FOR375

MAP PROJECTIONS AND COORDINATE SYSTEMS

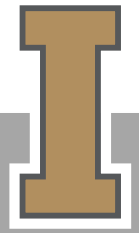
SPRING 2016

Lecture 2 – Map Projections and Coordinate Systems

University of Idaho
College of Natural Resources

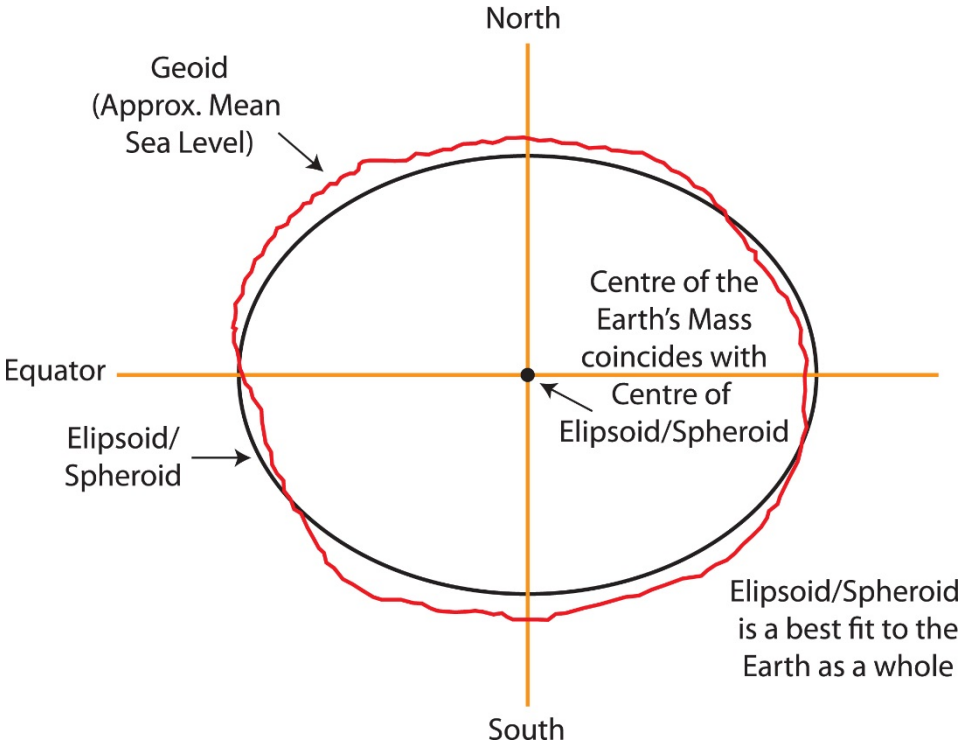
MAP PROJECTIONS & COORDINATE SYSTEMS

- Models of the Earth
- Map Projections & Datums
- Map Coordinate Systems
- Map Coordinate Systems on USGS Topo Maps
- Map Reading & Position Determination
- Material from: Bolstad, 2012 (Chpt. 3);



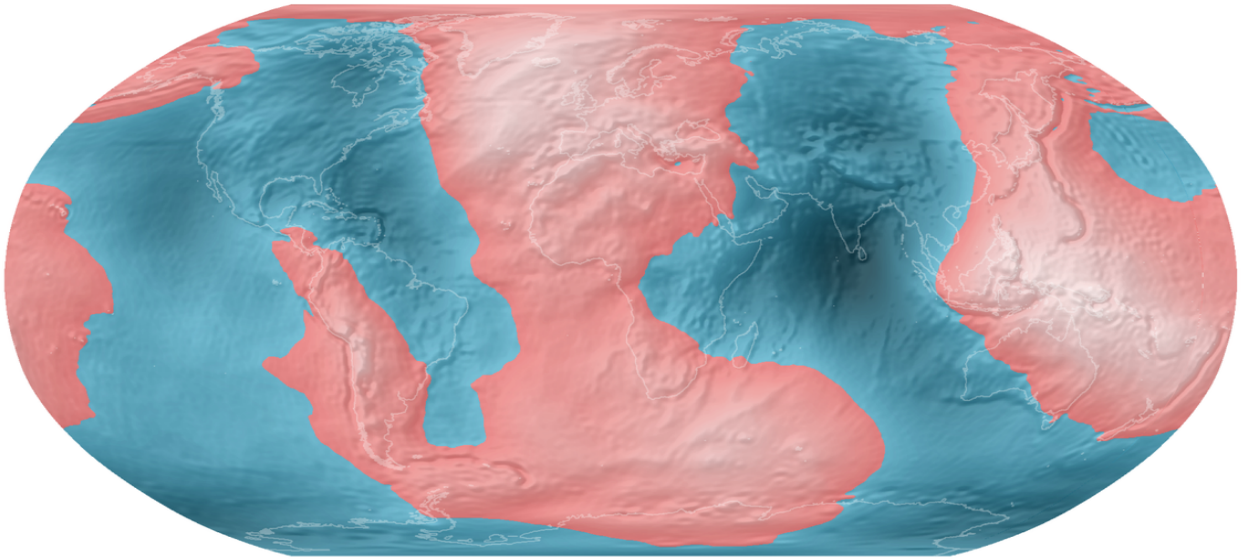
Ellipsoid: mathematical surface obtained by revolving an ellipse about the earth's polar axis. Selected to give a good fit to the geoid

Geoid: is the earth's mean sea level surface – everywhere perpendicular to the direction of gravity, because of variations in the earth's mass distribution, the geoid has an irregular shape.



Deviation of the Geoid from the idealized figure of the Earth

(difference between the EGM96 geoid and the WGS84 reference ellipsoid)



Red areas are above the idealized ellipsoid; blue areas are below.

- Lines of constant longitude are called meridians
- Lines of constant latitude are called parallels
- Locations can be defined based on a spherical coordinate in angular units of longitude and latitude

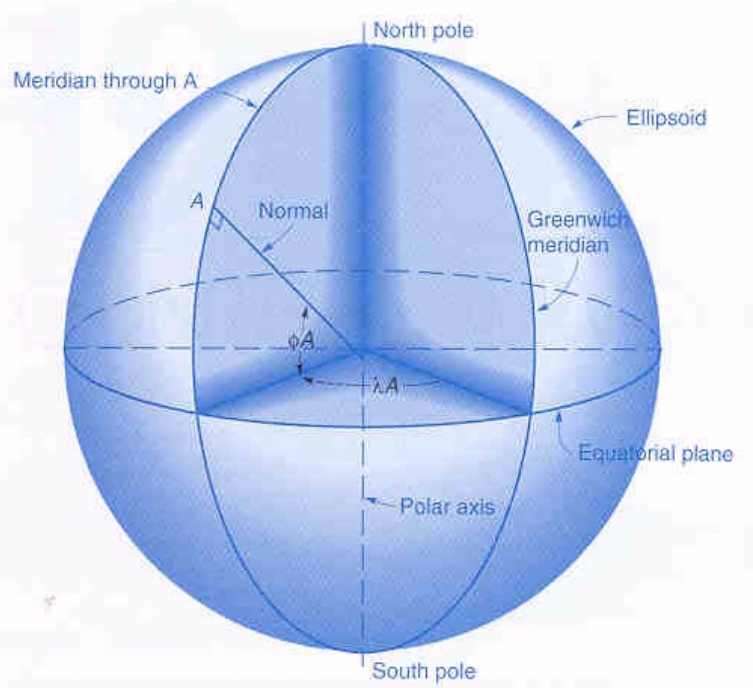
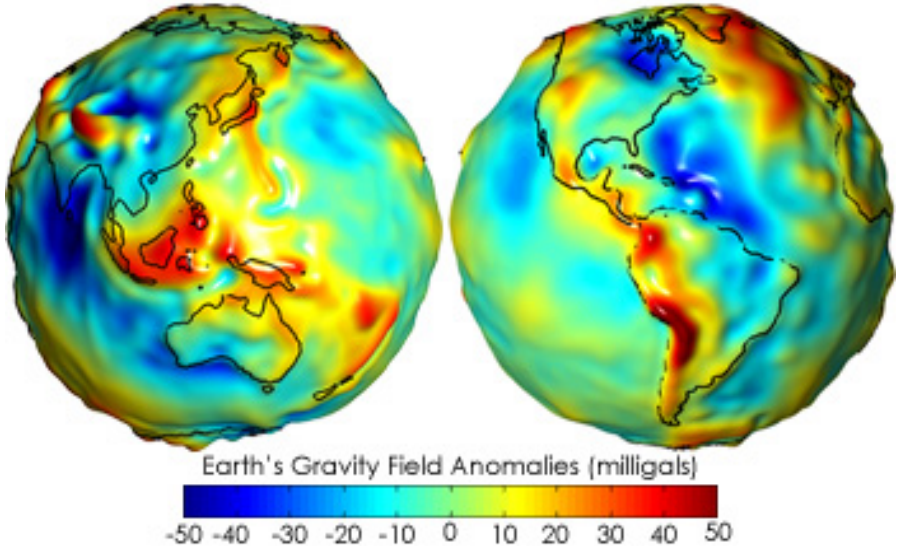


Figure 19-2 Geodetic latitude ϕ_A and geodetic longitude λ_A.

