GeoDesigning in the Cloud:
Online Design of Low Distortion Projections

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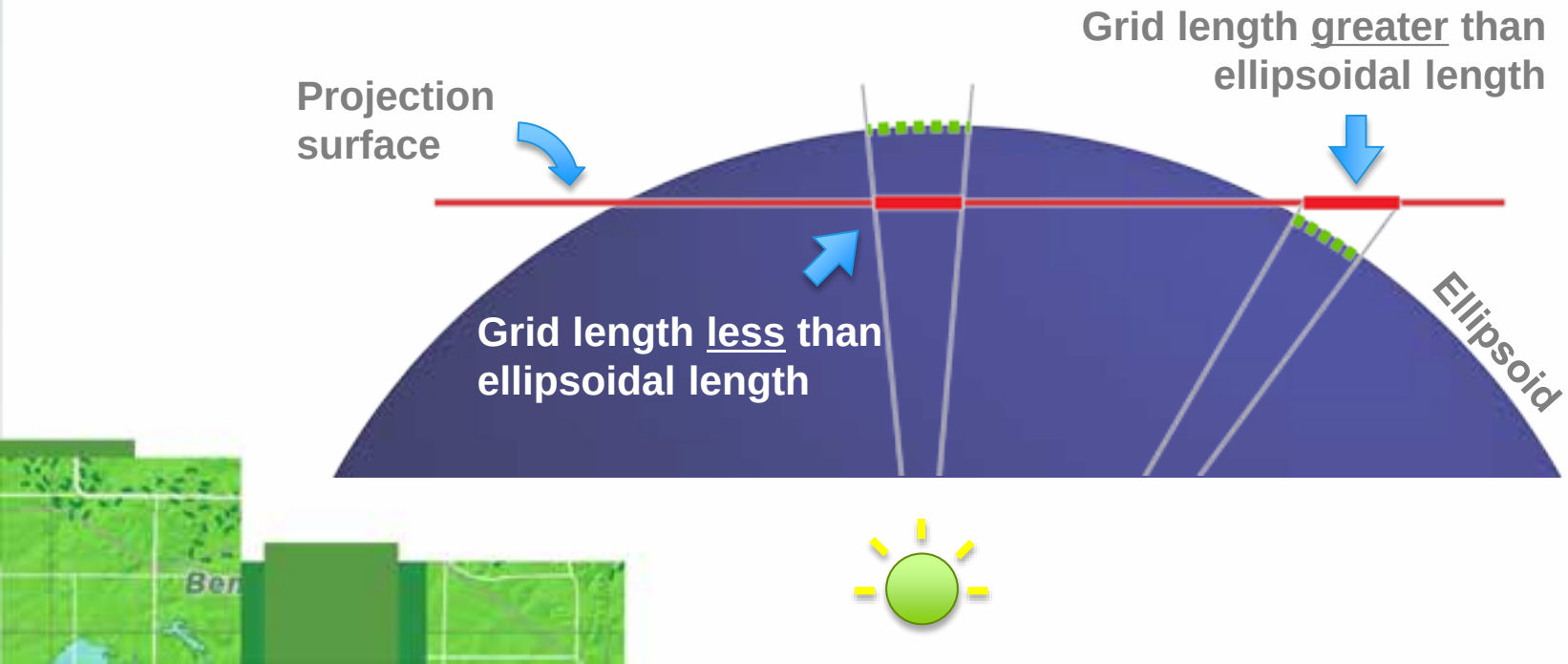
Map projections

- **Portray all or part of the round Earth on a flat surface**
- **Mathematical functions transforming coordinates from the curved surface to a plane**
- **A curved surface cannot be represented on a plane without distortion**
- **There is no way around this**
  - **Map projections are always distorted — it is a *Fact of Life***

Map projection distortion

Linear distortion

- **The difference in distance between a pair of projected (map grid) coordinates and the true "ground" distance on the surface of the earth**
- **Can be *positive* or *negative***



Low distortion

- **Some users want/expect a “low distortion” product, even if they don’t realize it**
  - **Engineering plans**
  - **Survey plats**
  - **As-built surveys**

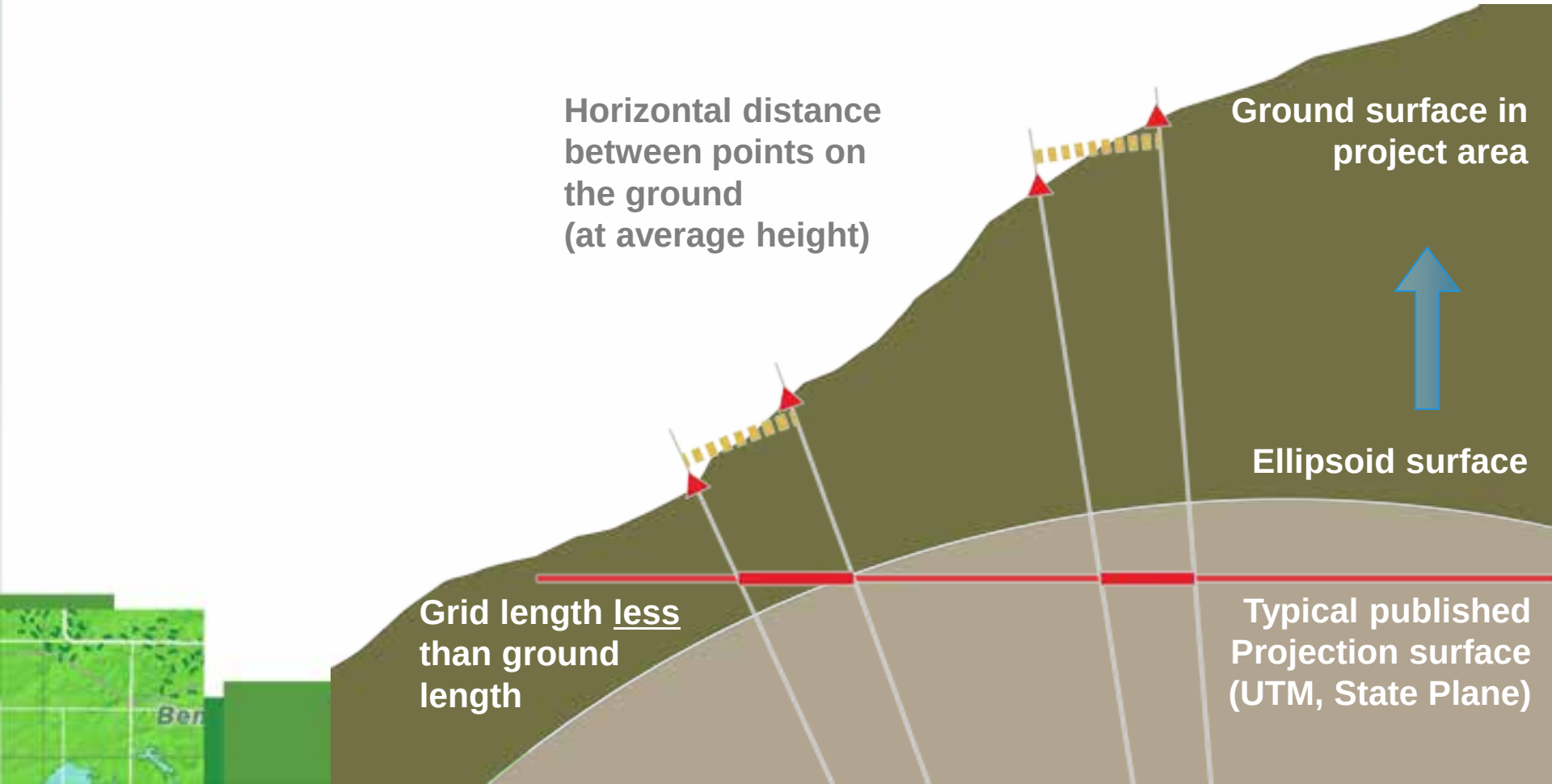
- **They also want linear distortion to be the same in all directions (“conformal”)**
- **Distortion is computable – not the same as “error”**
- **It is IMPOSSIBLE to get rid of distortion, but it can be MINIMIZED**

