New NAD83(2011) Adjustment

MNDOT Survey Technical Conference
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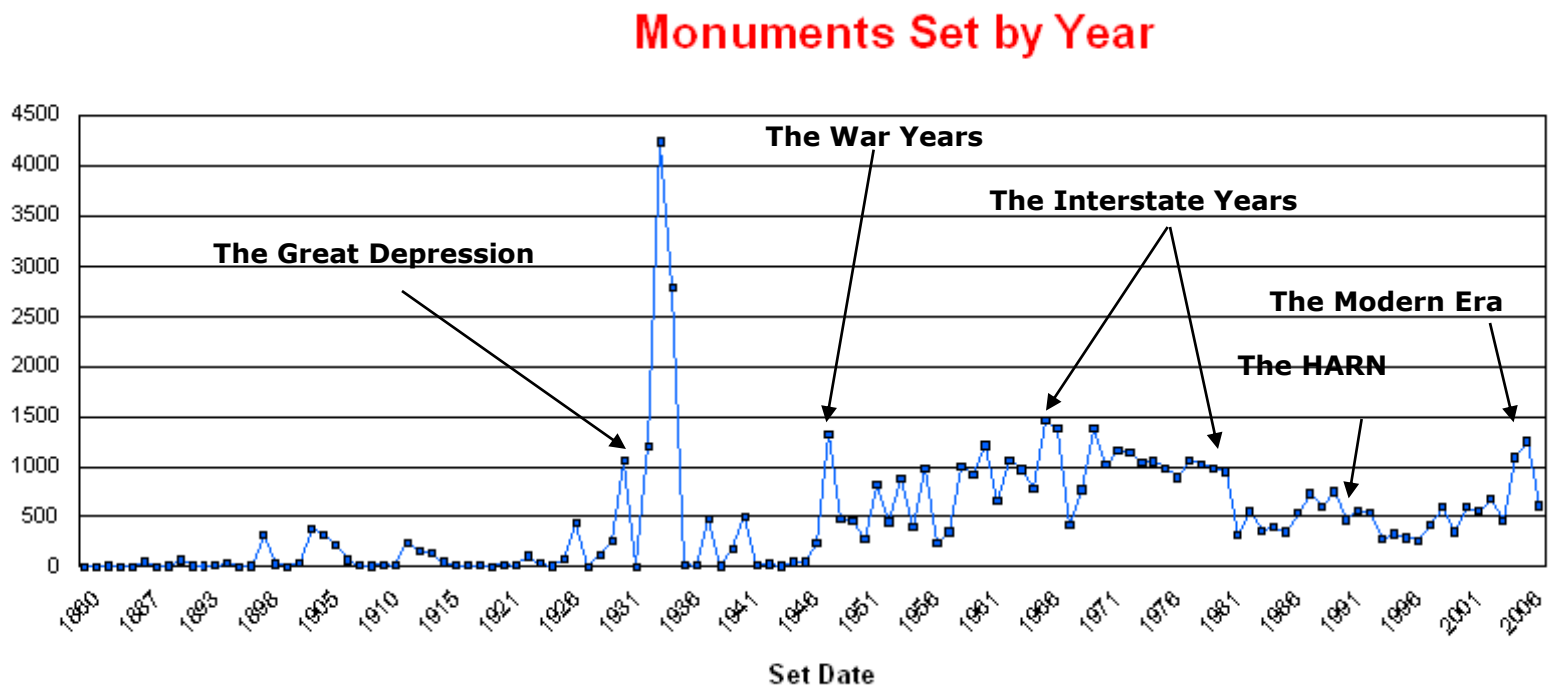
A Brief History of Time in MN

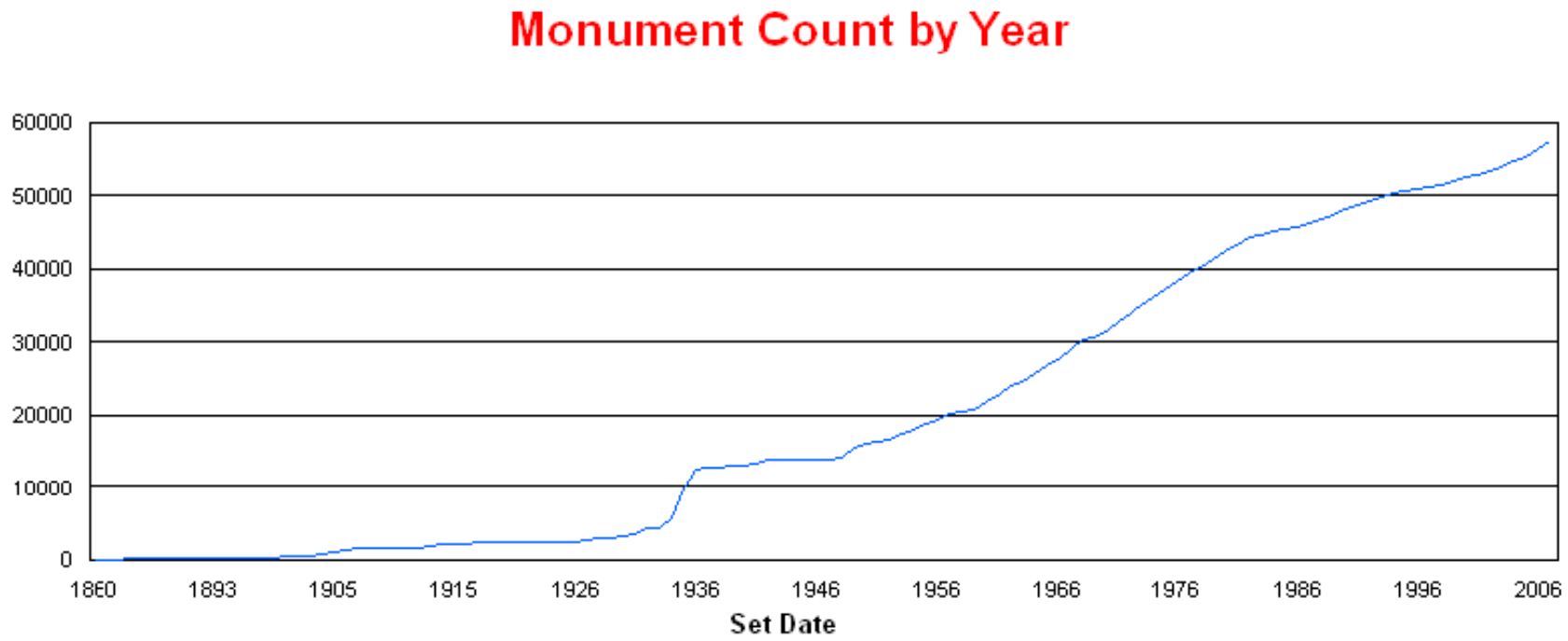
- Reveal the development of the physical Geodetic Control Placement in MN from 1860 through 2007.
- Outline the historical Datums and Adjustments used over time.

The Big Picture



The Big Picture

- Total = 59408
- Good = 39641, Destroyed = 12944, Other Cond = 6823



Sample Legend

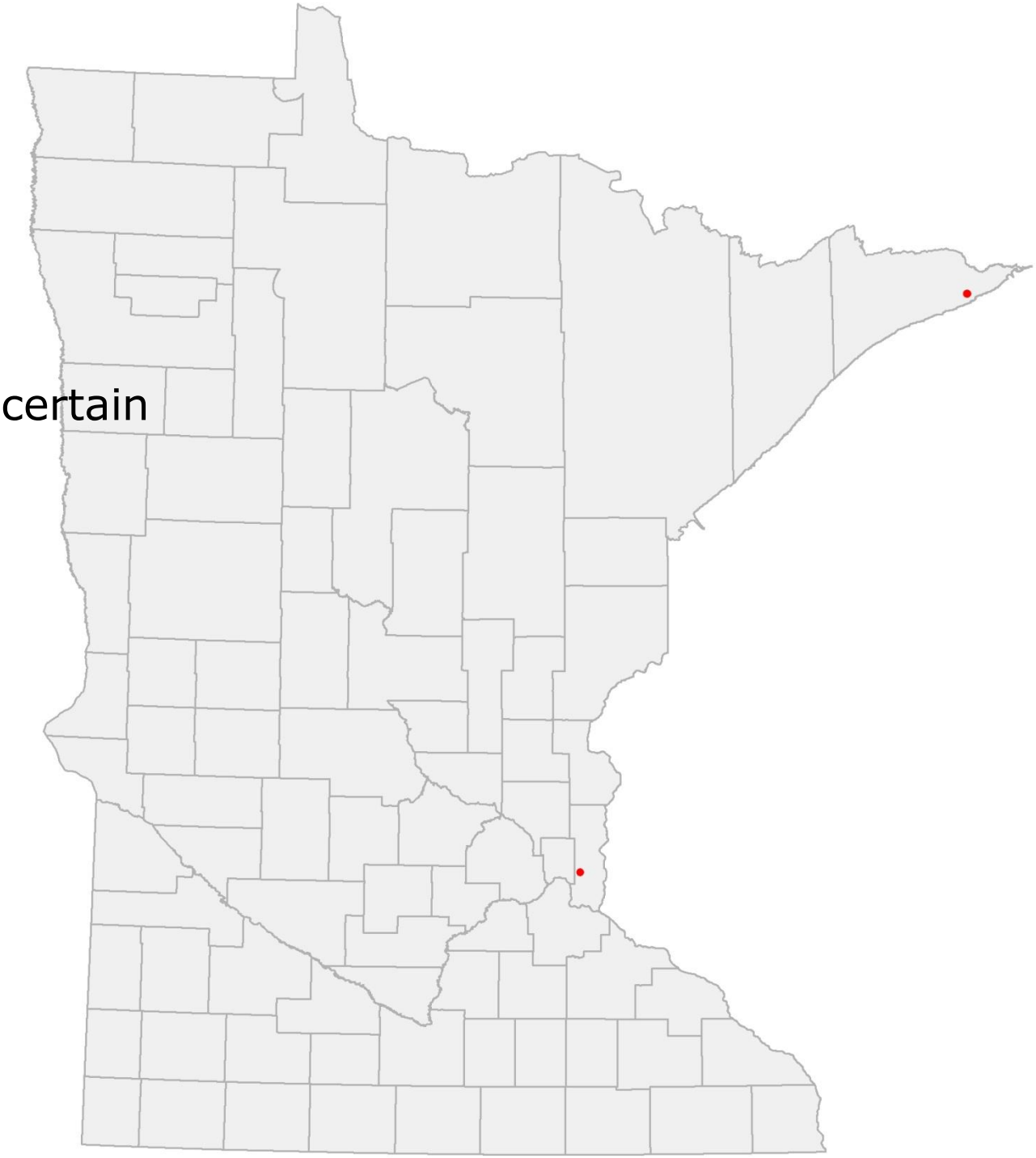
Marks Set in the 2000 Decade

Contributors of Geodetic Control Data and number of marks

- National Agencies
- Inter-State or Inter Province Agencies
- State, Province, Commonwealth, and Territorial Agencies
- County Agencies
- Other Agencies

