The Wisconsin County Coordinate System:

Redefinition of the Foundation

WLIA

March 2, 2006

Ted Koch – State Cartographer’s Office
Alan Vonderohe – UW-Madison
Mike Koutnik - ESRI
John Ellingson – Jackson County

WLIA Coordinate Systems Task Force

- **Today's Presentation:**

  - Al Vonderohe – WCCS: Redesign Objectives, Strategy, and Methodology
  - John Ellingson – WCCS: Testing the Redesign
  - Mike Koutnik – GIS applications
  - Ted Koch – Summary & Questions

WLIA Coordinate Systems Task Force

- **Mission:**
  - Analyze and document the foundations of the WCCS
  - Investigate, analyze and document software implementations of WCCS
  - Investigate the redesign of the WCCS
  - Register WCCS with standards setting organization
  - Document WCCS proceedings
  - Develop user-focused documentation
  - Evaluate and make recommendations regarding statutory changes
  - Present TF recommendations to WLIA Board

WLIA Coordinate Systems Task Force

- **Task Force Members:**
  - Tom Bushy ESRI
  - Diann Danielsen Dane County
  - John Ellingson Jackson County
  - Pat Ford Brown County
  - Gene Hafermann WI Dept of Transportation
  - David Hart UW-Madison Sea Grant
  - Ted Koch State Cartographer, Chair
  - Mike Koutnik ESRI
  - John Laedlein WI Dept of Natural Resources
  - Gerald Mahun Madison Area Technical College
  - David Moyer, Acting State Advisor Nat’l Geodetic Survey
  - Karl Sandsness Ayres Associates
  - Glen Schaefer WI Dept of Transportation
  - Jerry Sullivan WI Dept of Administration
  - Al Vonderohe UW-Madison, Dep’t of Civil & Environmental Engineering
  - Jay Yearwood City of Appleton
  - AJ Wortley State Cartographer’s Office

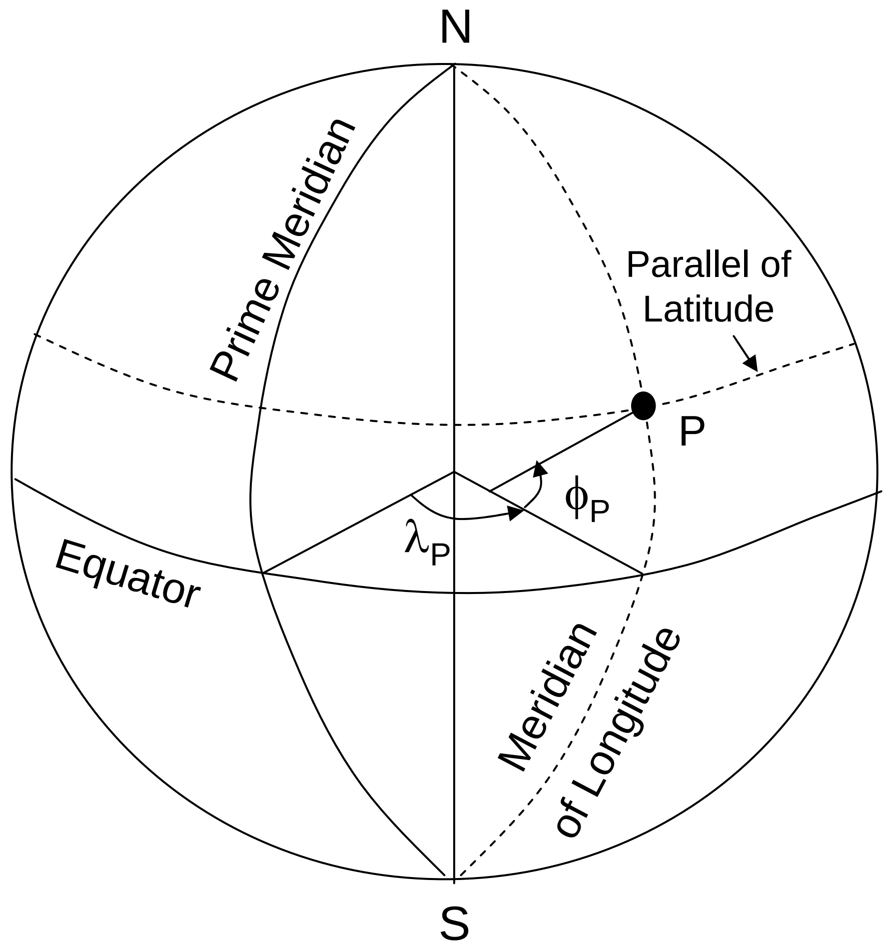
WLIA Coordinate Systems Task Force

- **Task Force Accomplishments – Past Year**
  - 6 meetings in past 12 months
  - Task Force decision to move ahead with redesign
  - WLIB directs Strategic Initiative Grant to fund redesign
  - Jackson County administers redesign contract
  - Initial redesign work is completed and tested
  - Various public presentations on Task Force work
  - Discussions on "next steps" regarding documentation & education

From
WCCS (Wisconsin County Coordinate System)
To
WISCRS (Wisconsin County Reference Systems)

Alan Vonderohe

Fundamental Descriptors of Position



Ellipsoid

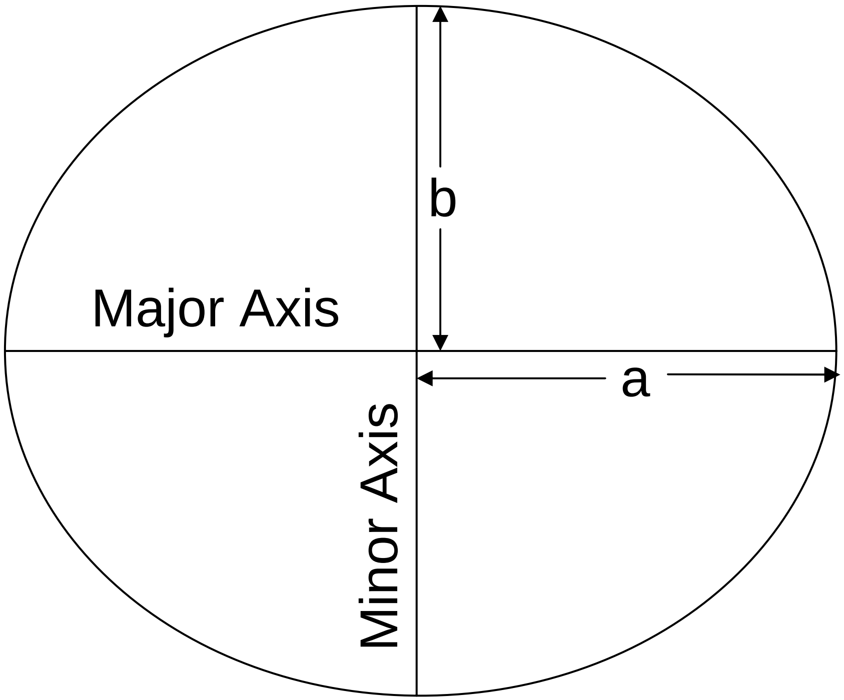
Meridian of Longitude

Prime Meridian

Parallel of Latitude

Latitude (ϕ_P) and Longitude (λ_P) of point P

Elements of an Ellipse



a = Semi-Major Axis

b = Semi-Minor Axis

Rotate about minor axis to generate oblate spheroid.

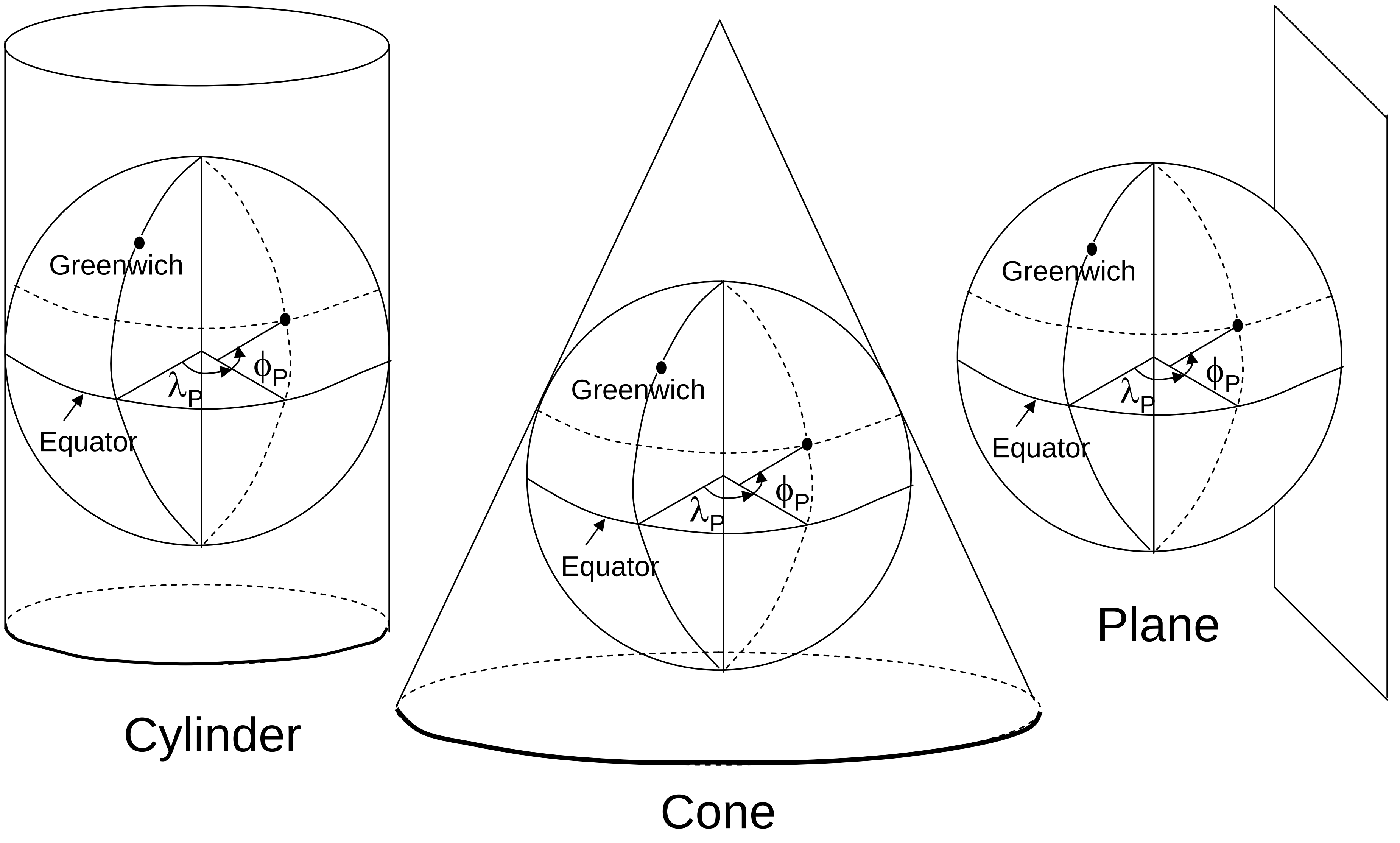
Spheroid used for current national geodetic datum (NAD83) is named “GRS 80”:

