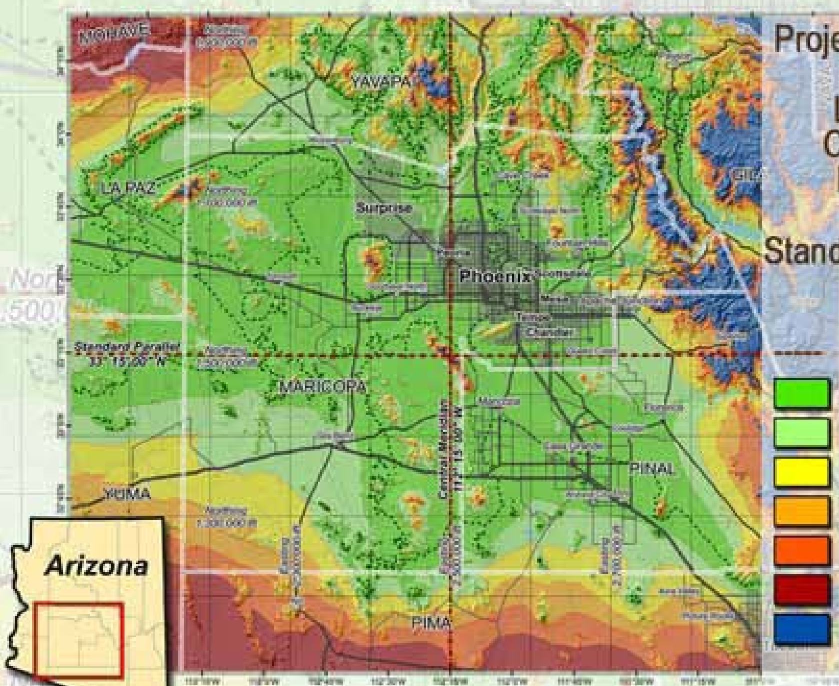
ACEC
2007 ENGINEERING EXCELLENCE AWARDS

LOW DISTORTION PROJECTION

CENTRAL ARIZONA



Projection type: Lambert Conformal Conic (single parallel)
Latitude of origin: 33° 15' 00" N
Central meridian: 112° 15' 00" W
False northing: 1,500,00.000 ift
False Easting: 2,500,00.000 ift
Standard parallel scale: 1.000 045 (exact)

Linear Distortion

- Zero distortion
- ± 20 ppm = ± .1 ft/mile
- ± (20 - 40 ppm) = ± (.1 - .2) ft/mile
- ± (40 - 60 ppm) = ± (.2 - .3) ft/mile
- ± (60 - 80 ppm) = ± (.3 - .4) ft/mile
- ± (80 - 100 ppm) = ± (.4 - .5) ft/mile
- > +100 ppm = (> +.5 ft/mile)
- < -100 ppm = (< -.5 ft/mile)

GREEN MEANS GOOD!

TITLE: LOW DISTORTION PROJECTION
LOCATION: CENTRAL ARIZONA
CLIENT: CITY OF SURPRISE
SURPRISE, ARIZONA
ENTERING FIRM: DAVID EVANS AND ASSOCIATES, INC.

2141 EAST HIGHLAND AVENUE, SUITE 200
PHOENIX, ARIZONA 85016

DAVID EVANS AND ASSOCIATES INC.

Geodetic Analysis, LLC

SURPRISE ARIZONA

SURPRISE
ARIZONA

Land Survey Department
12425 W. Bell Rd., D-100
Surprise, AZ 85374
Ph 623-222-7543
Fax 623-222-7501

American Council of Engineering Companies of Arizona
1309 East Echo Lane
Phoenix, AZ 85020

Re: Low Distortion Projection

In 2006, the City of Surprise formed its first Land Survey Department in response to the rapid pace of development in the city. It was realized that this would be the perfect time to establish a new mapping projection that could be utilized for all engineering, development, and GIS projects for the foreseeable future. State Plane Coordinates (SPC) have been the basis of all mapping and development projects previously and though useful, has many inherently poor characteristics. Developed by the Federal Government for each state in the 1930's, State Plane Coordinates are based on political boundaries, and referenced to sea-level elevation, taking no account for local geographic topography. The use of this reference datum produces distortions of over 150 Parts Per Million (PPM) or ¾ of a foot per mile when converting from the SPCs to true ground positions. This antiquated system worked fine for the low precision capabilities of historical land surveying practices and instrumentation but with modern high precision long range capabilities, the system became inadequate. The development of a projection which produced near identical values between grid and ground points without the necessity or conversion calculations was needed.

Brian Fisher RLS, of David Evans and Associates was chosen to develop such a projection which would fit the City of Surprise Planning Area with the stipulation that distortion values not exceed 40-60 PPM and restricted to two zones. This was felt to be the best we could expect and would be sufficient for the city's needs.

What was produced was far beyond expectations. Brian developed a near-ground based, single zone, Lambert Conformal Conic projection that fit not only Surprise, but the entire Maricopa County area and much of the developable portion of Pinal County with linear distortions of less than 20 PPM.

This amazing projection will allow anyone doing surveying, engineering and GIS development to coordinate and associate all projects onto one simple mathematical base not only in Surprise, but anywhere within all of Maricopa County. For the first time there is the potential to consolidate every municipality, agencies such as McDOT, the County Assessor, GIS Department and all agencies concerned with development and mapping onto one common base. This projection will become the standard upon which all development will be related for many decades to come.

Ron Dry

Ron Dry RLS
Chief Land Surveyor
City of Surprise, Arizona

City of Peoria
Information Technology
8343 West Monroe Street, Peoria, Arizona 85345
Ph: 623-773-7218 Fax: 623-773-7270

American Council of Engineering Companies of Arizona
1309 E Echo Lane
Phoenix, AZ 85020

To whom it may concern,

This letter has been generated in response to the City of Surprise ***Low Distortion Projection*** project of 2007. As Geographic Information System (GIS) Supervisor for the City of Peoria, I have the unique opportunity to see firsthand the great benefit of this project to the GIS community within our region. This project (as proposed and adopted through the City of Surprise) has opened up a new avenue to assist in the alleviation of potential problems between the GIS "grid" environment and the commonly used "ground" coordinate systems used in most cadastral/boundary surveying. I have been very impressed with the willingness of both Surprise and their respective consultants to "think out of the box" and generate a projection, and tool kit benefiting the greatest number of users in the valley of the sun.

Key to this projection will be the simple ability to share basic survey data amongst multiple jurisdictions – having a common GROUND and GRID environment will provide an ease of use of collected survey information within the region, including (but are certainly not limited to) infrastructure management (as-built inventory, blue stake recon, etc), cadastral integration, boundary (jurisdictional) reconciliation, and emergency management uses. Communication, data sharing, and system integration are key components of GIS implementation and success, extending this communication beyond specific GIS activities and integrating with the building blocks of data creation (surveying data) will greatly enhance the regions ability to communicate quickly, efficiently, and (most importantly) accurately in times of calm as well as emergency.

Bravo to the City of Surprise in this effort, and may all jurisdictions take advantage of this "tool" to aid in GIS development around our region.

Sincerely,

Timothy J. Smothers – GIS Supervisor
City of Peoria, AZ
623.773.7671
timothy.smothers@peoriaaz.gov

Maricopa County
Department of Public Works

2901 W. Durango St
Phx, AZ 85009
Phone: 602-506-4622
Fax: 602-506-4858
www.maricopa.gov

American Council of Engineering Companies of Arizona
1309 East Echo Lane
Phoenix, AZ 85020

Re: 2007 Engineering Excellence Awards – Low Distortion Project

Dear Sirs:

David Evans and Associates has developed a projection which matches ground for a substantially large portion of Maricopa County. The benefits of such a projection could save engineers, surveyor and GIS professionals in both the private and public sector a significant amount of time and reduce the chances of coordinate system errors. This time savings, although difficult to quantify, will ultimately allow tax payer dollars to go further.

Maricopa County Department of Transportation is currently taking a serious look at implementing this projection for a vast majority of its projects in the future.

