AUTODESK. UNIVERSITY

CLASS ID - CES322656

Beyond State Plane – a look at custom Ground Coordinate Systems in Civil 3D/Map 3D

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Learning Objectives

- Learn how to create a custom Ground coordinate system definition.
- Learn how to decipher the Survey Data that was provided.
- Learn how to Transform Points from one coordinate system to another.
- Validating your new custom Ground coordinate system definition.

Description

This class presents a deeper dive into Coordinate Systems in Autocad Civil 3D/Map 3D. Learn how to create your own custom Ground Coordinate System, that spatially references your specific project or city. Now when you Map Import GIS Data it gets scaled from Grid to Ground, also Lats/Longs are now correct. Some would refer this to a pseudo Low Distortion Projection (LDP). In the United States there are two separate Map projections that are used to define our State Plane Coordinate System, Lambert and Transverse Mercator. In this class we will create two different LDP coordinate systems with the two said Projections.

Speaker

Ken has been working in the Civil Engineering and Surveying fields for over 30 years. He is currently working for ECAD Inc. In Denver, Colorado. He is the Autocad Civil 3D, Technical Specialist, specializing in Autocad Software solutions for the Civil Engineering, GIS, Mining, Surveying and Mapping communities. He is also a Civil 3D Professional and Autodesk Certified Instructor. Ken has spoken at the 2012 Wyoming Engineering Society (WES) Conference, the 2014 & 2015 New Mexico Professional Land Surveyors (NMPLS) Conference and the 2011, 2016 & 2017 Professional Land Surveyors of Colorado (PLSC) Conference. Ken brings a wealth of knowledge to “how we do Engineering and Surveying in CAD”.
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Introduction:

The goal of this handout is to instruct the readers on how to define a Custom Ground Coordinate System Definition (CGCSD) in Autocad Civil 3D and Map 3D. Infraworks will also recognize these new CGCSD. This might also be described as a pseudo Low Distortion Projection (LDP). This new CGCSD will have the Combined Scale Factor included in the definition, thus transforming any GIS data from Grid to Ground. There are several advantages to this, 1.) Latitude and Longitude will be true. 2.) It satisfies the needs of everyone, Surveying, Engineering, Construction and GIS. Thus, importing/exporting data to any and all other coordinate zones is no longer a problem.

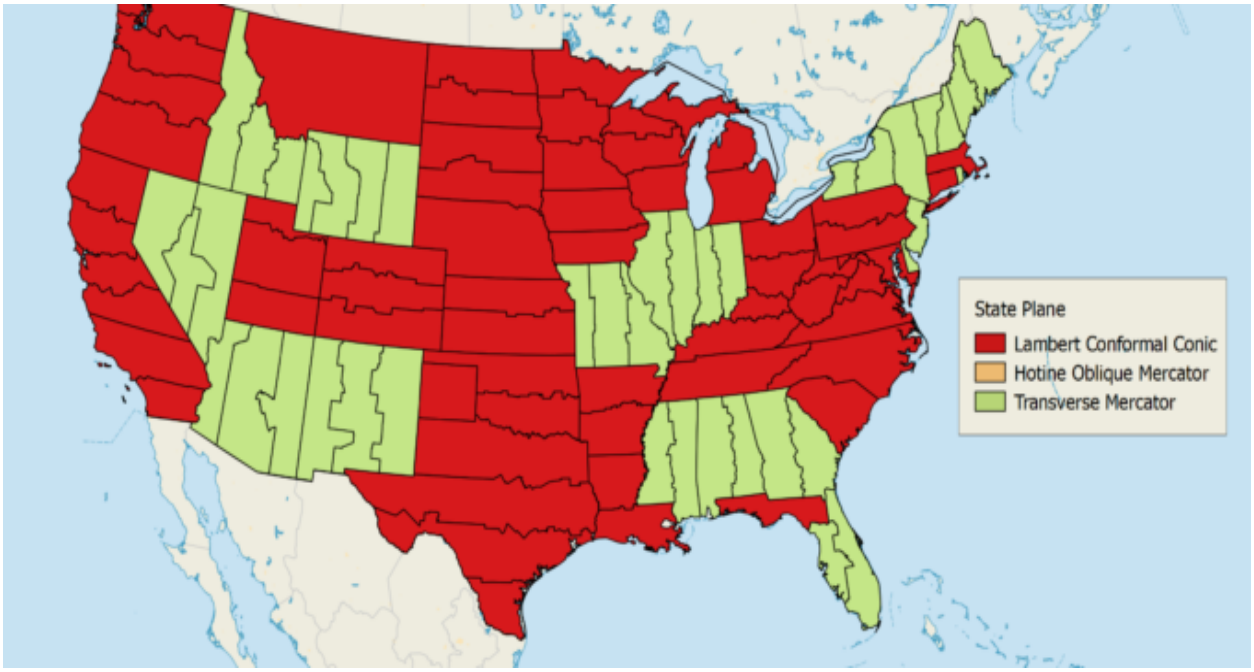
In order to define this CGSD there are hand full of items we need first:

1.) Your particular Units. i.e. Feet, Meter, etc.
2.) Survey Data.
3.) Geodetic Reference or Datum. i.e. NAD83.
4.) Map Projection. i.e. Lambert or Transverse Mercator.
5.) Point of Origin, with State Plane Coordinate NE and Lat/Long
6.) Combined Scale Factor.
7.) Truncation factors if needed.
8.) National Geodetic Survey (NGS) Website Link: https://www.ngs.noaa.gov/datasheets/

This handout will cover defining two distinct situations. One will be in Colorado, that is a Road Project and the other is for the City of Gallup, New Mexico. Both states having two different projections.

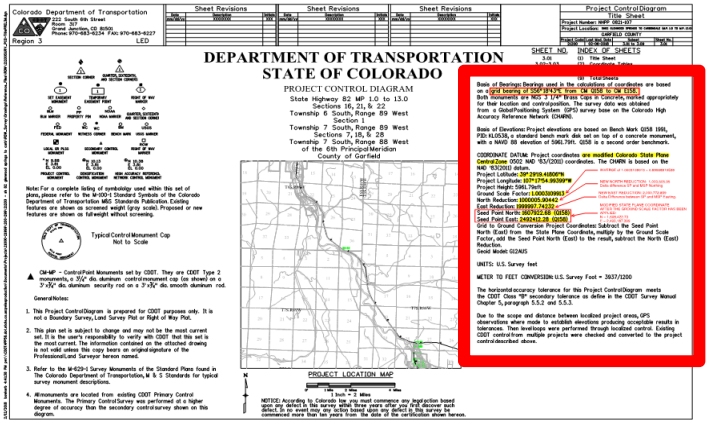
Creating a Ground Coordinate System using the Lambert Projection:

One of the most critical items of defining your own custom coordinate system is determining the Combined Scale Factor and the Map Projection. In the United States there are two predominate Map Projections for the State Plane Coordinate zones. They are Lambert Conformal Conic and Transverse Mercator.



Deciphering the Survey Data:

There can be several ways your Survey data can be delivered. It is important to read the cover sheet from your Surveyor and obtain all the Coordinate Datum information or Metadata. In our case this is what was provided by the Surveyor of record. I have highlighted the critical items in yellow.



Basis of Bearings: Bearings used in the calculations of coordinates are based on a grid bearing of S56°18'43"E from CM Q158 to CM E158.
Both monuments are NGS 3 1/4" Brass Caps in Concrete, marked appropriately for their location and control position. The survey data was obtained from a Global Positioning System (GPS) survey base on the Colorado High Accuracy Reference Network (CHARN).