- a = 6378137.0 m
- b = 6356752.3141403 m

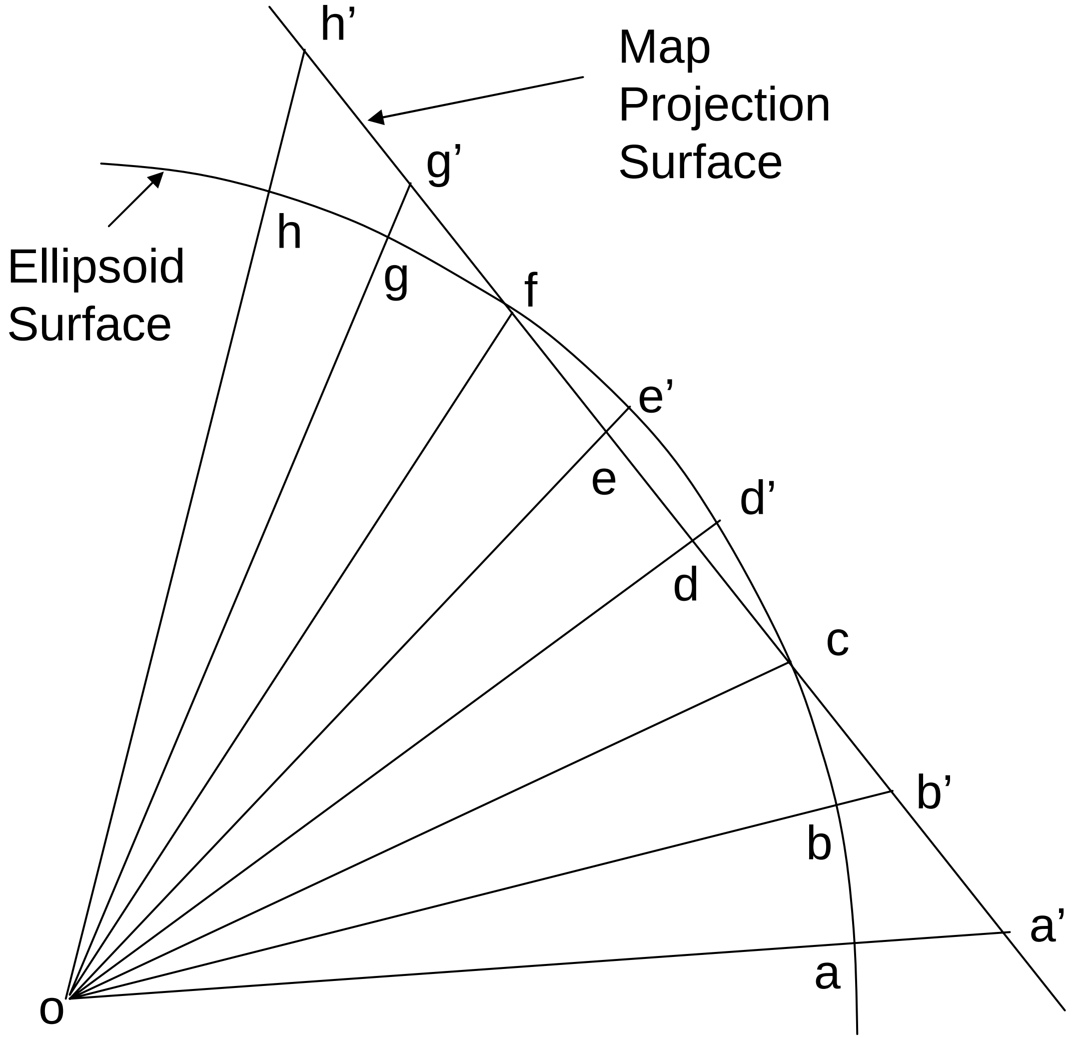
Computational and Visualization Problem

- Latitude / Longitude are angular, not rectangular coordinates.
- Ellipsoid surface cannot be cut and laid flat.
- Latitude / Longitude must be projected to a “developable” surface to obtain rectangular coordinates.

Developable Surfaces



One Way to Conceptualize “Projection”



Points on the ellipsoid are projected to the projection surface by straight lines from the center of the ellipsoid.

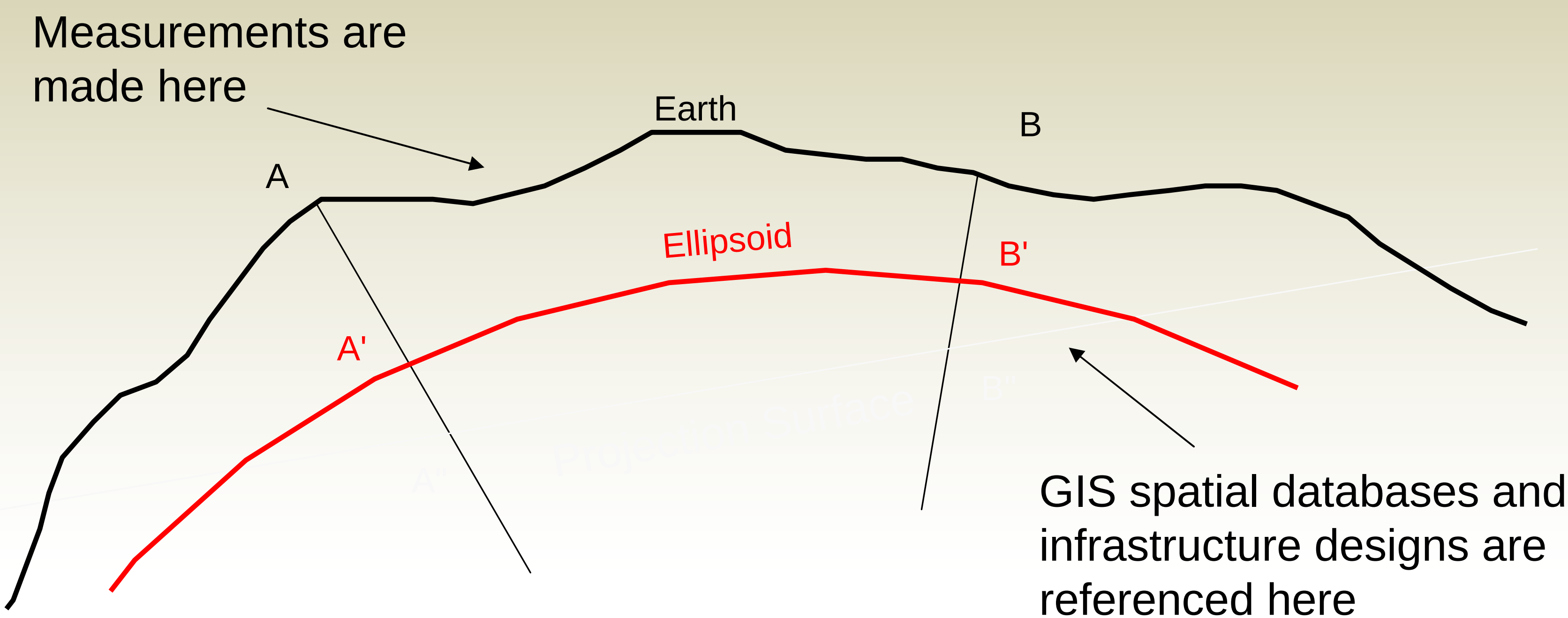
Note scale factor and how it varies across the projection surface.

Note: Some map projections are purely mathematical and have no graphical counterpart.