The problem

- Trying to cover the *largest area* with the *least distortion*
- An *optimization* problem
  - Goals are at odds with one another
- Complex design process

- Linear distortion is a function of:
  - Earth curvature (esp. for large areas)
  - Height
  - Projection scale
  - Projection axis location
  - Projection axis orientation (Oblique Mercator)

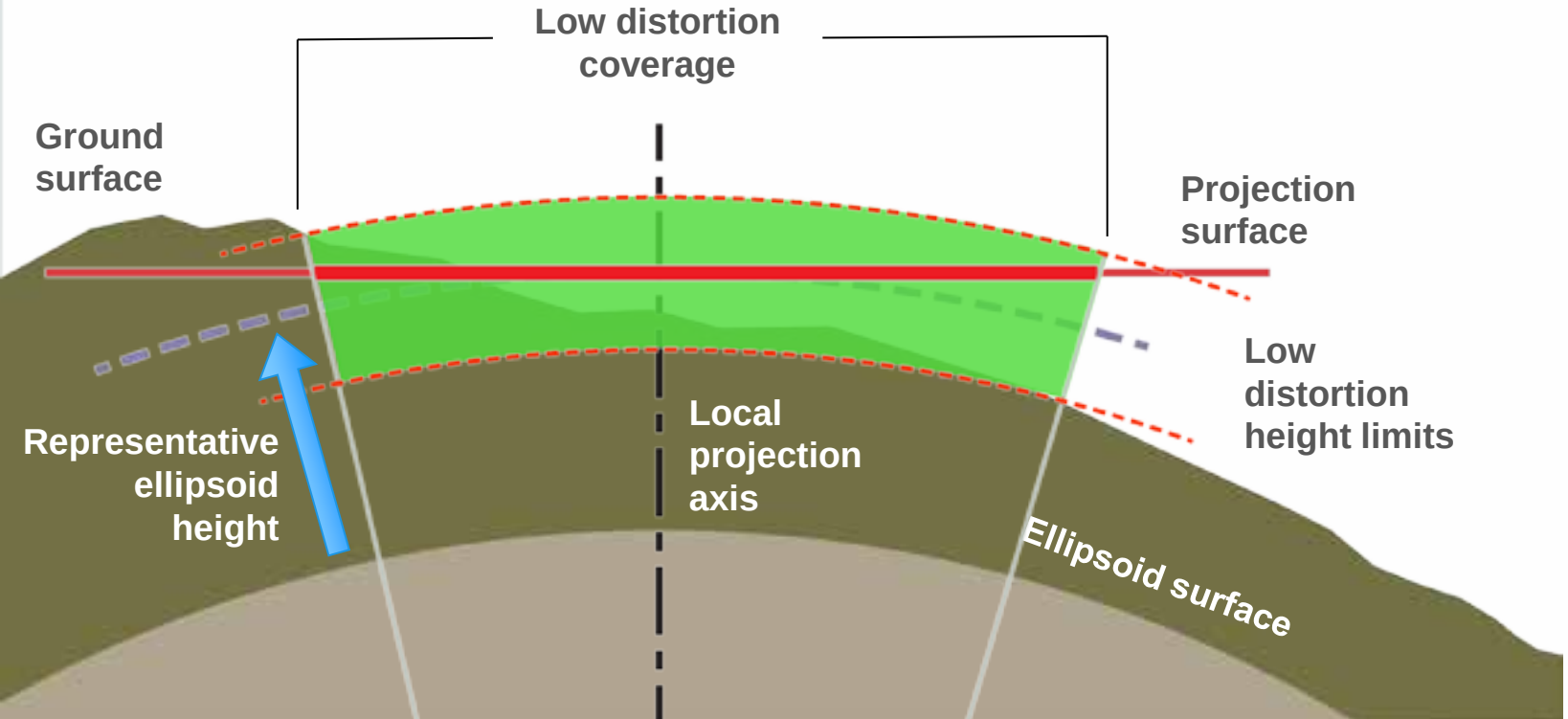
We work at ground



Low Distortion Projections (LDPs)

- **Custom, rigorously defined map projections**

Conformal projections



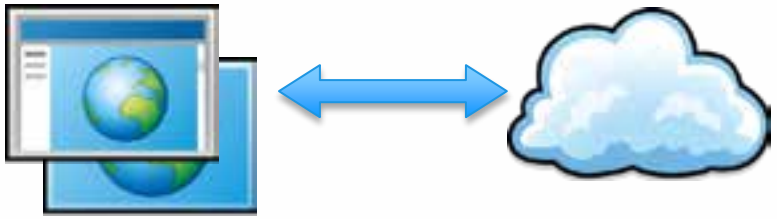
Some characteristics of LDPs

- Cover the *largest area* with the *least distortion*
- Map projection definitions are clean and simple
- Register perfectly with data having different projections and the same Geographic Coordinate System (GCS)
- Enables direct use of survey data in a GIS
  - … no “rubbersheeting”
- Compatible with a wide variety of software packages
- Designing an LDP