Basis of Elevations: Project elevations are based on Bench Mark Q158 1991, PID: KL0538, a standard bench mark disk set on top of a concrete monument, with a NAVD 88 elevation of 5961.79ft. Q158 is a second order benchmark.

COORDINATE DATUM: Project coordinates are modified Colorado State Plane Central Zone 0502 NAD '83/(2011) coordinates. The CHARN is based on the NAD '83(2011) datum.
Project Latitude: 39°29'19.41806"N
Project Longitude: 107°17'54.99399"W
Project Height: 5961.79sft
Ground Scale Factor: 1.0003109913
North Reduction: 1000005.90442
East Reduction: 1999997.74232
Seed Point North: 1607922.68 (Q158)
Seed Point East: 2492412.28 (Q158)
Grid to Ground Conversion Project Coordinates: Subtract the Seed Point North (East) from the State Plane Coordinate, multiply by the Ground Scale Factor, add the Seed Point North (East) to the result, subtract the North (East) Reduction.
Geoid Model: G12AUS

UNITS: U.S. Survey feet

METER TO FEET CONVERSION: U.S. Survey Foot = 3937/1200

The horizontal accuracy tolerance for this Project Control Diagram meets the CDOT Class "B" secondary tolerance as define in the CDOT Survey Manual Chapter 5, paragraph 5.5.2 and 5.5.3.

Due to the scope and distance between localized project areas, GPS observations where made to establish elevations producing acceptable results in tolerances. Then level loops were performed through localized control. Existing CDOT control from multiple projects were checked and converted to the project control described above.

The first item is a Basis of Bearing. This will give us a frame of reference with respect to Rotation. The next item is the Geodetic Datum or Reference, which in this case is NAD83 (90% of my custom coordinate systems are NAD83). The above indicates a coordinate system that is being truncated. Meaning that we will have Project Coordinates that will be completely different than Grid Coordinates (State Plane). This requires a North and South Reduction factors. In

addition, this Project falls in Colorado State Plane, Central Zone, US Survey Feet. Colorado is a Lambert Conformal Conic (Projection) State, the State Plane zones run East-West.

Project Coordinates Table

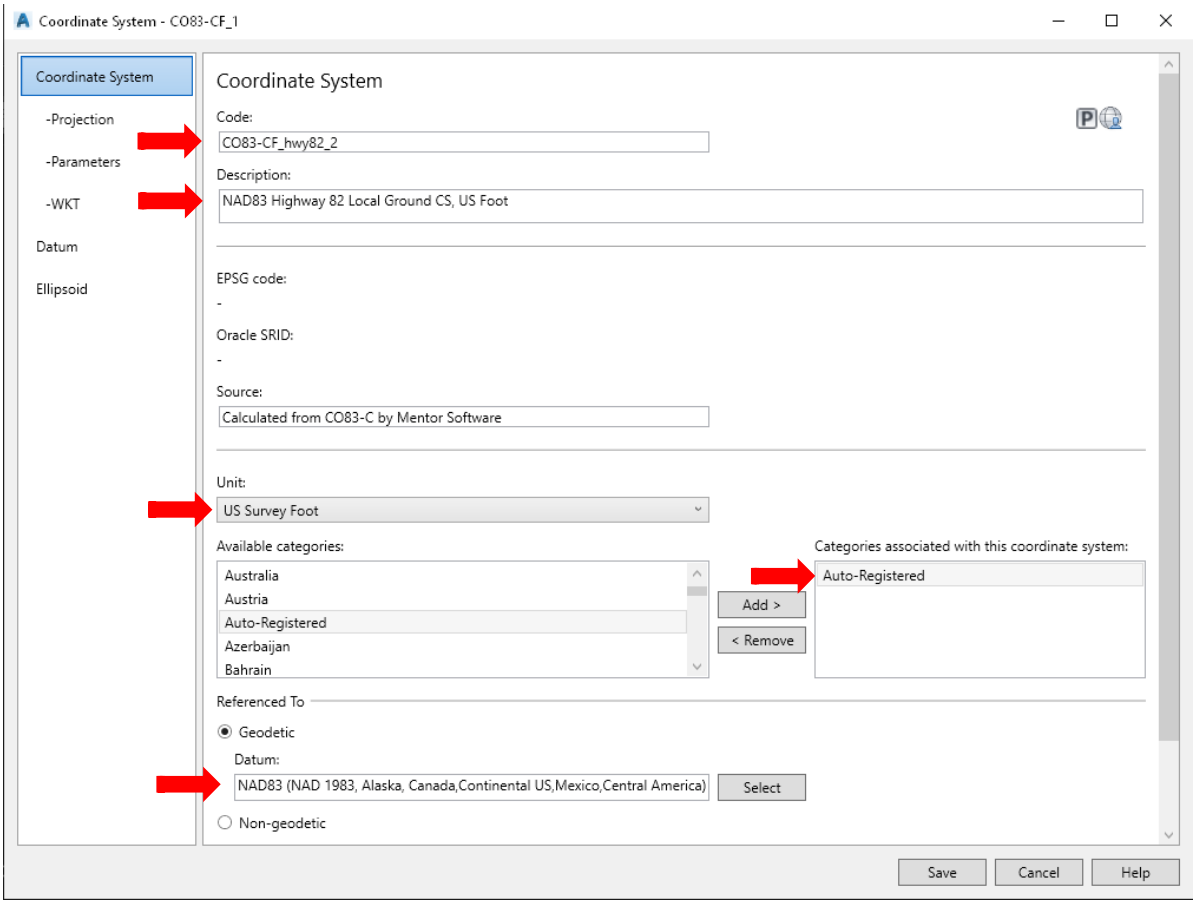
PROJECT COORDINATE TABLE				
Point No.	Project Coordinates		Elev(ft) (NAVD88)	Description
	Northing(ft)	Easting(ft)		
CARB COR	575248.64	516229.56		COR STATION
CBN	561611.03	559631.11	6589.75	NGS 3 1/4" BRASS CAP IN BRIDGE ABUT
E158	554774.98	572133.11	6754.31	NGS 3 1/4" BRASS CAP IN BRIDGE ABUT
Q158	607916.78	492414.54	5961.79	NGS 3 1/4" BRASS CAP IN CONCRETE
ROSEBUD	617904.40	487367.81	5859.57	NGS 3 1/4" BRASS CAP IN CONCRETE

GEODETIC COORDINATE TABLE								
Point No.	Geodetic Coordinates NAD-83(XX) (CHARN)		Elip Height (NAVD88) (m)	Ortho Height ft	Scale Factor	NAD 83(XX) Zone XXXX		Description
	Latitude(N)	Longitude(W)				SP Northing ft	SP Easting ft	
8R GPS	39°32'08.62859"	107°19'30.02192"	1756.773	5811.202	0.999689105	1625188.21200	2485307.75700	1 1/2" BRASS CDOT CONTROL MONUMENT IN CONCRETE
11 GPS	39°31'46.98050"	107°19'32.02387"	1758.453	5816.901	0.999689105	1623001.47800	2485106.93500	1 1/2" ALUMINUM CAP ON REBAR
CARB COR GPS	39°24'0".24152"	107°12'43.51794"	1879.673	6216.400	0.999949520	1575264.70000	25162'9.90000	COR STATION
CBN GPS	39°21'54.22953"	107°03'27.87563"	1994.171	6590.086	0.999946500	1561631.33000	2559607.95000	NGS 3 1/4" BRASS CAP IN BRIDGE ABUT
E158 GPS	39°20'48.78060"	107°00'47.30726"	2044.386	6754.311	0.999945090	1554797.41000	2572106.07000	NGS 3 1/4" BRASS CAP IN BRIDGE ABUT
Q158 GPS	39°29'19.41806"	107°17'54.99399"	1802.349	5961.781	0.999958750	1607922.68000	24924'2.28000	NGS 3 1/4" BRASS CAP IN CONCRETE
ROSEBUD GPS	39°30'57.08902"	107°19'01.88237"	1771.337	5859.499	0.999962070	1617907.20000	2487367.12000	NGS 3 1/4" BRASS CAP IN CONCRETE