Ground-to-Grid

Problem: Length distortion occurs when projecting from:

- Ground (Earth) to ellipsoid
- Ellipsoid to projection surface



Ground-to-Grid

- Two step process to obtain grid (map projection) distances from ground distances:

$$D_{ellipsoid} = (D_{ground})(EllipsoidFactor)$$

- Or

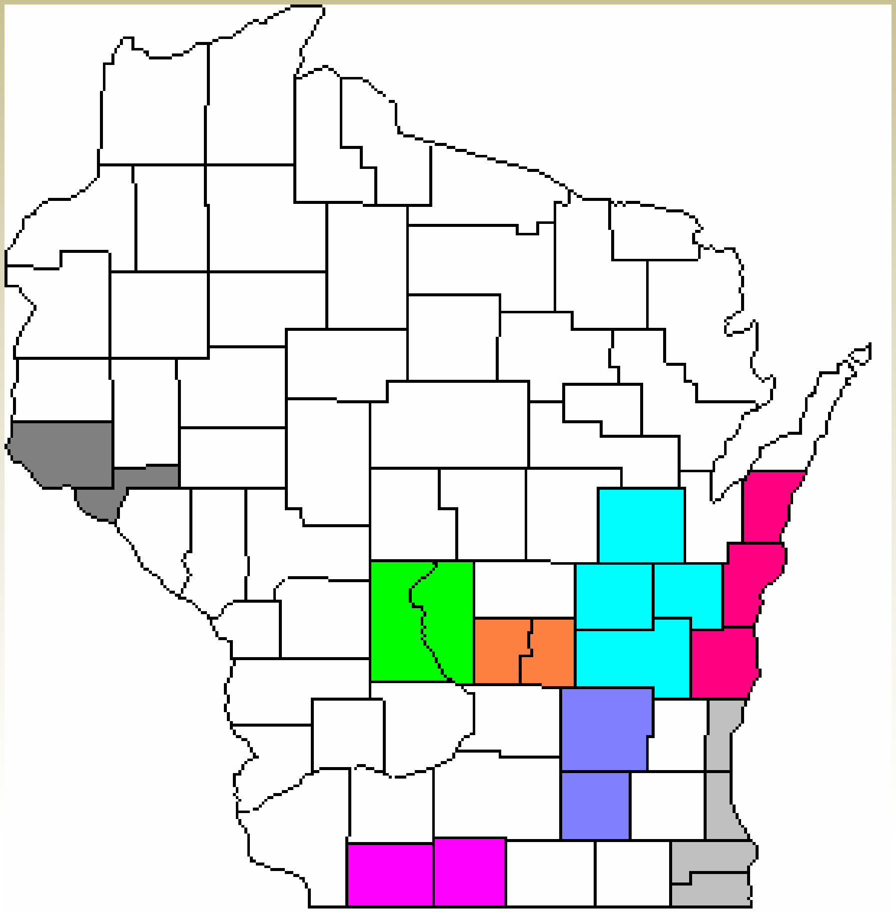
$$D_{grid} = (D_{ellipsoid})(ScaleFactor)$$

$$D_{grid} = (D_{ground})(EllipsoidFactor)(ScaleFactor)$$

Wisconsin County Coordinates

- Original WCCS Objective:
  1. Make differences between ground distances and grid distances negligible for most applications.
- Original Design Strategy:
  1. Restrict extent of each projection so scale factor is approximately equal to one everywhere.
  2. For each projection, enlarge the ellipsoid by adding an amount that brings it to about the mean elevation of the terrain. This causes the ellipsoid factor to be approximately equal to one everywhere.

Wisconsin County Coordinates



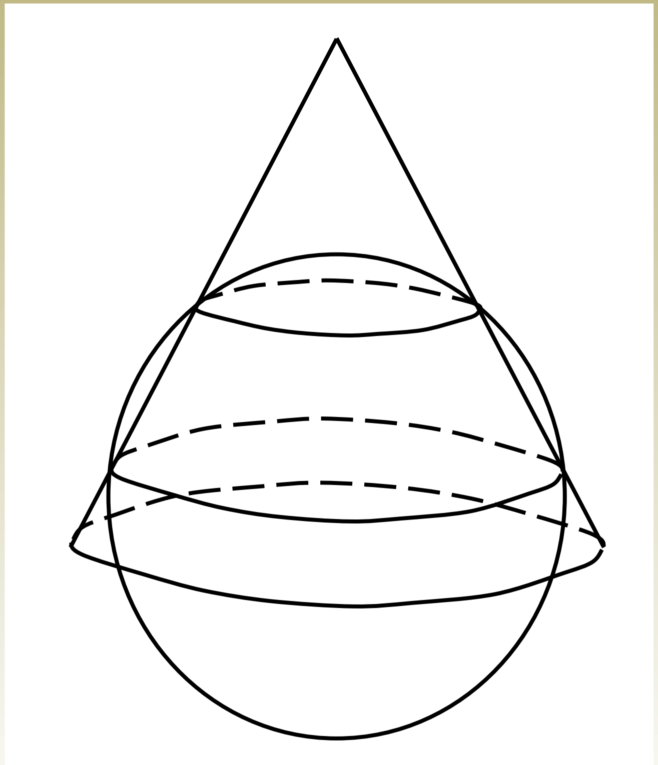
72 Counties

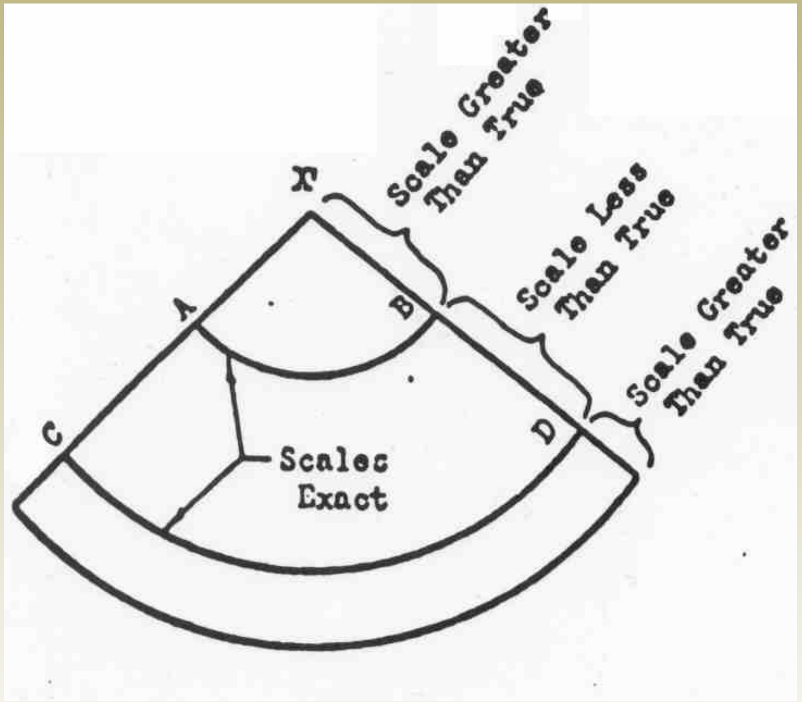
59 Coordinate Systems

24 Lambert

35 Transverse Mercator

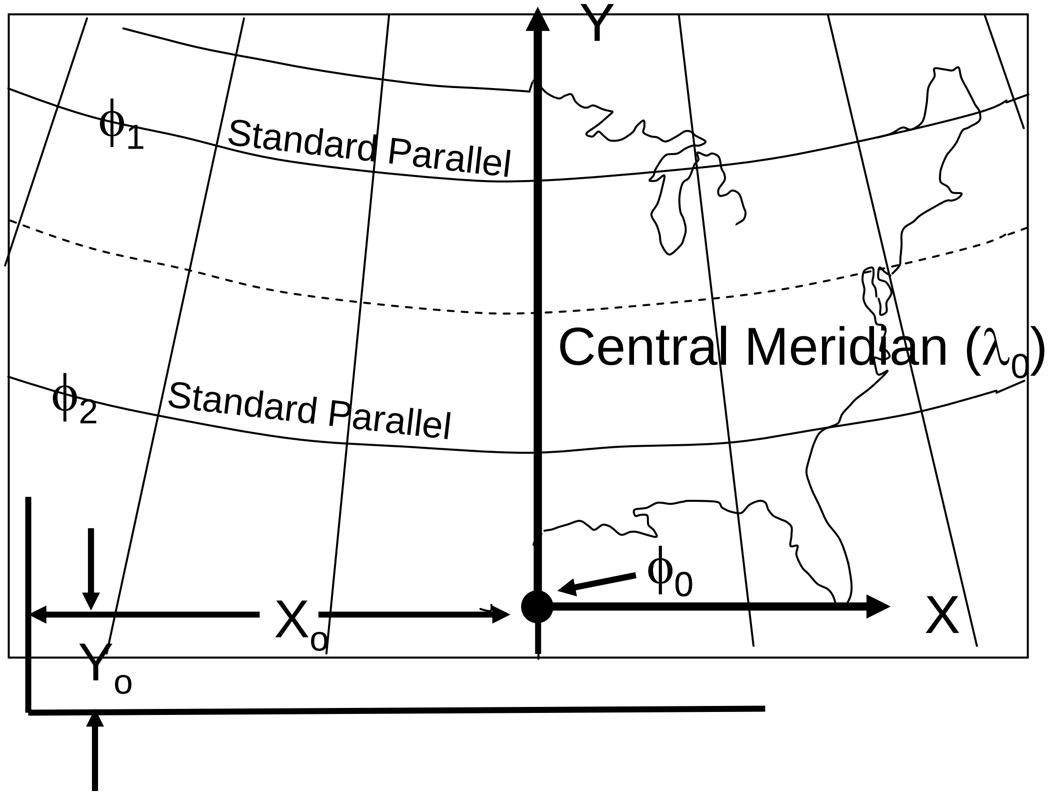
Lambert Conformal Conical Projection





Scale variation is greater north-south than east-west.

Lambert Conformal Conical Projection



Alternative to ϕ_1, ϕ_2 is ϕ_0,k_0 (latitude and scale factor at central parallel).