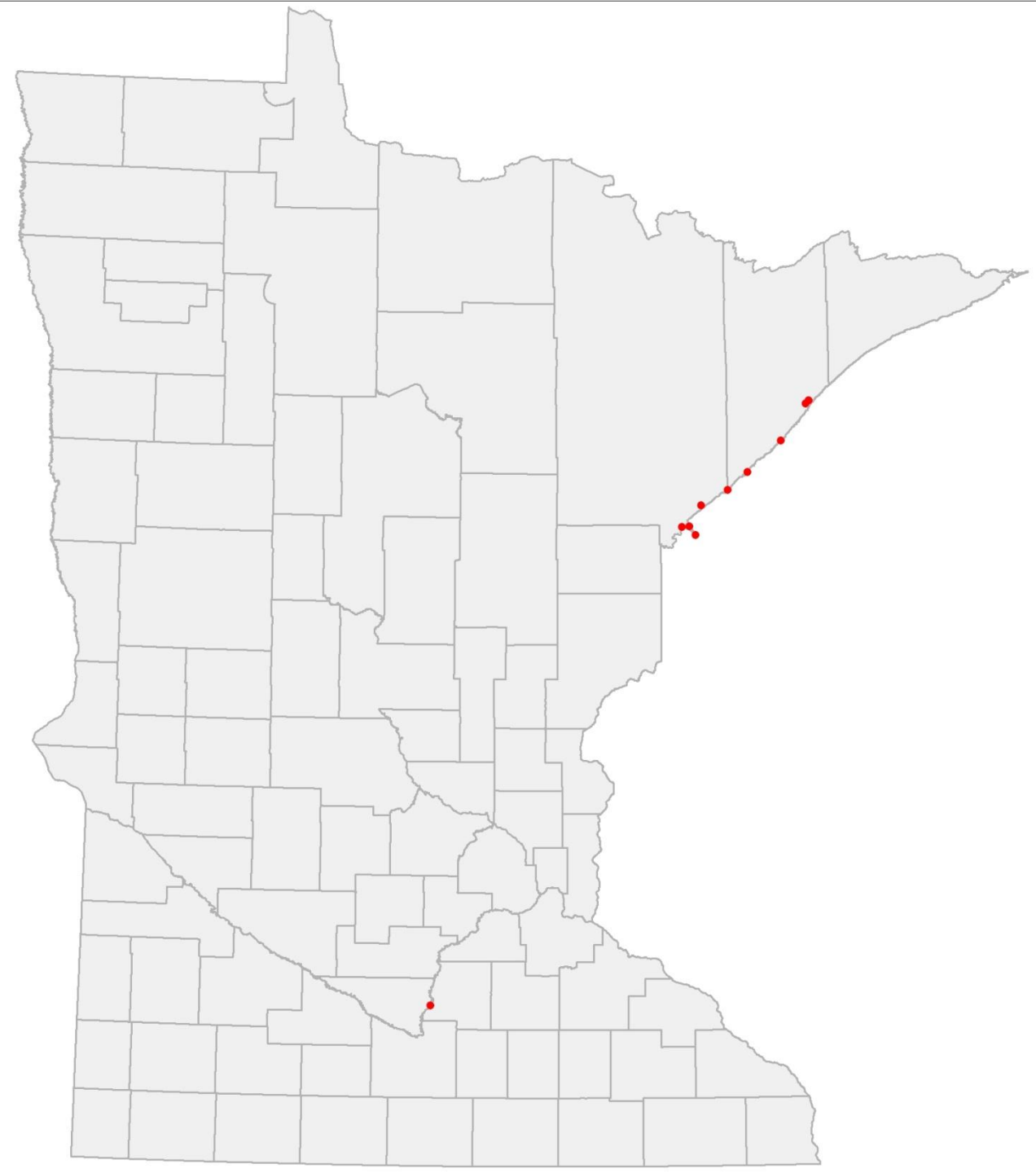
1860-1869

- 3 marks
- Old set dates are uncertain



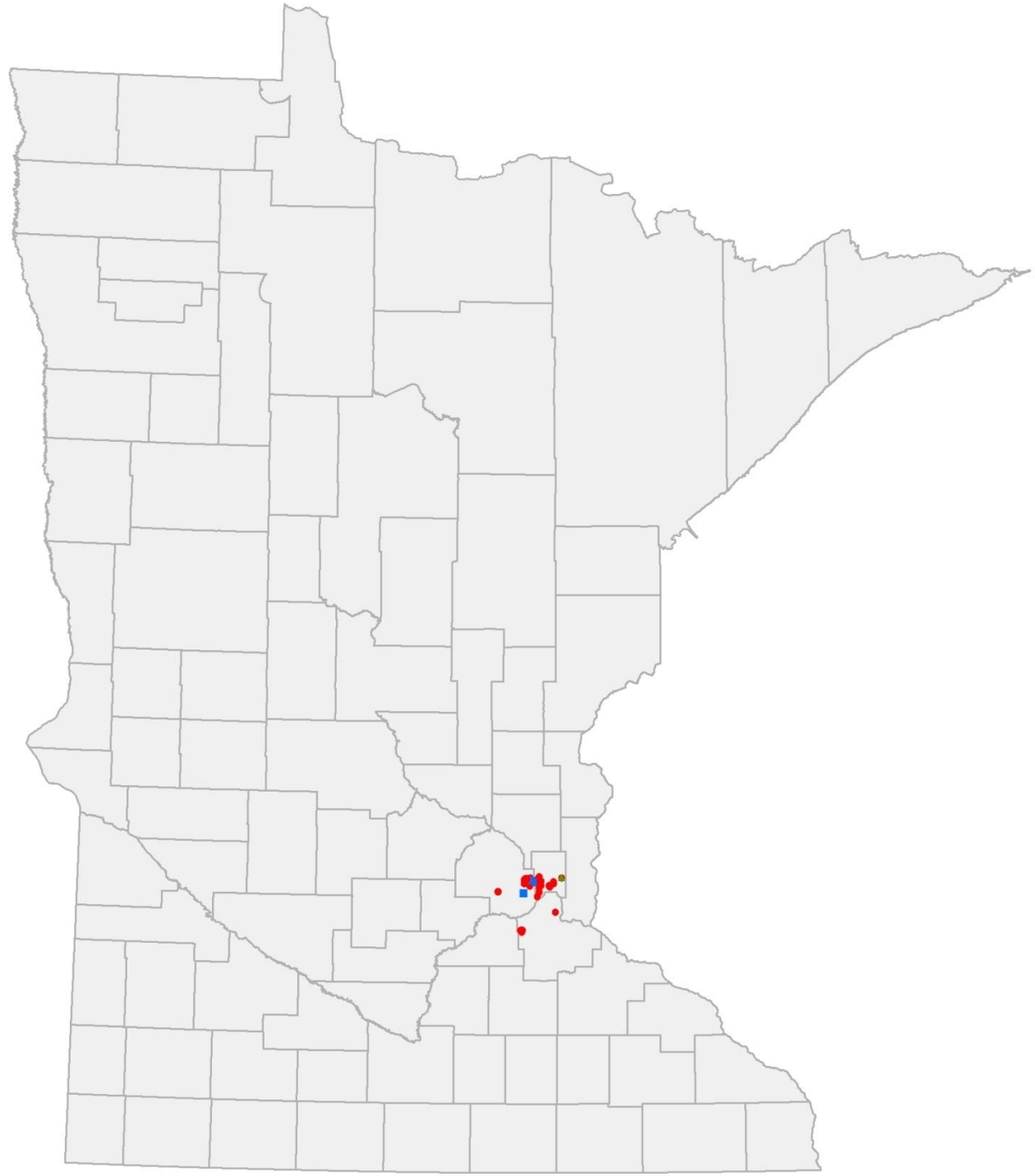
1870-1879

- 11 marks
- US Lake Survey
- Army Corps



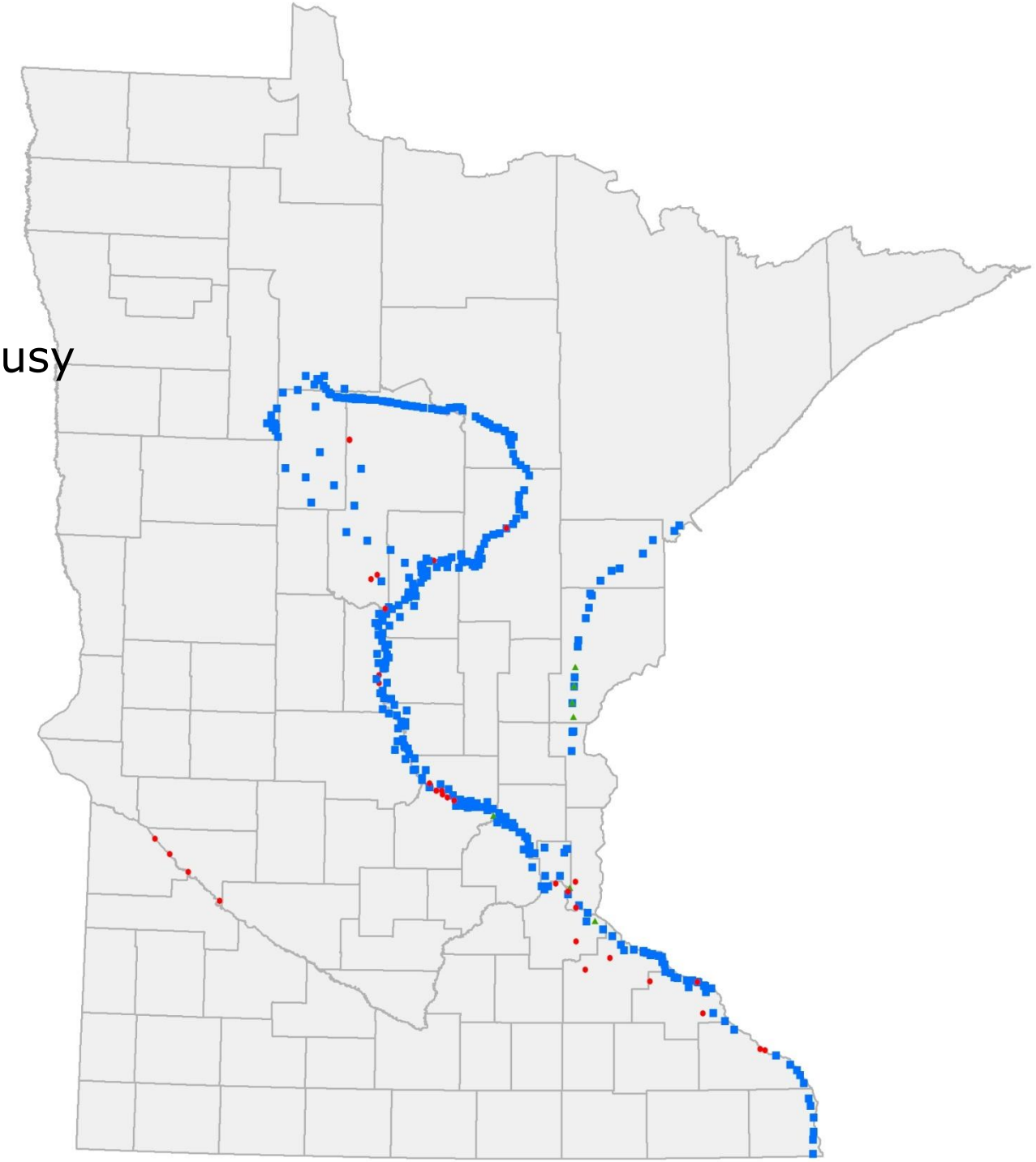
1880-1889

- 55 marks
- Army Corps
- Miss River Comm
- and unknowns



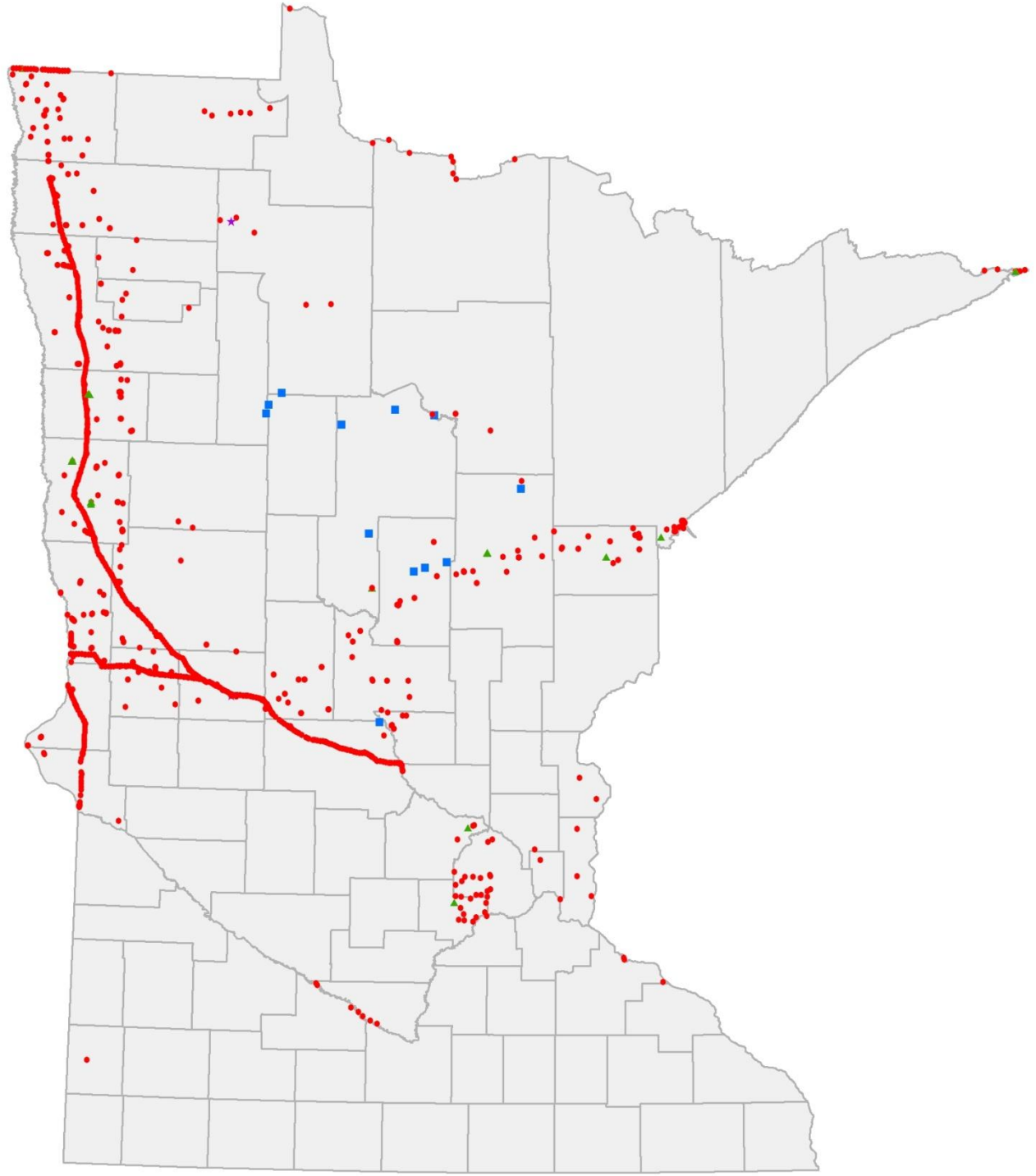
1890-1899

- The MRC has been busy
- Army Corps too



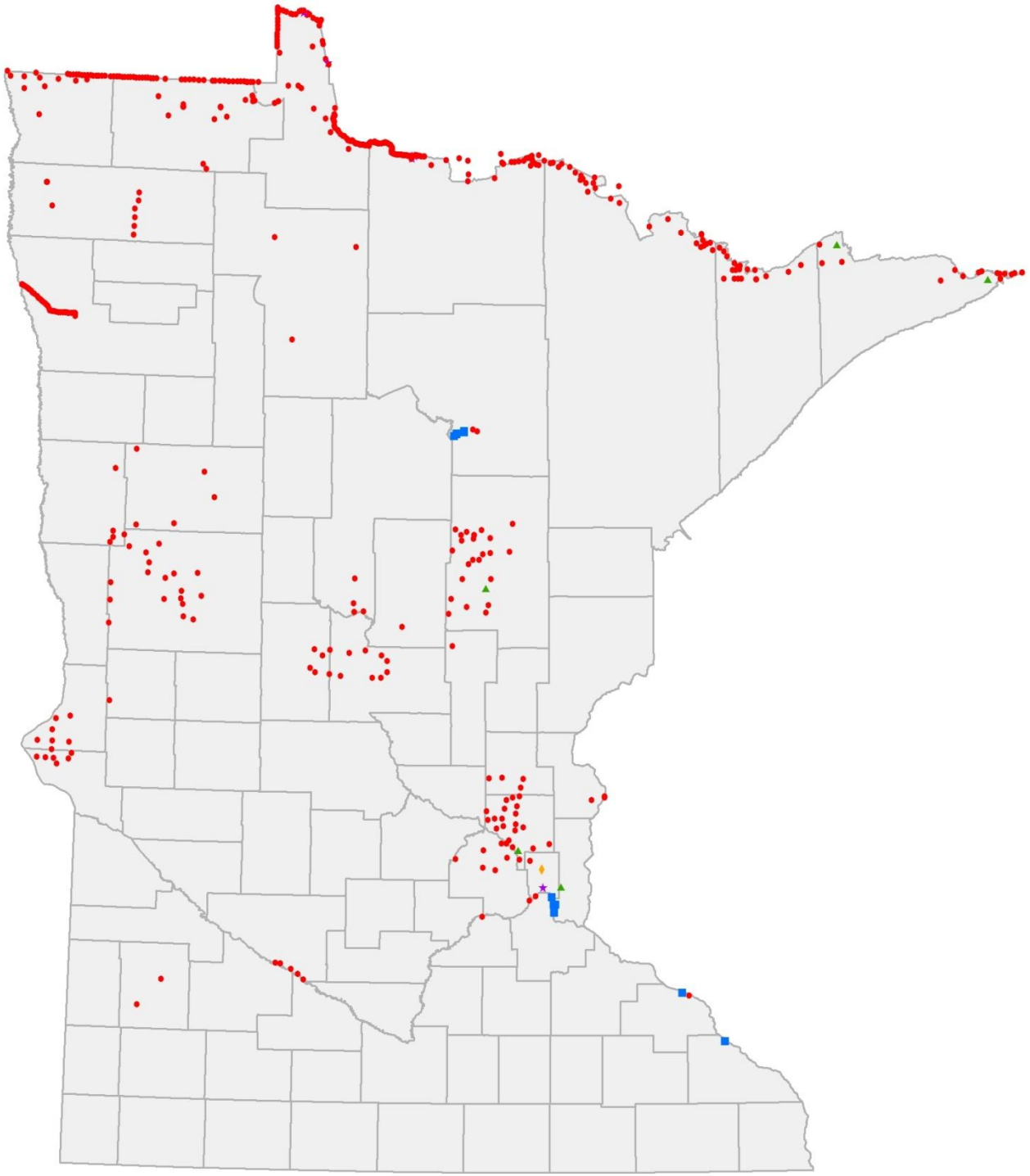
1900-1909

- Closely spaced dots are level lines
- Scattered dots represent triangulation arcs



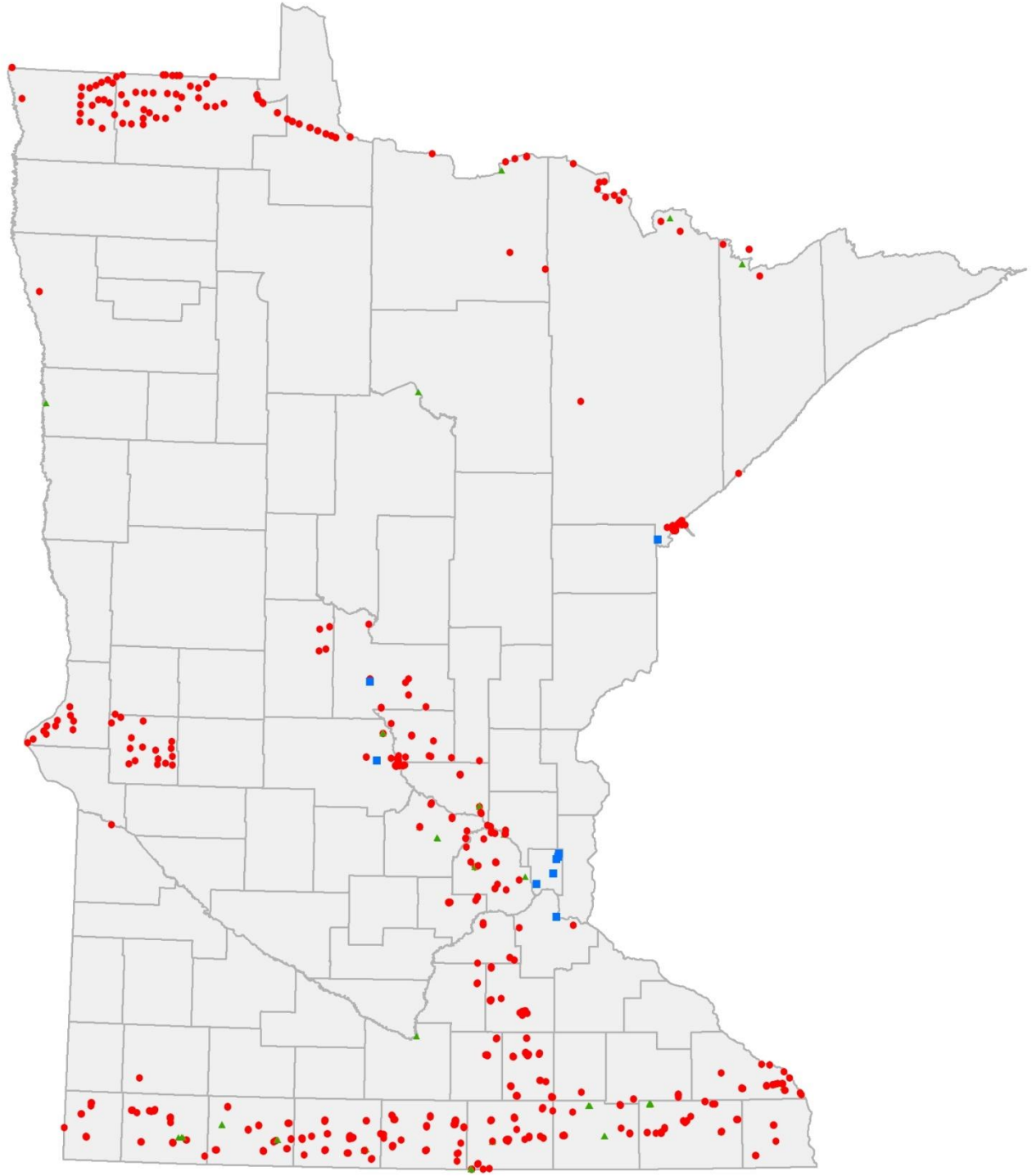
1910-1919

- International Boundary Commission



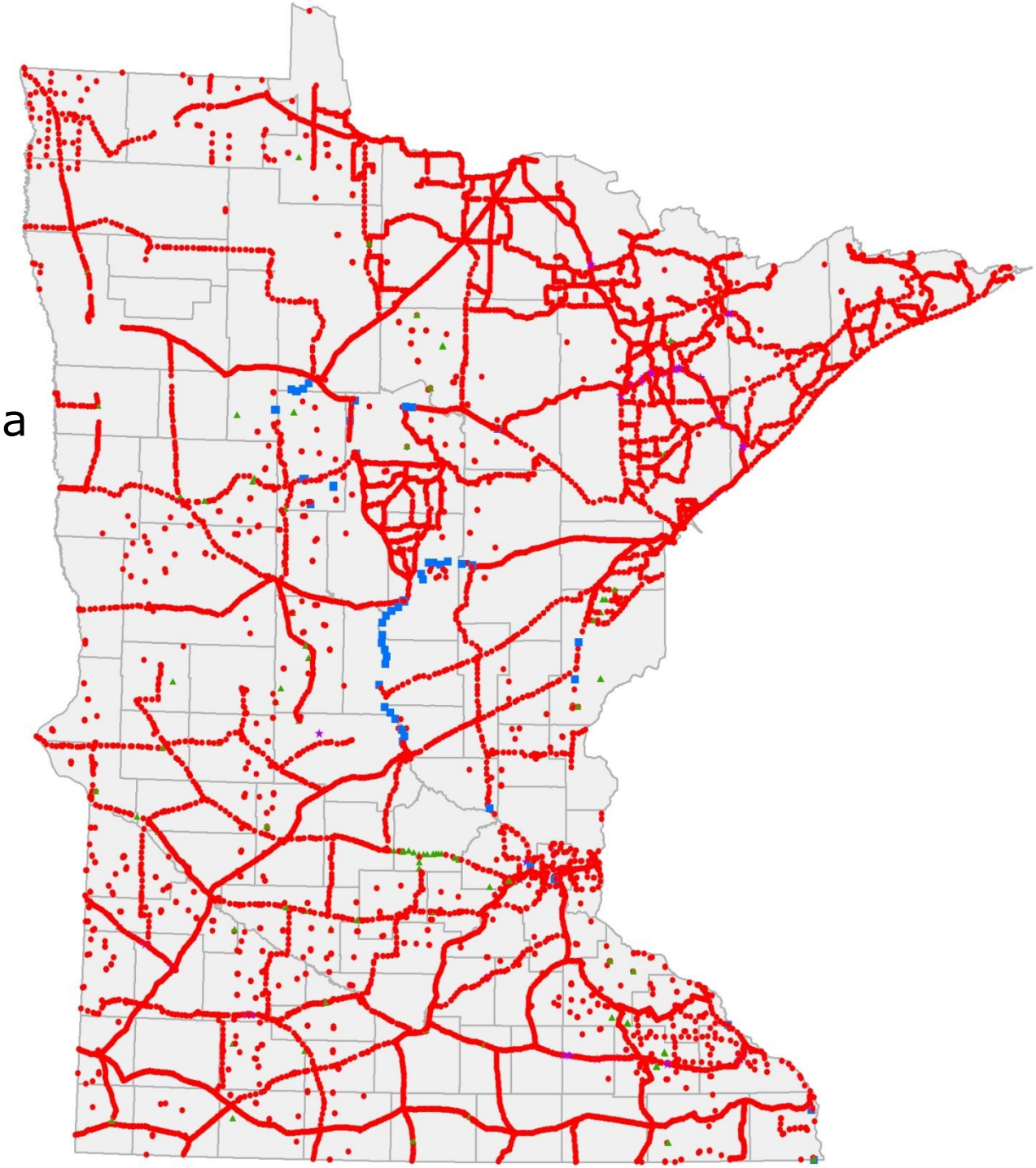
1920-1929

- Connecting the 1890-1909 triangulation to extensive Triangulation across southern MN