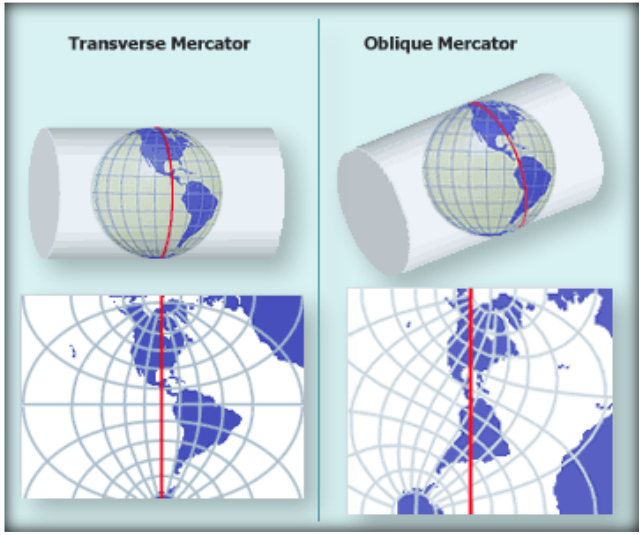
MAP PROJECTIONS & COORDINATE SYSTEMS

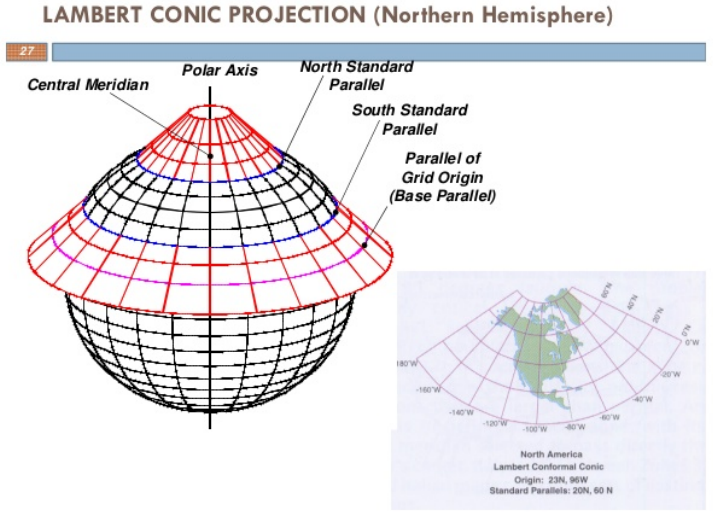
Difficult to use a spherical coordinate system such as a geodetic coordinate system (longitude, latitude) with angular measurements – not intuitive for measuring distances and areas on the earth's surface.



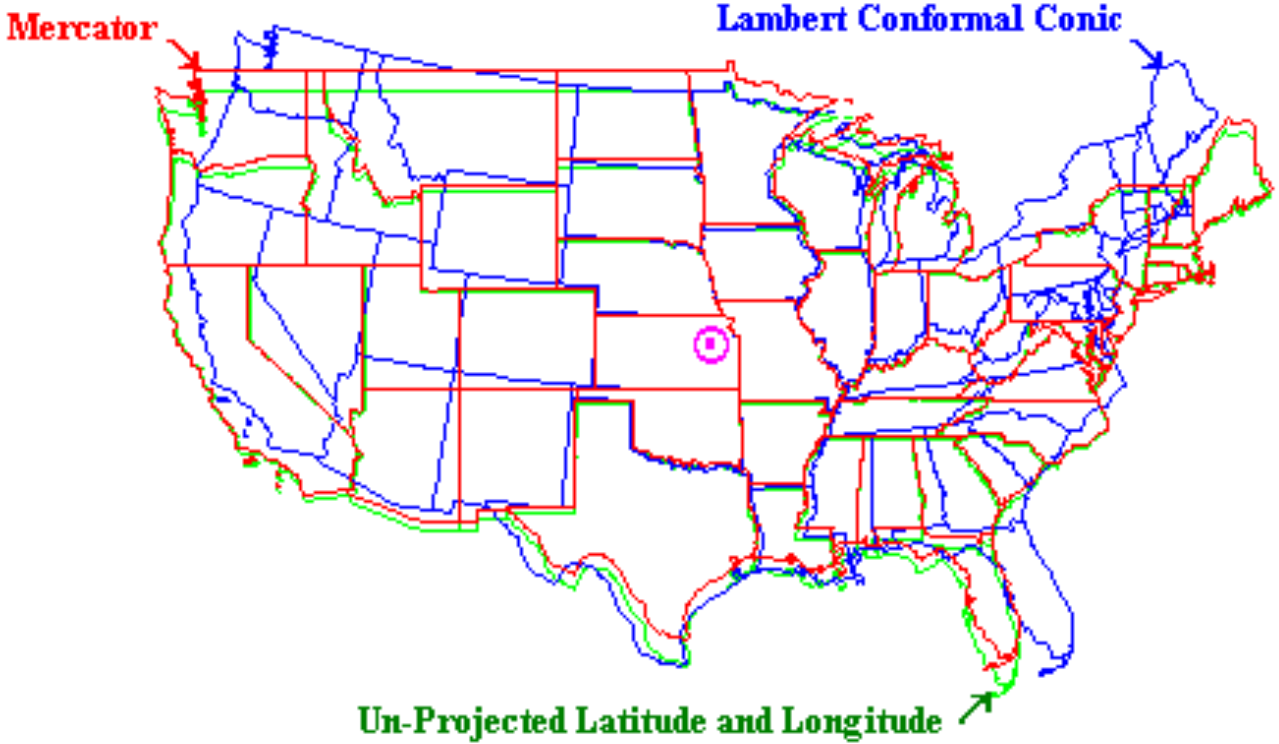
Map Projections: to convert geodetic positions of a portion of the earth's surface to plane rectangular coordinates, points are projected mathematically from the ellipsoid to some imaginary developable surface - plane that can be rolled out flat

Map Coordinate Systems: quantitative coordinate systems - based on mathematical projection models, often a cartesian coordinate system (i.e. x, y axes) representing relative positions within a particular map projection





Three Map Projections Centered at 39 N and 96 W

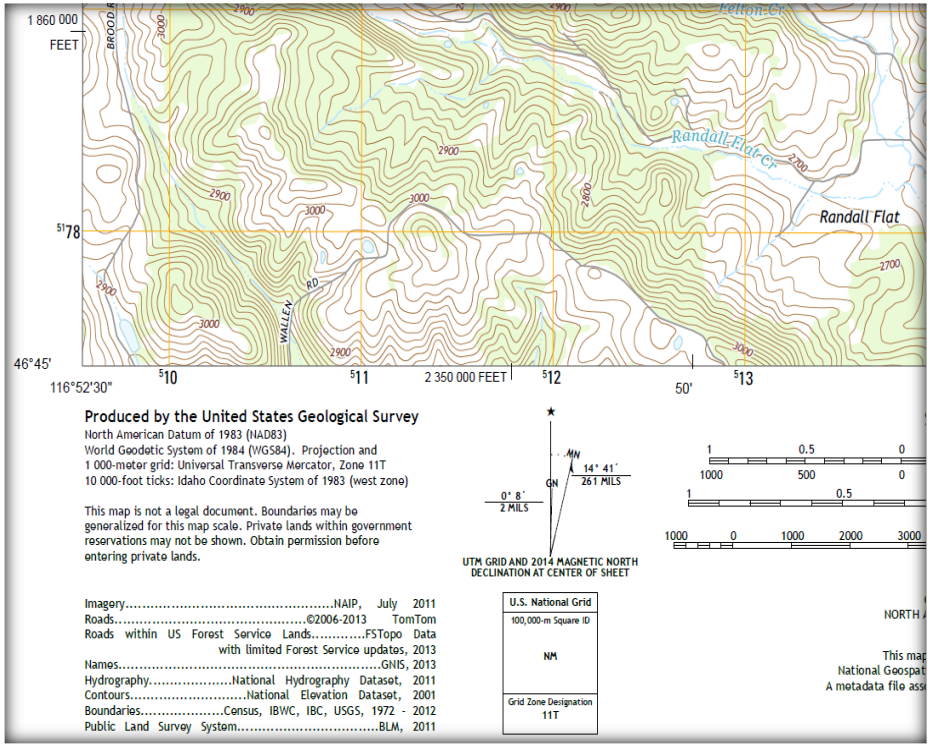


Peter H. Dana 6/23/97

MAP PROJECTIONS & COORDINATE SYSTEMS

USGS 7.5’ Topographic maps - coordinate systems

- Geodetic (geographic): latitude, longitude (deg., min, sec.)
- State Plane: easting, northing (feet)
- Universal Transverse Mercator: easting, northing (meters)
- GLO, U.S. Public Land Survey: Township, Range, Section