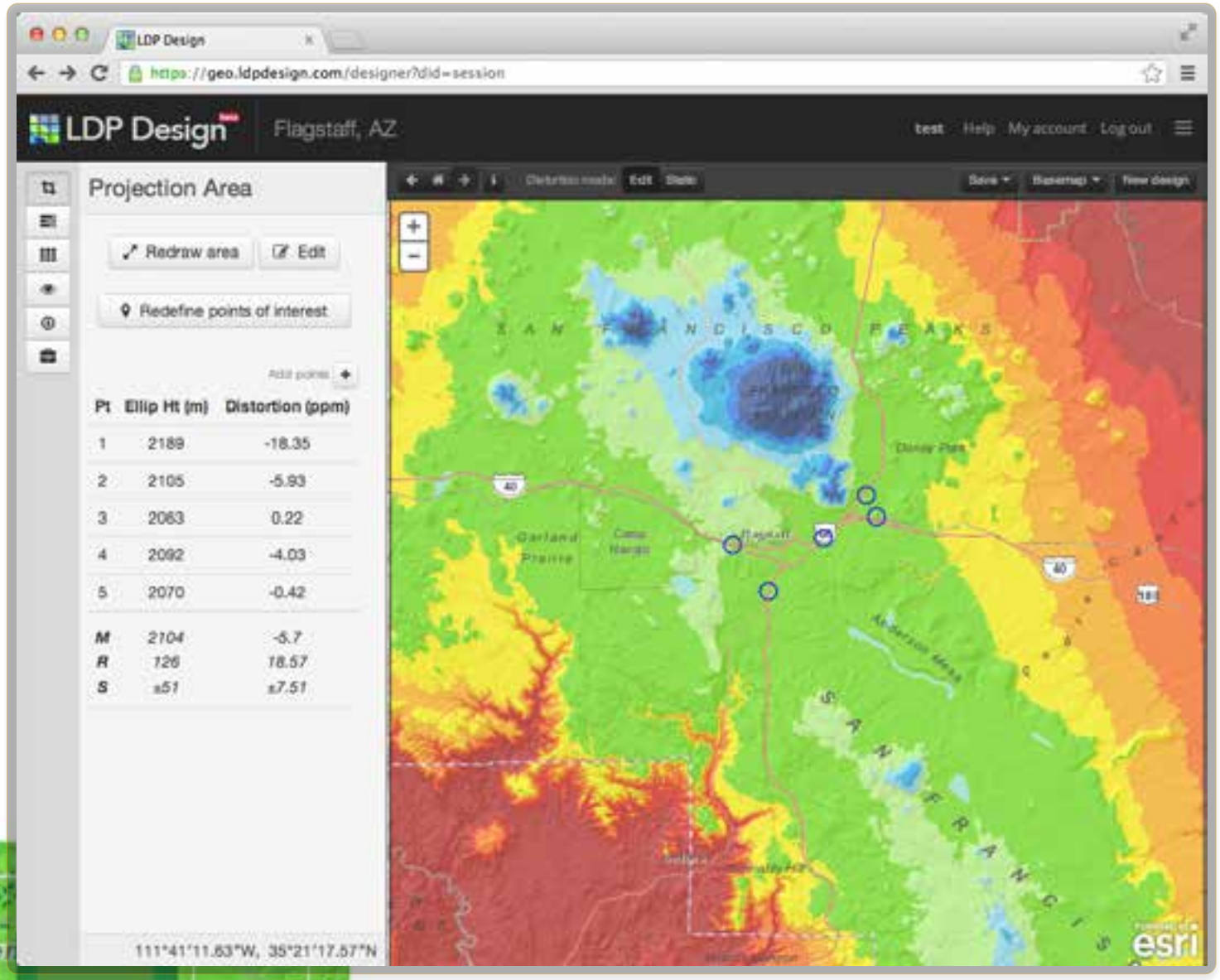
LDP Design

LDP Design

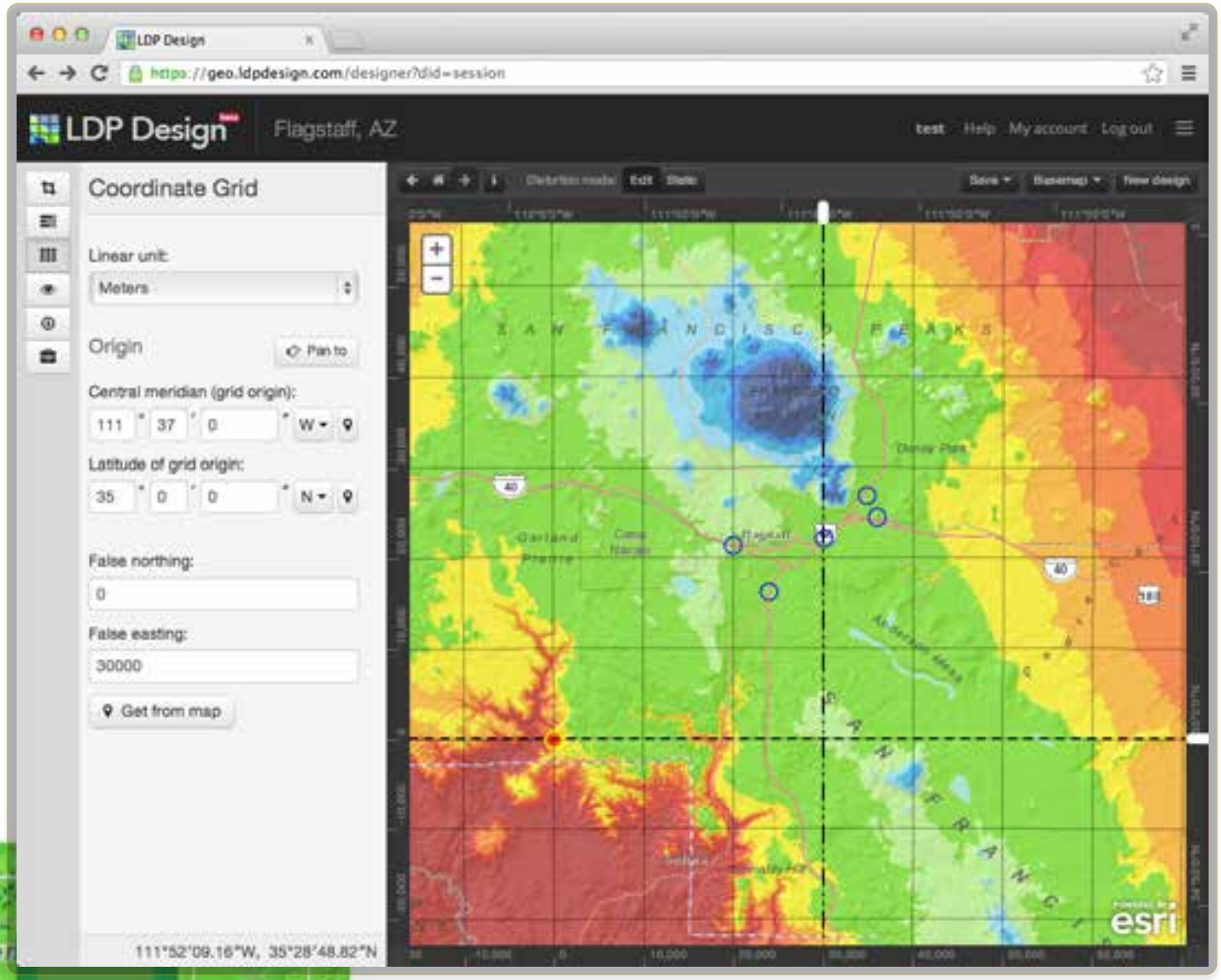
- **LDP Design is a tool that facilitates optimal design of Low Distortion Projections**
  - **Provides a map-centric, intuitive interface**
  - **Visualize distortion in parts per million (ppm = mm per km)**
  - **Real-time design performance feedback**
  - **It is an ArcGIS JavaScript API web application**
    - **Process-intensive tasks are done in the cloud**



