, which crisscross the state. The state plane coordinate system provides for a common reference (map projection) for conversions (transformations) between other coordinate systems including the zones of the OCRS. The Figures below (Figures 1.4.0.1 & 1.4.0.2) depict total linear distortion (at the topographic surface of the Earth) for both the North and South Oregon State Plane zones. Note that the minimum level of distortion (±40 ppm) covers a relatively small area and large urban areas of the State have significantly higher distortion.

Figures 1.4.0.1 & 1.4.0.2





1.4.1 Oregon State Plane Coordinate System definitions

OREGON NORTH ZONE (Designation 3601)
Oregon State Plane North - NAD 1983
Lambert Conformal Conic Two Standard Parallel Projection (Secant)
Central Meridian: -120° 30’ (W)
Latitude of Origin: 43° 40’
Standard Parallel (South): 44° 20’
Standard Parallel (North): 46°
False Northing: 0.000 m
False Easting: 2 500 000.000 m
Max scale error: ~1:9 500 (±105 ppm) *Note:* This maximum scale error is distortion with respect to the ellipsoid, not the topographic surface, and occurs along the central parallel. The actual distortion at the topographic surface is typically greater, and it changes at a rate of 4.8 ppm per 100-ft change in height.

North zone county coverage:
BAKER, BENTON, CLACKAMAS, CLATSOP, COLUMBIA, GILLIAM, GRANT, HOOD RIVER, JEFFERSON, LINCOLN, LINN, MARION, MORROW, MULTNOMAH, POLK, SHERMAN, TILLAMOOK, UMATILLA, UNION, WALLOWA, WASCO, WASHINGTON, WHEELER, YAMHILL.

OREGON SOUTH ZONE (Designation 3602)
Oregon State Plane South - NAD 1983
Lambert Conformal Conic Two Standard Parallel Projection (Secant)
Central Meridian: -120° 30’ (W)
Latitude of Origin: 41° 40’
Standard Parallel (South): 42° 20’
Standard Parallel (North): 44°
False Northing: 0.000 m
False Easting: 1 500 000.000 m
Max scale error: ~1:9 500 (±105 ppm) *Note:* This maximum scale error is distortion with respect to the ellipsoid, not the topographic surface, and occurs along the central parallel. The actual distortion at the topographic surface is typically greater, and it changes at a rate of 4.8 ppm per 100-ft change in height.

South zone county coverage:
COOS, CROOK, CURRY, DESCHUTES, DOUGLAS, HARNEY, JACKSON, JOSEPHINE, KLAMATH, LAKE, LANE, MALHEUR.

1.5 Local Datum Plane Coordinate (LDPC) method vs. Low Distortion Projection (LDP) method

1.5.1 Local Datum Plane Coordinate systems

In the late 1930’s, ODOT adopted a system known as ‘Local Datum Plane Coordinates’ (LDPC) that scaled State Plane Coordinates to a plane close to the average ground elevation for a specific highway project. A ‘Combined Scale Factor’ was calculated from a ‘Projection Scale Factor’ (based on the local latitude at the center of a project) expressed as a ratio, multiplied by a ‘Sea Level Factor’ (originally based on the representative project elevation above sea level where (NGVD 29) sea level and ellipsoid height were coincidental). Traditionally these factors were determined from tables $_{(14)}$. Later with the advent of NAVD 88 and computer geodesy programs the ‘height above the ellipsoid’ was used in place of the elevation above sea level. Essentially, this project 'Combined Scale Factor' was divided into the Oregon State Plane northing and easting coordinate values of the project control points, thereby scaling the values of the control points to yield LDPC coordinates. This method allows for the LDPC grid measurements to closely match actual ground distances measured and the project basis of bearing still remains the same as the Oregon State Plane grid. While this system generally works well, there are some inherent problems with this system:

- LDPC systems represent only small low distortion areas (i.e., in general does not minimize distortion over as large an area as can be achieved using a customized map projection).
- LDPC coordinates look similar to state plane coordinates, but are NOT. Some have called them Modified State Plane which can be confusing to users.
- As a scaled up version of a true map projection, it cannot be geo-referenced or converted on-the-fly to any other may projection without first performing a reversion calculation back to State Plane Coordinates.
- Each project is on a unique stand-alone LDPC system initially created for a specific project only. Generally, measurement errors may increase to an undesirable level if the project size exceeds 6 to 10 miles in length.
- Not directly compatible with recognized datum or the National Spatial Reference System (NSRS).

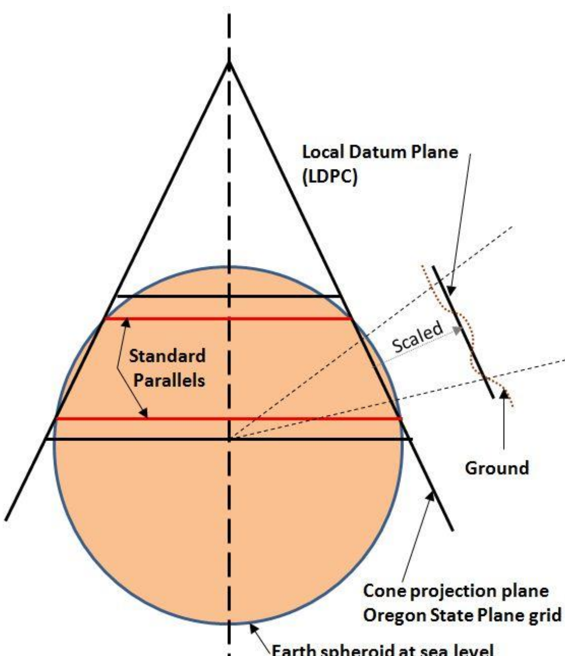


Figure 1.5: Local Datum Plane Coordinate System scaled from Oregon State Plane [mla]

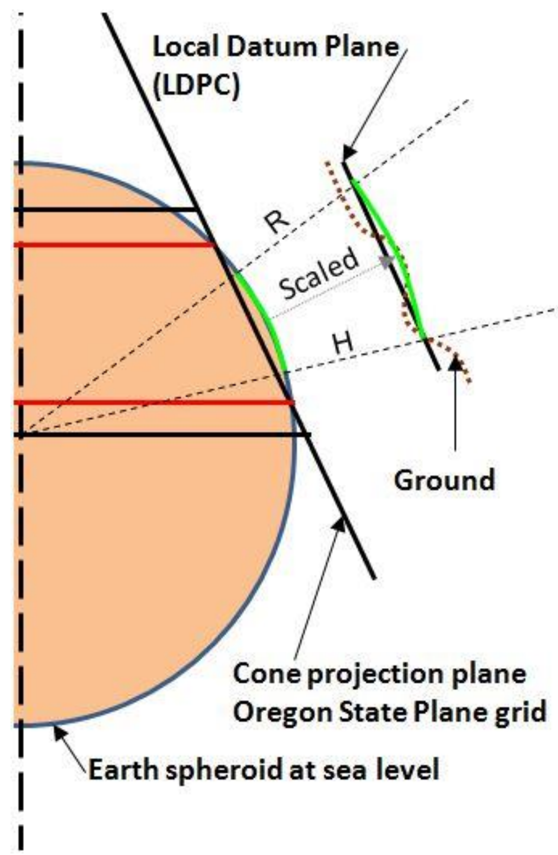


Figure 1.5.1: Local Datum Plane Coordinate System enlarged to show spheroid to LDPC plane [mla]

1.5.2 Low distortion map projection systems

Low distortion map projections (like those within the OCRS coordinate system) are based on true conformal projections designed to cover specific portions of urban and rural areas of the state. For conformal projections (e.g., Transverse Mercator, Lambert Conformal Conic, Stereographic, Oblique Mercator (RSO), regular Mercator, etc.), linear distortion is the same in every direction from a point. That is, the scale at any particular point is the same in any direction and figures on the surface of the Earth tend to retain their original form on the map. In addition, angles on the Earth are the same as on the map. The term 'low distortion' refers to minimizing the lineal horizontal distortion from two effects: 1) representing a curved surface on a plane and 2) departure of the elevated topography from the projection surface due to variation in the regional height of the area covered. See Section 2.2 for more information on map projection distortion.

The advantages of a low distortion map projection are:

- Grid coordinate zone distances very closely match the same distance measured on the ground.
- Allow for larger areas (than LDPC) to be covered with overall less distortion.
- A low distortion map projection may be used by many people, and agencies in a given community and therefore coordinates for survey and mapping work become common.
- Reduced convergence angle (if the central meridian is centered within the zone).
- Quantitative distortion levels can be determined from topographic heights.
- Clean zone parameter definitions compatible with common surveying, engineering, and GIS software.
- Easy to transform between other coordinate systems.
- Maintains a relationship to the National Spatial Reference System (NSRS) by allowing direct use of published NSRS control coordinates (i.e., latitude, longitude, and ellipsoid height).
- Can cover entire cities and counties making them useful for regional mapping and GIS.
- They are available and coded into popular survey and mapping software for anyone to use.

1.5.3 Projection grid coordinates

Because calculations relating latitude and longitude to positions of points on a given map can become quite involved, rectangular grids have been developed for the use of surveyors, engineers, and GIS mapping professionals. In this way, each point may be designated merely by its distance from two perpendicular axes on the 'plane' map. The '*Y*' axis normally coincides with a chosen central meridian, '*y*' increasing north. The '*X*' axis is perpendicular to the '*Y*' axis at a latitude of origin on the central meridian, with '*x*' increasing east. Commonly, '*x*' and '*y*' coordinates are called "eastings" and "northings," respectively, and to avoid negative coordinates may have "false eastings" and "false northings" added to relate to the projection grid origin.

Chapter 2 Coordinate System Geodesy

2.1 Types of conformal map projections used for the OCRS

2.1.1 Lambert Conformal Conic projection

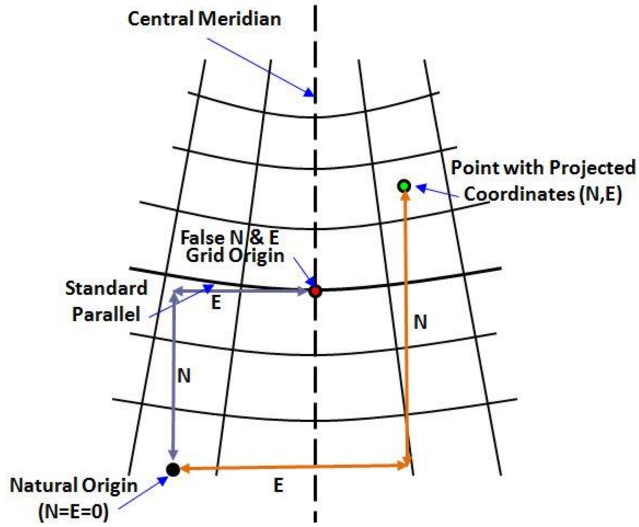


Figure 2.1.1: Diagram for a Lambert Conical Conformal Projection with one standard parallel [mla]

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 <u>tangent</u> (or above the globe in the case of a low distortion projection) or with two standard parallels <u>secant</u> (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 (such as the OCRS 'low distortion zones') is designed as a single parallel Lambert projection. The cone of the projection is typically <u>scaled up</u> from the ellipsoid to 'best fit' an area and range of topographic height on the Earth's surface (see Figure 2.2.3).

2.1.2 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.

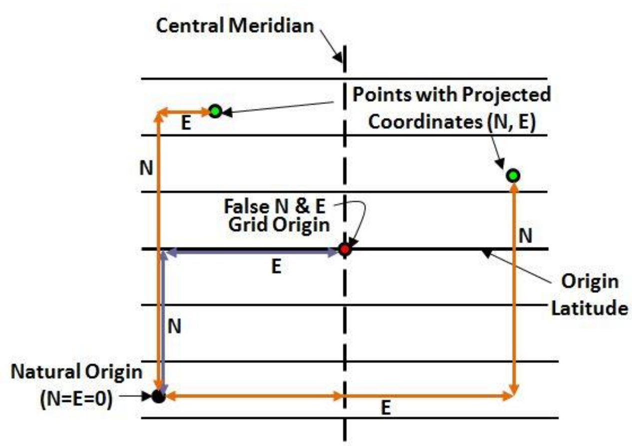


Figure 2.1.2: Diagram for a Transverse Mercator Projection [mla]

2.1.3 Oblique Mercator (RSO) projection

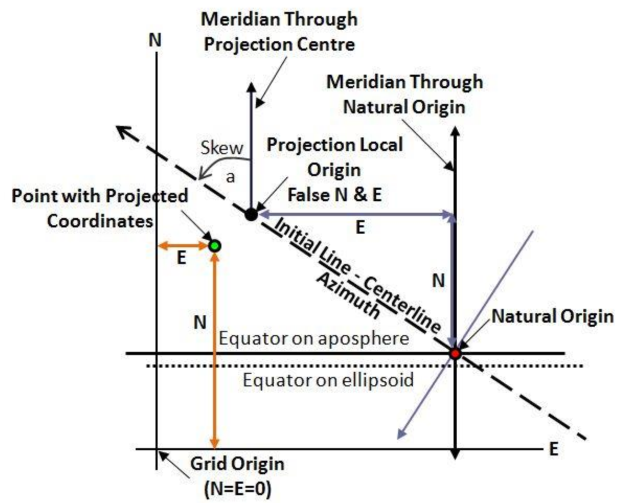


Figure 2.1.3: Diagram for a Oblique Mercator (RSO) Projection [mla]

Various forms of the Oblique Mercator (OM) projection have been developed, and the ellipsoidal form used for the OCRS (as well as some State Plane systems) was published by Martin Hotine in 1947(8). Hotine called it the Rectified Skew Orthomorphic (RSO) projection, and it still goes by this name in some publications and software. It is an oblique form (rotated cylinder) of the Mercator conformal map projection. The 'Initial Line' is the centerline (projection skew axis) and is specified with one point and an azimuth (or skew angle) which may be positive or negative (right or left). This projection is typically used for long linear features that run at 'angle' to what would otherwise be normal north-south or east-west conventions. Here the projection centerline is along a geodesic, at an oblique angle (rotated cylinder), and the process is to specify the projection local origin latitude and longitude together with the centerline (Initial Line) azimuth to be the line that runs parallel and centered near the alignment of the key object or landform such as a coast line, river, or island chain feature of the Earth. Along this Initial Line the scale is true (one) much like the normal Mercator projection and perpendicular from this line the scale varies from one. This projection works well when the areas of study are relatively close to this line. The specified 'grid origin' is located where north and east axes are zero. In contrast, the 'natural origin' of the projected coordinates is located where the 'Initial Line' of the projection crosses the 'equator of the aposphere' (a surface of constant total curvature), which is near (but not coincident with) the ellipsoid equator (see Figure 2.1.3). The ellipsoid is conform-ally mapped onto the aposphere, and then to a cylinder, which ensures that the projection is strictly conformal. However, unlike the TM projection, where the scale is constant along the central meridian, the scale (with respect to the ellipsoid) is not quite constant along the Initial Line (rather it is constant with respect to the aposphere). But the variation in scale along the Initial Line is small for areas the size of the state of Oregon. For example, the scale on the Initial Line of the OCRS Oregon Coast zone nominally equals 1, but it actually equals exactly 1 only at the local origin, and increases to 1.000 000 25 (+0.25 ppm) at the south end of the zone (42° 00' N) and decreases to 0.999 999 95 (-0.05 ppm) at the north end of the zone (46° 20' N). Note that this projection can also be defined by specifying the Initial Line using two points. However, the conventional use for the OCRS definitions was a single point and a skew azimuth.

2.2 Managing map projection distortion

2.2.1 Distortion is unavoidable

Johann Carl Friedrich Gauss's (1777–1855) Theorema Egregium (Remarkable Theorem) mathematically proved that a curved surface (such as the Earth's ellipsoid model) cannot be represented on a plane without distortion. Since any method of representing a sphere's surface on a plane is a map projection, all map projections produce distortion and every distinct map projection distorts in a distinct way. For low distortion projections, deciding on the type of map projection in order to minimize the distortion for an area of the earth may not be an obvious or clear-cut task.

2.2.2 Two general types of map projection distortion by Michael L. Dennis, PE, RLS

1. Linear distortion - The difference in distance between a pair of grid (map) coordinates when compared to the true (ground) distance is shown by δ in tables 2.2.2.1 and 2.2.2.2. This may be expressed as a ratio of distortion length to ground length: E.g., feet of distortion per mile; parts per million (= mm per km). *Note:* 1 foot / mile = 189 ppm = 189 mm / km.

Linear distortion can be positive or negative:
Negative distortion means the grid (map) length is shorter than the "true" horizontal (ground) length.
Positive distortion means the grid (map) length is longer than the "true" horizontal (ground) length.

(continued on next page)

Linear distortion due to Earth curvature

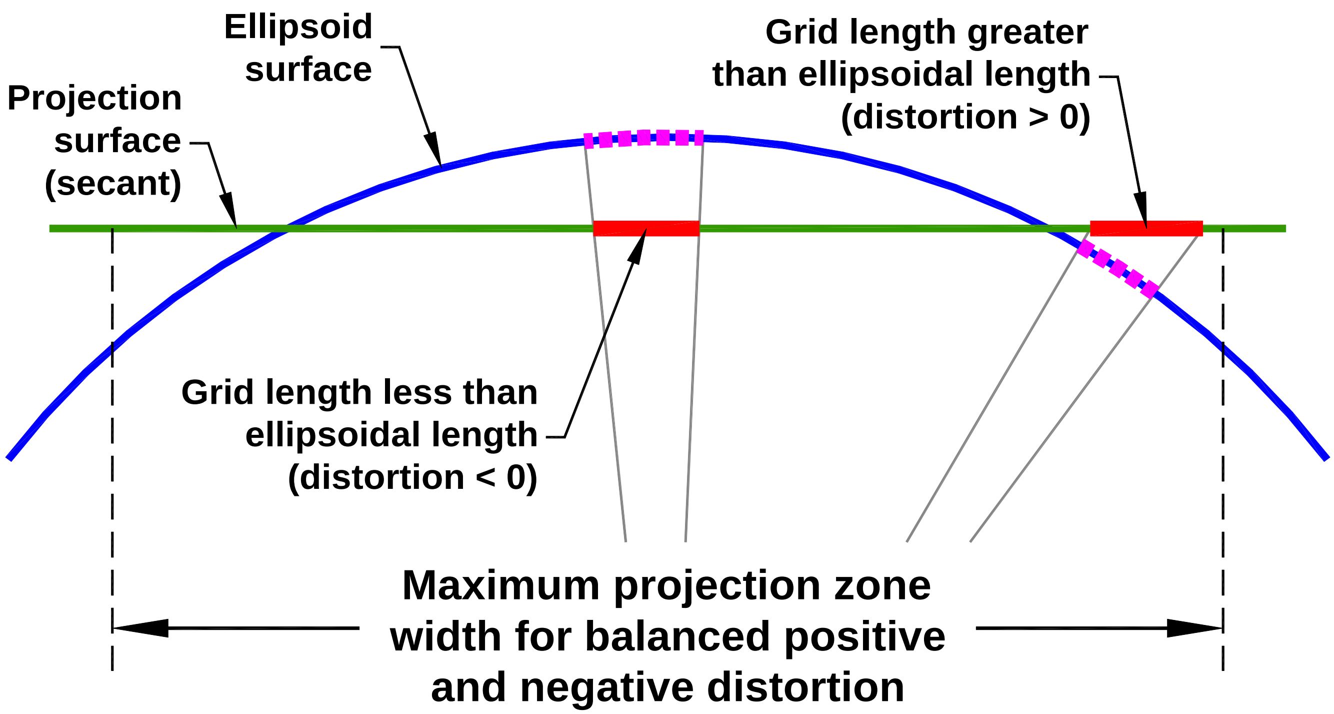


Figure 2.2.2.1: Diagram of lineal distortion due to earth curvature [mld]

Table 2.2.2.1

Maximum zone width for secant projections (km and miles)	Maximum linear horizontal distortion, δ		
	Parts per million (mm/km)	Feet per mile	Ratio (absolute value)
25 km (16 miles)	±1 ppm	±0.005 ft/mile	1 : 1,000,000
57 km (35 miles)	±5 ppm	±0.026 ft/mile	1 : 200,000
81 km (50 miles)	±10 ppm	±0.05 ft/mile	1 : 100,000
114 km (71 miles)	±20 ppm	±0.1 ft/mile	1 : 50,000
180 km (112 miles)	±50 ppm	±0.3 ft/mile	1 : 20,000
255 km (158 miles) e.g., SPCS*	±100 ppm	±0.5 ft/mile	1 : 10,000
510 km (317 miles) e.g., UTM†	±400 ppm	±2.1 ft/mile	1 : 2,500

*State Plane Coordinate System; zone width shown is valid between ~0° and 45° latitude
†Universal Transverse Mercator; zone width shown is valid between ~30° and 60° latitude

Linear distortion due to ground height above ellipsoid

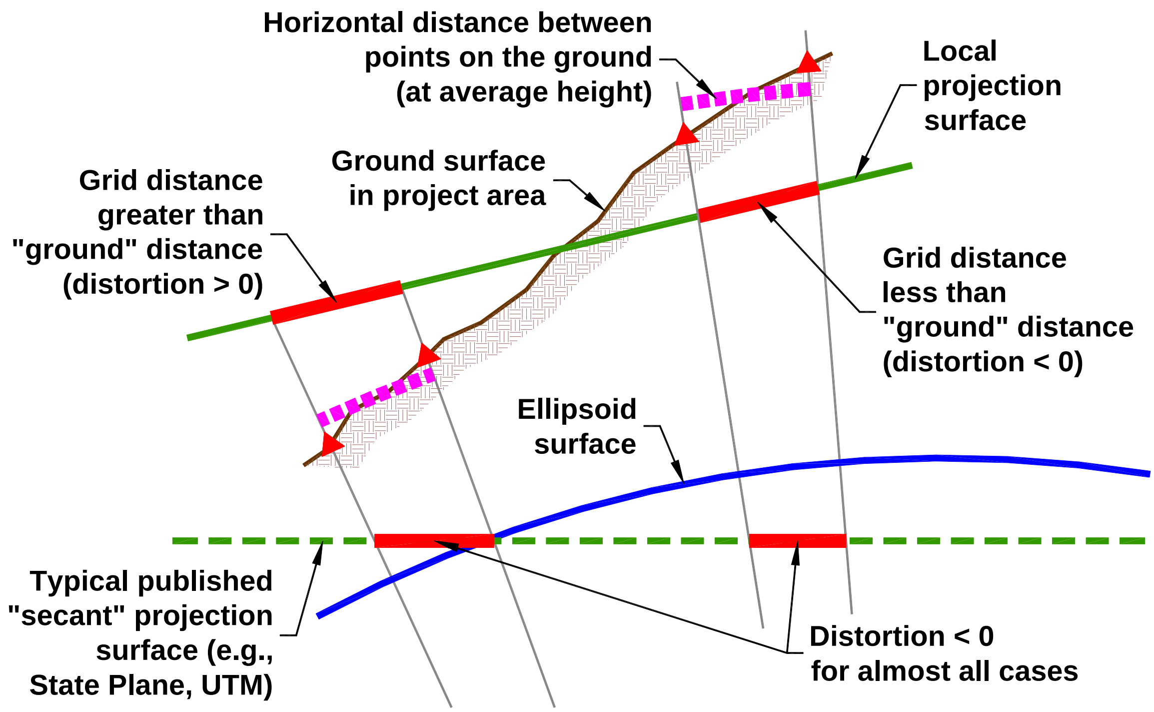


Figure 2.2.2.2: Diagram of lineal distortion due to ground height [mld]

Table 2.2.2.2

Height below (–) and above (+) projection surface	Maximum linear horizontal distortion, *δ*		
	Parts per million (mm/km)	**Feet per mile**	**Ratio (absolute value)**
±30 m (±100 ft)	±4.8 ppm	±0.025 ft/mile	~1 : 209,000
±120 m (±400 ft)	±19 ppm	±0.10 ft/mile	~1 : 52,000
±300 m (±1000 ft)	±48 ppm	±0.25 ft/mile	~1 : 21,000
+600 m (+2000 ft)*	–96 ppm	–0.50 ft/mile	~1 : 10,500
+1000 m (+3300 ft)**	–158 ppm	–0.83 ft/mile	~1 : 6,300
+4400 m (+14,400 ft)†	–688 ppm	–3.6 ft/mile	~1 : 1,500

*Approximate mean topographic height of North America (US, Canada, and Central America)
** Approximate mean topographic height of western coterminous US (west of 100°W longitude)
† Approximate maximum topographic height in coterminous US

Rule of Thumb:

A 30 m (100-ft) change in height causes a 4.8 ppm change in distortion

Creating an LDP and minimizing distortion by the methods described in this document only makes sense for conformal projections. For conformal projections (e.g., Transverse Mercator, Lambert Conformal Conic, Stereographic, Oblique Mercator (RSO), regular Mercator, etc.), linear distortion is the same in every direction from a point. For all non-conformal projections (such as equal area projections), linear distortion generally varies with direction, so there is no single unique linear distortion (or "scale") at any point.

2. Angular distortion - For conformal projections (e.g., Transverse Mercator, Lambert Conformal Conic, Stereographic, Oblique Mercator, etc.), this equals the *convergence* (*mapping*) *angle* (γ). The convergence angle is the difference between grid (map) north and true (geodetic) north. Convergence angle is zero on the projection central meridian, positive east of the central meridian, and negative west of the central meridian as shown in table 2.2.2.3 below.

The magnitude of the convergence angle increases with distance from the central meridian, and its rate of change increases with increasing latitude.

Table 2.2.2.3 shows 'convergence angles' at a distance of one mile (1.6 km) east (positive) and west (negative) of projection central meridian (for both Transverse Mercator and Lambert Conformal Conic projections).

Table 2.2.2.3

Latitude	Convergence angle 1 mile from CM	Latitude	Convergence angle 1 mile from CM
0°	0° 00' 00"	50°	±0° 01' 02"
10°	±0° 00' 09"	60°	±0° 01' 30"
20°	±0° 00' 19"	70°	±0° 02' 23"
30°	±0° 00' 30"	80°	±0° 04' 54"
40°	±0° 00' 44"	89°	±0° 49' 32"

Usually convergence is not as much of a concern as linear distortion, and it can only be minimized by staying close to the projection central meridian (or limiting surveying and mapping activities to equatorial regions of the Earth). Note that the convergence angle is zero for the regular Mercator projection, but this projection is not suitable for large-scale mapping in non-equatorial regions. In many areas, distortion due to variation in ground height is greater than that due to curvature. **The total linear distortion of grid (map) coordinates is a combination of distortion due to Earth curvature and distortion due to ground height above the ellipsoid.**

2.2.3 Six steps for designing a Low Distortion Projection (LDP) by Michael L. Dennis, PE, RLS

Step 1. Define the project area and choose a representative ellipsoid height, h_o (not elevation)

The average height of an area may not be appropriate (e.g., for projects near a mountain). Usually there is no need to estimate height to an accuracy of better than about ±6 m (±20 ft). Note that as the size of the area increases, the effect of Earth curvature on distortion increases, and it must be considered in addition to the effect of topographic height, E.g., for areas wider than about 56 km (35 miles) perpendicular to the projection axis (i.e., ~28 km or ~18 miles either side of projection axis), distortion due to curvature alone exceeds parts per million (ppm). The "projection axis" is defined in step #2.

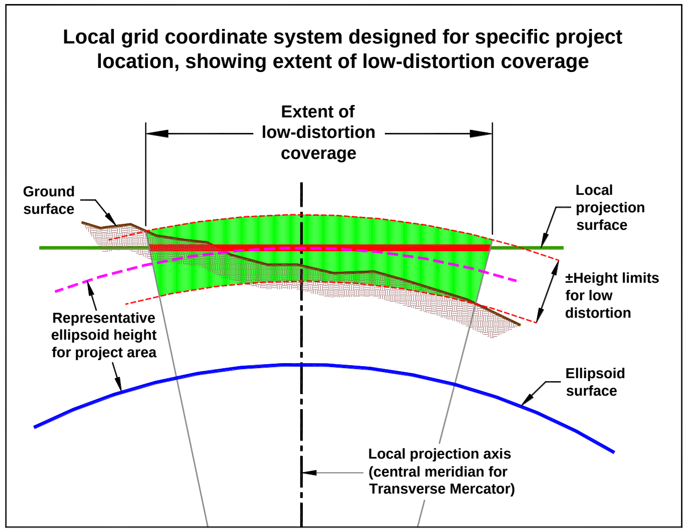


Figure 2.2.3: Diagram shows the effect of scaling the projection to a representative height above the ellipsoid [md]

Step 2. Choose the projection type and place the projection axis near the centroid of the project area. Select a well-known and widely used conformal projection, such as the Transverse Mercator (TM), one-parallel Lambert Conformal Conic (LCC), or Oblique Mercator (OM/RSO).

When minimizing distortion, it will not always be obvious which projection type to use, but for small areas (< ~55 km or ~35 miles wide perpendicular to the projection axis), usually both the TM and LCC will provide satisfactory results.

When in doubt, the TM is a good choice for most applications, since it is probably the map projection supported across the broadest range of software packages. However, commercial software vendors are adding more user-definable projections, and so over time the problem of projection availability should diminish.

In nearly all cases, a two-parallel LCC should ***not*** be used for an LDP with the NAD 83 datum definition (but note that some software may not support a one-parallel LCC). A two-parallel LCC should not be used because the reason there are two parallels is to make the projection secant to the ellipsoid (i.e., the central parallel scale is less than 1). This is at odds with the usual objective of scaling the projection so that the developable surface is at the topographic surface, which is typically above the ellipsoid, particularly in areas where reduction in distortion is desired.

The OM (RSO) projection can be very useful for minimizing distortion over large areas, especially areas that are more than about 56 km (35 miles) long in an oblique direction. It can also be useful in areas where the topographic slope varies gradually and more-or-less uniformly in a direction other than north-south or east-west. The disadvantage of this projection is that it is more difficult to evaluate, since another parameter must be optimized (the projection skew axis). In addition, this projection is more complex, and may not be available in as many software packages as the TM and LCC.

The Oblique Stereographic (OS) projection can also provide satisfactory results for small areas, but it has the disadvantage of not conforming to Earth curvature in any direction. In situations where this projection works well, there really is no reason to use it, because the TM projection will give equally good (if not better) results. In very rare cases this projection might give the best results, such as bowl-shaped areas.

Bear in mind that universal commercial software support is not an essential requirement for selecting a projection. In the rare cases where third parties must use a coordinate system based on a projection not supported in their software, it is always possible for them to get on the coordinate system implicitly (i.e., by using a best-fit procedure based on coordinate values).

The 'projection axis' is the line along which projection scale is constant (with respect to the ellipsoid). It is the central meridian for the TM projection, the standard (central) parallel for the one-parallel LCC projection, the (implicitly defined) central parallel for the two-parallel LCC projection, and the skew axis for the OM projection (actually the scale is not quite constant along the skew axis, as discussed in Section 2.1.3). The OS projection does not have a projection axis (projection scale is only constant at one point).

Place the central meridian of the projection near the east-west "middle" of the project area in order to minimize convergence angles (i.e., the difference between geodetic and grid north).

In some cases, it may be advantageous to offset the projection axis from project centroid (e.g., if topographic height increases or decreases gradually and more-or-less uniformly perpendicular to the projection axis).

Step 3. Scale the central meridian of the projection to representative ground height, h_o

Compute map projection axis scale factor "at ground": $k_0 = 1 + \frac{h_0}{R_G}$

For the TM projection, k_0 is the central meridian scale factor.

For the one-parallel LCC projection, k_0 is the standard (central) parallel scale factor.

For the OM projection, k_0 is the projection skew axis scale at the local origin.

For the OS projection, k_0 is the scale at the projection origin.

R_G is the geometric mean radius of curvature, $R_G = \frac{a\sqrt{1-e^2}}{1-e^2\sin^2\varphi}$

and φ = geodetic latitude of point, and for the GRS-80 ellipsoid:

a = semi-major axis = 6,378,137 m (exact) = 20,925,646.325 international ft.
= 20,925,604.474 US survey ft.

e^2 = first eccentricity squared = $2f - f^2$

f = geometric flattening = 1 / 298.257222101

Alternatively, can initially approximate R_G since k_0 will likely be refined in Step #4, by using R_G values in Table 2.2.3.1.

Geometric mean radius of curvature at various latitudes for the GRS-80 ellipsoid (rounded to the nearest 1000 meters and feet).

Table 2.2.3.1

Latitude	***R***R_G (meters)	R_G (feet)	Latitude	R_G (meters)	R_G (feet)
0°	6,357,000	20,855,000	50°	6,382,000	20,938,000
10°	6,358,000	20,860,000	60°	6,389,000	20,961,000
20°	6,362,000	20,872,000	70°	6,395,000	20,980,000
30°	6,367,000	20,890,000	80°	6,398,000	20,992,000
40°	6,374,000	20,913,000	90°	6,400,000	20,996,000

Step 4. Check the distortion at points distributed throughout project area

The best approach here is to compute distortion over entire area and generate distortion contours (this ensures optimal low-distortion coverage). This may require repeated evaluation using different k_0 values. It may also warrant trying different projection axis locations and different projection types.

Distortion computed at a point (at ellipsoid height *h*) as $\delta = k\left(\dfrac{R_G}{R_G + h}\right) - 1$

Where *k* = projection grid point scale factor (i.e. "distortion" with respect to the ellipsoid at a specific point). Note that computation of *k* is rather involved, and is often done by commercially available software. However, if your software does not compute *k*, or if you want to check the accuracy of *k* computed by your software, equations for doing so for the TM and LCC projections are provided later in this document. Because δ is a small number for low distortion projections, it is helpful to multiply δ by 1,000,000 to express distortion in parts per million (ppm).

Step 5. Keep the definition simple and clean

Define k_0 to <u>no more</u> than six decimal places, e.g., 1.000206 (exact). *Note:* A change of one unit in the sixth decimal place equals distortion caused by a 6.4-meter (21-foot) change in height. Defining central meridian and latitude of grid origin to nearest whole arc-minute is usually adequate (e.g., central meridian = 111°48'00" W).

Define grid origin using whole values with as few digits as possible (e.g., false easting = 50,000 for a system with maximum easting coordinate value < 100,000). Note that the grid origin definition has no effect whatsoever on the map projection distortion.

It is strongly recommended that the coordinate values everywhere in the design area be distinct from other coordinate system values for that area (such as State Plane or UTM) in order to reduce the risk of confusing the LDP with other systems. *Note:* In some applications, there may be an advantage to using other criteria for defining the grid origin. For example, it may be desirable for all coordinates in the design area to have the same number of digits (such as six digits, i.e., between 100,000 and 999,999). In other cases, it may be useful to make the coordinates distinct from State Plane by using larger rather than smaller coordinates, especially if the LDP covers a very large area.

Step 6. Explicitly define linear unit and geometric reference system (i.e., geodetic datum)

E.g., Linear unit = metric; (or) Linear unit = international foot; Geometric reference system = NAD 83 (2007).

The international foot is shorter than the US survey foot by 2 ppm. Because coordinate systems typically use large values, it is critical that the type of foot used be identified (the values differ by 1 foot per 500,000 feet). *Note:* The reference system realization (i.e., "datum tag") is not an essential component of the coordinate system definition. However, the datum tag is an essential component for defining the spatial data used within the coordinate system. This is shown in a metadata example later in this document. For NAD 83, the NGS convention is to give the datum tag in parentheses after the datum name, usually as the year in which the datum was "realized" as part of a network adjustment. Common datum tags are listed below:

- "2007" for the NSRS2007 (National Spatial Reference System of 2007) realization.
- "199*x*" for the various HARN (or HPGN) realizations, where *x* is the last digit of the year of the adjustment (usually done for a particular state). For example, a HARN/HPGN adjustment for Oregon was done in 1991, so its datum tag is "1991" (there was also a FBN/CBN survey performed in 1998 with a corresponding "1998" datum tag). The HARN and HPGN abbreviations are equivalent, and they stand for "High Accuracy Reference Network" and "High Precision Geodetic Network", respectively.
- "CORS" for the realization based on the CORS network, and corresponding to epoch 2002.00 or more recently epoch 2010.00 for the coterminous US and Hawaii (and 2003.00 in Alaska).
- "1986" for the original NAD 83 realization. Because of the coordinate changes that occurred as part of the HARN/HPGN and the national adjustments of passive marks, this original "1986" realization is not appropriate for data with horizontal accuracies of better than about 1 meter.
- When the frame/datum realization changes so do the coordinates even though the map projection parameters are the same.

2.3 What constitutes a complete coordinate system?

A complete 3D coordinate system is made up of a combination of horizontal (geometric) reference frame and vertical datum, geoid model, and a map projection definition. Each of these has certain aspects to consider which are briefly discussed below.

2.3.1 Ellipsoid models

The overall shape of the earth is modeled by an ellipsoid of revolution (sometimes referred to as a spheroid). In order to imagine an ellipsoid model for the earth, align the shorter axis with the polar axis of the earth. Centrifugal force caused by the earth's rotation creates a 'squash' effect where the radius of the earth is greater at the equator. The shape of the ellipsoid representing the earth is defined by mathematical models. Defining the latitude and longitude of particular points on the earth defines the origin and orientation of the ellipsoid. The North American Datum of 1983 (NAD 83) uses an ellipsoid model called the Geodetic Reference System of 1980 (GRS-80), which is very similar to the original World Geodetic System of 1984 (WGS-84) ellipsoid. The origin and orientation of the first WGS84 ellipsoid and the GRS80 ellipsoid were identical. WGS-84 was created about the same time by the US Department of Defense. The WGS-84 frame definition has been minutely refined over time by changing the origin and orientation, although the WGS-84 ellipsoid parameters as shown in Table 2.3.1 remain fixed.

Table 2.3.1

Ellipsoid Model	Semi-Major Axis (exact by definition)	Semi-Minor Axis (computed)	Reciprocal Flattening (exact by definition)
WGS-84	6 378 137	6 356 752.314245	298.257223563
GRS-80	6 378 137	6 356 752.314140	298.257222101

WGS84 system is a global frame and its realizations take into account the fact that the earth is in dynamic motion due to the shifting of tectonic plates around the world. However, NAD 83 is fixed to the North American plate, and the different realizations of NAD 83 reflect the coordinate changes relative to the CORS but the GRS80 ellipsoid parameters remains fixed. Consequently, NAD 83 in the continental United States moves south and west approximately 1-2 centimeters per year in relation to WGS84. The frame realization of WGS84 is normally updated when the ITRF is updated as shown in Table 2.3.2.