1 860 000
FEET
Pelton Cr
Randall Flat Cr
Randall Flat
WALLEN RD
46°45'
116°52'30"
2 350 000 FEET
50'
Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and
1 000-meter grid: Universal Transverse Mercator, Zone 11T
10 000-foot ticks: Idaho Coordinate System of 1983 (west zone)
This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.
Imagery....NAIP, July 2011
Roads....©2006-2013 TomTom
Roads within US Forest Service Lands....FSTopo Data with limited Forest Service updates, 2013
Names....GNIS, 2013
Hydrography....National Hydrography Dataset, 2011
Contours....National Elevation Dataset, 2001
Boundaries....Census, IBWC, IBC, USGS, 1972 - 2012
Public Land Survey System....BLM, 2011
GN
MN
14° 41'
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0° 8'
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UTM GRID AND 2014 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
U.S. National Grid
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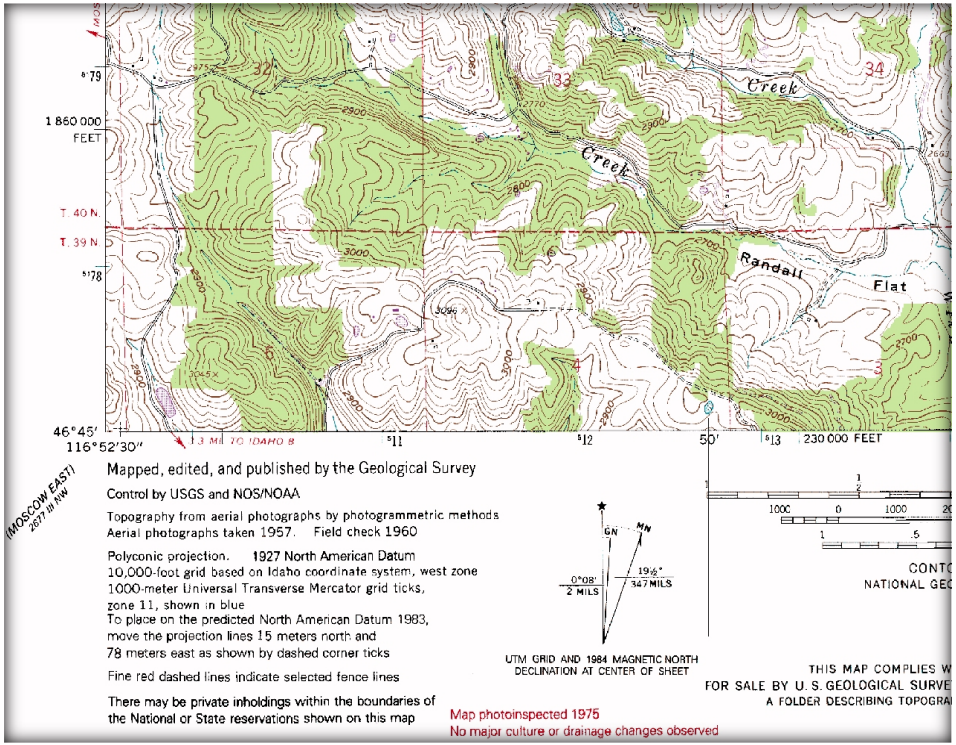
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Creek
Randall Flat
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(MOSCOW EAST)
2677 III NW
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA
Topography from aerial photographs by photogrammetric methods
Aerial photographs taken 1957. Field check 1960
Polyconic projection. 1927 North American Datum
10,000-foot grid based on Idaho coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks,
zone 11, shown in blue
To place on the predicted North American Datum 1983,
move the projection lines 15 meters north and
78 meters east as shown by dashed corner ticks
Fine red dashed lines indicate selected fence lines
There may be private inholdings within the boundaries of the National or State reservations shown on this map
GN
MN
19½°
347 MILS
0°08'
2 MILS
UTM GRID AND 1984 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
1000 0 1000
Map photoinspected 1975
No major culture or drainage changes observed
THIS MAP COMPLIES W
FOR SALE BY U. S. GEOLOGICAL SURVE
A FOLDER DESCRIBING TOPOGRA

usngcenter.org/portfolio-item/usng-gis-data/

Apps | John Halleck's ... | matrices - Is a ... | Calculate distan... | Exploratory Dat... | Using R for Mul... | Working with g... | Next Generatio... | Quick-R: Discri... | Save to Mendel...

USNG U.S. National Grid Information Center

Home | About | Apps & GPS | Data, Software, Tools | Library | Maps & Readers | Markers | Training | Viewers

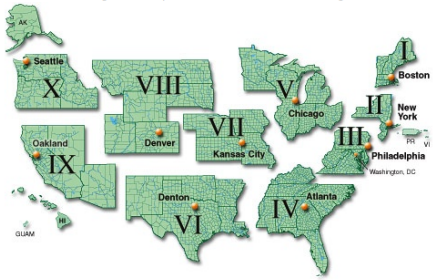
Data

USNG Data are available, usually in GIS Shapefile format, from the National Geospatial-Intelligence Agency (NGA) and from other providers, such as SharedGeo, that hosts data created by the USNG National Implementation Center (TUNIC) at Delta State University.

Links to data sources are provide below and organized by FEMA regions and USNG grid zones.

Data by FEMA Regions

Click on FEMA region in map or use link in table below to go to data download page.



Region	States Serving	Download Data
Region I	CT, MA, ME, NH, RI, VT	Data for Region I
Region II	NJ, NY, PR, USVI	Data for Region II
Region III	DC, DE, MD, PA, VA, WV	Data for Region III

Search

USNG on EPC Updates

- Geospatial Lessons Learned from Disasters Webinar - October 6, 11:15 AM CDT
- Fire Hydrants to the Rescue
- FEMA Looking For Comments on Its New Flood Map Service Center
- White House Showcases Disaster Response Technologies
- The Best "Hands On" USNG Article Ever Written
- First Friday: June 2014
- Top Five Friday (I'm Late): May 2014
- Yarnell Hill Fire - One Year Later, Changes Still Needed
- Report Chides Wildland Firefighter Leadership on Deaths
- FEMA CIO Sees Value in Paper Maps

Map projections use different models for converting the ellipsoid to a rectangular coordinate system.

Each generates distortions in scale and shape of objects.

Lambert Conformal Conic Projection, scales vary N-S,E-W oriented states: Penn, Tenn (31 states)

Transverse Mercator Projection, scales vary E-W, N-S oriented states; Ill, Ind, Idaho (22 states)

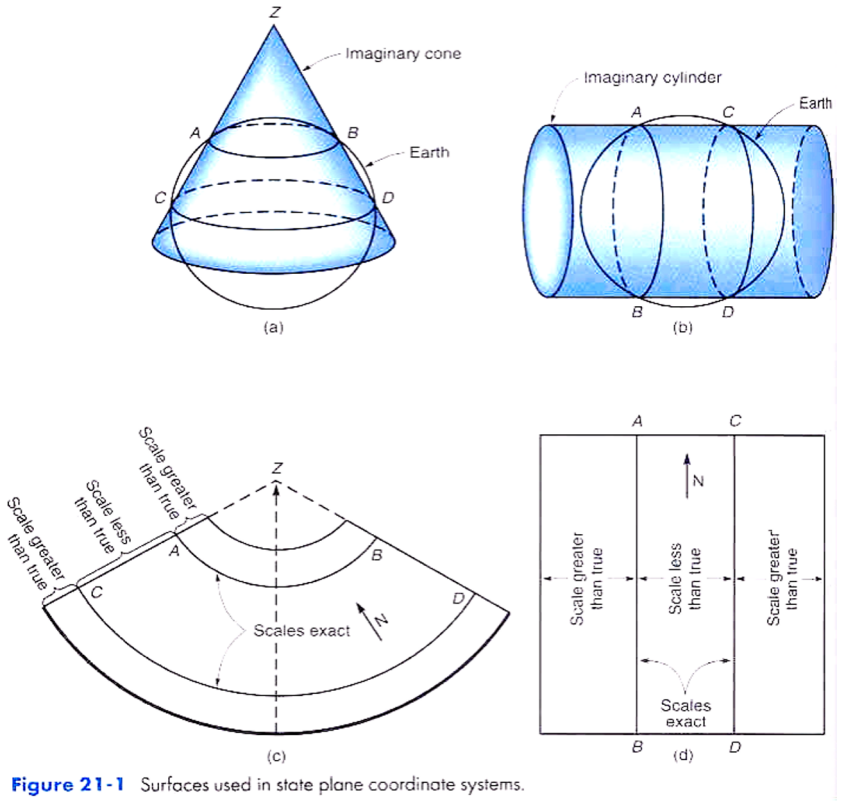
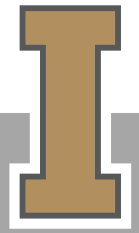


Figure 21-1 Surfaces used in state plane coordinate systems.

