

Implementing Height Mod in Minnesota – a 153 Year Journey

Impact of NAD83(2011) and GEOID12A

Dave Zenk

NGS Advisor

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Geodetic History in Minnesota.pdf

- I am working on a document that contains all these slides and a detailed explanation of the various datums and adjustments used over time in Minnesota.
- The finished document will be in PDF format and available from the OLM website.
- I expect it will be linked from here:
- <http://www.dot.state.mn.us/surveying/Geodetics/geodetics.html>

Sequence of Topics

- I plan to cover the topics in this order:
 - Mark Setting History by Decade and Agency
 - Horizontal Datums and Shifts
 - Vertical Datums and Shifts
 - GEOID Models and Shifts
 - Height Modernization Benefits

Mark Setting History by Decade and Agency

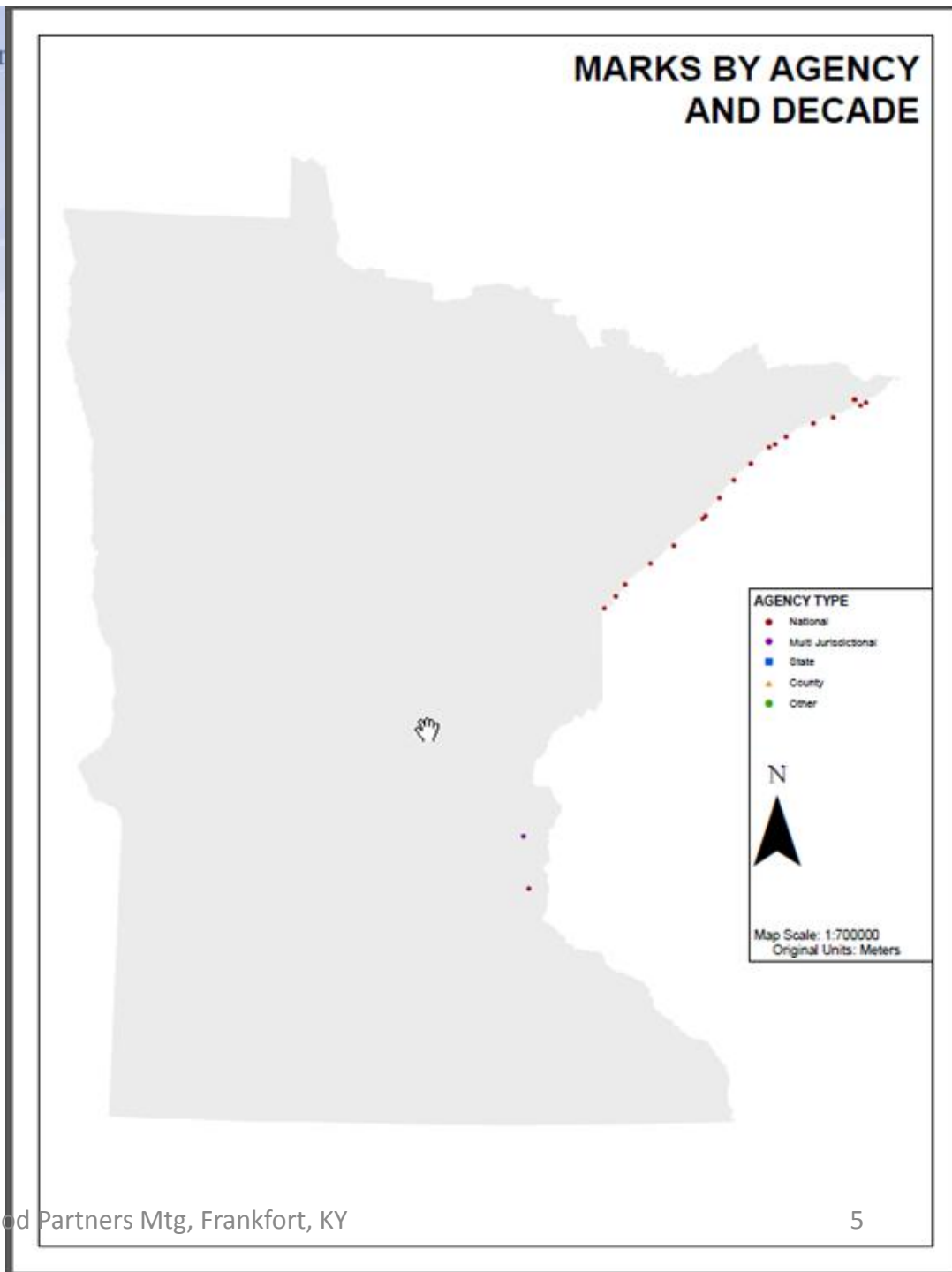
- The next 16 slides show how the Minnesota Geodetic Network grew to its current form.
- 79069 geodetic marks as of March 1, 2013.