LDP Design: Designer Web Application



LDP Design: Designer Web Application



LDP Design Demonstration

Oregon Coordinate Reference System (OCRS)

Bend-Redmond-Prineville LCC

- **One of twenty zones forming part of the OCRS**

Baker TM	Grants Pass-Ashland TM
Bend-Burns	Gresham-Warm Springs
Bend-Klamath Falls TM	La Grande TM
Bend-Redmond-Prineville LCC	Ontario TM
Canyonville-Grants Pass TM	Oregon Coast PM
Columbia River East LCC	Pendleton-La Grande
Columbia River West OM	Pendleton TM
Cottage Grove-Canyonville TM	Portland LCC
Dufur-Madras	Salem TM
Eugene TM	Santiam Pass

Oregon Department of Transportation (ODOT) Geometronics Unit

Oregon Coordinate Reference System (OCRS)

Technical Development Team

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ODOT Chief of Surveys/Geometronics Mgr.

Ken Bays, PLS
ODOT Lead Geodetic Surveyor

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Marion County Surveyor

Marcus Reedy, PLS
David Evans and Associates

Jim Griffis, PLS
David Evans and Associates

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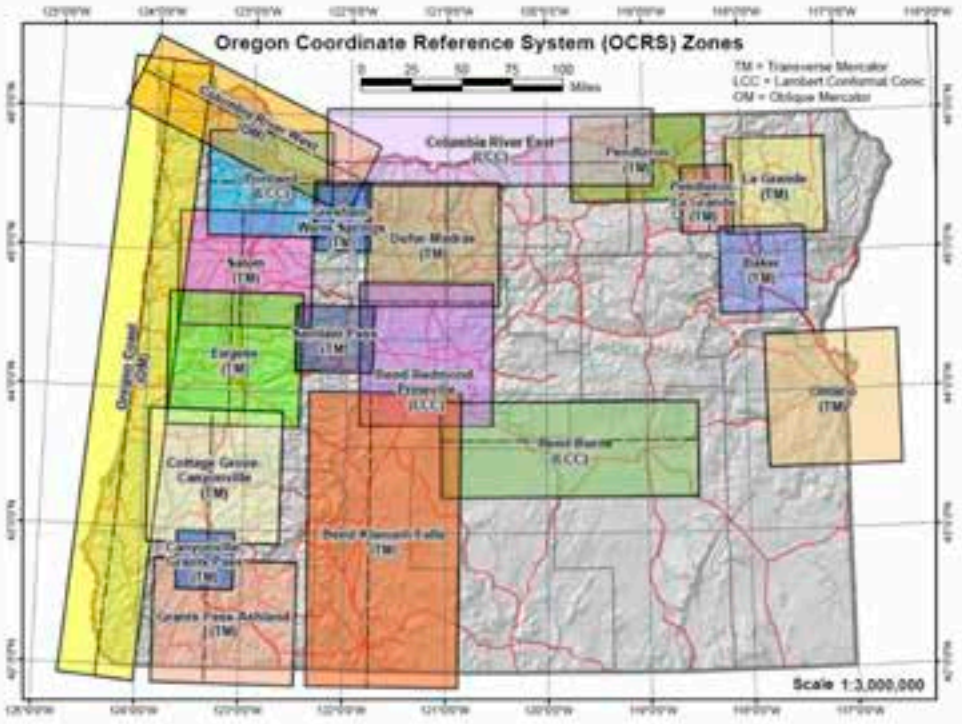
Assistant Professor, Oregon State Univ.



Consultant

Michael L. Dennis, RLS, PE
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For additional information on the Oregon Coordinate Reference System, see the OCRS Handbook and User Guide available on the ODOT Geometronics web page.