The Process:

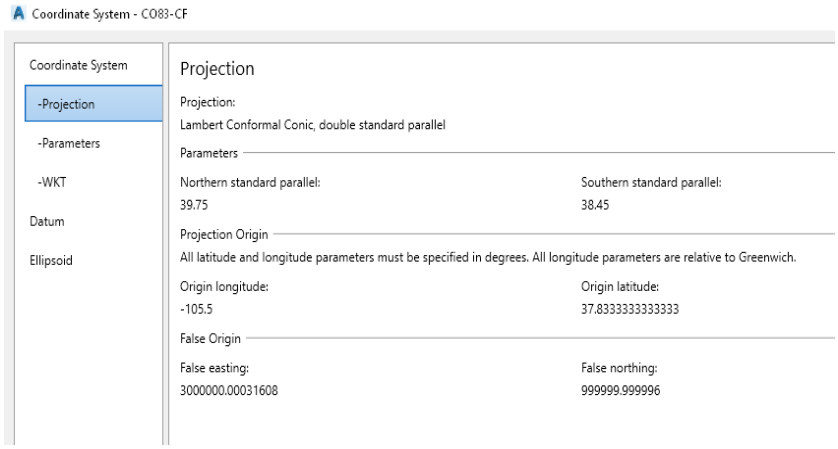
1. With anything else in Autocad we always start with UNITS. Make sure your source Template is set to Feet.
2. First create a drawing with your standard DWT Template. Once in the drawing type in the Command: MAPCSASSIGN and set the Coordinate the Coordinate System to CO83-CF, in our case.
3. Set or Import your control points in this drawing. These will be in State Plane Coordinates (Grid). Try to have a minimum of three control points, four would be optimum.
4. Since the Points Q158 and E158 are mentioned on the cover sheet, these will be the ones we use (see graph above).
5. Once Points are in a drawing make note of the Grid Northing & Eastings and Lat & Longs. They should match what is on the Geodetic Coordinate Table from above.
6. Export said points to a PNEZD text or csv file. Name the file with “CP_CO83-CF Grid Coordinates.csv”. Exit the Drawing.
7. Start another new drawing with your Template. Then Type in at the command Line MAPCSLIBRARY.
8. Search for CO83-CF, highlight then at the bottom of the dialog box will be Duplicate.
9. Once Duplicated look for CO83-CF_1. This will be your copy or duplicate of the existing state plane zone that you need.
10. Highlight this then select EDIT and the bottom of dialog box.

11. Coordinate System: Change the following fields with the RED highlighted arrows. For Code and Description give it something unique. i.e. your project info.



12. Once you have completed, then select the Projection on the left side to advance to the next step.

13. Projection: The existing Projection of CO83-CF is the “Lambert Conformal Conic, double standard parallel”. NOTICE No Scale Factor in this particular Projection.



Existing Projection of CO83-CF.

14. Under the Projection: click on the drop down and change to “Lambert Conformal Conic, with affine post-processor”. This Projection offers a Scale Factor entry.
15. Northern Standard Parallel remains at 39.75 Latitude. Southern Standard Parallel remains at 38.45 Latitude.
16. The truncation piece to get coordinates from Grid to Project (Ground). Do this both for Northing and Easting. This is all the info (from pages 5 & 6) on the Survey Cover Sheet of our Project.
    SPN = State Plane Northing (1607922.68 Q158)
    SPE = State Plane Easting (2492412.28 Q158)
    CSF = Combined Scale Factor (1.000319913)
    MSP = Modified State Plane Coordinate
    NR = Northing Reduction (1000005.904)
    ER = Easting Reduction (1999997.742)

    (SPN) x (CSF) = (MSP Northing)

    1607922.68 x 1.000319913 = N 1608422.73

    (SPE) x (CSF) = (MSP Easting)

    2492412.28 x 1.000319913 = E 2493187.39

    (MSP northing) – (SPN) = (Δ difference northing)

    1608422.73 - 1607922.68 = 500.05

    (Δ difference northing) + ER = (New ER) ……type this in the “Affine B0 coefficient” field. This will also have a negative value in front of it, because we are truncating from approx. 1.6 million down to approx. 600,000.

    500.05 + 1000005.904 = 1000505.95 “Affine B0 coefficient”

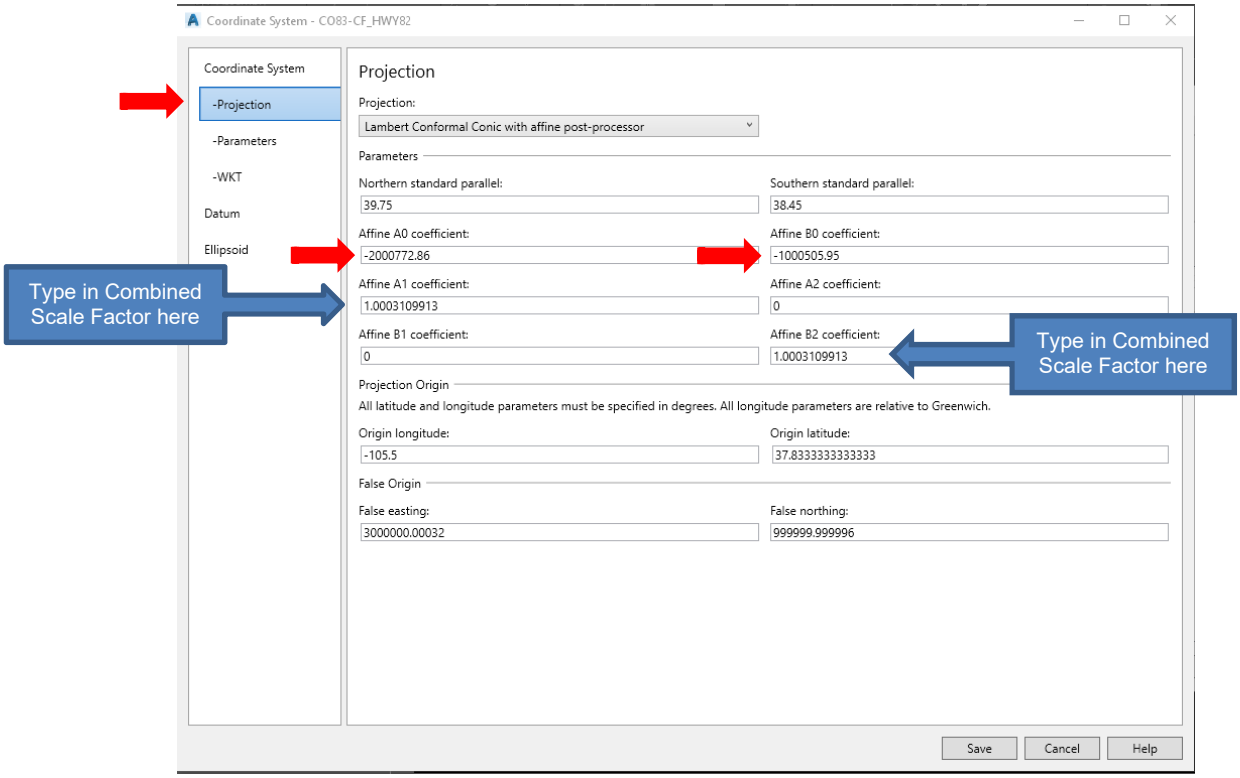
(MSP easting) – (SPE) = (Δ difference easting)

2493187.39 – 2492412.28 = 775.11

(Δ difference easting) + NR = (New NR) ……type this in the “Affine A0 coefficient” field. This will also have a negative value in front of it, because we are truncating from approx. 2.4 million down to approx. 400,000.