Mark Setting History Decade and Agency

- 1860 to 1869

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

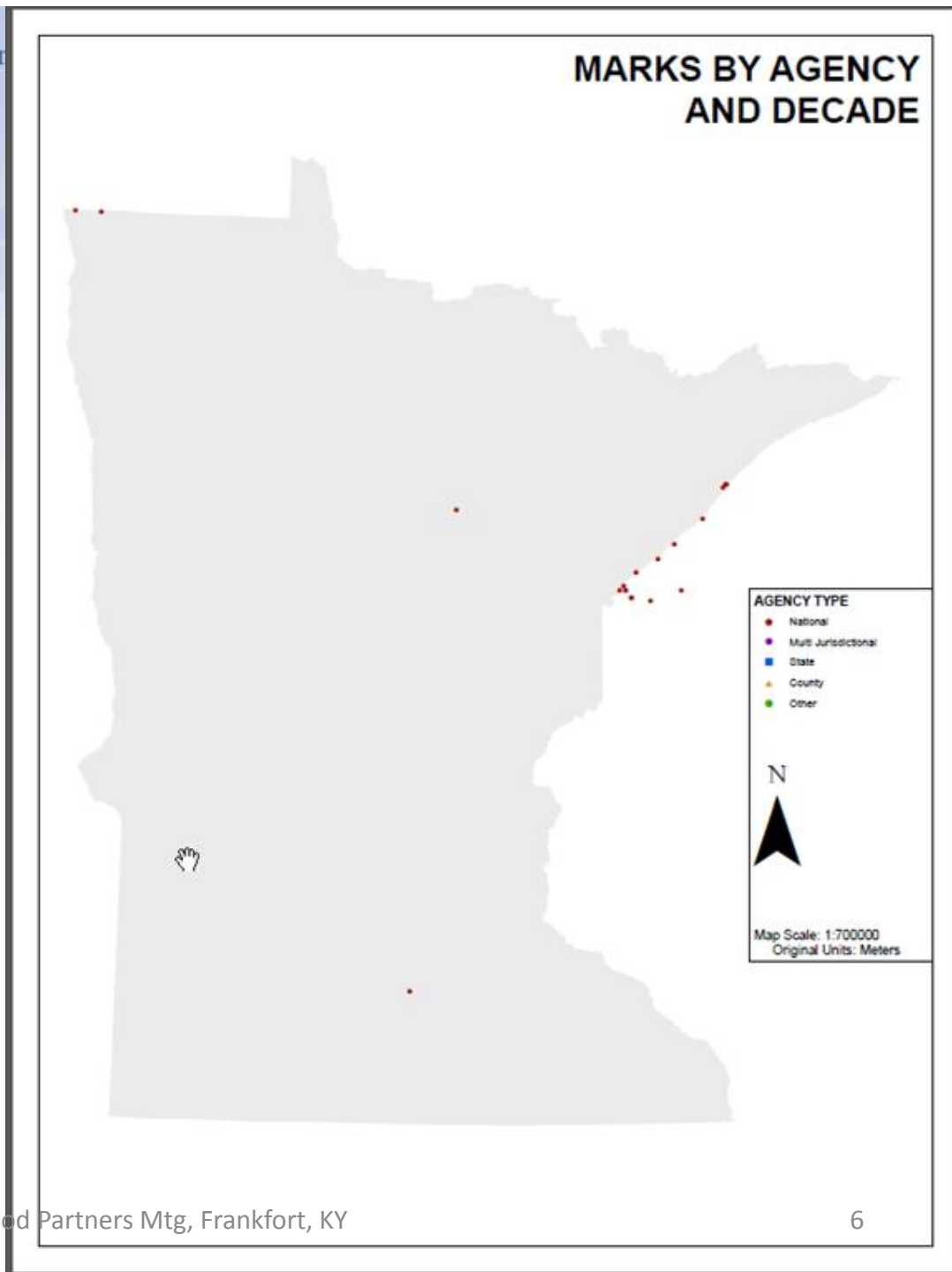


Mark Setting History Decade and Agency

- 1870 to 1879

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

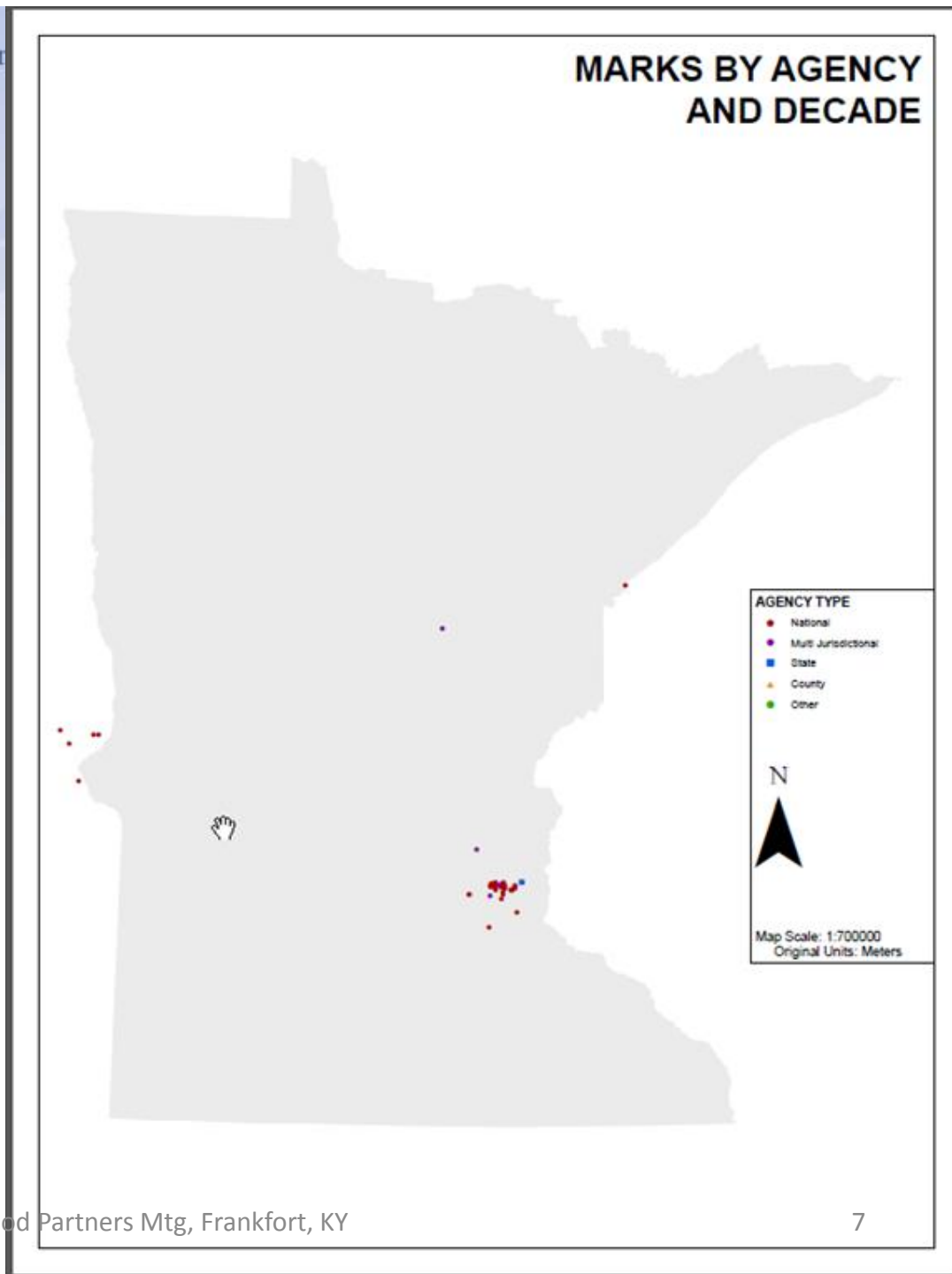


Mark Setting History Decade and Agency

- 1880 to 1889

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

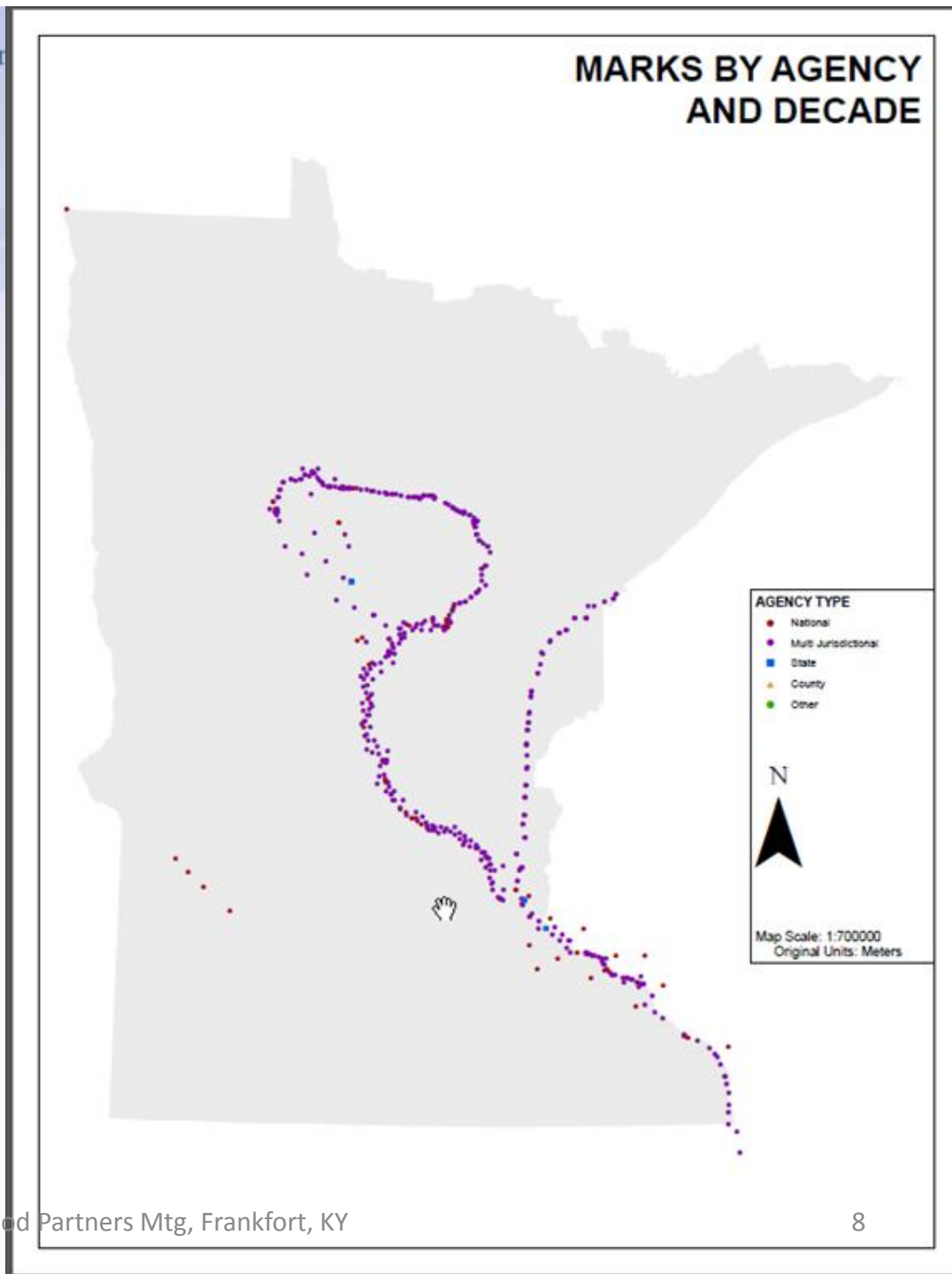


Mark Setting History Decade and Agency

- 1890 to 1899

AGENCY TYPE

- National
- Multi Jurisdictional
- State
- County
- Other

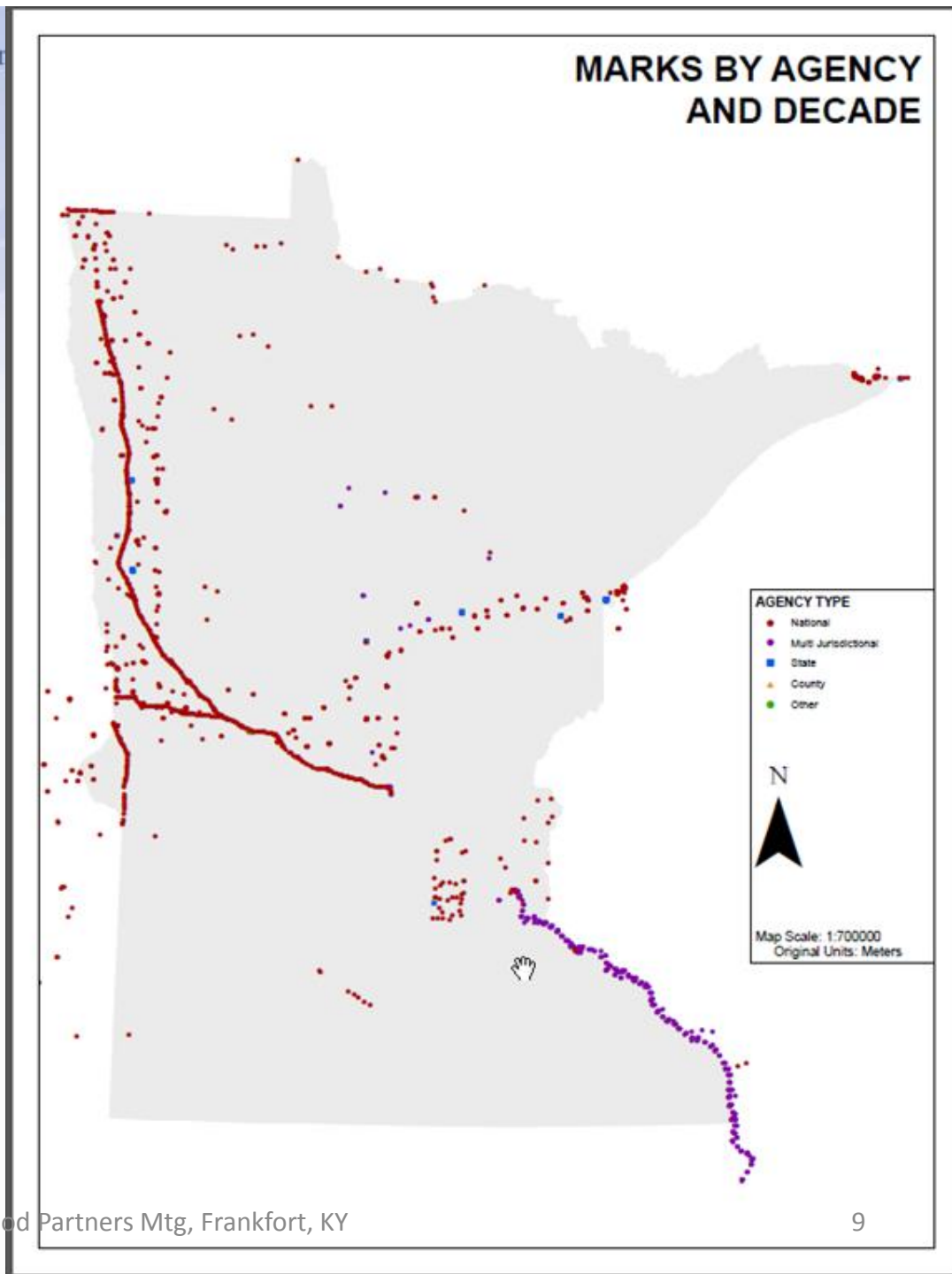


Mark Setting History Decade and Agency

- 1900 to 1909

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

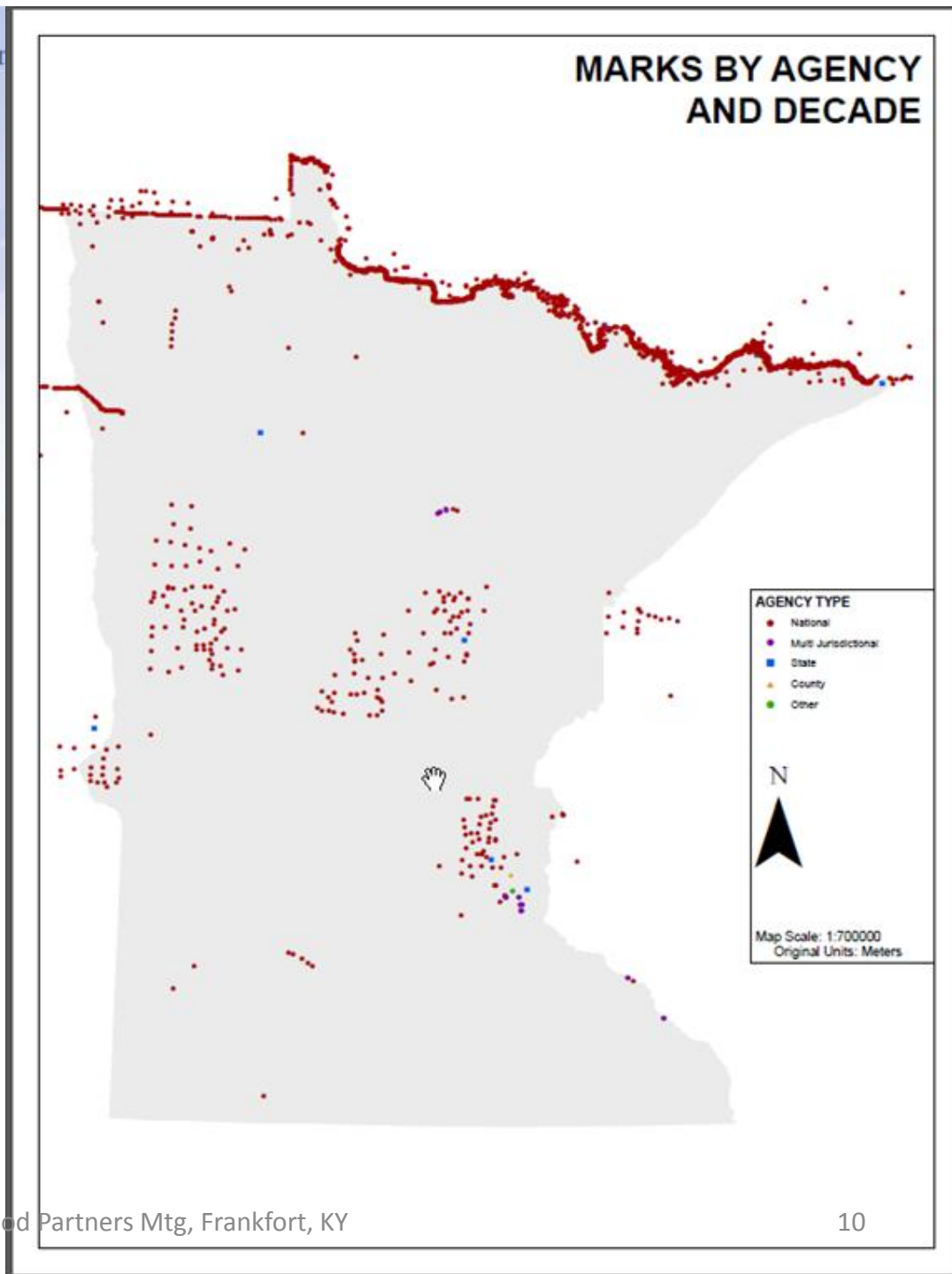