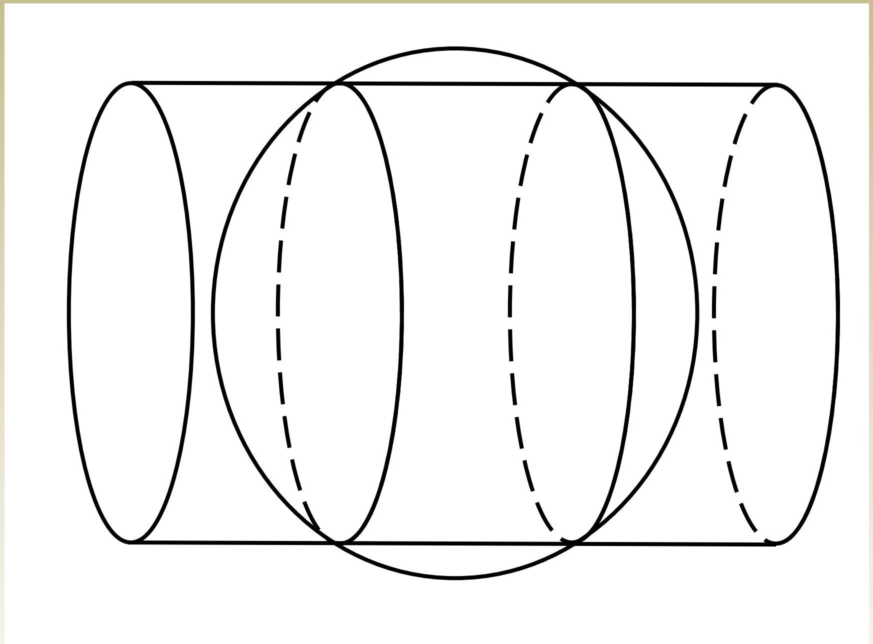
Projection Parameters:

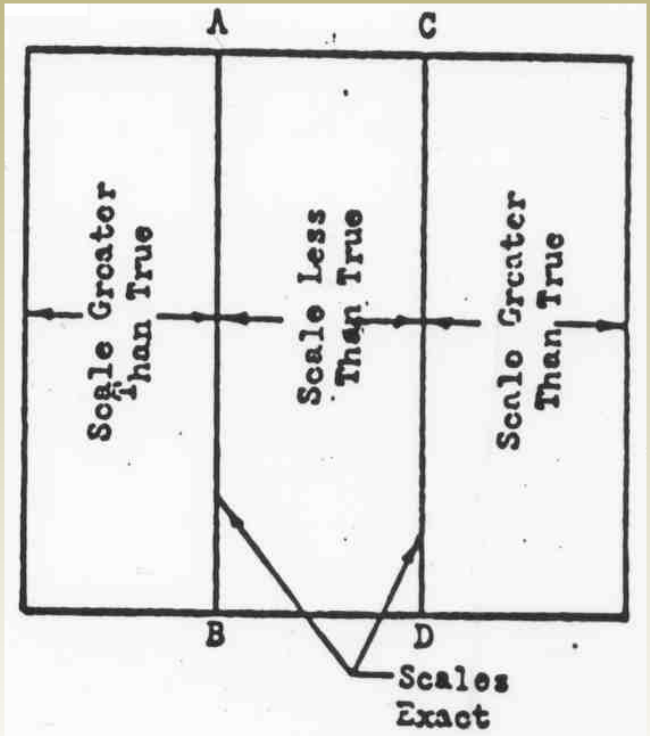
λ_0 (longitude of central meridian)

ϕ_1, ϕ_2 (latitudes of standard parallels)

ϕ_0, X_0,Y_0 (latitude, false easting, false northing of the coordinate origin)

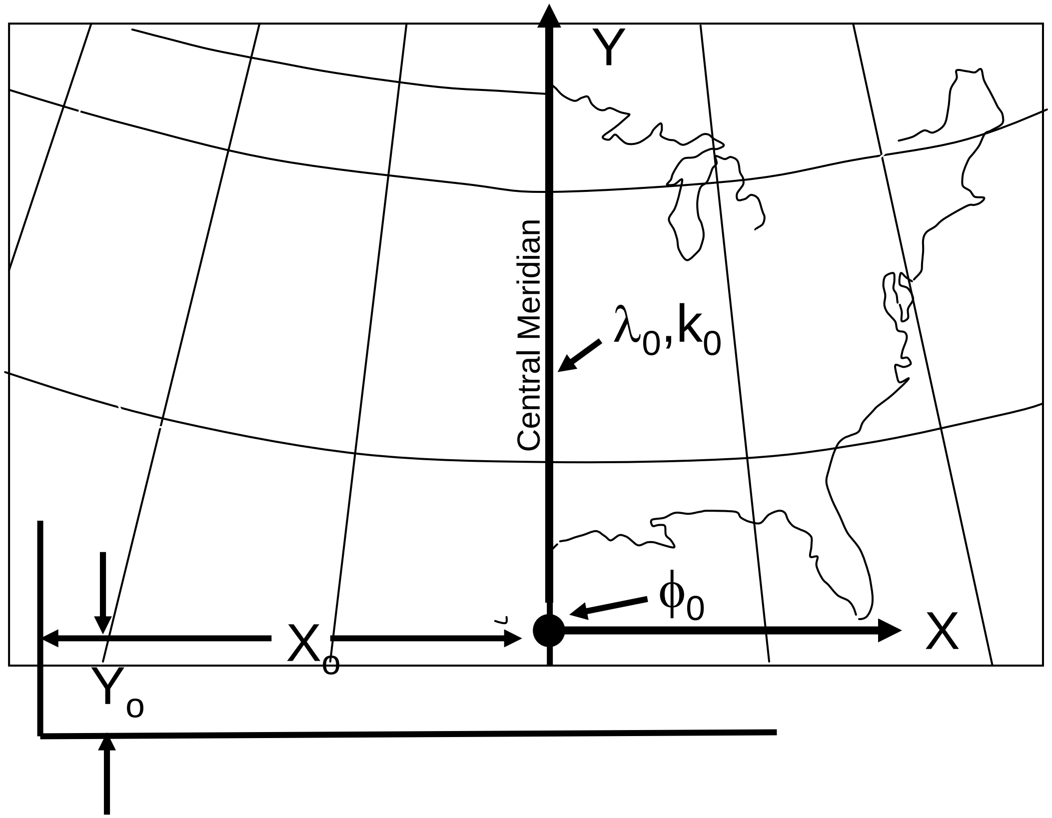
Transverse Mercator Projection





Scale variation is greater east-west than north-south.

Transverse Mercator Projection



Projection Parameters:

λ_0 (longitude of central meridian)

k_0 (scale factor along central meridian)

ϕ_0, X_0, Y_0 (latitude, false easting, false northing of the coordinate origin)

Wisconsin County Coordinates

- Problem:
  - Each projection has its own ellipsoid.
  - This makes it seem like each projection has its own datum.
  - Confusion abounds.

WLIA Task Force

- In 2004, WLIA formed the Wisconsin Coordinate Systems Task Force to address this and other spatial referencing issues.
- Ultimately, the Task Force recommended redesign of the system, established criteria, and obtained funding.

Redesign Objectives

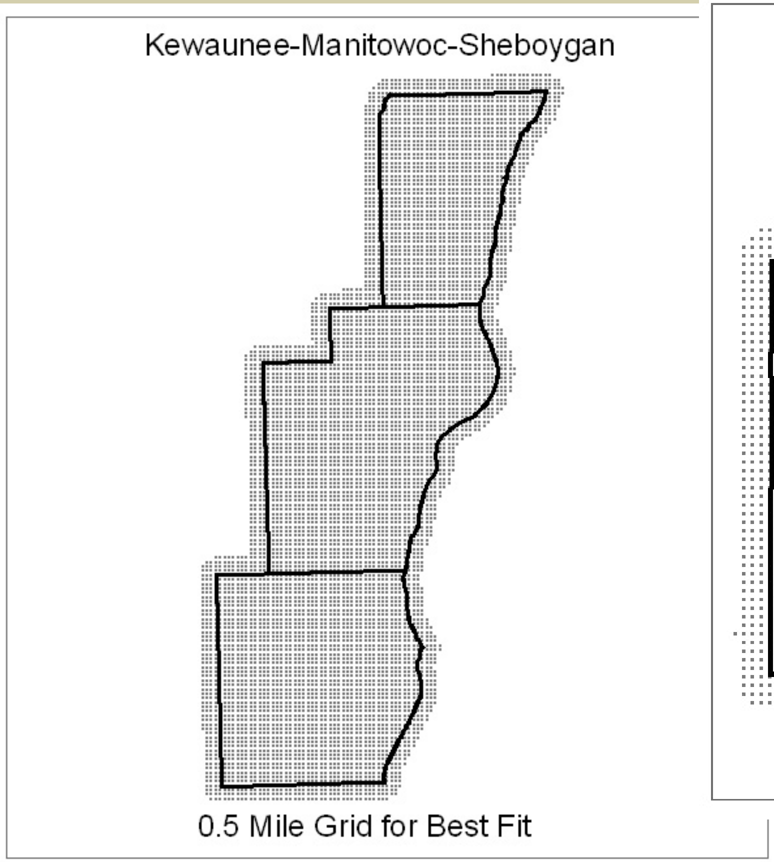
1. Redesign the coordinate systems so there is no need to enlarge the ellipsoid.
   - There will be only one ellipsoid (GRS80) for everyone.
2. Redesigned coordinates should not differ by more than 5mm from the originals anywhere on any projection.
   - Legacy data will be preserved.
   - Existing and new data can be combined without transforming either.