Table 2.3.2 Comparison of reference frames

Year	Frame realization (Epoch):	For practical purposes equivalent to:
1987	WGS 1984(ORIG)	NAD83(1986)
1994	WGS84(G730)	ITRF91/92
1997	WGS84(G873)	ITRF94/96
2002	WGS84(G1150)	ITRF00
2012	WGS84(G1674)	ITRF08(2005)
2013	WGS84(G1762) -improvement based on absolute antenna models for a better match to ITRF08(2005)	ITFR08(2005)
2016	WGS84(TBD) [expected in 2017]	ITRF14(2010.00)

2.3.2 Transformations between datums

Sometimes called the Helmert Transformation after Friedrich Robert Helmert (1843-1917), this seven parameter transformation is the typical (common) geodetic method for moving the coordinates of a point or group of points from one coordinate system referenced to one frame/datum into coordinates referenced to a different frame/datum for a given instant in time. For the purposes of this discussion, a (local) coordinate system contains the necessary elements to convert WGS-84 geodetic positions observed with GNSS to a particular coordinate/datum realization. Each projection zone coordinate system may be based on the choice of a particular defined datum, adjustment, and epoch such as NAD 83(2007), NAD 83(CORS96)2002 or other NAD 83 realizations (see software vendor choices). As previously described, the defined datum relies on an ellipsoid model such as GRS-80 (used for NAD 83 and the ITRS). These seven parameters account for the following:

Translation X- Translation along the X-axis
Translation Y- Translation along the Y-axis
Translation Z- Translation along the Z-axis
Scale Factor

Rotation X- Rotation about the X-axis
Rotation Y- Rotation about the Y-axis
Rotation Z- Rotation about the Z-axis

Transformation equations and parameters provide a means of transforming coordinates referenced to one datum (A) into coordinates referenced to a different datum (B) as shown in figure 2.3.2. In general, two three-dimensional coordinate systems in space are related to each other by the following equation for Cartesian coordinates:

$$[\ X\ Y\ Z\ ]\ \text{Datum 'A'} = [\ \Delta X\ \Delta Y\ \Delta Z\ ] + (\ 1 + \Delta S\ )\ [\ 1\ -Rz\ Ry\ Rz\ 1\ -Rx\ -Ry\ Rx\ 1\ ]\ [\ X\ Y\ Z\ ]\ \text{Datum 'B'}$$

Where;

ΔX: Shift along x-axis	Rx: Rotation about x-axis
ΔY: Shift along y-axis	Ry: Rotation about y-axis
ΔZ: Shift along z-axis	Rz: Rotation about z-axis
S: Scale factor	

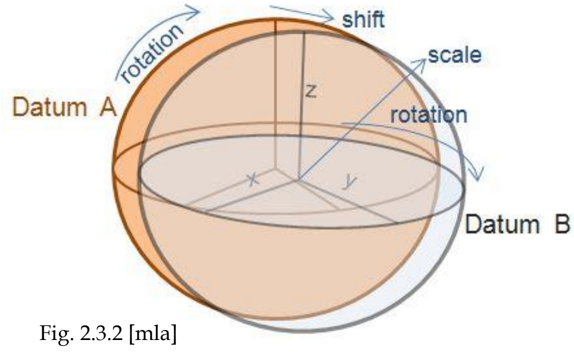


Fig. 2.3.2 [mla]

The first step is to know precisely the datum to which your input data are referenced. If your processing will require that this data be transformed to another coordinate system which is not based on the same datum, then you must consider the required datum transform. The following described example will consider the common case in which input data is referenced to WGS-84(G1150) and requires being converted to a coordinate system based on NAD 83(CORS96 or 2007). It is important to note here that for these particular datums, it will also be required to know the date to which the GNSS data are processed, also known as the epoch of the data.

To consider a seven-parameter datum transform from WGS-84 to NAD 83, obtaining the required parameters for the coordinate frame/datum transform is based on several assertions:
We can say that WGS-84(G1150) is equivalent to ITRF 00, the International Terrestrial Reference Frame (ITRF) of 2000, to an accuracy of approximately one centimeter [9]. Also, a 14-parameter (add time variables) transform has been defined between ITRF 00 and NAD 83(CORS96) and, for a given instant in time, the 14-parameter transformation may be represented as a 7-parameter coordinate frame transform. While no direct transforms have been defined from WGS-84(G1150) to NAD 83(CORS96), the transform from NAD 83(CORS96) is defined from ITRF 00 which creates the path through which the desired transform can be completed. This 14-parameter transformation is specified in "*Transforming Position and Velocities between the International Terrestrial Reference Frame of 2000 and North American Datum of 1983*", by Tomas Soler and Richard Snay[10]. Further discussion of 14-parameter transformations is beyond the scope of this document. For further discussion of this topic and tools for doing additional analysis, visit the NGS Horizontal Time-Dependent Positioning (HTDP) webpage. Tools are available at this site for transforming data between the frames/datums described here and several others. Velocities for positions can also be predicted here, as well as transformation of points on different frames/datums to different epochs.

Most GNSS processing software packages contain a large list of the world's datum or reference frames from which to select. Through time NGS has adopted several realizations of NAD 83 such as NAD 83(2007) and NAD 83(2011)2010.00 for the distribution of coordinates at ~70,000 passive geodetic control monuments that have been observed with GNSS. Both of these realizations were created by adjusting the GNSS data collected during various campaign-style geodetic surveys performed between the mid-1980's through 2010. Typically, for all stations on the stable North American plate, an epoch date will be shown.

2.3.3 Vertical reference datum

The North American Vertical Datum of 1988 (NAVD 88) was established in 1991 from a simultaneous, least squares, minimum constraint adjustment of Canadian, Mexican and United States leveling observations. It held fixed, the height of the primary tidal bench mark, named 'Father Point' in Rimouski, Quebec, Canada. Additional tidal bench mark elevations were not held due to the demonstrated variations in sea surface topography, i.e., the fact that mean sea level (as recorded by tide gages) is not a gravitational equipotential surface. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights and is the only current vertical datum that works seamlessly with GNSS observation measurements and NAD 83. GRAV-D is an ongoing project by the National Geodetic Survey to re-define the vertical datum of the US by 2022. The gravity-based vertical datum resulting from this project will be accurate at the 2 cm level or better where possible for much of the country. The project is currently underway and actively collecting gravity data across the United States and its holdings.

2.3.4 Geoid models

A hybrid geoid model i.e., currently GEOID12B (Conus) used in geodetic adjustments is comprised of a gravimetric scientific model constrained to a 'best fit' of the current benchmark monument network (currently GPSBM2012 in NAVD 88). This hybrid model is updated by the NGS approximately every three to six years as more gravity and bench mark data becomes available, and as new computational methods are developed. Measuring with GNSS equipment yields an ellipsoid height that must be converted to an orthometric height (elevation) with the application of hybrid geoid model (height/separation) such as GEOID12B. This geoid height is 'N', the ellipsoid height 'h', and the orthometric height 'H' for this conversion as shown in the equation H=h-(N) in the vertical datum NAVD88.

It is important to use the hybrid geoid model that was created using ellipsoid heights from the geometric adjustment that created them. Thus, GEOID12B makes use of the ellipsoid heights generated from the National Adjustment of 2011 (NA2011) and is meant to go with NAD 83(2011)2010.00 realization. If you are trying to match work completed in an earlier project using NAD 83(CORS96) 2002 then you should use GEOID09. The NGS 10-year plan outlines a transition to a pure gravimetric geoid model (from the GRAV-D project) and new geopotential datum by 2022.
See: http://www.ngs.noaa.gov/GRAV-D/

2.3.5 OCRS map projection parameter units

As part of the 'best practices' approach to the creation of these zones, all of the OCRS map projection parameters are provided in metric units. Careful attention is needed when entering these map projection coordinate systems into the coordinate system management section of your GNSS surveying, engineering, or GIS vendor software. When converting the provided metric data (false northing, false easting, etc.) to international feet, be sure to carry out the values to full sufficient significant figures (at least six decimal places) and check that the units are accepted by the software in the units you provide. Each software vendor (in the future) may elect to provide updated versions of their coordinate system management software with the OCRS zones already pre-installed. Until that time it is recommended that you enter the projection parameters in metric units. Assigning units for a particular project is a separate issue, and you may elect to choose units of International Feet (Oregon statute).

2.3.6 Adding a map projection to a coordinate system

Finally, a map projection must be chosen so the results can be displayed on a projected plane in a defined grid (northing's and easting's). In order to derive common northing and easting coordinates, a false northing and false easting are paired with the projection origin (central meridian and origin latitude). The map projection parameters (OCRS) provide a scale factor (based in part on the topographic height above ellipsoid) to better represent the local ground elevation within the useful limits (best range) of the zone topography (see figure 2.2.3). This scaling helps to define a threshold range in parts per million (ppm) of how closely the grid vs. ground distance measurements should match one another. For example, if the choice is to fit a threshold of ±10 parts per million (±10ppm) then the desire is to maintain an accuracy ratio maximum of 1:100 000, which would be a ten-fold improvement over the Oregon State Plane Coordinate System which has an accuracy ratio of ~1:10 000 with respect to ellipsoid, and significantly greater distortion at higher elevations.

Chapter 3 OCRS Map Projection Zones

3.1 The development of OCRS projection zones in Oregon

The development of each map OCRS projection zone involved a hands-on process by the Technical Development Team of interested stakeholders, together with the aid of Michael Dennis of Geodetic Analysis LLC, Sedona, Arizona. Mr. Dennis has created proprietary software to facilitate the visualization of low distortion map projection zones. Each zone was developed through a multi-step iterative process to derive the best result as determined by the Technical Team using the 'best practices' approach outlined in Chapter 1. At this point, the OCRS series of map projections for Oregon is considered complete, but time will tell if any will be added or modified later on. If you have questions or comments, please call and discuss your needs with the Geodetic Group of the ODOT Geometronics Unit in Salem.

3.1.1 The OCRS zone catalogue

Table 3.1.1

	Zone Name*	Projection	Latitude of Grid Origin	Standard Parallel & Grid Origin	Central Meridian	False Northing (m)	False Easting (m)	Scale (exact)
1	Baker	TM	44°30'00"N		117°50'00"W	0	40 000	1.000 160
2	Bend-Burns	LCC		43°40'00"N	119°45'00"W	60 000	120 000	1.000200
3	Bend-Klamath Falls	TM	41°45'00"N		121°45'00"W	0	80 000	1.000 200
4	Bend-Redmond-Prineville	LCC		44°40'00"N	121°15'00"W	130 000	80 000	1.000 120
5	Burns-Harper	TM	43°30'00"N		117°40'00"W	0	90 000	1.000140
6	Canyon City-Burns	TM	43°30'00"N		119°00'00"W	0	20 000	1.000 220
7	Canyonville-Grants Pass	TM	42°30'00"N		123°20'00"W	0	40 000	1.000 070
8	Coast Range North	LCC		45°35'00"N	123°25'00"W	20 000	30 000	1.000045
9	Columbia River East	LCC		45°40'00"N	120°30'00"W	30 000	150 000	1.000 008
10	Cottage Grove-Canyonville	TM	42°50'00"N		123°20'00"W	0	50 000	1.000 023
11	Dayville-Prarie City	TM	44°15'00"N		119°38'00"W	0	20 000	1.000 120
12	Denio-Burns	TM	41°45'00"N		118°25'00"W	0	80 000	1.000 190
13	Dufur-Madras	TM	44°30'00"N		121°00'00"W	0	80 000	1.000 110
14	Eugene	TM	43°45'00"N		123°10'00"W	0	50 000	1.000 015
15	Grants Pass-Ashland	TM	41°45'00"N		123°20'00"W	0	50 000	1.000 043
16	Gresham-Warm Springs	TM	45°00'00"N		122°20'00"W	0	10 000	1.000 050
17	Halfway	LCC		45°15'00"N	117°15'00"W	70 000	40 000	1.000 085
18	La Grande	TM	45°00'00"N		118°00'00"W	0	40 000	1.000 130
19	Medford-Diamond Lake	LCC		42°00'00"N	122°15'00"W	-60 000	60 000	1.000 040
20	Mitchell	LCC		47°00'00"N	120°15'00"W	290 000	30 000	0.999 270
21	North Central	LCC		46°10'00"N	120°30'00"W	140 000	100 000	1.000 000
22	Ochoco Summit	LCC		43°30'00"N	120°30'00"W	-80 000	40 000	1.000 060
23	Ontario	TM	43°15'00"N		117°00'00"W	0	80 000	1.000 100

	Zone Name*	Projection	Latitude of Grid Origin	Standard Parallel & Grid Origin	Central Meridian	False Northing (m)	False Easting (m)	Scale (exact)
24	Owyhee	TM	41°45'00"N		117°35'00"W	0	70 000	1.000 180
25	Pendleton	TM	45°15'00"N		119°10'00"W	0	60 000	1.000 045
26	Pendleton-La Grande	TM	45°05'00"N		118°20'00"W	0	30 000	1.000 175
27	Pilot Rock-Ukiah	LCC		46°10'00"N	119°00'00"W	130 000	50 000	1.000 025
28	Portland	LCC		45°30'00"N	122°45'00"W	50 000	100 000	1.000 002
29	Prairie City-Brogan	LCC		44°00'00"N	118°00'00"W	0	60 000	1.000 170
30	Riley-Lakeview	TM	41°45'00"N		120°20'00"W	0	70 000	1.000 215
31	Salem	TM	44°20'00"N		123°05'00"W	0	50 000	1.000 010
32	Santiam Pass	TM	44°05'00"N		122°30'00"W	0	0	1.000 155
33	Siskiyou Pass	LCC		42°30'00"N	122°35'00"W	60 000	10 000	1.000 150
34	Ukiah-Fox	LCC		45°15'00"N	119°00'00"W	90 000	30 000	1.000 140
35	Wallowa	TM	45°15'00"N		117°30'00"W	0	60 000	1.000 195
36	Warner Highway	LCC		42°30'00"N	120°00'00"W	60 000	40 000	1.000 245
37	Willamette Pass	TM	43°00'00"N		122°00'00"W	0	20 000	1.000 223
	Zone Name*	Projection	Latitude of Local Origin	Angle Skew or Azimuth	Longitude of Local Origin (m)	False Northing (m)	False Easting (m)	Scale (exact)
38	Columbia River West	OM/RSO	45°55'00"N	-65°	123°00'00"W	-3 000 000	7 000 000	1.000 000
39	Oregon Coast	OM/RSO	44°45'00"N	+5°	124°03'00"W	-4 600 000	-300 000	1.000 000

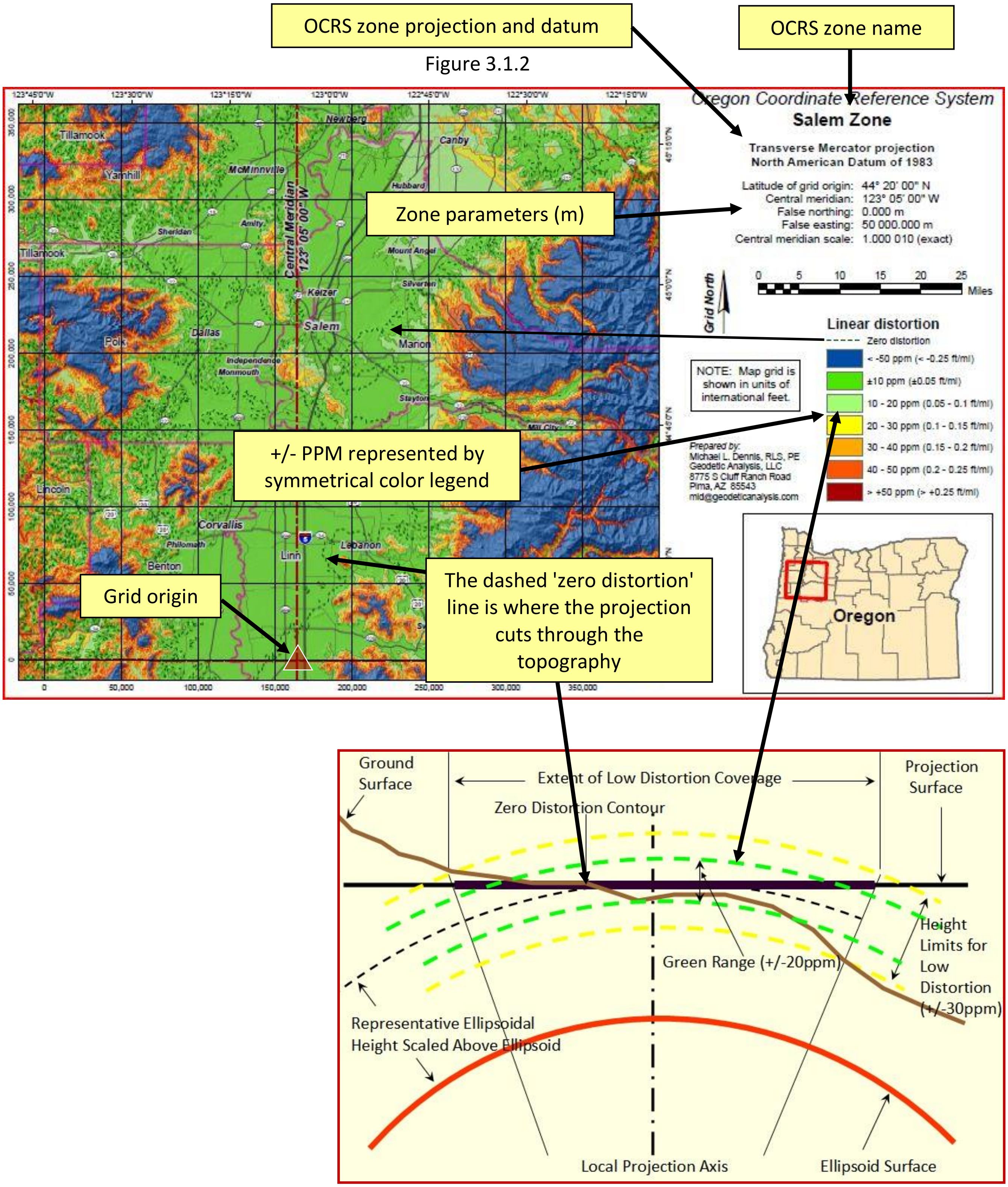
Zones in **red** were added to the OCRS in 2015/2016

Projection type: TM = Transverse Mercator, LCC = Lambert Conformal Conic (Single Parallel), OM/RSO = Oblique Mercator/Rectified Skew Orthomorphic.

- All zones designed with an initial target distortion level of ±10 ppm = 1:100 000 Ratio = ±0.05'/mile.
- All lineal units are metric (m).
- All zones reference the NAD 83 datum (GRS80)
- Refer to the OCRS map series shown in Appendix 'A'. The zone parameters in this table should match those on the map series. Note the revision date on each map.
- If you find a typo (error) please send an email to the ODOT Geometronics Section.

3.1.2 OCRS zone map interpretation

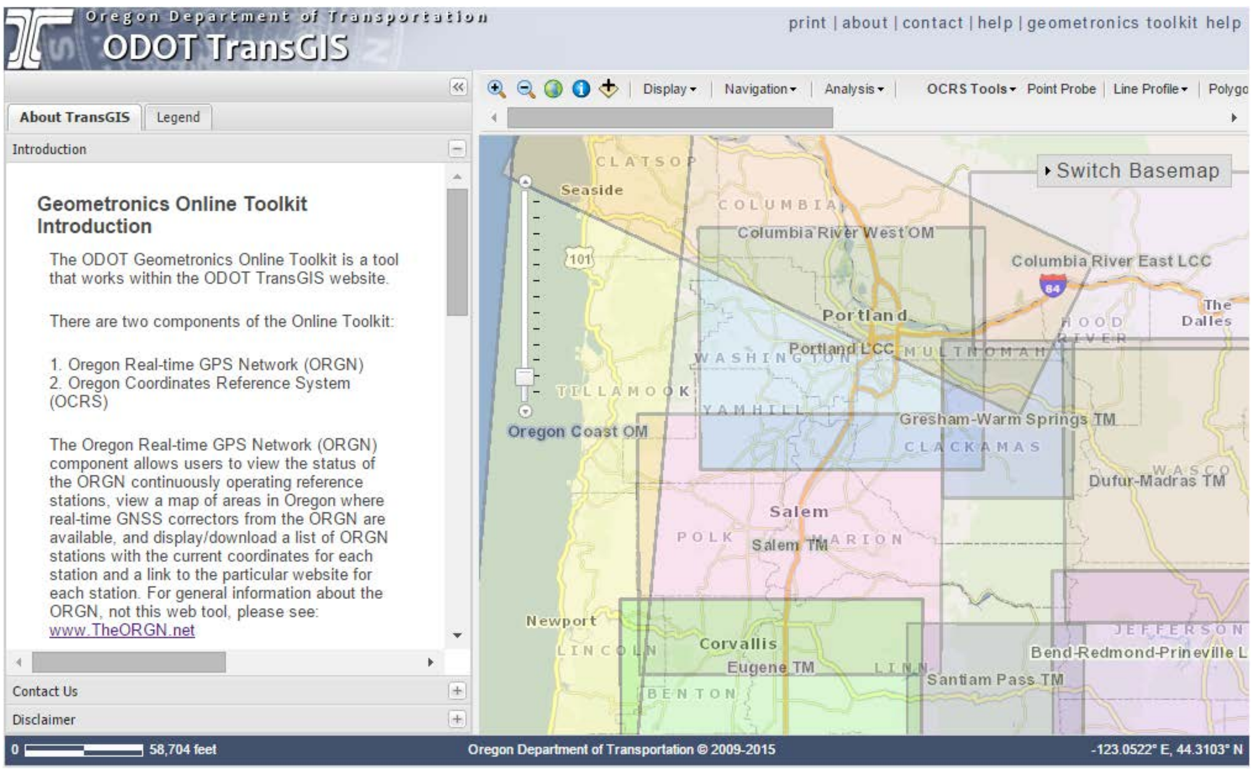
Figure 3.1.2



3.1.3 Picking a zone to use for a survey/engineering/GIS/mapping project

Many of OCRS map projection zones were designed with a zone overlap to allow users maximum choice in picking a zone to work in for their projects. For working in an overlap area, the users' goal would be to pick a zone that provides the least distortion in the project area, which often is correlated with elevation. *For example, the Salem Zone projection scale factor is larger (higher) than the Portland Zone projection so if you're working in that overlap area at a relative higher elevation it may make sense to use the Salem Zone.* So how do you make the decision on which zone to use if several zone raster's overlap your project site? The **ODOT Geometronics Online Toolkit** is designed to help you do just that. Go to the ODOT TransGIS website and follow the instructions to place your project location on the interactive map and see what the levels of distortion are for the zones that overlap your project.

Figure 3.1.3



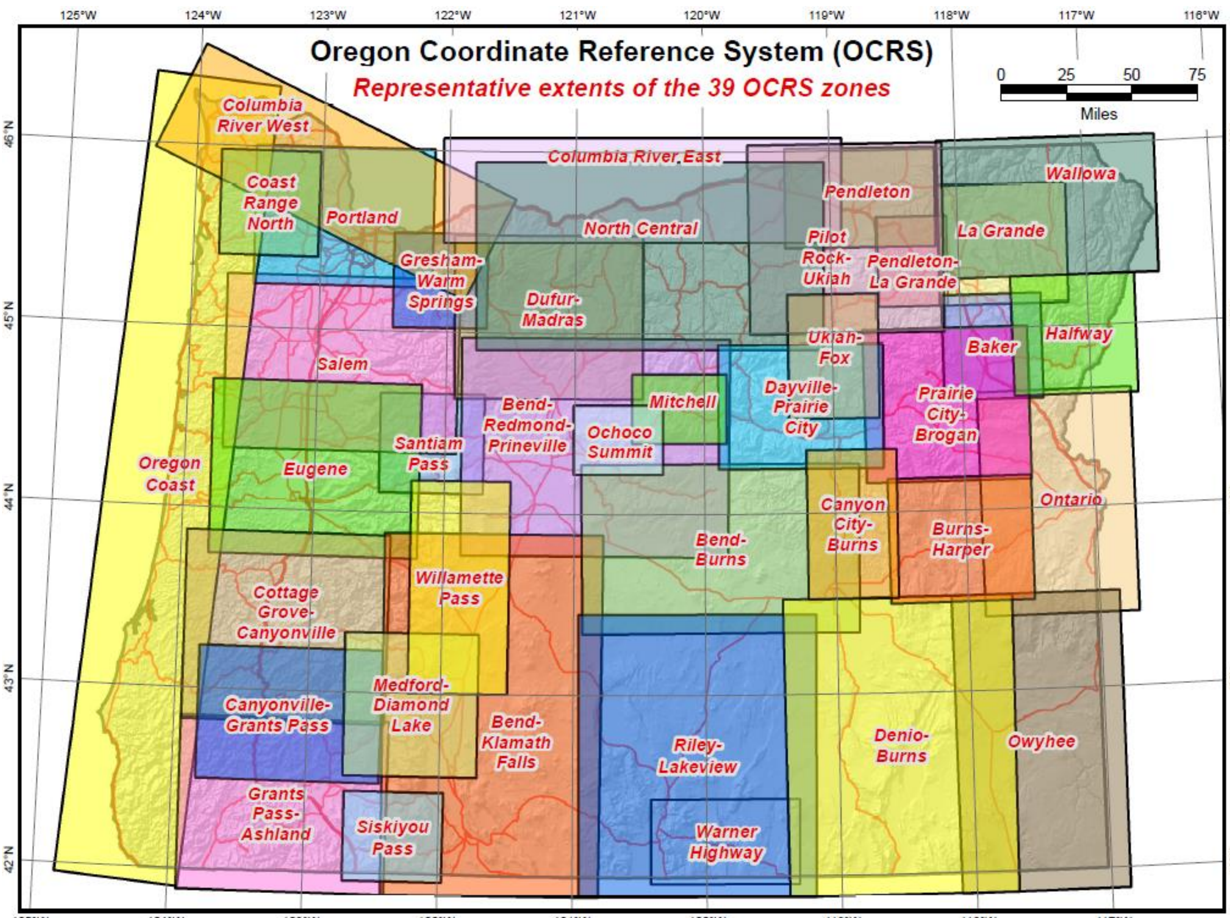
The OCRS Toolkit will provide you with the distortion levels for every zone overlapping your project area but it will <u>not</u> tell you if the actual OCRS coordinates will be negative in the easting or northing or both.

As a guideline, use the following rules.

Rule #1: Avoid using negative coordinate numbers. The zone parameters were optimized and specifically designed with map limits of positive northing and easting coordinates.
Rule #2: Use the recommended zone for the community (city or place) which may be found in Appendix 'A' on the left facing page next to each zone map. It is possible that a community may work equally well in more than one adjacent zone depending on the location of the project.
Rule #3: Use the zone your project is in unless your project overlaps into two or more zones. In the case of overlapping zones, use the zone with the lowest distortion level that also meets rules #1 and #2.
Rule #4: Always document your zone decision in your map metadata or survey narrative.

The following State of Oregon map shows all 39 OCRS zones as rectangles which are displayed in their native locations representing their approximate extents. The size of each rectangle considers the areas of low distortion coverage with positive coordinates. As shown the rectangles are not the absolute limits of the map projections and there may be areas outside of the rectangles (see the map set in Appendix 'A') where the zone coordinate system will still function well within the ± 10 to 20 ppm level.

Figure 3.1.3.1



Chapter 4 Using the OCRS in Software Programs

4.1 Adding an OCRS zone projection and coordinate system to software

When processing baselines and adjusting networks for projects it will be necessary to perform adjustments and input collected data from the field into projects created in certain vendor software. Input these OCRS zones into the appropriate 'coordinate system management/definition' module of that software. Because software processes change frequently we have removed specific help for vendor software. This chapter is designed to get you started, but it is recommended that you consult the 'help' documentation and tutorials of each piece of vendor software you plan to work with. Also, for future reference, please go to the ODOT Geometronics OCRS web page for updates and downloads.

If the OCRS zone series of projections is not already in your survey and mapping software consult with the software vendor to see if they will include them in their next software update. You can load them yourself if need be. The OCRS zone series are also available to everyone from the European Petroleum Surveyors Group (EPSG) website, which is a world-wide registry of map projection coordinate systems commonly included in survey equipment vendor software

For the purposes of entering these low distortion projection parameters into particular vendor software, normally define the datum as NAD 83 (which uses the GRS-80 reference ellipsoid) for the OCRS. The software may typically assume that there are no transformation parameters (zero transform) between WGS-84 and NAD 83, and that is acceptable (but not truly correct). Later, when starting an actual project, you may <u>seed</u> that project (within the software) with the local latitudes, longitudes, and heights for control points in the appropriate NAD 83 project datum realization, and time epoch chosen.

4.2 Dealing with future realizations of the National Spatial Reference System (NSRS)

Historically, the NSRS has updated coordinate realizations about every 5 years or so. Starting around 2022 the NGS will base the NSRS on a global geometric 3D frame matching the then current realization of the ITRF/IGS. Across the State of Oregon that means that coordinates will change from about 1.3 meters to about 1.6 meters from NAD 83(2011).
It will therefore be important to change the false easting and perhaps false northings of ALL of the OCRS zone parameters including the traditional State Plane zones so that the northings and eastings in the new NSRS realization do not look the same as the northings and eastings in the prior NSRS. The NGS did this for all States State Plane Coordinate Systems when they migrated from NAD 27 to NAD 83 but now each State is encouraged to decide what changes they should make and then inform the NGS so they may include those changes in products and services such as OPUS. ODOT Geometronics will plan to call a meeting of the **734-005-0015 OAR Committee** to review and approve the suggested changes to all of the zone parameters. If the datum (datum realization) changes, the northings and eastings will also change.

4.3 Checking zone parameter entry into vendor software to confirm correct grid northing's and easting's

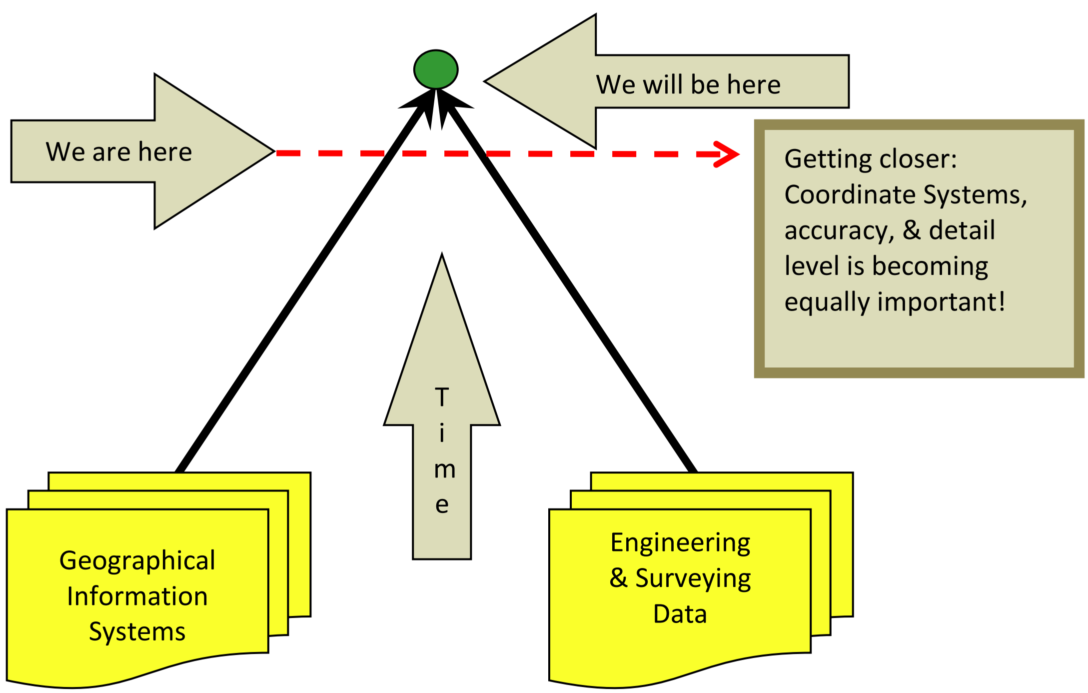
In Appendix 'A' on the left side of each map there is a section that offers a virtual check for three locations in each OCRS zone. If you have entered the OCRS zone parameters into your vendor's software and successfully created coordinate systems, then, by entering the input lat/long values (as local) from the table, your project grid coordinates should <u>match</u> these results exactly to five decimal places. The provided coordinates are virtual and independent of any frame realization (datum). Regardless of the software, match these output values exactly (Some Trimble output varies in the ~last decimal place for the OM/RSO projections). If you do not match, go back and make sure you have entered the zone parameters correctly into your vendor software. If you still do not match northing and easting coordinate output, then contact the software vendor. Surveyors and mappers should understand that when frame realizations change the northing and easting coordinates will also change for the same passive marks.

4.4 Low Distortion Projects in the GIS Community

Modern GIS software incorporates on-the-fly projection changes. This allows users to simultaneously display data from differing coordinate systems in a common coordinate system on the computer screen. Low distortion projection systems can thus be easily and seamlessly incorporated for display of GIS databases. An advantage to LDPs is the fact that the historical data need not be modified. Past data can still reside in its original coordinate system and merely be re-projected in real-time into the new coordinate system for use with new LDP data. This will allow cities and counties to adopt the OCRS while still using their original data without modification. New data can be acquired in the best OCRS zone for the area and still be used with the historical data or other data collected by other agencies in different coordinate systems with minimal effort by the user. Many cities and counties in Oregon use GIS data to manage their resources. Thus, because the OCRS LDPs generally cover large areas of a County, an LDP will provide excellent coverage for the entire area that an agency or community is concerned with. See Appendix 'A' for a recommended communities for each zone map.

GIS calculations of route distances, cut/fill volumes, etc. will be more accurate with use of OCRS zones because of the minimized distortion. Existing coordinate systems may be adequate for large, statewide analyses where data resolution is low (e.g. large grids cell sizes > 30m). The development of LDPs allows for new high resolution data (e.g. small grid cell sizes 0.1m to 2m) and digital terrain models (DTM) from LIDAR and other new technologies to be analyzed with minimal distortion in GIS environments when studies are performed on a localized county or city areas. Existing coordinate systems would provide a substantial amount of distortion when analyzing these DTMs. Hence, LDPs will allow for the development of more accurate GIS databases and help bridge the gap between GIS and surveying for mapping.

Figure 4.4



4.4.1 Managing GIS Data

Geographic Information System managers administer data. Data includes spatial and attribute information that is provided from many sources. The spatial data locates features across the landscape while the attributes provide characteristics of the features. GIS managers use the same reference frameworks as surveyors to define positions in space.

Nearly all GIS operations require accurate locations of geographic features. Accurate locations allow GIS users to integrate and/or combine information from various sources. Critical to the accurate locations of features is a record of the coordinate system and associated projection parameters. GIS managers often incorporate surveyed data into geographic databases. Conversion of coordinate information into a different map projection system from which it was collected is usually necessary. Critical to this process is a well-defined set of existing and desired map projection parameters.

The OCRS low distortion projection zones provide another reference system in which data will be collected. By having detailed descriptions of properties of the map projection, GIS software can re-project and transform the geographic locations of dataset elements into any appropriate coordinate system. This allows the integration of multiple GIS layers, a fundamental GIS capability.

A GIS or mapping project based on one of the new low distortion coordinate systems has significant advantages. The design of the coordinate system allows field based measurements (data collection) to be directly utilized in the GIS without translation, saving time and reducing error. The size, position and orientation of features in the system can match ground conditions, increasing confidence and reducing the need for repetitive observation.

Chapter 5 Testing Ground vs. Grid Distances in an OCRS Zone

5.1 OCRS zone field and office test methods

The general purpose for performing tests on LDP zones is to make sure that the zone maps representing the levels of PPM are accurately shown and may be relied upon by users. Survey measurements performed at any location on the map will have a specific GRID to GROUND relationship. That relationship may be verified by the following test methods.

As part of the development of low distortion projections for Oregon, field tests and calculations were employed to compare grid distances measured with GNSS between two distinct points while working in a project defined by an OCRS zone coordinate system with the direct distance measured on the ground between the same two points. If the two comparative distances were less than or equal to the projections designed threshold of, say, ±10 ppm, then the goal was met.

Short, medium and long baselines were chosen to simulate the extreme limits of how people might use the projections. The short baselines chosen were on NGS Calibrated Baselines (CBL) because they represent ~1100 m to ~1400 m distances and are accessible in several of the zones. Also, the horizontal ground distances as measured by the NGS, with electronic distance measurement (EDM) were a matter of record for comparison. Multiple fast static GNSS measurements were taken simultaneously at the end points of each baseline and then processed with baseline processing software while in the particular OCRS grid zone coordinate system. The grid vs. ground distances were then compared to see if the threshold was met.

A similar test was conducted for medium baseline lengths of ~3000 m to ~5000 m distances and for this test two baselines were set (temporary points) and the horizontal ground distance measured with a (previously checked) Total Station. One baseline was oriented east-west and the other north-south and each line was measured with the Total Station (direct and reverse readings for a total of 30 measurements). The average of those measurements was again compared with multiple fast static GNSS measurements and then processed with baseline processing software while in the particular OCRS grid zone coordinate system. The grid vs. ground distances were then compared to see if the threshold was met.

For the test on long baseline lengths of ~20 000 m to ~80 000 m, one of the goals was to choose particular points beyond the edge of the planned useful area of the zone to 'break' the desired threshold and prove that it fails where it should fail (i.e., exceed the ppm design threshold). For this test, random Plate Boundary Observatory (PBO) CORS station data were used. For the grid distance baseline calculation, 24 hour RINEX files were downloaded for various PBO CORS stations, and the baselines between points were processed with baseline processing software in the particular OCRS zone grid coordinate system. Since the ground distances were too long to physically measure with an EDM, the ground distances were calculated using the Vincinty inverse formula. The curved horizontal "ground" distance was computed by scaling the Vincenty GRS-80 ellipsoid distance to the topographic surface. The scale factor to do this was computed using the mean ellipsoid height of the end points and the geometric mean radius of curvature at the mean latitude of the endpoints.