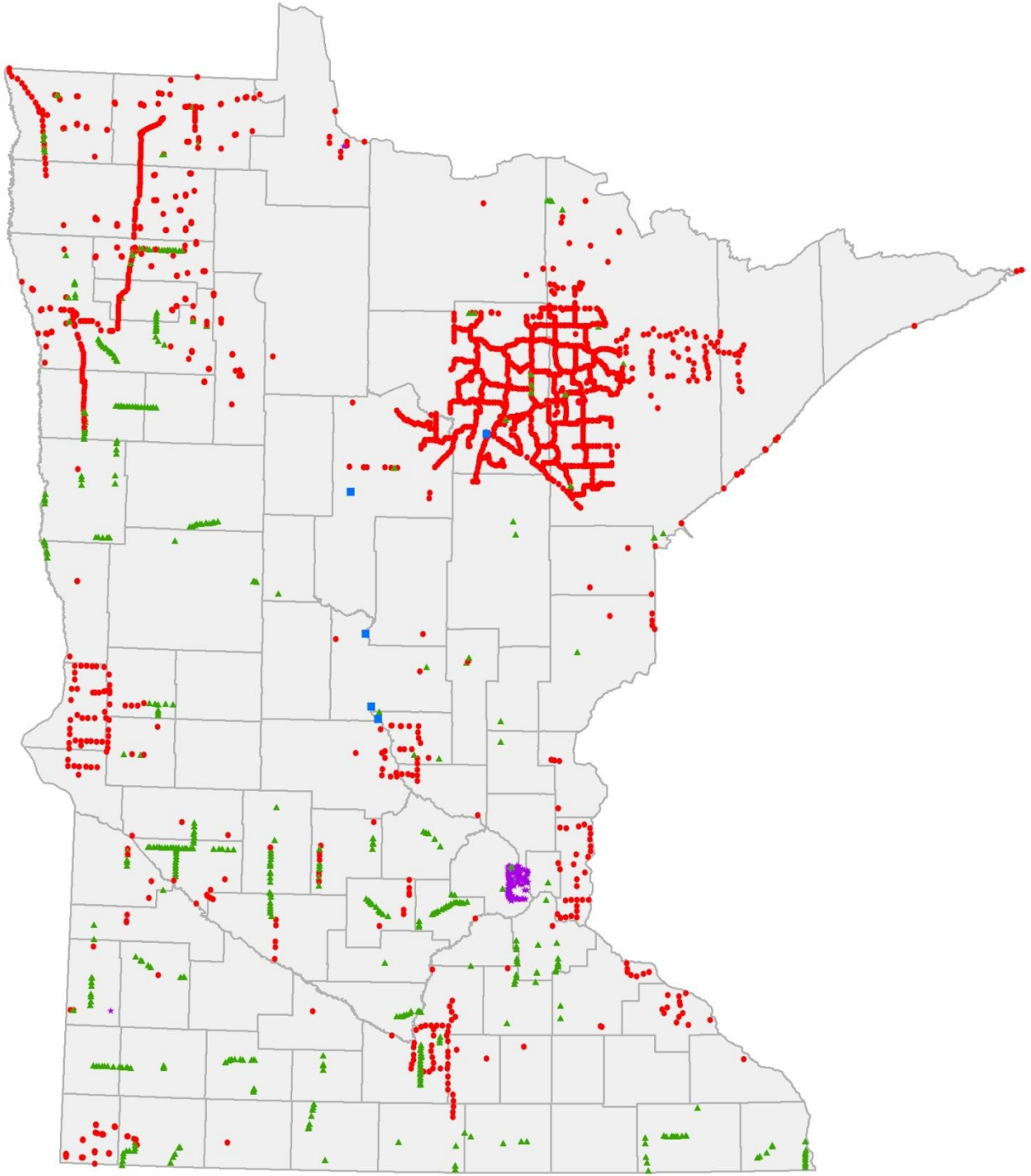
1930-1939

- Great Depression
- WPA and CCC make a contribution to geodetic leveling



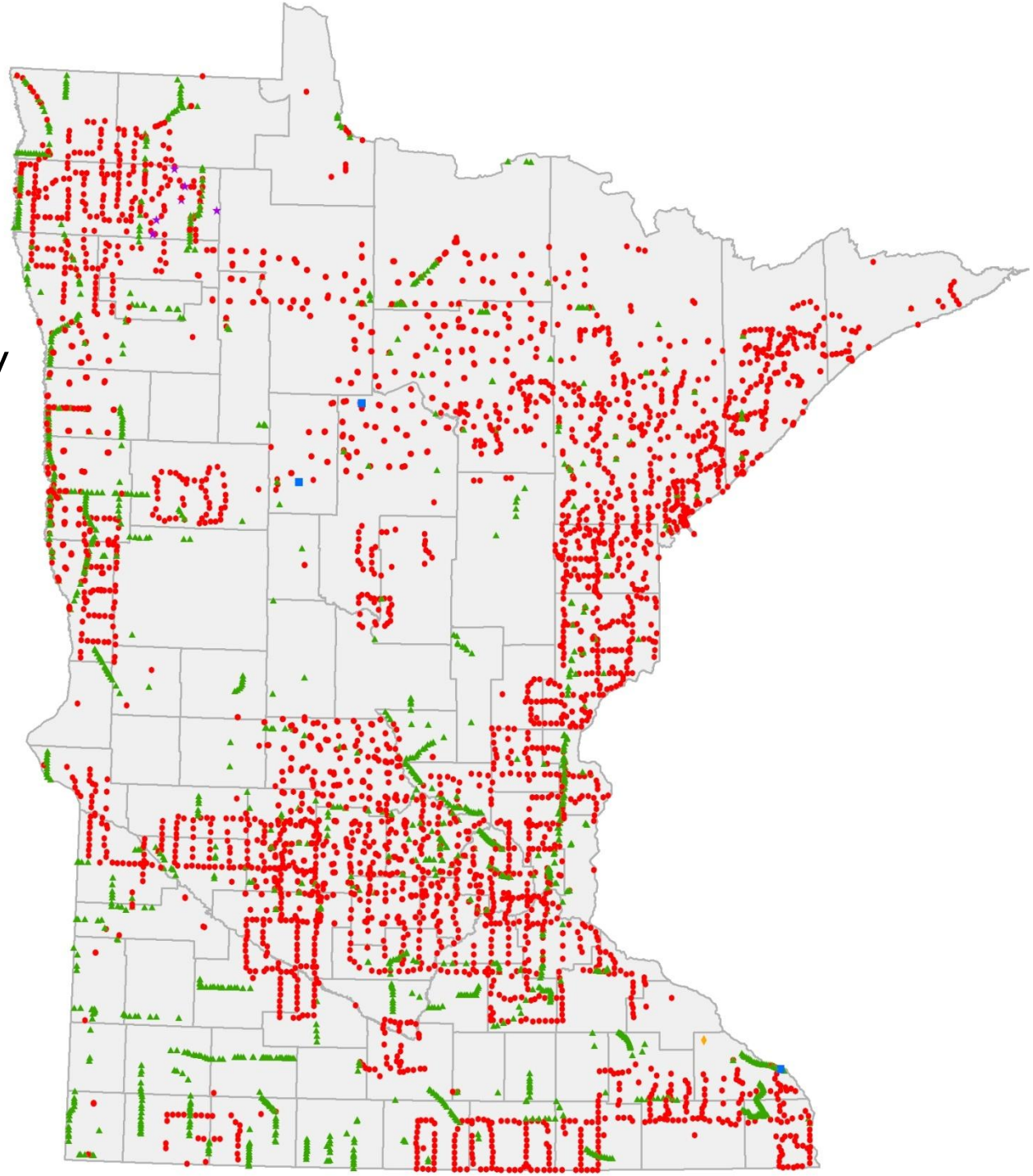
1940-1949

- Pre-War
  - Continuation of WPA/CCC leveling
- Post-War
  - US Geological Survey begins benchmark leveling campaign to support Quadrangle Mapping
- Built on existing leveling lines from the 1930's



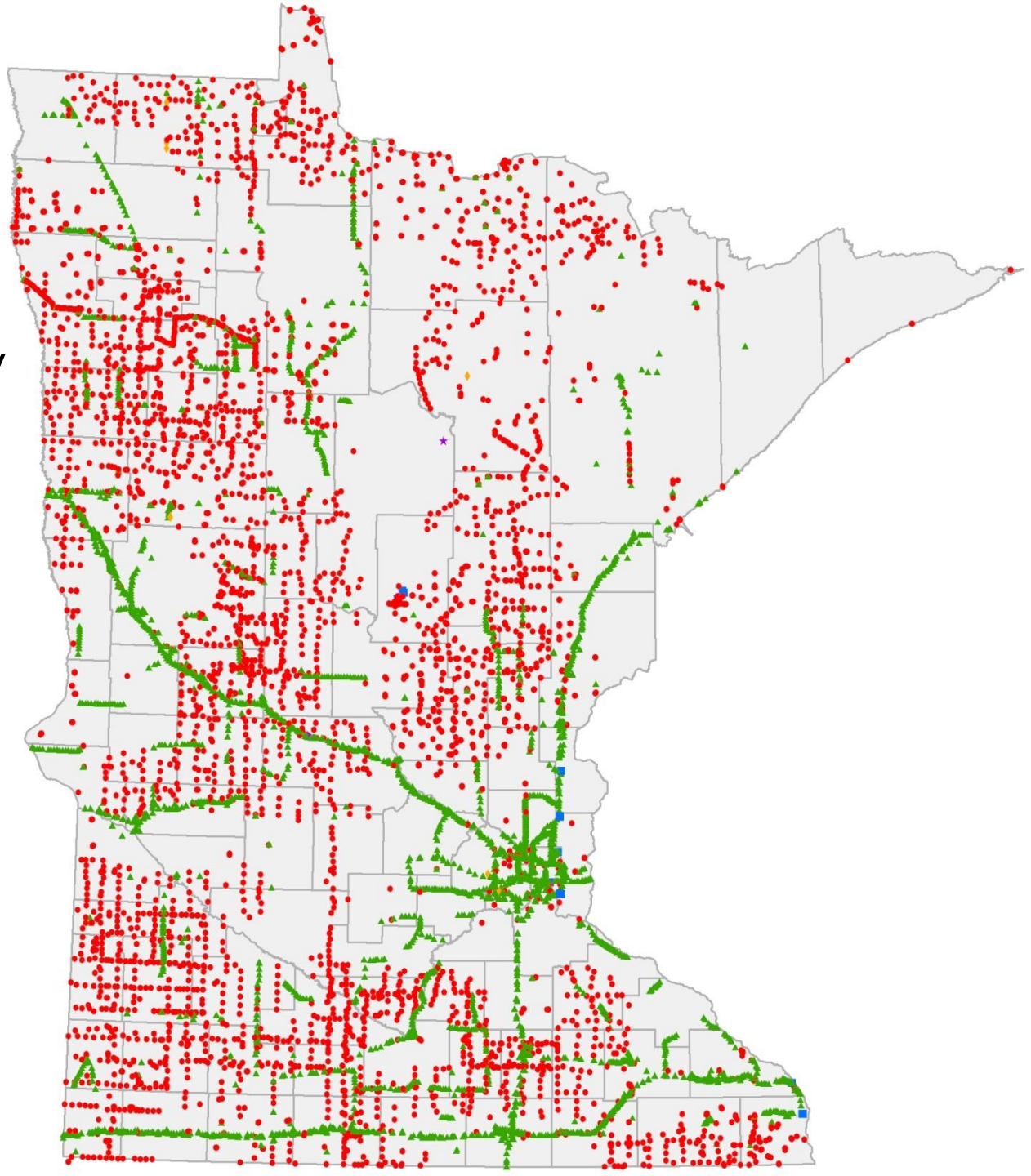
1950-1959

- US Geological Survey expands benchmark leveling campaign to support Quadrangle Mapping



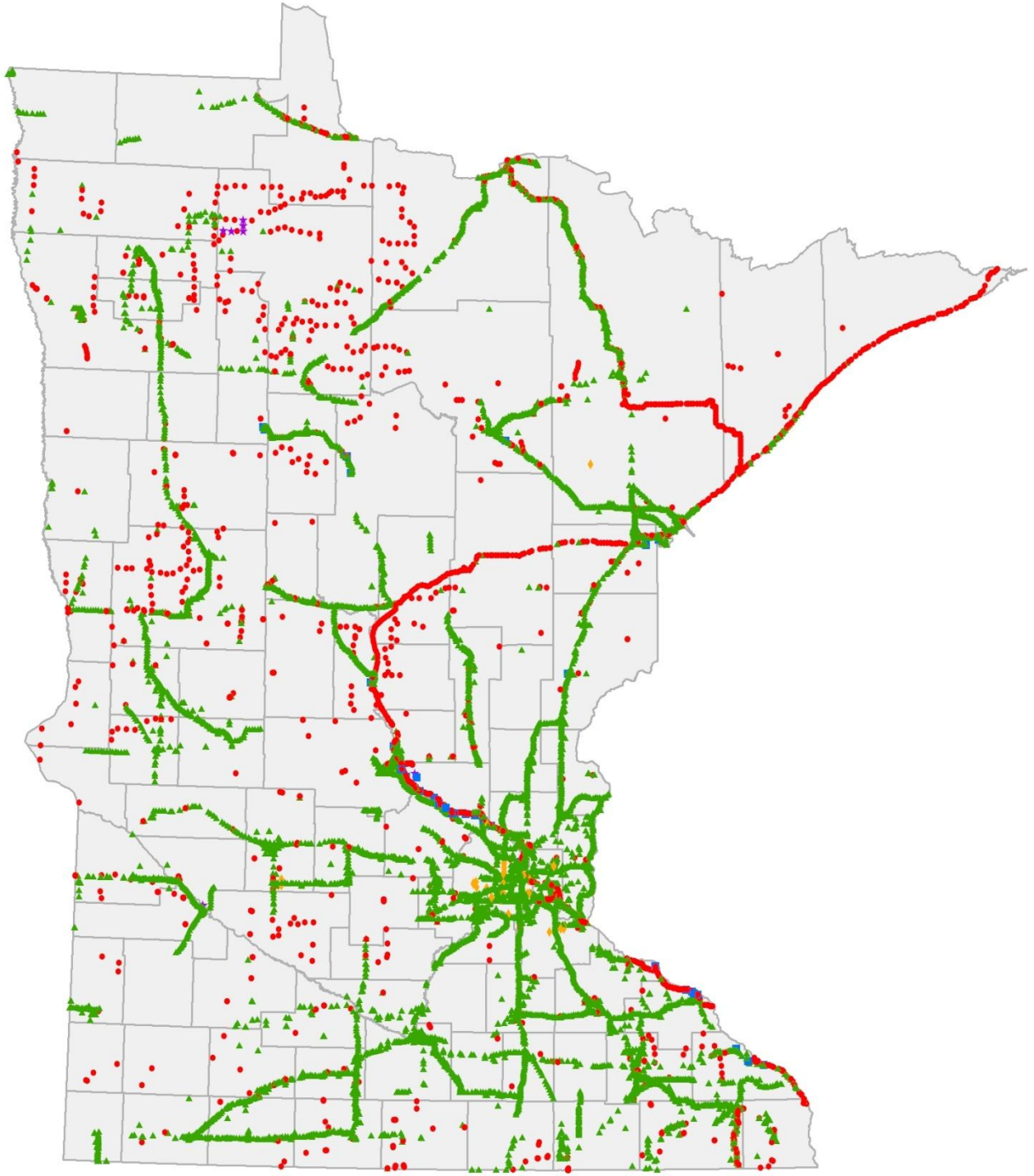
1960-1969

- US Geological Survey expands benchmark leveling campaign to support Quadrangle Mapping
- MHD begins Interstate surveys
- MHD Geodetic Unit started