Sincerely,

John J. Rose R.L.S.
Maricopa County Department of Transportation
Survey Manager

Executive Summary

Project Title:

Low Distortion Projection

Category:

Survey Mapping, GIS/LIS, Photogrammetry

The Project Problem: Prepare a new mapping system, called a Low Distortion Projection (LDP) that will meet three key requirements. First, produce an LDP with a close relativity to the surface of the Earth. Second, select an LDP that works with as many kinds of survey and mapping equipment and software as possible. Third, the map projection shall cover the largest geographic area possible, as long as it doesn't conflict with the above two requirements. The third provision is to include not only the City's internal needs, but also as many adjacent communities as practical, in as few zones as possible.

The Project Solution: DEA's team used the map projection formulas published for the State Plane Coordinate system (SPC) in a new way. The team completely reevaluated how map projections are designed. The classical approach to map design has always been oriented at 'sea level' and within municipal or arbitrary geometric boundaries. There has not previously been consideration to the topographic surface of the region. This LDP design solution incorporates digital elevation model data from the United States Geological Survey (USGS), in conjunction with Geoid model data from the National Geodetic Survey (NGS) to calculate the fit of the final map, where the map is most used, at the ground. The result is a map that provides seamless interchangeability of data for the City's mapping requirements.

Project Description

Project Title:

Low Distortion Projection

Category:

Survey Mapping, GIS/LIS, Photogrammetry

a. Role of the entrant's firm in the project.

DEA's client manager, Tom Lute, RLS has over twenty years of experience in Arizona. Lute oversaw the contracting, and overall performance of the project. DEA's project surveyor Brian Fisher, RLS has over a decade of surveying experience in Central Arizona, and is Adjunct Faculty at Phoenix College, and has for the past three years taught courses in the Geodesy and Map Projections. Having this local experience has helped develop his understanding of the needs of Engineers and Surveyors in the metro Phoenix area. DEA's QA/QC manager, Michael Magyar, LSIT who has over a decade of surveying experience in Central Arizona, reviewed every phase of the design process.

b. Role of others consultants participating in the project.

Geodetic Analysis, LLC's principal Michael Dennis, RLS, PE aided in the design process by developing computer programs and map illustrations. Dennis who lectures nationally on geodesy and map projections has over six years of experience in Arizona.

c. Brief description of the entrant's contribution to the project addressing each of the following:

Original or Innovative Application of New or Existing Techniques.

For over 500 years, the focus of large area cartography has been to orient map design at 'sea level' (the ellipsoid). This project takes a major move beyond that line of thinking.

The LDP is oriented at the surface of the earth *(see photo 5)*. The original State Plane Coordinates were first derived in the 1930's, and revised somewhat in 1980's. They were also initially conceptualized for surveys with linear accuracies of one in ten-thousand. Today's GPS surveys are close to one hundred times as precise. This has necessitated taking a new approach to how geodetic data is represented with a map projection. The calculation to go from a surface measurement to a map projection grid measurement involves an intermediate calculation to the ellipsoid (sea level). In the classical approach, the design of the map projection minimized the distortion between the map projection and sea level only. The elevation of the ground often compounded this distortion and resulted in a higher final correction. The LDP design approach starts with the ground data first, and fits the map projection grid directly to the ground. The result is a canceling of the elevation and sea level corrections to result in a lower final correction *(see photo 5)*. Fisher created the programs that were used to create vertical color graduated maps to show the profile view of the map distortions *(see photos 1 – 4)*. To do this, Fisher developed a new way of plotting flat map projections in relation to the round world *(see photos 1 - 2)*. The classical illustration method has been to show the earth as a round line, and the map projection as a flat line. Fisher's method flattened the earth first, and then graphed the map projection as a curved line in relation to it. On these special graphs, several map projections may be viewed simultaneously, and an easy comparison may be made with their distortional performance to the ground *(see photos 3 – 4)*. One of the many contributions Magyar made was to have a final coordinate value with a unique numerical value for both the northing and the easting. In the final map, coordinates that start with a one, are always a Northing (Y axis) value; coordinates that start with a two, are always an Easting (X axis) value. This simple addition gives a uniqueness to the data, and where formatting syntax differ, confusion is averted (as is the case between typical field survey data represented in Northing, Easting ordered data (Y,X) and the typical CAD environment where (X,Y) data is the typical syntax). Magyar also suggested that projection parameters be defined in full integer values, irrespective of the unit they are converted to. We have done this where possible, and where not, the number of digits past the decimal place has been minimized, with values being rational numbers in as many bases as possible. An example of integer values in multiple units is illustrated by the false Northing and Easting of the projection: Northing at the grid origin 1,500,000 international feet which converts to exactly 457,200 meters; Easting at the grid origin, 2,500,000 international feet which converts to exactly 762,000 meters. Another example of simplified units is the central meridian of the projection. The State Plane Coordinate equivalent is Central Zone. The Central Meridian is 111 degrees, 55 minutes. The decimal degree equivalent is 111.916666… (repeating decimal). The Central Meridian of this projection is 112 degrees 15 minutes, or 112.25 (exact), the latter being much simpler than its' SPC counterpart. Dennis combined the United States Geological Survey (USGS) Digital Elevation Model (DEM) data with National Geodetic Survey (NGS) Geoid data to create an ellipsoidal height terrain dataset. This hybrid elevation model made direct modeling of the final map plane distortions possible (see photo 6). Dennis also created the planometric color graduated contour maps to show the plan view of the map distortions *(see photos 7 – 8)*.

Future Value to the Engineering Profession.

State Plane Coordinates have been fundamentally unchanged for nearly eighty years. LDP's are the evolution of SPC. This project provides a working product for the Central Arizona region that should satisfy the map requirements well into the foreseeable future. The legacy of this project is further guaranteed by several factors. First and foremost is the benefit of simplicity in the final product. The design process of the projection is very complicated, and requires many applications of advanced knowledge and skill. Conversely, the end defining parameters are very simple. These parameters are easily communicated between Engineering, Surveying, Planning and Mapping professionals. The data sharing between all of these professionals is streamlined and errors from data conversions are eliminated. Secondly, the map projection distortion has been reduced to such a small amount, it does not require additional data reduction for surveying, mapping, engineering and all but the very esoteric of scientific projects requirements (see exhibit 9). It is the opinion of this design teem that there is no foreseeable need in the near future to require a more precise system.

Social, Economic, and Sustainable Design Considerations.

This project has long reaching social benefits in that it covers all the municipalities in Central Arizona. The economic benefits are many. First, there are no additional design costs for any community that wishes to adopt the map projection. Second, there is a reduced cost to the public at large because this projection fully facilitates rapid and correct data exchange between: Geographic Information Systems (GIS); Computer Aided Drafting (CAD); Global Positioning System (GPS); and classical survey equipment such as Total Stations using field data collector computers. The traditional terrestrially observed survey 'ground' measurements do not need to be reduced to the map grid, because the grid is at the ground already. This not only simplifies field survey efforts for the typical surveyor, but also fully bridges the gap between the two principal types of field survey equipment (GPS and total stations).

Complexity.

The compilation and management of the datasets used in the design process require advanced computer and programming skills. Understanding and programming the formula used in the map projection computations require a higher understanding of mathematics. Conceptualizing across the multiple forms and realizations of geometric space (Euclidian, spherical/elliptical, geophysical, etc.) requires advanced understandings of mathematics, geomatics and geodesy. This design team was selected specifically because of its cumulative advanced standing in the aforementioned.

Exceeding client needs. Including budgeted and actual costs, scheduled and actual date of completion.

We have vastly exceeded the client's needs and expectation. This project was completed quickly and on budget. During the initial examination and determination of the scope of the project, not even the design team realized how well our final product would turn out. We had enough of a cursory understanding of the region to know that we could easily fit the city within a maximum of two zones or map regions. After fully modeling the region however, we were very happy to discover a different approach for the City, which covered the developable area of all of Maricopa, and most of Pinal, parts of southern Yavapai, parts of southeastern La Paz, and northwestern Yuma Counties. This project has been a great success, and all involved are very proud of the legacy it will leave behind.