Oregon Department of Transportation

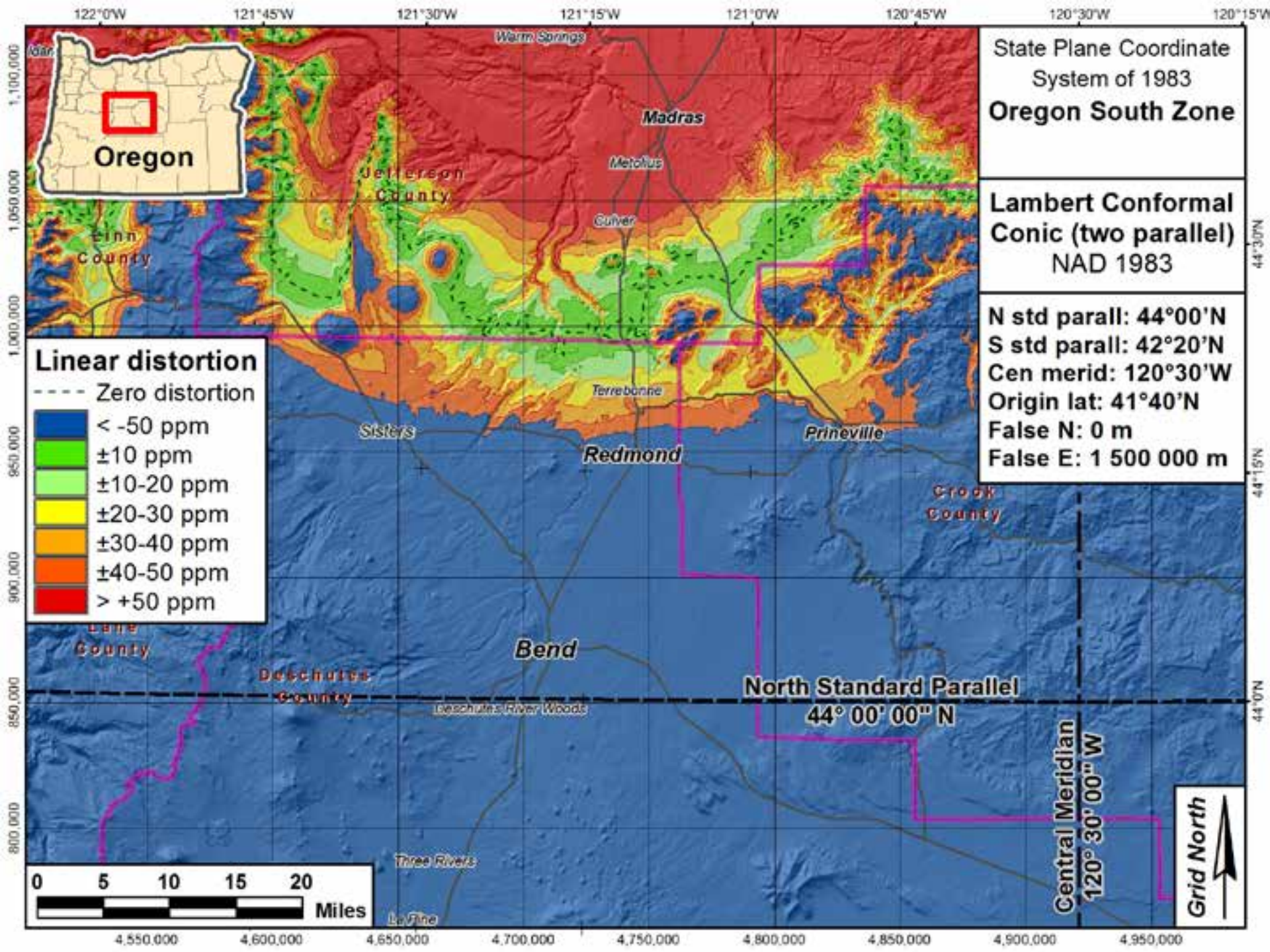
March, 25th 2011

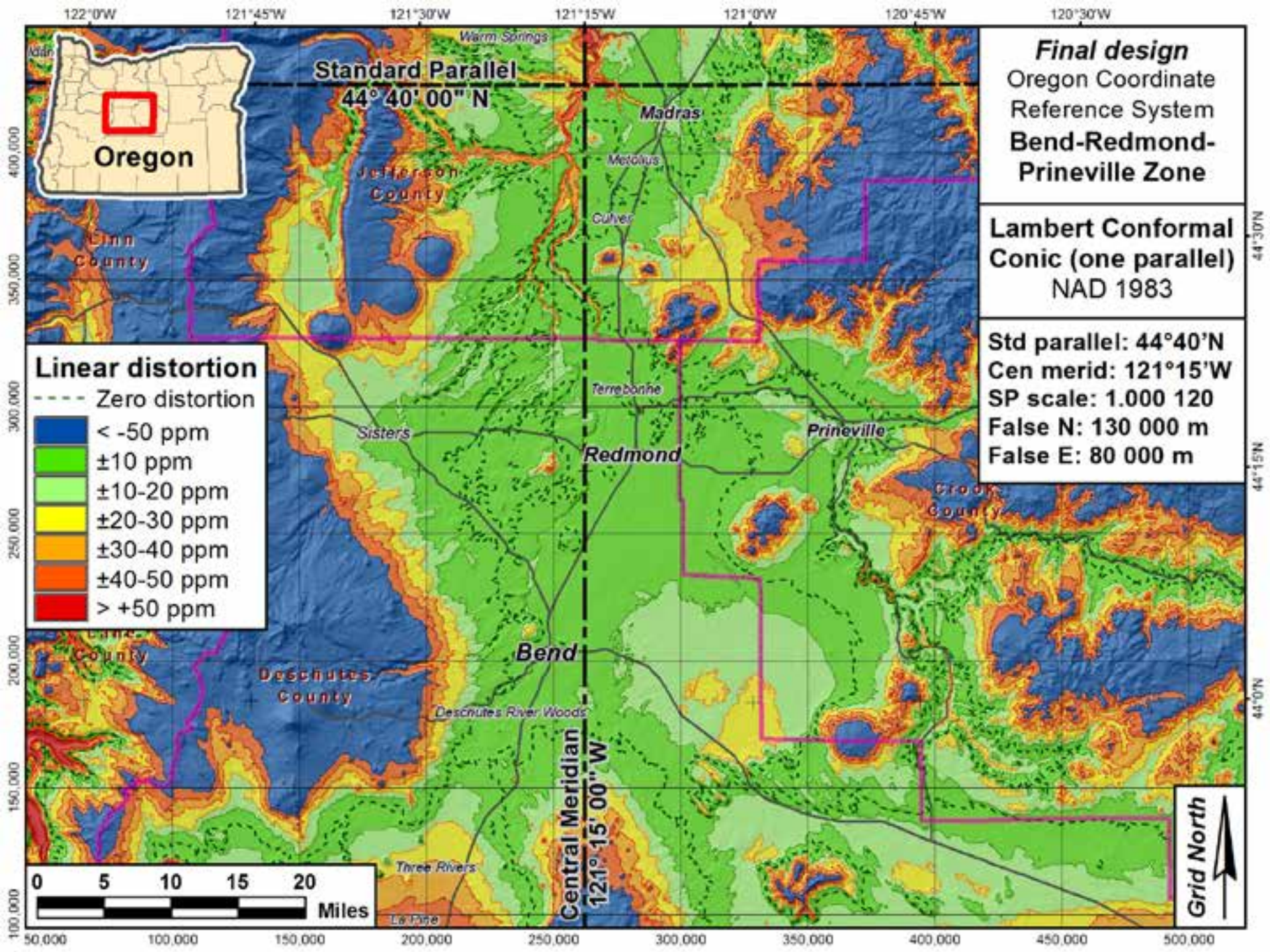
Not just for design of new systems

Evaluate existing designs as a means of comparison and as educational tool

- **Check distortion of existing systems**
  - **For example, State Plane, UTM**

- **OCRS LDP vs. Oregon State Plane, South Zone**


Oregon
State Plane Coordinate System of 1983
Oregon South Zone
Lambert Conformal Conic (two parallel)
NAD 1983
N std parall: 44°00'N
S std parall: 42°20'N
Cen merid: 120°30'W
Origin lat: 41°40'N
False N: 0 m
False E: 1 500 000 m
Linear distortion
Zero distortion
< -50 ppm
±10 ppm
±10-20 ppm
±20-30 ppm
±30-40 ppm
±40-50 ppm
> +50 ppm
North Standard Parallel
44° 00' 00" N
Central Meridian
120° 30' 00" W
Grid North
0 5 10 15 20
Miles
Warm Springs
Madras
Metolius
Jefferson County
Culver
Linn County
Terrebonne
Sisters
Redmond
Prineville
Crook County
Bend
Deschutes County
Deschutes River Woods
Three Rivers
La Pine
122°0'W
121°45'W
121°30'W
121°15'W
121°0'W
120°45'W
120°30'W
120°15'W
1,100,000
1,050,000
1,000,000
950,000
900,000
850,000
800,000
44°30'N
44°15'N
44°0'N
4,550,000
4,600,000
4,650,000
4,700,000
4,750,000
4,800,000
4,850,000
4,900,000
4,950,000