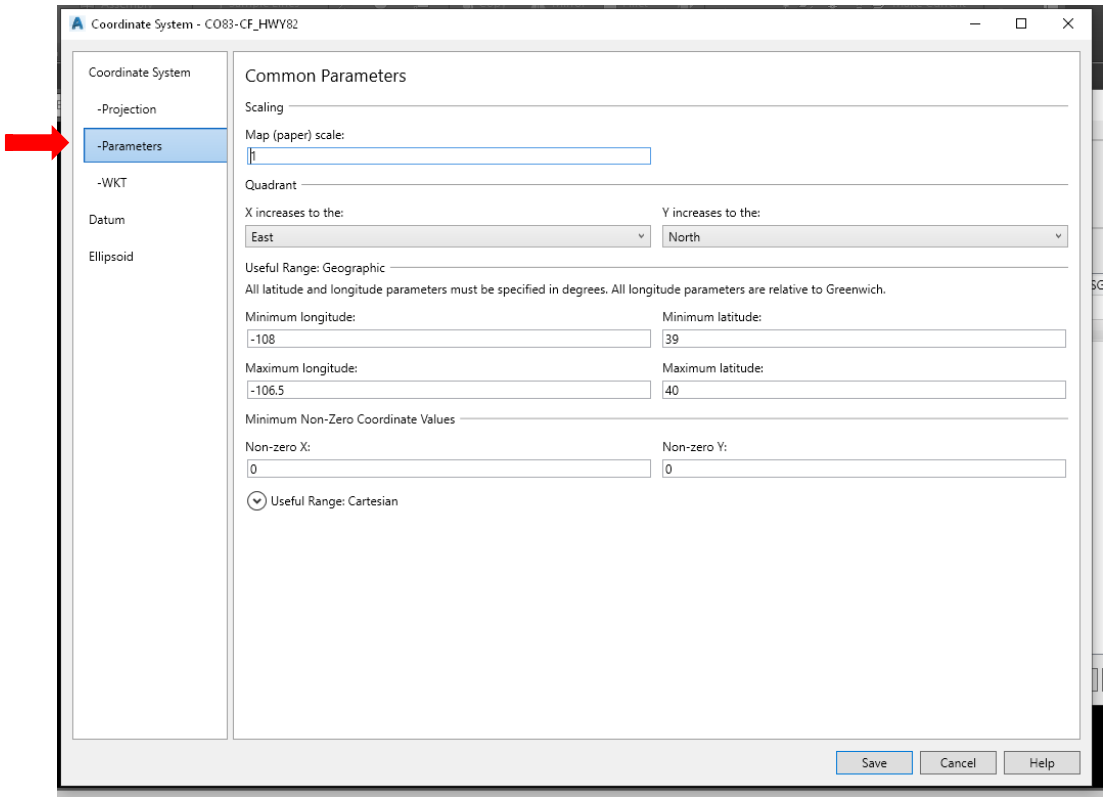
775.11 + 1999997.742 = 2000772.86 “Affine A0 coefficient”.

17. In the “Affine A1 & B1 coefficient” fields type in the Combined Scale Factor.



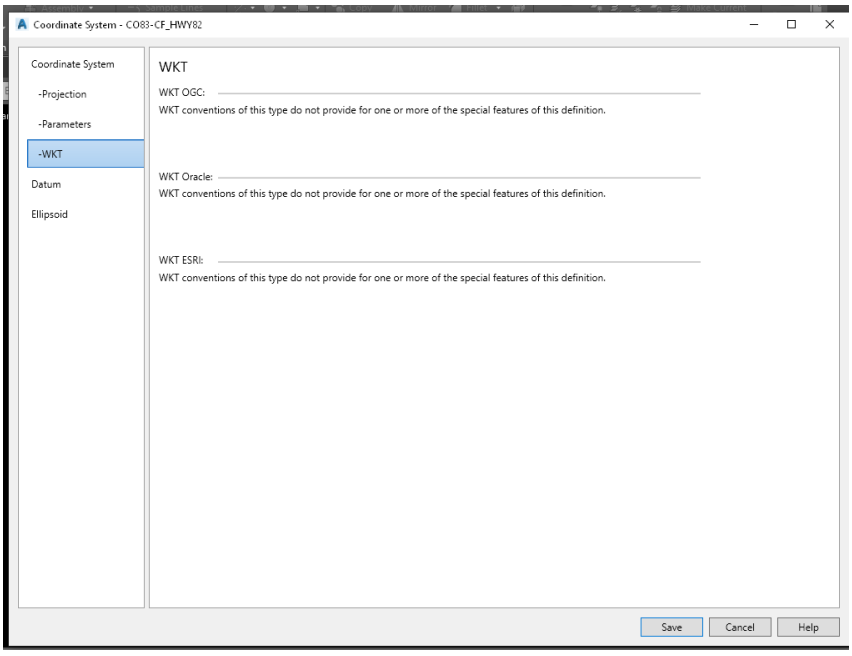
18. Leave the “Origin Latitude” & “Origin Longitude” as is.
19. Leave the “False Easting” & “False Northing” as is.

20. Next Select the Parameters in the top left.

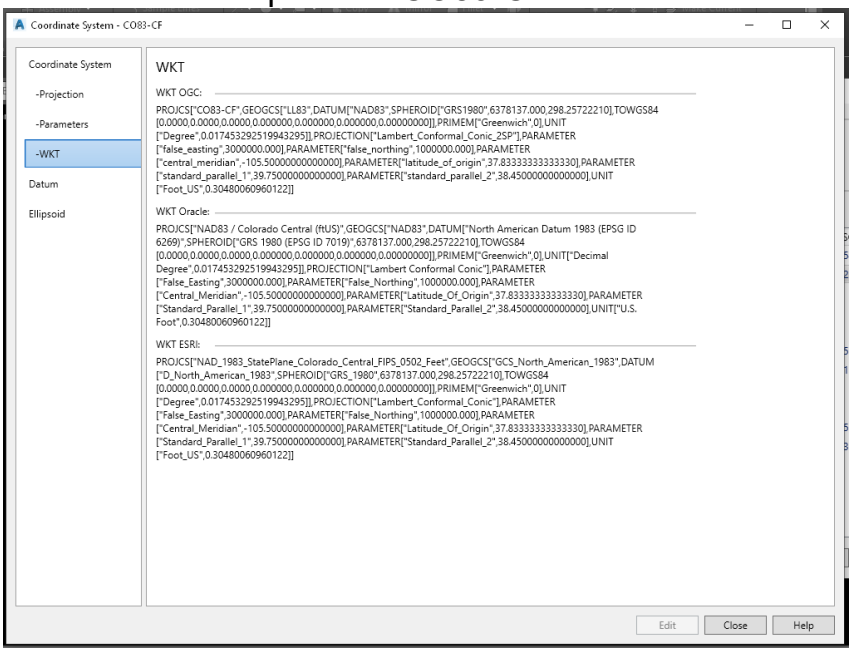


21. The Parameters are the extents of your new CGCSD. This could vary from Project to Project or City to City. In my case I set the Min/Max Lat and Long to just larger than my project area.
22. Next select WKT in the Top Left. WKT stands for Well-Known Text Markup Language. You will notice three definitions of WKT. These are definitions for OGC, Oracle and ESRI. ESRI PRJ files can be generated from this information.
23. A caveat of using this particular Projection is the WKT portion of the Coordinate System Definition gets wiped. This may be an issue for other programs that use this. However, within Autodesk programs there is no issue. This has also been reported to Autodesk, Case number 14415891, CIVIL-24258.