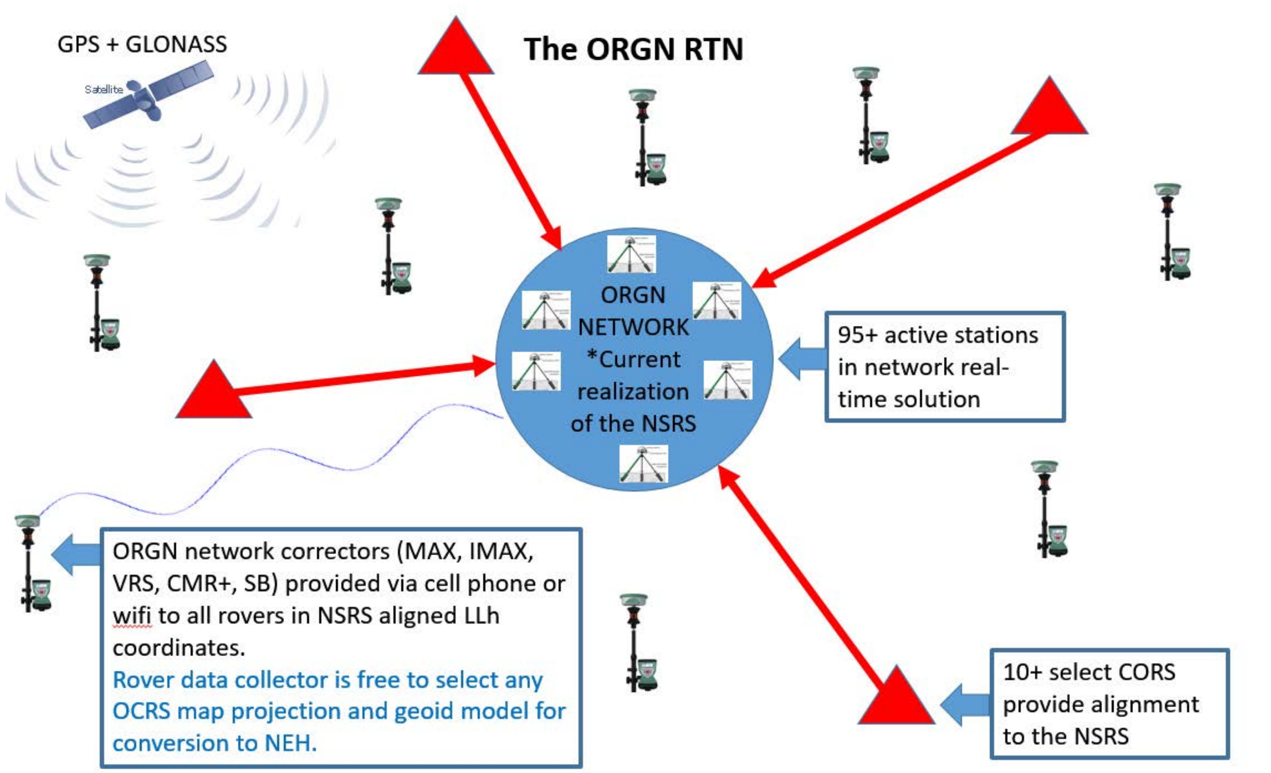
Chapter 6 The OCRS and the Oregon Real-Time GNSS Network (ORGN)

6.1 Using the ORGN with the OCRS

The Oregon Department of Transportation (ODOT) Geometronics Unit operates and maintains the ORGN Real-Time GNSS network. The ORGN supplies real-time GNSS network correctors to rovers in the field and also provides data logged RINEX files for all of the active stations in the network. ODOT policy requires that the ORGN be aligned with the National Spatial Reference System (NSRS). To maintain this alignment, the network is constrained to selected NGS Continually Operating Reference Stations (CORS) and adjusted using the NGS program OPUS-Projects. The ORGN broadcasts network correctors providing latitude, longitude, and ellipsoid height (in the current NSRS) to user's rovers around the State.

At the rover receiver, data collection occurs in conjunction with the current project and the chosen coordinate system including a map projection zone such as one from the OCRS series. If you wish to work in a particular OCRS zone you can enter the zone projection parameters into your rovers' data collector coordinate system manager software (or download the data from the office software) and pick that particular coordinate system and geoid model for the current project you are working in. Once these steps are complete you should see, on the data collector screen, the selected zone northing and easting grid coordinates and the orthometric height in real-time. They would be converted (transformed) from the (rover) observed, ORGN broadcast, geodetic reference coordinates automatically. In order to get vertical datum orthometric heights you must select the appropriate geoid model on the rover data collector as well. For more information on the ORGN, see: www.theorgn.net.

Figure 6.1 How the ORGN works



6.2 Field Checking Distances on your own project (Grid vs. Ground)

Each OCRS zone coordinate system was developed so that grid and ground distances match very closely within a given elevation range (within ± 10-20 ppm). If you are working near the fringe of a zone, or at elevations significantly (more than about a hundred feet) above or below the elevation limits of the zone's low distortion area, then you may want to check the ppm result between control points in your project.

To do this, pick the two farthest points in your project that you can measure directly between with an EDM (total station) or with RTK using the ORGN. Measure the horizontal ground distance between the points and record the ground distance measurement. Care must be taken to make sure your data collector is recording the ground distance and not automatically converting to a pre-defined coordinate system. Then, change to a particular OCRS grid Zone map projection in your data collector which will convert your ground distance to grid. Record that distance. Then inverse the grid distance between the same two points. Subtract the grid distance from the ground distance (absolute value). Compare this absolute value difference with the ppm threshold desired. At 0 ppm the grid distance would exactly match the ground distance. See the example in Table 6.2

Table 6.2 Example test

Ground Distance =	1239.998m	Grid Distance =	1239.990m
Absolute Difference =	.008m		
OCRS Zone PPM Goal =	10 =	1:100 000 Threshold =	0.0124m
Test	**is 0.008<=0.0124**	**Yes**	**Pass (within threshold)**

In this case, the actual ppm is well under the ±10 ppm level threshold. If the actual ppm is greater than ±10, then determine how much greater, and judge for yourself if you should be using that particular zone for your project location. There is nothing particularly wrong with exceeding the ±10 ppm level threshold if it makes sense for your project work. Even working at higher elevations up to 50 ppm level would be an improvement over using the Oregon State Plane Coordinate System. It's your choice on how you use the OCRS map projection zones and which one you choose to work in.

This type of test can also be performed using GNSS data. One way to do this is to calculate the ground distance between the measured coordinates using Vincenty's formula with the geometric mean radius of curvature, as described previously. Many commercial surveying software packages can also compute the ground distance (it is recommended that the ground distance value be checked to ensure it is correctly computed).

Another method is to use a delta XYZ GNSS vector to estimate the horizontal ground distance between points. Neglecting curvature, this can be computed as:

$$H = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2 - \Delta h^2}$$

Where: ΔX, ΔY, ΔZ are the GNSS vector components (as ECEF Cartesian coordinate deltas)
Δh = change in ellipsoid height between vector end points

Accounting for curvature increases this horizontal ground distance, but for distances of less than 20 miles (about 30 km), the increase is less than 1 ppm (i.e., less than 3 cm).

The curvature correction factor can be approximated as:

$$C = (2R\sin^{-1}(H \div 2R)) \div H$$

where R is the earth radius. A value of R = 6 378 000 m (20,925,000 ft) works well for Oregon. The (straight) horizontal distance is multiplied by the correction factor to get the curved horizontal ground distance. Note that there is no need to account for refraction, because the GNSS vector is computed, not observed.

Chapter 7 Legislative Adoption and Registration with the NGS

7.1 OCRS Legislative Adoption

The OCRS now contains 39 low distortion map projection zones that cover the entire State of Oregon. The OCRS zones have been thoroughly tested, and generally accepted by a wide audience of Oregon professional surveyors, engineers, GIS, cartographic, and academic professionals around the state.

Senate Bill 877 was enacted in Oregon in 2011 to allow the use of the OCRS or legacy State Plane Coordinate Systems whenever the use of State Plane systems was previously allowed by State law. There is no requirement to use the OCRS written into Senate Bill 877. Both the OCRS and Oregon SPCS are collectively part of the Oregon Coordinate System.

Senate Bill 877 details follow:

SB 877, Section 7 (1), required the Oregon DOT to adopt Oregon Administrative Rules (OAR) as further described.

SB 877, Section 7 (2), required the Oregon DOT to establish an Advisory Committee, as described in ORS 183.333.

SB 877, Section 7 (3), required the Oregon DOT to appoint the following Advisory Committee members:

a. Two members representing ODOT
b. Two members who are County Surveyors in Oregon and are also members of the Oregon Association of County Engineers and Surveyors.
c. Two members representing Professional Land Surveyors in private practice in Oregon
d. One member representing the entity reorganized and renamed as the Oregon Geographic Information Council by Executive Order 94-16

SB 877, Section 7 (4), requires that Administrative rules adopted or amended pursuant to Section 7 must be approved by a majority of the members of the Advisory Committee.

Legislative adoption of the OCRS provided viable evidence of acceptance by the engineering, surveying, and mapping professionals within the State of Oregon as well as Federal agencies such as the Bureau of Land Management, National Geodetic Survey, and the Federal Emergency Management Agency.

The Oregon Transportation Commission adopted the OAR defining the OCRS defining the Oregon Coordinate System (734-005-0005, 734005-0010, 734-005-0015) on December 21, 2011. The rules were filed with the Secretary of State on December 22, 2011 and became effective on January 1, 2012.

These rules moved all definitions and parameters of the existing Oregon State Plane zones from ORS Chapter 93 to the OAR rules as described above. Also the OCRS definitions and parameters were placed under the control of the OAR rules as described above.

On December 15, 2016, the Oregon Transportation Commission approved the 19 additional OCRS zones for a total of 39 OCRS zones in Oregon.

The administrative rules concerning the OCRS are listed on the Secretary of State's State Archives website under the ODOT Highway Division, Chapter 34, Division 5 (Oregon Coordinate Systems).
To make an Administrative Rule change the Advisory Committee must first vote to approve the rule change. Also the Oregon Department of Justice must review a statement of the purpose and fiscal impact of the amendment, provide notices to the public and post to the Oregon Legislature. Ultimately, the rule change must be approved by the Oregon Transportation Commission. This process is facilitated by the ODOT Administrative Rule Coordinator.

7.2 NGS Policy on Registration of the OCRS

POLICY ON CHANGES TO PLANE COORDINATE SYSTEMS, April 11, 2001
http://www.ngs.noaa.gov/INFO/Policy/SPCS4.html

The National Geodetic Survey (NGS) recognizes that States may want to implement changes to their existing State Plane Coordinate System (SPCS) parameters especially when a new NSRS frame/datum realization is introduced so that northing and easting coordinates in the new system look markedly different than the old frame/datum realization northings and eastings. Also States may desire to create and employ additional low distortion map projections. These changes could include: adding or deleting zones, changing existing zone boundaries, and/or changing the geometric parameters (e.g., false northing/easting, origin, central meridian, etc.). NGS also recognizes that State and local surveying, mapping, and Geographic Information System (GIS) communities may develop grid systems to support a variety of agency or local activities that may somewhat differ from the NGS policy detailed below. This policy details only those elements which must be generally met for NGS to publish these coordinate systems and include in products and services such as OPUS. This policy may change over time.

The NGS recommends that any proposed changes be thoroughly discussed and approved at the DOT level followed by a conversation with NGS staff, including the NGS Regional Advisor, prior to submitting a request to the Director of NGS.

NGS (current policy as of this writing) will adopt changes to SPCS or add supplemental projections into NSRS only under the following conditions:

1. All requests for changes must be submitted in writing to the Director, NGS, and must be co-signed by those State agencies and organizations most involved in the use, collection, and distribution of spatial data including, but not limited to, the State Department of Transportation, State Office of GIS, and state land surveyor professional organizations. Hereafter these groups are referred to as the "State." Required agencies and organizations will be determined by NGS on a state-by-state basis. A similar request must also be submitted to the U.S. Geological Survey (USGS) to ensure integrity of NSRS with USGS national mapping products and services.
2. All new SPC zones or supplemental projections shall use the two basic map projections, the Lambert Conformal Conic or the Mercator (transverse or oblique), defined at the surface of the ellipsoid of the current Datum (Geodetic Reference System 1980 - GRS 80).
3. All changes must be adopted by State Law (or State Regulation when such Regulation is regulated by public notices and hearings and no opposition exist). Such Law must include a complete description of the revised SPCS zones and geometric parameters. A specified conversion factor between meters and feet (U.S. Survey or International) is strongly recommended to be included in the legislation. NGS will publish coordinates only in those legislated units.
4. Zones will continue to be defined by International, State and county boundaries, and by the counties contained therein. (See Federal Register Notice "Policy on Publication of Plane Coordinates," Vol. 42, Nol. 57, pages 15943-15944, published March 24, 1977.)
5. SPCS changes will ensure that the resulting coordinate differences are sufficiently large (by at least 10,000 meters) to ensure that no confusion will exist with the current NAD 83 coordinate values.
6. A naming convention shall be developed that ensures a distinct labeling between the existing and revised new coordinate zones.
7. Should NGS estimate significant expenses resulting from changes to the existing SPCS, NGS may require State reimbursement? These costs would be for coordinate conversion, data base

extraction and publication software required to support computation, publication and distribution of new coordinate values as part of NSRS.

8. To facilitate public awareness, the State shall develop an education program that includes an article detailing the rationale for the development of the changes, the process of review and examination of the issues, the final design criteria, and a workshop or seminar to be presented at a State-wide surveying and mapping conference. The article shall be submitted for publication in one or more surveying and mapping periodicals (e.g., American Congress on Surveying and Mapping Bulletin, Professional Surveyor, or P.O.B. magazines). In addition, this article will be made available on the web sites of the sponsoring agencies defined as the "State." Any requests for technical support from NGS requiring travel expenses for NGS personnel shall be reimbursed by the State.

References

Presentations and papers

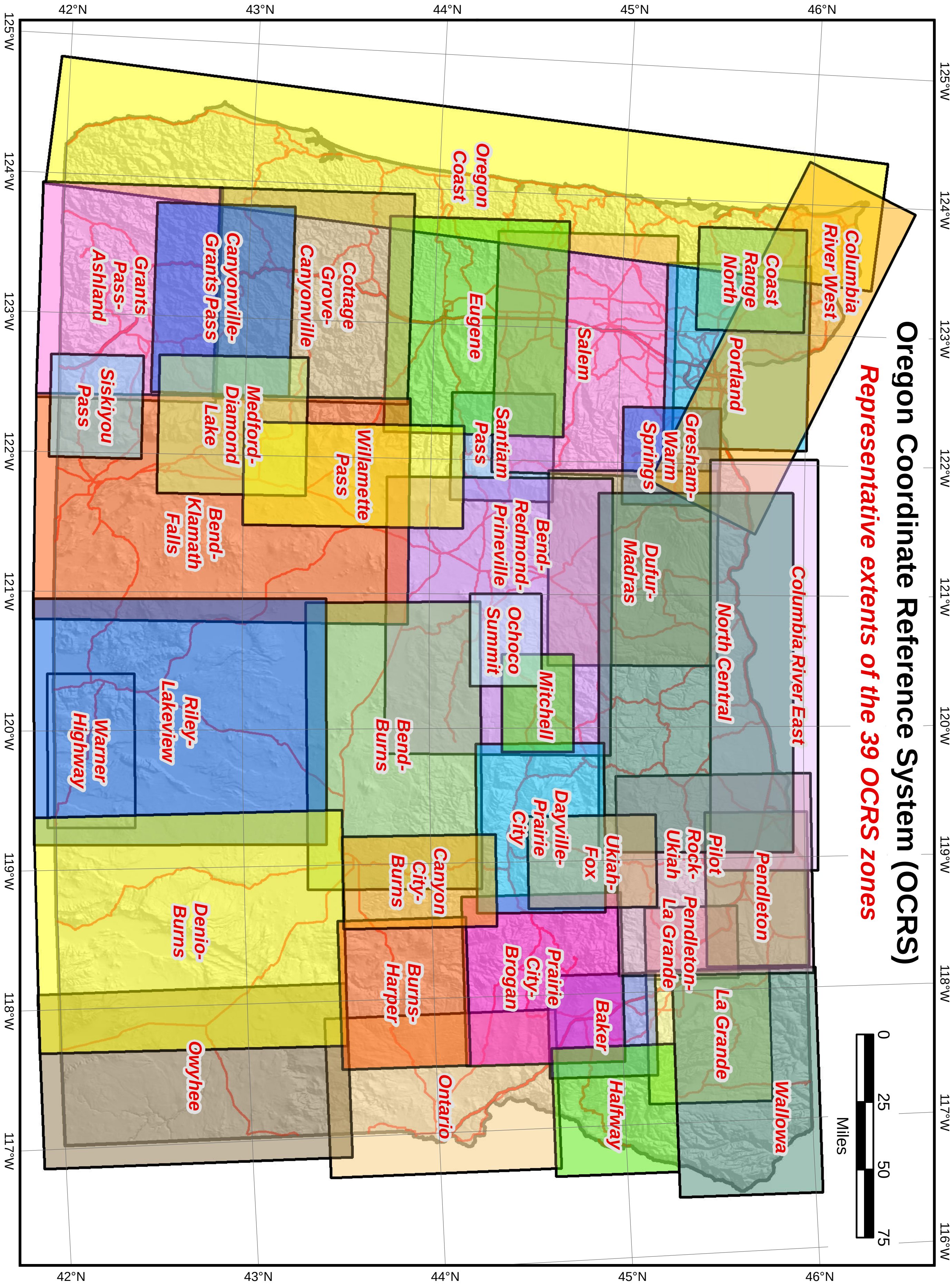
1. *ODOT/OGUG Low Distortion Projection Workshop Presentation*, November 4th, 2008, Ron Singh.
2. *Ground Truth - Low Distortion Projections for Surveying and GIS*, Oregon Edition 2008 – Presentation by Michael Dennis, RLS, PE.
3. *Ground Truth - Design and Documentation of Low Distortion Projections for Surveying and GIS, Arizona Edition November 2008*, Michael L. Dennis, RLS, PE.
4. *Low Distortion Map Projections (Local Map Projections) Academic Perspective* – OGUG Meeting Presentation, November 4th, 2008, Jack Walker, Ph.D.

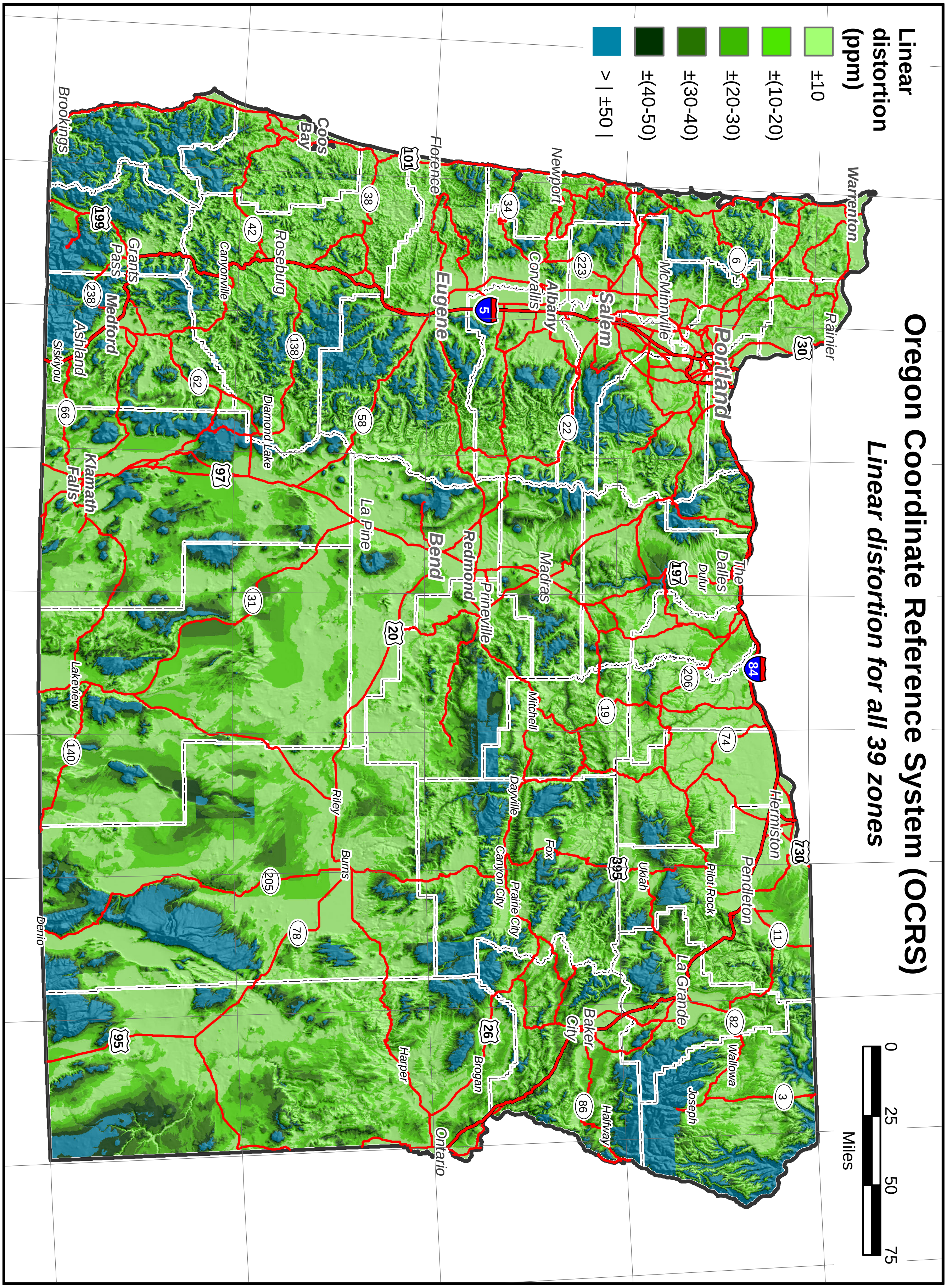
Federal and academic documents

5. U. S. Dept. of Commerce, *The Practical Use of the Oregon State Plane Coordinate System,* by Buford K. Meade, 1964
6. Federal Geographic Data Committee (1998) *Geospatial Positioning Accuracy Standards*, FGDC-STD-007.2-1998, Federal Geographic Data Committee, Reston, Virginia, USA, 128 pp., http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/, [includes Standards for Geodetic Networks (Part 2), National Standard for Spatial Data Accuracy (Part 3), and Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management (Part 4)].
7. National Geodetic Survey, *User Guidelines for Single Base Real Time GNSS Positioning v3.0,* by William Henning, Lead Author
8. Snyder, J.P. (1987) *Map Projections - A Working Manual*, U.S. Geological Survey Professional Paper 1395, U.S. Government Printing Office, Washington, D.C., USA, 383 pp.
9. "*A Refinement to the World Geodetic System 1984 Reference Frame*", by Merrigan, Swift, Wong, and Saffel.
10. "*Transforming Position and Velocities between the International Terrestrial Reference Frame of 2000 and North American Datum of 1983*", by Tomas Soler and Richard Snay.
11. National Imagery and Mapping Agency, 2000, *Department of Defense World Geodetic System of 1984: Its Definition and Relationships with Local Geodetic Systems (3rd Edition), Amendment 1, NIMA Technical Report 8350.2*, National Imagery and Mapping Agency (now the National Geospatial-Intelligence Agency), 175 pp., http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html.
12. Vincenty, T., 1975. *Direct and inverse solutions of geodesics on the ellipsoid with application of nested equations, Survey Review, Vol. 23, No. 176, pp. 88-93*, http://www.ngs.noaa.gov/PUBS_LIB/ inverse.pdf.
13. National Geodetic Survey, *NOAA Manual NOS NGS 5, State Plane Coordinate System of 1983*, James E. Stem, 1989. http://www.ngs.noaa.gov/PUBS_LIB/ManualNOSNGS5.pdf
14. War Department Corps of Engineers, *Plane Co-ordinate Computation for the State or Oregon*, with tables by the US Coast and Geodetic Survey, ~1964

Appendix A

OCRS Zone Maps
with
Recommended communities
Sample virtual coordinates


Oregon Coordinate Reference System (OCRS)
Representative extents of the 39 OCRS zones
Columbia River West
Coast Range North
Oregon Coast
Portland
Salem
Eugene
Cottage Grove-Canyonville
Canyonville-Grants Pass
Grants Pass-Ashland
Siskiyou Pass
Medford-Diamond Lake
Willamette Pass
Santiam Pass
Gresham-Warm Springs
Columbia River East
North Central
Dufur-Madras
Bend-Redmond-Prineville
Bend-Klamath Falls
Ochoco Summit
Mitchell
Riley-Lakeview
Warner Highway
Bend-Burns
Dayville-Prairie City
Ukiah-Fox
Pilot Rock-Ukiah
Pendleton
Pendleton-La Grande
Canyon City-Burns
Denio-Burns
Burns-Harper
Prairie City-Brogan
Baker
La Grande
Wallowa
Halfway
Owyhee
Ontario
Miles
0
25
50
75
42°N
43°N
44°N
45°N
46°N
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
116°W


Oregon Coordinate Reference System (OCRS)
Linear distortion for all 39 zones
Linear distortion (ppm)
±10
±(10-20)
±(20-30)
±(30-40)
±(40-50)
> | ±50 |
0
25
50
75
Miles
42°N
43°N
44°N
45°N
46°N
125°W
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
116°W
Portland
Salem
Eugene
Bend
Warrenton
Rainier
McMinnville
Newport
Corvallis
Albany
Florence
Coos Bay
Roseburg
Canyonville
Grants Pass
Medford
Ashland
Siskiyou
Brookings
Klamath Falls
Diamond Lake
La Pine
Redmond
Prineville
Madras
The Dalles
Dufur
Mitchell
Dayville
Canyon City
Prairie City
Fox
Ukiah
Pilot Rock
Pendleton
Hermiston
La Grande
Baker City
Wallowa
Joseph
Halfway
Ontario
Brogan
Harper
Burns
Riley
Lakeview
Denio

BAKER ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

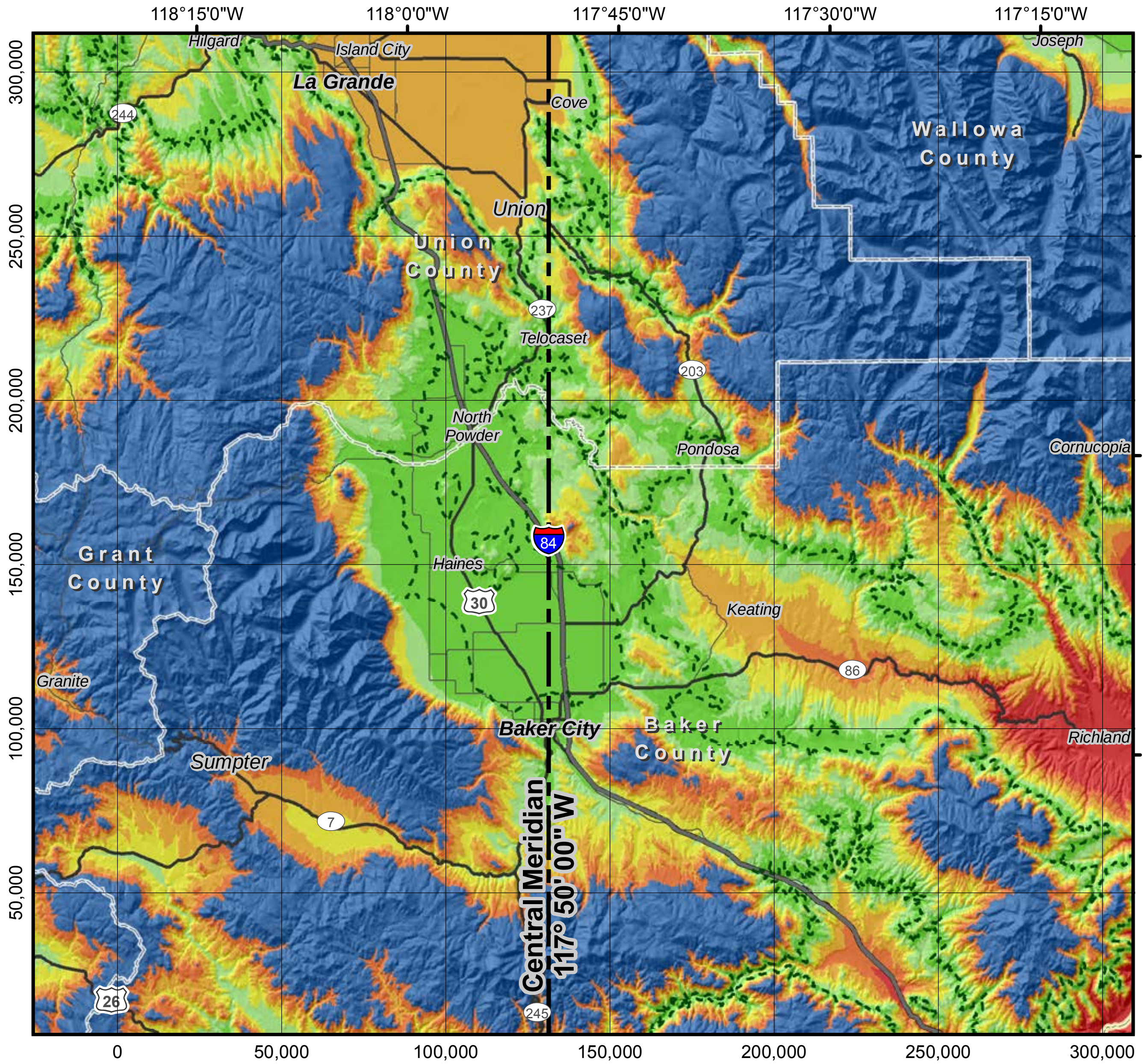
Parts of Baker County, and south Union County encompassing the communities of:

Baker City, Keating, Pondosa, Telocaset, North Powder, Haines

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Baker1	44 49 57.80936	117 48 54.56244	36980.20833	41437.60083
Baker2	44 52 07.48389	117 54 26.35126	40986.29136	34152.16275
Baker3	44 40 24.70946	117 59 40.97048	19299.09877	27201.54461



Oregon Coordinate Reference System

Baker Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	44° 30' 00" N
Central meridian:	117° 50' 00" W
False northing:	0.000 m
False easting:	40 000.000 m
Central meridian scale:	1.000 160 (exact)

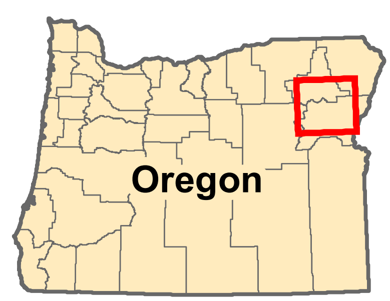
Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)

0 5 10 15 20
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz
Geodetic Analysis

Map created 7/10/2016

BEND-BURNS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

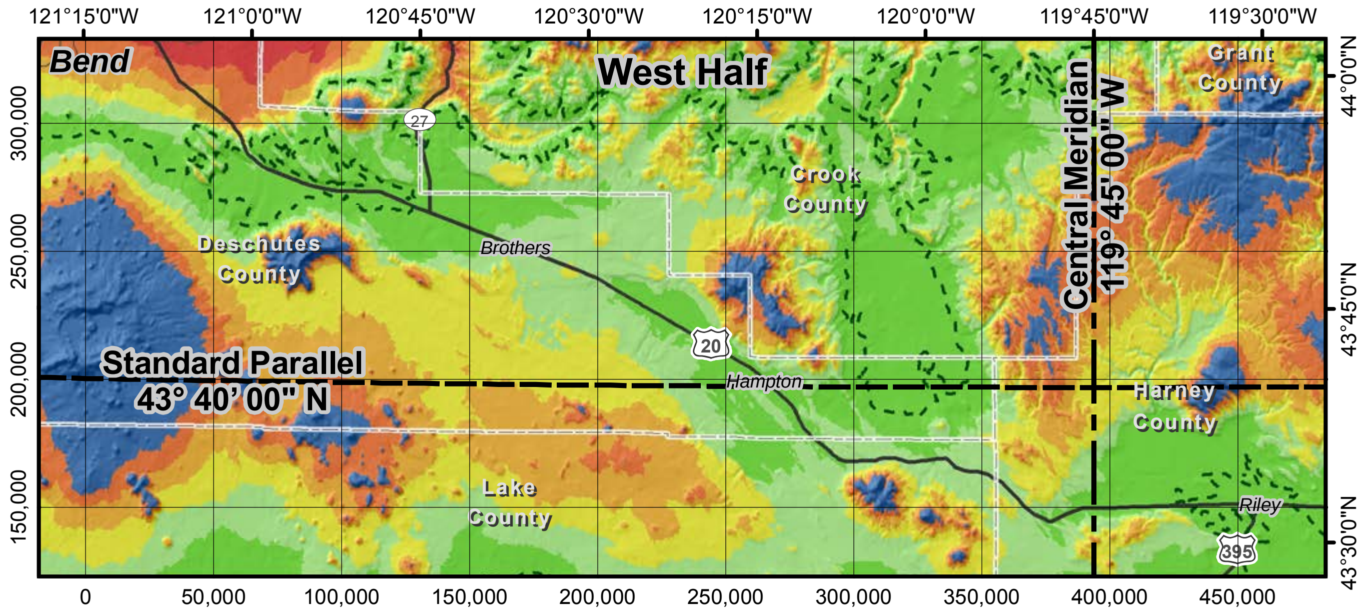
Parts of Deschutes County, south Crook County, north Lake County, and west Harney County encompassing the communities of:

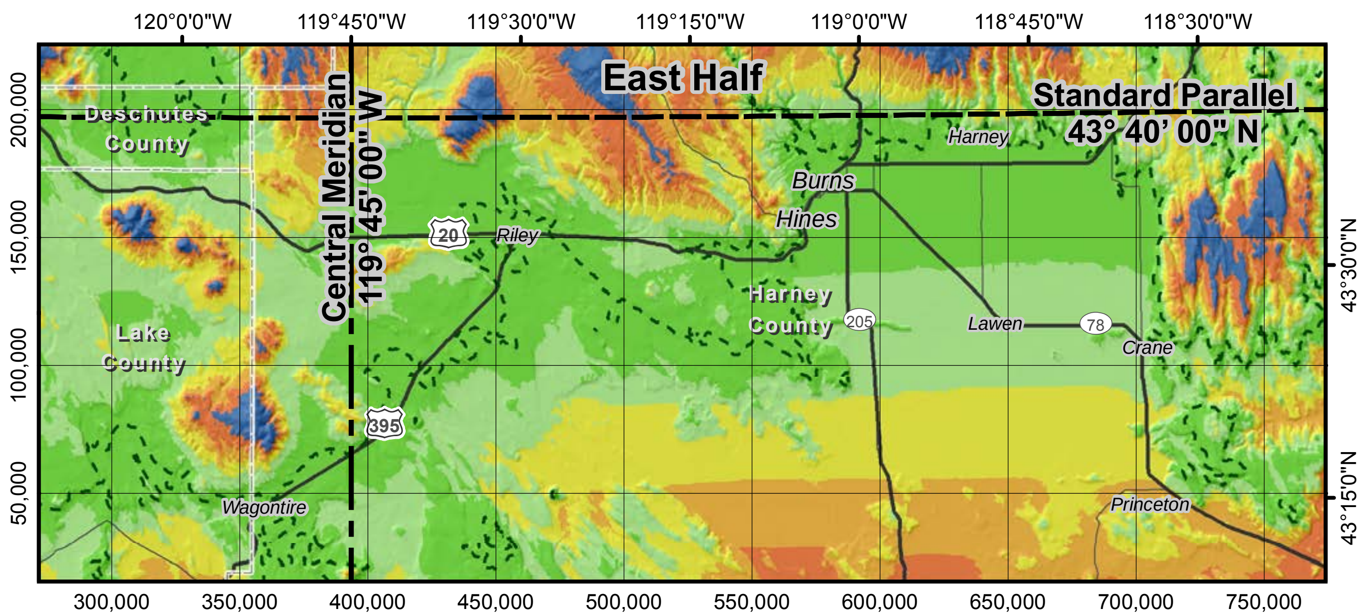
Brothers, Hampton, Riley, Burns, Hines, Wagontire, Lawen, Crane

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Bend-Burns1	43 12 59.24787	118 27 03.95863	10796.84894	225561.08353
Bend-Burns2	43 20 57.19424	119 53 31.05128	24733.52031	108487.85026
Bend-Burns3	43 35 07.15981	118 57 16.25662	51268.40968	184257.38779





Oregon Coordinate Reference System

Bend-Burns Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 43° 40' 00" N
Central meridian: 119° 45' 00" W
False northing: 60 000.000 m
False easting: 120 000.000 m
Standard parallel scale: 1.000 200 (exact)

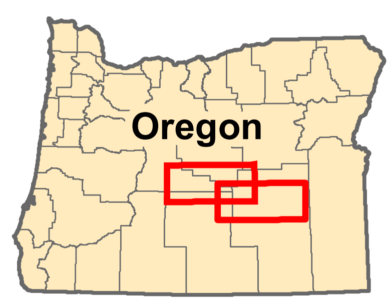
Scale 1:900,000
(when printed on 8-1/2" x 11" sheet)

Grid North

0 10 20 30
Miles

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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Geodetic ANALYSIS

Map created 7/10/2016

BEND-KLAMATH FALLS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

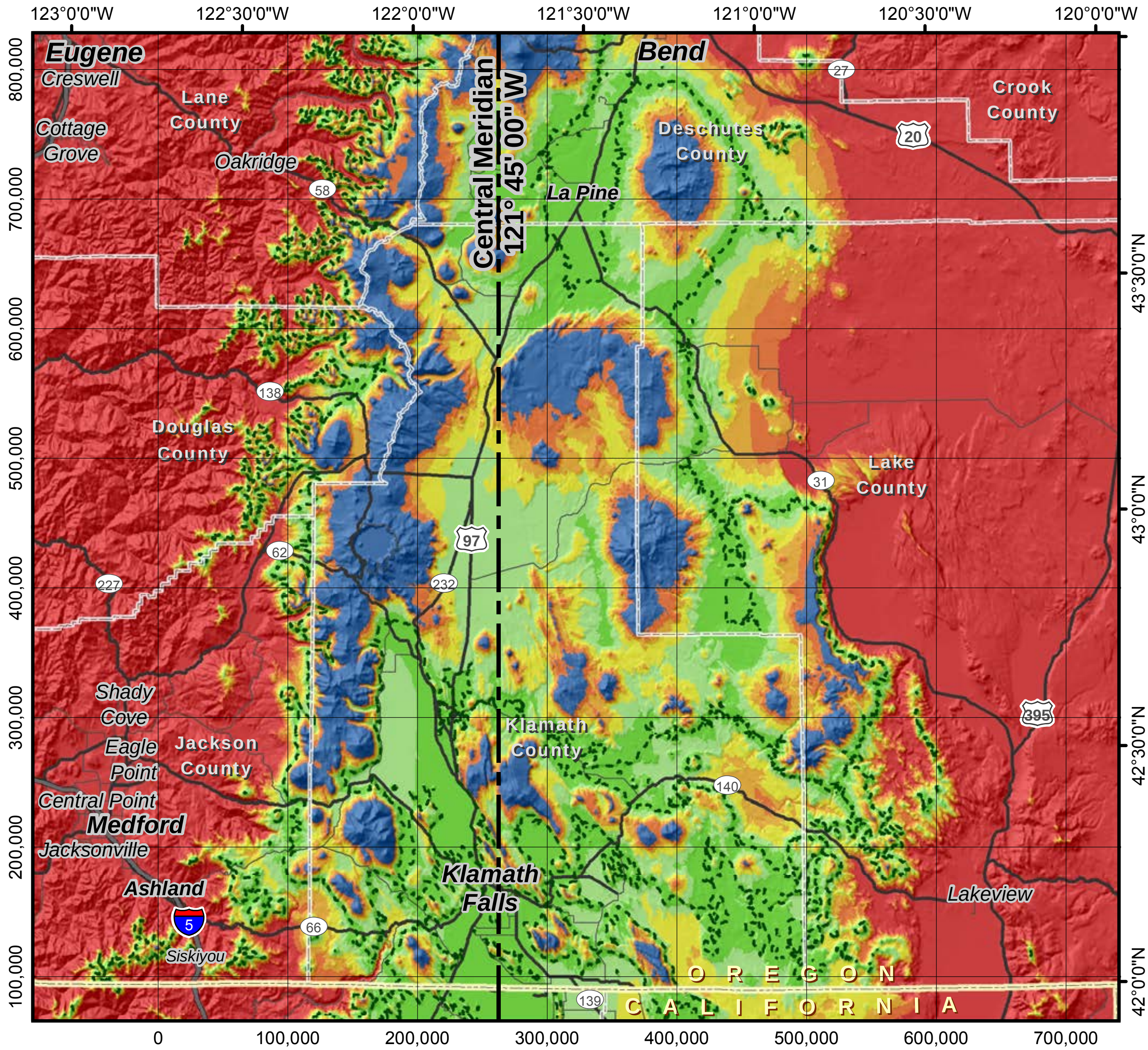
Parts of east Lane County, east Douglas County, east Jackson County, south Deschutes County, and Klamath County encompassing the communities of:

Lapine, Gilchrist, Crescent, Chemult, Kirk, Fort Klamath, Olene, Midland, Keno, Modoc Point, Klamath Falls, Chiloquin, Algoma, Hildebrand, Dairy, Yonna, Worden, Merrill

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Bend-Klamath Falls1	42 17 19.71674	121 40 09.54146	59862.74501	86655.66105
Bend-Klamath Falls2	42 25 06.01243	121 13 17.70770	74385.61148	123500.38364
Bend-Klamath Falls3	42 12 32.57089	121 44 50.17150	50997.92871	80225.49733



Oregon Coordinate Reference System
Bend-Klamath Falls Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	41° 45' 00" N
Central meridian:	121° 45' 00" W
False northing:	0.000 m
False easting:	80 000.000 m
Central meridian scale:	1.000 200 (exact)

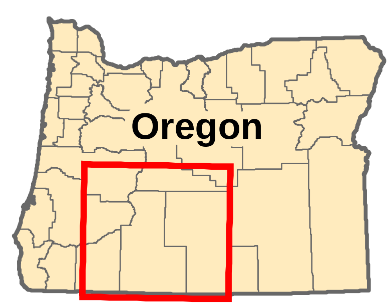
Scale 1:1,500,000
(when printed on 8-1/2" x 11" sheet)

0 10 20 30 40 50
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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Map created 7/10/2016

BEND-REDMOND-PRINEVILLE ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

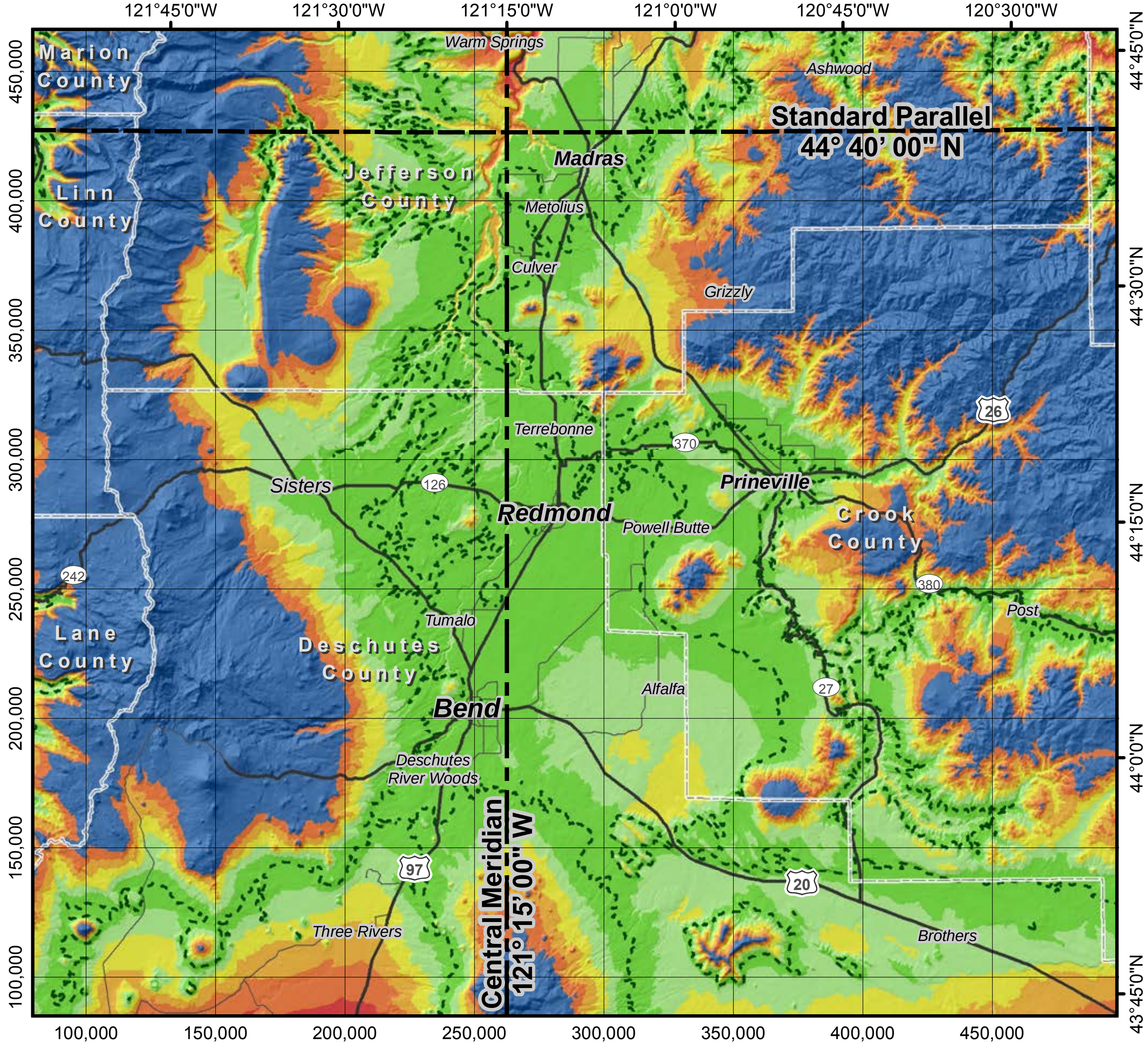
Parts of south Jefferson County, west Crook County, and Deschutes County encompassing the communities of:

Madras, Metolius, Culver, Terrebonne, Sisters, Redmond, Prineville, Powell Butte, Tumalo, Alfalfa, Bend, Brothers

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Bend-Redmond-Prineville1	44 15 35.14513	121 08 52.31624	84783.59542	88157.16577
Bend-Redmond-Prineville2	44 05 37.43097	121 12 11.97934	66327.93549	83738.15165
Bend-Redmond-Prineville3	44 18 20.44566	121 33 21.22192	89927.19462	55588.29029



Oregon Coordinate Reference System

Bend-Redmond-Prineville Zone

Lambert Conformal Conic projection (single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 44° 40' 00" N
Central meridian: 121° 15' 00" W
False northing: 130 000.000 m
False easting: 80 000.000 m
Standard parallel scale: 1.000 120 (exact)

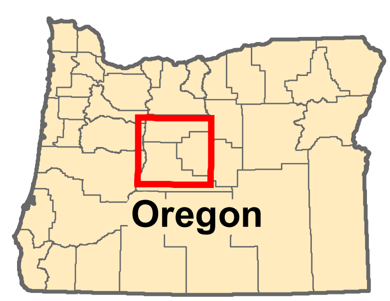
Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

Grid North

0 5 10 15 20 25
Miles

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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Geodetic Analysis

Map created 7/10/2016

BURNS-HARPER ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

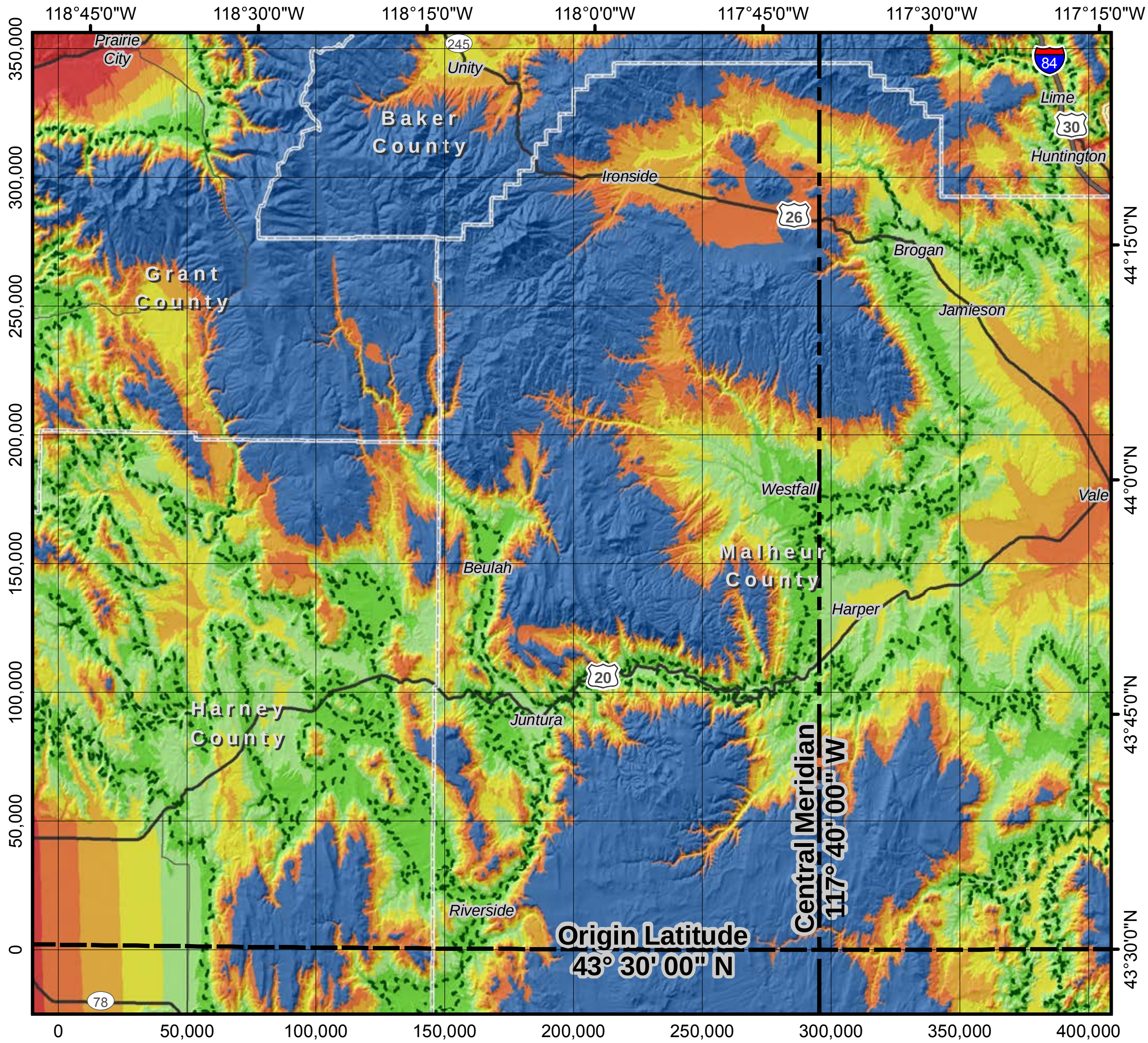
Parts of south Grant County, northeast Harney County, and Malheur County encompassing the communities of:

Beulah, Juntura, Harper, Westfall, Brogan, Riverside

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Burns-Harper1	44 15 00.00000	117 30 00.00000	83357.53001	103313.30456
Burns-Harper2	43 50 00.00000	118 30 00.00000	37378.06049	22965.20470
Burns-Harper3	43 40 00.00000	118 00 00.00000	18573.94894	63111.60573



Oregon Coordinate Reference System
Burns-Harper Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	43° 30' 00" N
Central meridian:	117° 40' 00" W
False northing:	0.000 m
False easting:	90 000.000 m
Central meridian scale:	1.000 140 (exact)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

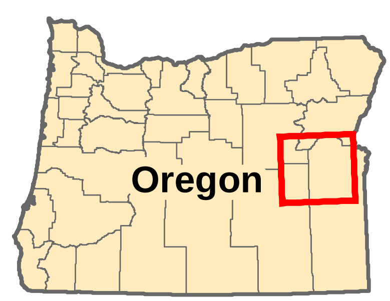
0 5 10 15 20 25
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz
Geodetic ANALYSIS

Map created 7/10/2016

CANYON CITY-BURNS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

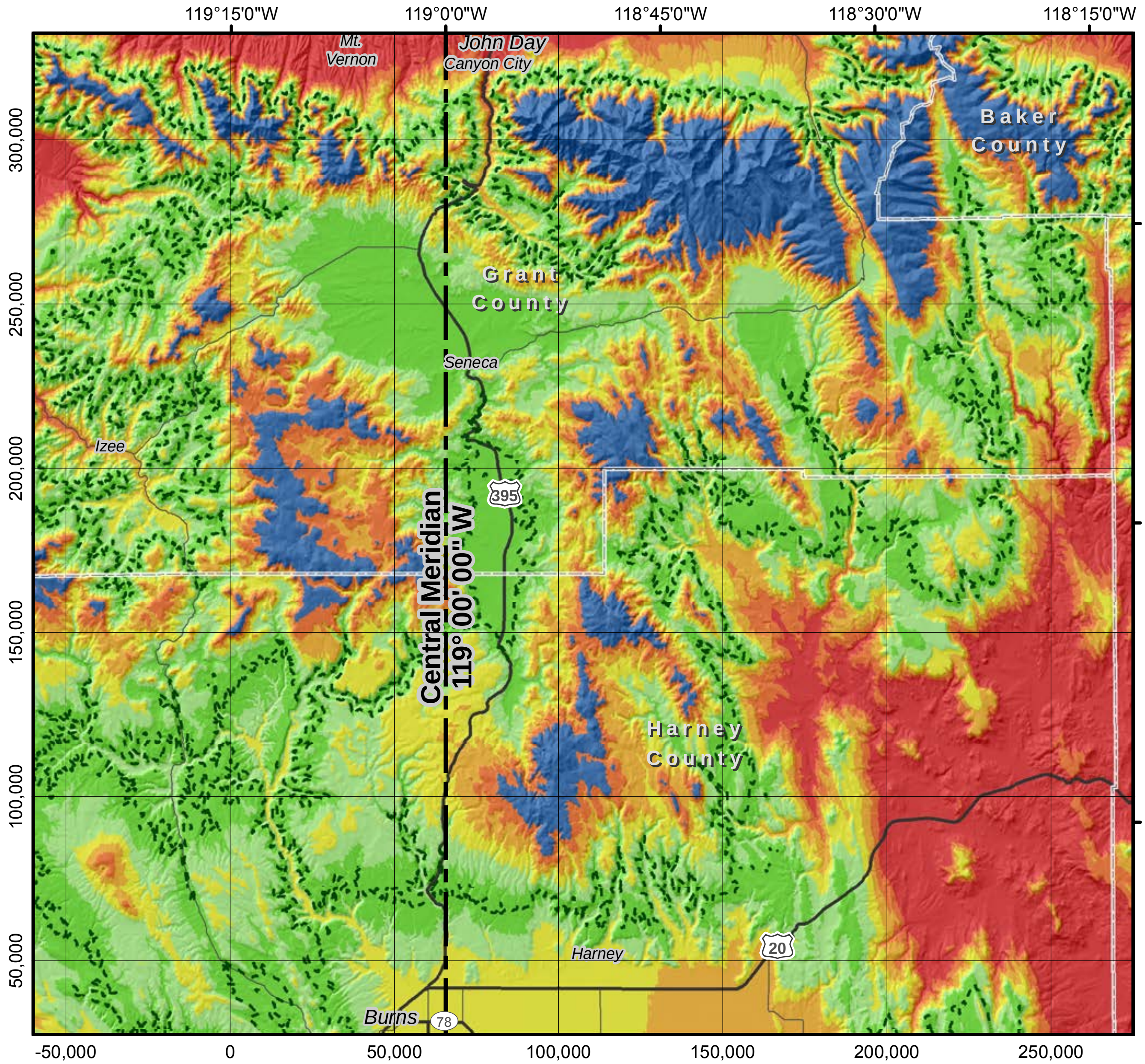
Parts of Grant County, Harney County, and southwest Baker County encompassing the communities of:

Seneca, Silvies, Trout Creek, Van, Izee

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Canyon City-Burns1	44 00 00.00000	119 00 00.00000	55565.90294	20000.00000
Canyon City-Burns2	43 50 00.00000	118 50 00.00000	37056.89883	33408.01218
Canyon City-Burns3	43 45 00.00000	118 55 00.00000	27785.71747	26713.32731



Oregon Coordinate Reference System

Canyon City-Burns Zone

Transverse Mercator projection
North American Datum of 1983

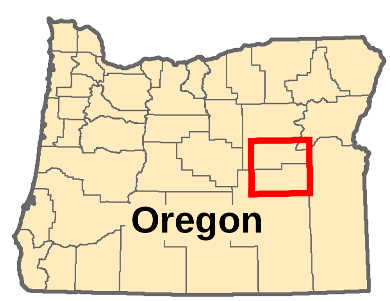
Latitude of grid origin: 43° 30' 00" N
Central meridian: 119° 00' 00" W
False northing: 0.000 m
False easting: 20 000.000 m
Central meridian scale: 1.000 220 (exact)

Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)

Grid North

0 5 10 15 20
Miles

Projected map grid is shown in units of international feet



Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Map created 6/7/2016

CANYONVILLE-GRANTS PASS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

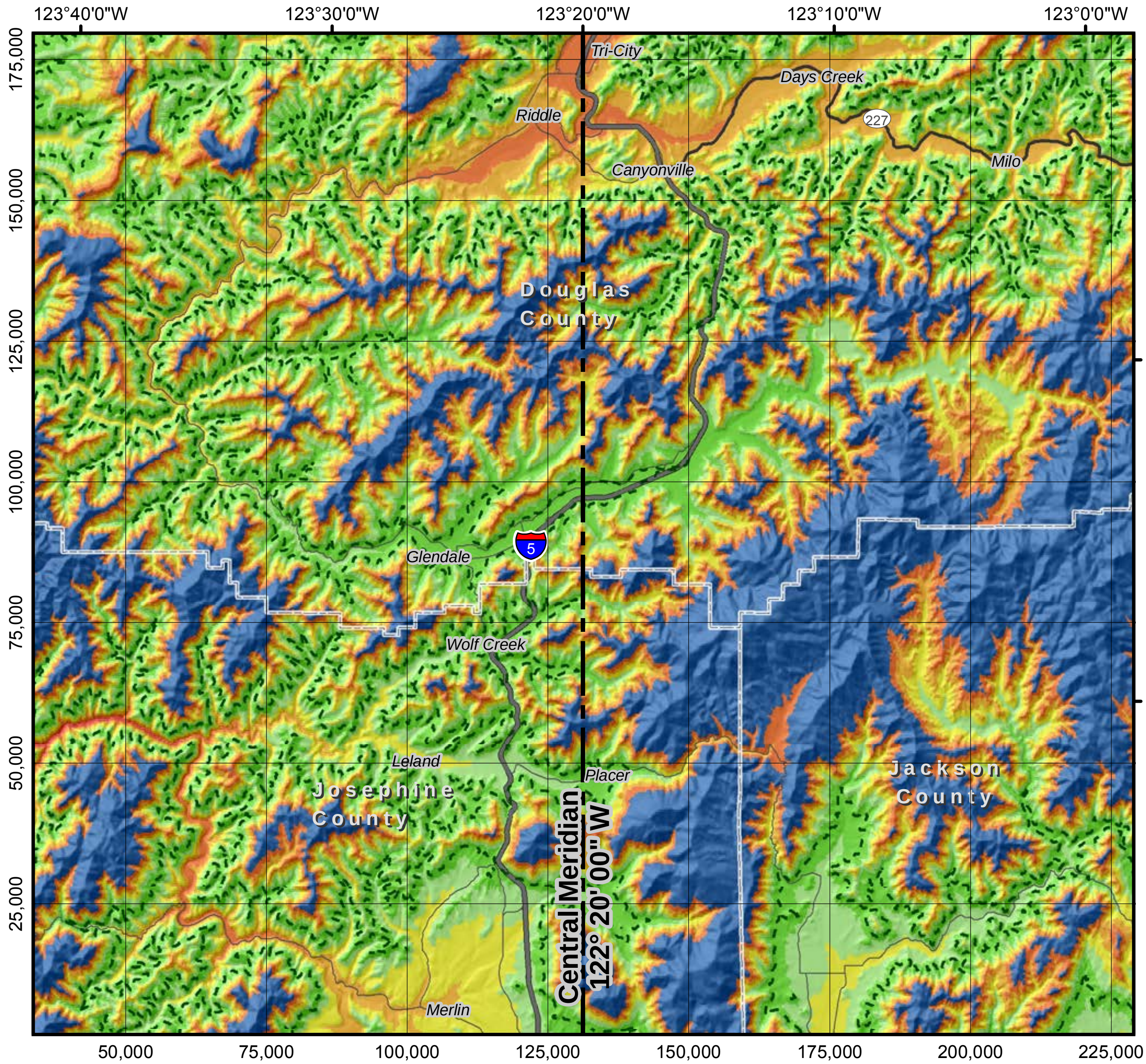
Parts of Douglas County, Josephine County, and west Jackson County encompassing the communities of:

Canyonville, Glendale, Wolf Creek, Leland, Wimer, Placer, Sunny Valley, Hugo, Three Pines

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Canyonville-Grants Pass1	42 37 15.80562	123 22 56.67677	13449.63952	35973.43780
Canyonville-Grants Pass2	42 48 41.75301	123 35 45.71429	34650.09185	18512.47686
Canyonville-Grants Pass3	42 47 56.60859	123 15 10.17963	33226.59339	46586.32144



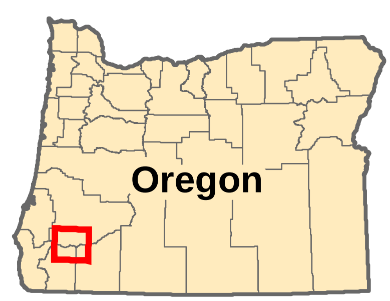
Oregon Coordinate Reference System

Canyonville-Grants Pass Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	42° 30' 00" N
Central meridian:	123° 20' 00" W
False northing:	0.000 m
False easting:	40 000.000 m
Central meridian scale:	1.000 070 (exact)

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:350,000
(when printed on 8-1/2" x 11" sheet)

0 5 10
Miles

Grid North

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Geodetic ANALYSIS

Map created 7/8/2016

COAST RANGE NORTH ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

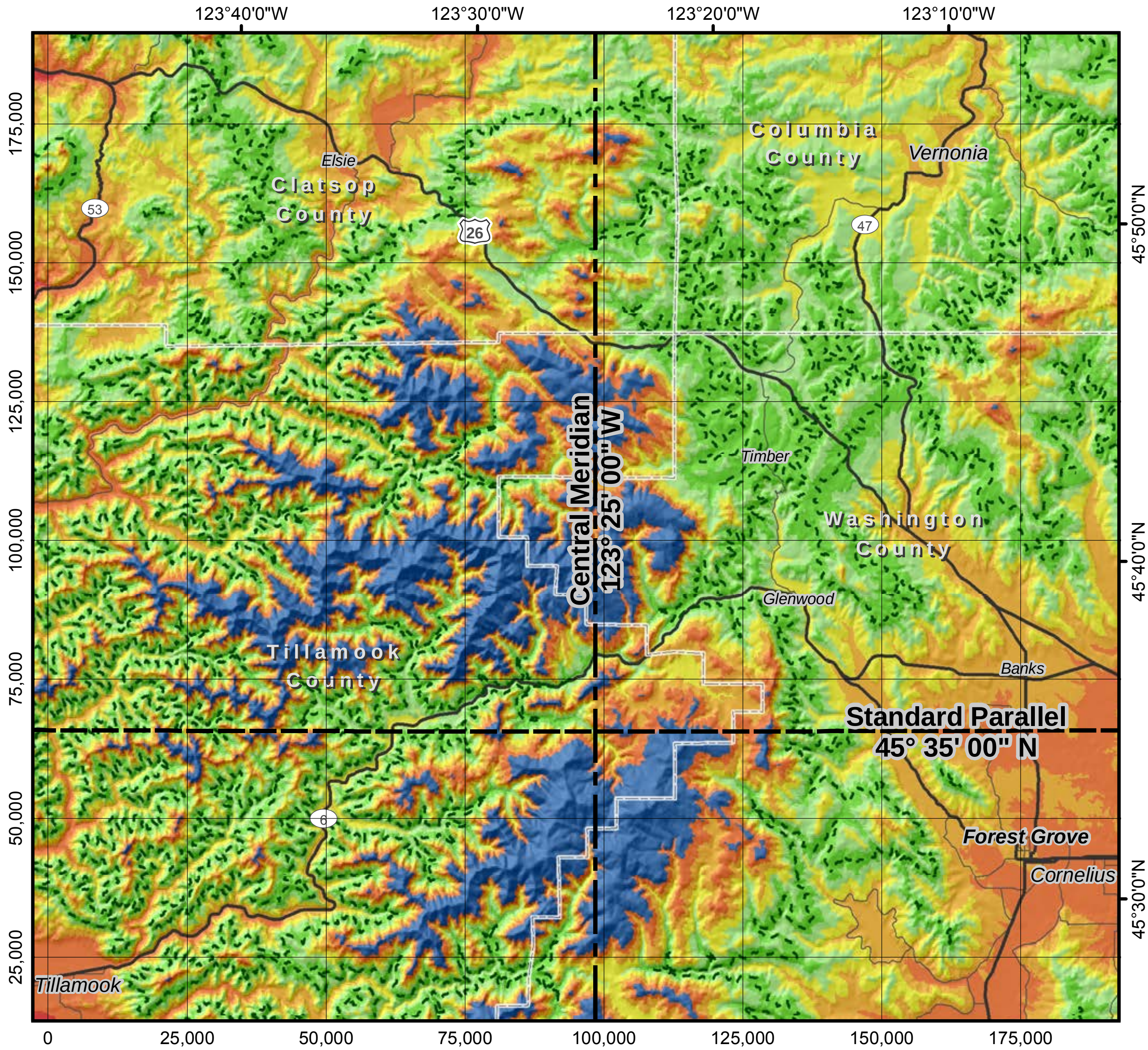
Parts of south Clatsop County, south Columbia County, east Tillamook and west Washington County encompassing the communities of:

Keasey, Clear Creek, Timber, Glenwood, Gales Creek, Jordan Creek, Cherry Grove

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Coast Range North1	45 50 00.00000	123 10 00.00000	47818.01306	49424.91472
Coast Range North2	45 40 00.00000	123 40 00.00000	29292.77904	10517.34959
Coast Range North3	45 35 00.00000	123 25 00.00000	20000.00000	30000.00000



Oregon Coordinate Reference System

Coast Range North Zone

Lambert Conformal Conic projection (single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 45° 35’ 00" N
Central meridian: 123° 25’ 00" W
False northing: 20 000.000 m
False easting: 30 000.000 m
Standard parallel scale: 1.000 045 (exact)

Scale 1:350,000
(when printed on 8-1/2" x 11" sheet)

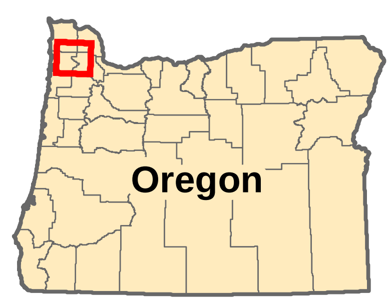
0 5 10
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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Geodetic ANALYSIS

Map created 6/7/2016

COLUMBIA RIVER EAST ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

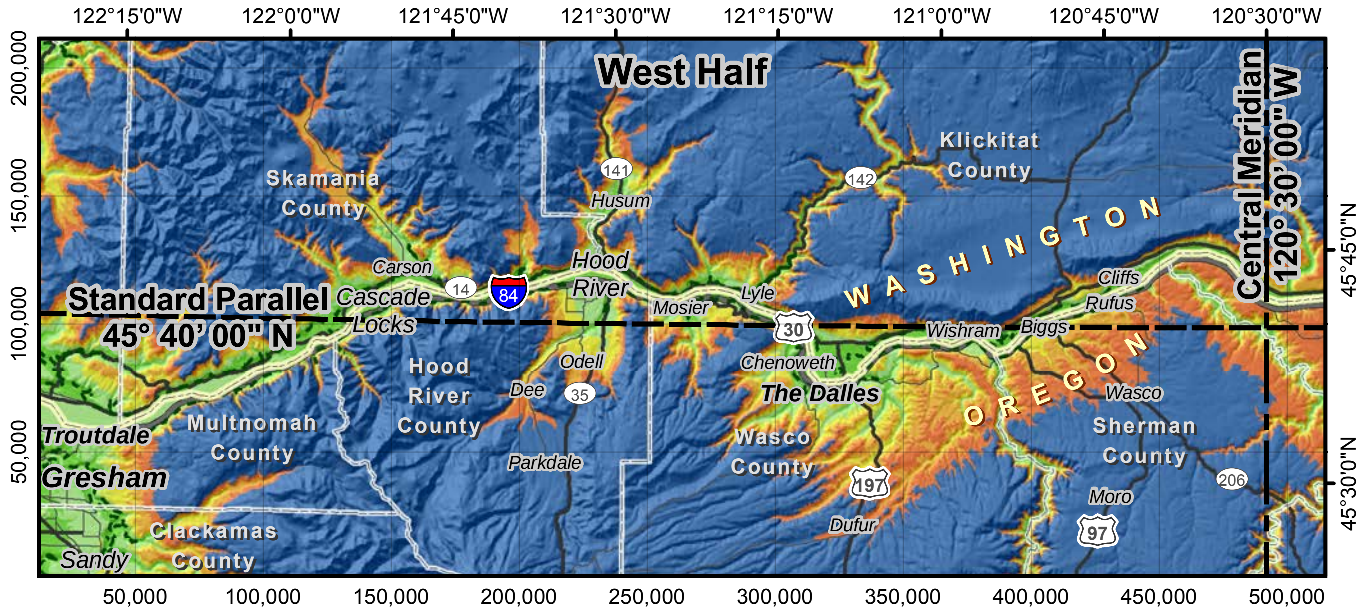
Parts of east Multnomah County, north Hood River County, north Wasco County, north Sherman County, north Gilliam County, north Morrow County, and north Umatilla County encompassing the communities of:

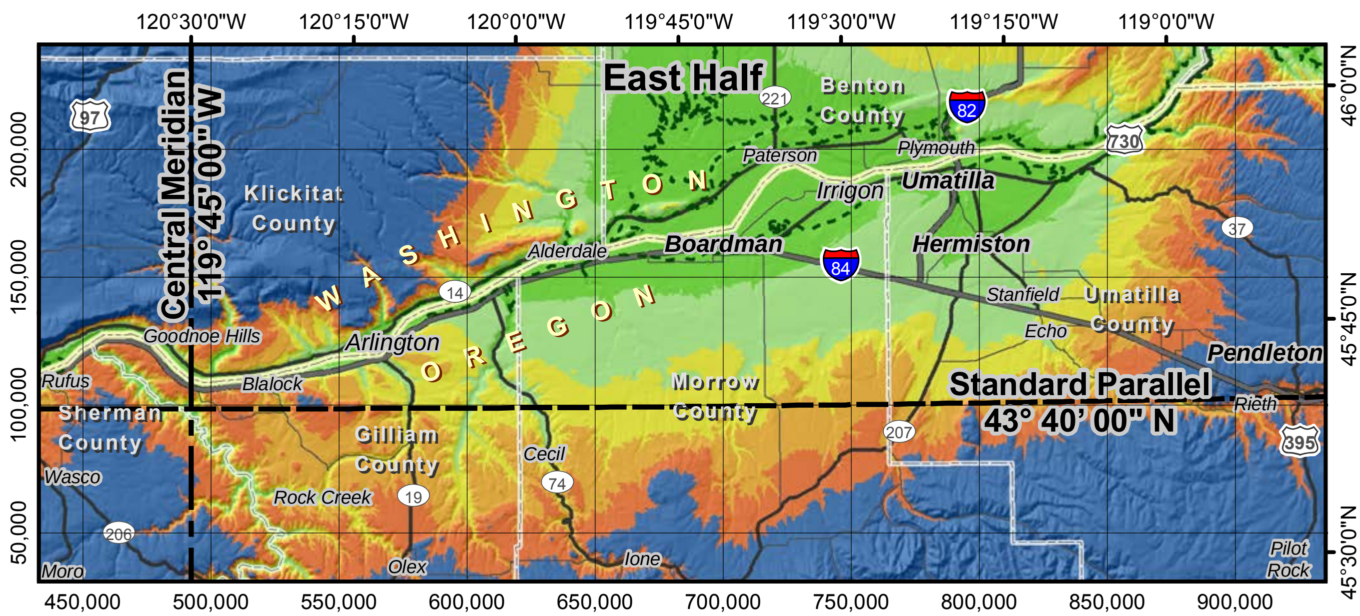
Gresham, Troutdale, Cascade Locks, Hood River, Mosier, Odell, Chenoweth, The Dalles, Biggs, Rufus, Blalock, Arlington, Boardman, Umatilla, Hermiston, Stanfield

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Columbia River East1	45 36 41.82270	122 01 15.12506	25007.74017	31373.11293
Columbia River East2	45 37 22.73728	121 58 40.65328	26208.05388	34742.89853
Columbia River East3	45 40 20.31754	121 52 36.28740	31549.15733	42729.28899





Oregon Coordinate Reference System

Columbia River East Zone

Lambert Conformal Conic projection (single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 45° 40' 00" N
Central meridian: 120° 30' 00" W
False northing: 30 000.000 m
False easting: 150 000.000 m
Standard parallel scale: 1.000 008 (exact)

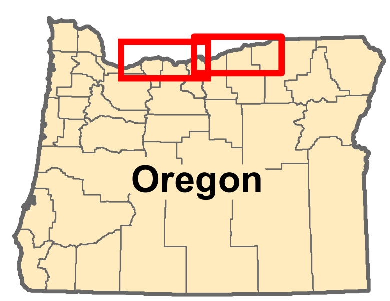
Scale 1:900,000
(when printed on 8-1/2" x 11" sheet)

0 10 20 30
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz
Geodetic Analysis

Map created 7/10/2016

COLUMBIA RIVER WEST ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

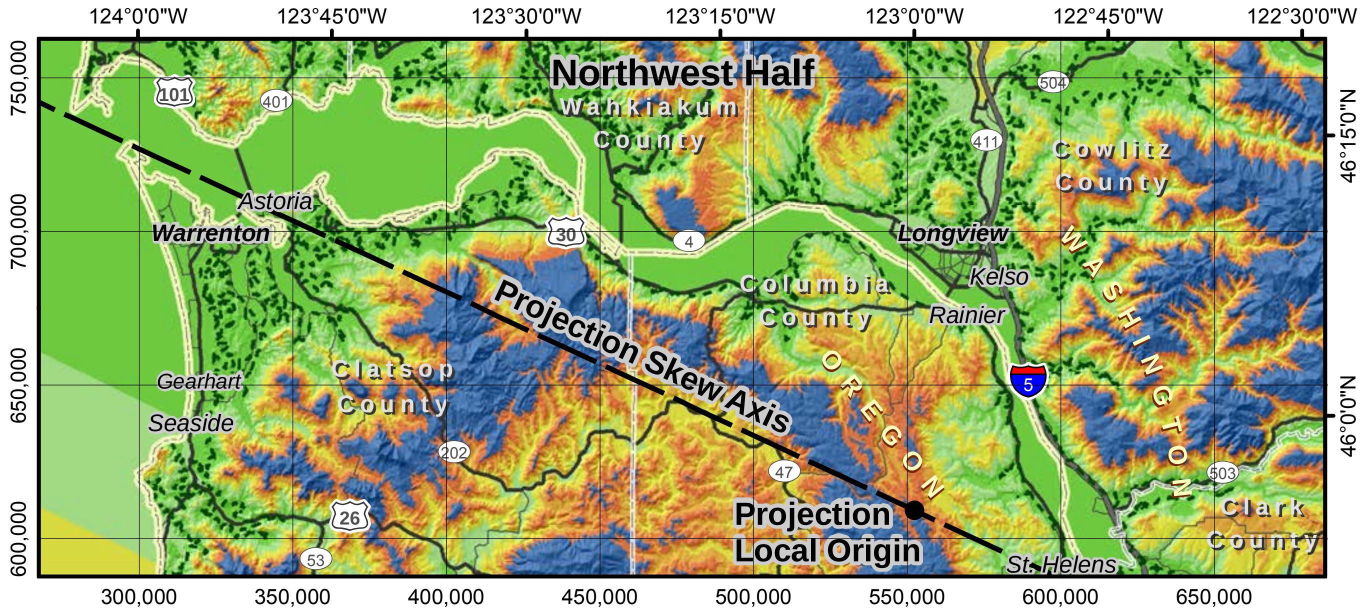
Parts of Clatsop County, Columbia County, east Washington County, north Multnomah County, and north Hood River County encompassing the communities of:

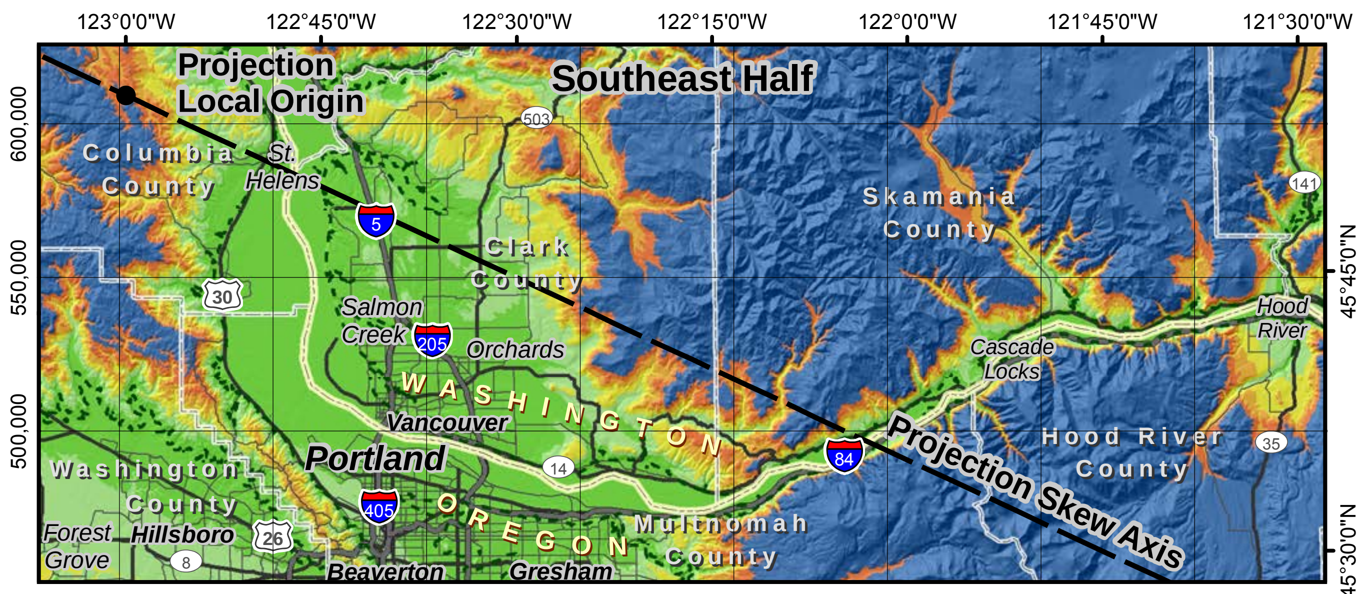
Warrenton, Astoria, Rainier, St. Helens

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Columbia River West1	46 12 17.57866	123 57 21.88345	218152.78553	94514.71992
Columbia River West2	45 46 15.02108	122 51 37.48609	169474.85476	179157.87759
Columbia River West3	46 10 24.21823	123 49 55.47899	214545.28450	104047.54956





Oregon Coordinate Reference System

Columbia River West Zone

Oblique Mercator projection
North American Datum of 1983

Latitude of local origin:	45° 55' 00" N
Longitude of local origin:	123° 00' 00" W
False northing:	-3 000 000.000 m
False easting:	7 000 000.000 m
Projection skew axis scale:	1.000 000 (exact)
Skew axis azimuth at origin:	-65° 00' 00"

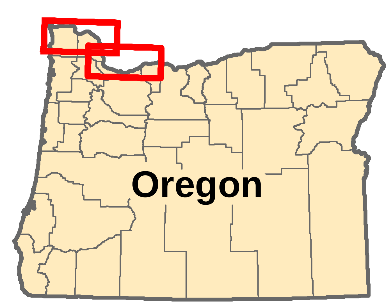
Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

Grid North

0 5 10 15 20 25

Miles

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Geodetic ANALYSIS

Map created 7/11/2016

COTTAGE GROVE-CANYONVILLE ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

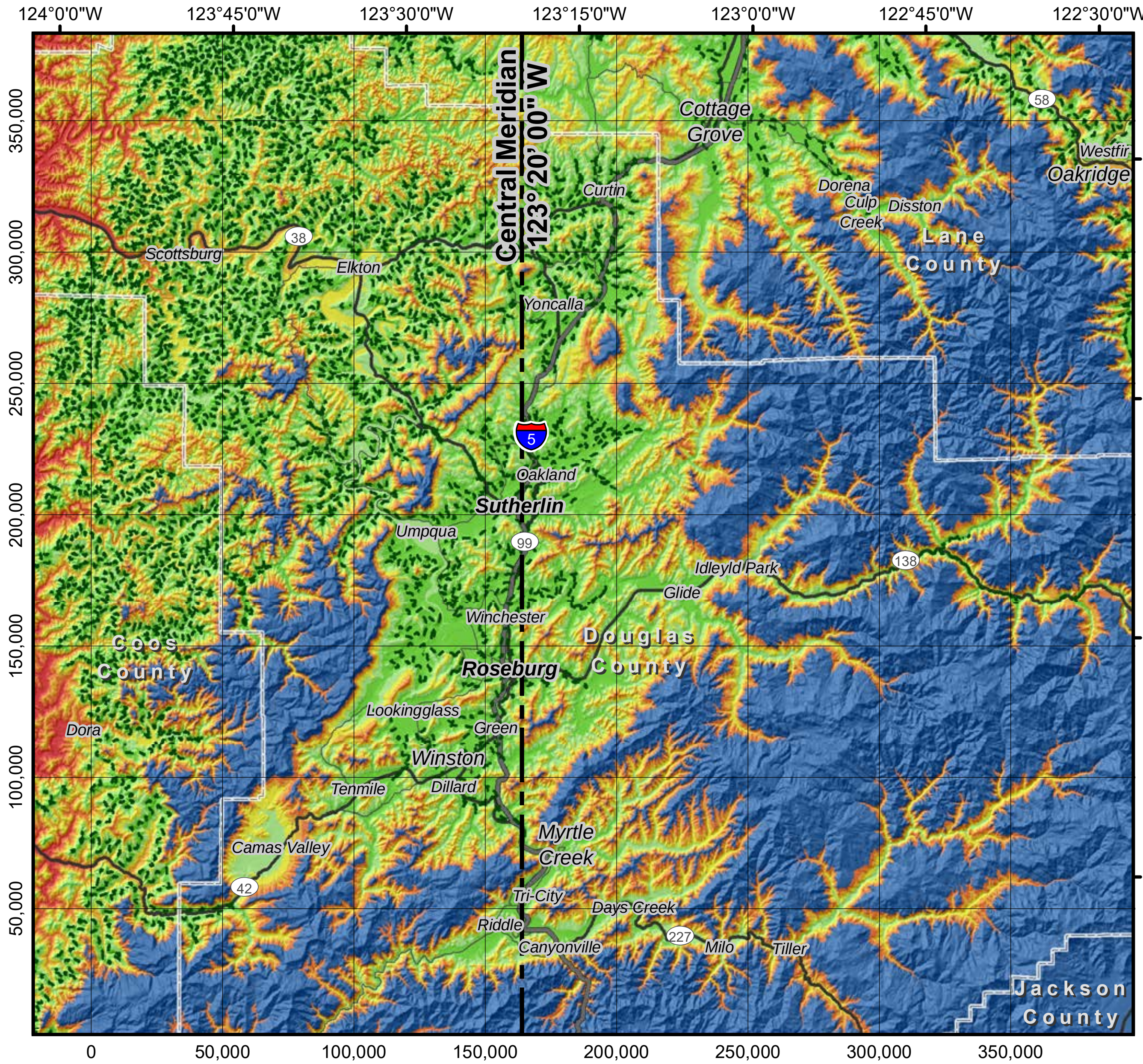
Parts of south Lane County and Douglas County encompassing the communities of:

Cottage Grove, Curtin, Scottsburg, Elkton, Yoncalla, Westfir, Oakridge, Oakland, Sutherlin, Umpqua, Winchester, Glide, Idleyld Park, Roseburg, Lookingglass, Green, Winston, Tenmile, Dillard, Camas Valley, Myrtle Creek, Tri-City, Days Creek, Riddle, Canyonville

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Cottage Grove-Canyonville1	43 12 39.61530	123 20 29.39067	41957.65613	49336.56065
Cottage Grove-Canyonville2	43 13 57.45207	123 21 19.11848	44359.97917	48214.67944
Cottage Grove-Canyonville3	43 42 20.44764	123 14 15.15491	96922.63912	57721.03085



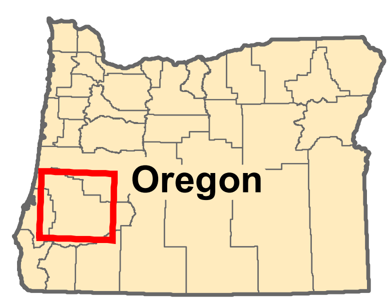
Oregon Coordinate Reference System

Cottage Grove-Canyonville Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 42° 50' 00" N
Central meridian: 123° 20' 00" W
False northing: 0.000 m
False easting: 50 000.000 m
Central meridian scale: 1.000 023 (exact)

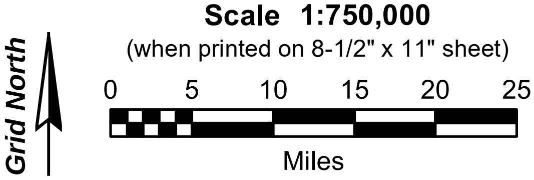
Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Map created 8/10/2016

DAYVILLE-PRAIRIE CITY ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

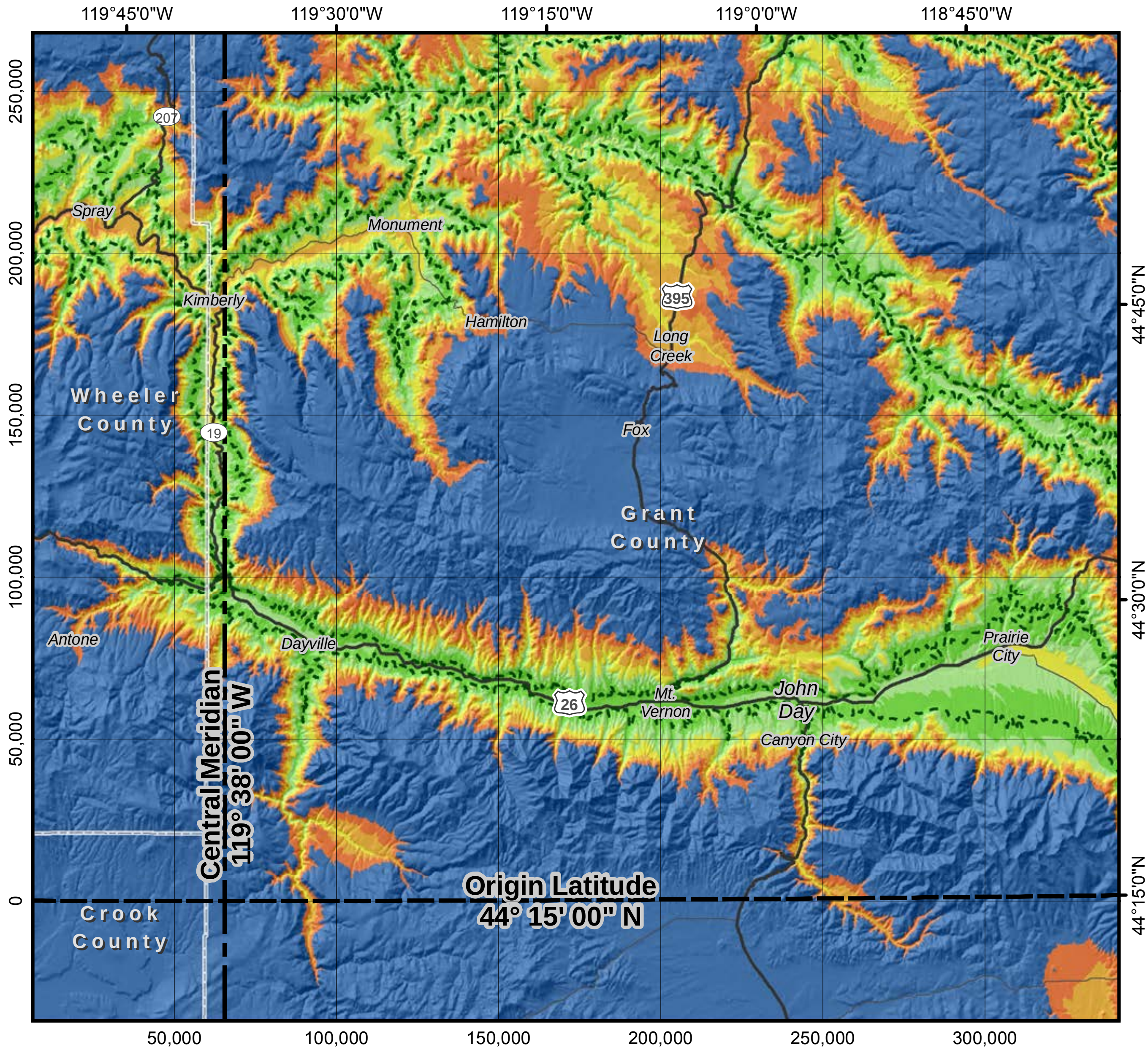
Parts of Grant County encompassing the communities of:

Spray, Kimberly, Monument, Hamilton, Dayville, Mt. Vernon, John Day, Canyon City, Prairie

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Dayville-Prairie City1	44 30 00.00000	118 45 00.00000	28162.85184	90259.59645
Dayville-Prairie City2	44 45 00.00000	119 30 00.00000	55576.32133	30559.79476
Dayville-Prairie City3	44 25 00.00000	119 15 00.00000	18593.50024	50533.39266



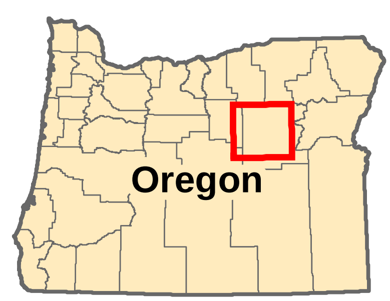
Oregon Coordinate Reference System

Dayville-Prairie City Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	44° 15' 00" N
Central meridian:	119° 38' 00" W
False northing:	0.000 m
False easting:	20 000.000 m
Central meridian scale:	1.000 120 (exact)

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)

0 5 10 15 20
Miles

Grid North

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz
Geodetic ANALYSIS

Map created 6/7/2016

DENIO-BURNS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

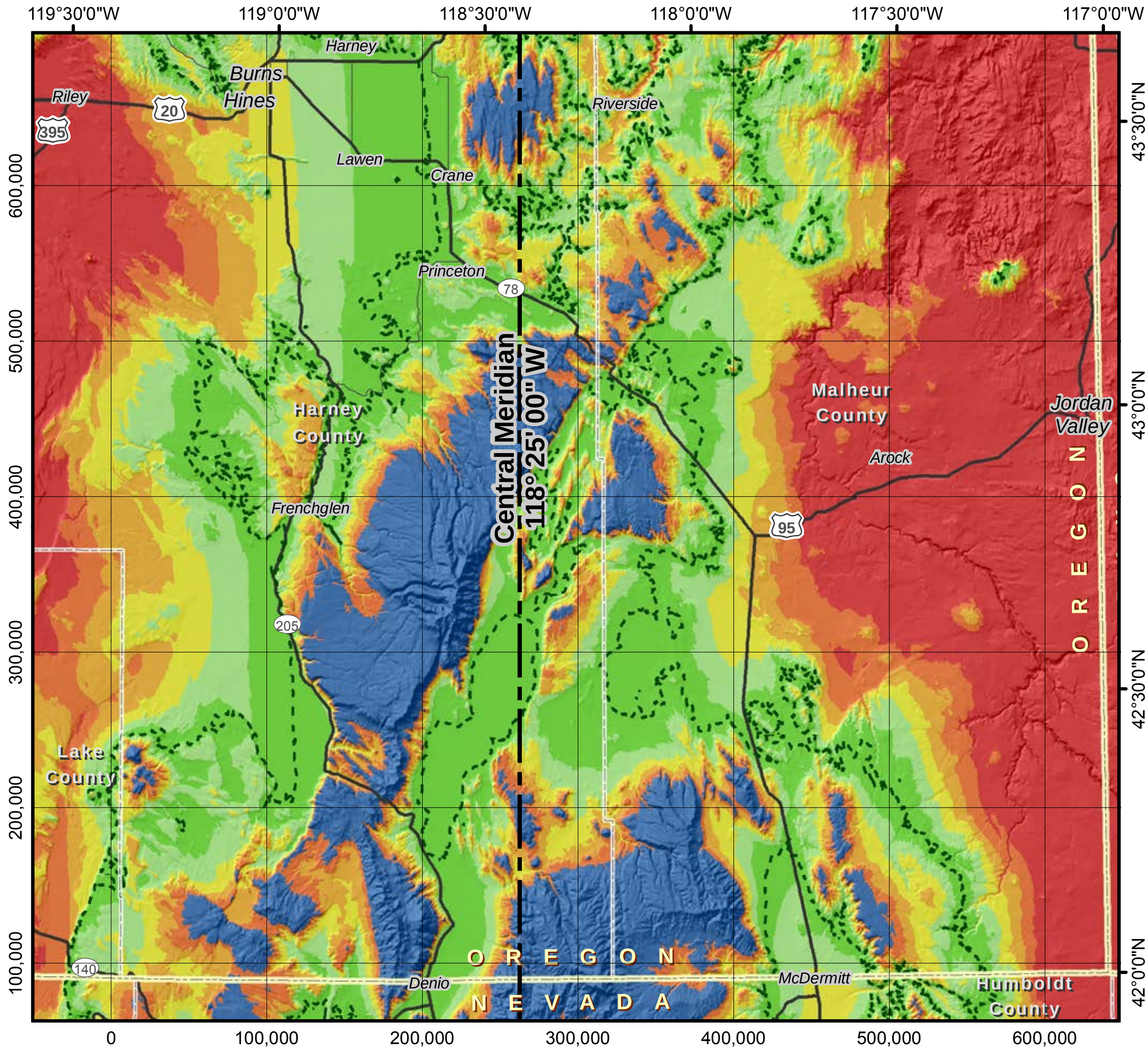
Parts of Harney County and Malheur County encompassing the communities of:

Harney, Lawen, Crane, Riverside, Princeton, Frenchglen, McDermitt

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Denio-Burns Zone1	43 25 00.00000	118 55 00.00000	185297.68973	39498.36436
Denio-Burns Zone2	43 00 00.00000	118 00 00.00000	138961.36998	113981.88003
Denio-Burns Zone3	42 15 00.00000	118 25 00.00000	55547.19416	80000.00000



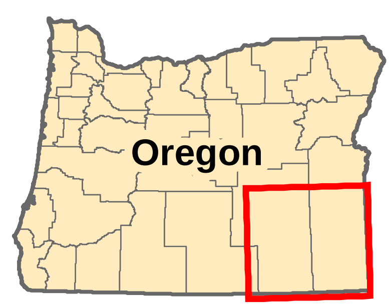
Oregon Coordinate Reference System

Denio-Burns Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 41° 45' 00" N
Central meridian: 118° 25' 00" W
False northing: 0.000 m
False easting: 80 000.000 m
Central meridian scale: 1.000 190 (exact)

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:1,250,000
(when printed on 8-1/2" x 11" sheet)

0 10 20 30 40
Miles

Grid North

Prepared by:
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mld@geodetic.xyz

Geodetic ANALYSIS

Map created 6/7/2016

DUFUR-MADRAS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

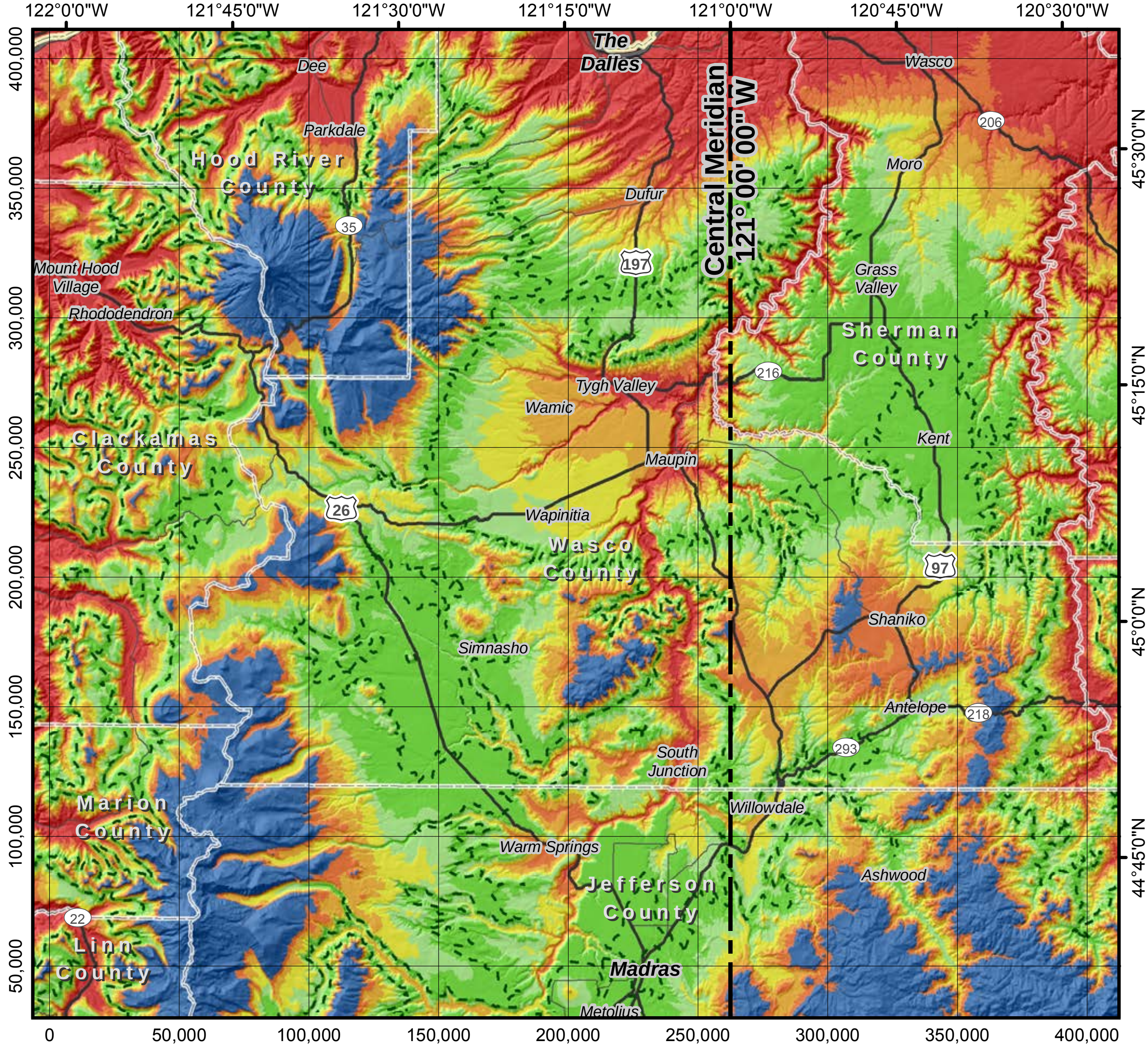
Parts of east Clackamas County, Sherman County, Wasco County, east Marion County, east Linn County, and north Jefferson County encompassing the communities of:

Dufur, Moro, Grass Valley, Kent, Tygh Valley, Wamic, Maupin, Wapinitia, Simnasho, Shaniko, Antelope, South Junction, Willowdale, Warm Springs, Ashwood, Madras

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Dufur-Madras1	45 30 08.26496	121 12 34.44887	111420.55961	63619.34714
Dufur-Madras2	44 48 58.86147	120 41 19.69993	35205.45835	104617.66329
Dufur-Madras3	44 51 05.56605	121 09 28.82604	39082.16381	67508.12646



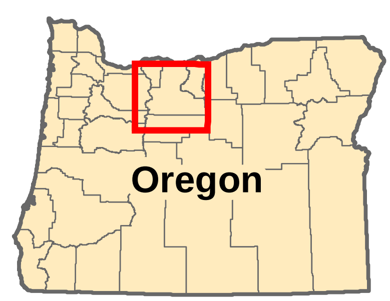
Oregon Coordinate Reference System

Dufur-Madras Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 44° 30’ 00" N
Central meridian: 121° 00’ 00" W
False northing: 0.000 m
False easting: 80 000.000 m
Central meridian scale: 1.000 110 (exact)

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

0 5 10 15 20 25
Miles

Grid North

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Map created 7/10/2016

EUGENE ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

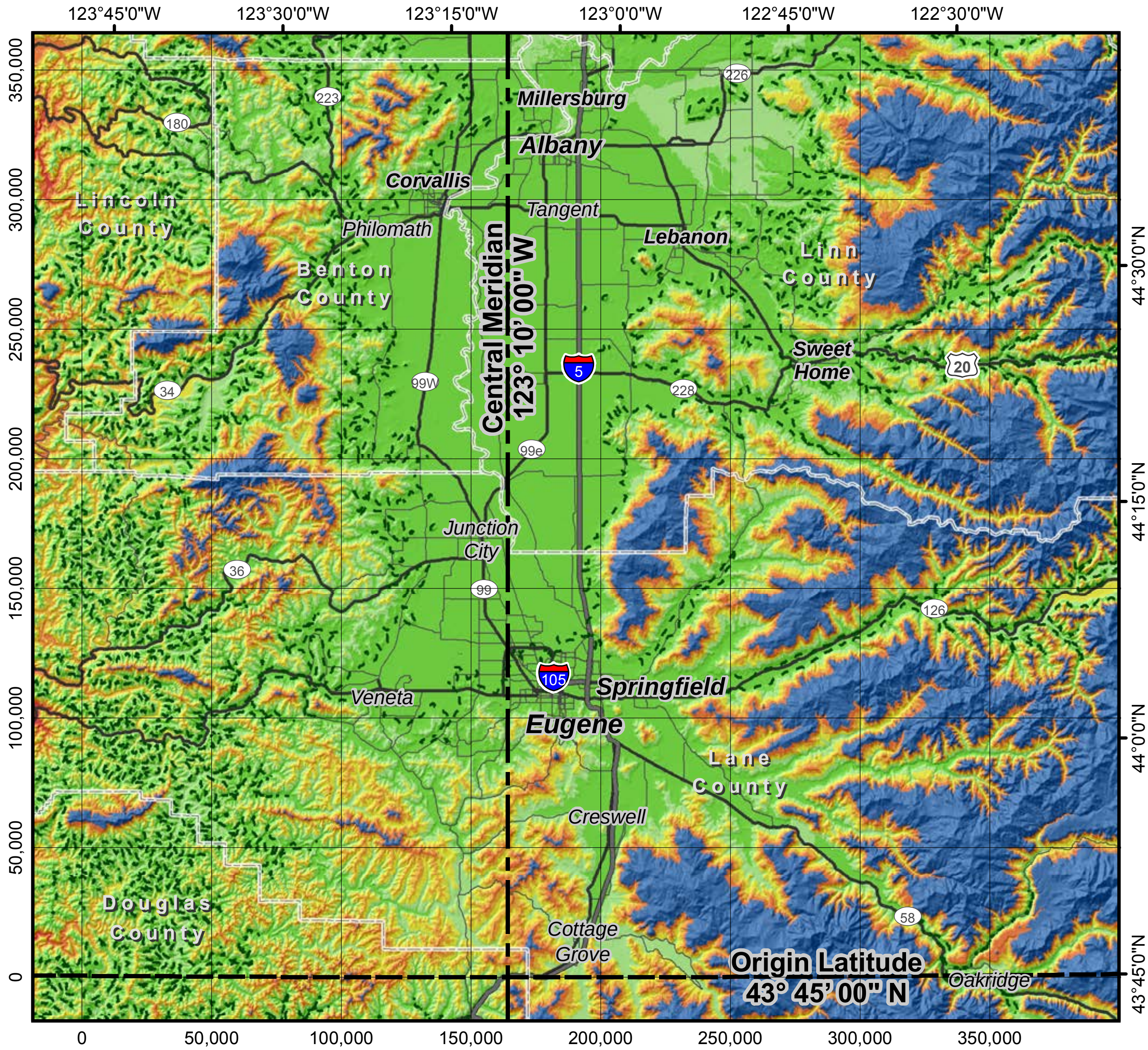
Parts of Benton County, Linn County, and Lane County encompassing the communities of:

Albany, Corvallis, Philomath, Tangent, Lebanon, Sweet Home, Junction City, Veneta, Eugene, Springfield, Creswell

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Eugene1	44 03 57.45763	123 05 53.28029	35109.31719	55490.78035
Eugene2	44 35 07.91068	123 18 16.51921	92851.07880	39047.00734
Eugene3	44 03 04.40693	123 05 24.25020	33472.46085	56138.37116



Oregon Coordinate Reference System

Eugene Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	43° 45' 00" N
Central meridian:	123° 10' 00" W
False northing:	0.000 m
False easting:	50 000.000 m
Central meridian scale:	1.000 015 (exact)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

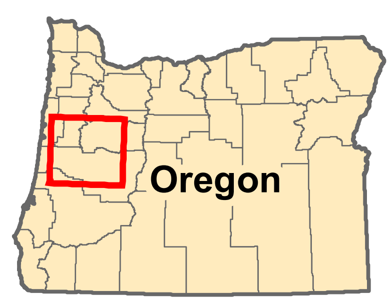
0 5 10 15 20 25
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Map created 7/10/2016

GRANTS PASS-ASHLAND ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

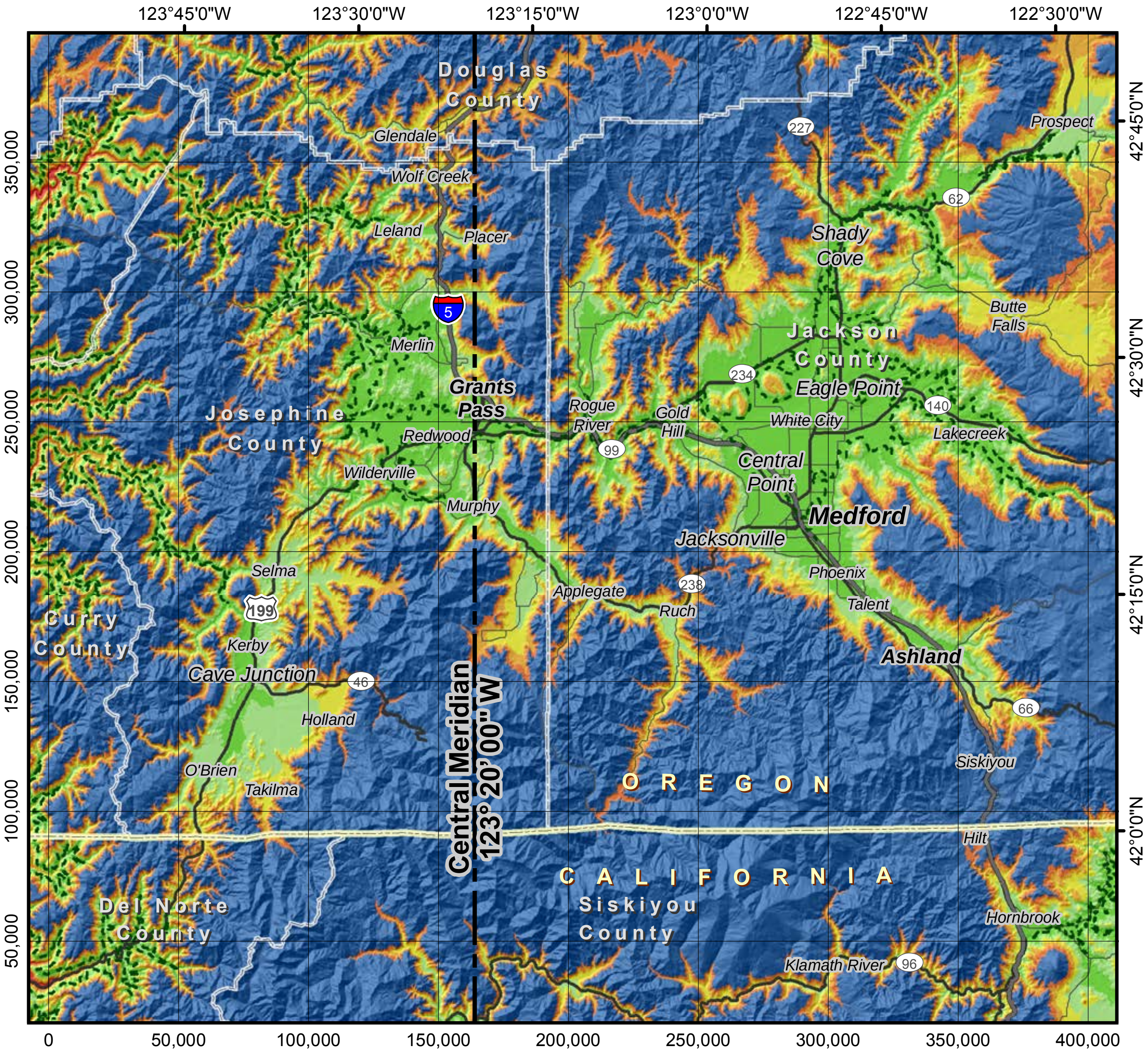
Parts of Josephine County, and Jackson County encompassing the communities of:

Merlin, Grants Pass, Redwood, Wilderville, Selma, Kerby, Cave Junction, O'Brien, Murphy, Rogue River, Gold Hill, Eagle Point, White City, Central Point, Lakecreek, Medford, Jacksonville, Phoenix, Talent, Ashland

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Grants Pass-Ashland1	42 06 16.06850	123 40 53.51268	39431.29476	21197.50808
Grants Pass-Ashland2	42 12 56.39712	122 42 25.17018	51915.05751	101719.61390
Grants Pass-Ashland3	42 22 01.47650	122 52 28.13141	68646.39250	87798.66183



Oregon Coordinate Reference System

Grants Pass-Ashland Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 41° 45' 00" N
Central meridian: 123° 20' 00" W
False northing: 0.000 m
False easting: 50 000.000 m
Central meridian scale: 1.000 043 (exact)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

0 5 10 15 20 25

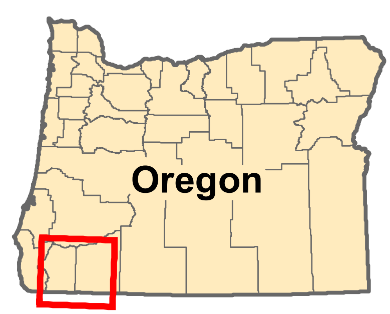
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Geodetic ANALYSIS

Map created 7/10/2016

GRESHAM-WARM SPRINGS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

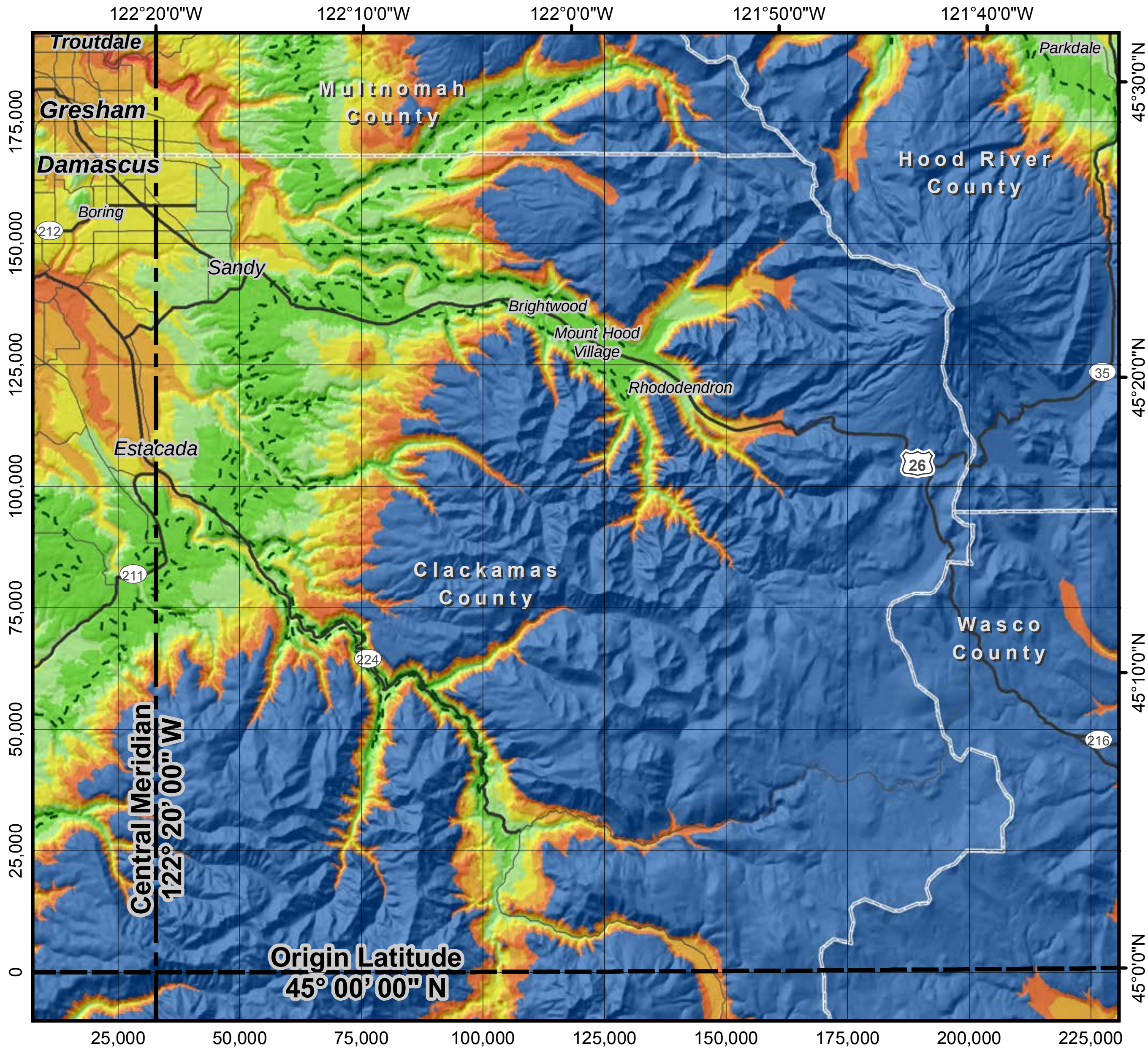
Parts of Multnomah County, Hood River County and Clackamas County encompassing the communities of:

Boring, Sandy, Brightwood, Mt. Hood Village, Rhododendron, Estacada, Parkdale

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Gresham-Warm Springs1	45 26 55.28190	122 08 55.83937	49884.67201	24433.12050
Gresham-Warm Springs2	45 27 14.92001	122 16 12.82641	50476.35587	14936.31760
Gresham-Warm Springs3	45 27 35.13762	122 34 20.65976	51126.42321	-8699.65627