Mark Setting History Decade and Agency

- 1910 to 1919

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

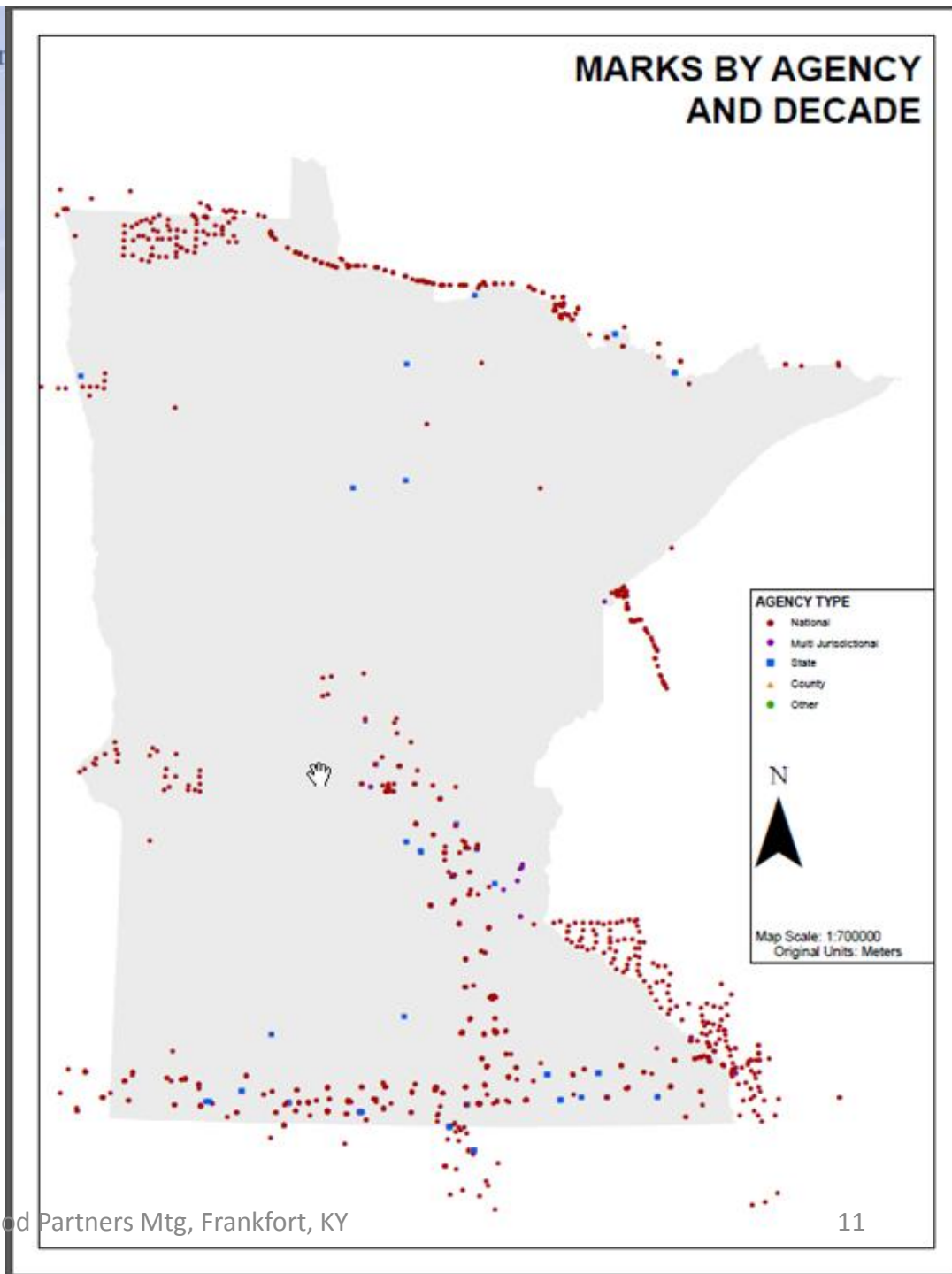


Mark Setting History Decade and Agency

- 1920 to 1929

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

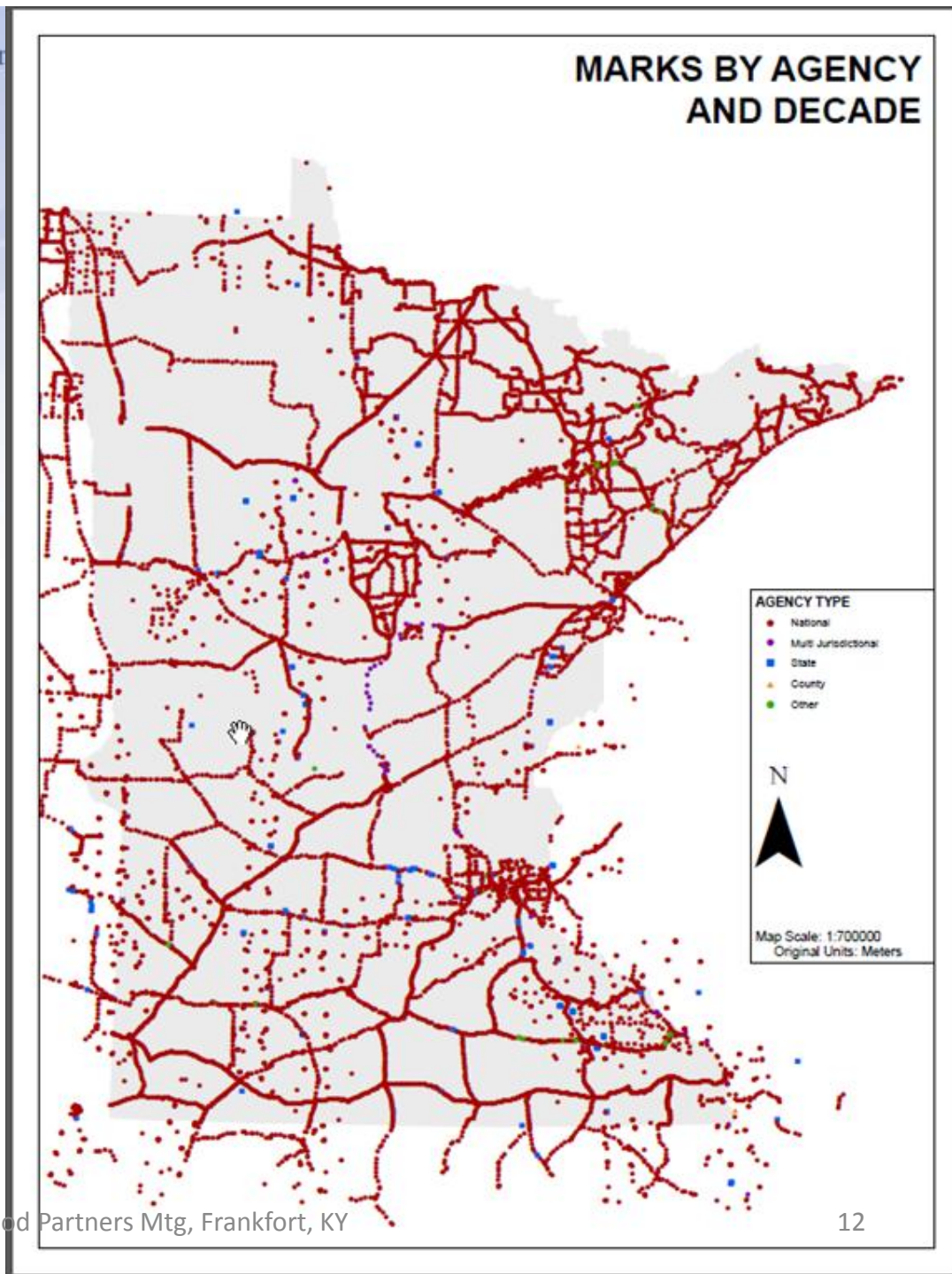


Mark Setting History Decade and Agency

- 1930 to 1939

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

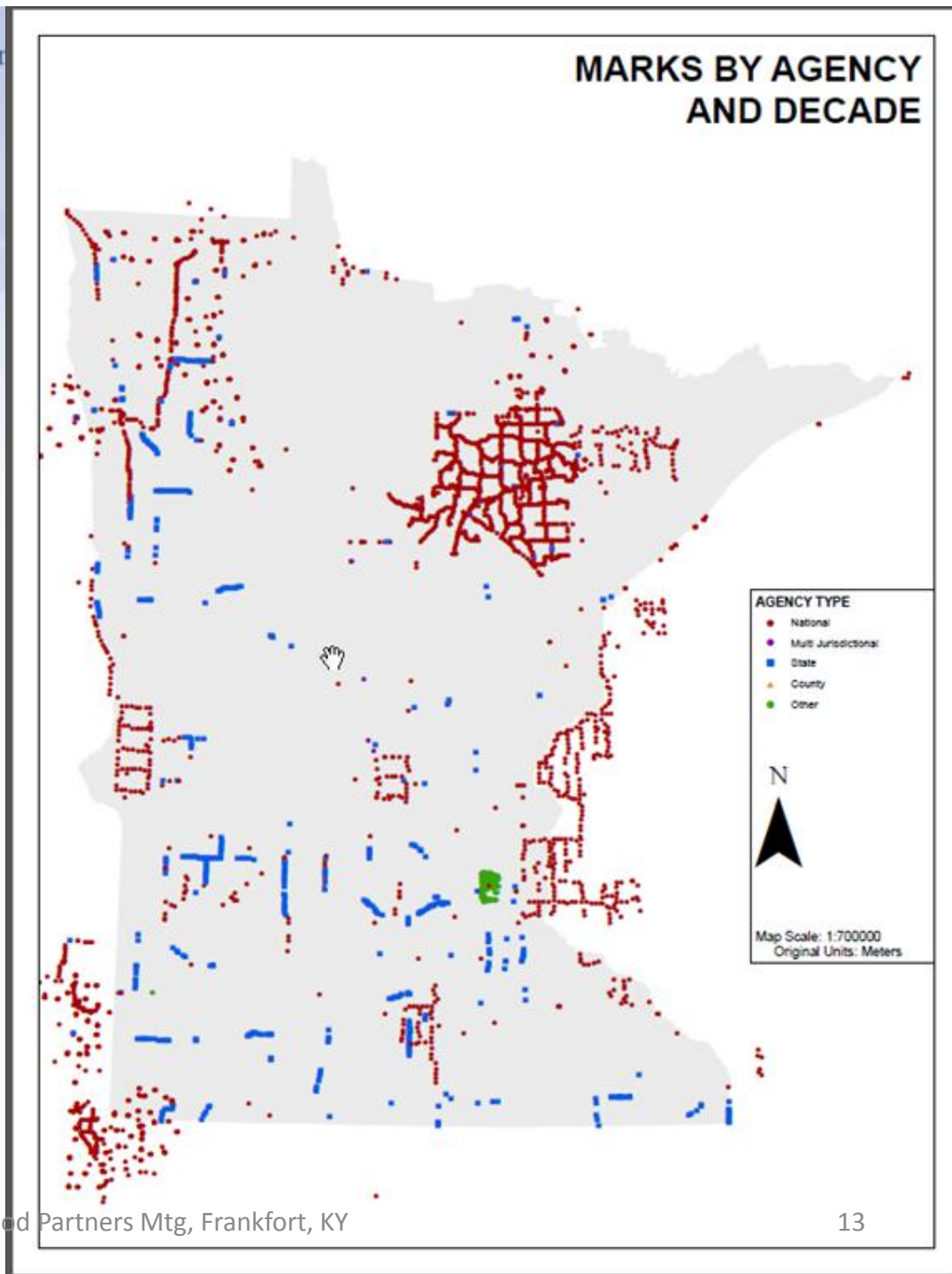


Mark Setting History Decade and Agency

- 1940 to 1949

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

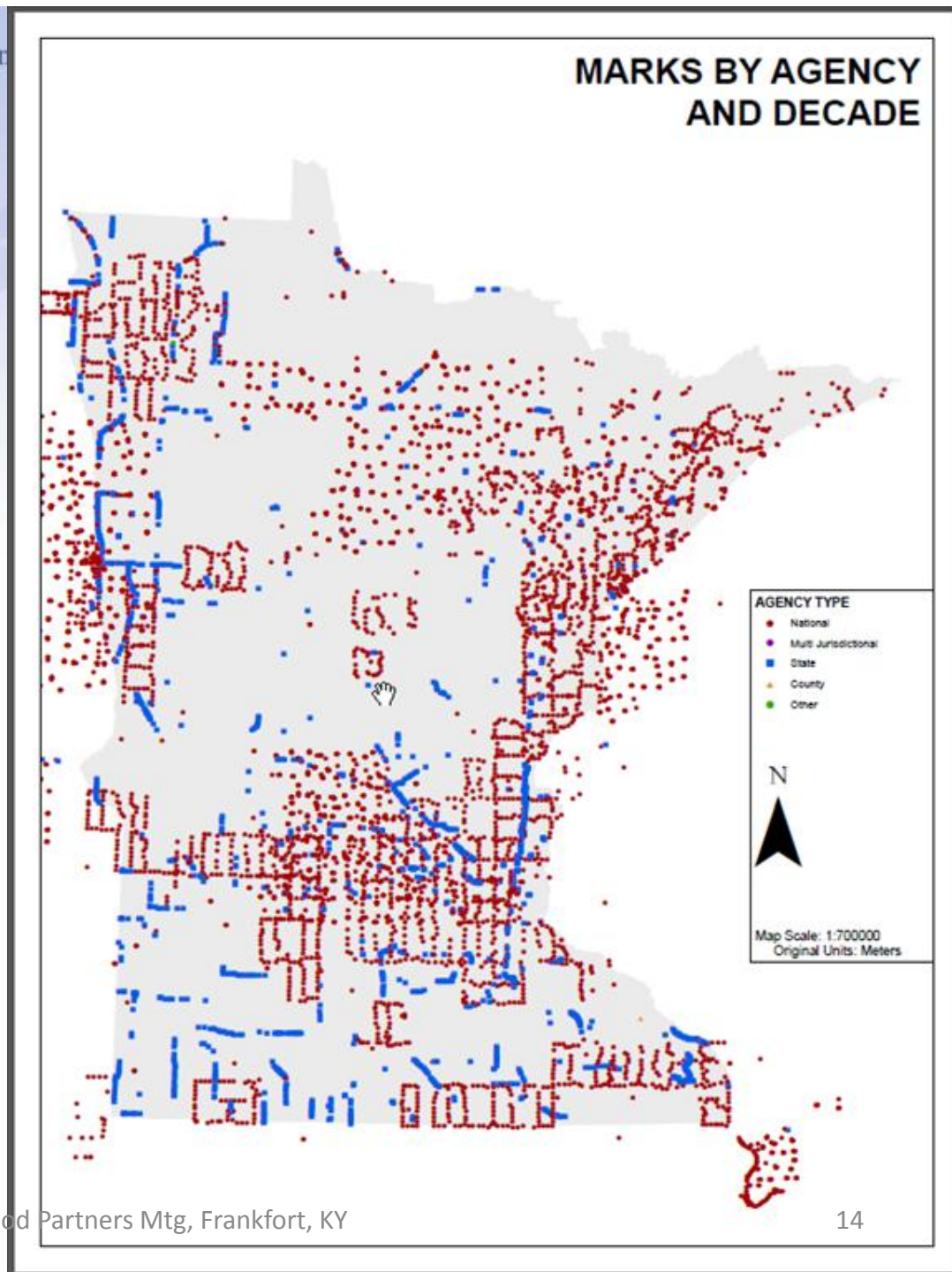


Mark Setting History Decade and Agency

- 1950 to 1959

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

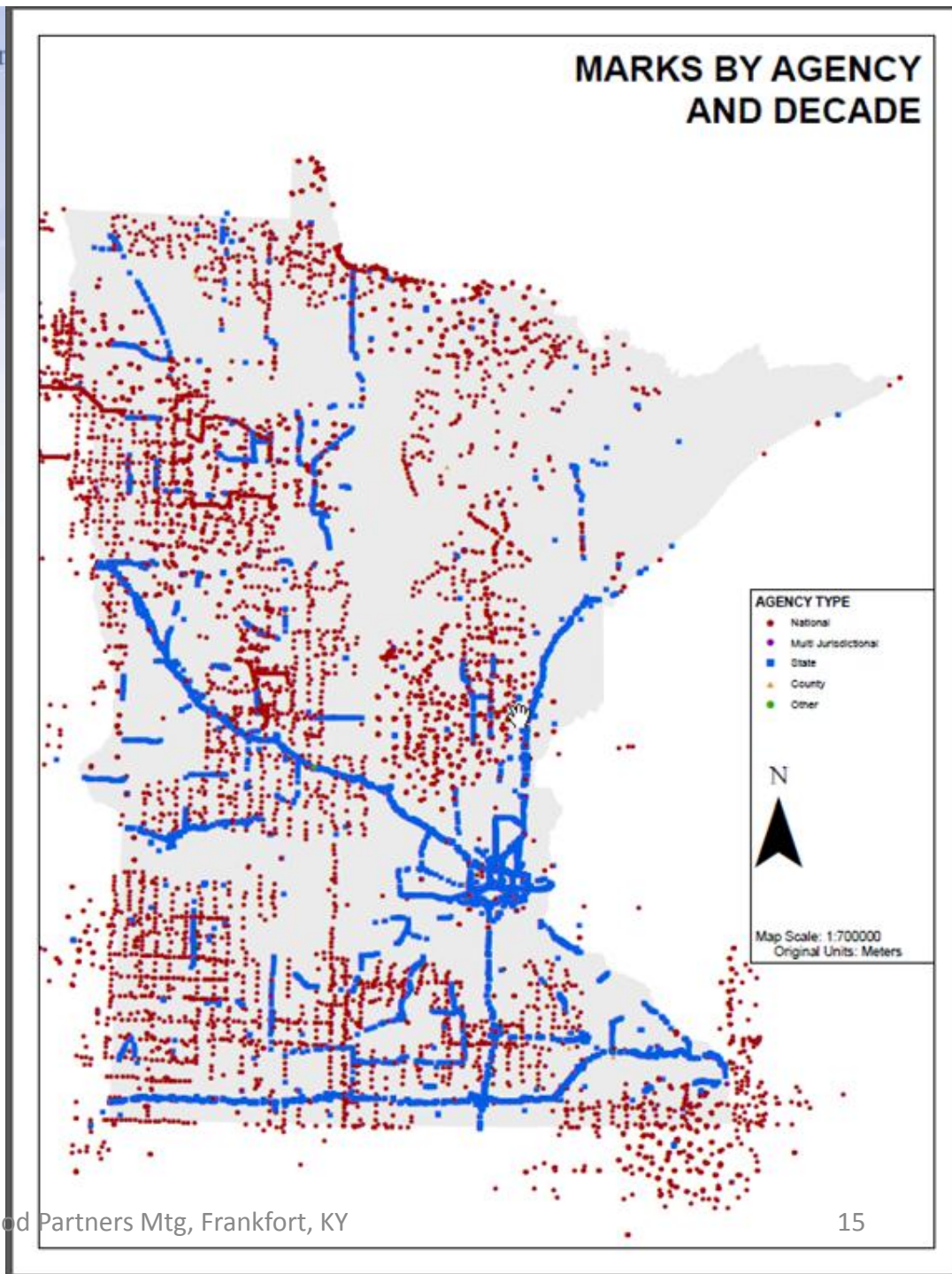


Mark Setting History Decade and Agency