Snapshot of our new CGCSD WKT after we change Projection to “Lambert Conformal Conic, with affine post-processor”.

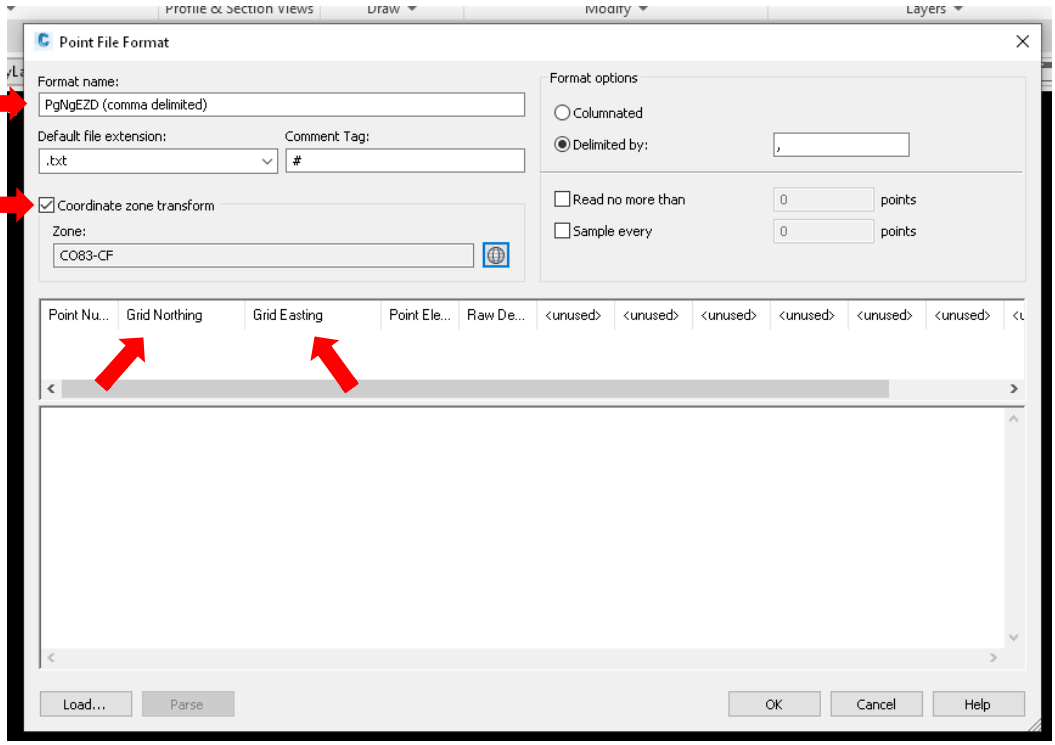


Snapshot of CO83-CF WKT.

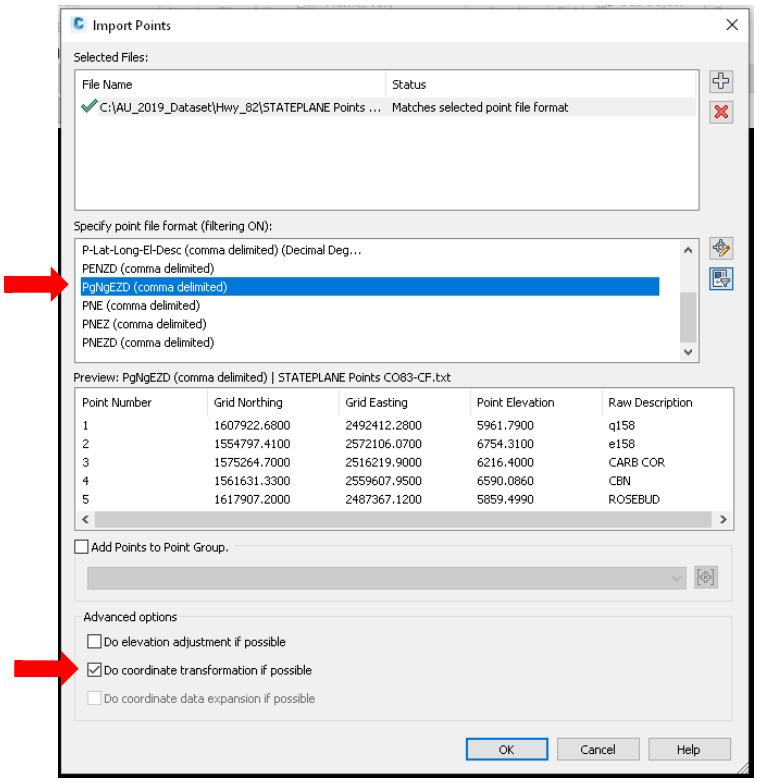


21. That’s it, click on Save at the bottom of the dialog box.

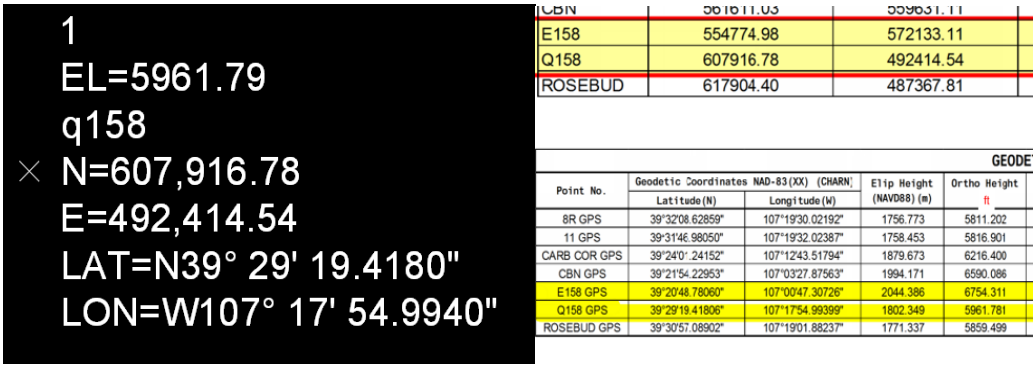
22. Make sure to exit Civil 3D/Map 2D entirely and then come back in to start using your new CGCSD.
23. The last step to test your new CGCSD. We will reference Step 6 from above. The text file we exported “CP_CO83-CF Grid Coordinates.csv” will now come into play. Start a new Drawing with your DWT Template. Assign your new coordinate system to that drawing. Go to Settings Tab in Toolspace > Points > Point File Format. Right click on the PNEZD (comma delimited) format and make a copy. Rename this Point File Format PgNgEZD (comma delimited). Click on the Northing and Easting headers and change them to Grid Northing and Grid Easting. Lastly check the “Coordinate Zone Transform” box and set your coordinate system to the State Plane zone you are transforming from. Then select OK.