Final design
Oregon Coordinate Reference System
Bend-Redmond-Prineville Zone
Lambert Conformal Conic (one parallel)
NAD 1983
Std parallel: 44°40'N
Cen merid: 121°15'W
SP scale: 1.000 120
False N: 130 000 m
False E: 80 000 m
Standard Parallel 44° 40' 00" N
Central Meridian 121° 15' 00" W
Oregon
Linear distortion
Zero distortion
< -50 ppm
±10 ppm
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Warm Springs
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Deschutes County
Deschutes River Woods
Three Rivers
La Pine
0 5 10 15 20 Miles
Grid North
122°0'W
121°45'W
121°30'W
121°15'W
121°0'W
120°45'W
120°30'W
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
500,000
44°30'N
44°15'N
44°0'N

Not just for design of new systems

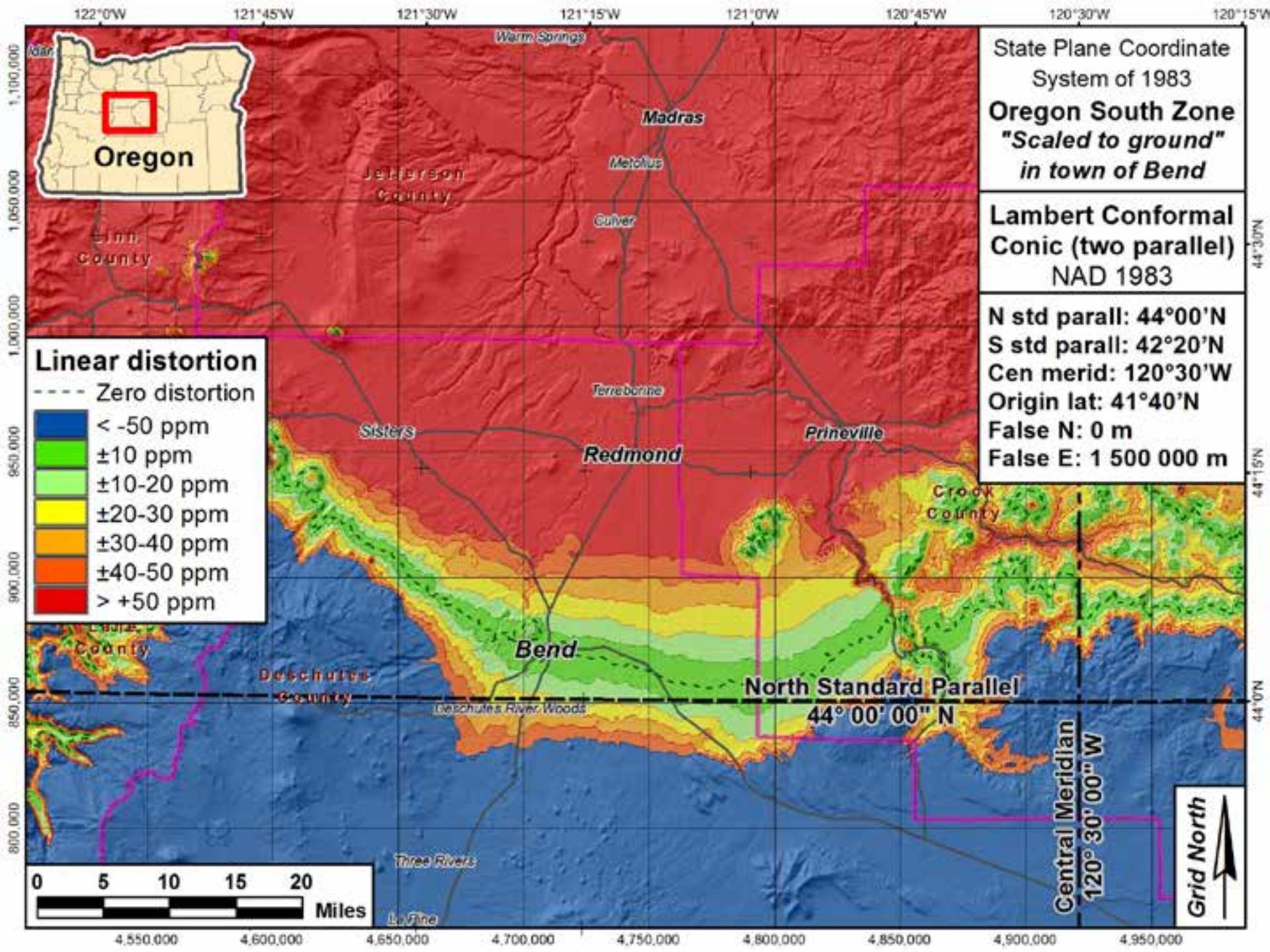
Evaluate existing designs as a means of comparison and as educational tool

- **Check distortion of existing systems**
  - **For example, State Plane, UTM**

- **OCRS LDP vs. Oregon State Plane, South Zone**

- **OCRS LDP vs. Oregon State Plane, South Zone**

  “scaled to ground”