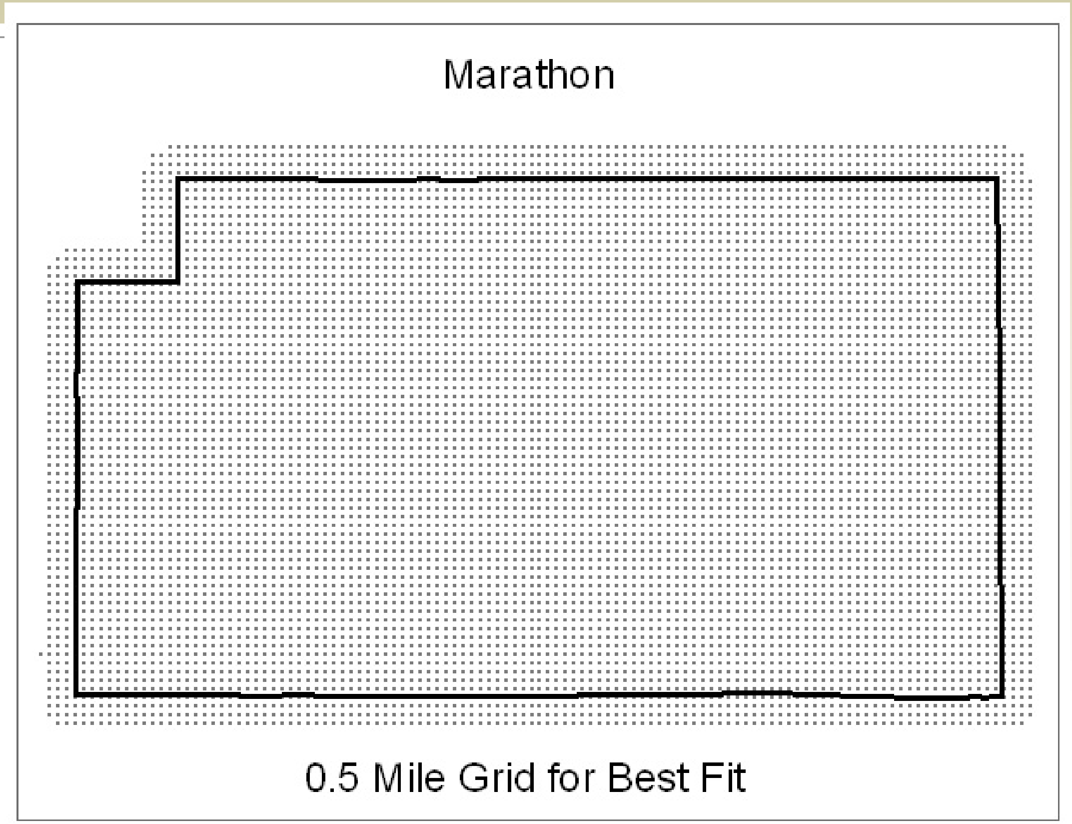
Redesign Strategy

1. Multiply scale factor on Central Meridian (Transverse Mercator) or Central Parallel (Lambert) by inverse of ellipsoid factor to obtain provisional scale factor.
   - Causes ellipsoid factor and scale factor to be approximate reciprocals of one another, so when they are multiplied together the result is approximately equal to one.
2. Adjust false northing, false easting, and provisional scale factor to account for effects of differences of the two ellipsoids (GRS80 and enlarged).

Redesign Methodology

- Methodology:
  1. Use DNR statewide map to obtain boundaries for each projection.
  2. Generate a 0.5-mile grid of test points within a 2-mile buffer for each projection.





Redesign Methodology

- Methodology:
  3. Compute provisional scale factor for each projection.
  4. Using provisional scale factor, compute provisional county coordinates for each grid point.
  5. Compute original county coordinates for each grid point.
  6. Develop observation equations for each grid point:

$$(E_{original} - E_o) + v_{Eoriginal} = S(E_{provisional} - E_o) + \Delta E_o$$

$$(N_{original} - N_o) + v_{Noriginal} = S(N_{provisional} - N_o) + \Delta N_o$$

Redesign Methodology

- Methodology:
  7. Compute least squares solution of about 10,000 equations for each projection to obtain shifts in false northing and false easting, and multiplier for provisional scale factor.
  8. Final Transverse Mercator parameters are:

$$\lambda_{o(redesigned)} = \lambda_{o(original)}; \phi_{o(redesigned)} = \phi_{o(original)}; k_{o(redesigned)} = k_{o(provisional)} * S;$$

$$E_{o(redesigned)} = E_{o(original)} + \Delta E_o; N_{o(redesigned)} = N_{o(original)} + \Delta N_o$$

Number of Transverse Mercator parameters is reduced from 7 to 5 (no need for design elevation and geoidal separation).

Redesign Methodology

- Methodology:

9. Final Lambert parameters are:

$$\lambda_{o(redesigned)} = \lambda_{o(original)}; \phi_{o(redesigned)} = \phi_{o(original)}; k_{o(redesigned)} = k_{o(provisional)} * S;$$
$$E_{o(redesigned)} = E_{o(original)} + \Delta E_o; N_{o(redesigned)} = N_{o(original)} + \Delta N_o$$

- Number of Lambert parameters is reduced from 8 to 5.
- $\phi_{o(original)}$ is computed from $\phi_{1(original)}$ and $\phi_{2(original)}$.
- Coordinate origin is shifted to ϕ_o, λ_o.
- $N_{o(original)}$ at new coordinate origin is computed, not given.

Redesign Methodology

- Methodology:
  10. Compute differences between redesigned and original coordinates at each grid point.
  11. Find maximum shifts in northings and eastings to check against 5mm tolerance.
  12. Prepare isoline (contour) maps of coordinate shifts.

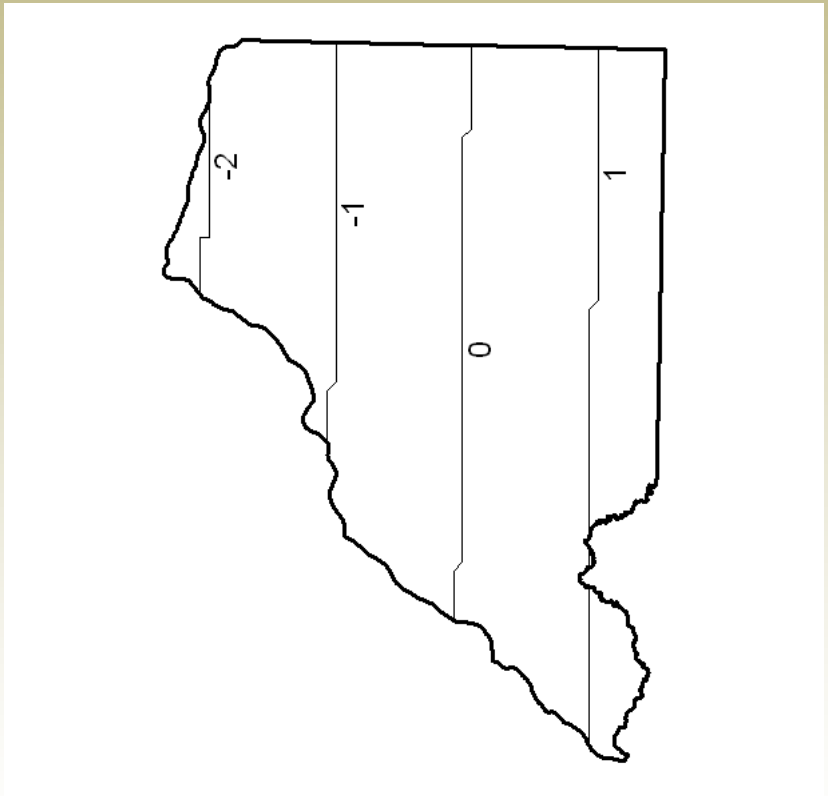
Redesign Results

- Results:
  - All coordinate systems meet the redesign criterion:
    - All coordinate shifts are less than 5mm.
  - Typical coordinate shifts range from

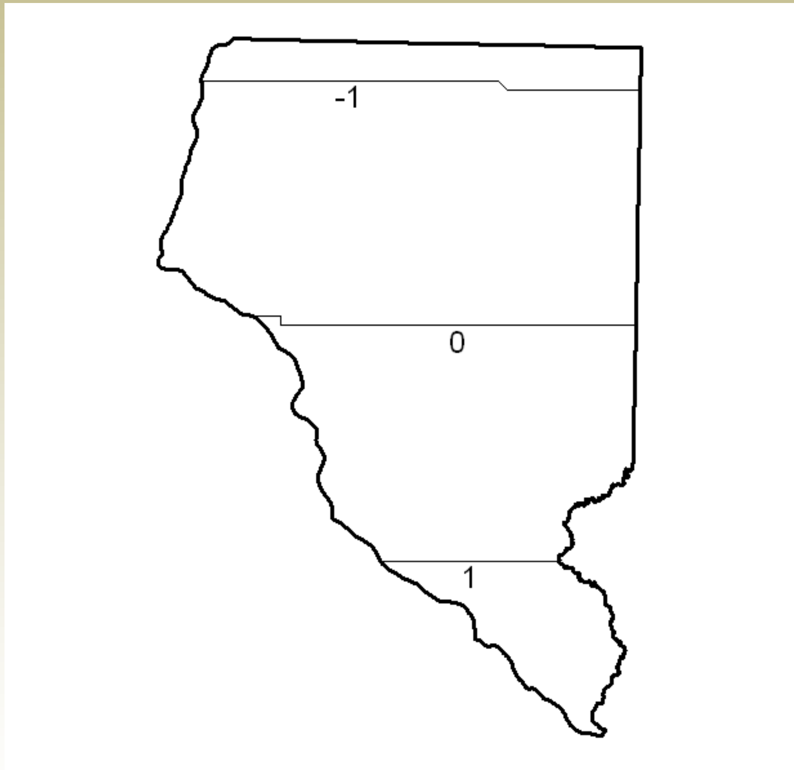
    –3mm to +3mm.
  - Some counties have maximum shifts of less than 1mm.
  - Maximum shifts are in Oneida and Vilas (Lambert) and Ashland and Forest (Transverse Mercator).