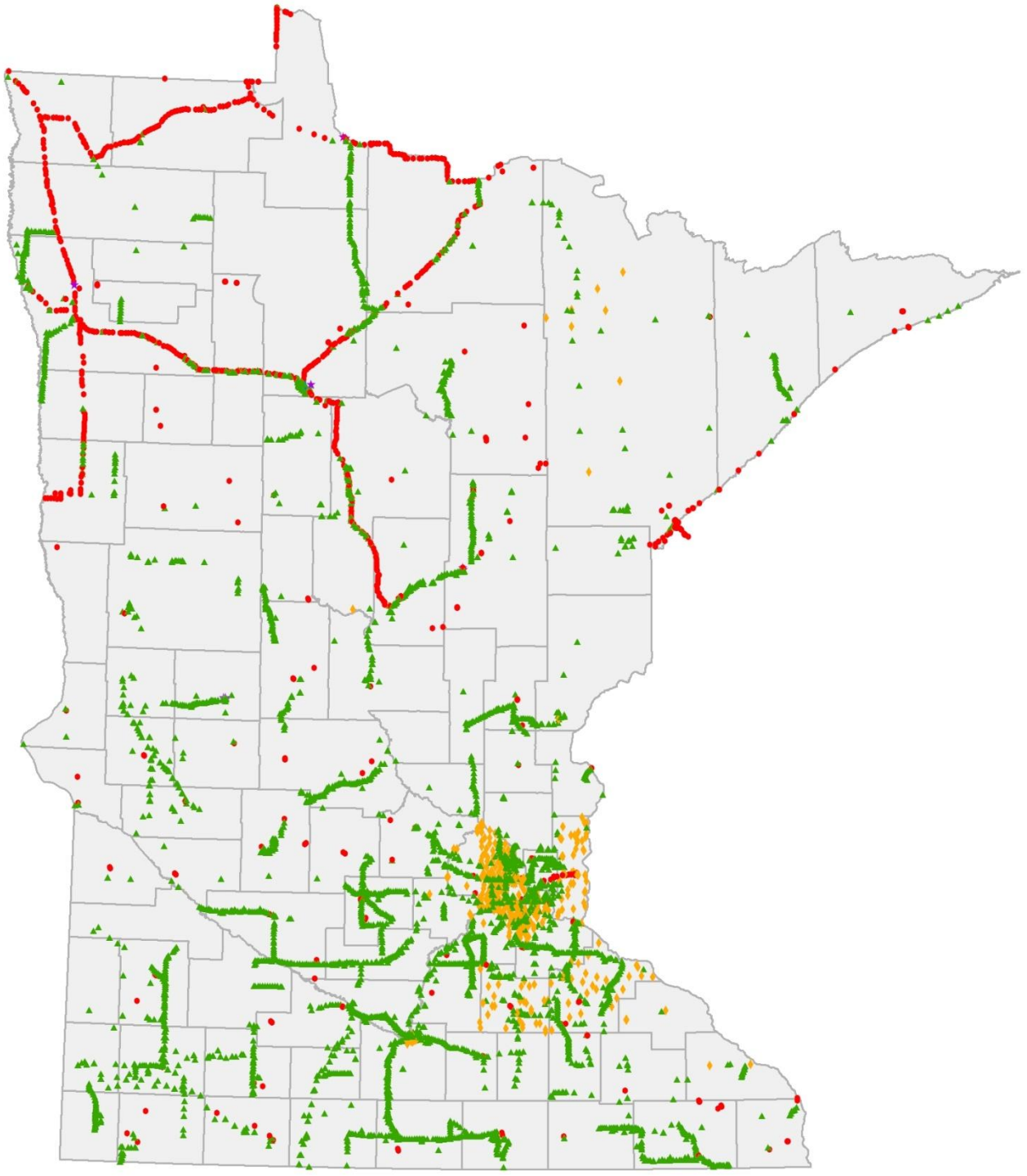
1970-1979

- State Highway corridors benefit from geodetic horizontal and vertical surveys



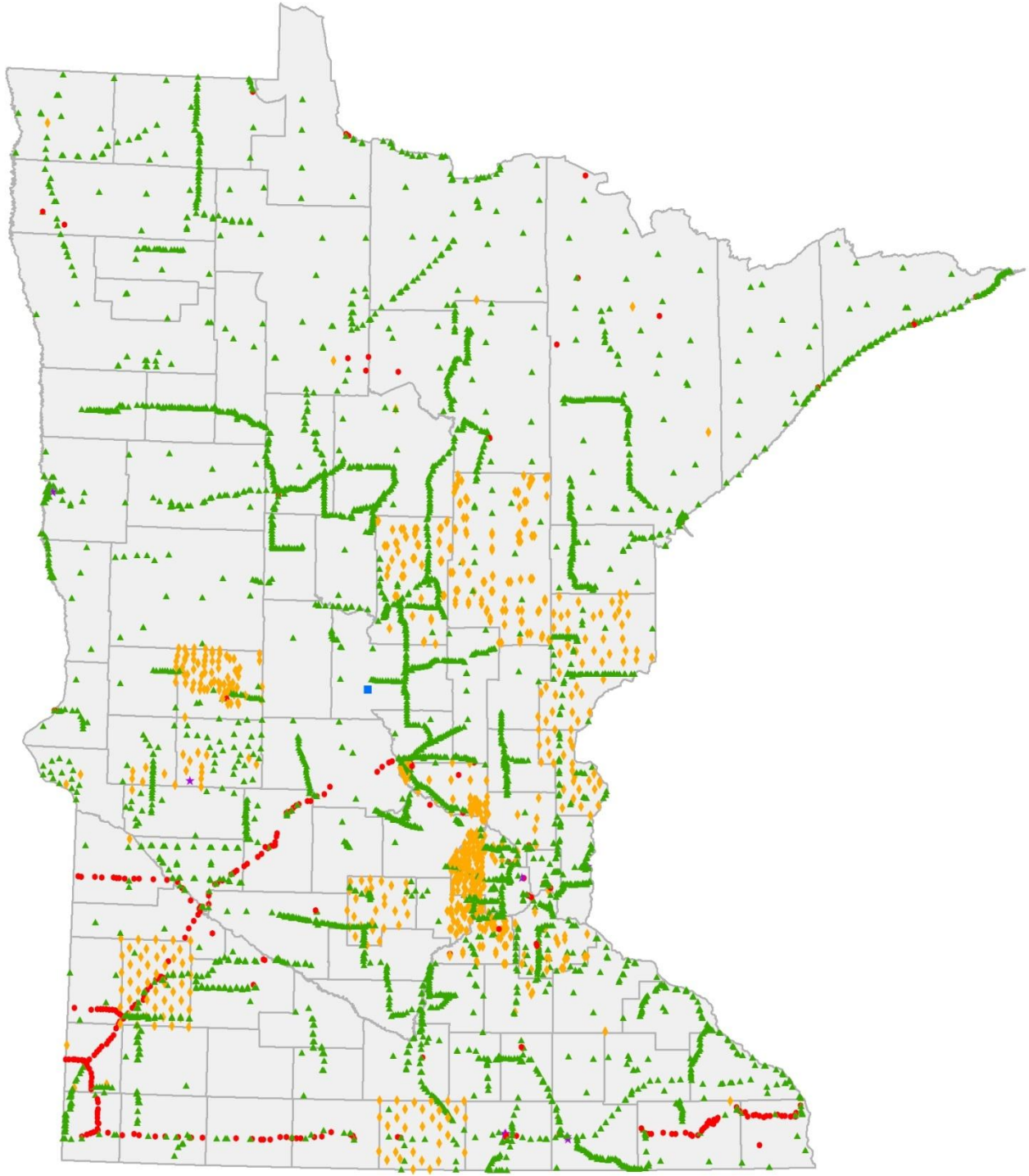
1980-1989

- State Highway corridors benefit from geodetic horizontal and vertical surveys
- Metro Area County GPS Surveys



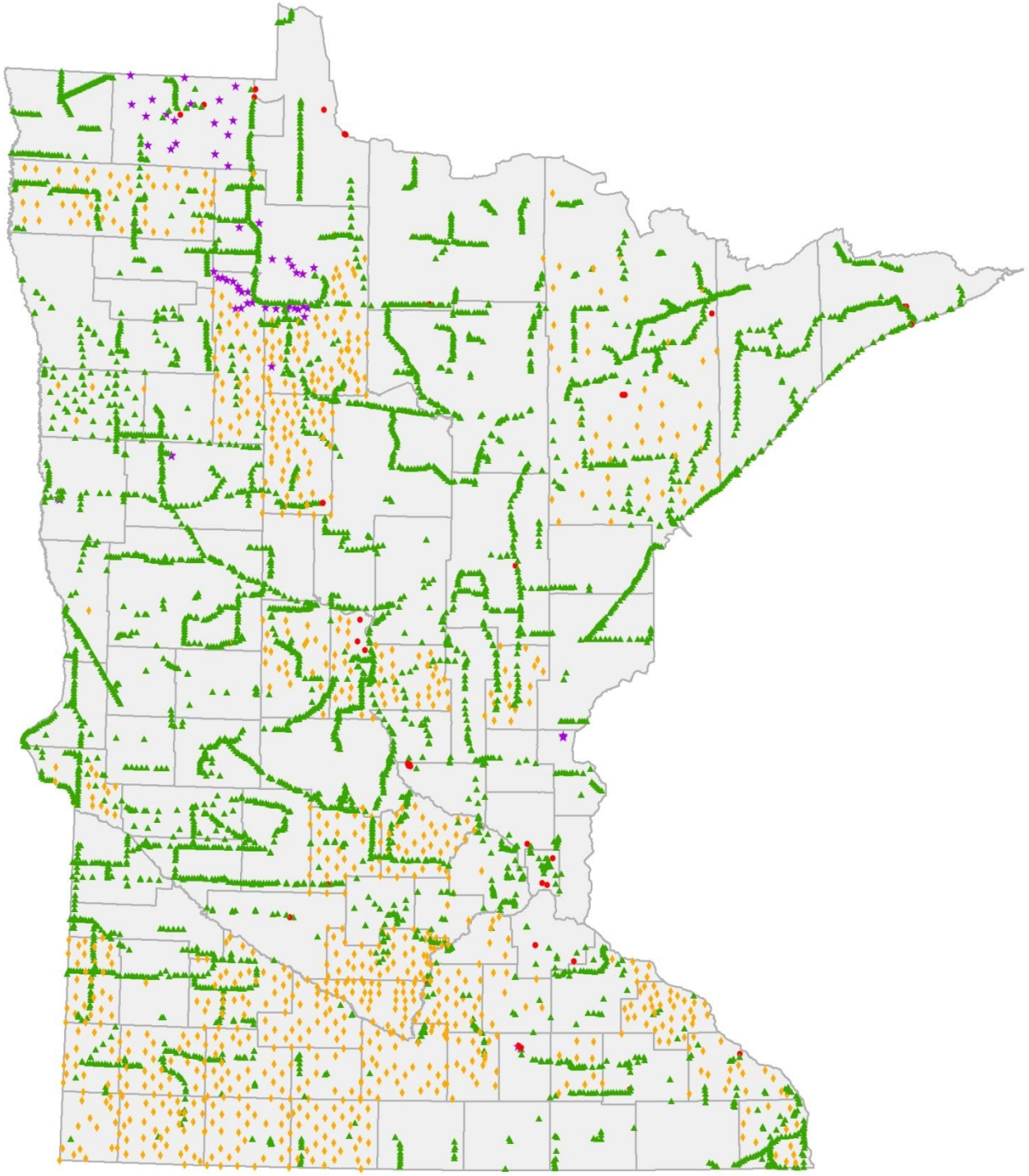
1990-1999

- State Highway corridors benefit from geodetic horizontal and vertical surveys
- County GPS Surveys expand



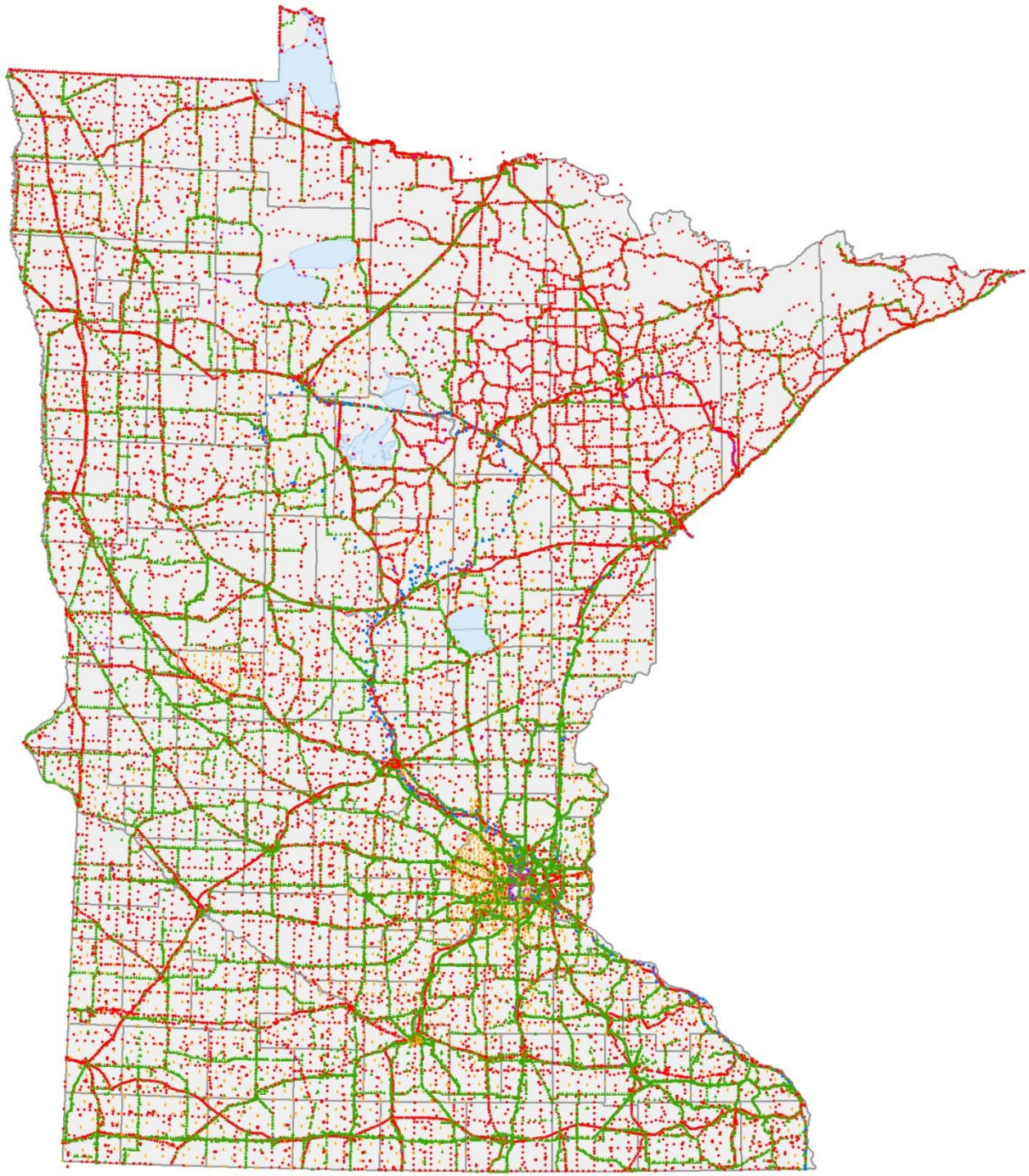
2000-2007

- County GPS Surveys expand
- Lots of leveling still occurring



1860-2007

- Cumulative Effort Pays Off!