24. Next you will go to the Insert Tab in the ribbon > Import Panel > Points from File. Browse to the File that has your State Plane Coordinates “CP_CO83-CF Grid Coordinates.csv” and select it. Make sure you select your PgNgEZD (comma delimited) format. Then check the box “Do Coordinate transformation if Possible” check box.



25. Check the coordinates and confirm they match Project Coordinates. Also check the Lat/Long and confirm if it is the same as State Plane.

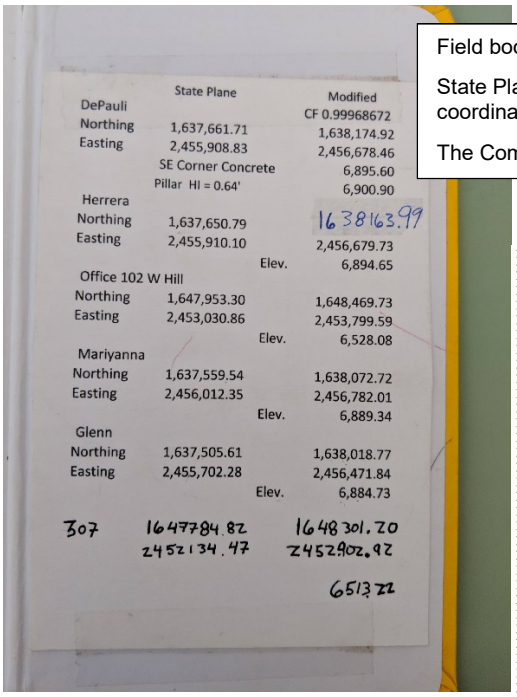


Creating a Ground Coordinate System using the Transverse Mercator Projection:

As mentioned above, with anything else in Autocad we always start with UNITS. Make sure your source Template is set to Feet.

In this scenario we are creating a custom Ground Coordinate System for the City of Gallup in western New Mexico. In this case the Surveyor of a of a Private firm has local Control already setup based on a Modified State Plane System. So, all we are going to do is multiply the State

Plane Coordinate by the Combined Scale Factor. This will be a Modified State Plane value. Here is what we have.



Field book of Control Points from Surveyor:

State Plane (Grid) and Modified State Plane (GND) coordinates.

The Combined Scale Factor (Top Right pic).

Data Sheet for NGS Gallup

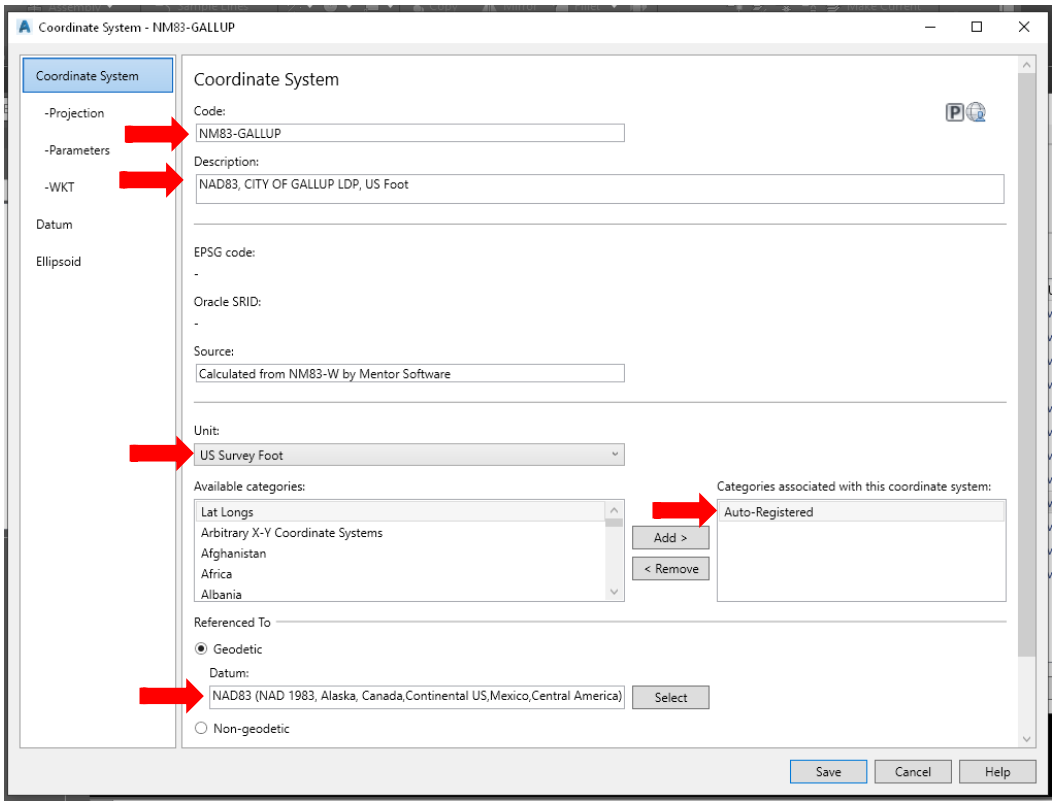
```
FP0541                          *CURRENT SURVEY CONTROL
FP0541
FP0541* NAD 83(1992) POSITION- 35 31 33.44475(N) 108 44 10.70707(W)   ADJUSTED
FP0541* NAVD 88 ORTHO HEIGHT -   2012.9    (meters)      6604.     (feet) VERTCON
FP0541
FP0541  GEOID HEIGHT    -         -21.182 (meters)                      GEOID12B
FP0541  LAPLACE CORR    -           3.85  (seconds)                     DEFLEC12B
FP0541  HORZ ORDER      -  SECOND
FP0541
FP0541.The horizontal coordinates were established by classical geodetic methods
FP0541.and adjusted by the National Geodetic Survey in December 1993.
FP0541.
FP0541.The NAVD 88 height was computed by applying the VERTCON shift value to
FP0541.the NGVD 29 height (displayed under SUPERSEDED SURVEY CONTROL.)
FP0541
FP0541.Significant digits in the geoid height do not necessarily reflect accuracy.
FP0541.GEOID12B height accuracy estimate available here.
FP0541
FP0541.The Laplace correction was computed from DEFLEC12B derived deflections.
FP0541
FP0541. The following values were computed from the NAD 83(1992) position.
FP0541
FP0541;                    North         East      Units Scale Factor Converg.
FP0541;SPC NM W     -   502,304.240   748,105.781   MT  0.99999929   -0 31 29.0
FP0541;SPC NM W     - 1,647,976.49  2,454,410.38   sFT  0.99999929   -0 31 29.0
FP0541;UTM  12      - 3,933,728.983   705,252.708   MT  1.00011918   +1 18 57.0
FP0541
FP0541!                 -  Elev Factor  x  Scale Factor =  Combined Factor
FP0541!SPC NM W     -   0.99968749  x   0.99999929  =   0.99968678
FP0541!UTM  12      -   0.99968749  x   1.00011918  =   0.99980663
```

The pic of the Field Book gives us the State Plane Coordinates and the Local Ground Coordinates of the city. This way we have something to compare. In addition, I went to the NGS (National Geodetic Survey) website to look for an NGS monument in the area (NGS Gallup). The NGS Data sheet gives us the State Plane Coordinate, Lat/Long and the combined Scale Factor. Take note that the combined scale factor given to me from the local Surveyor is very close to what we see on the NGS Data Sheet.