Oregon
State Plane Coordinate System of 1983
Oregon South Zone
"Scaled to ground"
in town of Bend
Lambert Conformal Conic (two parallel)
NAD 1983
N std parall: 44°00'N
S std parall: 42°20'N
Cen merid: 120°30'W
Origin lat: 41°40'N
False N: 0 m
False E: 1 500 000 m
Linear distortion
Zero distortion
< -50 ppm
±10 ppm
±10-20 ppm
±20-30 ppm
±30-40 ppm
±40-50 ppm
> +50 ppm
North Standard Parallel
44° 00' 00" N
Central Meridian
120° 30' 00" W
Grid North
0 5 10 15 20
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Warm Springs
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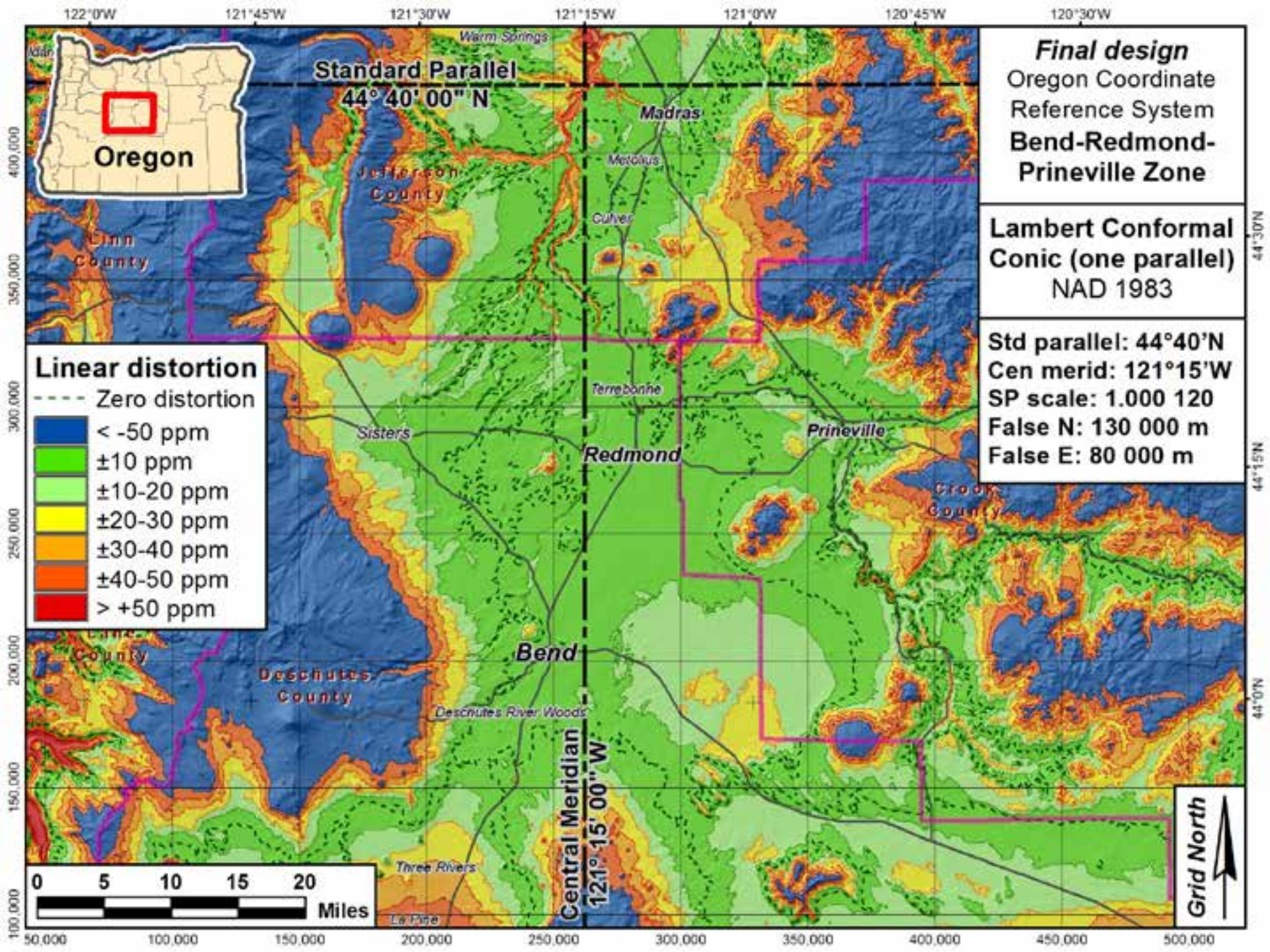
4,900,000
4,950,000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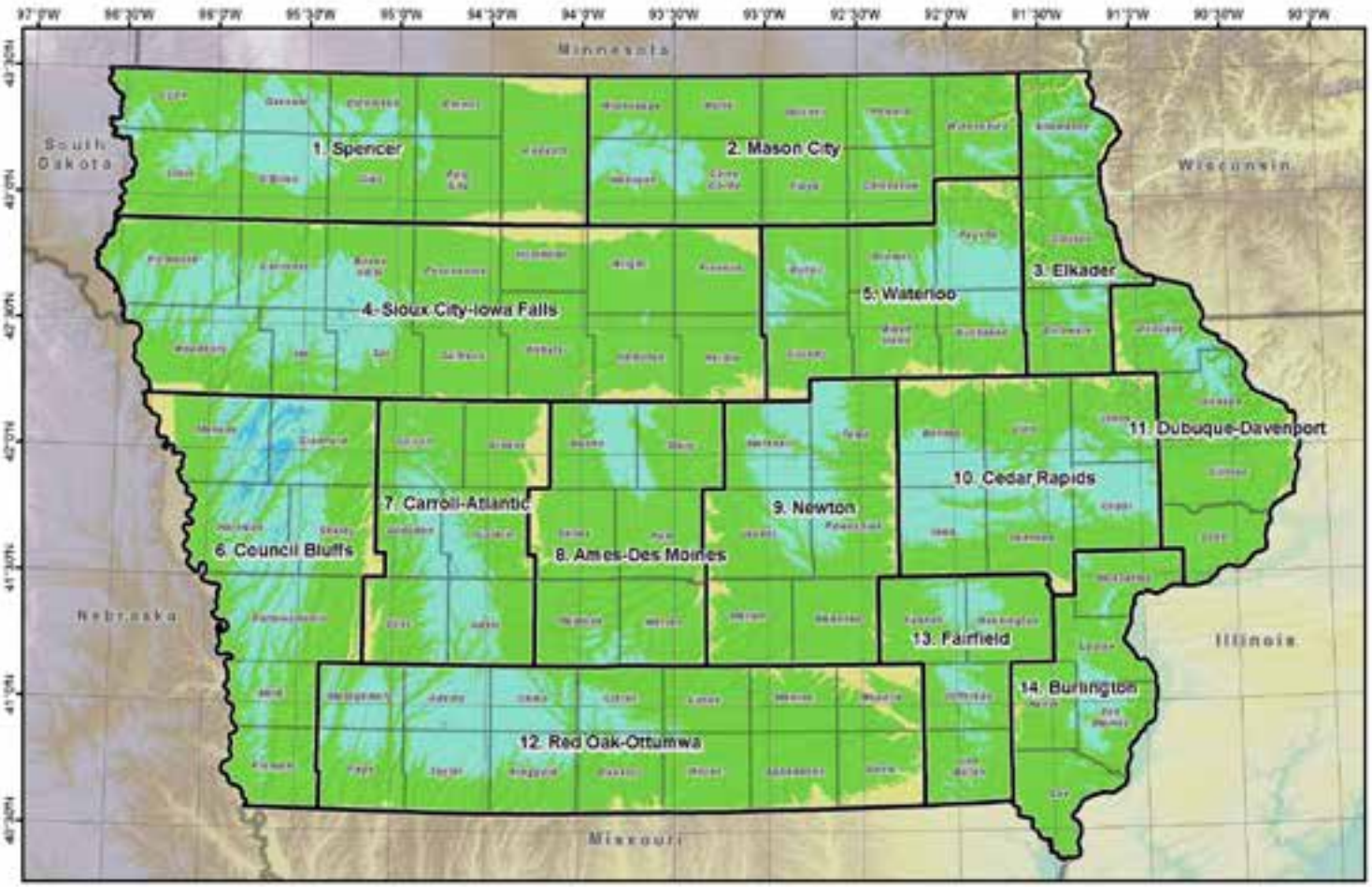
0 5 10 15 20 Miles
Grid North
122°0'W
121°45'W
121°30'W
121°15'W
121°0'W
120°45'W
120°30'W
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
100,000
150,000
200,000
250,000
300,000
350,000
400,000
450,000
500,000
44°30'N
44°15'N
44°0'N