Historical Datums in MN

- Horizontal
  - United States Standard Datum of 1913,
    - North American Datum, just NAD, not NAD13!
  - North American Datum of 1927
    - NAD27 – almost same datum, new adjustment
  - North American Datum of 1983
    - NAD83 – new datum, several adjustments
      - 1986, 1996, 2007

Sample Datum/Adjustment Shifts

TUCKY MNDT	Nicollet County Coordinates (meters)				
Datum Tag	Easting	E Shift		Northing	N Shift
NAD27	n/a			n/a	
		n/a			n/a
NAD83(1986)	176327.286			82099.219	
		-0.026			-0.109
NAD83(1996)	176327.312			82099.328	
		0.012			-0.015
NAD83(2007)	176327.300			82099.343	

Sample Datum/Adjustment Shifts

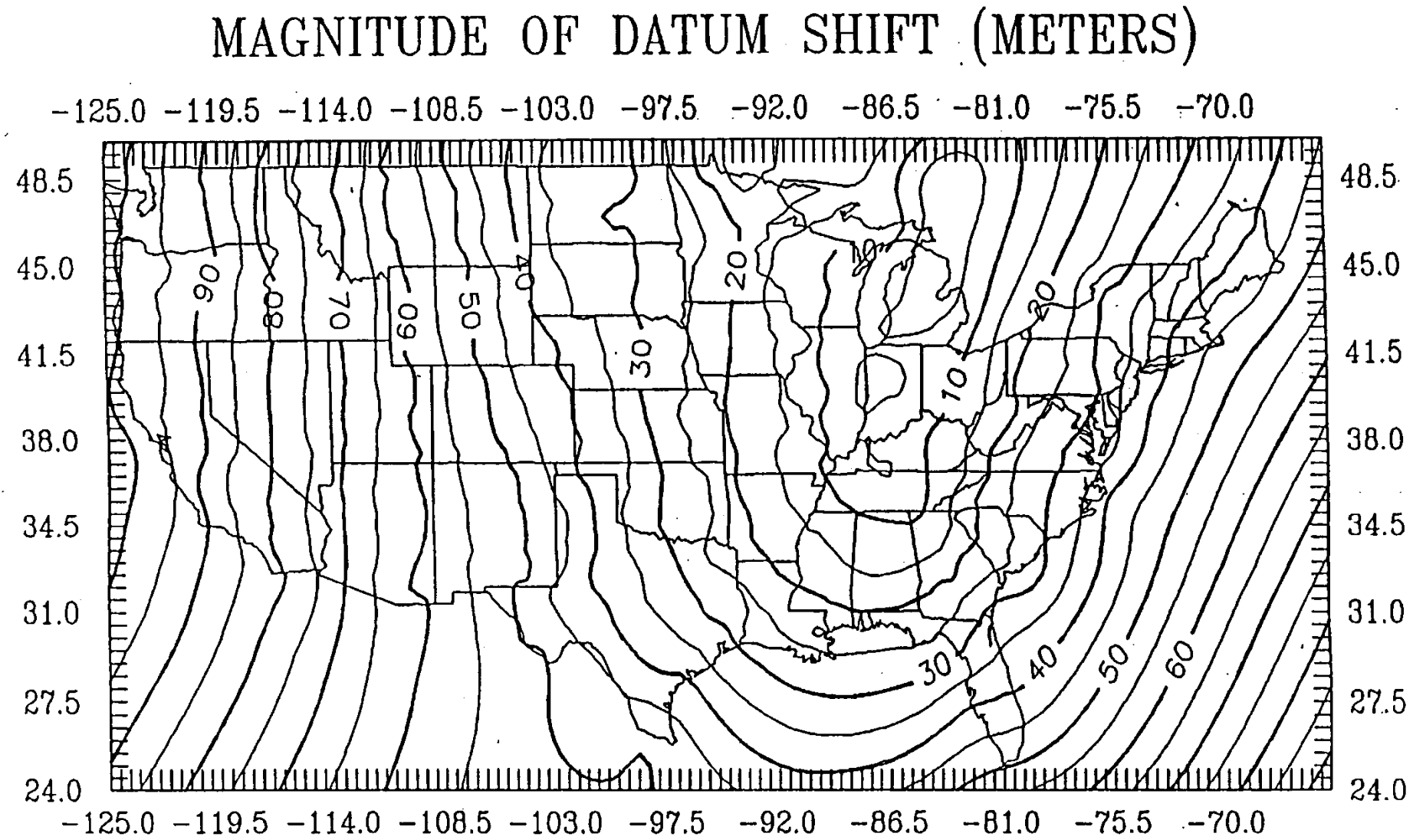
ANTRIM MNDT					
Datum Tag	Longitude	Lon Shift (m)		Latitude	Lat Shift (m)
NAD27	94 26 33.36931			43 52 36.98645	
		26.357			-3.232
NAD83(1986)	94 26 34.22535			43 52 36.83501	
		0.137			0.057
NAD83(1996)	94 26 34.22980			43 52 36.83769	
		0.010			0.014
NAD83(2007)	94 26 34.23013			43 52 36.83833	

Sample Datum/Adjustment Shifts

APGAR MNDT					
Datum Tag	Longitude	Lon Shift (m)		Latitude	Lat Shift (m)
NAD27	93 31 49.11572			44 47 03.08770	
		25.631			-2.836
NAD83(1986)	93 31 49.94811			44 47 02.95481	
		0.031			0.111
NAD83(1996)	93 31 49.94913			44 47 02.96001	
		n/a			n/a
NAD83(2007)	not GPS			not GPS	

Historical Datums in MN

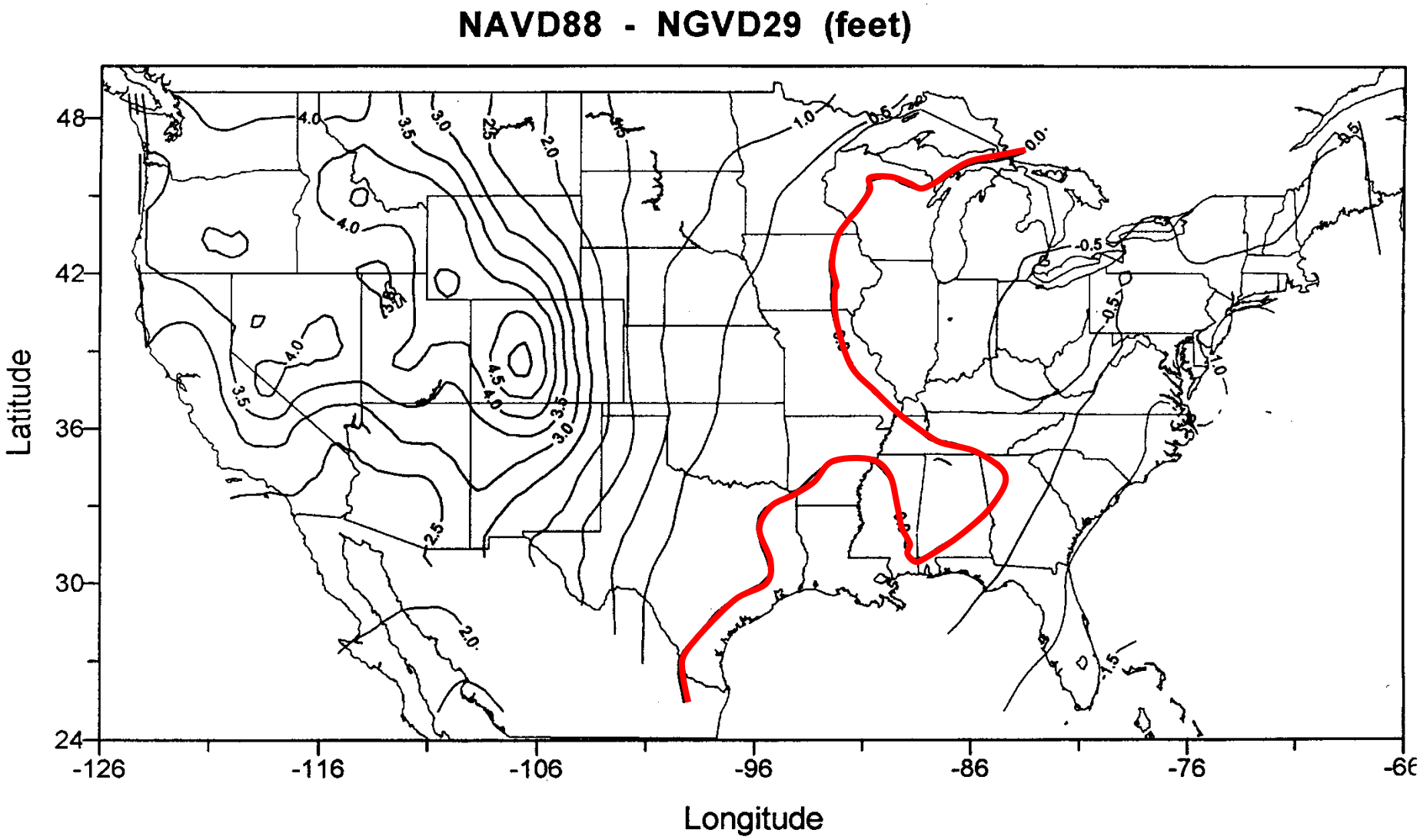
- Shifts from NAD27 to NAD83



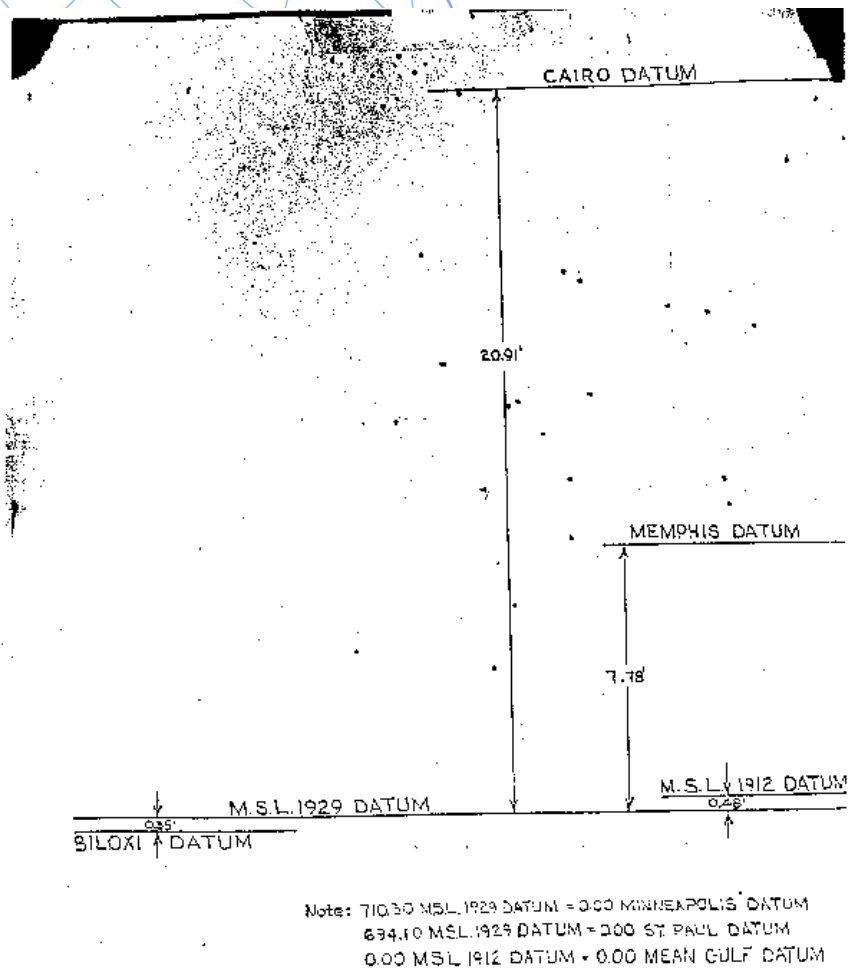
Historical Datums in MN

- Vertical
  - Great Lakes Datums
    - USLS1903, USLS1935, IGLD1955, IGLD1985
  - Mississippi River Datums
    - Cairo, Memphis, Mean Gulf Level, others
  - St Paul City Datum (-694.28 ft)
  - Minneapolis City Datum (-710.48 ft)
  - National Geodetic Vertical Datum of 1929 (NGVD29)
  - North American Vertical Datum of 1988 (NAVD88)

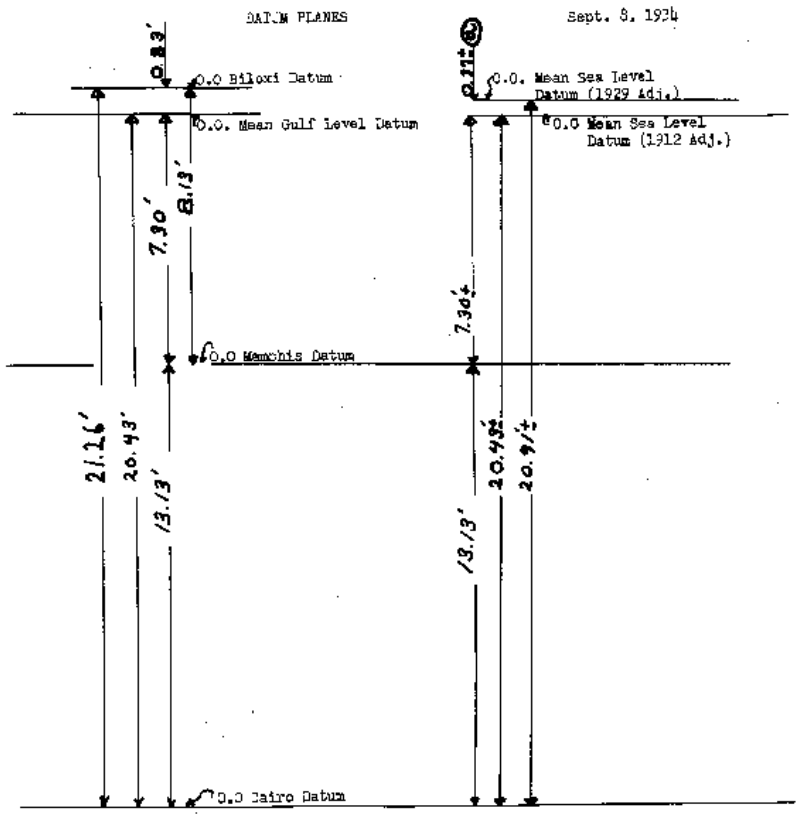
Historical Datums in MN



General Relationships Among Vertical Datums



Note: 710.30 MSL 1929 DATUM = 0.00 MINNEAPOLIS DATUM
694.10 MSL 1929 DATUM = 0.00 ST PAUL DATUM
0.00 MSL 1912 DATUM = 0.00 MEAN GULF DATUM



(e) The difference between Mean Sea Level (1912 Adj.) and Biloxi, Mean Gulf Level, Memphis, and Cairo datums is a variable because the Mean Sea Level (1912 Adj.) elevations are adjusted into U.S. Level Net while elevations given on the other datums have not been adjusted into the U.S. Level Net. This is also true of the Mean Sea Level (1929 Adj.) elevations.

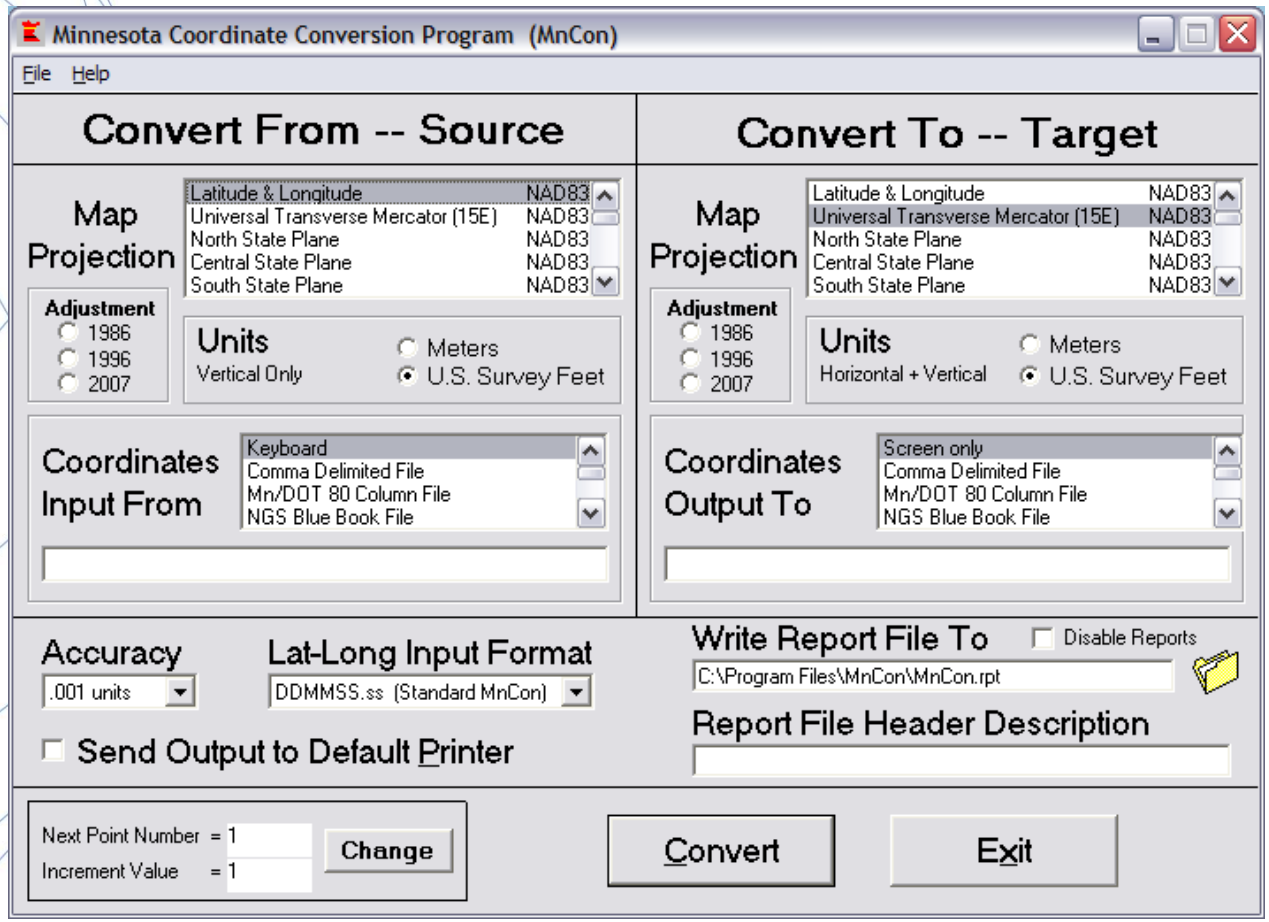
Historical Datums in MN

- National Height Modernization
  - GPS + GEOID = ORTHOMETRIC HEIGHT
- 3D Datum of 2022
  - Is this the Future?
  - If everything is moving, what does a datum mean?
  - Is there anything that's not moving?
- WANT MORE DETAIL?
  - http://www.olmweb.dot.state.mn.us
  - Technology and Tools – then download:
    - 2007 Adjustment of the National Spatial Reference System in Minnesota
    - Geodetic History in MN

Datum Conversion Tools

- HORIZONTAL Conversion Tools
  - NADCON - NGS converter from NAD27 to NAD83
  - MNCON – MNDOT written conversion tool
  - CONAD – DOS program from MNDOT, use MNCON now
- VERTICAL Conversion Tools
  - VERTCON - NGS converter from NAD27 to NAD83
- Combined Conversion Tools
  - CORPSCON – US Army Corps of Engineers
    - Combines NADCON and VERTCON