MAP PROJECTIONS & COORDINATE SYSTEMS

USGS 7.5’ Topographic maps - coordinate systems

Geodetic (geographic): latitude, longitude (deg., min, sec.)
State Plane: easting, northing (feet)
Universal Transverse Mercator: easting, northing (meters)
GLO, U.S. Public Land Survey: Township, Range, Section



REFERENCE DATUMS (HORIZONTAL, VERTICAL) – US GEODETIC SURVEY

- Horizontal and vertical datums consist of a network of control monuments and bench marks whose horizontal positions and elevations have been determined by precise geodetic control surveys.
- NAD 27 - Clarke ellipsoid (1866), Meades Ranch – origin (25k pt)
- NAD 83 - GRS - 80 ellipsoid, Earth's mass center (270k pts)
- WGS 84
- NGVD29 (26 sea level gauging stations US & Canada)
- NAVD88 (625k km of control leveling, crustal movements..)

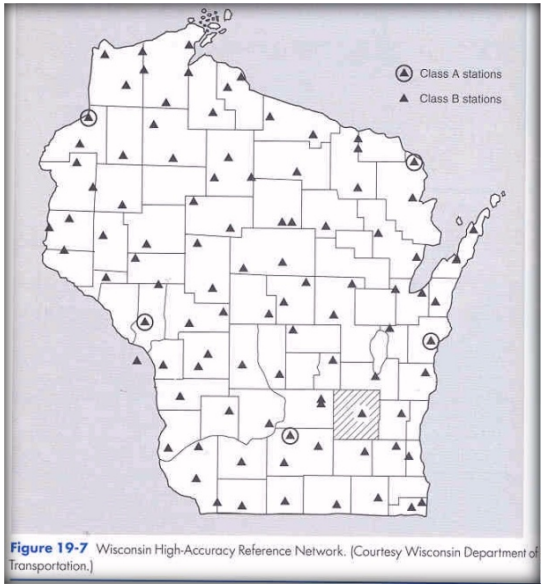


Figure 19-7 Wisconsin High-Accuracy Reference Network. [Courtesy Wisconsin Department of Transportation.]

Control point networks exist as known points with ground monuments (benchmarks) around the world

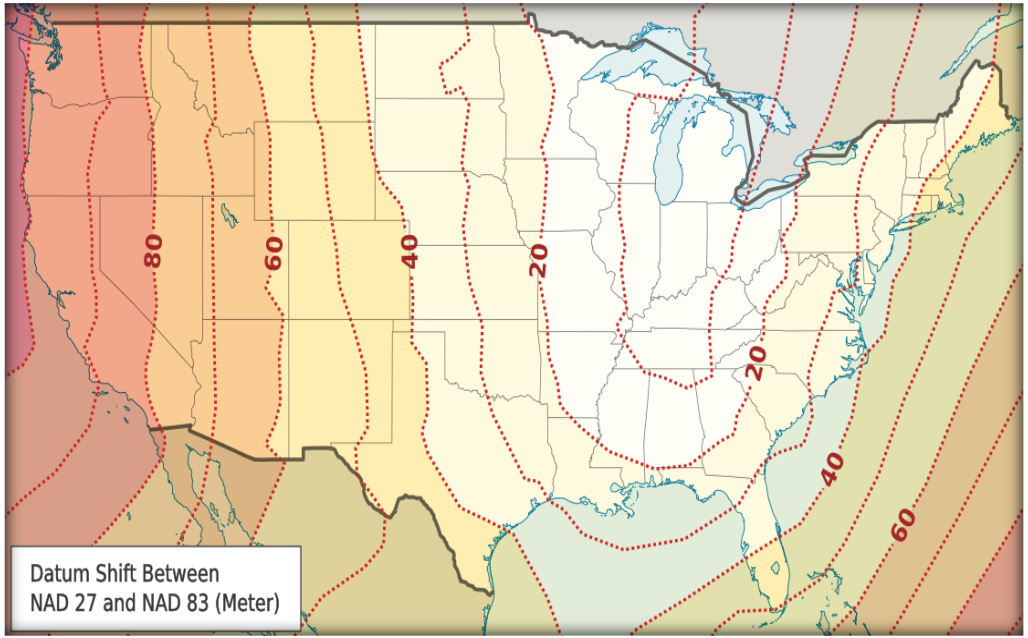
MAP PROJECTIONS AND COORDINATE SYSTEMS – DATUM TRANSFORMATIONS

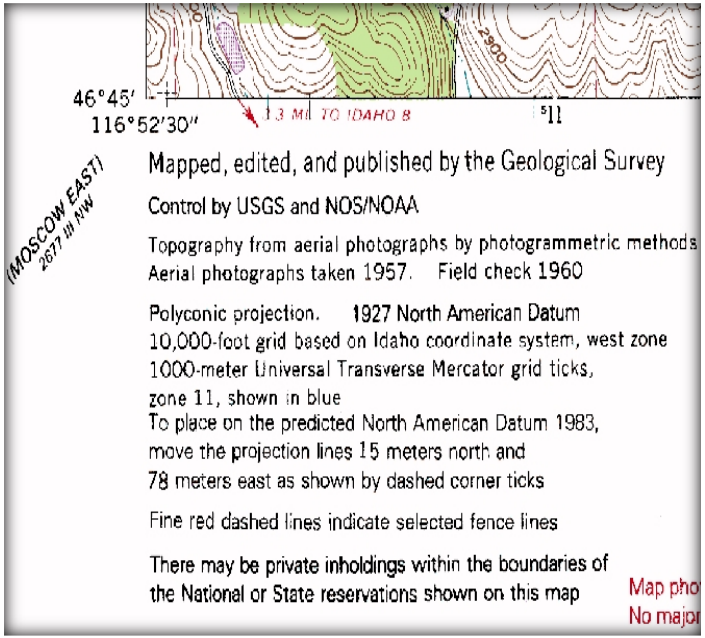
- Datum transformations account for differences in geographic coordinates due to changes in the shape or origin of the spheroid/ellipsoid, and in some cases datum adjustments.

- Map projections are usually considered exact transformations because they are based on a specific mathematical formula (although some empirically based map projections also exist). Datum transformations are considered empirical (based on measurement) because they are based on “data” or survey points

North American Datum of 1927 (NAD 27) is "The *horizontal control datum* for the United States that was defined by a single location and azimuth on the Clarke spheroid of 1866, with origin at (the survey station) Meades Ranch." ... The geoidal height at Meades Ranch was assumed to be zero. "Geodetic positions on the North American Datum of 1927 were derived from the (coordinates of and an azimuth at Meades Ranch) through a readjustment of the triangulation of the entire network in which Laplace azimuths were introduced, and the Bowie method was used.“

The North American Datum of 1983 (NAD 83) is the horizontal control datum for the United States, Canada, Mexico, and Central America, based on a geocentric origin and the Geodetic Reference System 1980.This datum, NAD 83, is the current geodetic reference system. NAD 83 is based on the adjustment of 250,000 points, including 600 satellite Doppler stations, which constrain the system to a geocentric origin.





When transforming from one map projection to another that includes a datum change, it's usually best to first transform back to Geographic coordinates first, then re-project. See Bolstad Fig. 3-47