Iowa Regional Coordinate System (IaRCS)

- **Made up of 14 zones:**

1. Spencer (LCC)
2. Mason City (LCC)
3. Elkader (TM)
4. Sioux City-Iowa Falls (LCC)
5. Waterloo (LCC)
6. Council Bluffs (TM)
7. Carroll-Atlantic (TM)
8. Ames-Des Moines (TM)
9. Newton (TM)
10. Cedar Rapids (LCC)
11. Dubuque-Davenport (TM)
12. Red Oak-Ottumwa (LCC)
13. Fairfield (TM)
14. Burlington (TM)

Within ±10 ppm = 73.628%
Within ±20 ppm = 99.605%
Within ±25 ppm = 99.999%
Outside ±25 ppm = 0.001%



Iowa Regional Coordinate System

All zones referenced to the North American Datum of 1983

Linear distortion (parts per million)

- -20 to -25 ppm
- -10 to -20 ppm
- ±10 ppm (±0.05 ft/mi)
- +10 to +20 ppm
- +20 to +25 ppm

Statewide LDP statistics

Minimum:	-25.9 ppm
Maximum:	+25.9 ppm
Mean:	-3.9 ppm
Std dev:	±7.5 ppm

Portion of the state that is

within ±10 ppm	= 73.629%
within ±20 ppm	= 99.605%
within ±25 ppm	= 99.999%
outside ±25 ppm	= 0.001%

Linear unit is US survey foot (sft)
1 sft = 1200 / 3937 meter (exact)

0 20 40 80 Miles

Designed and prepared by
Michael L. Dennis, PLS, PE
Geodetic
Gary G. Brown, PLS, CP
GB Consulting

Prepared for
Iowa Department of Transportation
February 2014
IOWADOT

Projection types

LCC = Lambert Conformal Conic
TM = Transverse Mercator

1. Spencer (LCC)

Std. parallels & grid origin:	43° 12' 00" N
Central meridian:	95° 15' 00" W
False northing:	1,500,000.000 sft
False easting:	1,500,000.000 sft
Standard parallel scale:	1.000 262 (exact)

2. Mason City (LCC)

Std. parallels & grid origin:	43° 12' 00" N
Central meridian:	93° 45' 00" W
False northing:	1,500,000.000 sft
False easting:	1,500,000.000 sft
Standard parallel scale:	1.000 245 (exact)

3. Elkader (TM)

Latitude of grid origin:	42° 15' 00" N
Central meridian:	91° 15' 00" W
False northing:	4,500,000.000 sft
False easting:	1,500,000.000 sft
Central meridian scale:	1.000 236 (exact)

4. Sioux City-Iowa Falls (LCC)

Std. parallels & grid origin:	42° 12' 00" N
Central meridian:	93° 30' 00" W
False northing:	6,000,000.000 sft
False easting:	14,500,000.000 sft
Standard parallel scale:	1.000 240 (exact)

5. Waterloo (LCC)

Std. parallels & grid origin:	42° 30' 00" N
Central meridian:	92° 15' 00" W
False northing:	6,000,000.000 sft
False easting:	1,500,000.000 sft
Standard parallel scale:	1.000 222 (exact)

6. Council Bluffs (TM)

Latitude of grid origin:	40° 15' 00" N
Central meridian:	95° 45' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Central meridian scale:	1.000 209 (exact)

7. Carroll-Atlantic (TM)

Latitude of grid origin:	40° 15' 00" N
Central meridian:	94° 30' 00" W
False northing:	4,500,000.000 sft
False easting:	0.000 sft
Central meridian scale:	1.000 246 (exact)

8. Ames-Des Moines (TM)

Latitude of grid origin:	40° 15' 00" N
Central meridian:	93° 45' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Central meridian scale:	1.000 221 (exact)

9. Newton (TM)

Latitude of grid origin:	40° 15' 00" N
Central meridian:	93° 45' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Central meridian scale:	1.000 221 (exact)

10. Cedar Rapids (LCC)

Std. parallels & grid origin:	41° 30' 00" N
Central meridian:	91° 30' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Standard parallel scale:	1.000 220 (exact)

11. Dubuque-Davenport (TM)

Latitude of grid origin:	40° 15' 00" N
Central meridian:	90° 45' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Central meridian scale:	1.000 227 (exact)

12. Red Oak-Ottumwa (LCC)

Std. parallels & grid origin:	40° 15' 00" N
Central meridian:	93° 30' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Standard parallel scale:	1.000 227 (exact)

13. Fairfield (TM)

Latitude of grid origin:	40° 15' 00" N
Central meridian:	91° 45' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Central meridian scale:	1.000 209 (exact)

14. Burlington (TM)

Latitude of grid origin:	40° 15' 00" N
Central meridian:	91° 15' 00" W
False northing:	0.000 sft
False easting:	6,500,000.000 sft
Central meridian scale:	1.000 210 (exact)

Working on:

- Automatically create designs best-fit to topography
  - Can dramatically improve performance in sloping terrain
- Modernize (yet honor) legacy systems
  - Preserve projected coordinate values with up-to-date datum (GCS)
- Georeference existing modified systems
  - E.g., State Plane systems “scaled to ground”
- Guidance for defining LDPs in software packages
- Increasing coverage around the world
- Adding LDP coordinates to NGS Datasheets and OPUS solution reports

Summary

- **LDP Design makes it easier to minimize distortion over the largest area possible**
  - **Performance and simplicity superior to other methods**
  - **Large area coverage reduces proliferation of local systems**
- **Satisfies needs of surveying, engineering, and GIS users**
  - **Compatible with wide variety of software**
  - **Works for GPS and terrestrial (e.g., total station) data**
  - **Enables *direct* use of survey and engineering data in GIS**
- **LDP Design web app *GREATLY* simplifies design of optimal low-distortion coordinate systems!**

Thank You

geo.ldpdesign.com