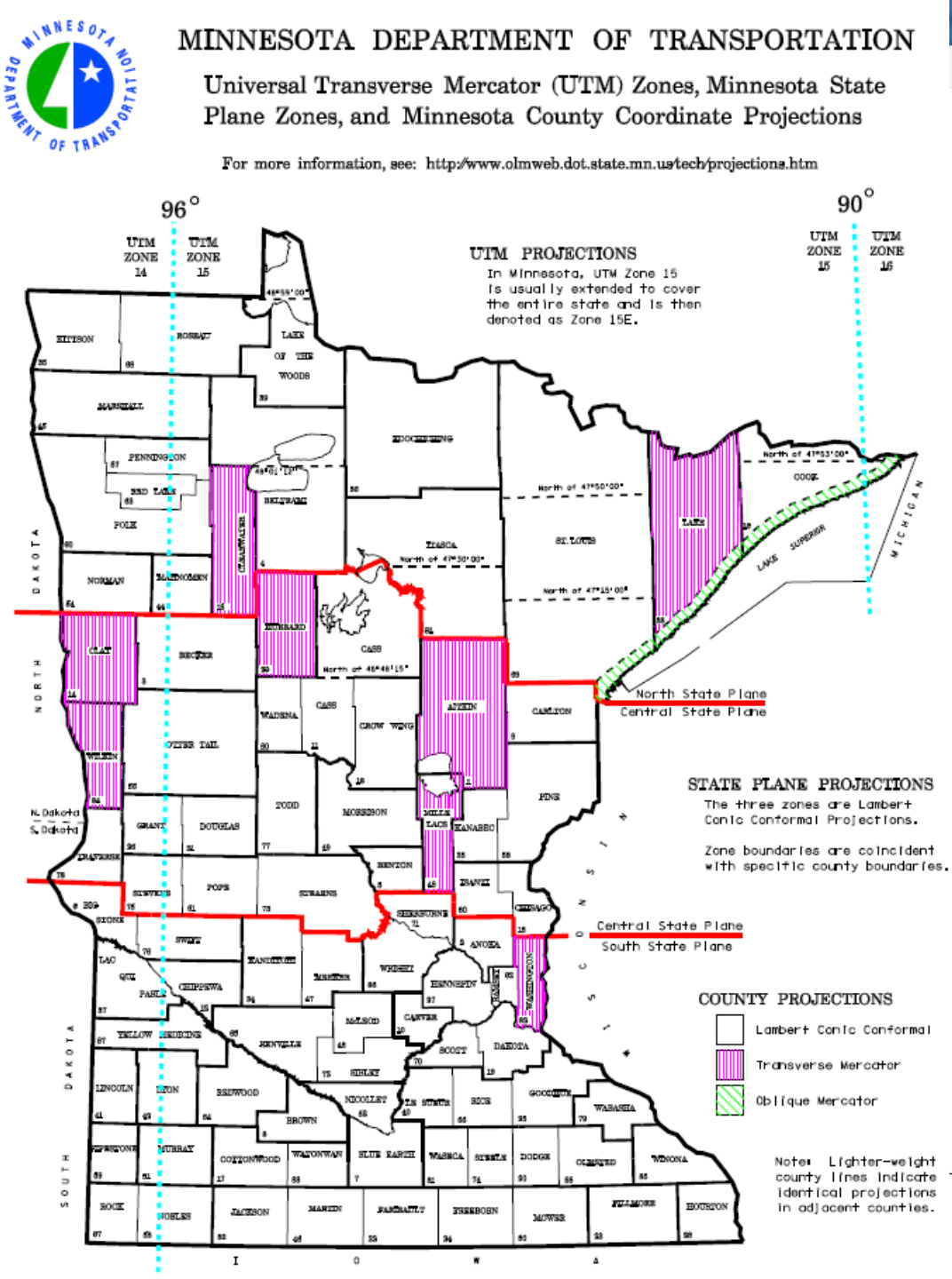
MNCON



http://www.olmweb.dot.state.mn.us/tech/OlmSoftware.html#MCN

MN Map Projections and Parameters

http://www.olmweb.dot.state.mn.us/tech/Projections.htm



New NAD83(2011) Adjustment

- NAD83(1986) Original realization
  - Consisted (almost) entirely of classical (optical) observations
- NAD83(1996)
  - "High Precision Geodetic Network" (HPGN) and High Accuracy Reference Network" (HARN) realizations
  - Most done in 1990s, essentially state-by-state
  - Based on GNSS but classical stations included in adjustments

New NAD83(2011) Adjustment

- NAD83(2007) National Re-Adjustment of 2007
  - Used NAD 83(CORS96) epoch 2002.0 as constraint
  - Simultaneous nationwide adjustment (GNSS only)
- Needed badly to resolve the state-by-state biases of the "HARN" era adjustments.
- Underlying CORS coordinates were known to be less-than-perfect, but the Multi-Year CORS Solution (MYCS) was not even close to completed.

New NAD83(2011) Adjustment

- Completion of MYCS in 2011 made a set of constraints available that could truly be described as: "state-of-the art"
  - Reprocessed all CORS GPS data 1994-2011
  - 2264 CORS & other global GPS tracking stations
  - New orbits were computed for all satellites for all years.
  - The X,Y,Z and Vx,Vy,Vz for every CORS was solved for as unknowns in a set of millions of equations
  - Accurate computed velocities and consistent coordinates for all CORS

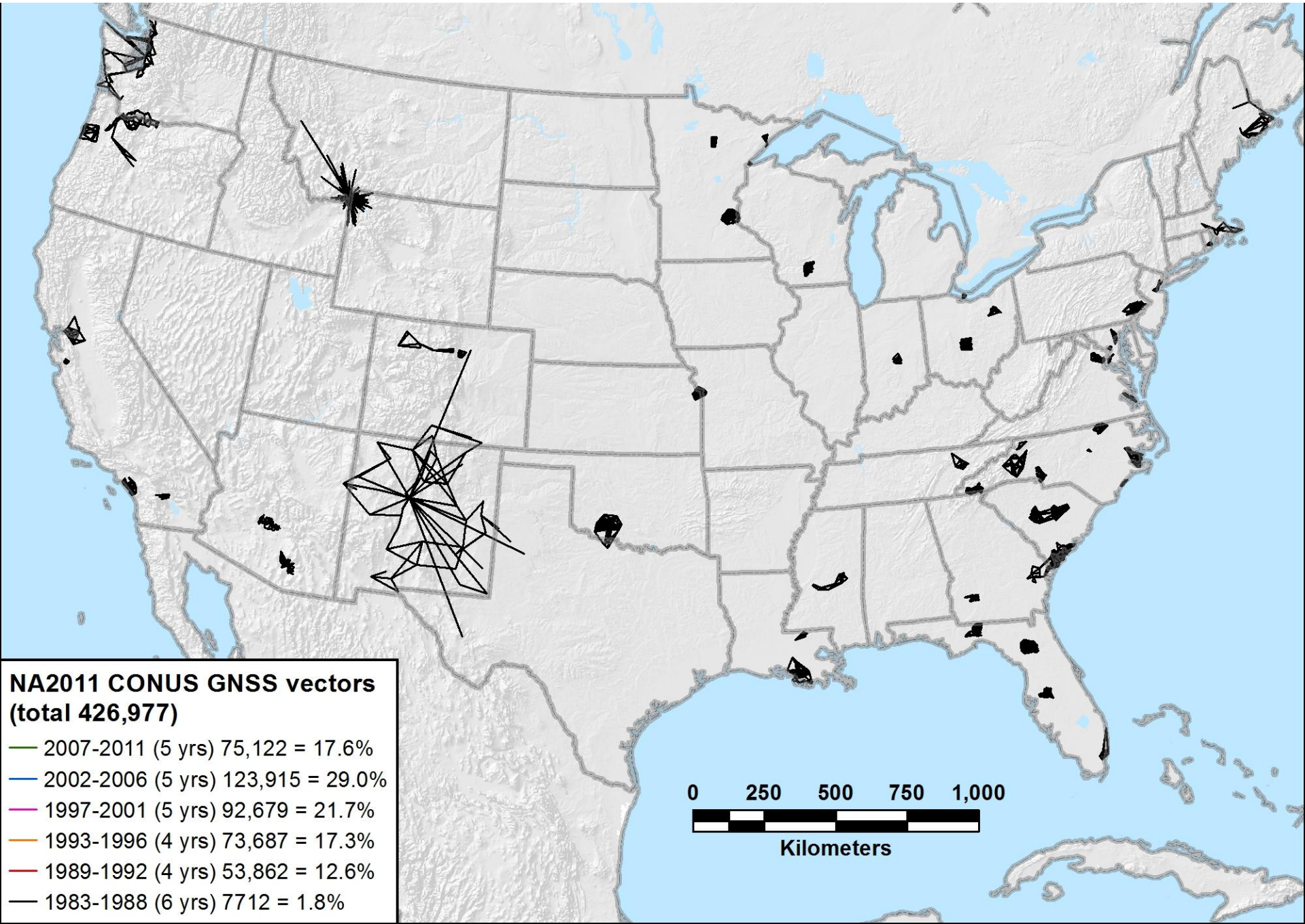
New NAD83(2011) Adjustment

- Using the MYCS coordinates and velocities as constraints – the new adjustment could include:
  - 4196 projects
  - 80,077 stations
  - 430,766 vectors total – approx 387,000 enabled
- New realization: NAD 83(2011) epoch 2010.00

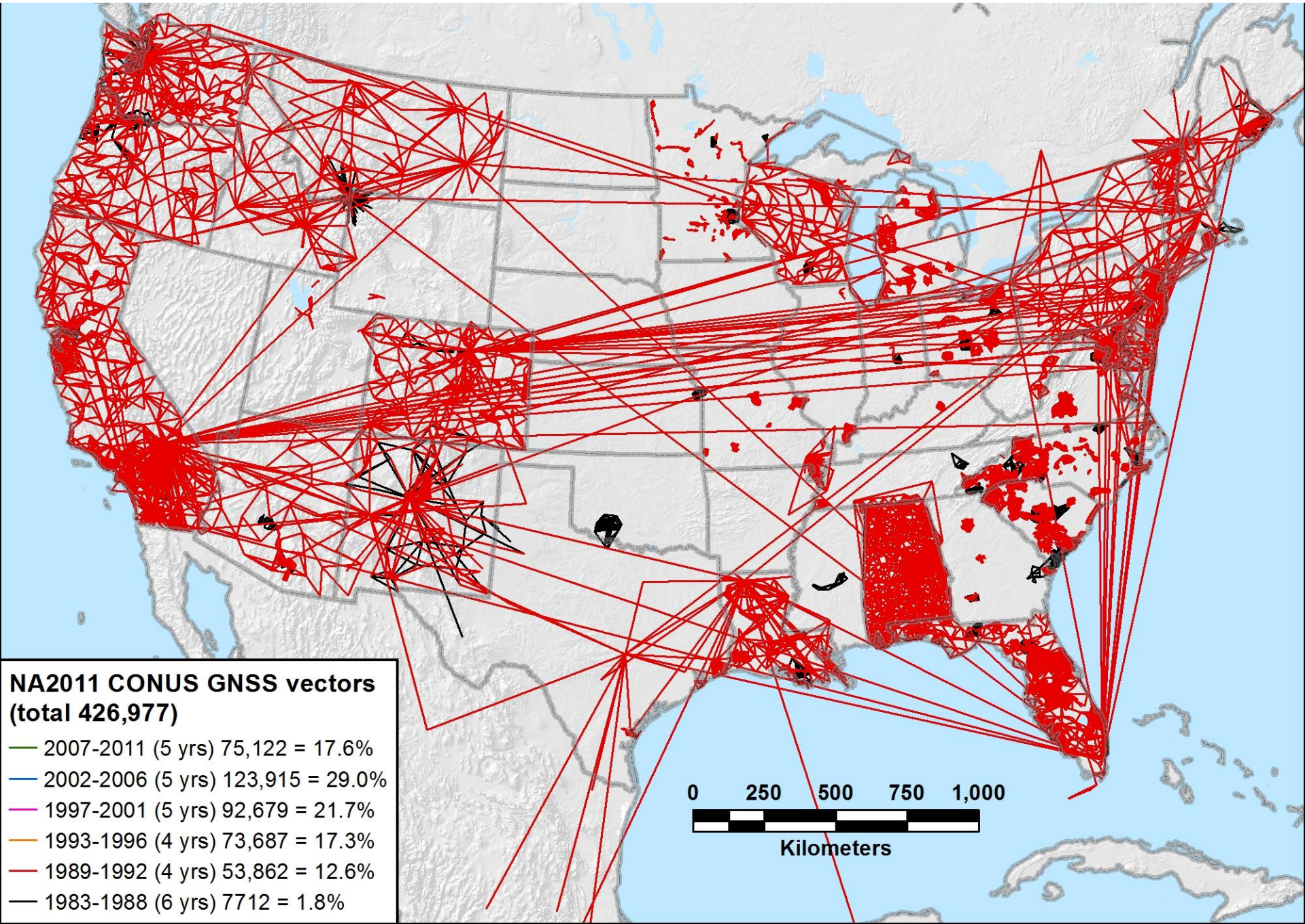
New NAD83(2011) Adjustment

- Build up of network over time

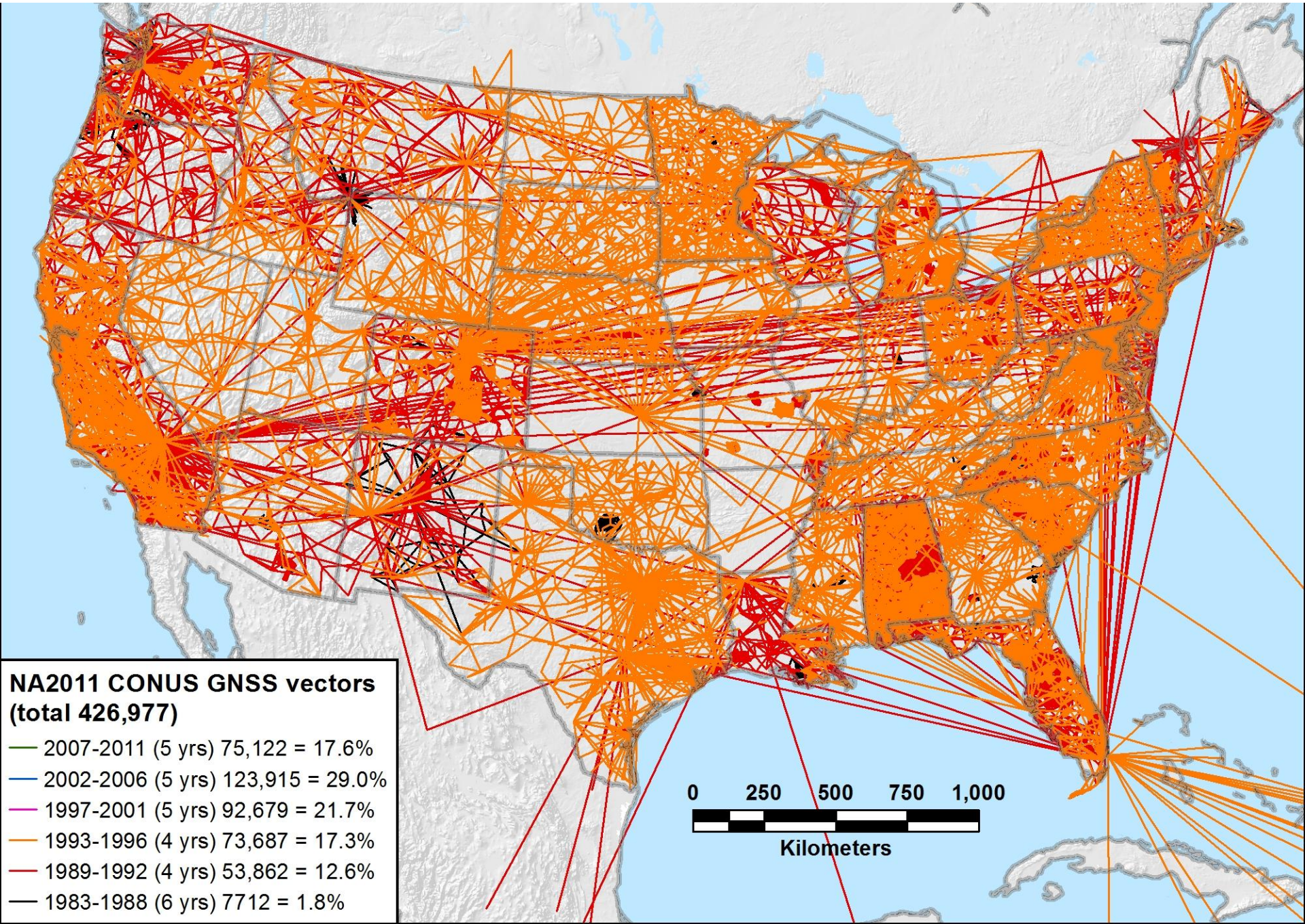
NA2011 CONUS 1983-1988 (6 yrs) 7712 vectors (1.8%)