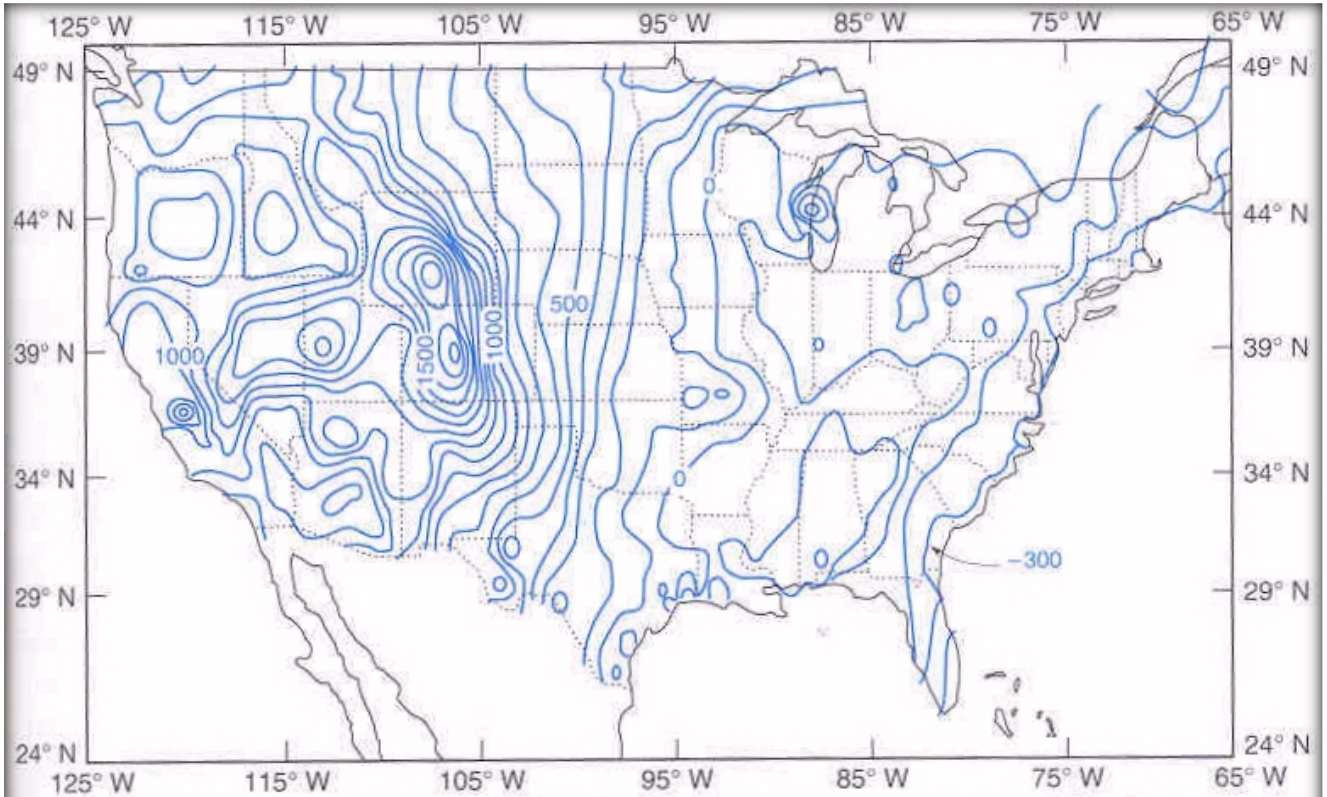
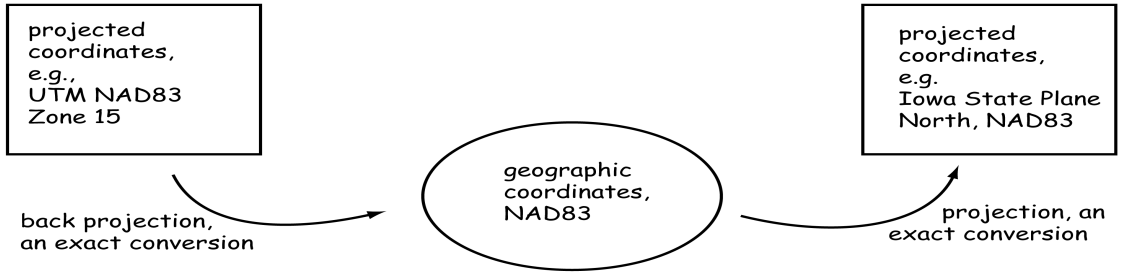
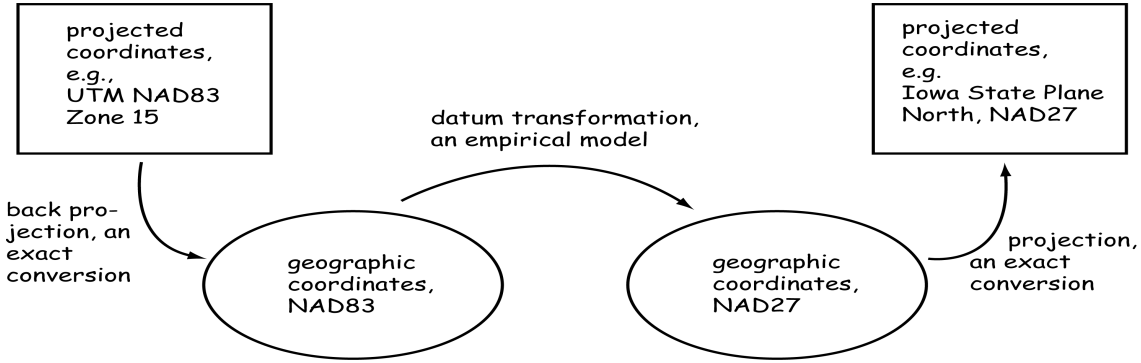


Figure 19-4 Approximate shift in vertical datum (in millimeters). Values shown are NAVD88 minus NGVD29. (Adapted from National Geodetic Survey map.)

a) From one projection to another - same datum



b) From one projection to another - different datums



MAP PROJECTIONS & COORDINATE SYSTEMS

USGS 7.5’ Topographic maps - coordinate systems

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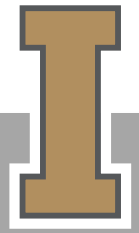
Universal Transverse Mercator: easting, northing (meters)
GLO, U.S. Public Land Survey: Township, Range, Section



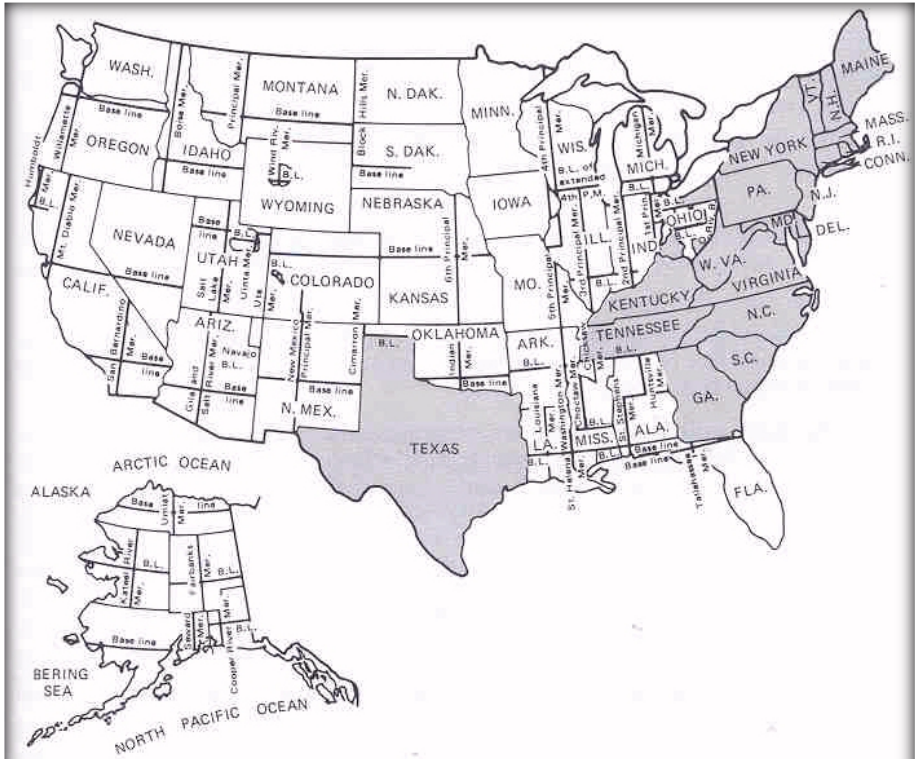
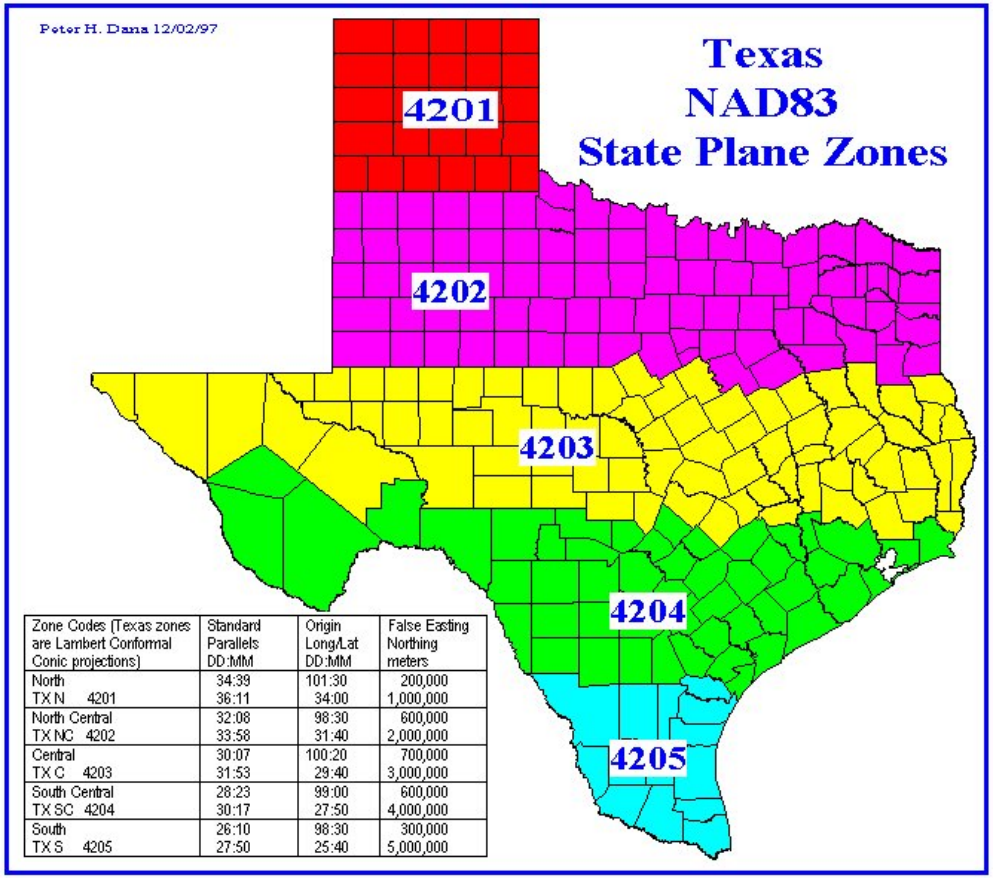


Figure 23-1 Areas covered by the public-lands surveys, with principal meridians shown. Areas excluded are shaded. (Hawaii, although not shown on this map, would also be shaded. Texas has a rectangular system similar to the U.S. public land system.)