- 1960 to 1969

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

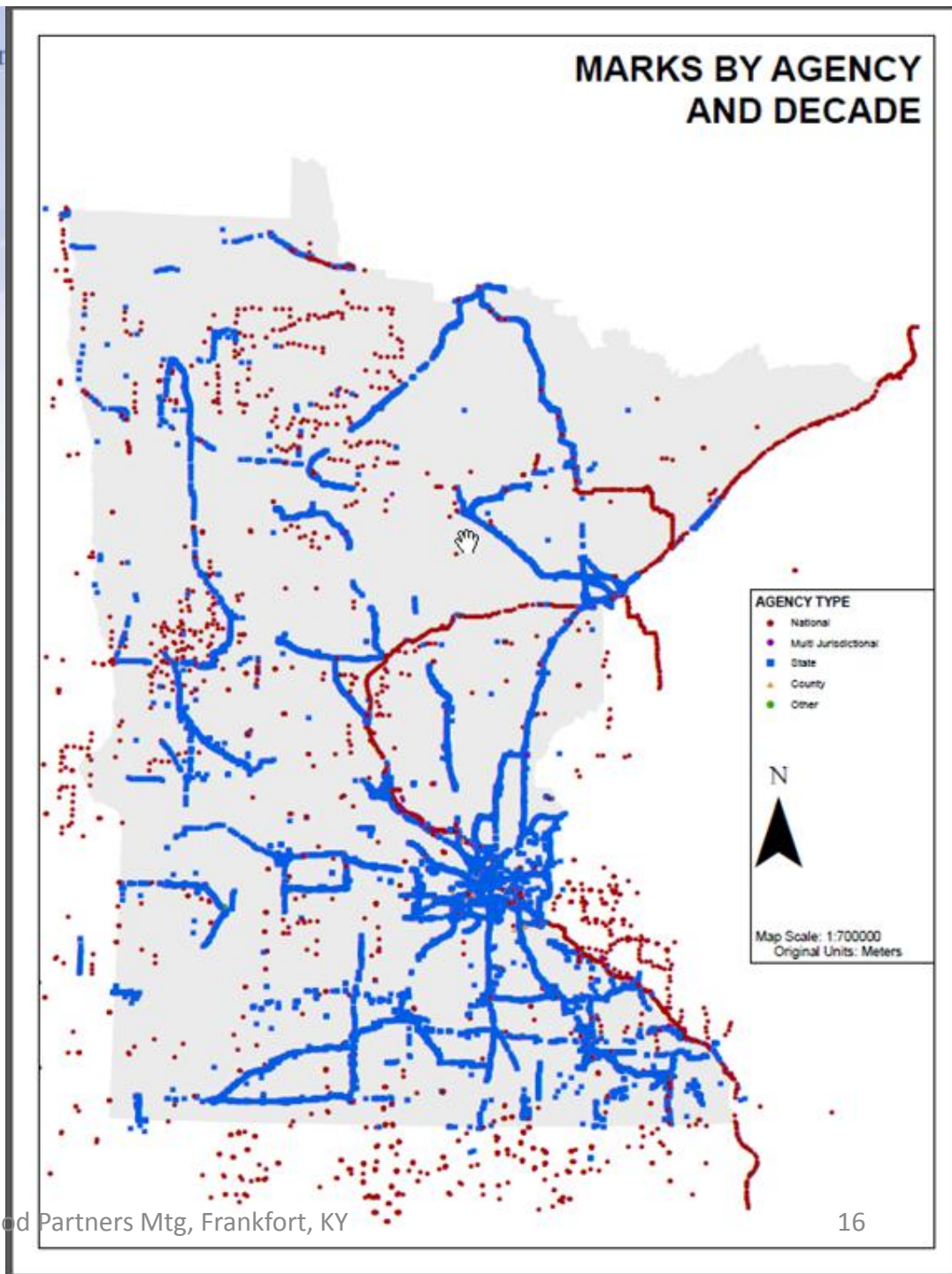


Mark Setting History Decade and Agency

- 1970 to 1979

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

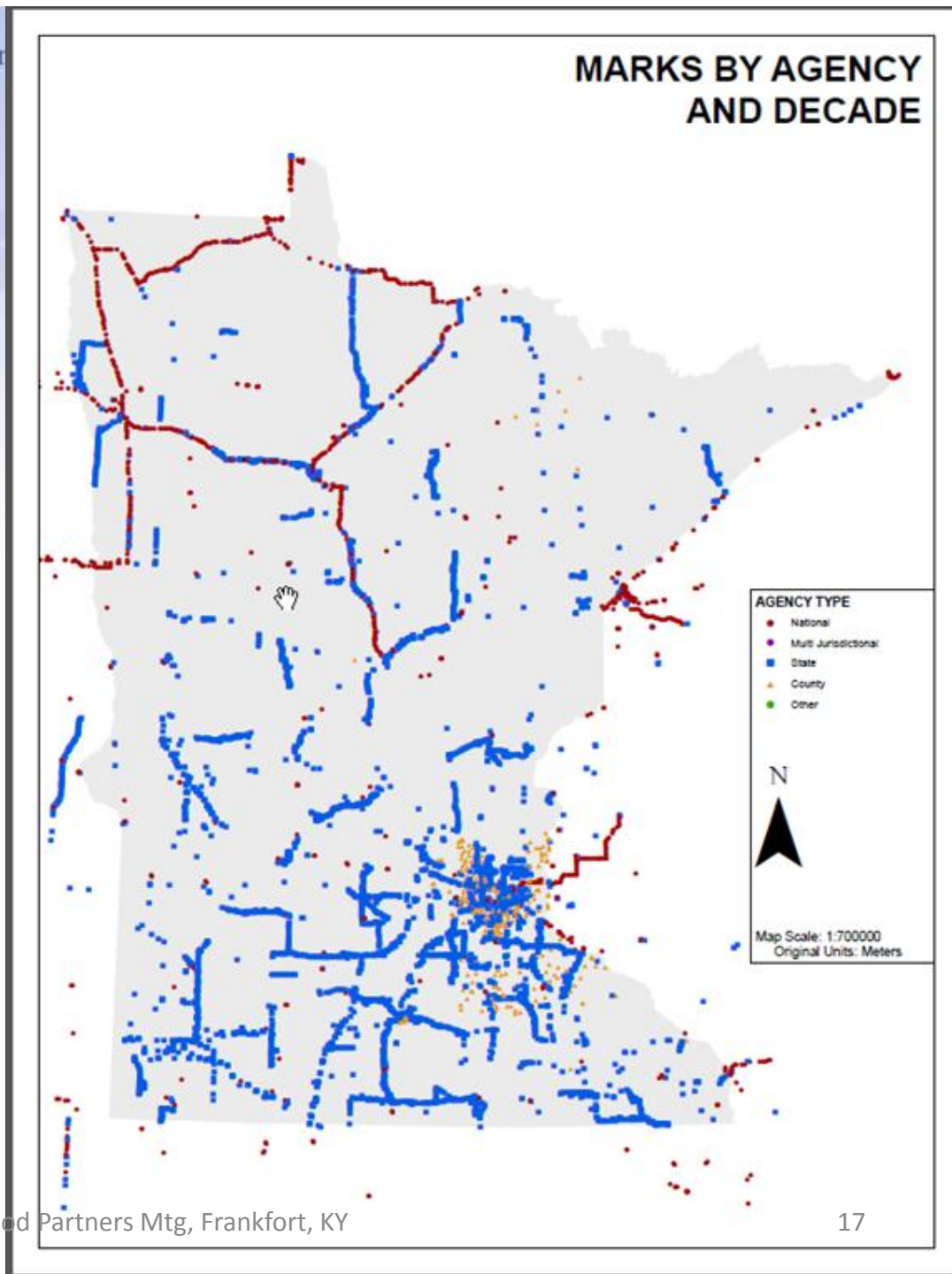


Mark Setting History Decade and Agency

- 1980 to 1989

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

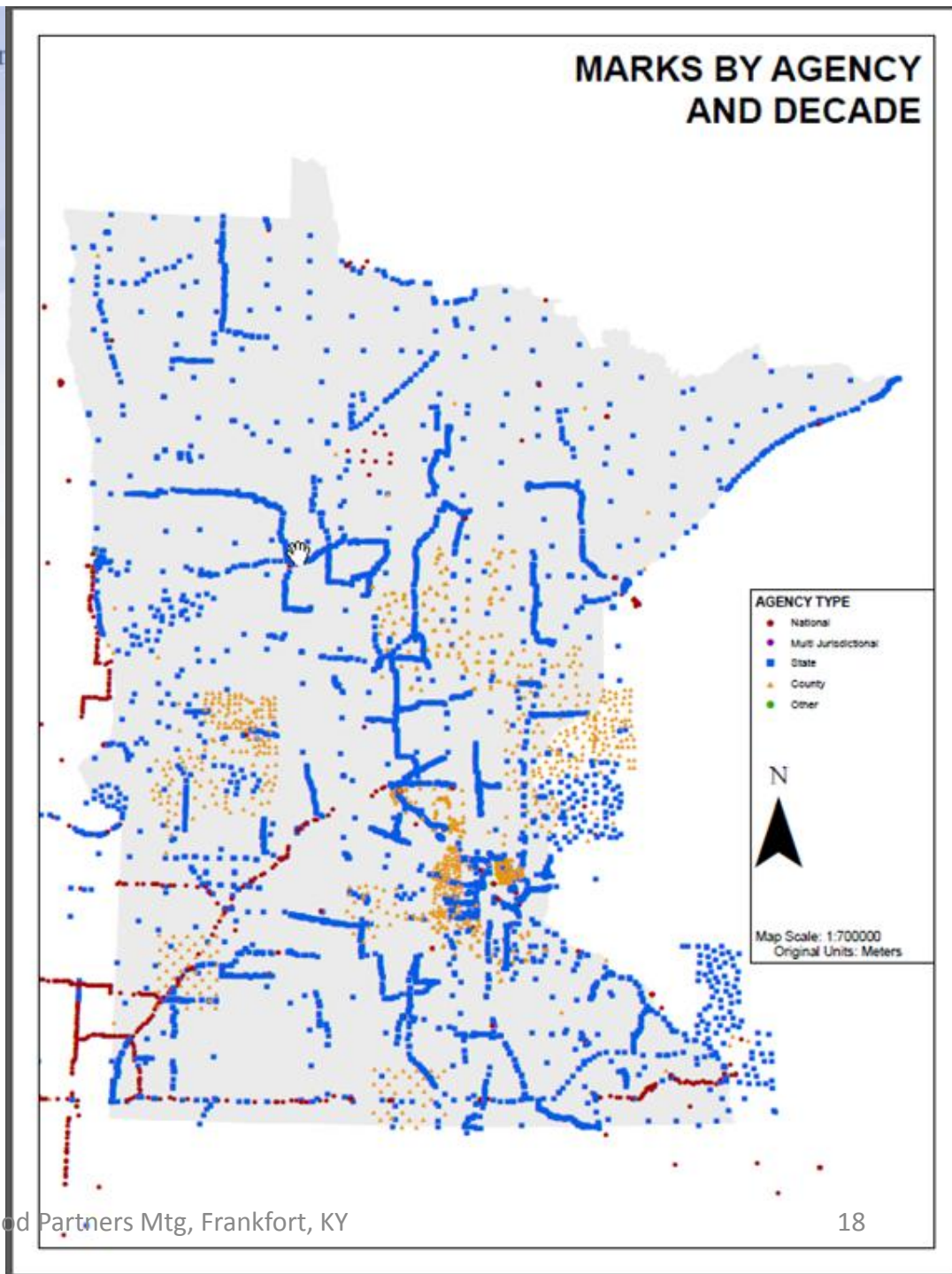


Mark Setting History Decade and Agency

- 1990 to 1999

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

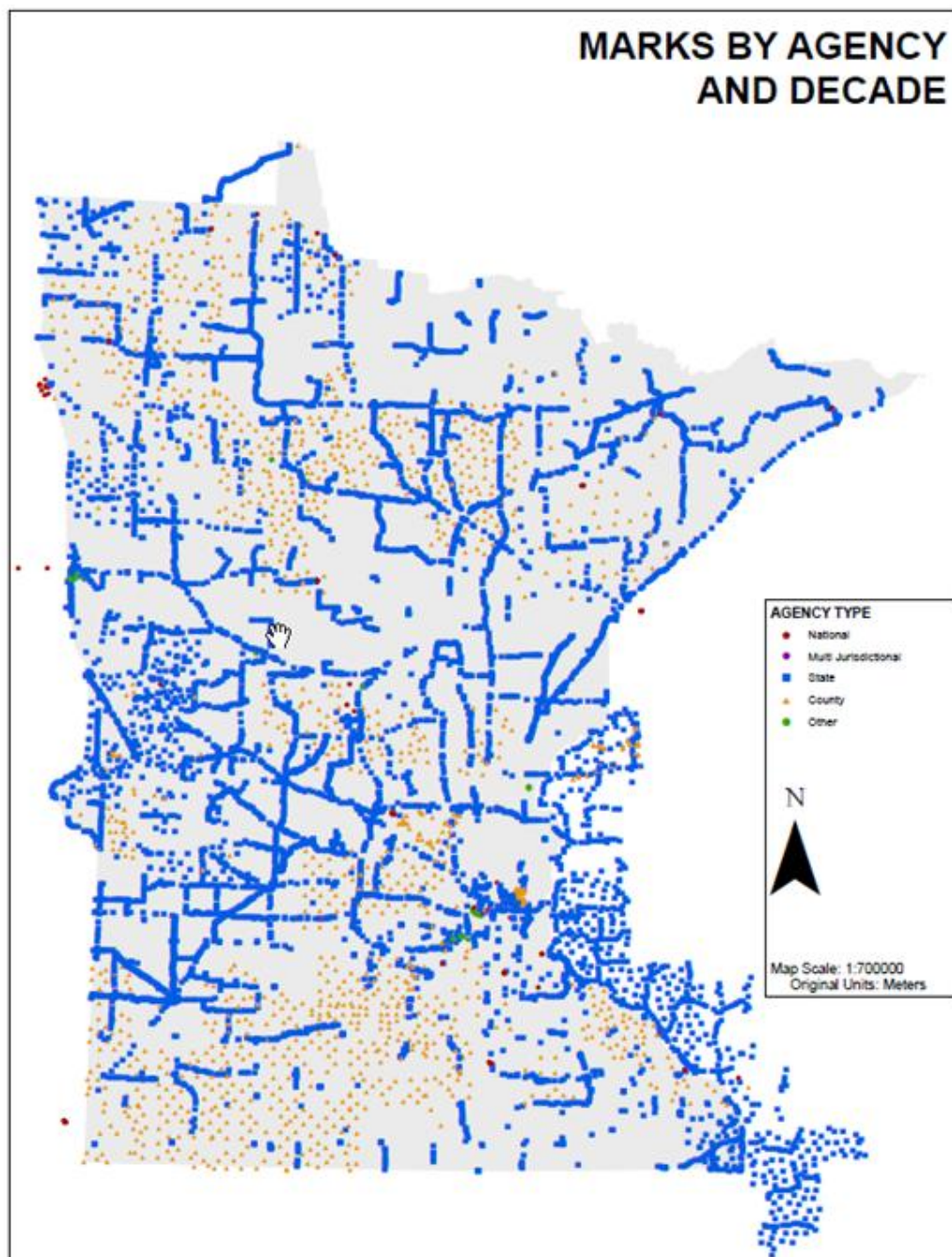


Mark Setting History Decade and Agency

- 2000 to 2009

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

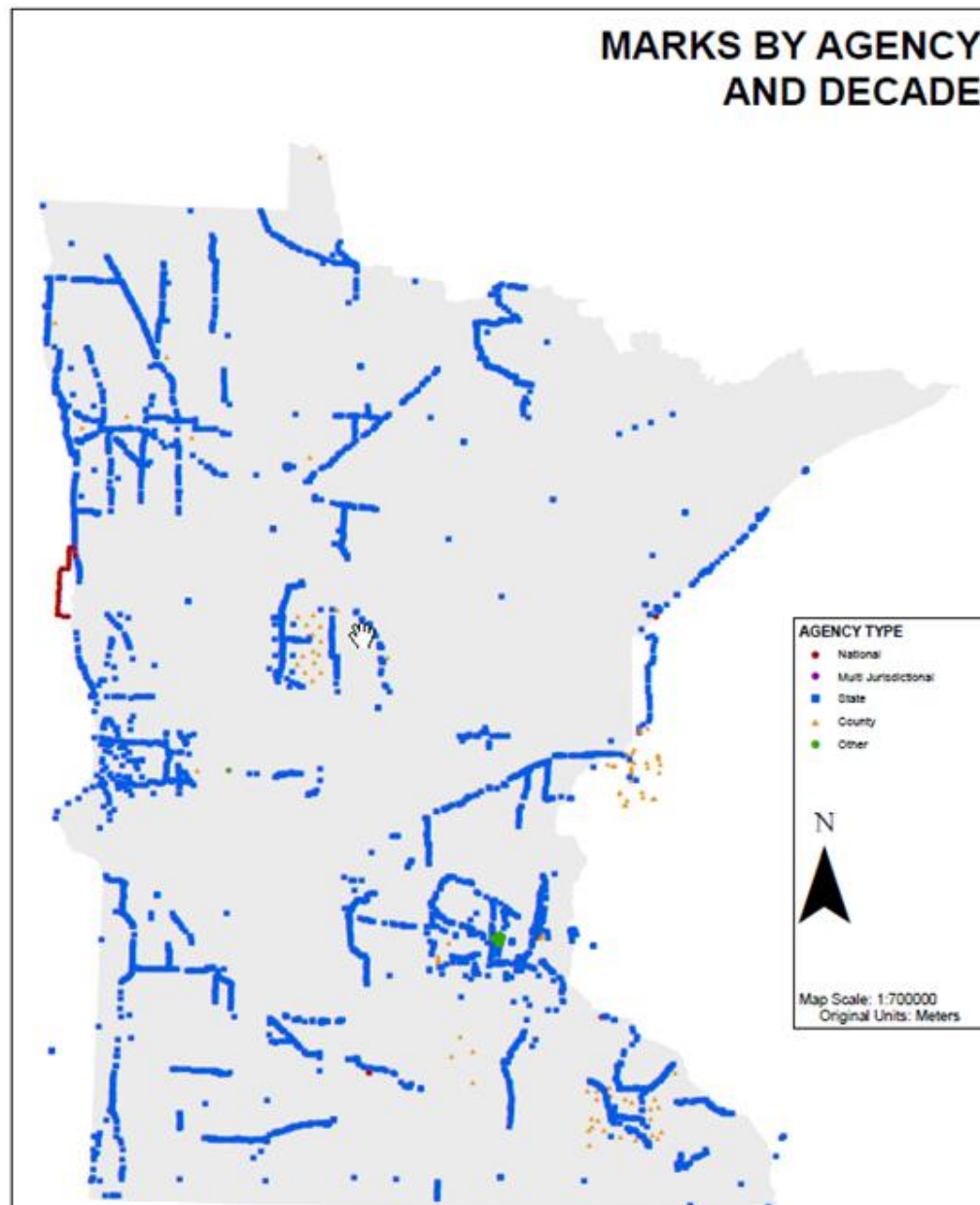


Mark Setting History Decade and Agency

- 2010 to 2013