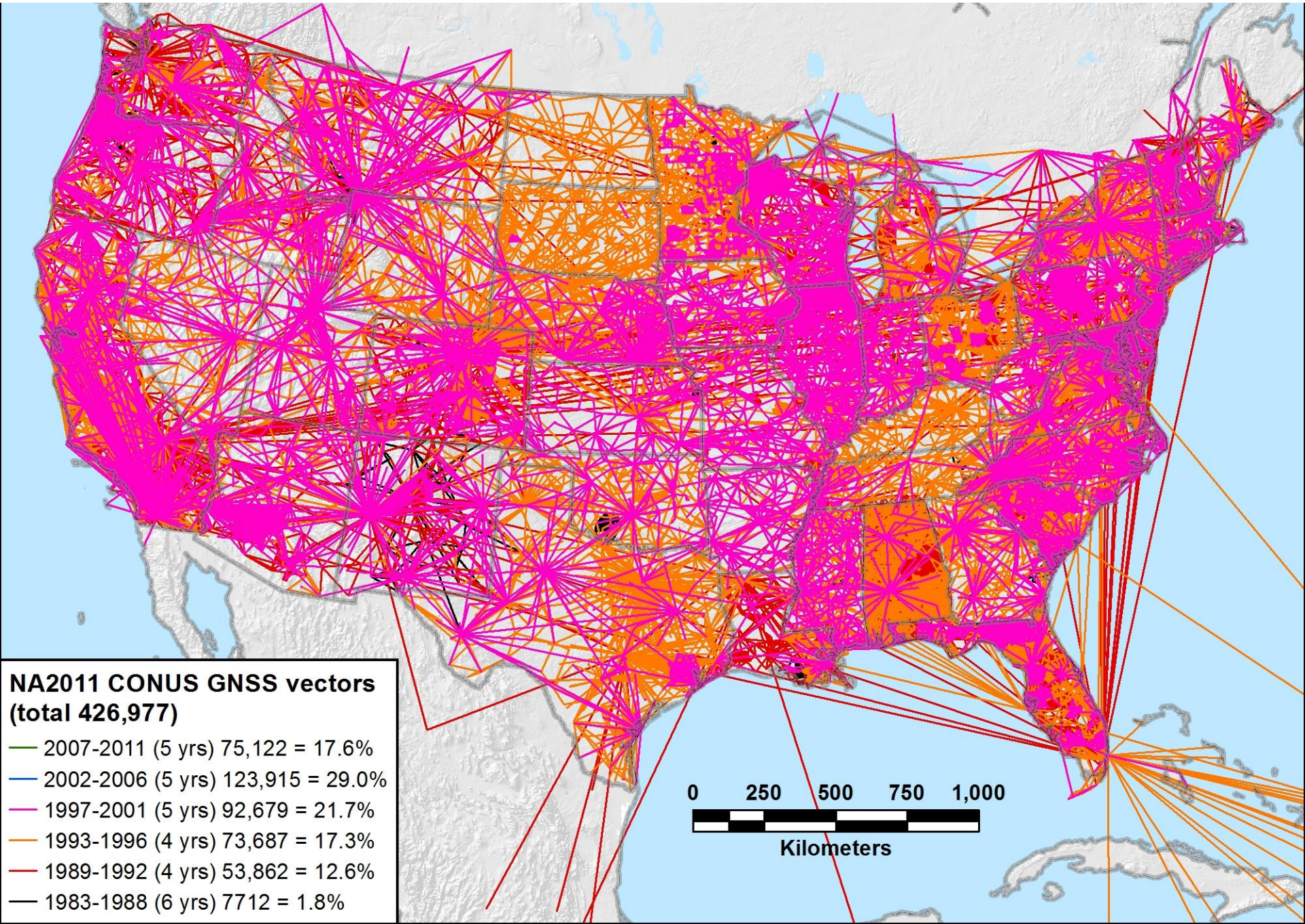
NA2011 CONUS 1983-1992 (10 yrs) 61,574 vectors (14.4%)



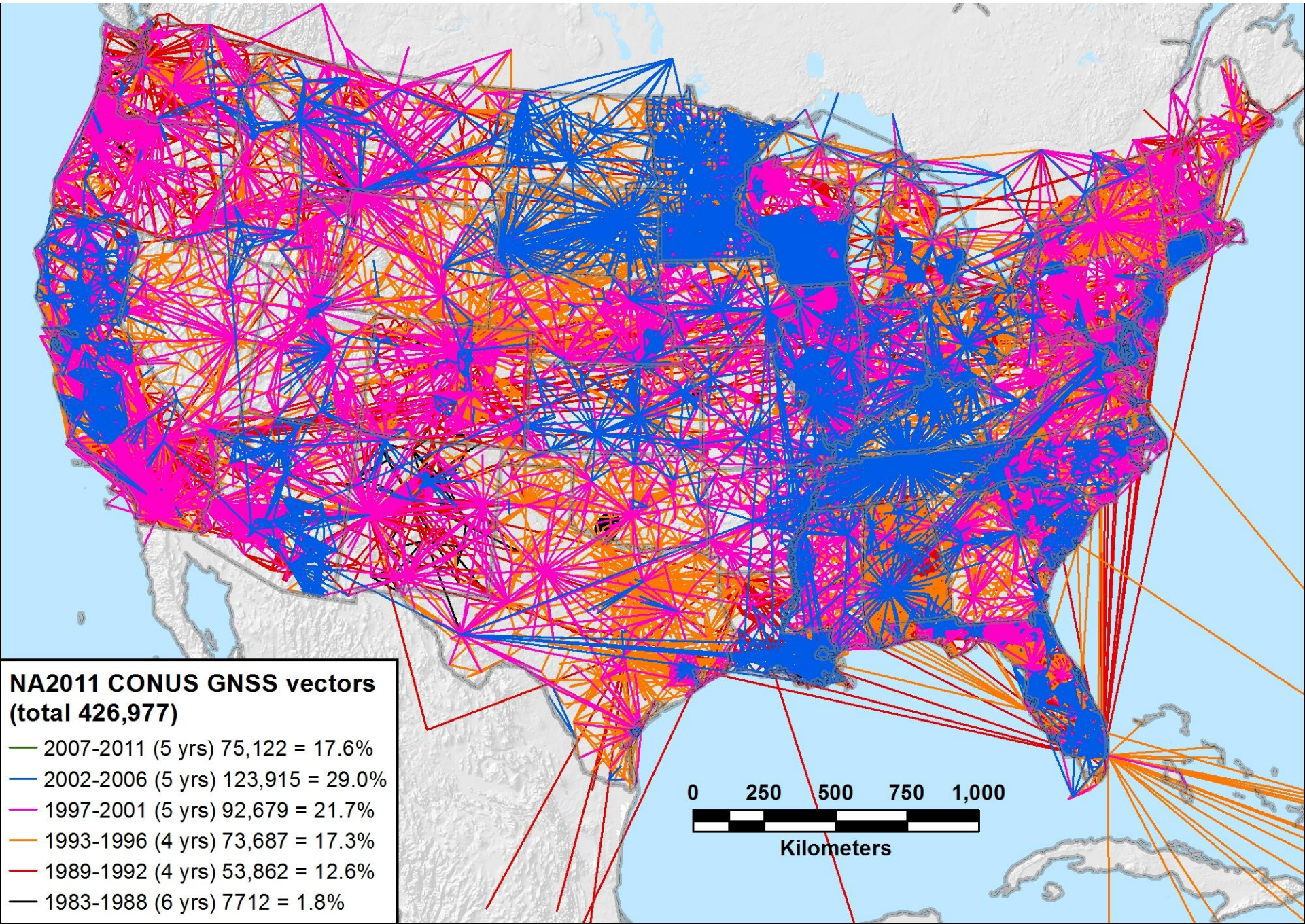
NA2011 CONUS 1983-1996 (14 yrs) 135,261 vectors (31.7%)



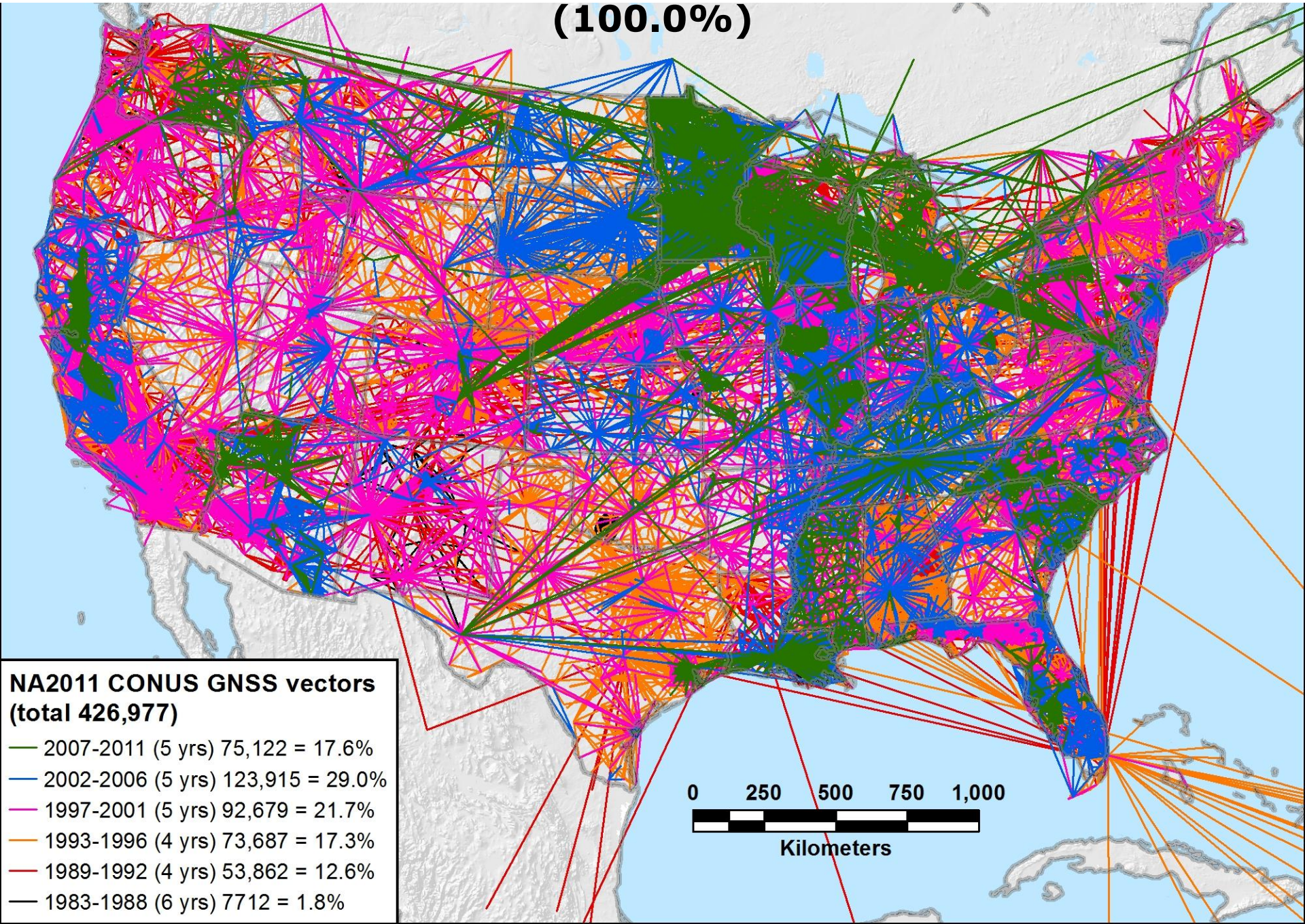
NA2011 CONUS 1983-2001 (19 yrs) 227,940 vectors (53.4%)



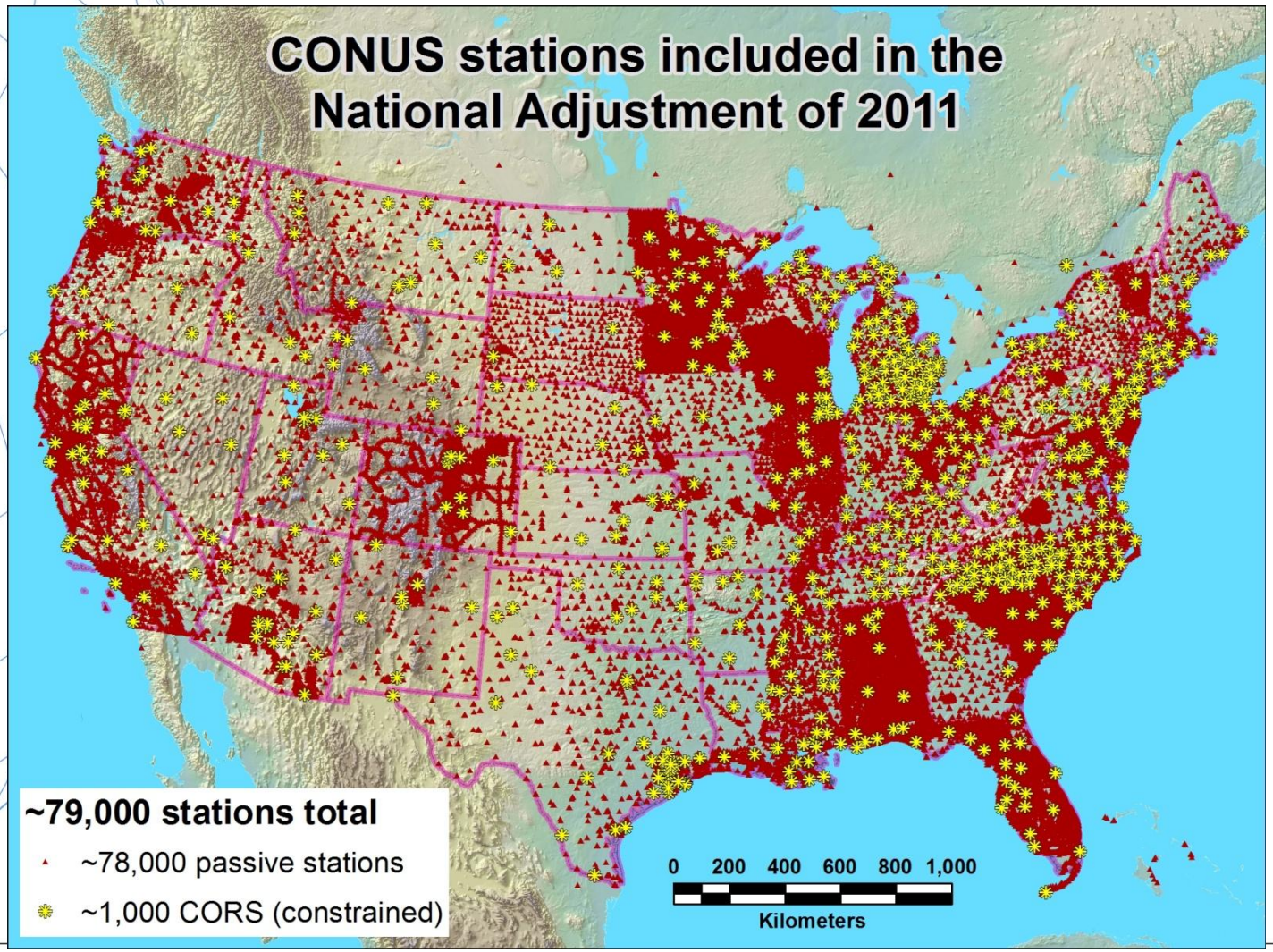
NA2011 CONUS 1983-2006 (24 yrs) 351,855 vectors (82.4%)



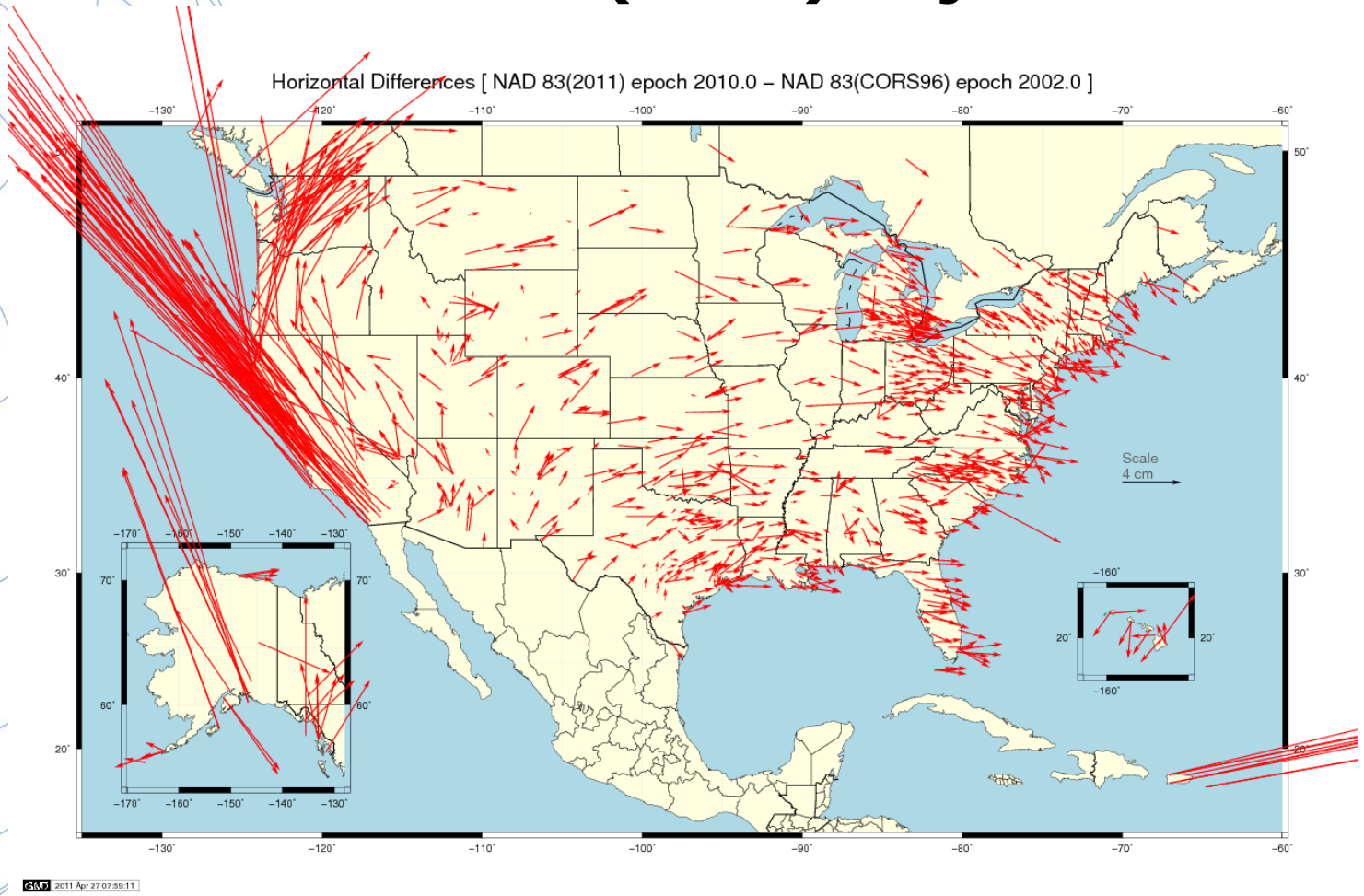
NA2011 CONUS 1983-2011 (29 yrs) 426,977 vectors (100.0%)