The Process:

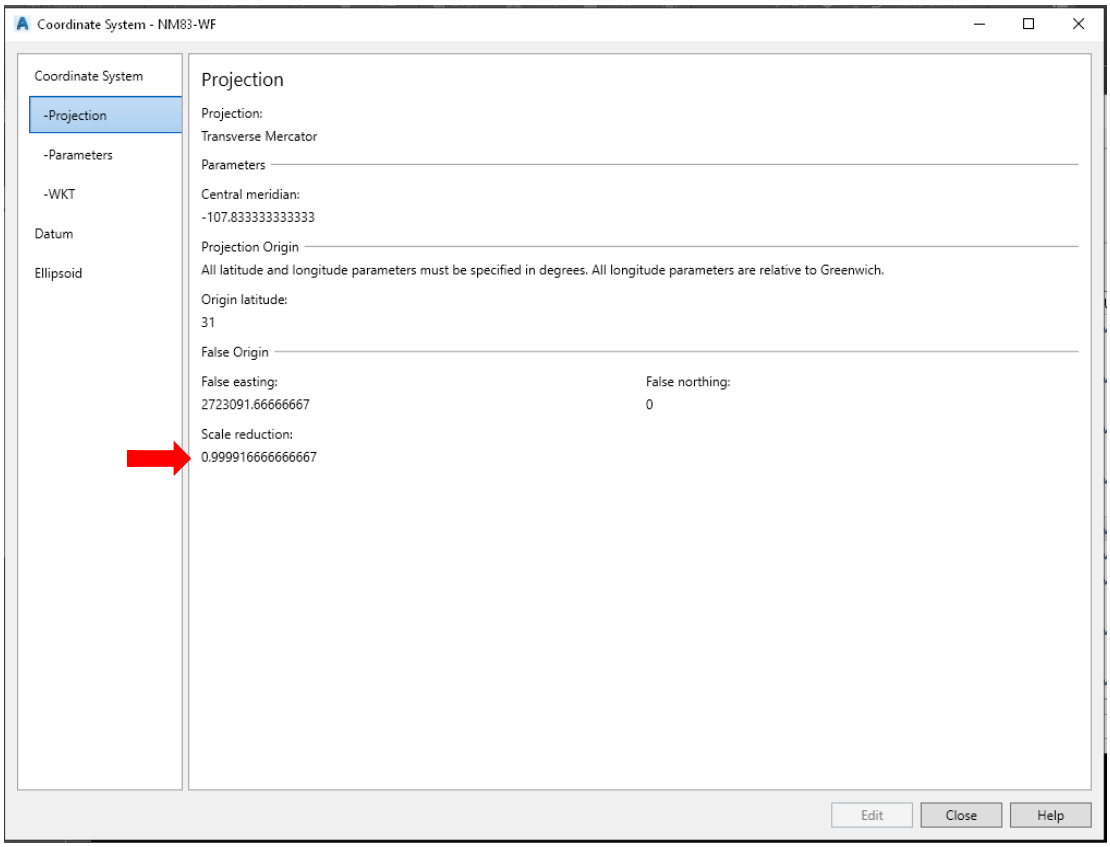
1. First create a drawing with your standard DWT Template. Once in the drawing type in the Command: MAPCSASSIGN and set the Coordinate the Coordinate System to NM83-WF, in our case.
2. Set or Import your control points in this drawing. These will be in State Plane Coordinates (Grid). Try to have a minimum of three control points, four would be optimum.
3. Once Points are in a drawing make note of the Grid Northing & Eastings and Lat & Longs. The Grid Northings and Eastings should match what is on the field book from above.
4. Export said points to a PNEZD text or csv file. Name the file with “CP_NM83-WF Grid Coordinates.csv”. Exit the Drawing.
5. Start another new drawing with your Template. Then Type in at the command Line MAPCSLIBRARY.
6. Search for NM83-WF, highlight then at the bottom of the dialog box, select Duplicate.

7. Once Duplicated look for NM83-WF_1. This will be your copy or duplicate of the existing state plane zone that you need.
8. Highlight NM83-WF_1 then select EDIT at the bottom of dialog box.
9. Coordinate System: change the following fields with the RED highlighted arrows. For Code and Description give it something unique. i.e. your project or city info.



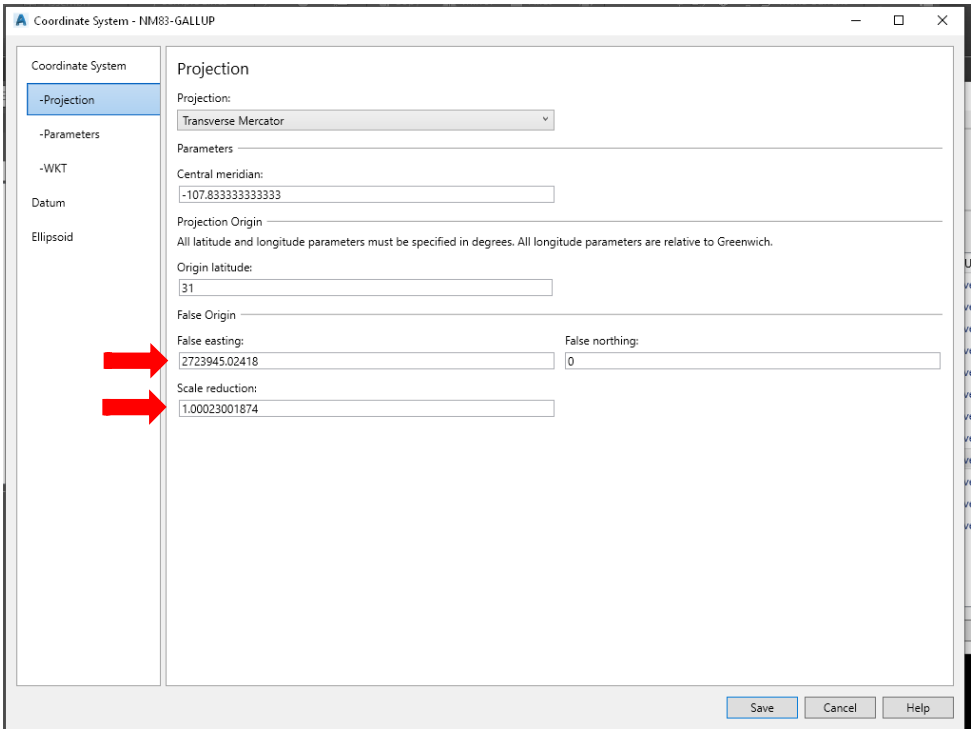
10. Once you have completed, then select the Projection on the top left side to advance to the next step.