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other

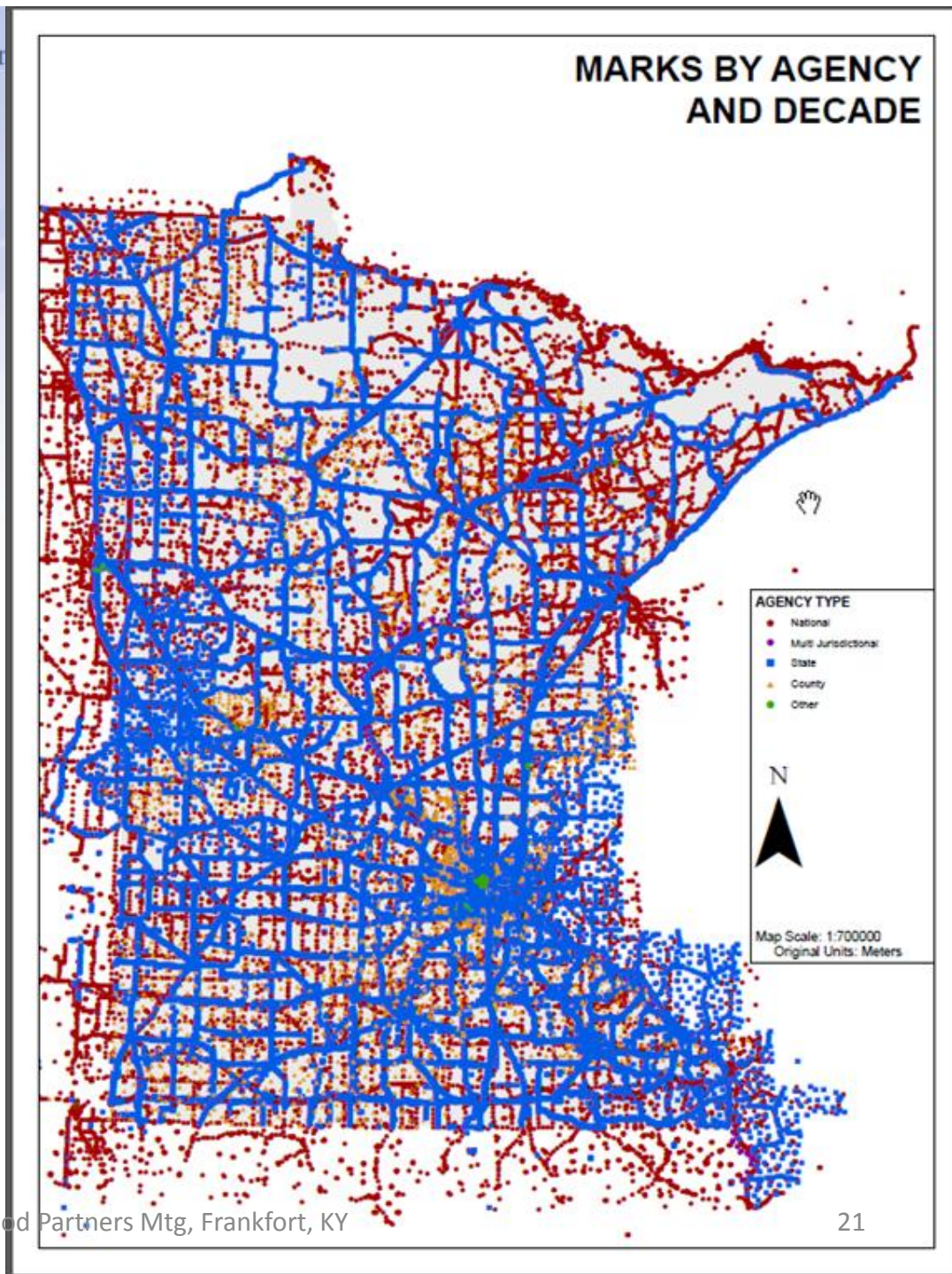


Mark Setting History Decade and Agency

- 1860 to 2013

AGENCY TYPE

- ◆ National
- ◆ Multi Jurisdictional
- State
- ▲ County
- Other



Horizontal Datums and Shifts

- There have been several horizontal datums in the United States that affect Minnesota
 - US Standard Datum (only 384 marks in MN)
 - NAD27
 - NAD83

Horizontal Datums and Shifts

- The coordinates of a mark are determined in an adjustment.
- NAD83 has had new data added over time and several adjustments have been made to incorporate it.
 - NAD83(1986) the “original” adjustment
 - NAD83(1996) the so-called HARN adjustment
 - NAD83(2007) never mind
 - NAD83(2011) the one we’ve been waiting for

Horizontal Datums and Shifts

- A word about WGS84