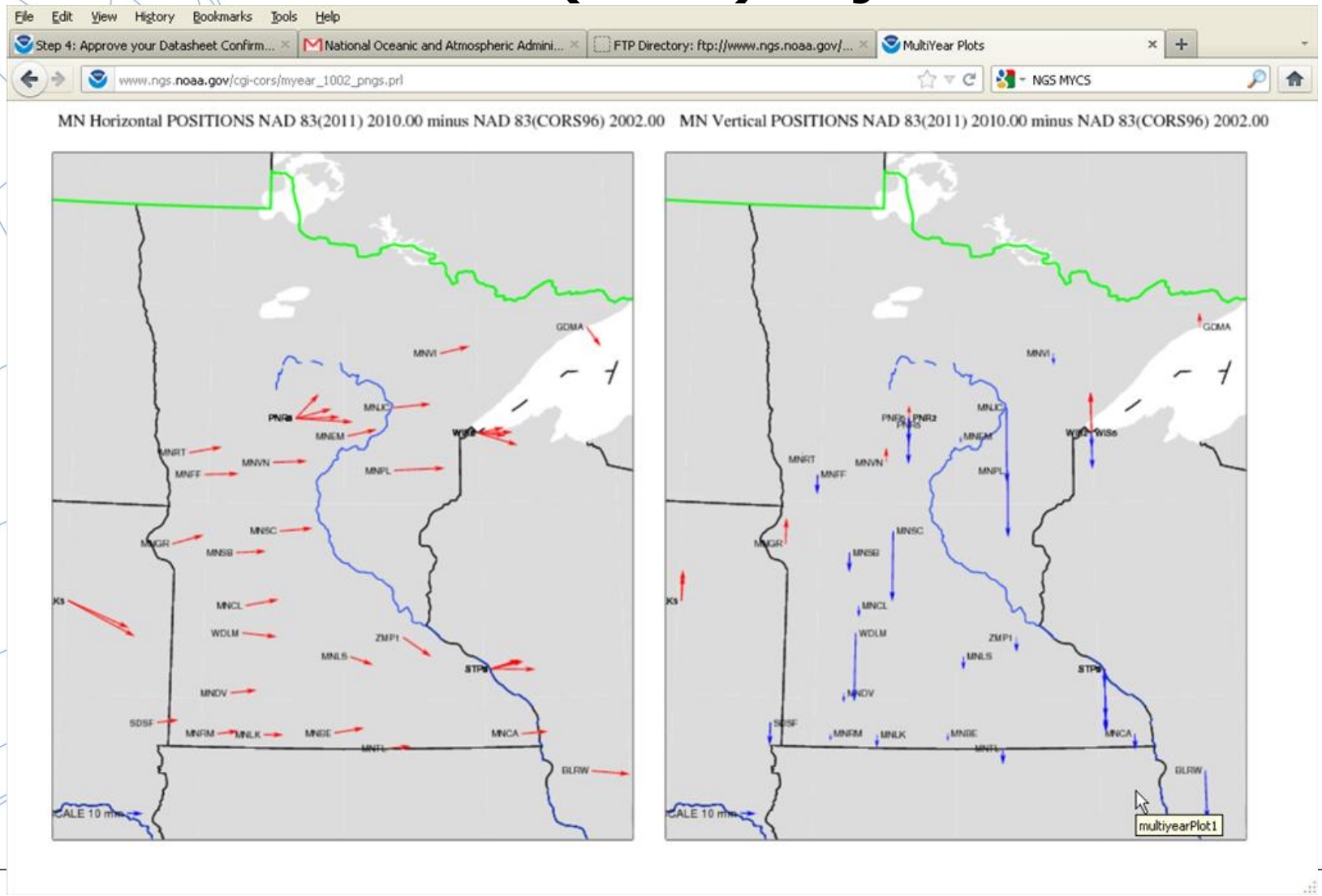
New NAD83(2011) Adjustment



New NAD83(2011) Adjustment



New NAD83(2011) Adjustment



New NAD83(2011) Adjustment

- NAD 83(CORS96) epoch 2002.00 → NAD 83(2011) epoch 2010.00
- Expect overall coordinate change about same as MYCS
  - Horizontal: Mean ~2 cm (±8 cm), median ~0 cm
  - Vertical: Mean ~ -1 cm (±2 cm), median ~ -1 cm
  - This is for change in realization ***and*** reference epoch

New NAD83(2011) Adjustment

- Changes in Ellipsoid Heights mean that a new GEOID Model will be needed.
- New hybrid geoid model (GEOID12)
  - Use NAD 83(2011) epoch 2010.00 ellipsoid heights on NAVD 88 benchmarks
  - Might also use OPUS-Database results on NAVD 88 BMs
  - Plan release same time as NA2011

New NAD83(2011) Adjustment

- Multi-Year CORS Solution
  - Officially released coordinates September 2011
- National Adjustment of 2011
  - Goal: Complete by mid-April 2012
  - Deadline for submitted projects was Aug 31, 2011
- OPUS (Online Positioning User Service)
  - Provides solutions referenced both to previous (CORS96) and new (MYCS) coordinates
  - Dual solutions will be available until NA2011 complete

Example of MN SHIFTS

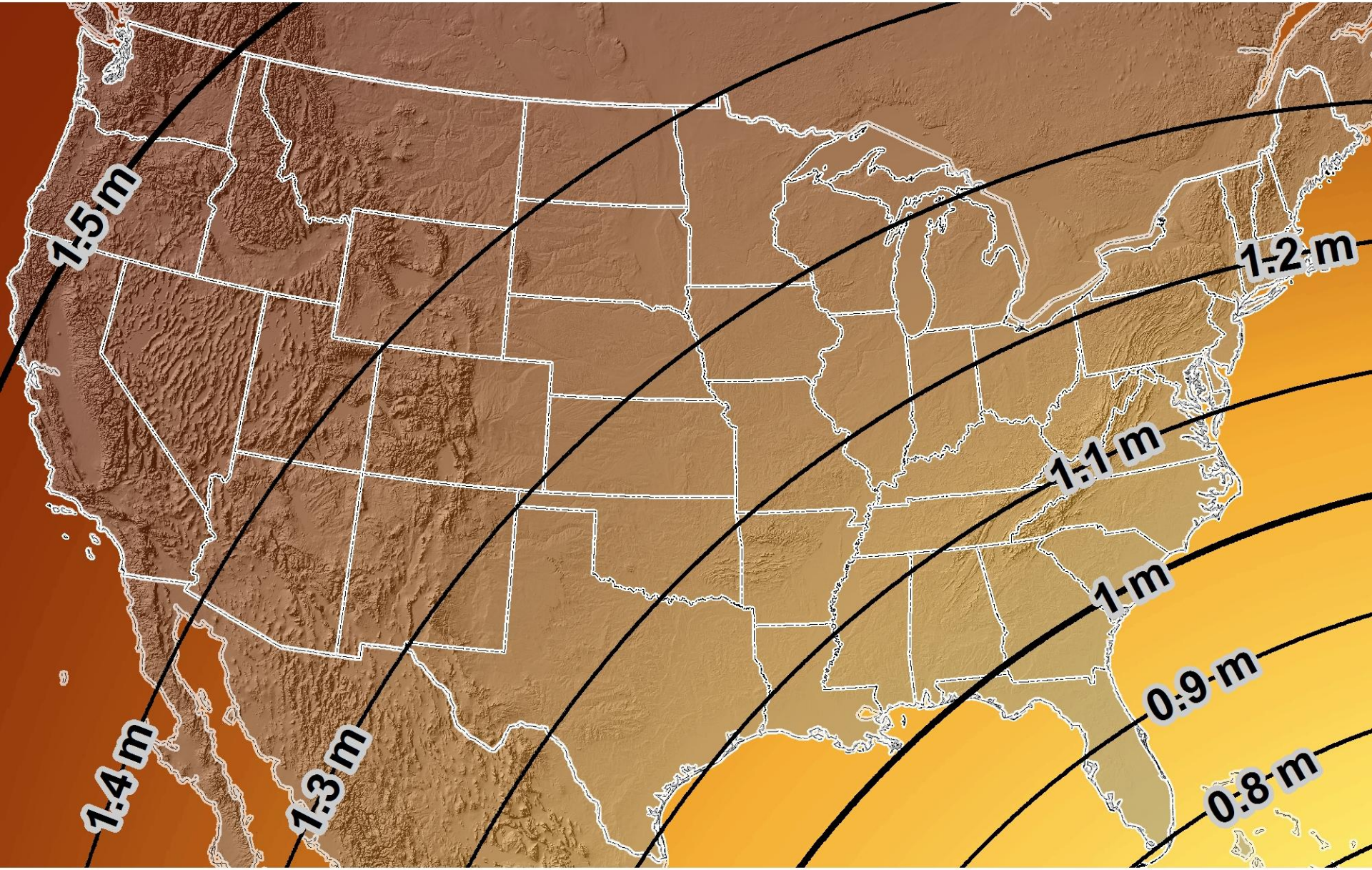
UTM Zone 15 in meters

Station	NAD83(2007)	NAD83(2011)	Difference
ELY - Northing	5306096.855	5306096.831	-0.024 m
ELY - Easting	587259.898	587259.915	0.017 m
ELY - Upping	426.128	426.11	-0.018 m
ERSKINE- Northing	5283196.818	5283196.795	-0.023 m
ERSKINE - Easting	275921.843	275921.857	0.014 m
ERSKINE - Upping	359.368	359.349	-0.019 m
PIPESTONE - Northing	4875689.152	4875689.128	-0.024 m
PIPESTONE - Easting	714434.071	714434.086	0.015 m
PIPESTONE - Upping	502.901	502.887	-0.014 m
WASECA- Northing	4879146.744	4879146.719	-0.025 m
WASECA - Easting	459854.521	459854.536	0.015 m
WASECA - Upping	328.725	328.708	-0.017 m

Future Datum

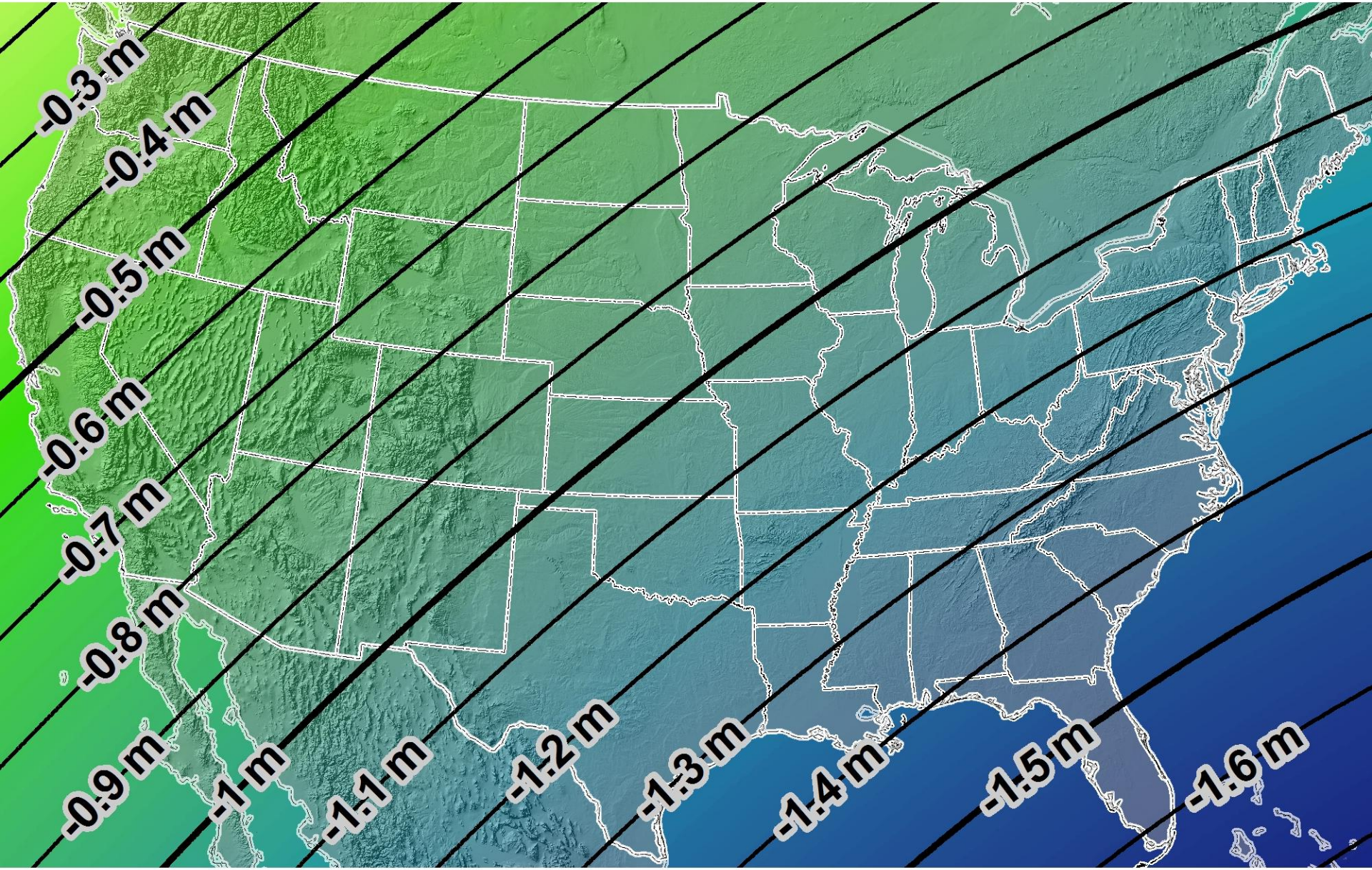
- NGS is planning to release an all-new 3D datum
- Timeline not definite.
- Consider 10 years away.

Estimated horizontal change from NAD 83 to new geometric datum



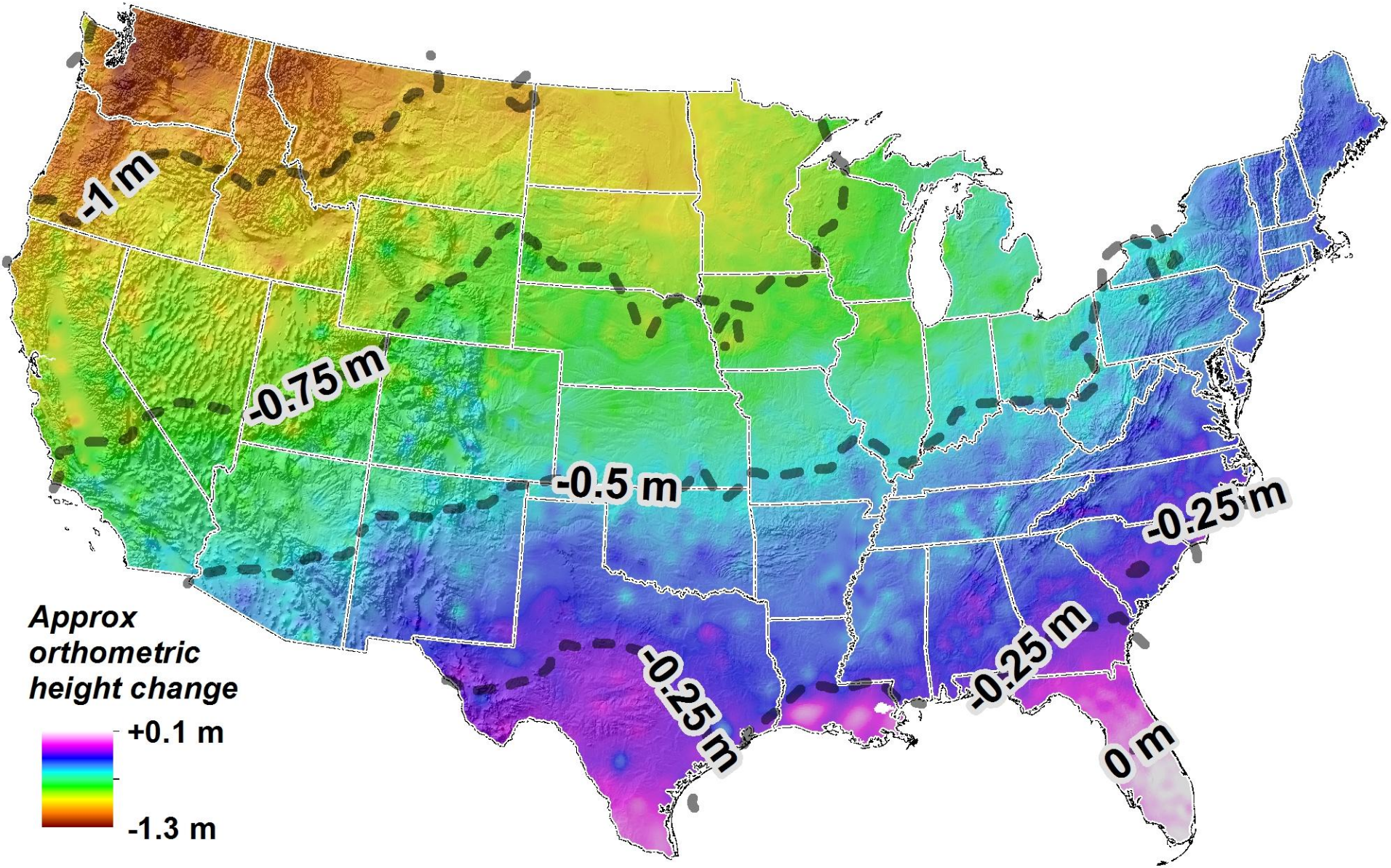
Delta Horizontal = (ITRF 05) minus (NAD 83) at 2020.0

Estimated ellipsoid height change from NAD 83 to new geometric datum



Delta h = h(ITRF 05) minus h(NAD 83) at 2020.0

Approximate predicted change from NAVD 88 to new vertical datum



Predicted change estimated as NAVD 88 "zero" (datum) surface *minus* most recent NGS gravimetric geoid (USGG2009)