FOR IMMEDIATE RELEASE:

Contact:
Brian Fisher, RLS
602-678-5151 (voice)
602-678-5155 (fax)
bsf@deainc.com
www.deainc.com

Low Distortion Projection, Where Grid is Ground

Surprise Arizona, August 22, 2007 - Announcing the City's new coordinate system, where grid is ground, and where Survey, Mapping and Engineering data can now be freely and easily exchanged accurately and quickly.

The City's Chief Land Surveyor, Ron Dry, RLS, consulted Brian Fisher, RLS of David Evans and Associates, Inc, and Michael Dennis, RLS, PE of Geodetic Analysis, LLC, to create a seamless mapping projection that can be used by all users. The resulting Low Distortion Projection (LDP) has met all of the City's needs.

"What was produced was far beyond expectations" says Dry, "This amazing projection will allow anyone doing surveying, engineering and GIS development to coordinate and associate all projects onto one simple mathematical base not only in Surprise, but anywhere within all of Maricopa County. This projection will become the standard upon which all development will be related for many decades to come".

Maricopa County Department of Transportation, Survey Manager, John Rose, RLS said "The benefits of such a project could save engineers, surveyors and GIS professionals in

–MORE-

both the private and public sector a significant amount of time and reduce the chances of coordinate system errors. This time savings, although difficult to quantify, will ultimately allow tax payer dollars to go further."

Neighboring City, Peoria's GIS Supervisor, Timothy J. Smothers said "Communication, data sharing, and system integration are key components of GIS implementation and success, extending this communication beyond specific GIS activities and integrating with the building blocks of data creation (survey data) will greatly enhance the regions ability to communicate quickly, efficiently, and (most importantly) accurately in times of calm as well as emergency."

The LDP is an evolution from its predecessor, the State Plane Coordinate (SPC). With the introduction of high accuracy measuring equipment a new system was needed. The same formulas were used in the development with a key distinguishing difference. The original SPC was designed at sea level, and did not take into consideration the topographic surface of the earth. Doing this made the maps produced in SPC distorted in comparison to the measurements taken on the ground. The LDP grid is not at sea level, but at the ground. The final LDP product is much easy to use compared to SPC.

For additional information contact Robert Dykman, Marketing Coordinator, or Brian Fisher, RLS, Project Surveyor. www.deainc.com

David Evans and Associates, inc. is a full service Land Survey, Civil Engineering and Planning consulting firm in several western states including Arizona.

- END-

Photograph Index

Photo № 1: Illustration showing two methods of visualizing the relationship between the round world, and planer map projections. The traditional approach shows the world as round, and the map as flat. Fisher's approach shows the world as flat, and the map as rounded.

Photo № 2: Illustration showing multiple map projections simultaneously in both a round, and flat earth view.

Photo № 3: Profile view, looking west along the meridian 112.55 degrees. Graph shows four map projection posibilities for comparison. The green line is the final LDP, the blue lines were potential possibilities examined during the design process, and the red line is SPC.

Photo № 4: Profile view, looking north along the parallel 33.8 degrees. Graph shows five map projection possibilities for comparison. The green line is the final LDP, the blue lines were potential possibilities examined during the design process, the red line is SPC, and the orange line is UTM.

Photo № 5: Illustration showing the relationships (scale) between the ground, the ellipsoid (sea level) and the map projection grid. The final scale, Ssg (combined scale) is minimized using the LDP.

Photo № 6: Illustration showing the method of combining USGS DEM data with NGS Geoid data, to create an ellipsoidal height model used in map plane distortion calculations.

Photo № 7: Plan view map showing color rendered contours of the map distortions with State Plane Coordinates. Blue means bad.

Photo № 8: Plan view map showing color rendered contours of the map distortions with Low Distortion Projection. Green means good.

Photo № 9: Graph of linear distortions calculated over various distances, using several different base map projections, and with different linear ratios/scales/PPM values.

Photo №10: Photo of a computer operator using GIS and the LDP to process survey field data.

Photo № 11: Photo of a survey field crew taking terrestrial measurements from GPS derived control, and transferring them seamlessly into a sub terrain traverse.

Photo № 12: Photo of construction equipment working on the ground.

Photo № 13: Photo of a GPS receiver collecting data on a geodetic control project.

Photo № 14: Photo of a geodetic control station.

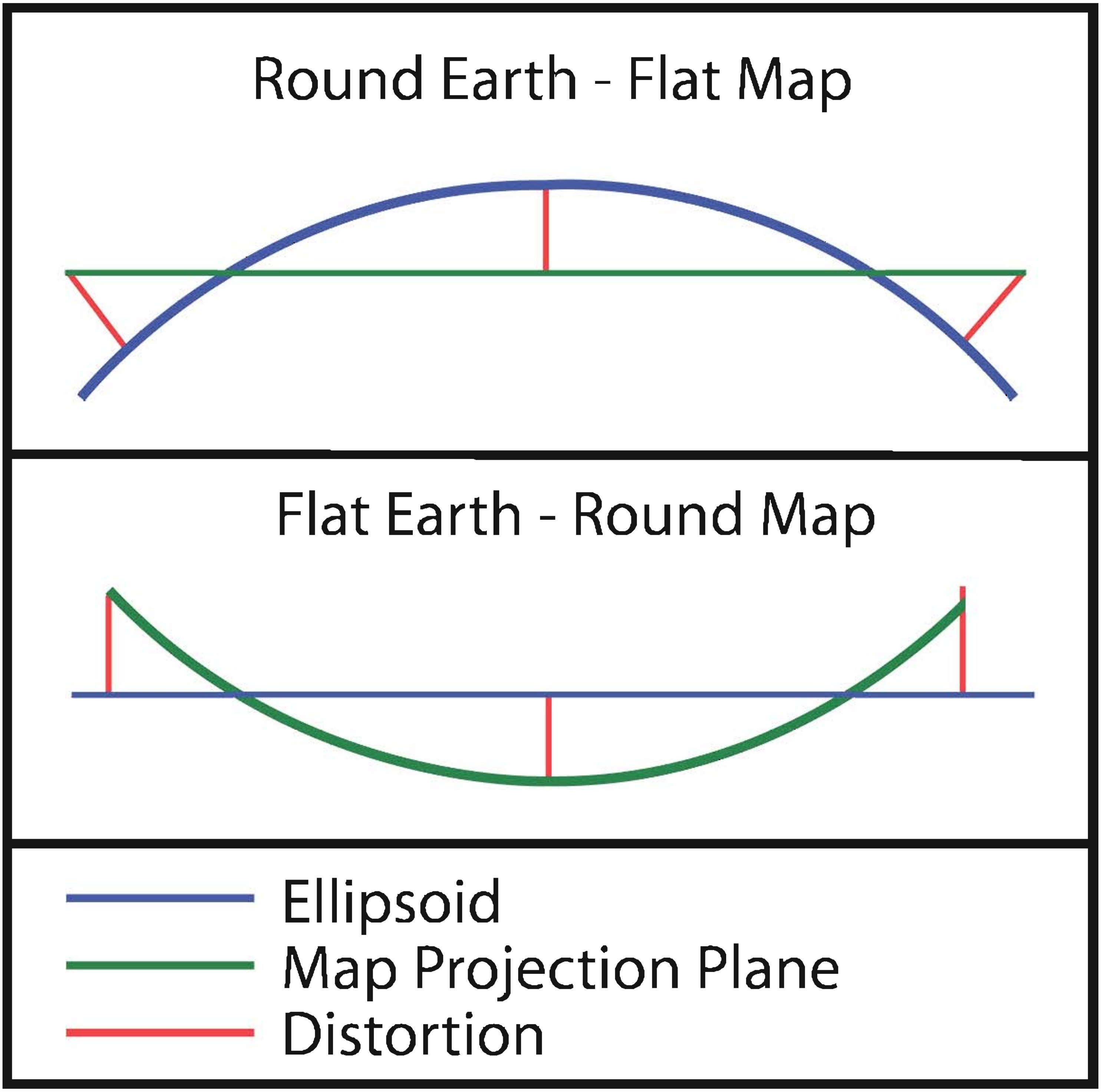

Round Earth - Flat Map
Flat Earth - Round Map
Ellipsoid
Map Projection Plane
Distortion