- WGS84 is the datum within which the GPS satellite orbits are expressed.
- Back in 1986, NAD83 = WGS84
- Then science found that the center-of-mass of the Earth was not where we had thought it to be.

Horizontal Datums and Shifts

- In GPS weeks G730, G873, G1150, the DoD altered WGS84 to follow the science, leaving NAD83 glued to the surface of North America.
- There is now about 2 meters between the center of WGS84 and NAD83.
- SOMEDAY (maybe 2022?) NGS will develop an all-new datum – both HOR and VERT
- Please remember $WGS84 \neq NAD83$
 - Coordinate difference about 1.2 meters NW-SE

Horizontal Datums and Shifts

- Many people have asked me to portray the differences between each of these adjustments, so they can understand what to expect in coordinate comparisons
 - NAD27 -> NAD83(1986)
 - NAD83(1986) -> NAD83(1996)
 - NAD83(1996) -> NAD83(2007)
 - NAD83(2007) -> NAD83(2011)

Horizontal Datums and Shifts

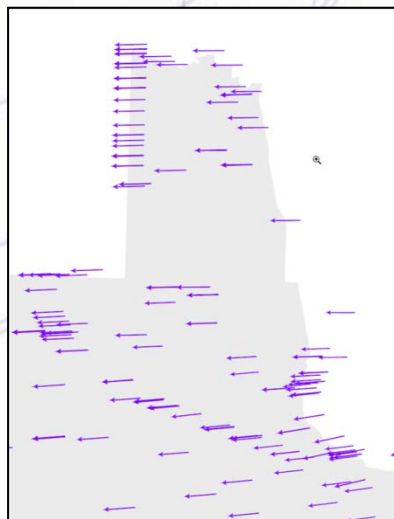
- Each shift has 2 components
 - Azimuth and Distance
- Each map shows an arrow scaled to the shift and pointing from OLD to NEW
- Azimuths are becoming less variable and the amount of shift is decreasing over time, indicating a convergence toward correctness and consistency.

Horizontal Datums and Shifts

- In the following maps, I will show the whole map, along with a detailed inset.
- I note that a finished PDF will contain these maps and users will be able to ZOOM IN to see the detail in their area of interest.
- <http://www.dot.state.mn.us/surveying/Geodetics/geodetics.html>

Horizontal Datums and Shifts

- NAD27 -> NAD83(1986)