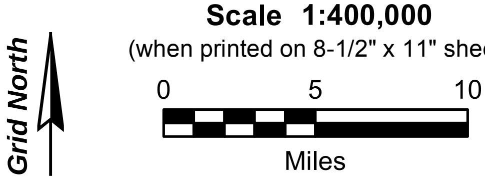
Oregon Coordinate Reference System

Gresham-Warm Springs Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 45° 00' 00" N
Central meridian: 122° 20' 00" W
False northing: 0.000 m
False easting: 10 000.000 m
Central meridian scale: 1.000 050 (exact)

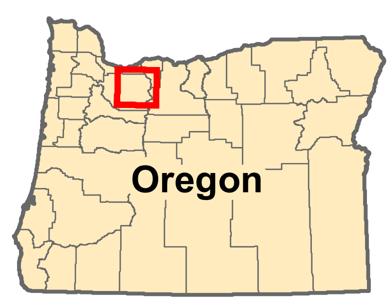
Scale 1:400,000
(when printed on 8-1/2" x 11" sheet)



Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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mld@geodetic.xyz
Geodetic Analysis

Map created 7/8/2016

HALFWAY ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

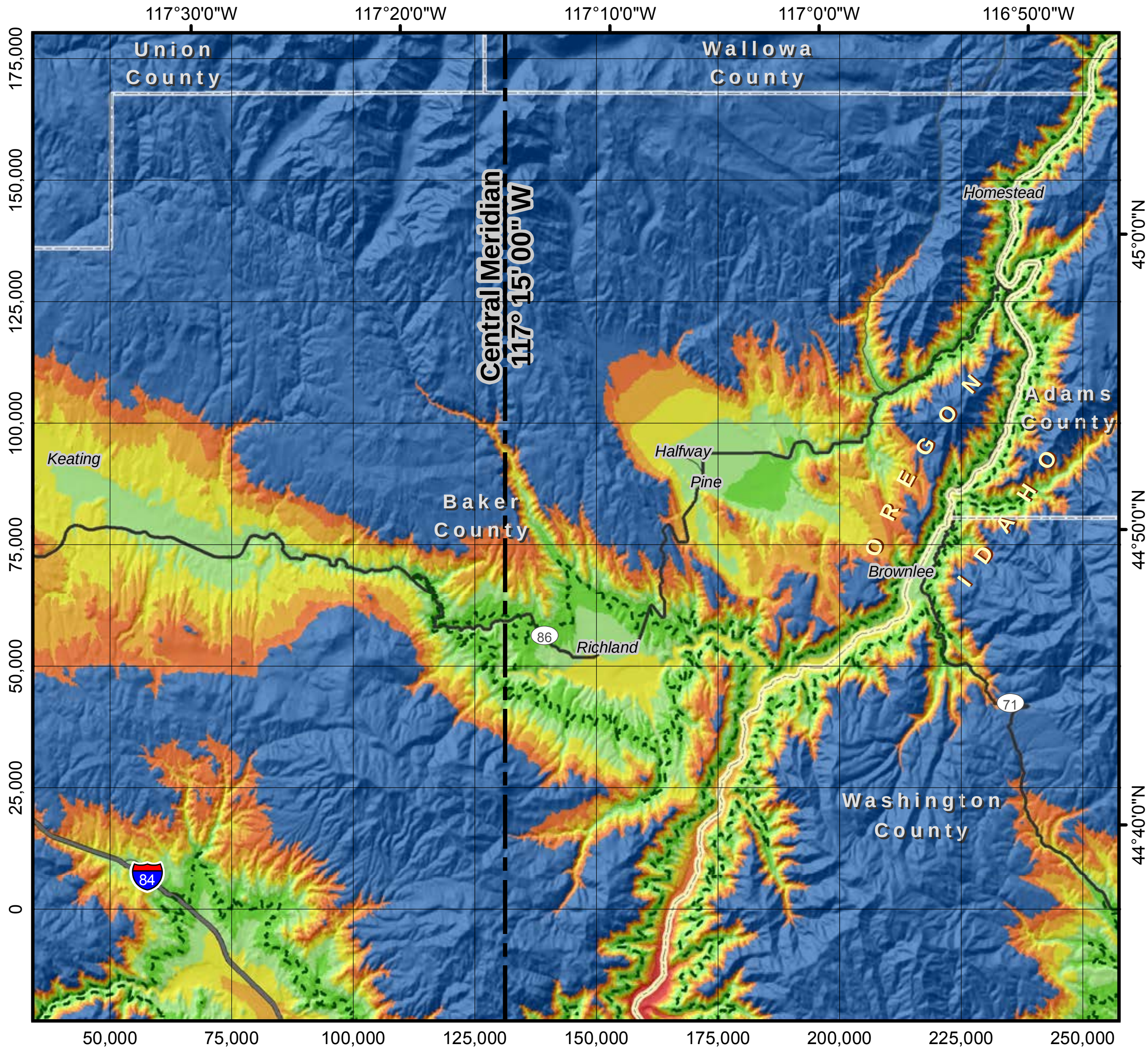
Parts of Baker County, Adams County, Washington County and southeast Wallowa County encompassing the communities of:

Keating, Richland, Halfway, Pine, Brownlee, Homestead

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Halfway1	45 50 00.00000	117 30 00.00000	134869.77436	20573.48558
Halfway2	45 00 00.00000	117 15 00.00000	42213.99556	40000.00000
Halfway3	44 44 00.00000	117 10 00.00000	12579.75429	46601.80257



Oregon Coordinate Reference System

Halfway Zone

Lambert Conformal Conic projection (single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 45° 15' 00" N
Central meridian: 117° 15' 00" W
False northing: 70 000.000 m
False easting: 40 000.000 m
Standard parallel scale: 1.000 085 (exact)

Scale 1:400,000
(when printed on 8-1/2" x 11" sheet)

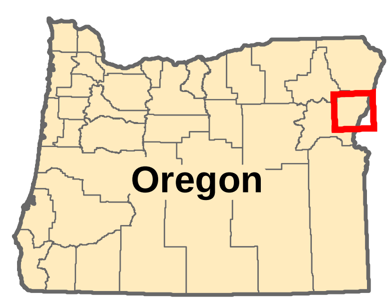
0 5 10
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Map created 6/7/2016

LA GRANDE ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

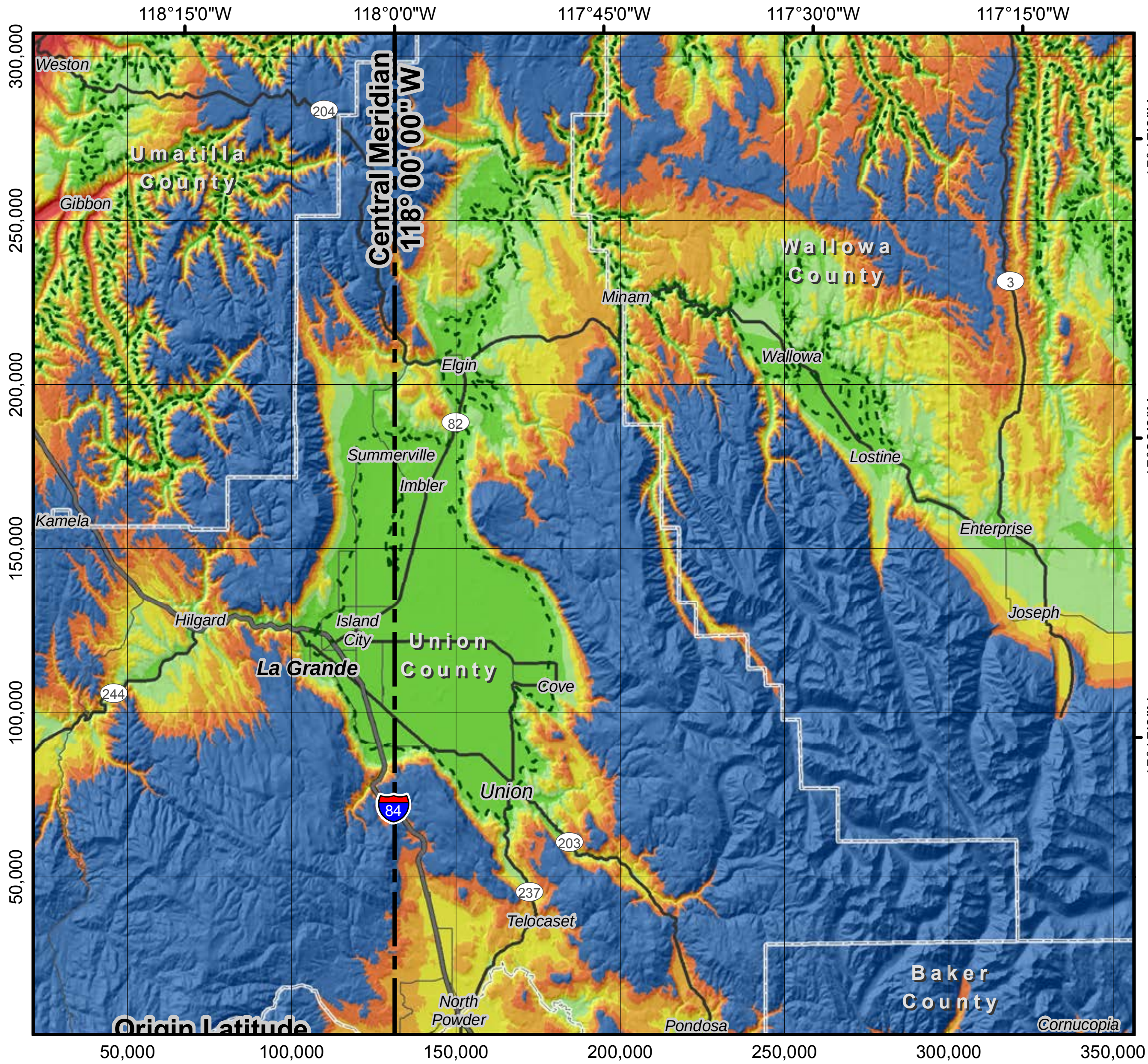
Parts of east Umatilla County, Wallowa County, and Union County encompassing the communities of:

Weston, Elgin, Minam, Wallowa, Lostine, Enterprise, Joseph, Summerville, Imbler, Island City, Hilgard, La Grande, Cove, Union

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
La Grande1	45 17 13.18990	118 00 45.92076	31899.53873	38999.15169
La Grande2	45 17 15.70482	118 00 43.70866	31977.18073	39047.37636
La Grande3	45 17 48.36576	117 49 12.11261	33001.29294	54118.35633

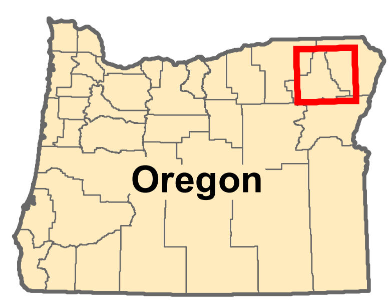


Oregon Coordinate Reference System
La Grande Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	45° 00' 00" N
Central meridian:	118° 00' 00" W
False northing:	0.000 m
False easting:	40 000.000 m
Central meridian scale:	1.000 130 (exact)

Projected map grid is shown in units of international feet



Linear distortion
- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)

0 5 10 15 20
Miles

Grid North

Prepared by:
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mld@geodetic.xyz

Map created 7/10/2016

MEDFORD-DIAMOND LAKE ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

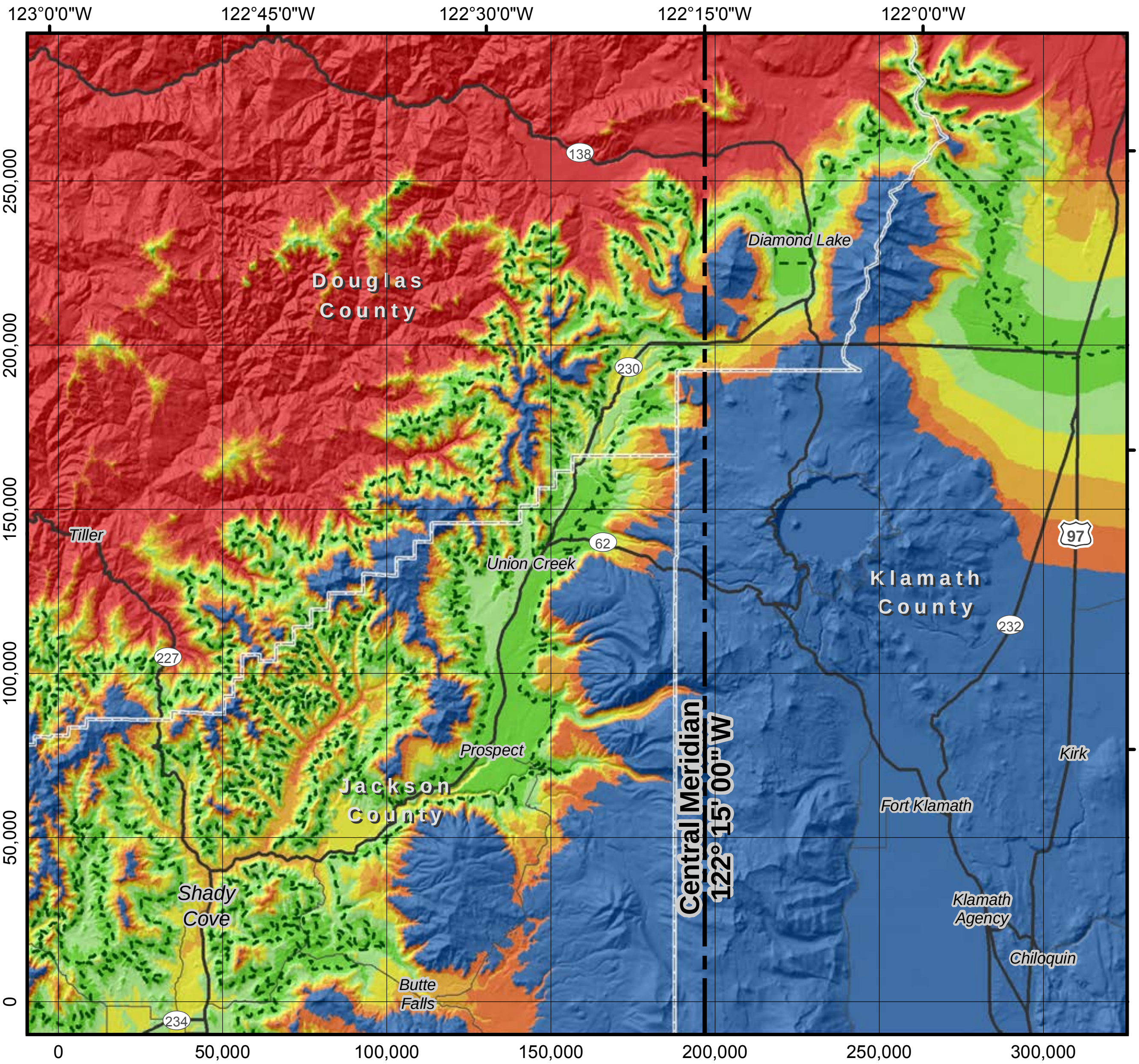
Parts of east Douglas, north Jackson, and northwest Klamath County encompassing the communities of:

Diamond Lake, Union Creek, Prospect, Shady Cove, Butte Falls

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Medford-Diamond Lake1	42 40 00.00000	122 45 00.00000	14177.49480	19005.63839
Medford-Diamond Lake2	43 15 00.00000	122 00 00.00000	78903.02981	80308.03073
Medford-Diamond Lake3	42 45 00.00000	122 30 00.00000	23346.02212	39529.76273



Oregon Coordinate Reference System

Medford-Diamond Lake Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 42° 00' 00" N
Central meridian: 122° 15' 00" W
False northing: -60 000.000 m
False easting: 60 000.000 m
Standard parallel scale: 1.000 040 (exact)

Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)

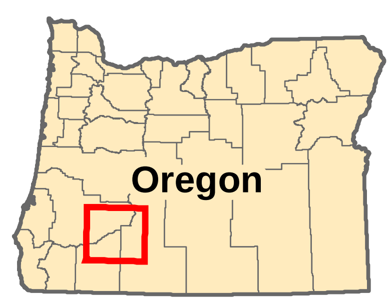
Grid North

0 5 10 15 20
Miles

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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Geodetic Analysis

Map created 6/7/2016

MITCHELL ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

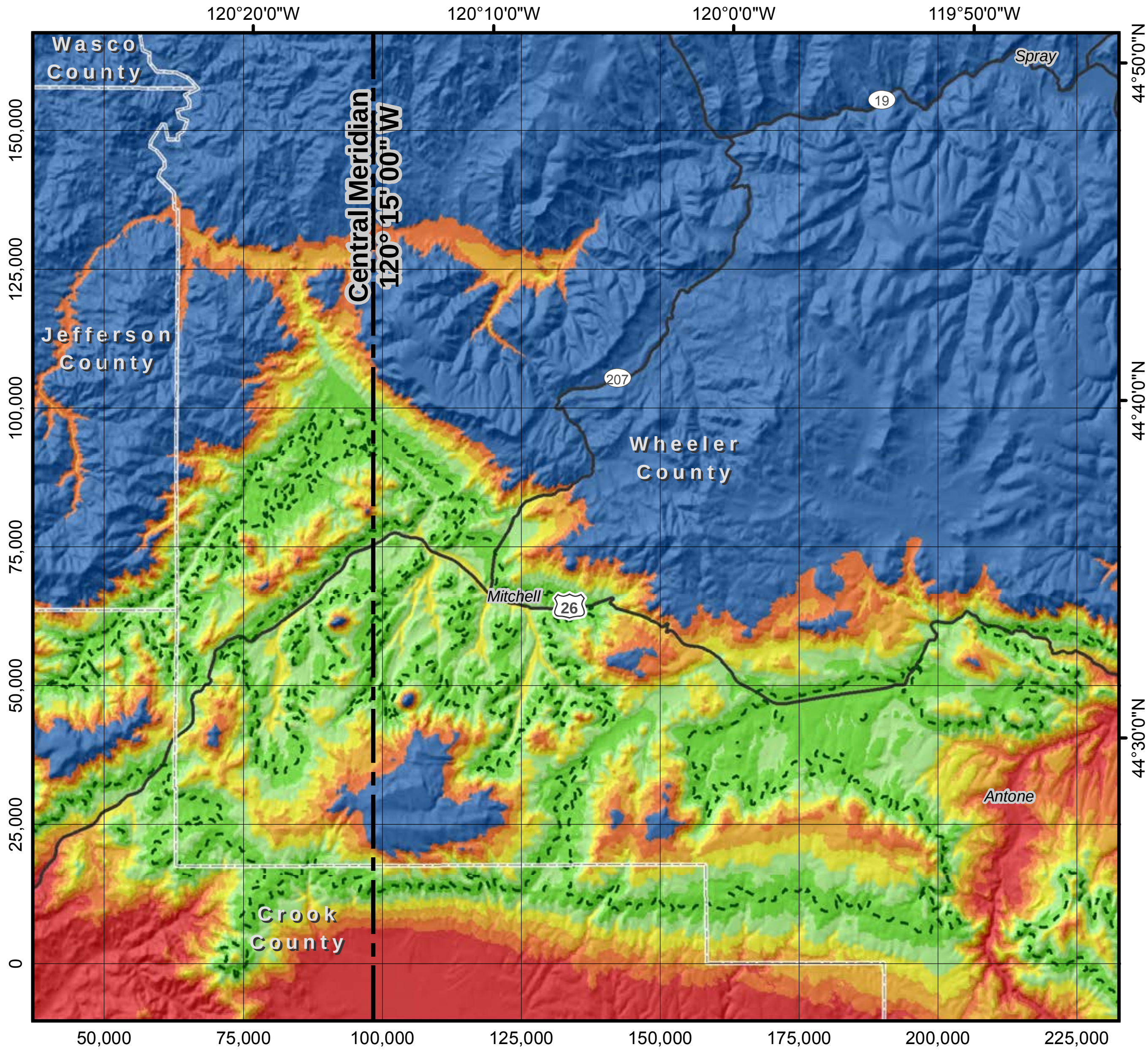
Parts of southeast Jefferson County, northeast Crook County, and south Wheeler County encompassing the communities of:

Mitchell, Antone

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Mitchell1	44 45 00.00000	119 55 00.00000	40090.37369	56396.97808
Mitchell2	44 40 00.00000	120 16 00.00000	30773.32957	28678.17691
Mitchell3	44 30 00.00000	120 10 00.00000	12253.44199	36628.81764



Oregon Coordinate Reference System

Mitchell Zone

Lambert Conformal Conic projection (single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 47° 00' 00" N
Central meridian: 120° 15' 00" W
False northing: 290 000.000 m
False easting: 30 000.000 m
Standard parallel scale: 0.999 270 (exact)

Scale 1:350,000
(when printed on 8-1/2" x 11" sheet)

0 5 10
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Prepared by:
Michael L. Dennis, RLS, PE
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Geodetic ANALYSIS

Map created 7/4/2016

NORTH CENTRAL ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

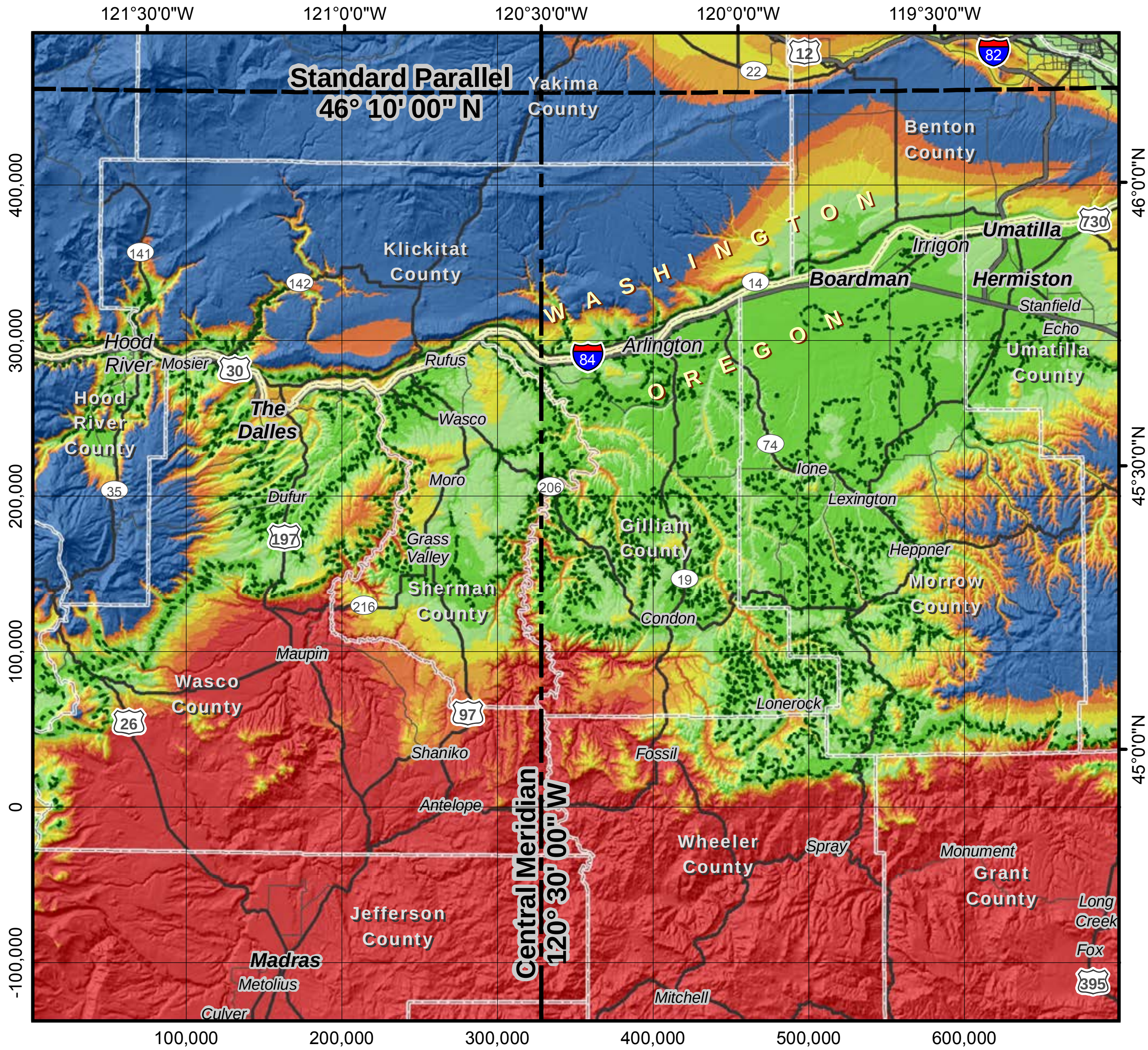
Parts of northeast Hood River County, north Wasco County, Sherman County, Gilliam County, Morrow County, northwest Umatilla County, and northeast Wheeler County encompassing the communities of:

The Dalles, Dufur, Rufus, Wasco, Grass Valley, Arlington, Boardman, Irrigon, Umatilla, Hermiston, Stanfield, Echo, Condon, Lone, Lexington, Heppner, Lonerock

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
North Central1	45 45 00.00000	119 30 00.00000	94176.71550	177811.41737
North Central2	45 35 00.00000	121 10 00.00000	75380.39919	47969.47628
North Central3	45 00 00.00000	120 30 00.00000	10324.07586	100000.00000



Oregon Coordinate Reference System

North Central Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

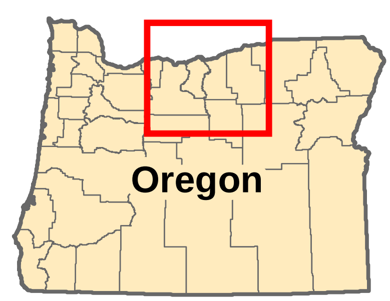
Stnd parallel & grid origin: 46° 10' 00" N
Central meridian: 120° 30' 00" W
False northing: 140 000.000 m
False easting: 100 000.000 m
Standard parallel scale: 1.000 000 (exact)

Scale 1:1,250,000
(when printed on 8-1/2" x 11" sheet)

Grid North

0 10 20 30 40
Miles

Projected map grid is shown in units of international feet



Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)

Prepared by:
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Geodetic Analysis

Map created 6/7/2016

OCHOCO SUMMIT ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

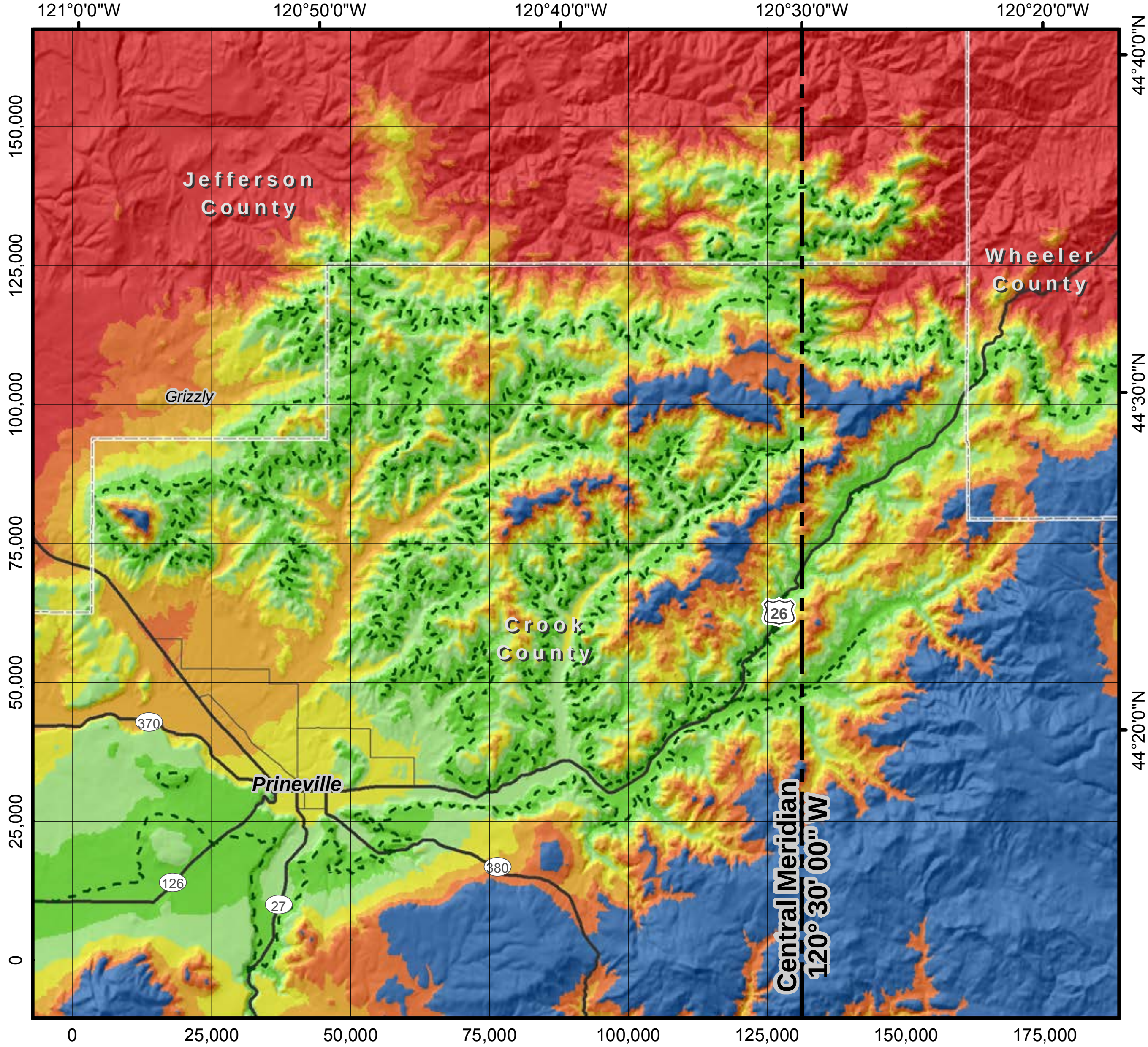
Parts of southeast Jefferson County, southwest Wheeler County, and Crook County encompassing the communities of:

Prineville Airport, Ochoco Summit Pass Hwy. 26, Powell Butte, Bandit Springs Rest Stop

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Ochoco Summit1	44 30 00.00000	120 23 00.00000	31131.05996	49280.41900
Ochoco Summit2	44 32 00.00000	120 45 00.00000	34859.28878	20124.53891
Ochoco Summit3	44 20 00.00000	120 40 00.00000	12614.31087	26705.17262



Oregon Coordinate Reference System

Ochoco Summit Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 43° 30' 00" N
Central meridian: 120° 30' 00" W
False northing: -80 000.000 m
False easting: 40 000.000 m
Standard parallel scale: 1.000 060 (exact)

Scale 1:350,000
(when printed on 8-1/2" x 11" sheet)

0 5 10
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)

Prepared by:
Michael L. Dennis, RLS, PE
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Geodetic ANALYSIS

Map created 7/4/2016

ONTARIO ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

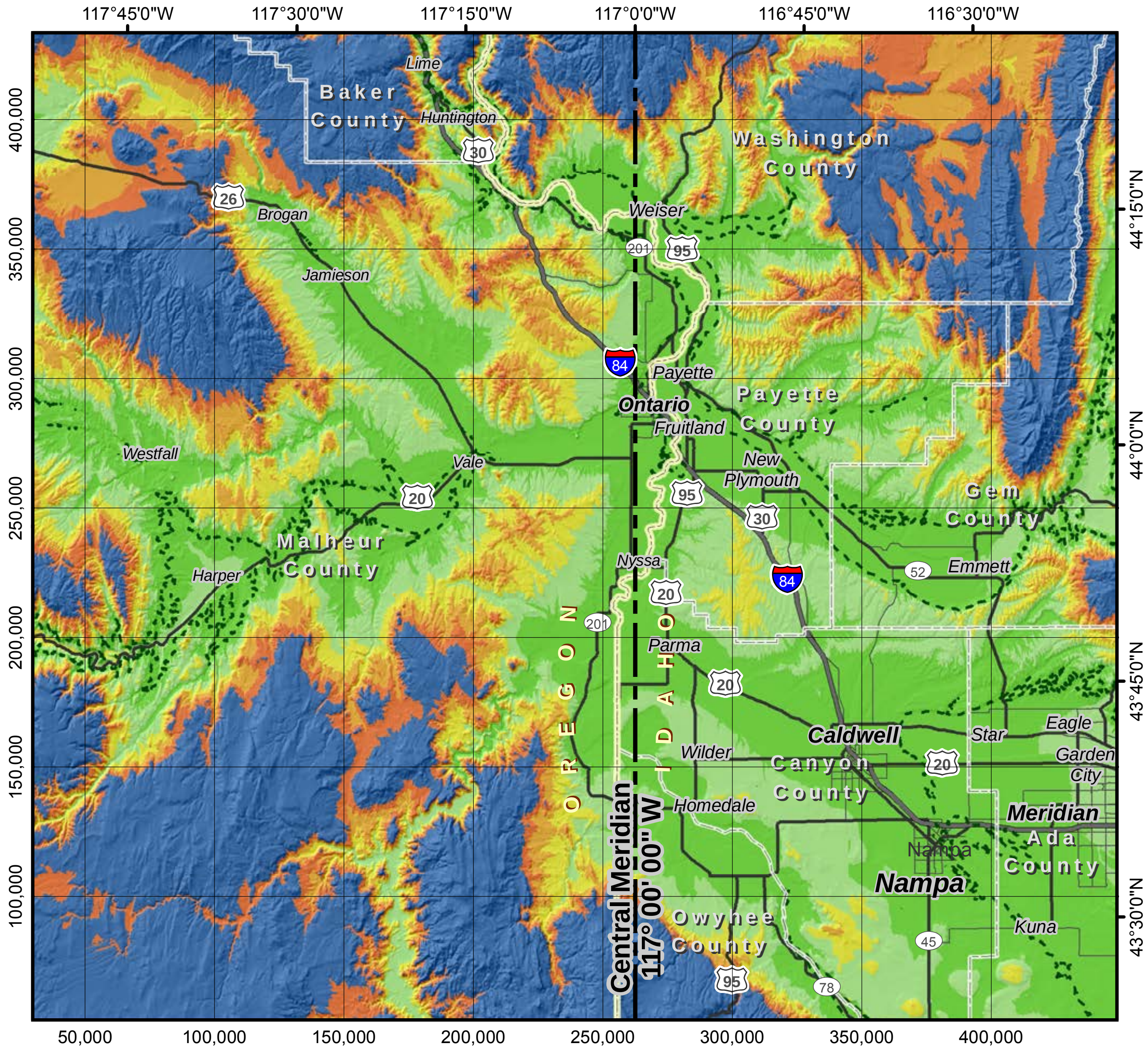
Parts of southeast Baker County, and northwest Malheur County encompassing the communities of:

Lime, Huntington, Brogan, Jamieson, Westfall, Harper, Vale, Ontario

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Ontario1	43 59 45.82871	117 06 22.74797	82905.08851	71471.15057
Ontario2	44 01 35.30352	117 01 02.04955	86278.96757	78618.04382
Ontario3	44 15 30.91593	117 34 57.00068	112237.85973	33478.59685



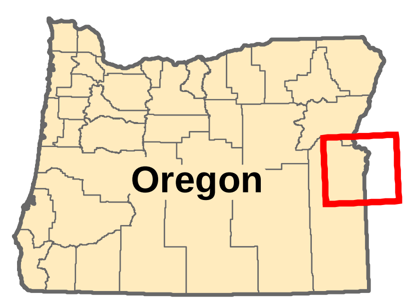
Oregon Coordinate Reference System

Ontario Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	43° 15' 00" N
Central meridian:	117° 00' 00" W
False northing:	0.000 m
False easting:	80 000.000 m
Central meridian scale:	1.000 100 (exact)

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

0 5 10 15 20 25
Miles

Grid North

Prepared by:
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mld@geodetic.xyz

Geodetic Analysis

Map created 7/10/2016

OREGON COAST ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

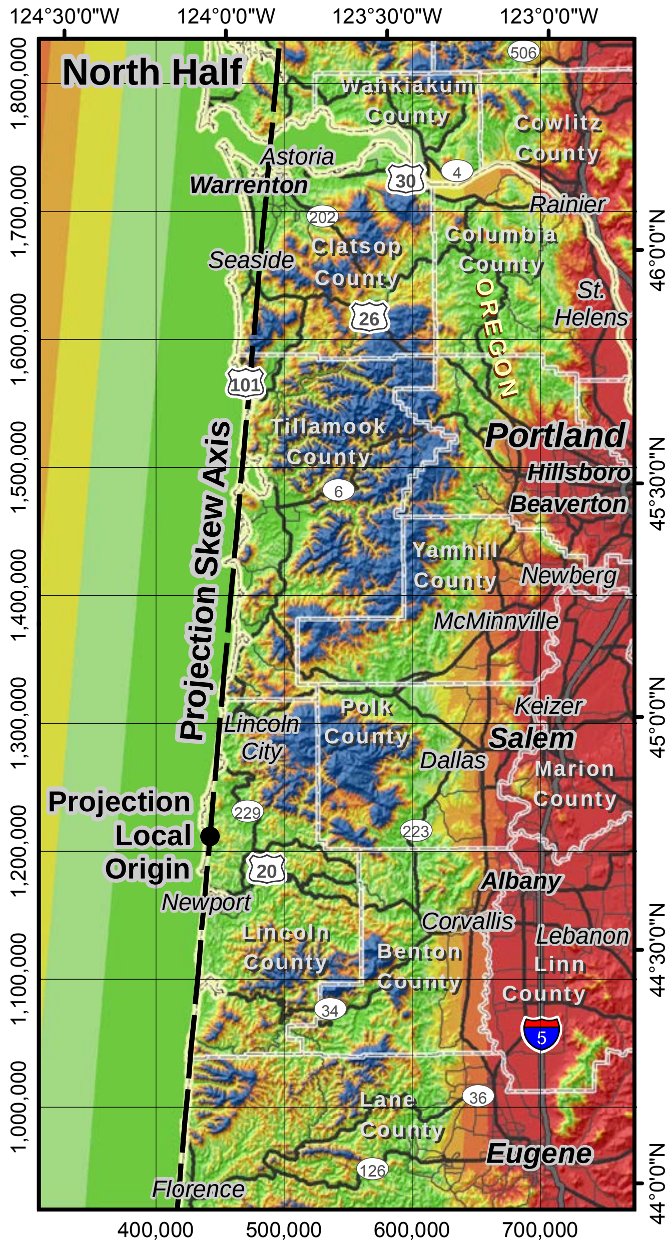
Parts of west Clatsop County, west Tillamook County, west Lincoln County, west Lane County, west Douglas, County, west Coos County, and west Curry County encompassing the communities of:

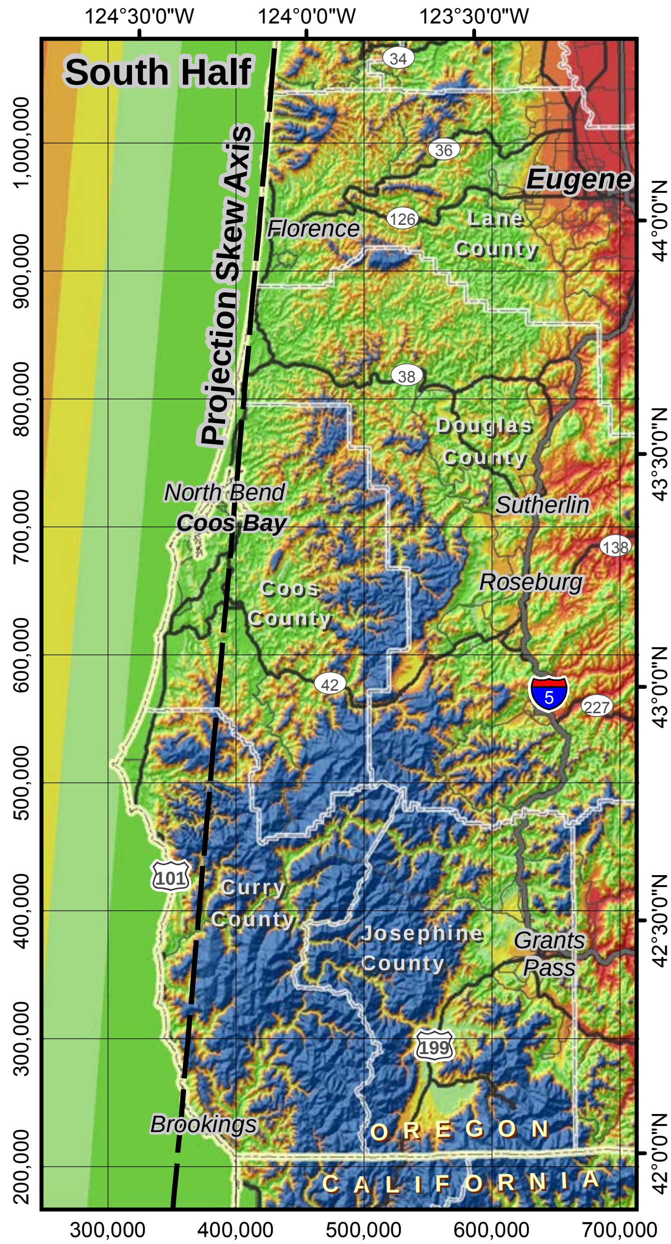
Warrenton, Seaside, Tillamook, Lincoln City, Newport, Waldport, Florence, North Bend, Coos Bay, Charleston, Bandon, Brookings

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Oregon Coast1	42 50 09.93918	124 33 47.98916	156617.94338	92771.55752
Oregon Coast2	43 59 00.96460	124 06 27.69262	283978.89187	130114.54983
Oregon Coast3	45 29 11.43812	123 58 41.18748	450992.95166	140363.83797





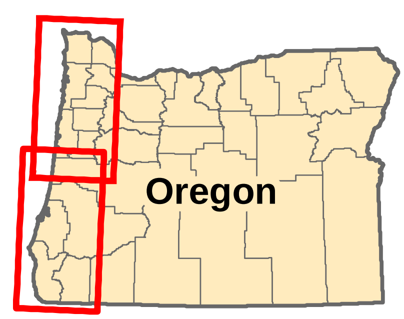
Oregon Coordinate Reference System

Oregon Coast Zone

Oblique Mercator projection
North American Datum of 1983

Latitude of local origin:	44° 45' 00" N
Longitude of local origin:	124° 03' 00" W
False northing:	-4 600 000.000 m
False easting:	-300 000.000 m
Projection skew axis scale:	1.000 000 (exact)
Skew axis azimuth at origin:	+5° 00' 00"

Projected map grid is shown in units of international feet



Linear distortion

- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Grid North

Scale 1:1,800,000
(when printed on 8-1/2" x 11" sheet)

0 10 20 30 40 50

Miles

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Geodetic Analysis

Map created 7/11/2016

OWYHEE ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

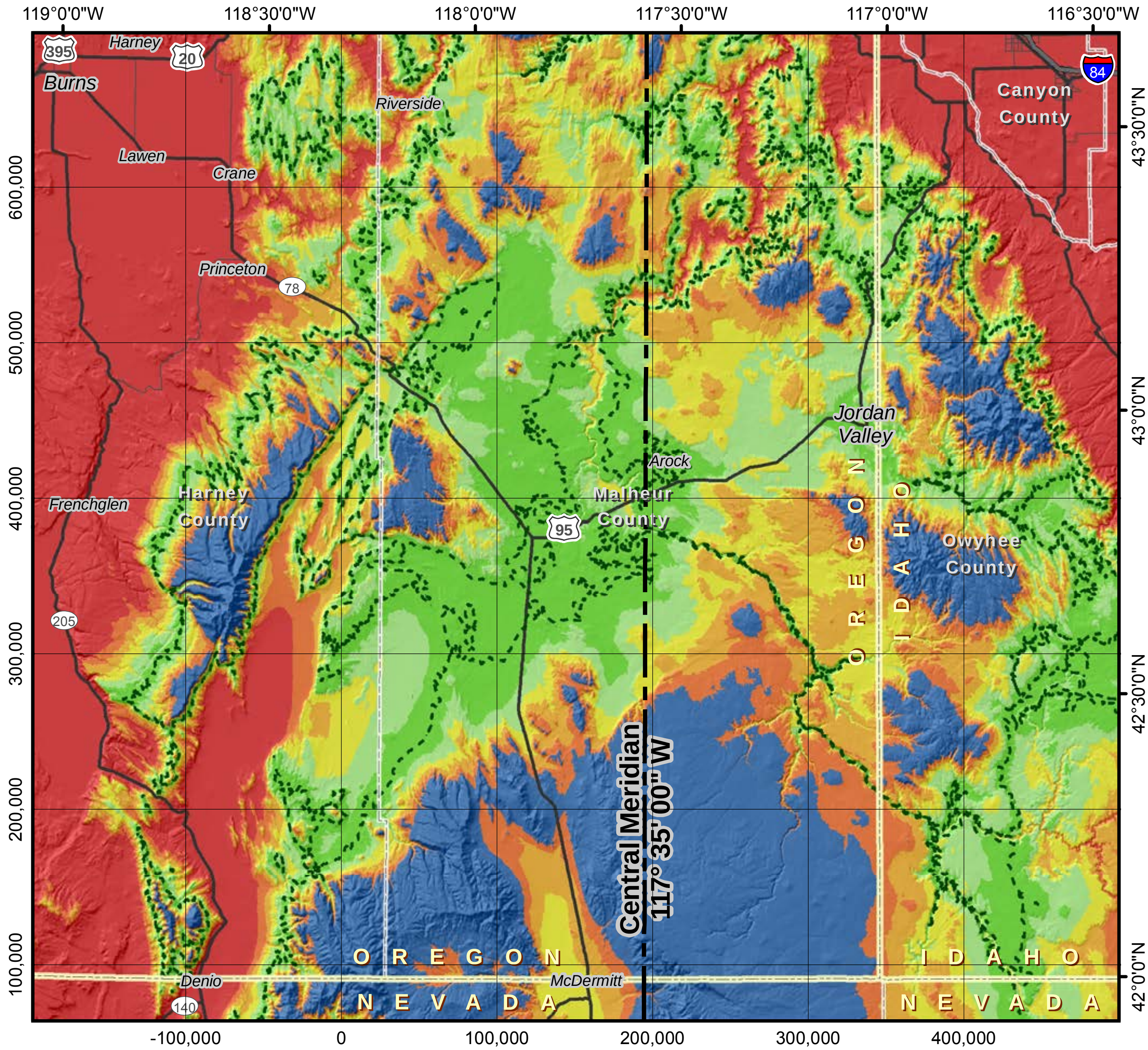
Parts of east Harney County, and Malheur County encompassing the communities of:

Arock, Crowley, Danner, Rome, Jordan Valley

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Owyhee1	43 05 00.00000	117 04 00.00000	148264.77269	112080.13297
Owyhee2	43 00 00.00000	118 00 00.00000	138959.98063	36018.45973
Owyhee3	42 15 00.00000	117 45 00.00000	55560.09179	56243.24291



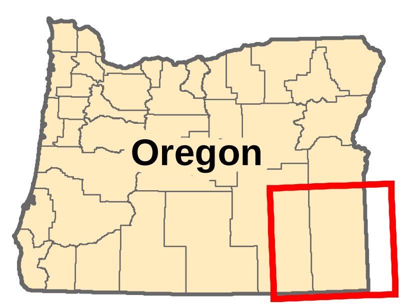
Oregon Coordinate Reference System

Owyhee Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	41° 45' 00" N
Central meridian:	117° 35' 00" W
False northing:	0.000 m
False easting:	70 000.000 m
Central meridian scale:	1.000 180 (exact)

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:1,250,000
(when printed on 8-1/2" x 11" sheet)

0 10 20 30 40
Miles

Grid North

Prepared by:
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Geodetic Analysis

Map created 7/2/2016

PENDLETON ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

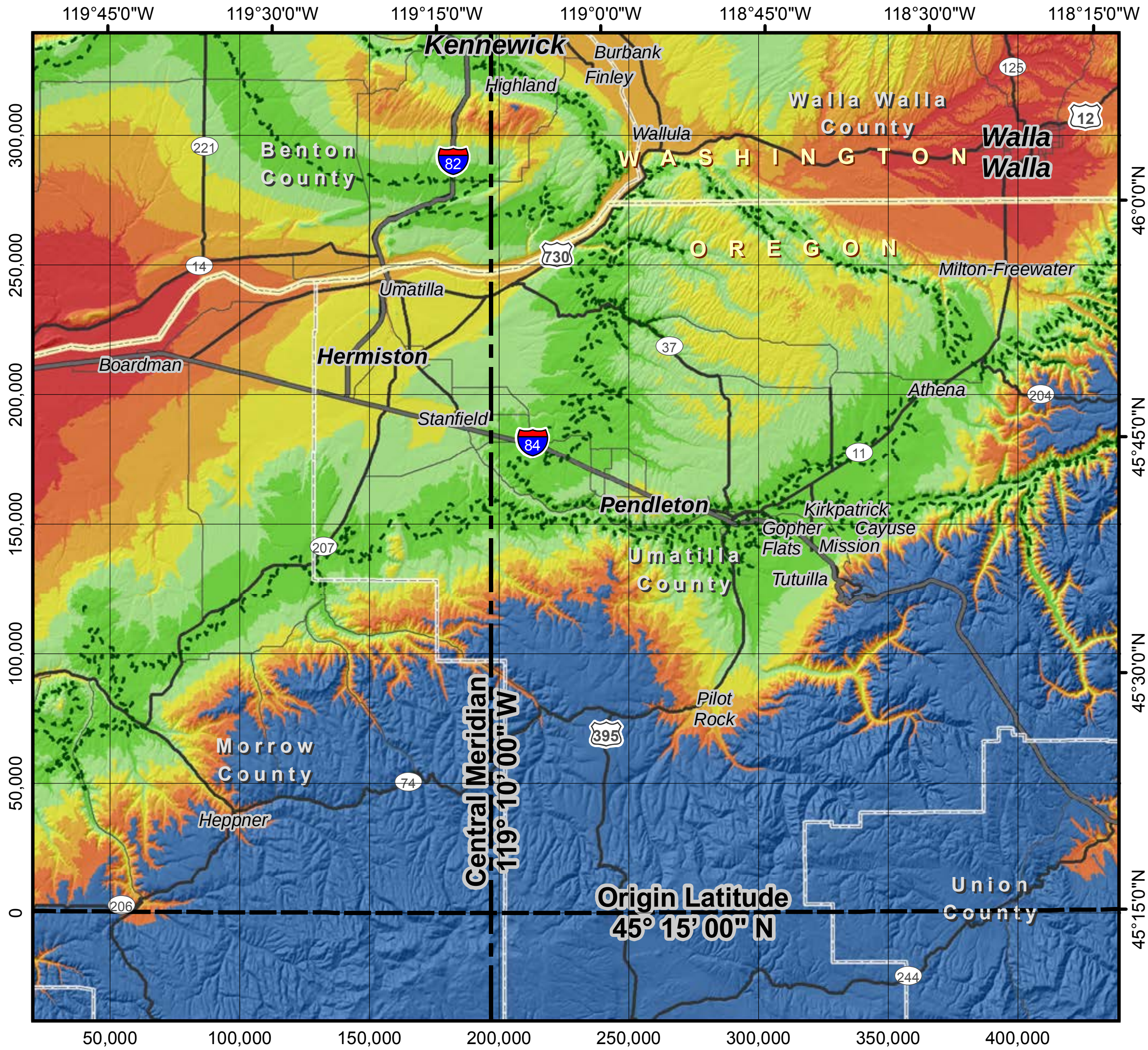
Parts of Umatilla County, and west Morrow County encompassing the communities of:

Stanfield, Pendleton, Kirkpatrick, Gopher, Cayuse, Flats, Mission, Tutuilla, Athena, Milton-Freewater, Helix, Pilot Rock

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Pendleton1	45 40 01.47744	118 46 38.96233	46430.01635	90328.59835
Pendleton2	45 40 10.42949	118 47 29.47552	46701.19336	89233.83305
Pendleton3	45 40 22.63117	118 48 49.44218	47070.05244	87501.19269



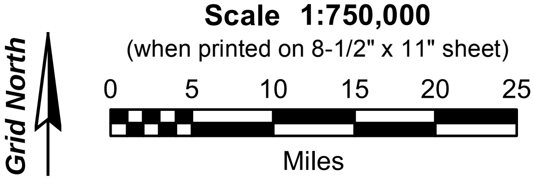
Oregon Coordinate Reference System

Pendleton Zone

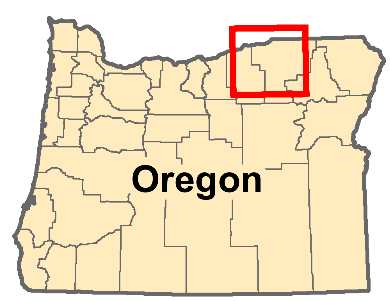
Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 45° 15' 00" N
Central meridian: 119° 10' 00" W
False northing: 0.000 m
False easting: 60 000.000 m
Central meridian scale: 1.000 045 (exact)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)



Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Geodetic ANALYSIS

Map created 7/10/2016

PENDLETON-LAGRANDE ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

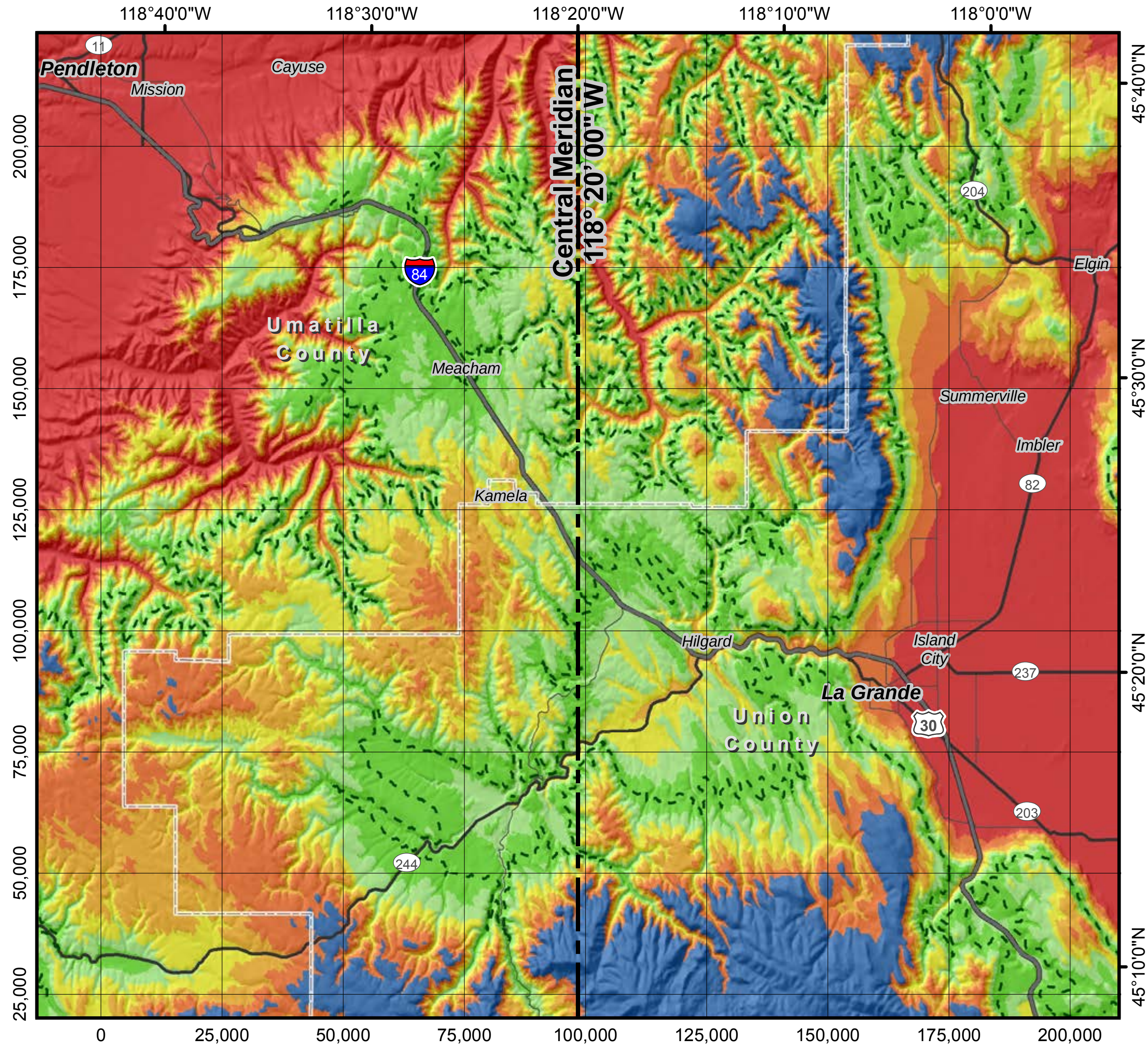
Parts of southeast Umatilla County, and Union County encompassing the communities of:

Meacham, Duncan, Mckay, Kamela, Hilgard, Perry, Starkey

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Pendleton-LaGrande1	45 35 58.22564	118 31 48.55554	57395.64145	14641.28669
Pendleton-LaGrande2	45 41 30.56154	118 51 14.66742	67770.86965	-10568.75761
Pendleton-LaGrande3	45 40 01.47744	118 46 38.96233	64984.08945	-4617.61867



Oregon Coordinate Reference System
Pendleton-La Grande Zone

Transverse Mercator projection
North American Datum of 1983

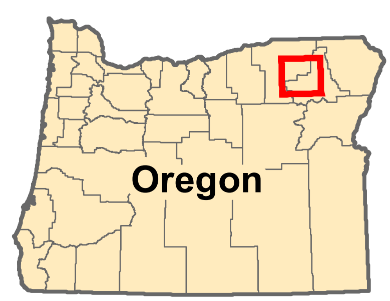
Latitude of grid origin: 45° 05' 00" N
Central meridian: 118° 20' 00" W
False northing: 0.000 m
False easting: 30 000.000 m
Central meridian scale: 1.000 175 (exact)

Scale 1:400,000
(when printed on 8-1/2" x 11" sheet)
0 5 10
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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mld@geodetic.xyz

Map created 7/8/2016

PILOT ROCK-UKIAH ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

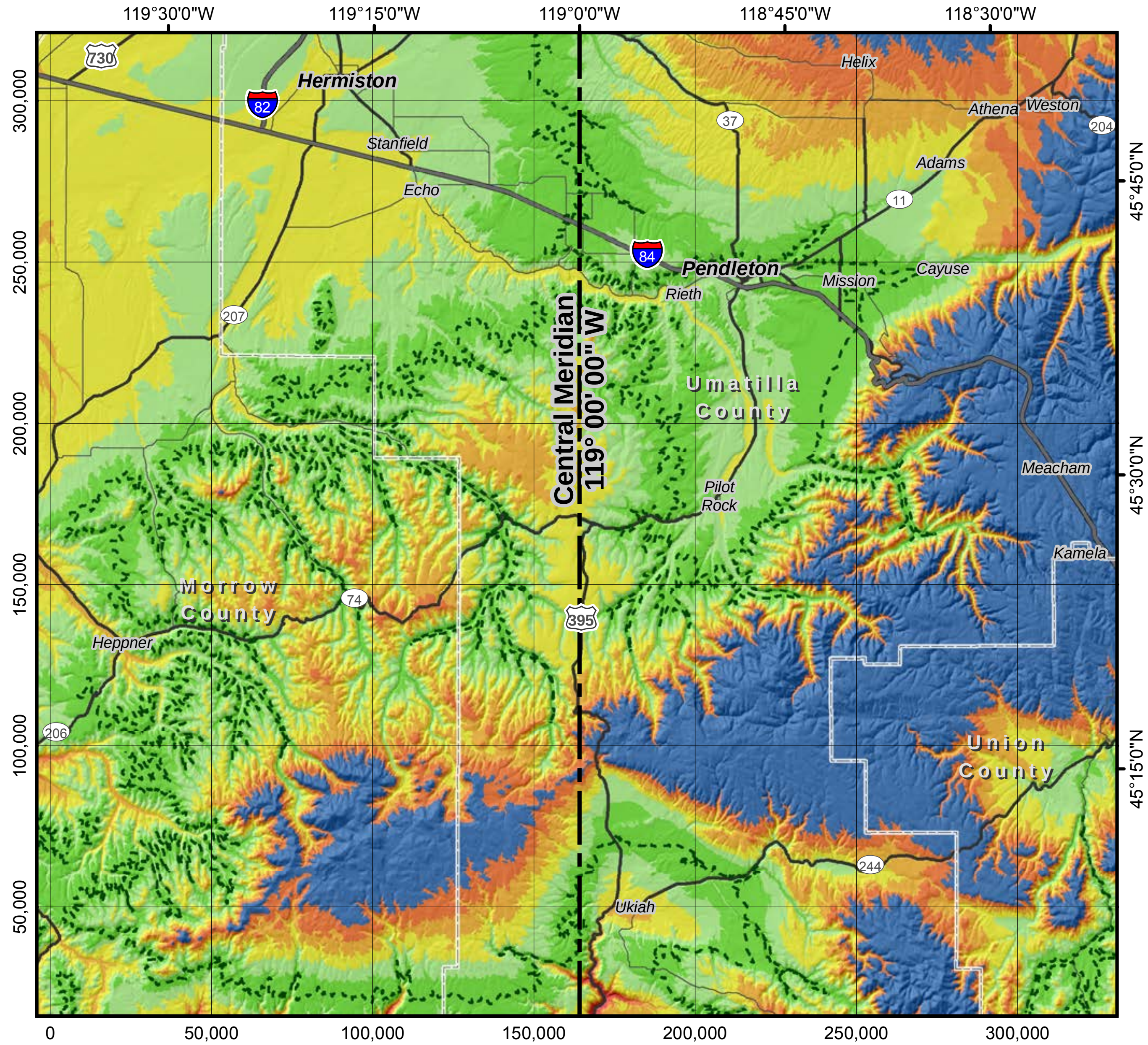
Parts of east Morrow County, Umatilla County, and northwest Union, County encompassing the communities of:

Pendleton, Mission, Cayuse, Rieth, Pilot Rock, Heppner

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Pilot Rock-Ukiah1	45 29 00.00000	118 50 00.00000	54058.91981	63031.42275
Pilot Rock-Ukiah2	45 08 00.00000	119 00 00.00000	15141.65609	50000.00000
Pilot Rock-Ukiah3	45 15 00.00000	118 45 00.00000	28140.54484	69628.74874



Oregon Coordinate Reference System

Pilot Rock-Ukiah Zone

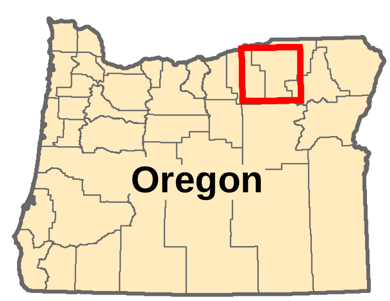
Lambert Conformal Conic projection (single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 46° 10' 00" N
Central meridian: 119° 00' 00" W
False northing: 130 000.000 m
False easting: 50 000.000 m
Standard parallel scale: 1.000 025 (exact)

Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)
0 5 10 15 20
Miles

Grid North

Projected map grid is shown in units of international feet



Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)

Prepared by:
Michael L. Dennis, RLS, PE
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Geodetic Analysis

Map created 6/7/2016

PORTLAND ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

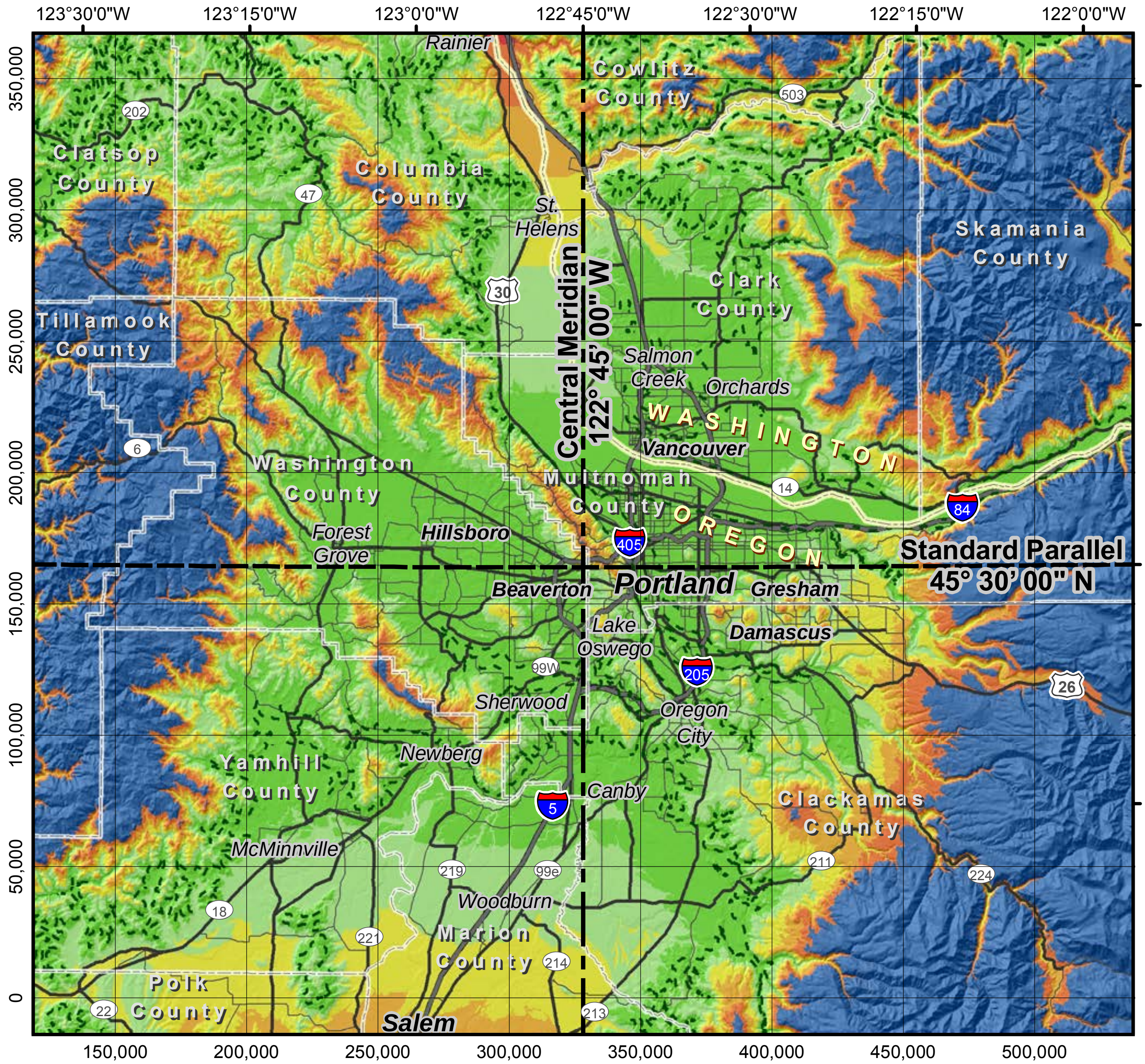
Parts of southeast Clatsop County, south Columbia County, Washington County, Yamhill County, north Marion County and Clackamas County encompassing the communities of:

Forest Grove, Hillsboro, Beaverton, Portland, Lake Oswego, Sherwood, Gresham, Oregon City, Canby, Newberg

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Portland1	45 18 00.17000	122 58 31.85235	27802.06823	82311.82137
Portland2	45 29 08.88672	122 47 50.56450	48423.08858	96296.00903
Portland3	45 31 23.21213	122 59 25.84389	52597.11898	81209.71492



Oregon Coordinate Reference System

Portland Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 45° 30' 00" N
Central meridian: 122° 45' 00" W
False northing: 50 000.000 m
False easting: 100 000.000 m
Standard parallel scale: 1.000 002 (exact)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

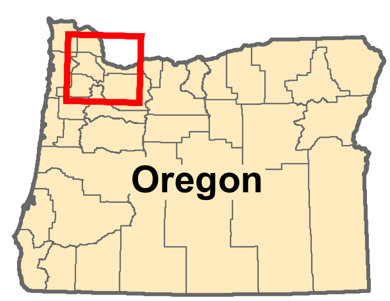
Grid North

0 5 10 15 20 25
Miles

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Geodetic Analysis

Map created 7/10/2016

PRAIRIE CITY-BROGAN ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

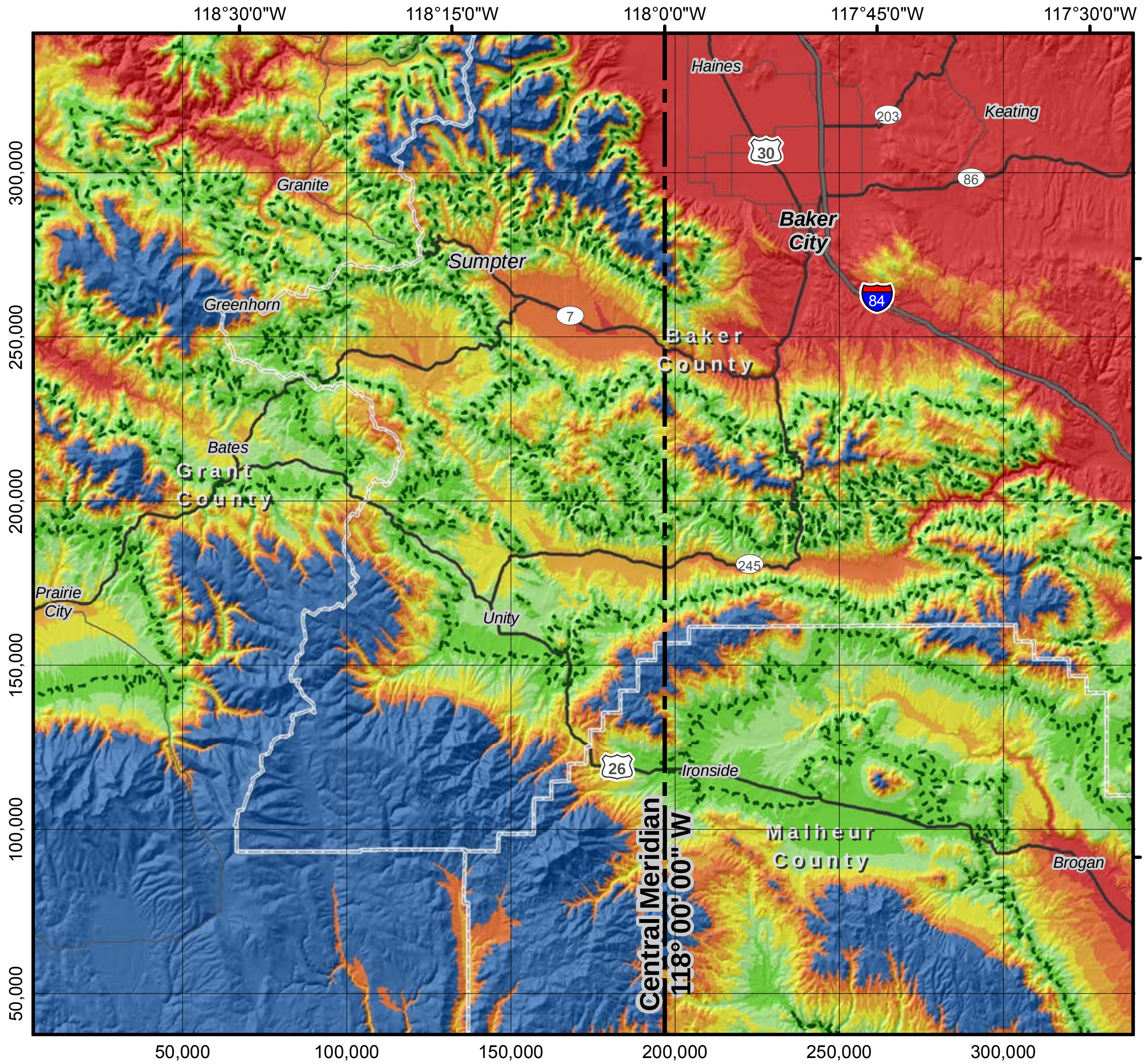
Parts of east Grant County, Baker County, and north Malheur County encompassing the communities of:

Granite, Sumpter, Bates, Dixie Summit, Unity, Ironside

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Prairie City-Brogan1	44 18 00.00000	117 50 00.00000	33353.81037	73302.59211
Prairie City-Brogan2	44 34 00.00000	118 30 00.00000	63098.88578	20272.10711
Prairie City-Brogan3	44 10 00.00000	118 10 00.00000	18535.62287	46667.46504



Oregon Coordinate Reference System

Prairie City-Brogan Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 44° 00' 00" N
Central meridian: 118° 00' 00" W
False northing: 0.000 m
False easting: 60 000.000 m
Standard parallel scale: 1.000 170 (exact)

Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)

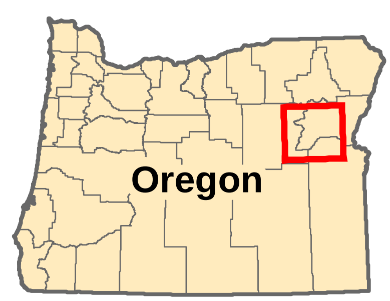
0 5 10 15 20
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
Michael L. Dennis, RLS, PE
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Geodetic ANALYSIS

Map created 6/7/2016

RILEY-LAKEVIEW ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

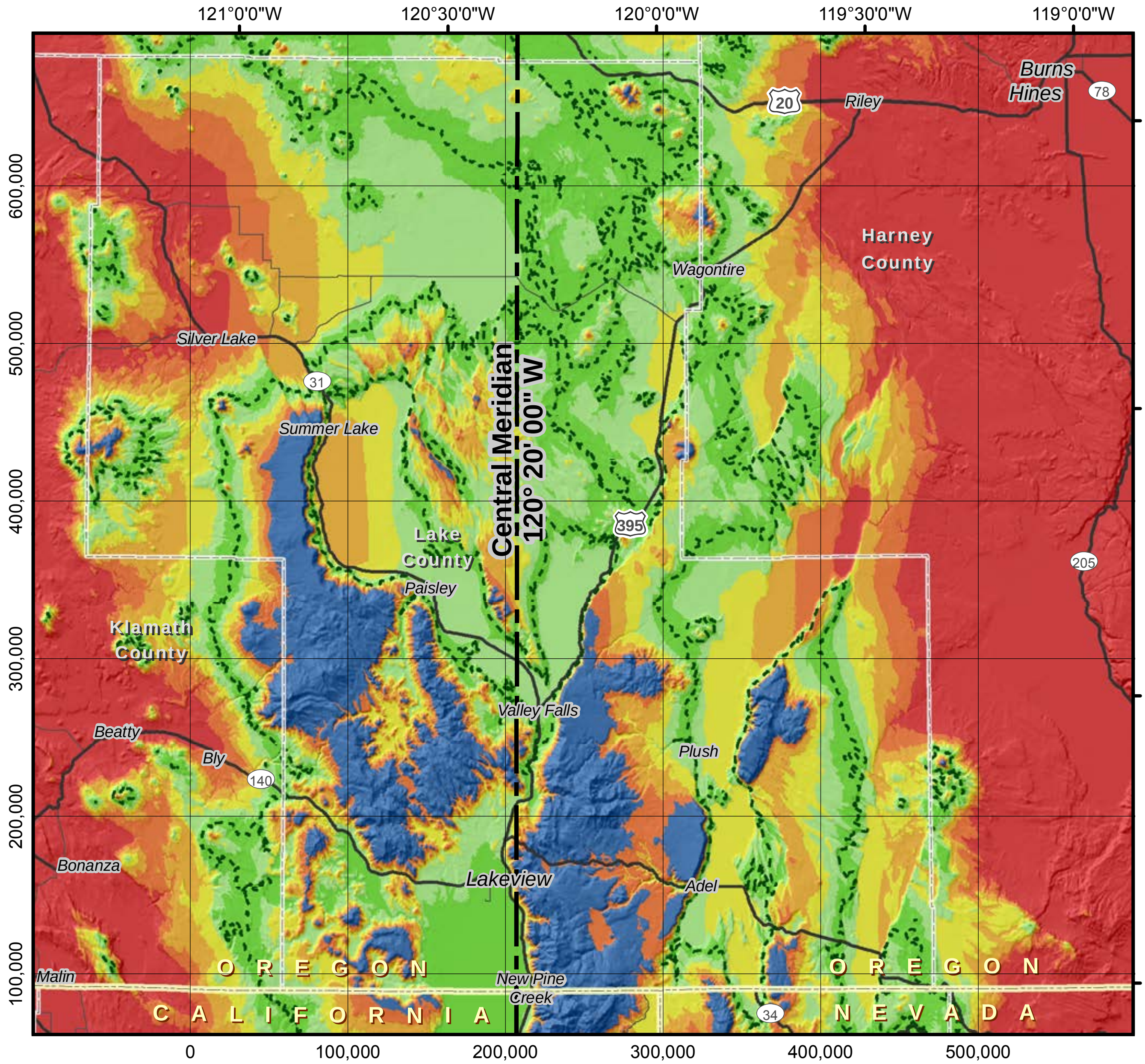
Parts of Lake County, southeast Klamath County, and west Harney County encompassing the communities of:

Paisley, Valley Falls, Wagontire, Lakeview, Plush, New Pine Creek

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Riley-Lakeview1	43 15 00.00000	119 52 00.00000	166766.10874	107905.98805
Riley-Lakeview2	43 00 00.00000	120 45 00.00000	138964.84335	36017.27059
Riley-Lakeview3	42 15 00.00000	120 10 00.00000	55562.03604	83757.23849



Oregon Coordinate Reference System

Riley-Lakeview Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 41° 45' 00" N
Central meridian: 120° 20' 00" W
False northing: 0.000 m
False easting: 70 000.000 m
Central meridian scale: 1.000 215 (exact)

Scale 1:1,250,000
(when printed on 8-1/2" x 11" sheet)

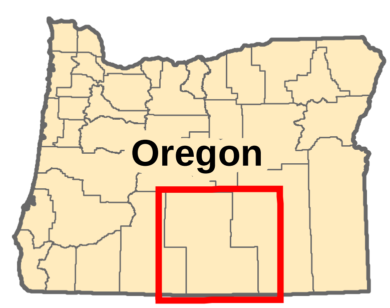
0 10 20 30 40
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)



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Geodetic ANALYSIS

Map created 7/2/2016

SALEM ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

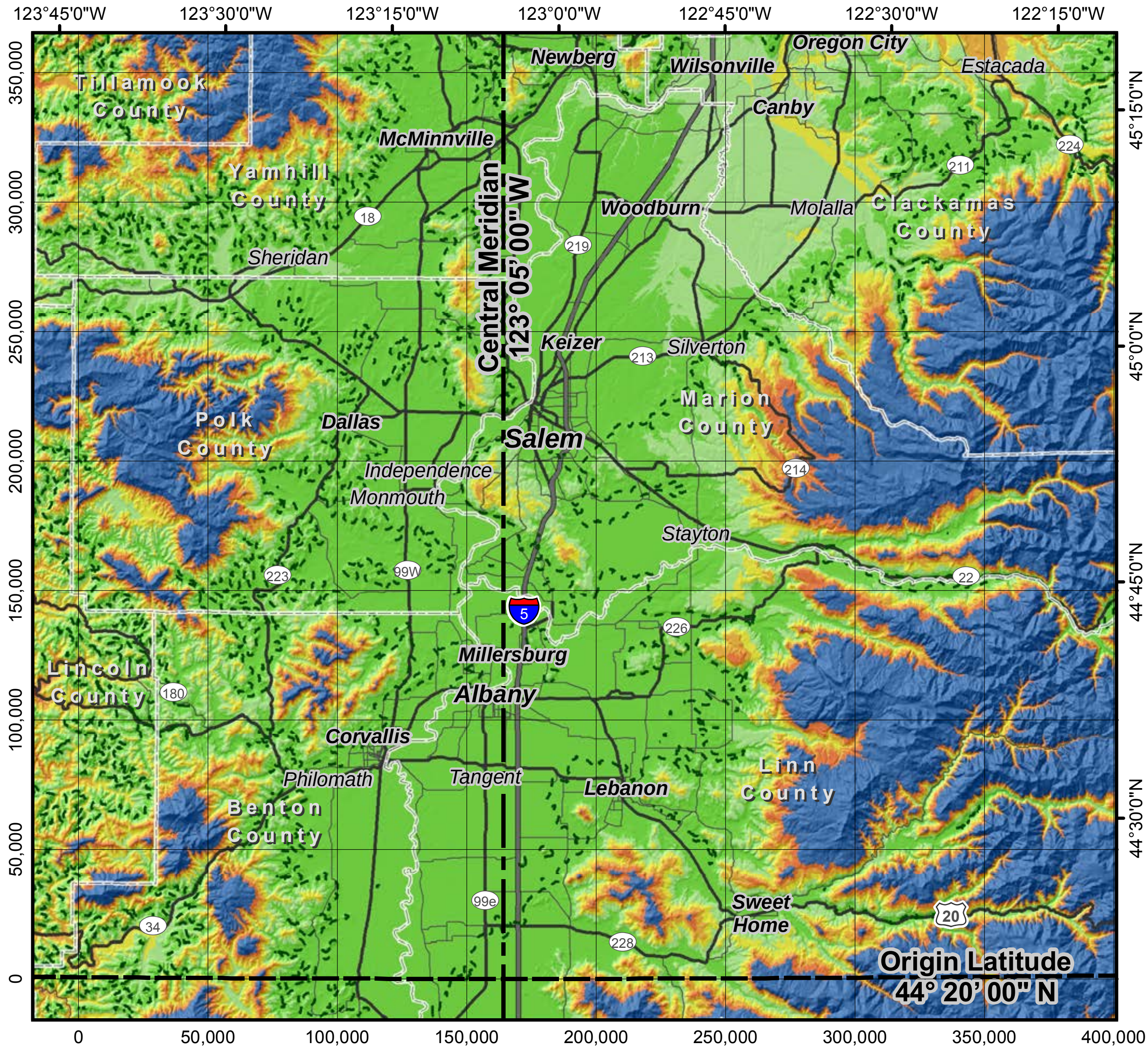
Parts of southeast Yamhill County, southwest Clackamas County, Polk County, Marion County, Benton County, and Linn County encompassing the communities of:

McMinnville, Woodburn, Molalla, Sheridan, Dallas, Independence, Monmouth, Salem, Keizer, Silverton, Stayton, Millersburg, Albany

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Salem1	44 35 07.91068	123 18 16.51921	28048.57816	32429.22836
Salem2	44 56 28.31372	123 06 08.10051	67549.65038	48506.92980
Salem3	44 58 25.70178	122 57 20.63967	71181.16936	60065.54709



Oregon Coordinate Reference System
Salem Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 44° 20' 00" N
Central meridian: 123° 05' 00" W
False northing: 0.000 m
False easting: 50 000.000 m
Central meridian scale: 1.000 010 (exact)

Scale 1:750,000
(when printed on 8-1/2" x 11" sheet)

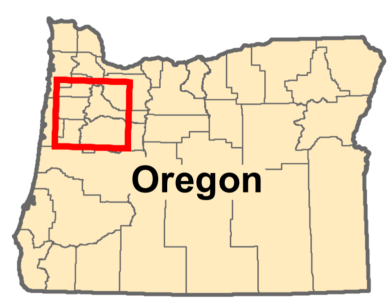
0 5 10 15 20 25
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)



Prepared by:
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Geodetic Analysis

Map created 7/10/2016

SANTIAM PASS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

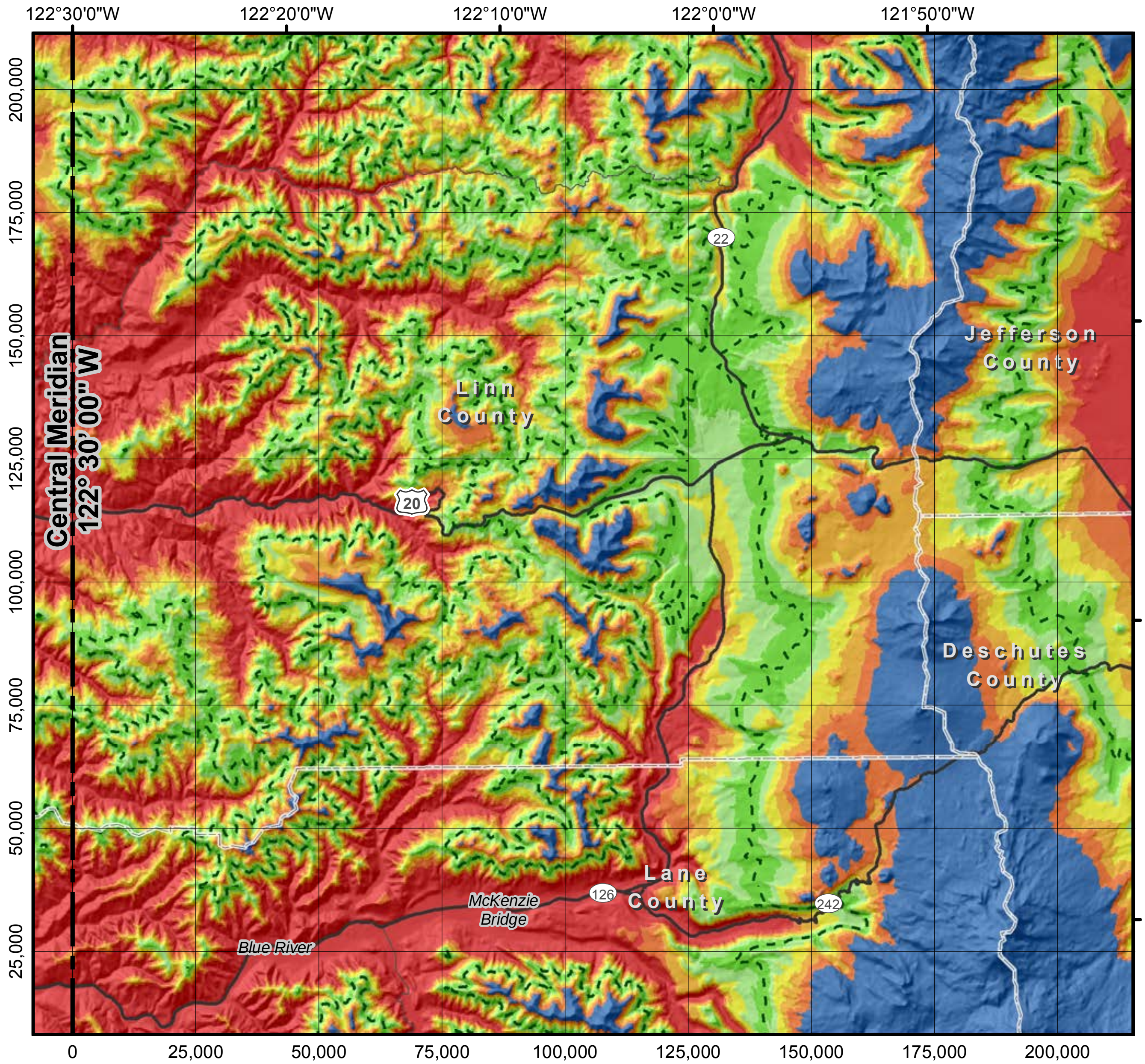
Parts of southeast Linn County, southwest Jefferson County, northwest Deschutes and northeast Lane County encompassing the communities of:

Santiam Junction Highways 126 and 20, Santiam Pass Highways 20 and 22, Hoodoo Ski Area, Suttle Lake

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Santiam Pass1	44 23 05.17700	121 55 40.80530	33659.19921	45587.37939
Santiam Pass2	44 26 02.55048	121 56 56.00645	39123.57959	43885.68277
Santiam Pass3	44 45 49.32354	122 38 12.10401	75623.61352	-10823.89864



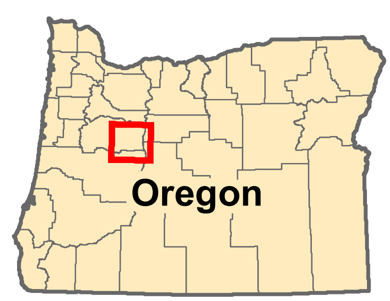
Oregon Coordinate Reference System

Santiam Pass Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 44° 05' 00" N
Central meridian: 122° 30' 00" W
False northing: 0.000 m
False easting: 0.000 m
Central meridian scale: 1.000 155 (exact)

Projected map grid is shown in units of international feet



Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)

Scale 1:400,000
(when printed on 8-1/2" x 11" sheet)

0 5 10
Miles

Grid North

Prepared by:
Michael L. Dennis, RLS, PE
mld@geodetic.xyz

Map created 7/8/2016

SISKIYOU PASS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

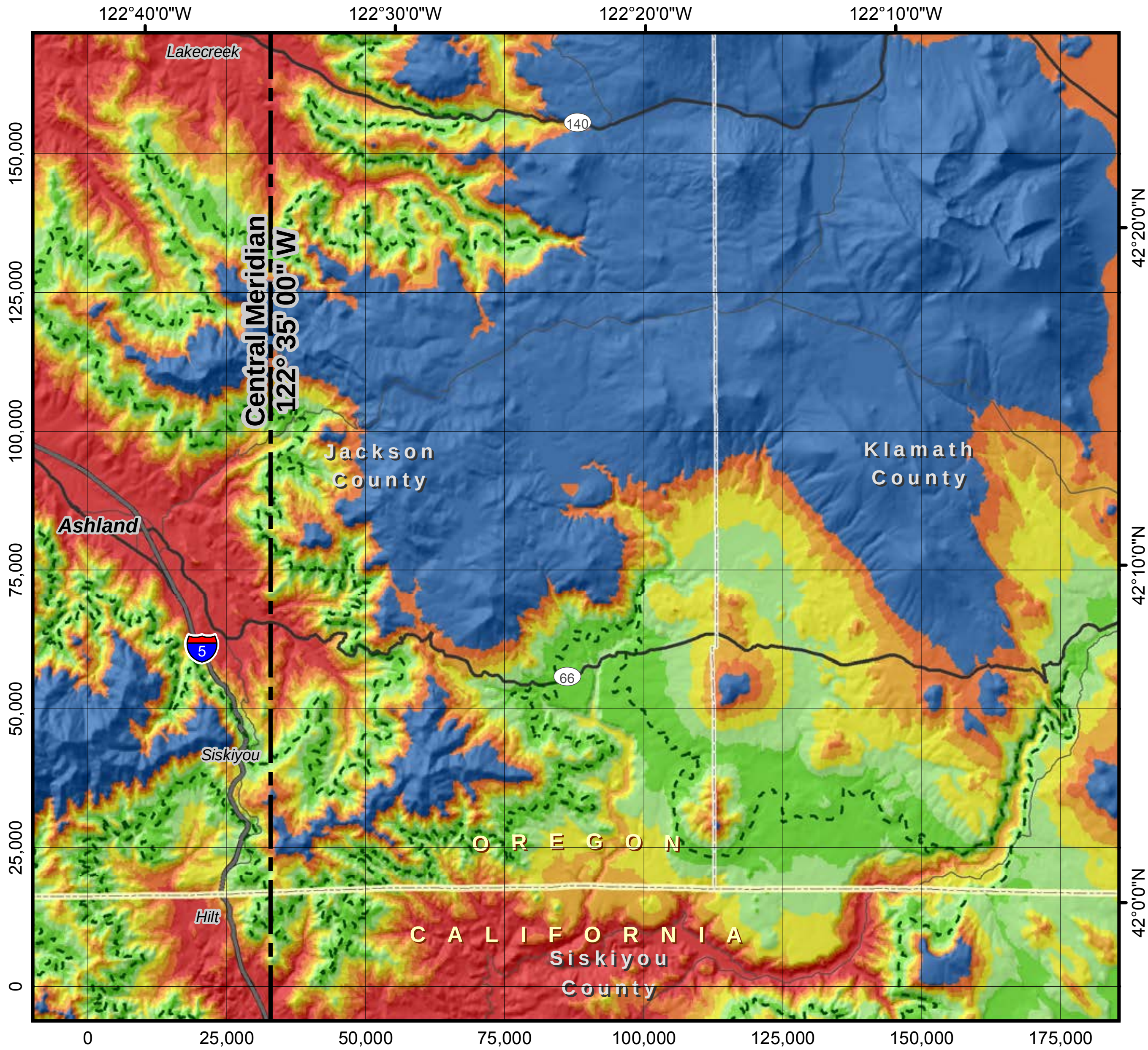
Parts of Jackson County and Klamath County encompassing the communities of:

Siskiyou Pass I-5 and Old Highway 99s, Mt. Ashland Ski Area, Colestin

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Siskiyou Pass1	42 07 00.00000	122 20 00.00000	17443.38623	30678.34448
Siskiyou Pass2	42 20 00.00000	122 40 00.00000	41487.00831	3130.86167
Siskiyou Pass3	42 00 00.00000	122 35 00.00000	4451.89751	10000.00000



Oregon Coordinate Reference System

Siskiyou Pass Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 42° 30' 00" N
Central meridian: 122° 35' 00" W
False northing: 60 000.000 m
False easting: 10 000.000 m
Standard parallel scale: 1.000 150 (exact)

Scale 1:350,000
(when printed on 8-1/2" x 11" sheet)

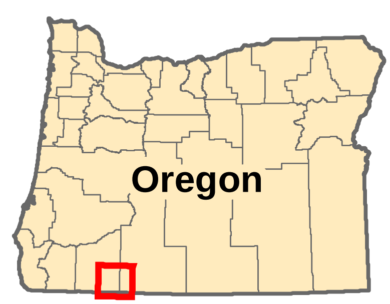
Grid North

0 5 10
Miles

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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mld@geodetic.xyz

Geodetic ANALYSIS

Map created 6/7/2016

UKIAH-FOX ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

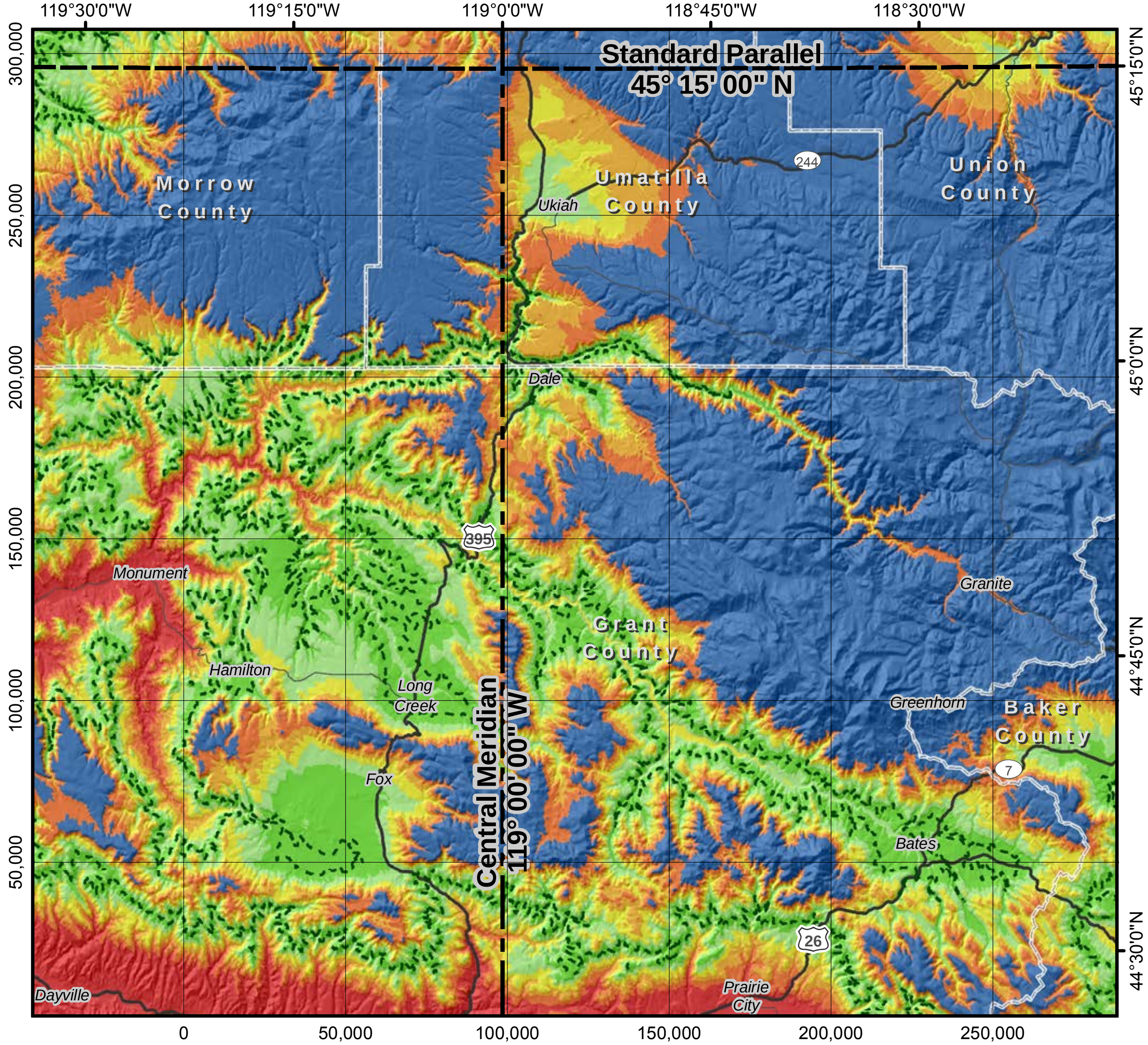
Parts of southeast Morrow County, south Umatilla County, southwest Union County, Grant County and west Baker County encompassing the communities of:

Ukiah, Dale, Hamilton, Long Creek, Fox, Bates

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Ukiah-Fox1	44 35 00.00000	118 30 00.00000	16024.27164	69716.07188
Ukiah-Fox2	45 10 00.00000	118 57 00.00000	80738.59769	33931.44990
Ukiah-Fox3	44 45 00.00000	119 00 00.00000	34425.63059	30000.00000



Oregon Coordinate Reference System

Ukiah-Fox Zone

Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin:	45° 15' 00" N
Central meridian:	119° 00' 00" W
False northing:	90 000.000 m
False easting:	30 000.000 m
Standard parallel scale:	1.000 140 (exact)

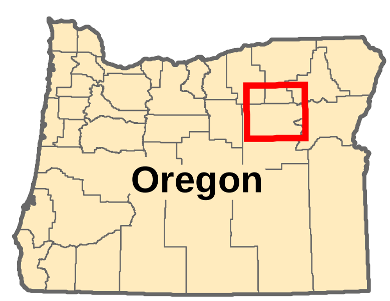
Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)

Grid North

0 5 10 15 20
Miles

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



Prepared by:
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Geodetic Analysis

Map created 6/7/2016

WALLOWA ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

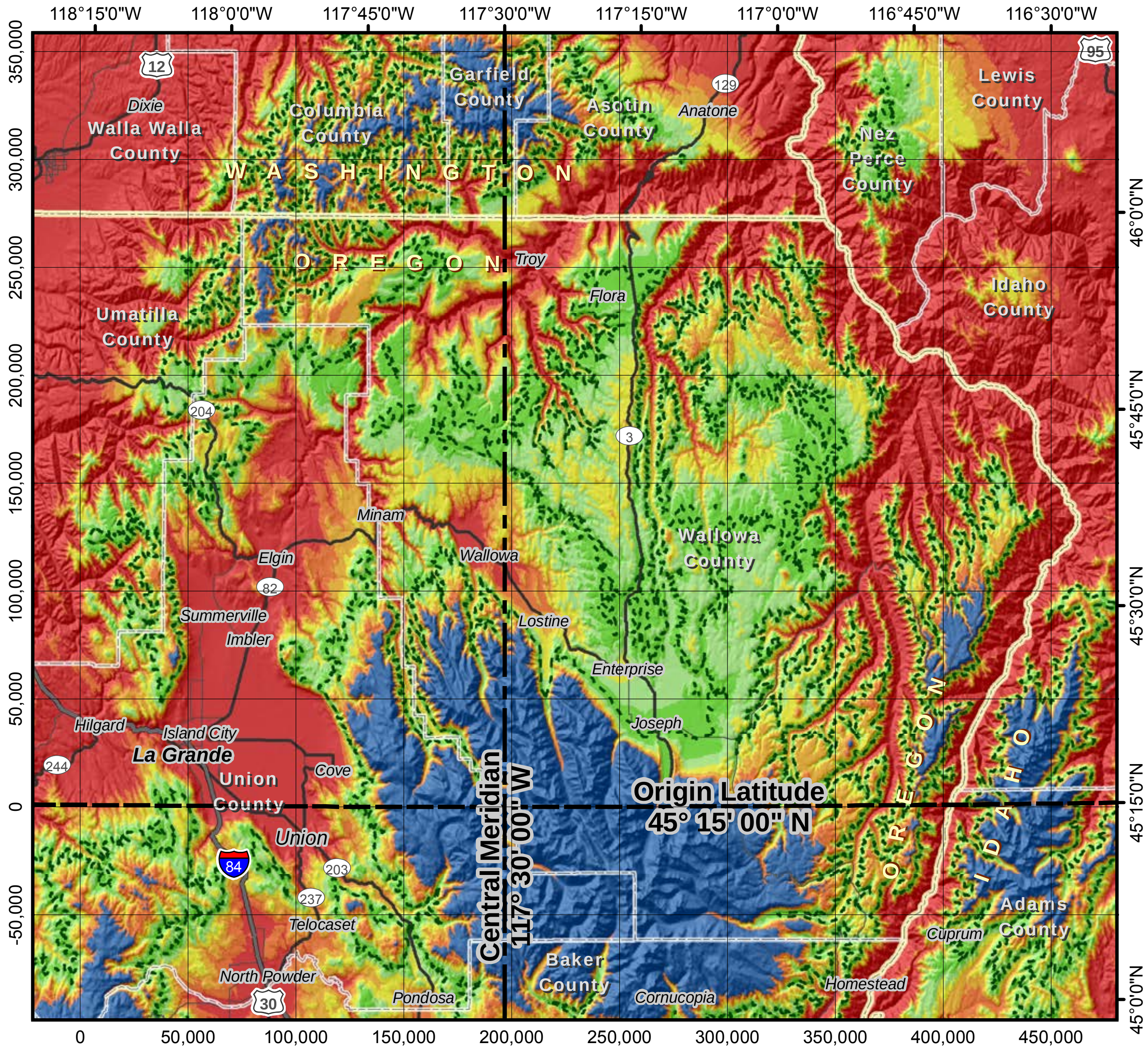
Parts of east Umatilla County, Union County, and Wallowa County encompassing the communities of:

Flora, Minam, Lostine, Enterprise, Joseph, Cornucopia

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Wallowa1	45 45 00.00000	117 00 00.00000	55703.23397	98913.28813
Wallowa2	45 50 00.00000	118 00 00.00000	64967.30160	21144.66324
Wallowa3	45 25 00.00000	117 20 00.00000	18540.17710	73048.08973



Oregon Coordinate Reference System

Wallowa Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin:	45° 15' 00" N
Central meridian:	117° 30' 00" W
False northing:	0.000 m
False easting:	60 000.000 m
Central meridian scale:	1.000 195 (exact)

Scale 1:900,000
(when printed on 8-1/2" x 11" sheet)

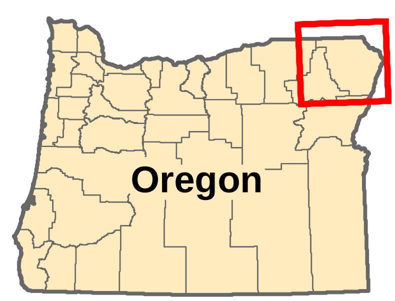
0 10 20 30
Miles

Grid North

Projected map grid is shown in units of international feet

Linear distortion

- - - Zero distortion
- < -50 ppm (< -0.25 ft/mi)
- ±10 ppm = ±0.05 ft/mi
- ±(10-20) ppm = ±(0.05-0.1) ft/mi
- ±(20-30) ppm = ±(0.1-0.15) ft/mi
- ±(30-40) ppm = ±(0.15-0.2) ft/mi
- ±(40-50) ppm) = ±(0.2-0.25) ft/mi
- > +50 ppm (> +0.25 ft/mi)



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Geodetic ANALYSIS

Map created 6/7/2016

WARNER HIGHWAY ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

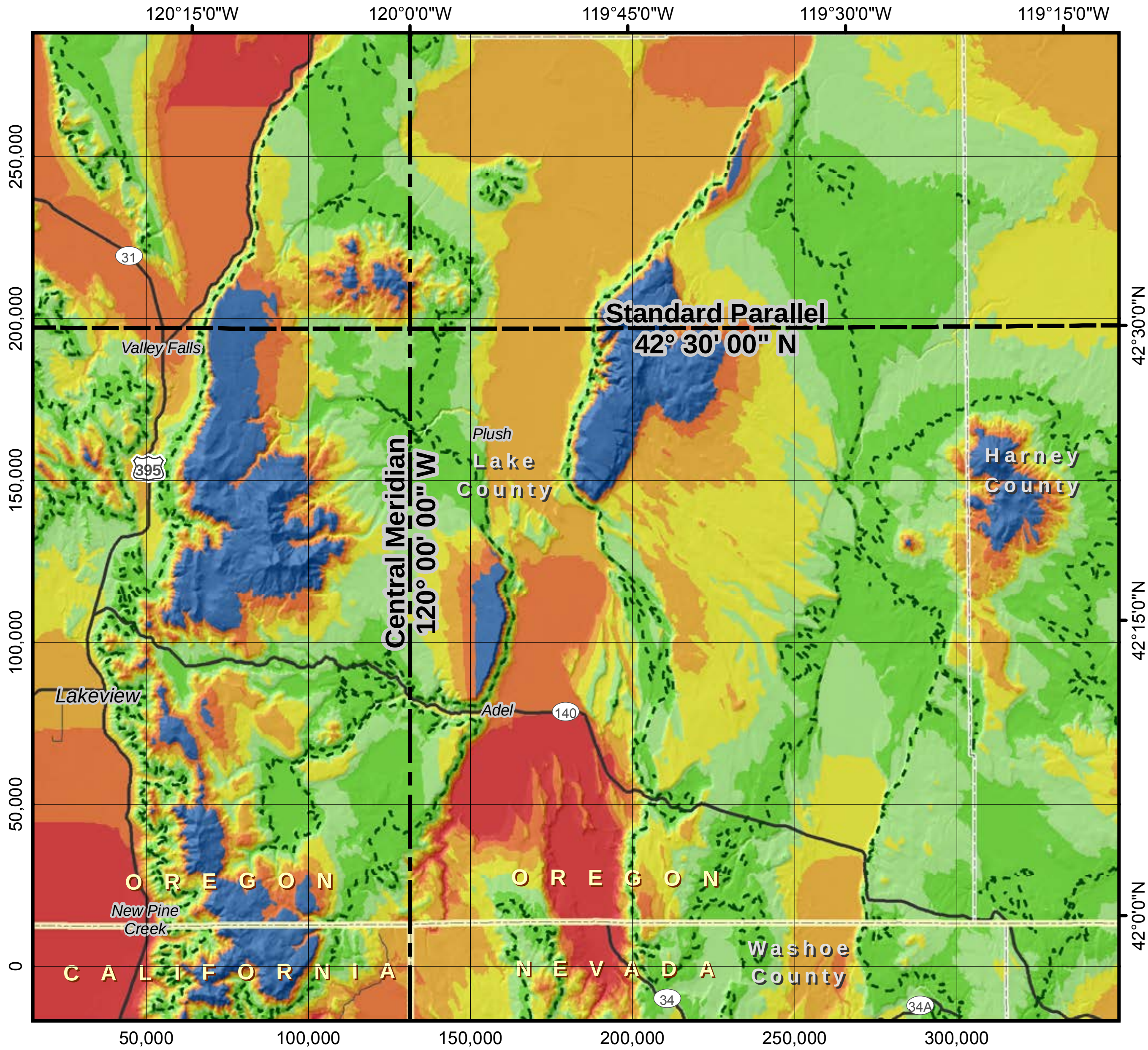
Parts of Lake County, and west Harney County encompassing the communities of:

Adel, Warner Highway 140, Warner Summit, Hart Mountain, Doherty Slide

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Warner Highway1	42 30 00.00000	119 30 00.00000	60121.18321	81109.33713
Warner Highway2	42 00 00.00000	119 20 00.00000	4663.77396	95248.89476
Warner Highway3	42 10 00.00000	120 00 00.00000	22964.13370	40000.00000

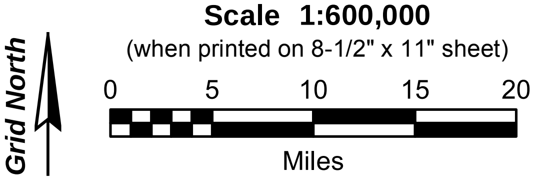


Oregon Coordinate Reference System
Warner Highway Zone

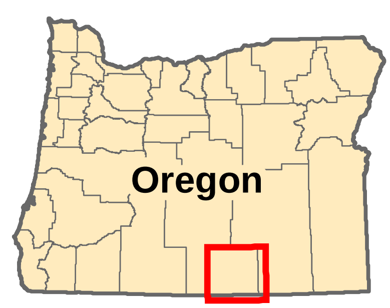
Lambert Conformal Conic projection
(single parallel)
North American Datum of 1983

Stnd parallel & grid origin: 42° 30' 00" N
Central meridian: 120° 00' 00" W
False northing: 60 000.000 m
False easting: 40 000.000 m
Standard parallel scale: 1.000 245 (exact)

Scale 1:600,000
(when printed on 8-1/2" x 11" sheet)



Projected map grid is shown in units of international feet



Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)

Prepared by:
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Map created 7/7/2016

WILLAMETTE PASS ZONE

Recommended Communities

It is recommended that OCRS users apply this zone when working in the vicinity of the following communities. More than one zone may work well for a community depending on the exact location and elevation of the project.

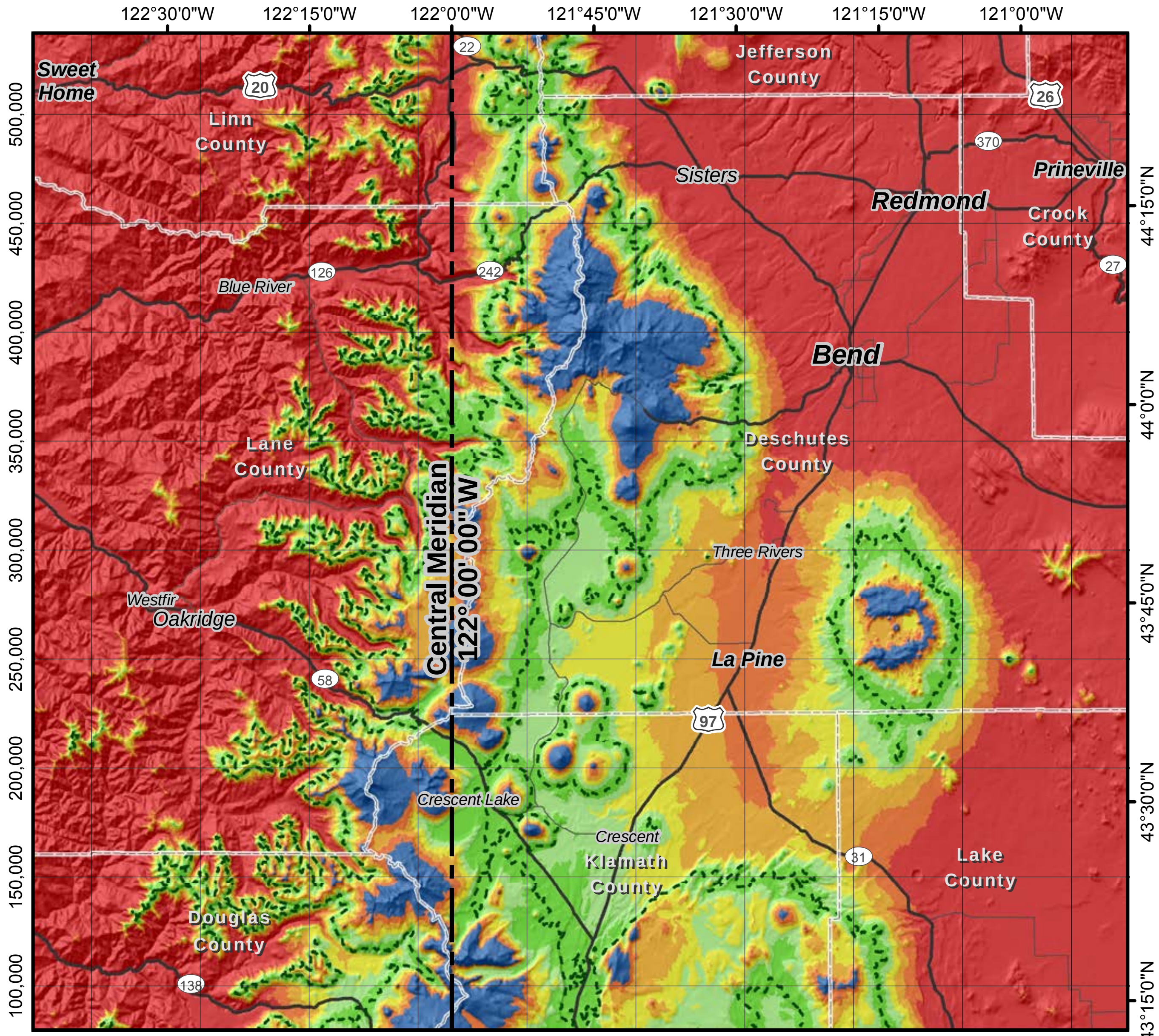
Parts of east Lane County, west Deschutes County and northwest Klamath County encompassing the communities of:

Willamette Pass Highway 58, Salt Creek Tunnel, Willamette Pass Ski Area, Crescent Lake, Crescent, Chemult

Zone parameter virtual grid coordinate software check

If you have entered the OCRS zone parameters into your vendor's software and successfully created new OCRS coordinate systems, then by entering the input lat/long values from the table below, your grid coordinates should match these results exactly to five decimal places.

Point Name	Latitude (N)	Longitude (W)	Northing (m)	Easting (m)
Willamette Pass1	44 25 00.00000	121 50 00.00000	157449.56348	33276.75354
Willamette Pass2	43 35 00.00000	122 00 00.00000	64821.86466	20000.00000
Willamette Pass3	43 30 00.00000	121 45 00.00000	55591.56308	40223.68195



Oregon Coordinate Reference System

Willamette Pass Zone

Transverse Mercator projection
North American Datum of 1983

Latitude of grid origin: 43° 00' 00" N
Central meridian: 122° 00' 00" W
False northing: 0.000 m
False easting: 20 000.000 m
Central meridian scale: 1.000 223 (exact)

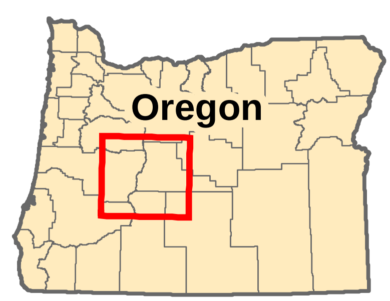
Scale 1:900,000
(when printed on 8-1/2" x 11" sheet)

Grid North

0 10 20 30
Miles

Projected map grid is shown in units of international feet

Linear distortion
- - - Zero distortion
< -50 ppm (< -0.25 ft/mi)
±10 ppm = ±0.05 ft/mi
±(10-20) ppm = ±(0.05-0.1) ft/mi
±(20-30) ppm = ±(0.1-0.15) ft/mi
±(30-40) ppm = ±(0.15-0.2) ft/mi
±(40-50) ppm) = ±(0.2-0.25) ft/mi
> +50 ppm (> +0.25 ft/mi)



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Geodetic ANALYSIS

Map created 6/7/2016