Photo # 1

Round Earth VS. Flat Earth Profile View

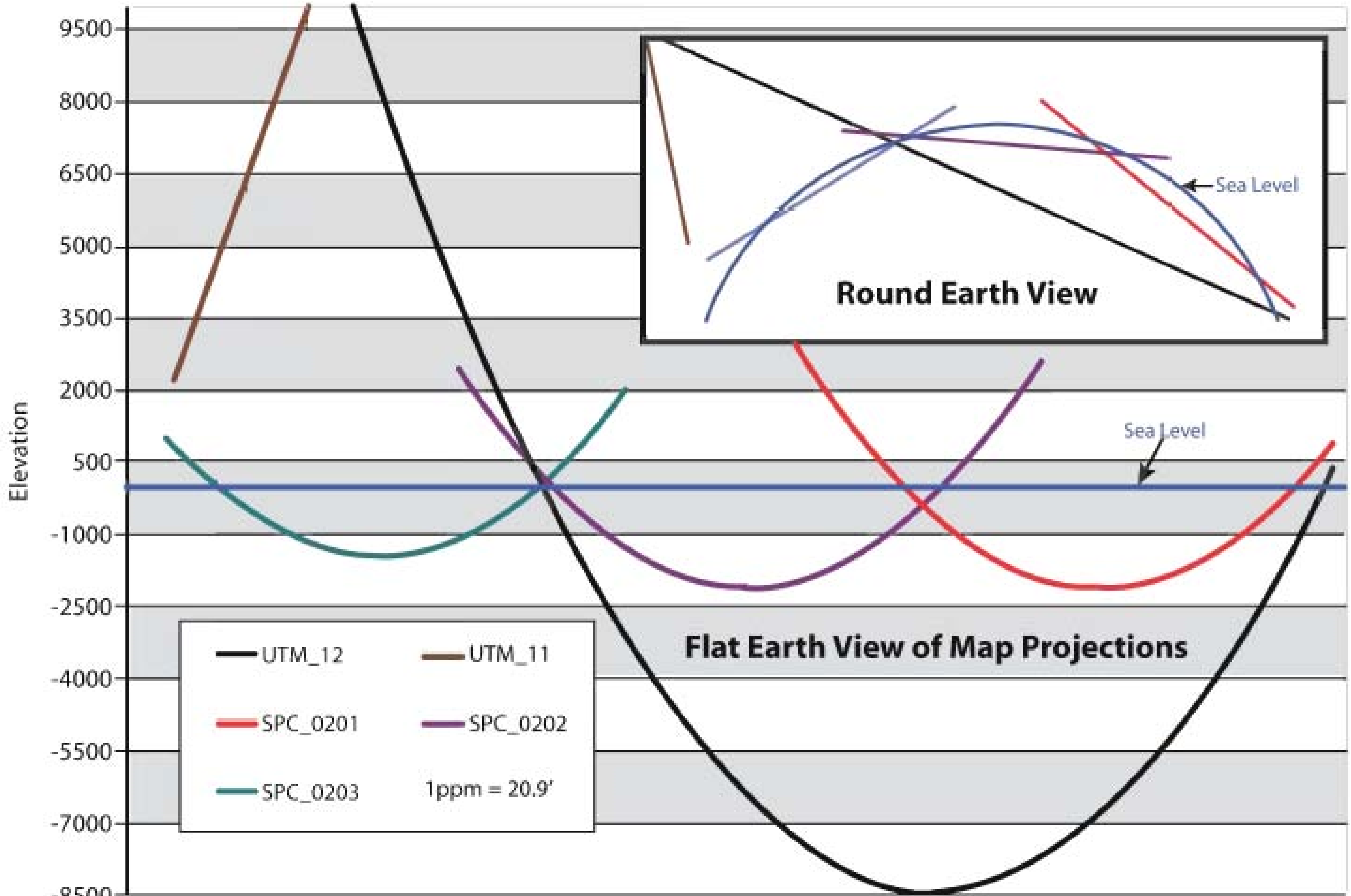


Photo # 2

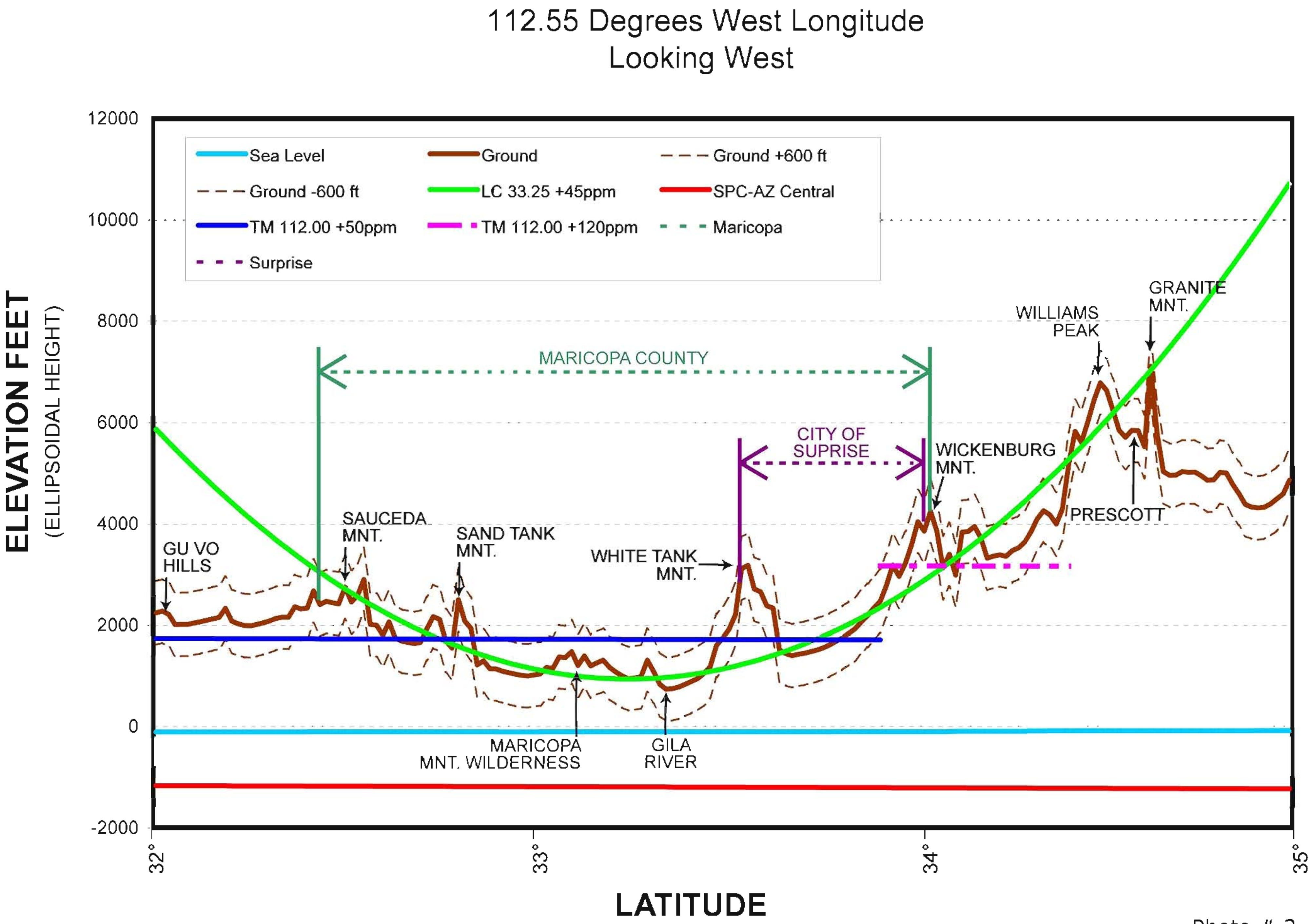
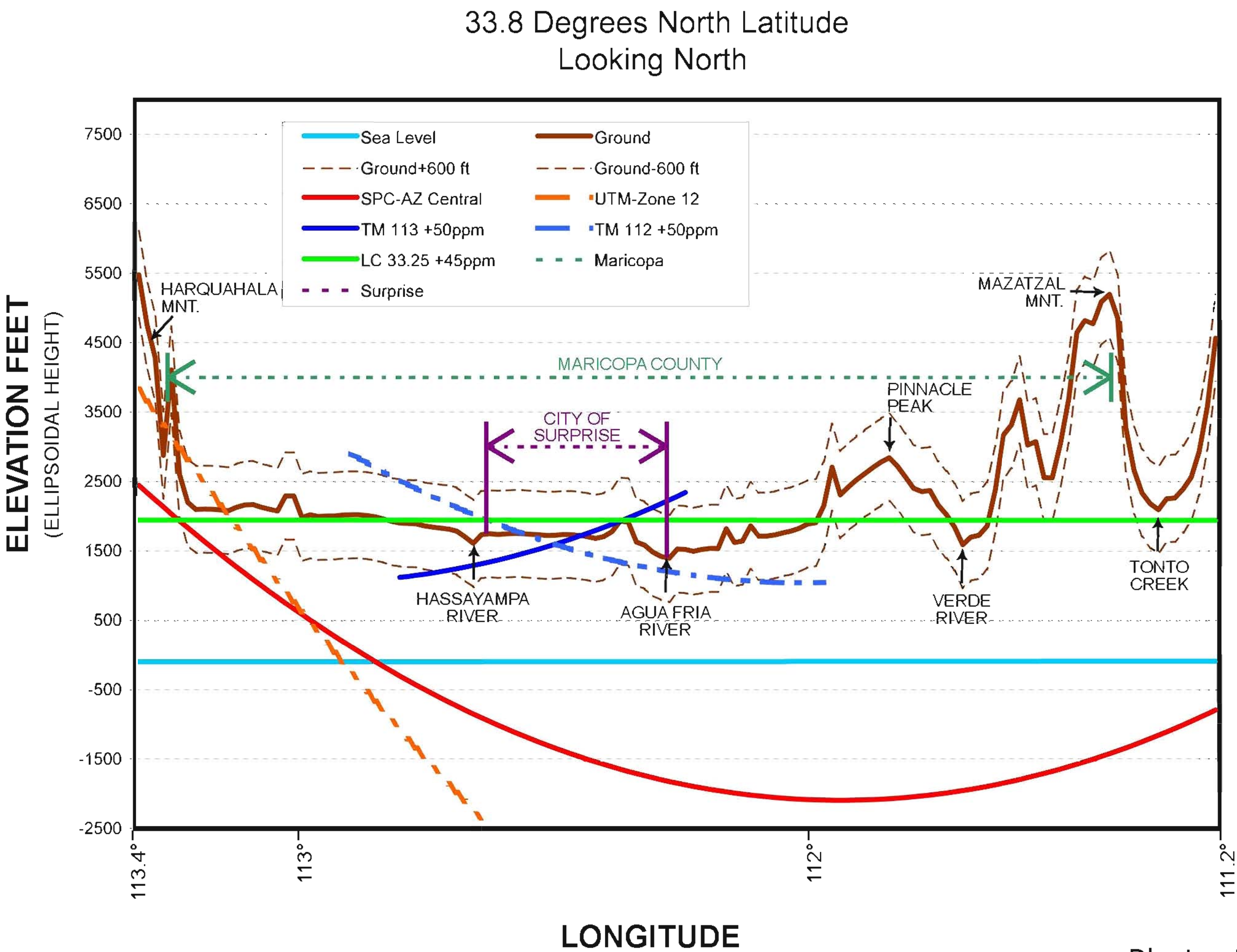

112.55 Degrees West Longitude
Looking West
ELEVATION FEET
(ELLIPSOIDAL HEIGHT)
12000
10000
8000
6000
4000
2000
0
-2000
Sea Level
Ground
Ground +600 ft
Ground -600 ft
LC 33.25 +45ppm
SPC-AZ Central
TM 112.00 +50ppm
TM 112.00 +120ppm
Maricopa
Surprise
MARICOPA COUNTY
CITY OF
SUPRISE
GU VO
HILLS
SAUCEDA
MNT.
SAND TANK
MNT.
WHITE TANK
MNT.
MARICOPA
MNT. WILDERNESS
GILA
RIVER