Coordinate Shifts

Buffalo County (Typical Transverse Mercator)



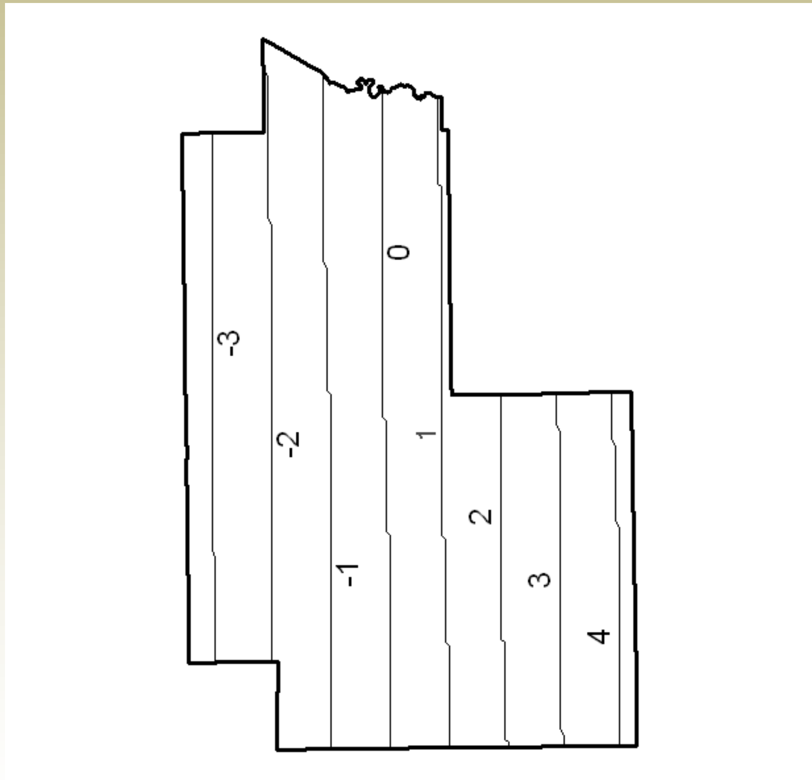
Shift in Easting (mm)



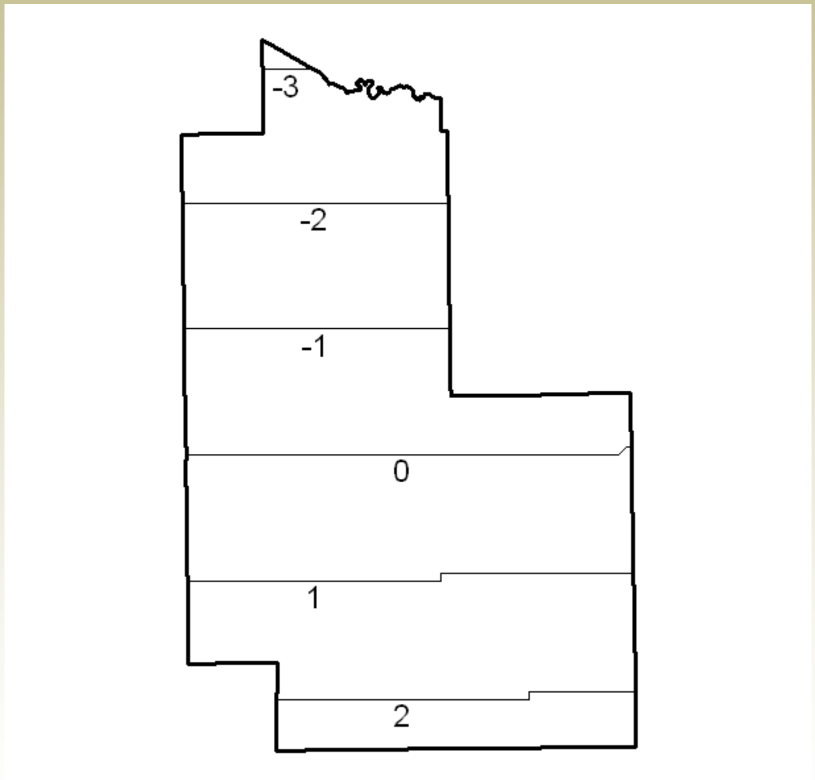
Shift in Northing (mm)

Coordinate Shifts

Forest County (Worst-Case Transverse Mercator)



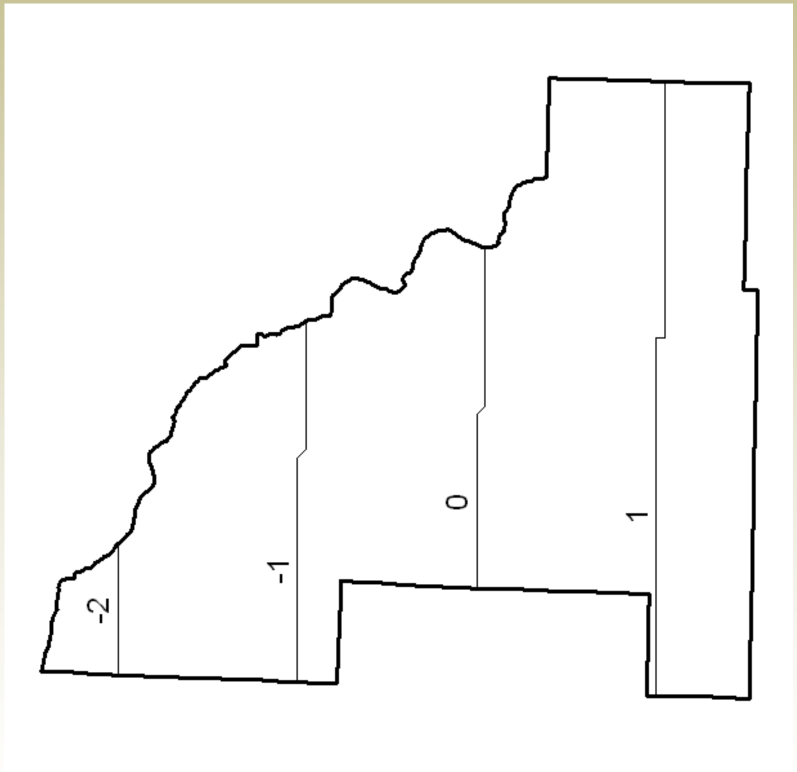
Shift in Easting (mm)



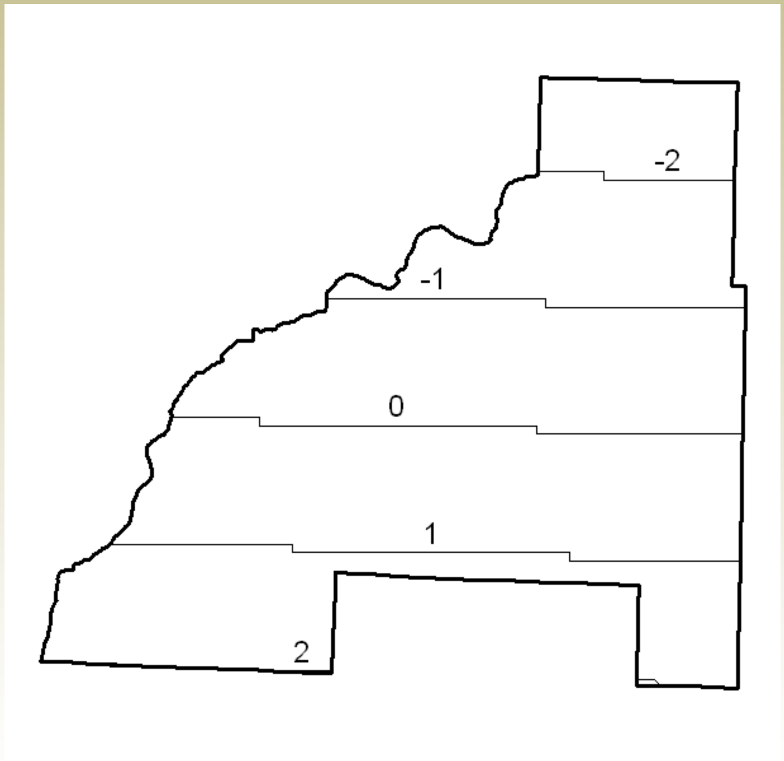
Shift in Northing (mm)

Coordinate Shifts

Burnett County (Typical Lambert)



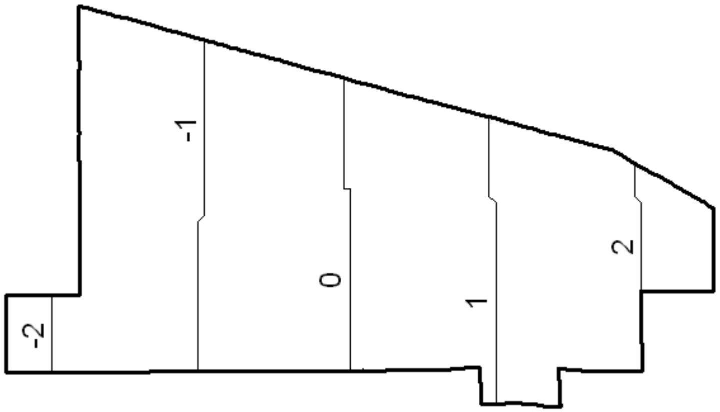
Shift in Easting (mm)



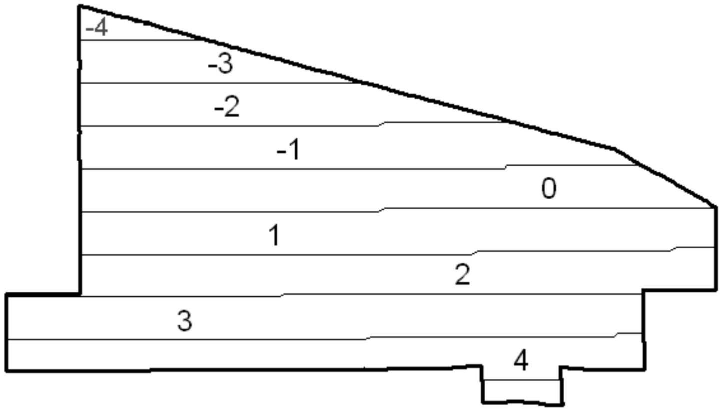
Shift in Northing (mm)

Coordinate Shifts

Vilas County (Worst-Case Lambert)



Shift in Easting (mm)



Shift in Northing (mm)

Status

- Validation:
  - Independent testing by four individuals using various software packages and programming techniques.
  - All have concluded that the redesign meets the 5mm criterion.
- Draft final report under review.
  - Final submittal during March.