State Plane

Individual states establish a baseline and meridian specific to the needs of that state (English Units – foot)

Idaho:
Boise meridian, baseline - Boise



Zone Codes (Texas zones are Lambert Conformal Conic projections)	Standard Parallels DD:MM	Origin Long/Lat DD:MM	False Easting Northing meters
North TX N 4201	34:39 36:11	101:30 34:00	200,000 1,000,000
North Central TX NC 4202	32:08 33:58	98:30 31:40	600,000 2,000,000
Central TX C 4203	30:07 31:53	100:20 29:40	700,000 3,000,000
South Central TX SC 4204	28:23 30:17	99:00 27:50	600,000 4,000,000
South TX S 4205	26:10 27:50	98:30 25:40	300,000 5,000,000

State Plane

Map Projections & Coordinate Systems

MAP PROJECTIONS & COORDINATE SYSTEMS

USGS 7.5’ Topographic maps - coordinate systems

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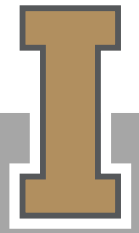
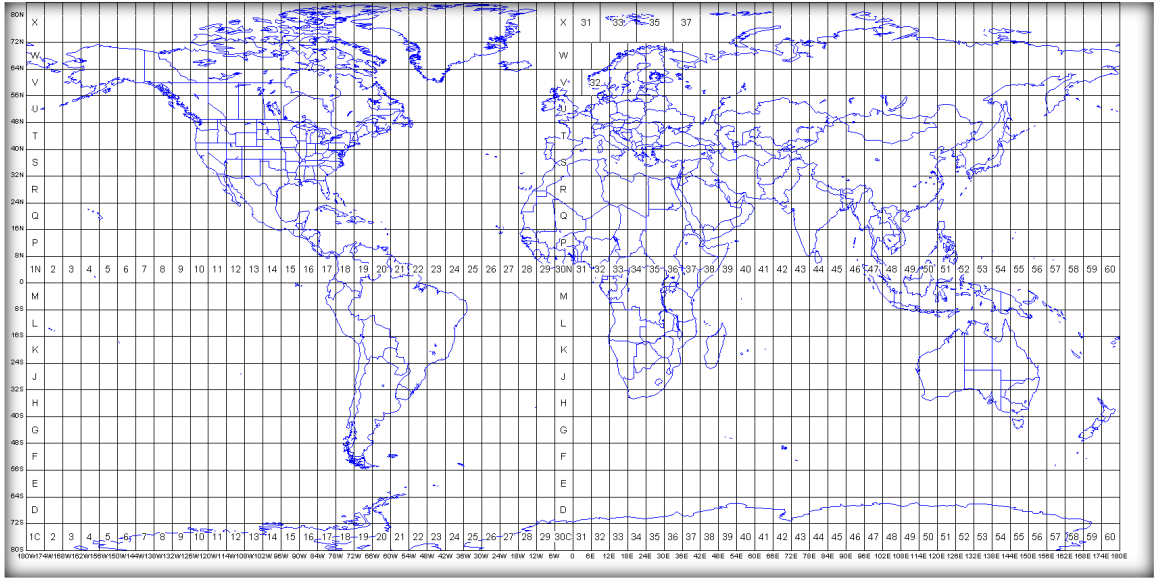
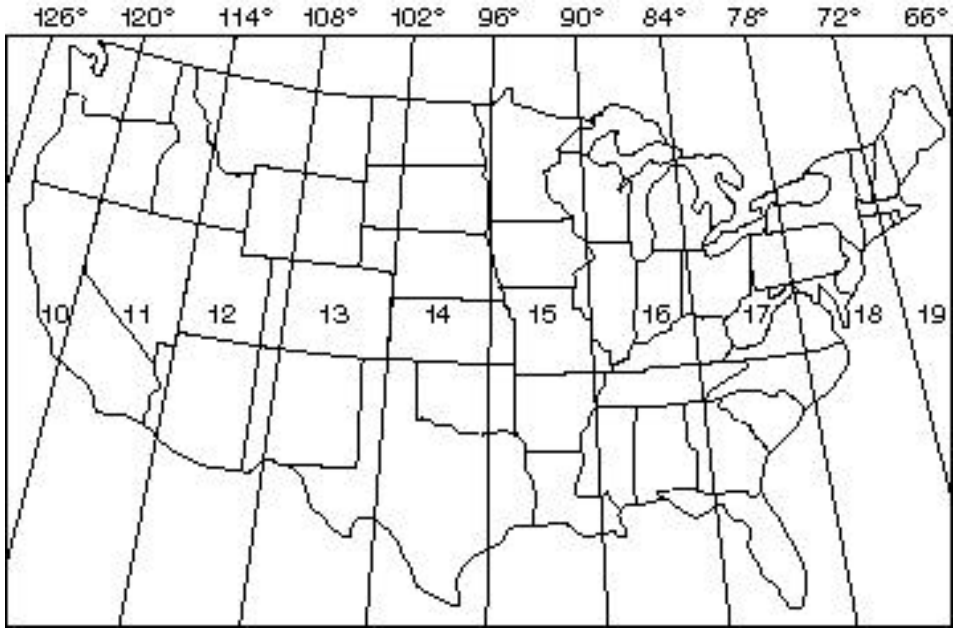


Map Projections & Coordinate Systems

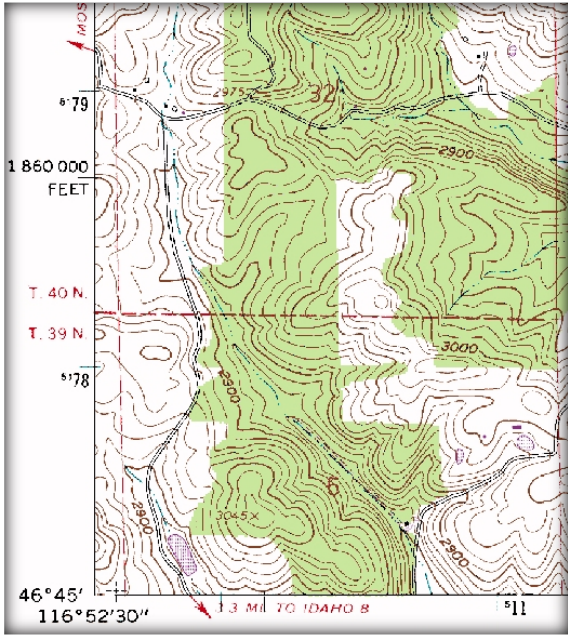
Universal Transverse Mercator coordinate system: worldwide coverage from 80º S lat to 84º N lat.

- Each zone is 6 º wide in longitude, 60 zones worldwide
- US UTM zones 10 (west coast) - 20 (east coast)





Universal Transverse Mercator (UTM) Map Projection



In Idaho, we use the Boise Central Meridian (117º Long.) for all easting coordinates, and a false easting is added so that all UTM easting coordinates are positive within zone 11. Idaho UTM more recently established.