WICKENBURG
MNT.
WILLIAMS
PEAK
GRANITE
MNT.
PRESCOTT
32°
33°
34°
35°
LATITUDE

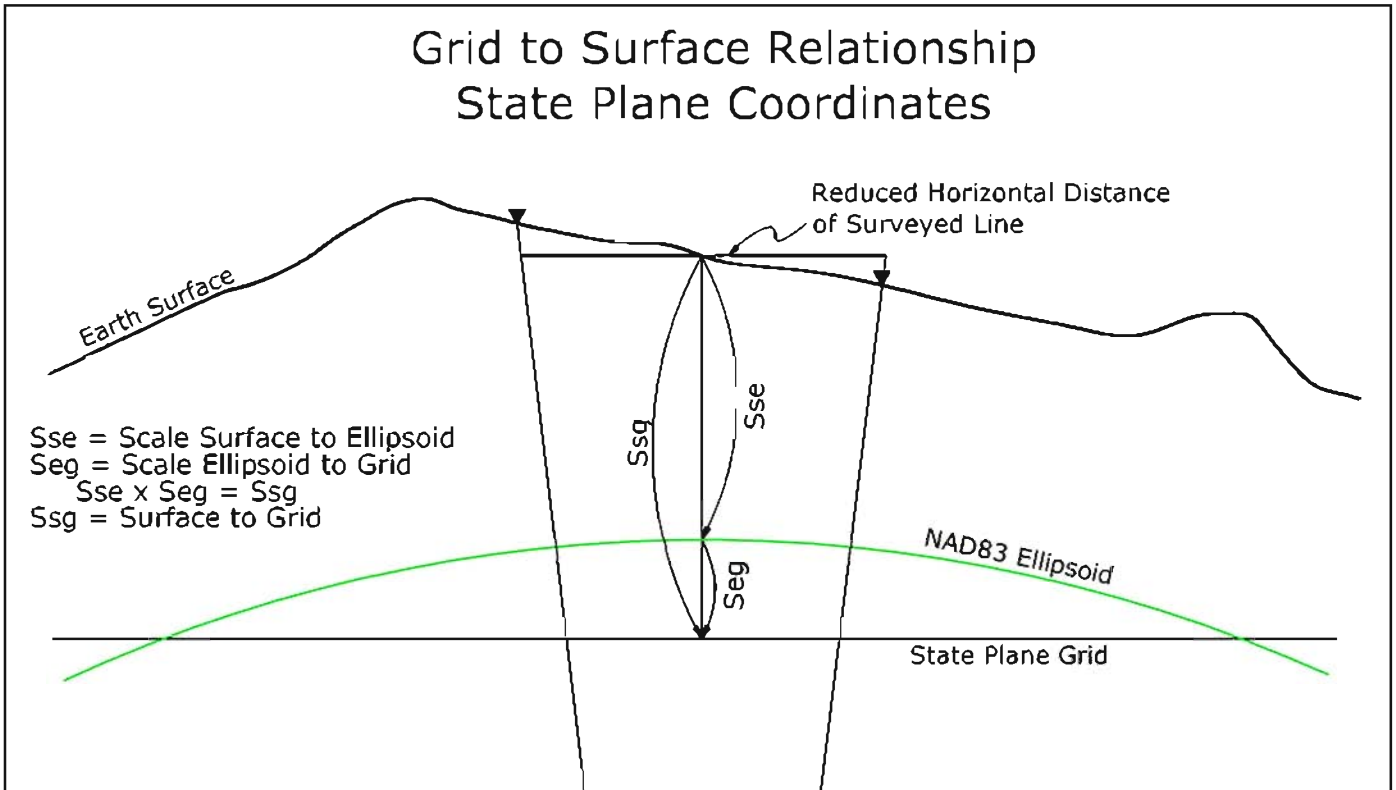
Photo # 3



33.8 Degrees North Latitude
Looking North
ELEVATION FEET
(ELLIPSOIDAL HEIGHT)
7500
6500
5500
4500
3500
2500
1500
500
-500
-1500
-2500
Sea Level
Ground
Ground+600 ft
Ground-600 ft
SPC-AZ Central
UTM-Zone 12
TM 113 +50ppm
TM 112 +50ppm
LC 33.25 +45ppm
Maricopa
Surprise
HARQUAHALA MNT.
MARICOPA COUNTY
CITY OF SURPRISE
PINNACLE PEAK
MAZATZAL MNT.
HASSAYAMPA RIVER
AGUA FRIA RIVER
VERDE RIVER
TONTO CREEK
113.4°
113°
112°
111.2°
LONGITUDE