WISCRS (Wisconsin County Reference Systems)

- The Task Force has decided:
  - - To retain the name "WCCS (Wisconsin County Coordinate System)" for the original.
  - - To name the redesigned **"WISCRS (Wisconsin County Reference Systems)".**
    - Individual county systems are suggested to be referred to as **"WISCRS, Dane County",** for example.

Wisconsin County Coordinate System

Testing the Redesign

John Ellingson, Land Information Coordinator
Jackson County

CONTACT INFORMATION

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- Tele: 715-284-0221

TO VIEW COORDINATE TEST DATA:

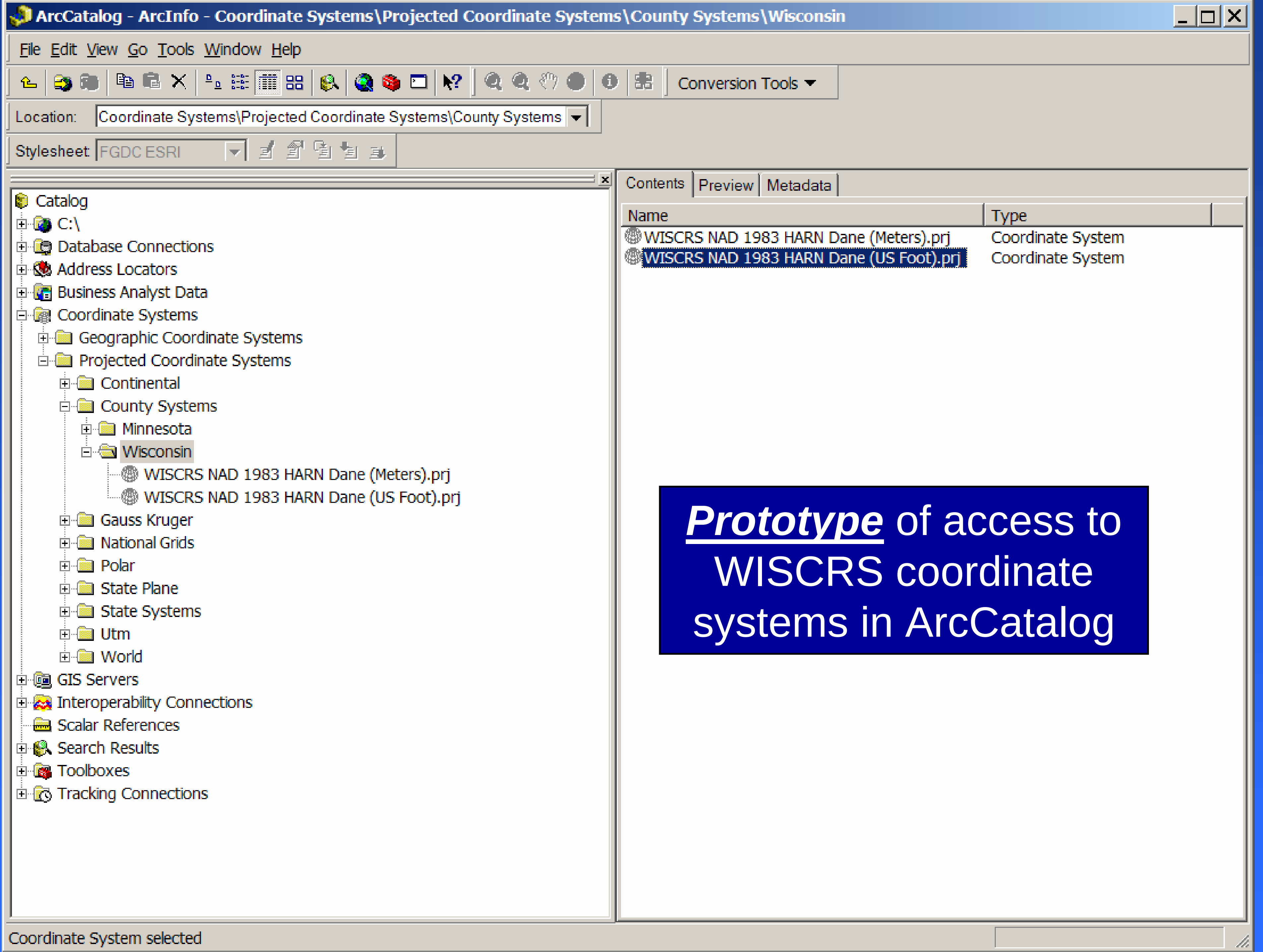
- Go To: www.sco.wisc.edu
- Click on: Coordinate Systems
- Click on: Task Force
- Click on: County Coordinate Test Point Data

  (Listed under Task Force Documents)

GIS Applications

Mike Koutnik
ESRI

Using WISCRS in ArcGIS Desktop



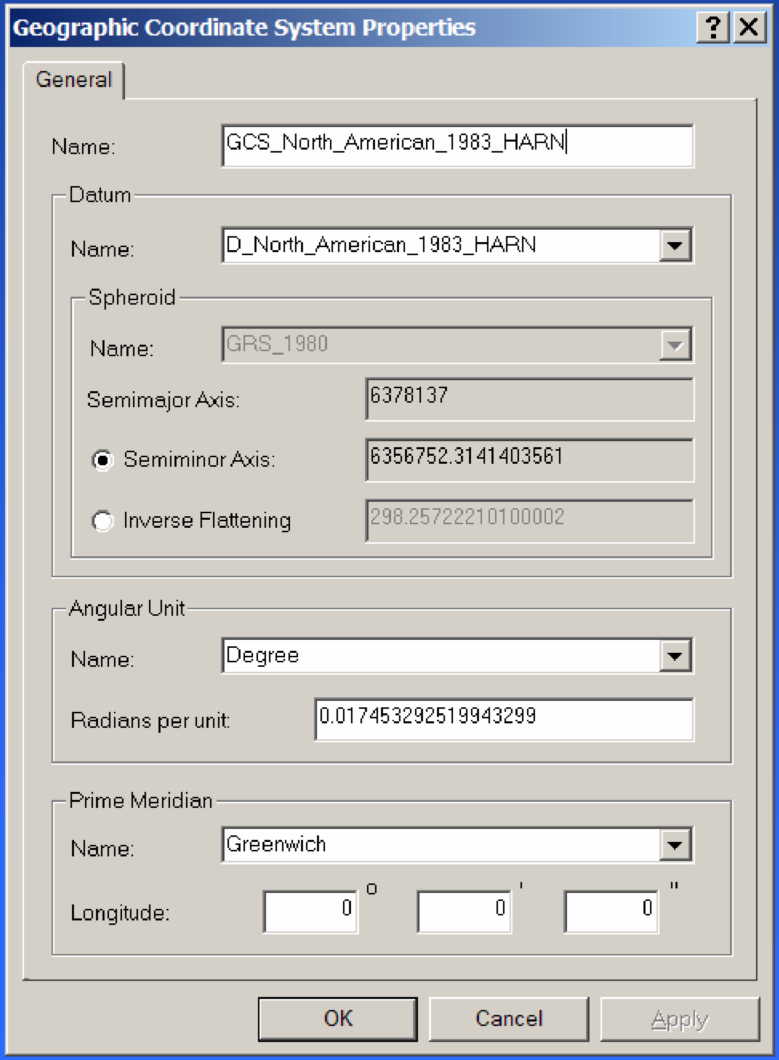
Prototype of access to WISCRS coordinate systems in ArcCatalog

Building a WISCRS .prj

- Geographic COORDYS
  - All counties use NAD 83 HARN
- Projected COORDSYS
  - Unique to each county

WISCRS Geographic Coordsys

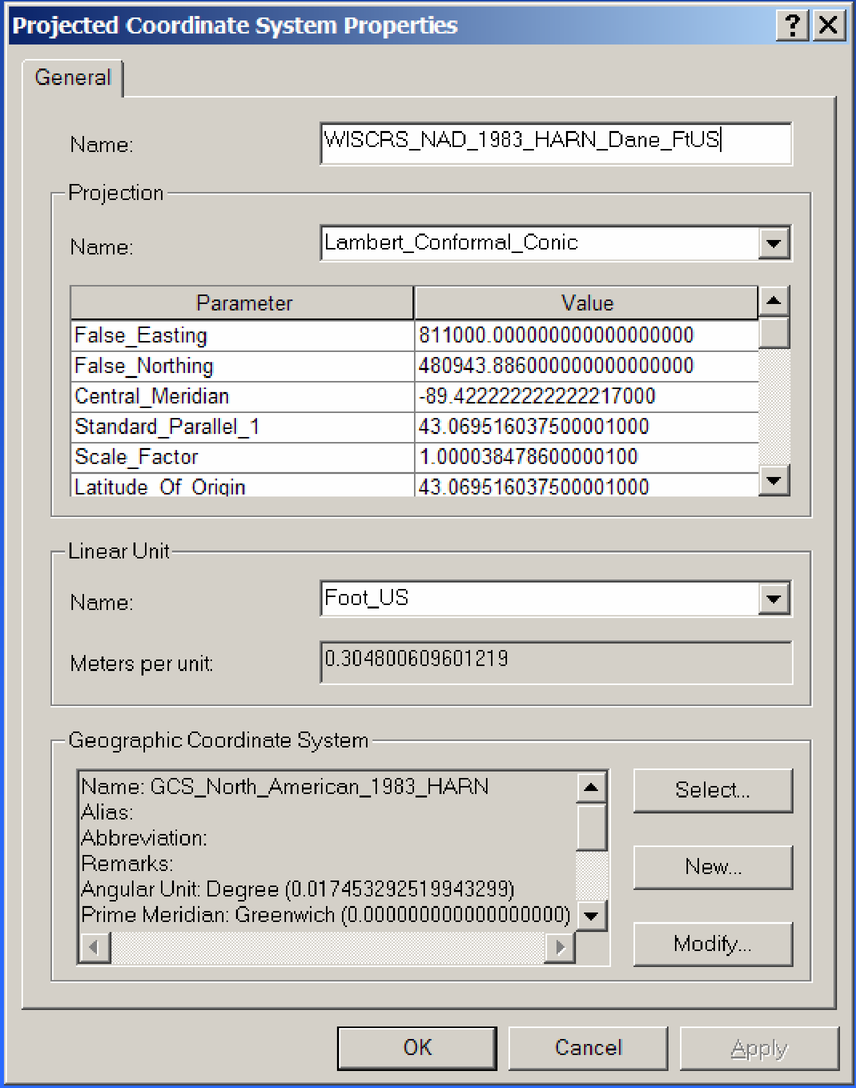
- Specified as NAD 83 HARN
- Same for all counties