MAP PROJECTIONS & COORDINATE SYSTEMS

USGS 7.5’ Topographic maps - coordinate systems

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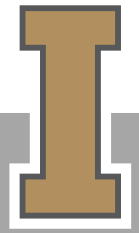
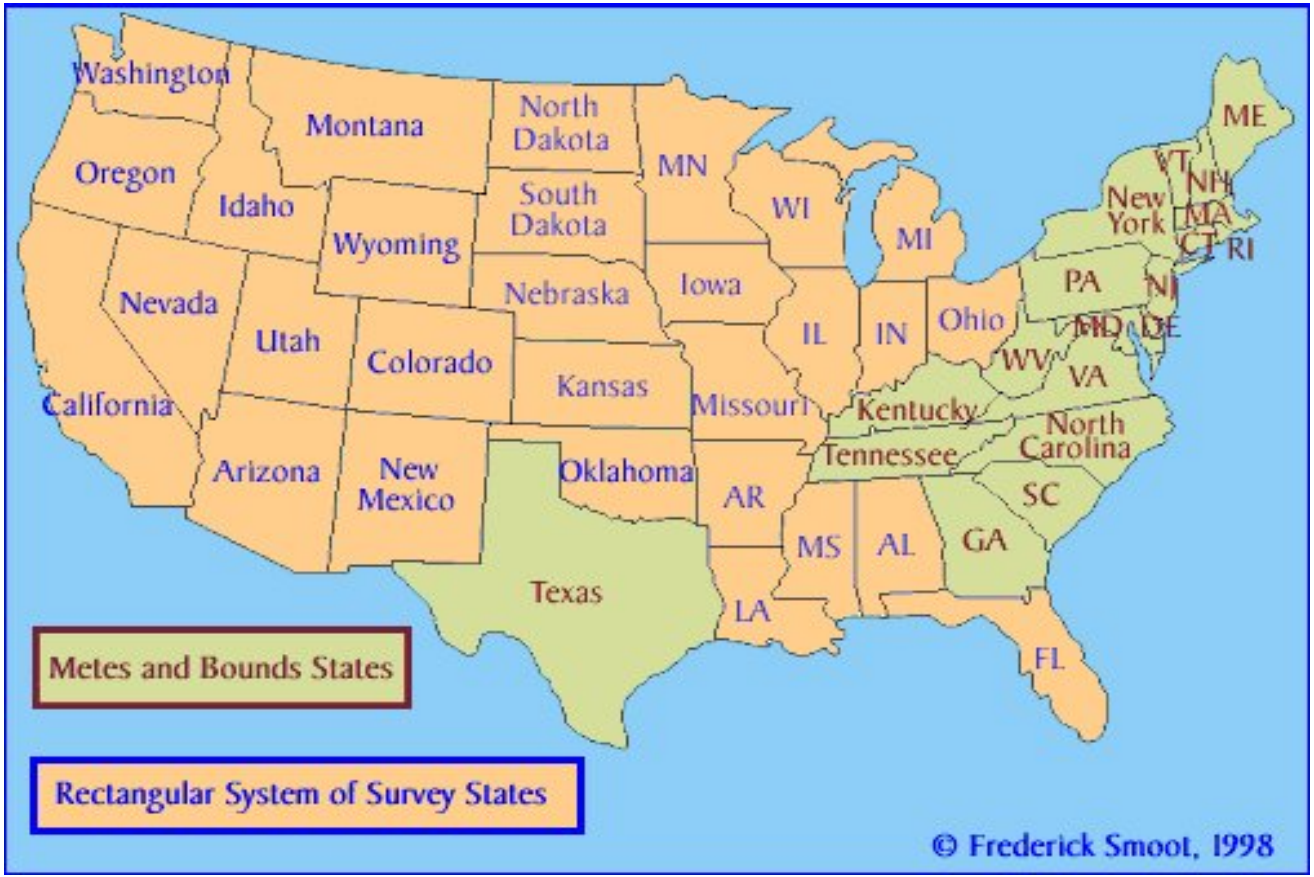


MAP PROJECTIONS & COORDINATE SYSTEMS, US PUBLIC LAND SURVEY

- The two major systems of legal land description used in the United States are: (1) metes and bounds and (2) rectangular survey system.
- The metes and bounds system was used in areas settled when the U.S. was still a colony of England.
- This system located tracts of land by describing the tract location to roads, trees, rocks, meanders or waterways, etc.


Washington
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MN
Iowa
Missouri
AR
LA
WI
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MI
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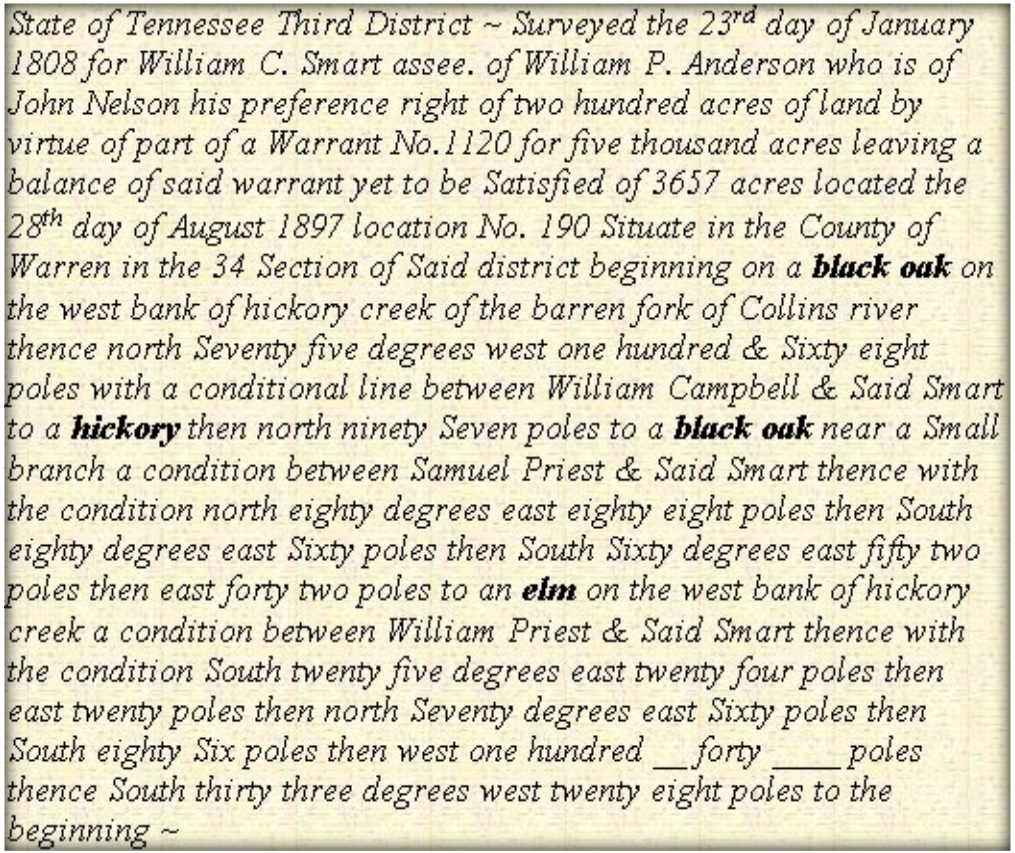
AL
Ohio
Kentucky
Tennessee
GA
FL
SC
North Carolina
VA
WV
PA
New York
MD
DE
NJ
CT
RI
MA
VT
NH
ME
Metes and Bounds States
Rectangular System of Survey States
© Frederick Smoot, 1998



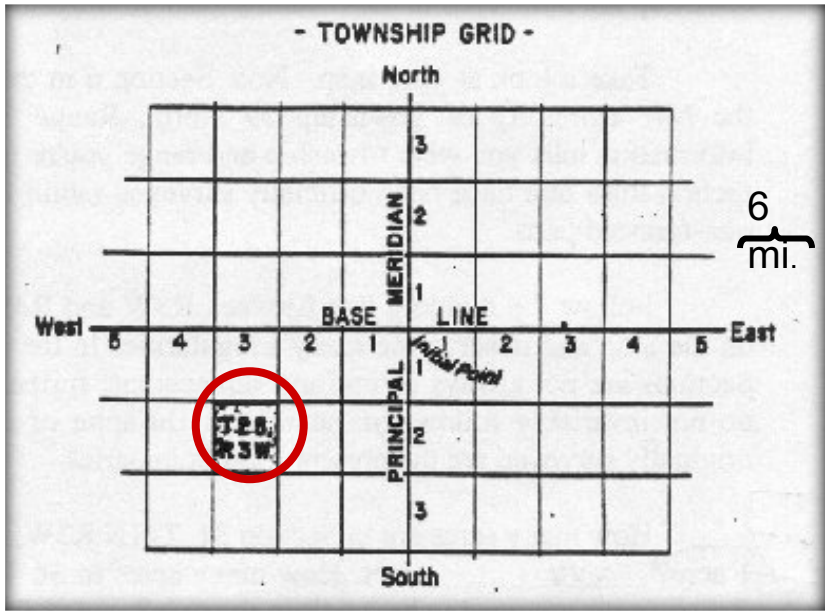
State of Tennessee Third District ~ Surveyed the 23rd day of January 1808 for William C. Smart assee. of William P. Anderson who is of John Nelson his preference right of two hundred acres of land by virtue of part of a Warrant No.1120 for five thousand acres leaving a balance of said warrant yet to be Satisfied of 3657 acres located the 28th day of August 1897 location No. 190 Situate in the County of Warren in the 34 Section of Said district beginning on a **black oak** on the west bank of hickory creek of the barren fork of Collins river thence north Seventy five degrees west one hundred & Sixty eight poles with a conditional line between William Campbell & Said Smart to a **hickory** then north ninety Seven poles to a **black oak** near a Small branch a condition between Samuel Priest & Said Smart thence with the condition north eighty degrees east eighty eight poles then South eighty degrees east Sixty poles then South Sixty degrees east fifty two poles then east forty two poles to an **elm** on the west bank of hickory creek a condition between William Priest & Said Smart thence with the condition South twenty five degrees east twenty four poles then east twenty poles then north Seventy degrees east Sixty poles then South eighty Six poles then west one hundred __ forty ____ poles thence South thirty three degrees west twenty eight poles to the beginning ~

Irregularly shaped tracts and loss of markers as time passes may cause many boundary disputes under this system.