Photo # 4

LINEAR MAP DISTORTIONS



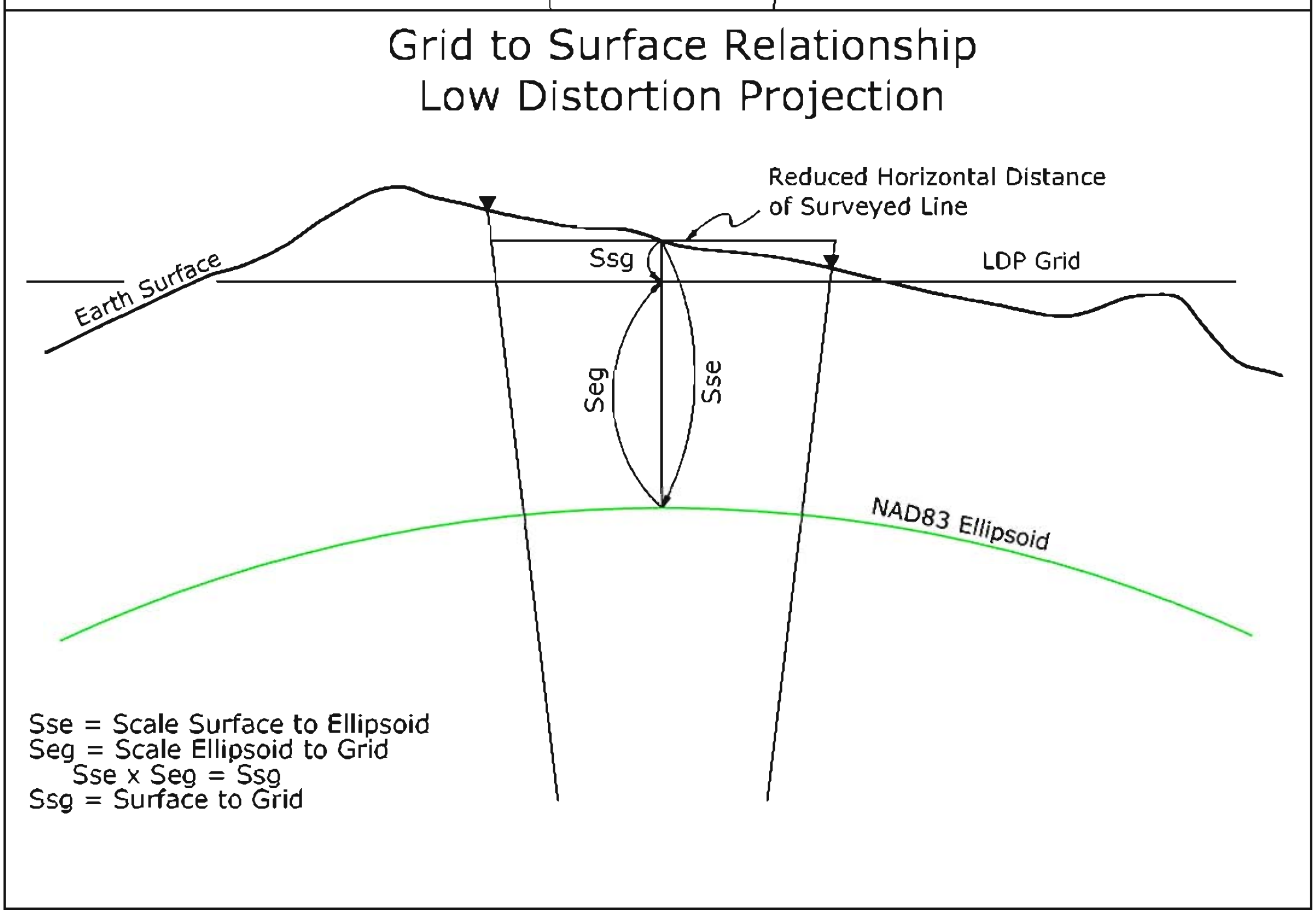


Photo # 5

Height Model Dataset Conversions

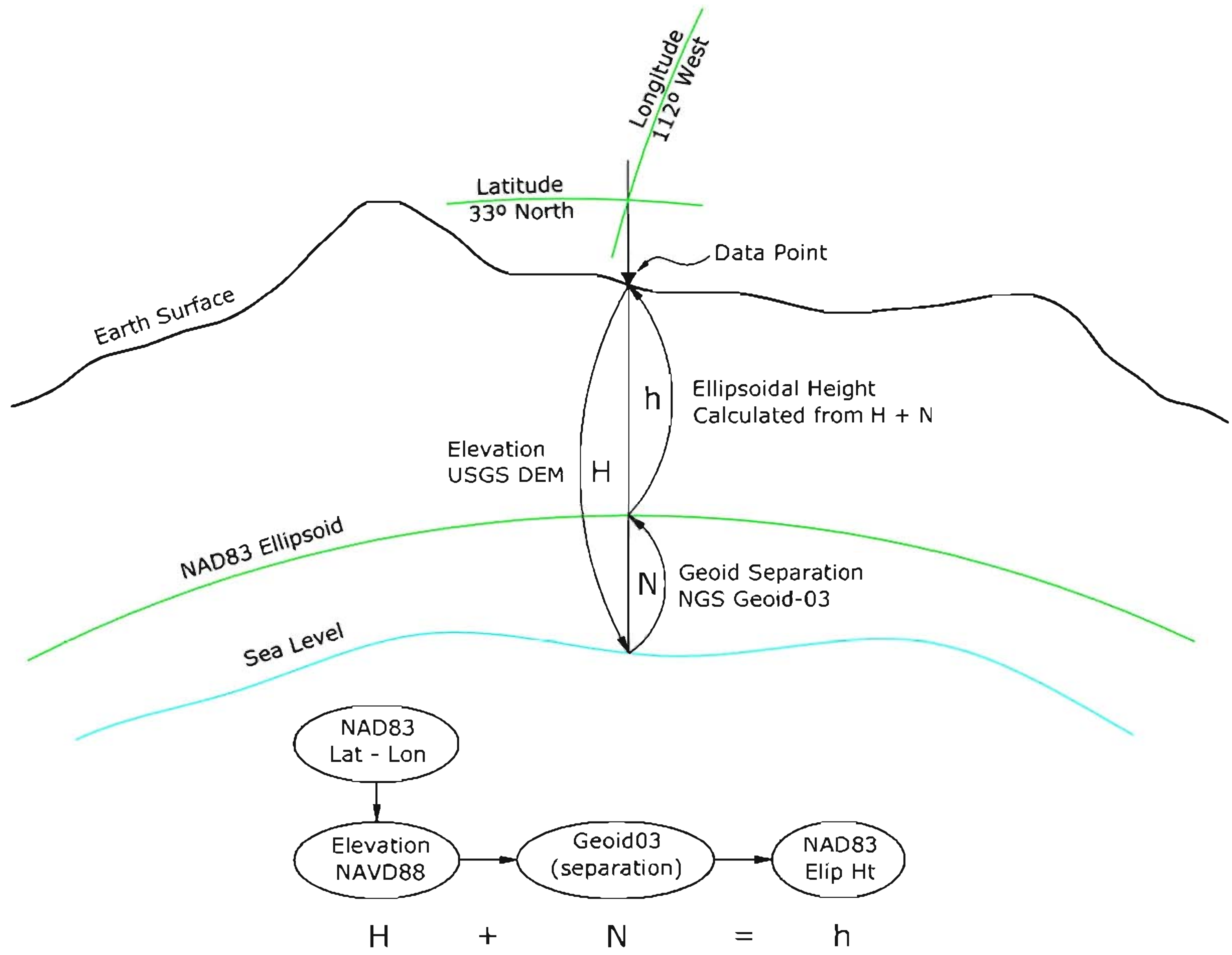
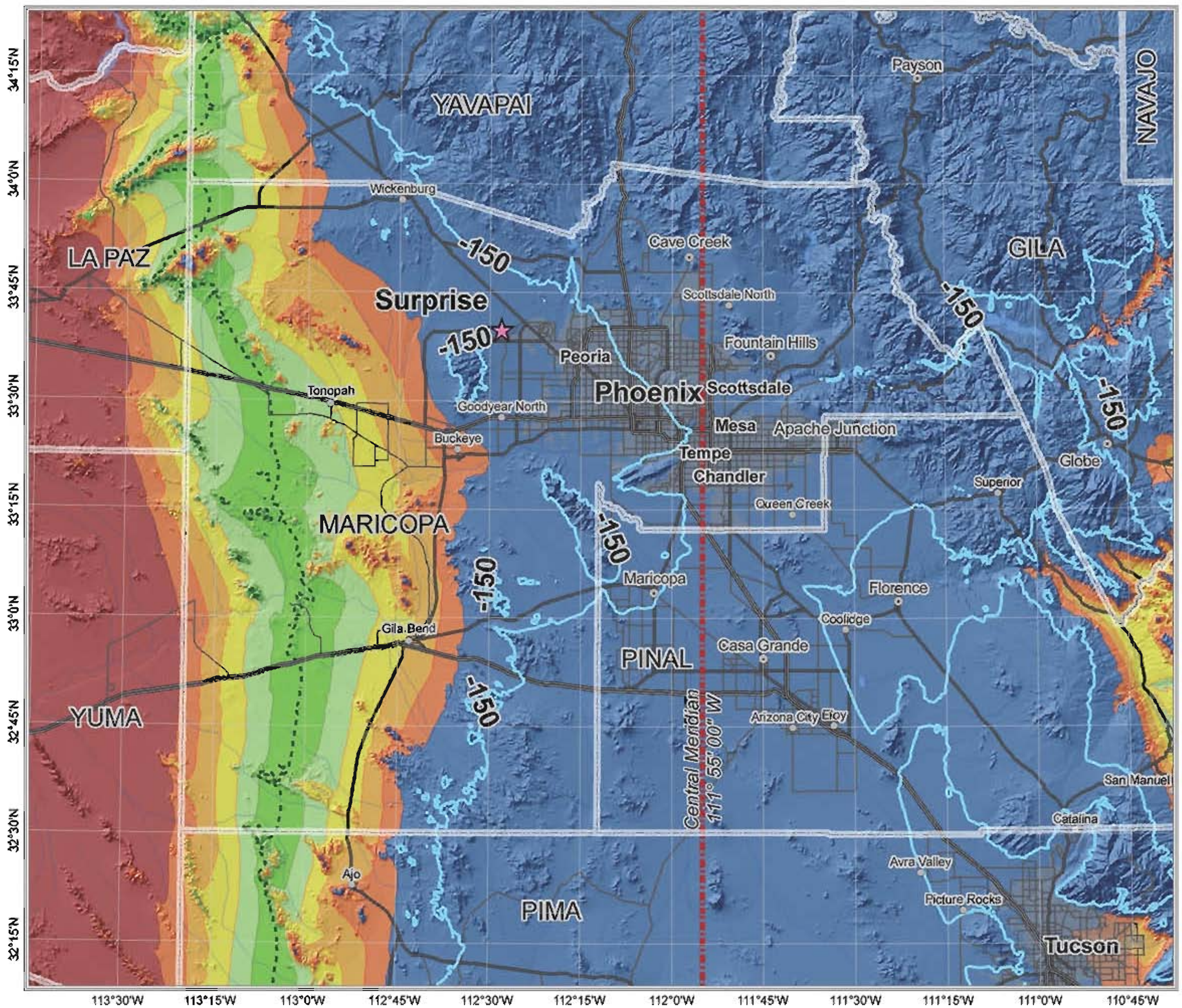


Photo # 6



City of Surprise, Arizona
State Plane Coordinate System of 1983, Arizona Central Zone

Linear unit: International foot
Geodetic datum: NAD 1983
Projection type: Transverse Mercator
Latitude of origin: 31°00'00" N
Central meridian: 111°55'00" W
False northing: 0.000 ift