WISCRS Projected Coordsys

Ex: Lambert Conic

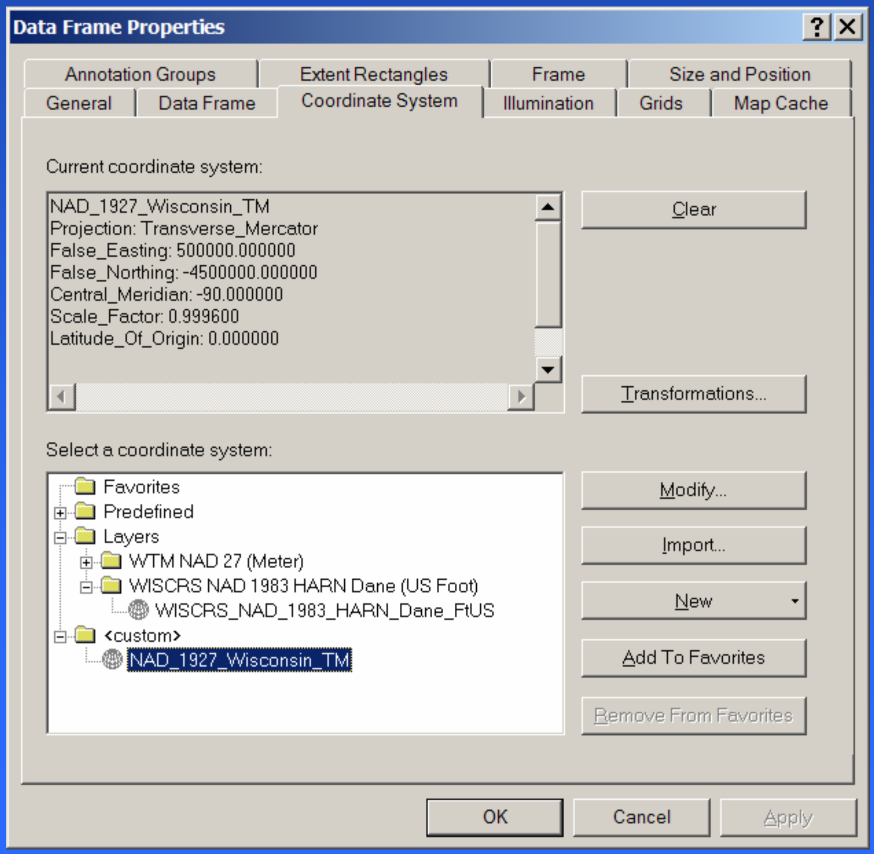
- Latitudes same for:
  - Latitude of Origin
  - Both standard parallels
- Scale factors can be greater than 1



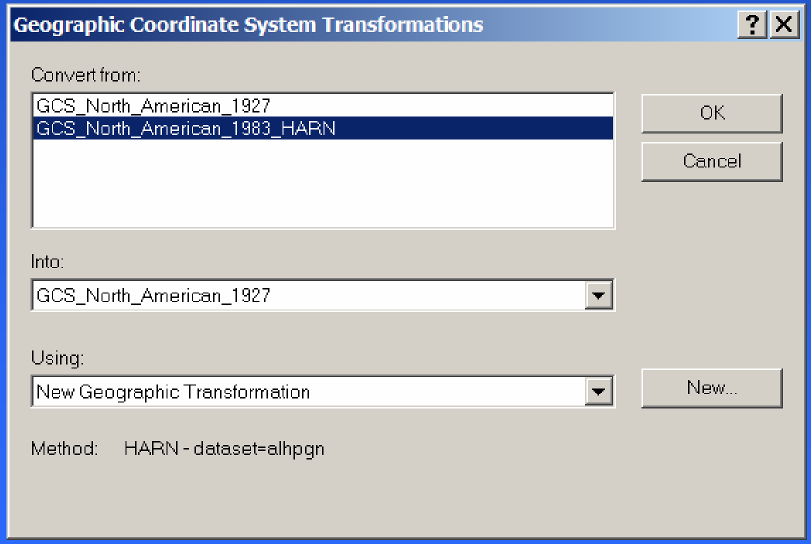
ArcMap Projections

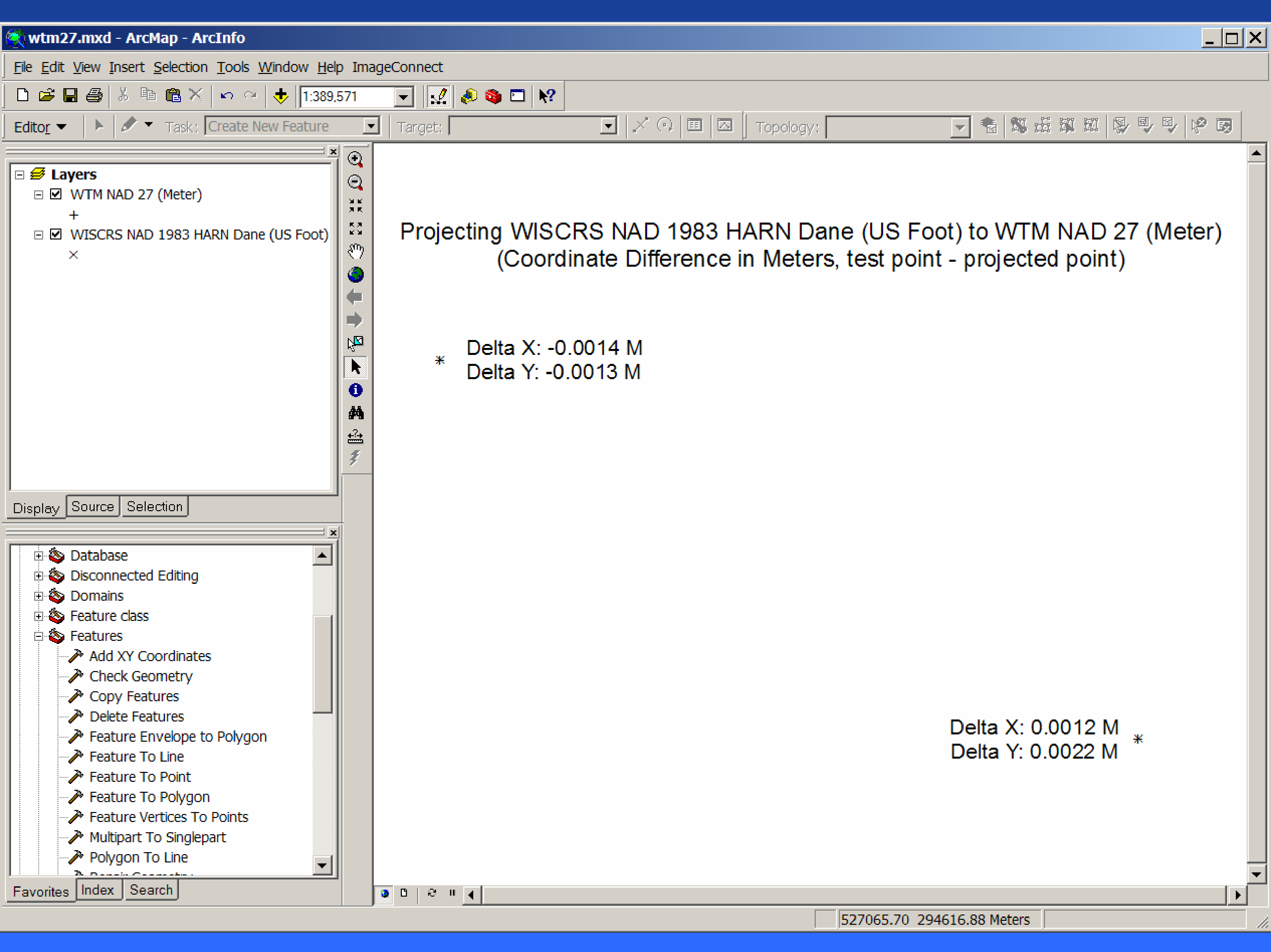
WISCRS Dane (Foot US) to WTM 27 (meters)

On-the-fly Projection



Setting the transformation method




wtm27.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help ImageConnect
1:389,571
Editor
Task: Create New Feature
Target:
Topology:
Layers
WTM NAD 27 (Meter)
WISCRS NAD 1983 HARN Dane (US Foot)
Display
Source
Selection
Database
Disconnected Editing
Domains
Feature class
Features
Add XY Coordinates
Check Geometry
Copy Features
Delete Features
Feature Envelope to Polygon
Feature To Line
Feature To Point
Feature To Polygon
Feature Vertices To Points
Multipart To Singlepart
Polygon To Line
Favorites
Index
Search
Projecting WISCRS NAD 1983 HARN Dane (US Foot) to WTM NAD 27 (Meter)
(Coordinate Difference in Meters, test point - projected point)
Delta X: -0.0014 M
Delta Y: -0.0013 M
Delta X: 0.0012 M
Delta Y: 0.0022 M
527065.70 294616.88 Meters

Questions?