11. Projection: The existing Projection of NM83-WF is “Transverse Mercator”. NOTICE; Scale Reduction Factor.



12. Leave the Projection to Transverse Mercator.
13. Leave the Central Meridian value.
14. Leave Origin Latitude value.
15. False Easting:

The Combined Scale Factor is 0.99968672 from pic Surveyor FB, above.
The Inverse of 0.99968672 is 1.00031337818
2723091.66666667 x 1.00031337818 = 2723945.02418 (new FE)

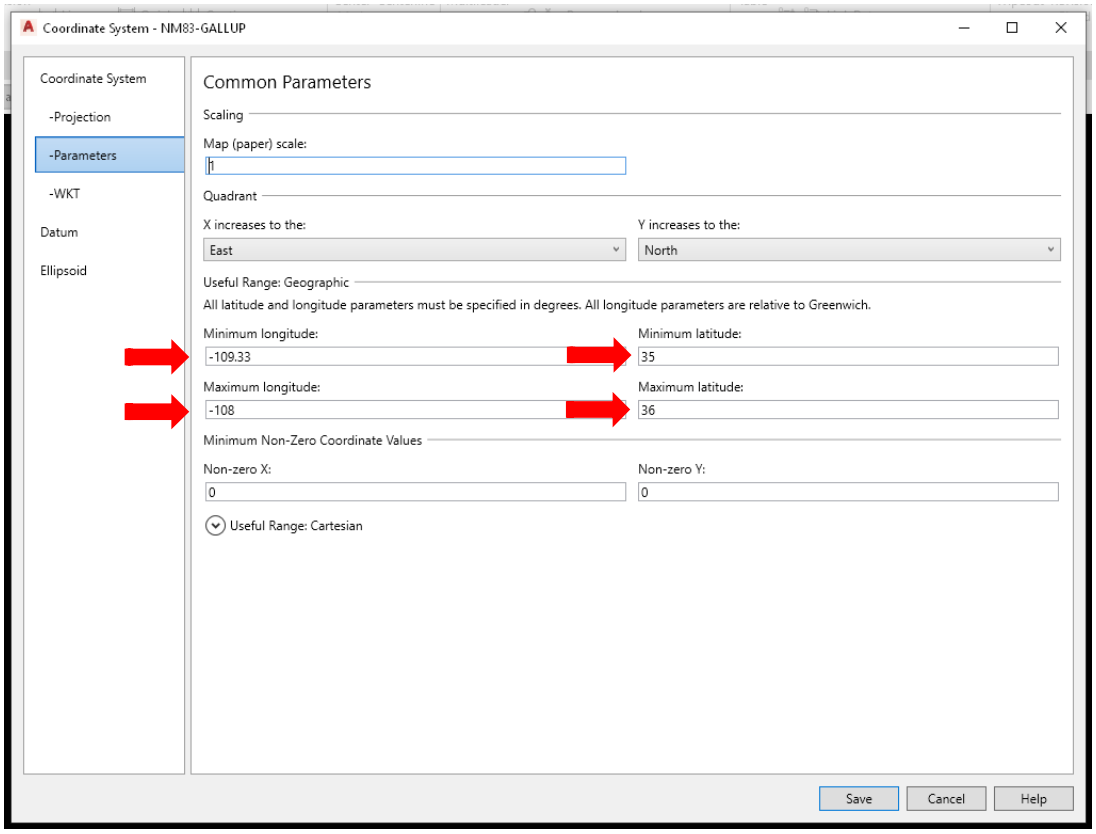


16. Scale Reduction:

Take the existing Scale Reduction number of 0.999916666666667
0.999916666666667 x 1.00031337818 = 1.00023001874 (new SR)

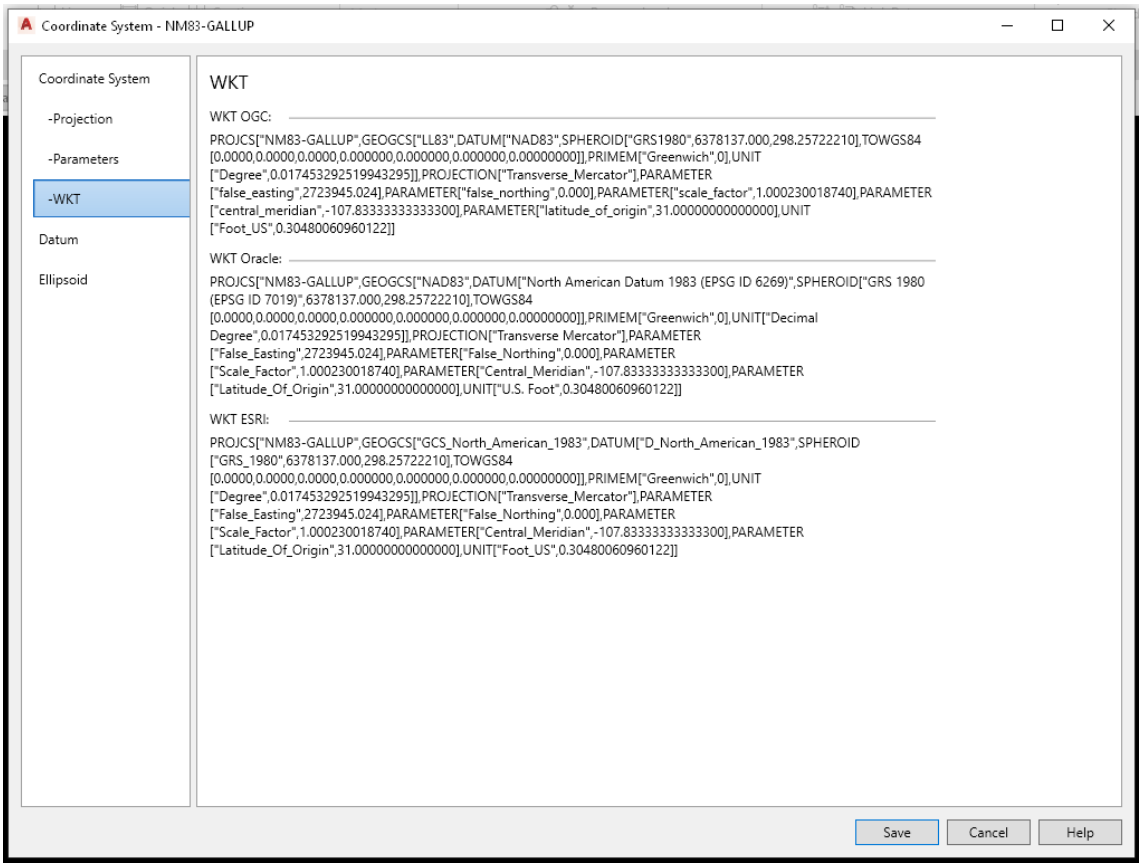
17. Once you have typed in the two new values, select Parameters on the top left.

18. Parameters: Parameters are the extents of your CGCSD. This could vary from Project to Project or City to City. In my case I set the Min/Max Lat and Long to just larger than the city Limits.



19. Everything else in this dialog box should be left to default. Next select the WKT in the Top Left.

20. In this coordinate system the WKT does not get wiped like we previously saw with the previous scenario. There is nothing we need to do here.



21. Select Save and the bottom of the dialog box.
22. Make sure to exit Civil 3D/Map 2D entirely and then come back it to start using your new Ground Coordinate System Definition.
23. We need to validate your new CGCSD. We will reference Step 6 from above. The text file we exported “CP_NM83-WF Grid Coordinates.csv” will now come into play. Start a new Drawing with your DWT Template. Assign your new coordinate system to that drawing. Go to Settings Tab in Toolspace > Points > Point File Format. Right click on the PNEZD (comma delimited) format and make a copy. Rename this Point File Format PgNgEZD (comma delimited). Click on the Northing and Easting headers and change them to Grid Northing and Grid Easting. Lastly check the “Coordinate Zone Transform” box and set your coordinate system to the State Plane zone you are transforming from. Then select OK.
24. Reference Step 24 from the previous scenario.
25. Also, one more test would be to download an ESRI SHP file from your local jurisdiction and import into your new Custom Ground Coordinate System. Just to confirm it falls in the right place.

Conclusion
Using a well-structured and documented approach we can build these coordinate systems relatively easy. We just use a combination of our Survey data and plugging the right numbers into a coordinate system definition we can now have a custom Ground Coordinate System Definition in Autocad Map 3D and/or Civil 3D.

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