False easting: 700,000.000 ift
Central meridian scale: 0.9999 (exact)

Grid North

Scale 1:1,000,000

0 10 20 30 40 50
Miles

Linear Distortion

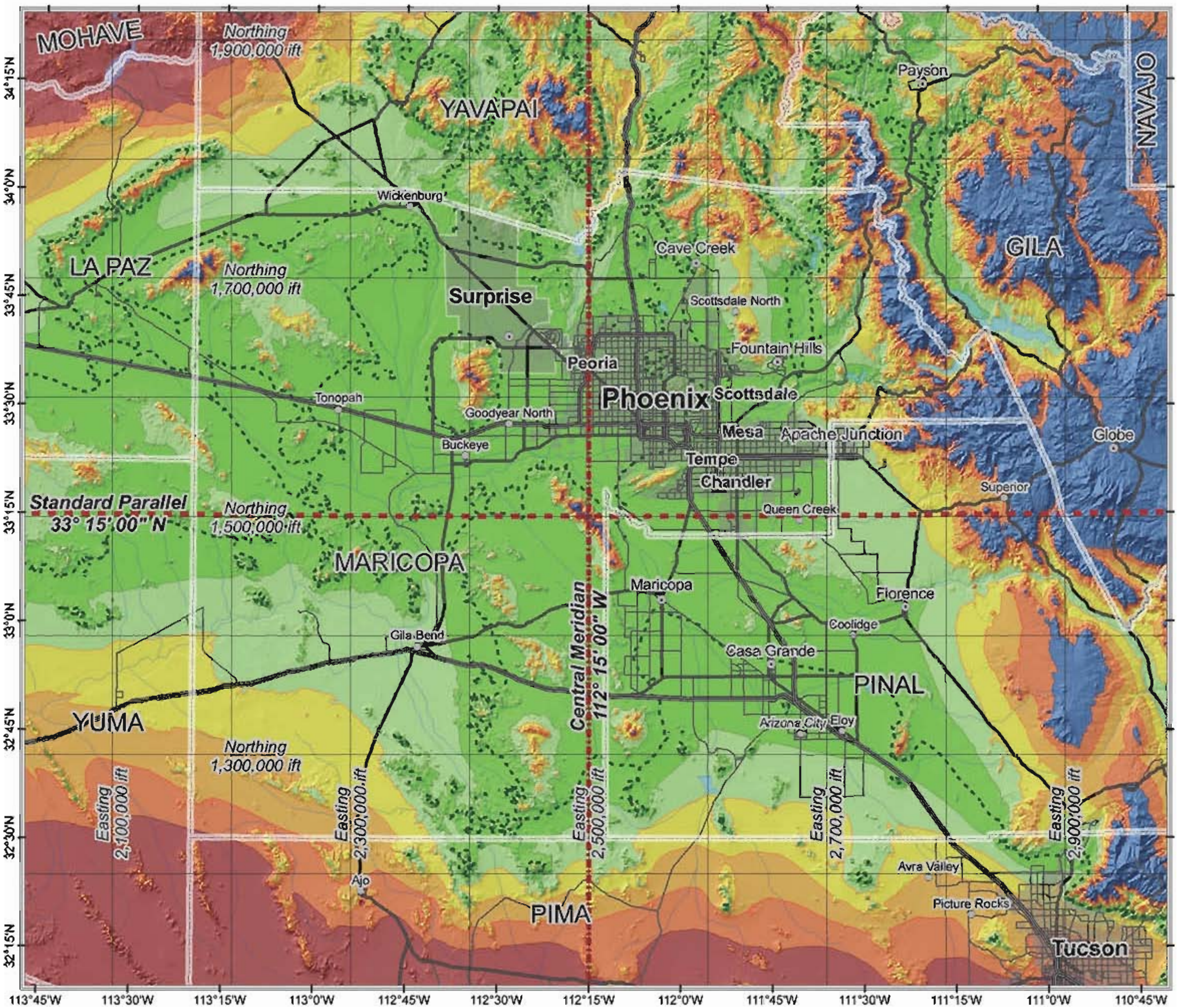
- ----- Zero distortion
- -150 ppm (-0.8 ft/mile)
- ±20 ppm = ±0.1 ft/mile
- ±(20 - 40) ppm = ±(0.1 - 0.2) ft/mile
- ±(40 - 60) ppm = ±(0.2 - 0.3) ft/mile
- ±(60 - 80) ppm = ±(0.3 - 0.4) ft/mile
- ±(80 - 100) ppm = ±(0.4 - 0.5) ft/mile
- > +100 ppm (> +0.5 ft/mile)
- < -100 ppm (< -0.5 ft/mile)