In 1784, the US adopted the rectangular survey system, which is used in 30 of the 50 states. This system is based on meridians (north-south lines) and baselines (east-west lines). There are 34 "principal meridians" in the United States; each has a baseline associated with it.

Map Projections & Coordinate Systems

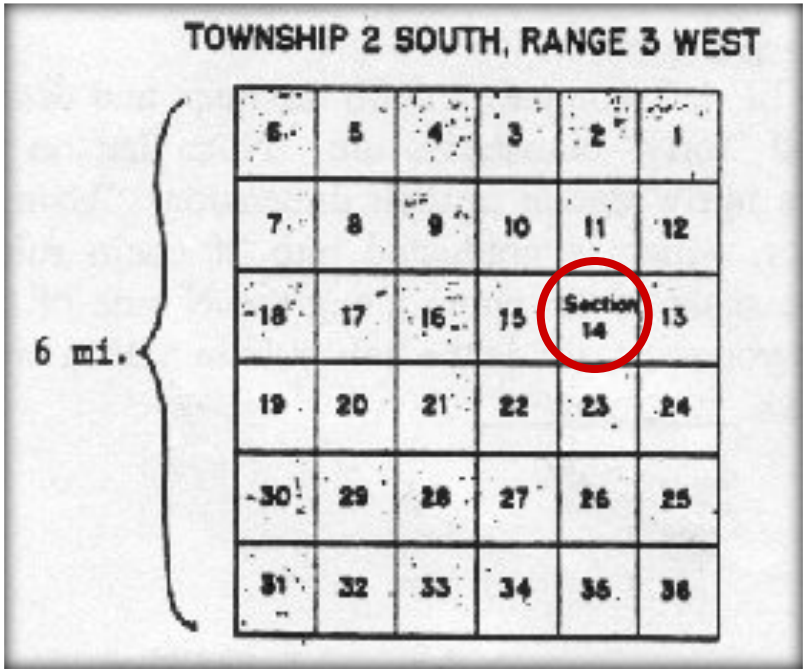
Tracts of land, called townships, are laid out beginning from the point where the meridian crosses its baseline (initial point). Townships are as close to 6 miles square as possible.



T2S, R3W

Map Projections & Coordinate Systems

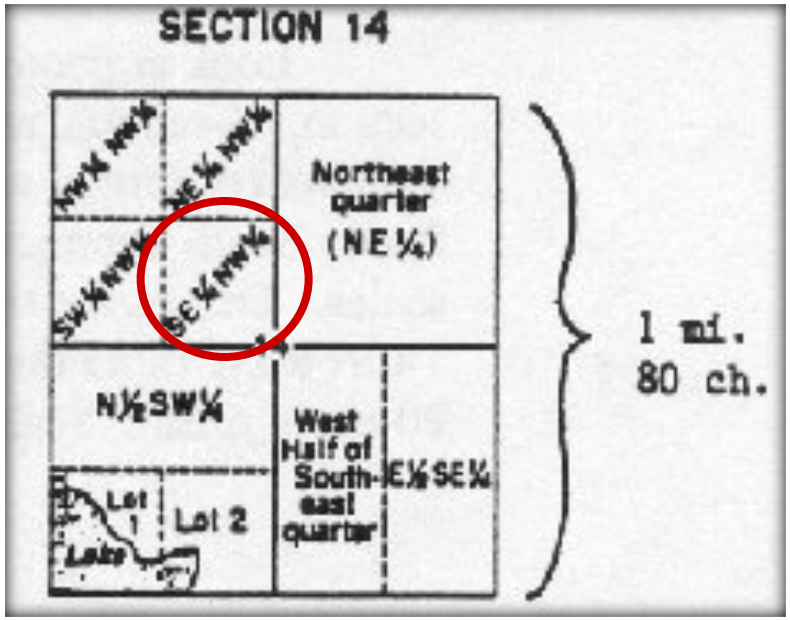
The sections are numbered from 1 to 36, beginning in the northeast corner. Each 1-mile square section contains “nominally” 640 acres.



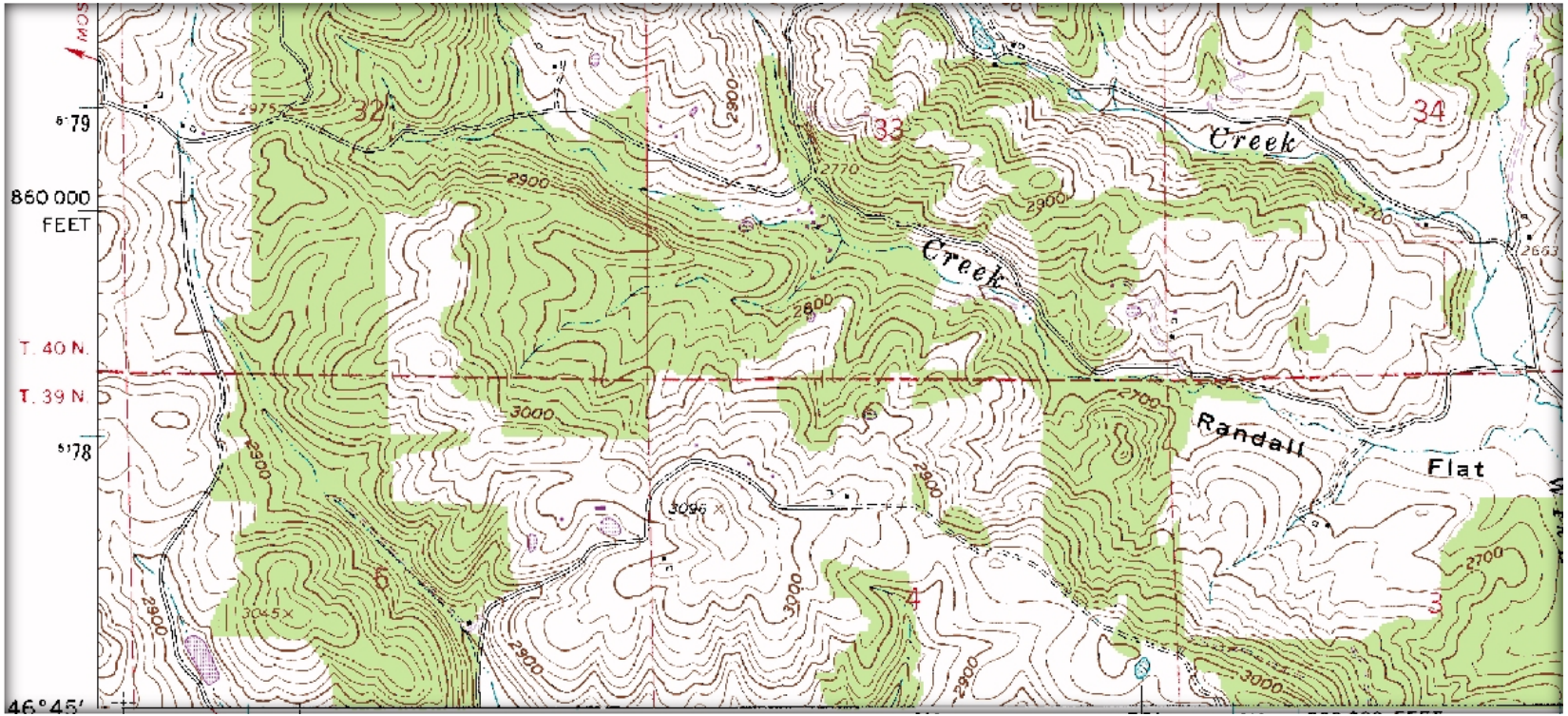
Section 14, T2S, R3W

Map Projections & Coordinate Systems

Areas smaller than a section are broken down into quarters of sections or sometimes halves of sections. These tracts may then be further broken into quarters or halves.



SE 1/4, NW 1/4, Section 14, T2S, R3W



Red lines on our 7.5' topo maps represent section lines. Red cross at the corners indicates there is a section corner monument in the ground (if topo map is up-to-date)

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What you should know:

- ellipsoids fit to the earth geoid are used to create a model of the earth
- map projections are used to mathematically project the ellipsoid onto a planar surface or flat map
- we use reference datums and ground control networks with monuments to connect real world locations to these map projections and ellipsoids
- what projections and coordinate systems (4) exist on our 7.5 minute topographic maps
- use any of these map coordinate systems to determine a position on our Moscow Mt. topographic map