Map displayed using State Plane Coordinate System of 1983, Arizona Central Zone (0202)

Prepared by:
Geodetic Analysis, LLC
8775 S Cluff Ranch Rd
Pima, AZ 85543
mld@geodeticanalysis.com

Vicinity Map

Photo # 7



Maricopa County, Arizona
Low Distortion Projection

Linear unit: International foot
Geodetic datum: NAD 1983
Projection type: Lambert Conformal Conic (single parallel)

Latitude of origin: 33° 15' 00" N
Central meridian: 112° 15' 00" W
False northing: 1,500,000.000 ift
False easting: 2,500,000.000 ift
Standard parallel scale: 1.000 045 (exact)

Grid North

Scale 1:1,000,000

0 10 20 30 40 50
Miles

Linear Distortion

- - - - - Zero distortion
±20 ppm = ±0.1 ft/mile
±(20 - 40) ppm = ±(0.1 - 0.2) ft/mile
±(40 - 60) ppm = ±(0.2 - 0.3) ft/mile
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±(80 - 100) ppm = ±(0.4 - 0.5) ft/mile
> +100 ppm (> +0.5 ft/mile)
< -100 ppm (< -0.5 ft/mile)

Funding for Maricopa LDP design provided by the City of Surprise, with special thanks to Ron Dry, City of Surprise Surveyor

Vicinity Map

Prepared by:
Geodetic Analysis, LLC
and
David Evans and Associates, Inc.

Photo # 8

Linear Map Projection Distortions Chart

Linear Ratio	Zone	Scale	PPM	Distortion in Distance (feet)			
				660	1320	2640	5280
1: 2,500	UTM	0.999 600	400	0.26	0.53	1.06	2.11
1: 6,500	SPC/Ground	0.999 846	154	0.10	0.20	0.41	0.81
1: 10,000	SPC	0.999 900	100	0.07	0.13	0.26	0.53
1: 15,000	SPC West	0.999 933	66.7	0.04	0.09	0.18	0.35
1: 25,000	LDP	0.999 960	40	0.03	0.05	0.11	0.21
1: 50,000	LDP	0.999 980	20	0.01	0.03	0.05	0.11
1: 100,000	LDP	0.999 990	10	0.01	0.01	0.03	0.05
1: 500,000	ppm/mile	0.999 998	2	0.00	0.00	0.01	0.01
1: 1,000,000	ppm/mile	0.999 999	1	0.00	0.00	0.00	0.005

Exhibit # 9

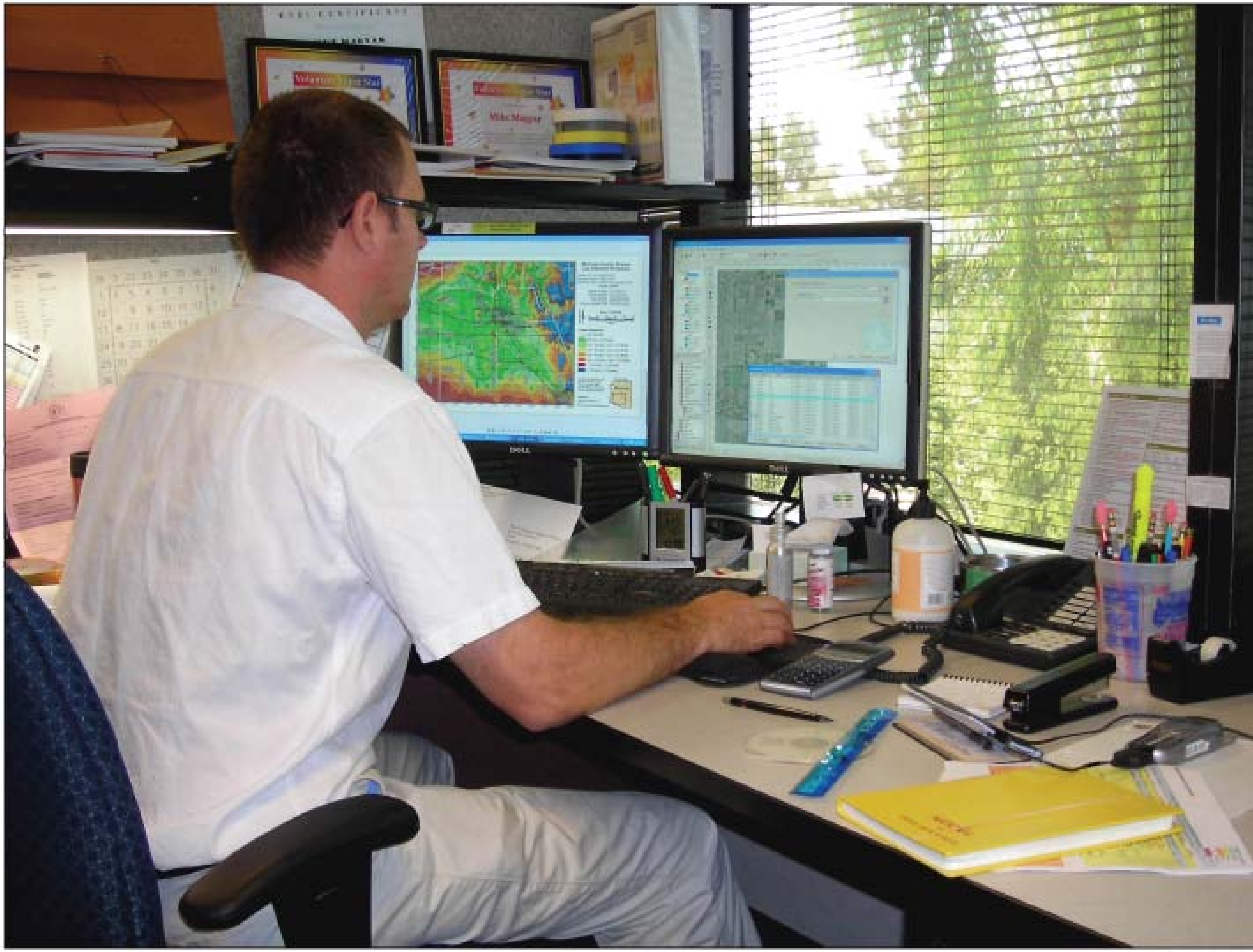

Photo #10

Photo #11

Photo # 12


Photo # 13


U.S. COAST & GEODETIC SURVEY
FOR INFORMATION WRITE TO THE DIRECTOR, WASHINGTON, D.C.
$250 FINE OR IMPRISONMENT FOR DISTURBING THIS MARK.
CONTROL
1971

Photo # 14