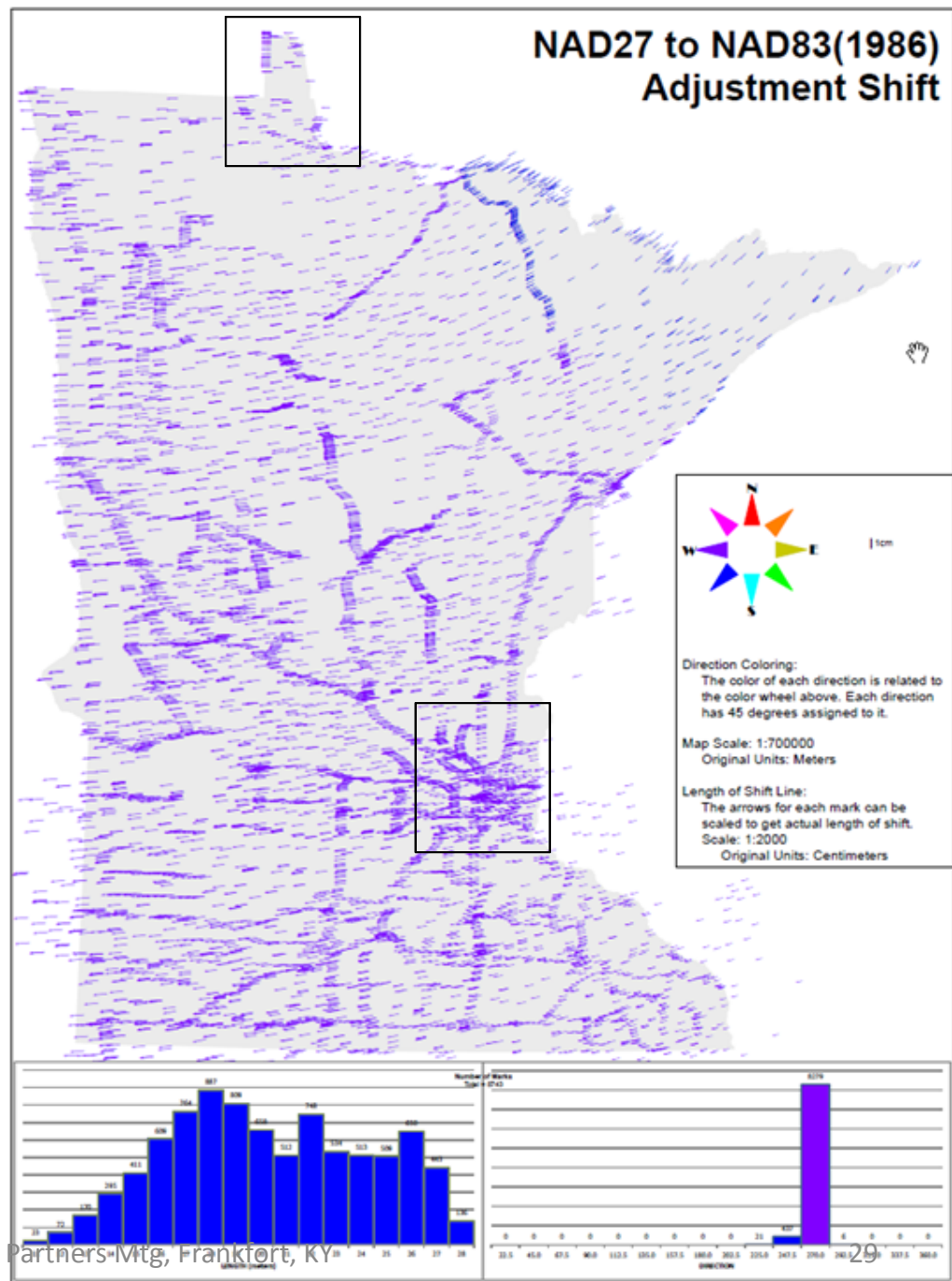
NW Angle



Metro

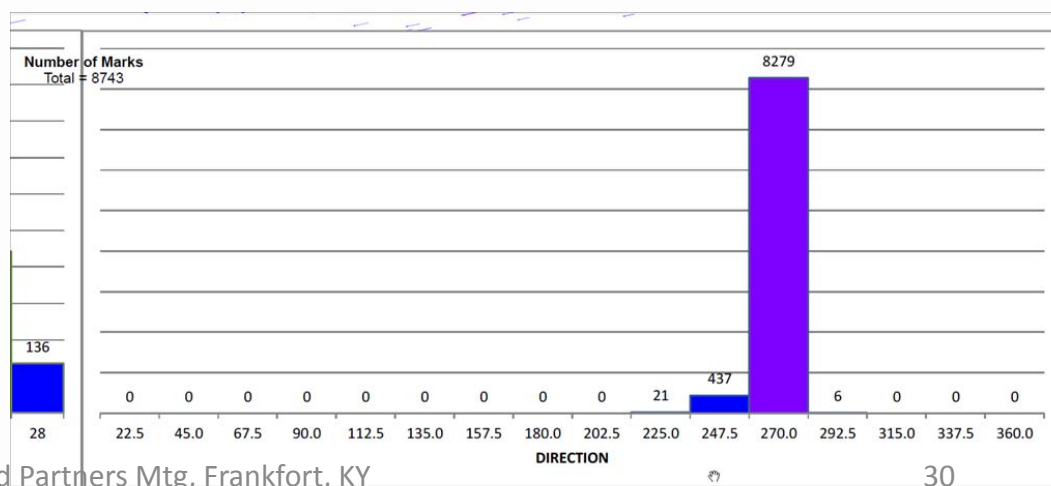
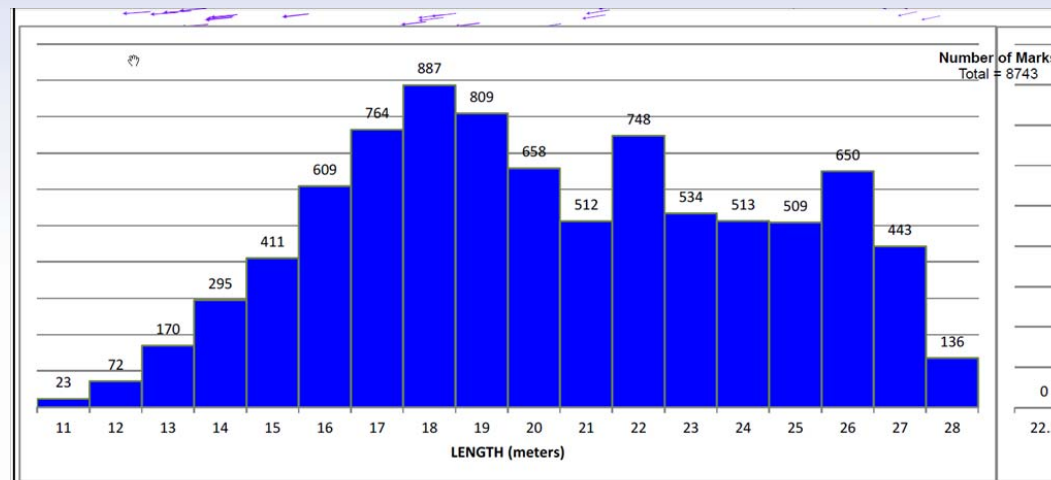
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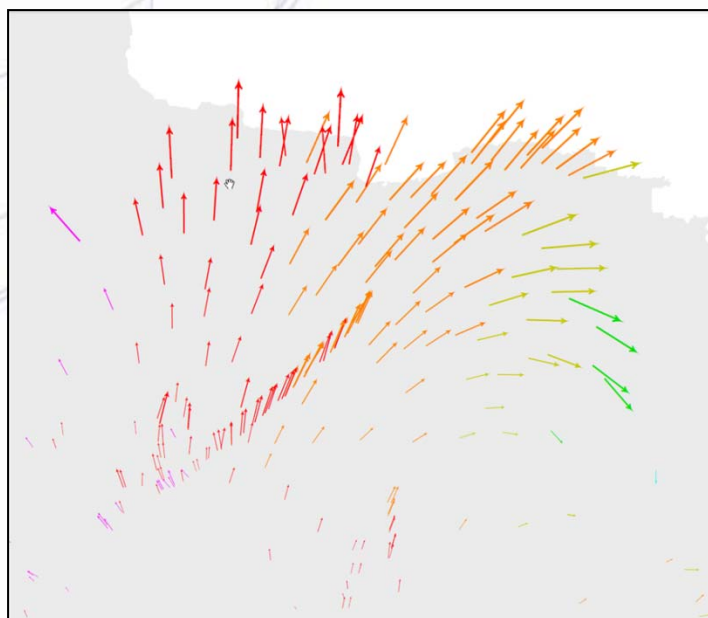
Horizontal Datums and Shifts

- NAD27 -> NAD83(1986)
- 8743 marks
- Shifts of 11 to 28 meters
- Very consistent azimuth



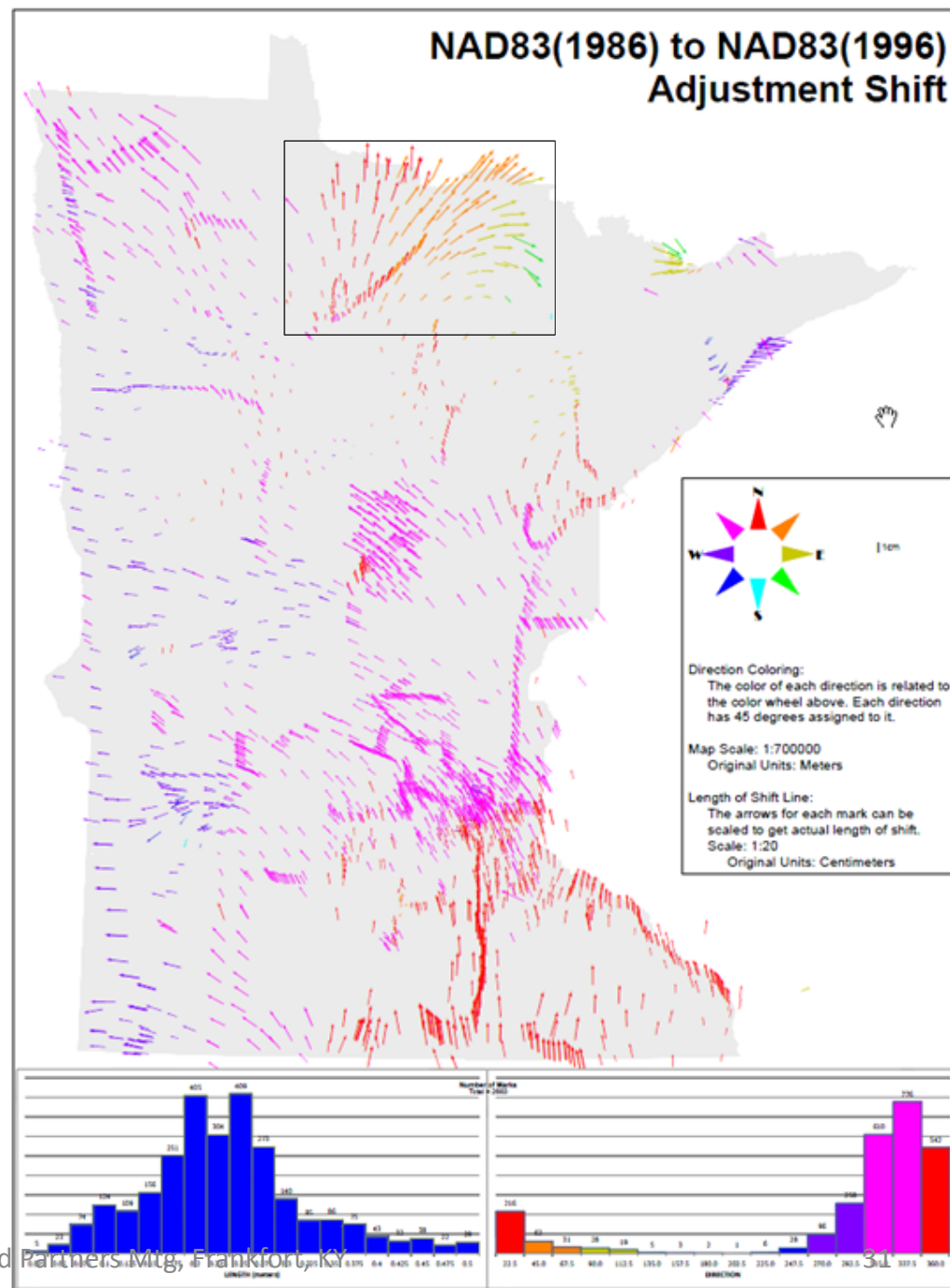
Horizontal Datums and Shifts

- NAD83(1986) -> NAD83(1996)
- 2683 marks
- Shifts of 0 to 0.5 meters
- Azimuth vary from 270 to 22



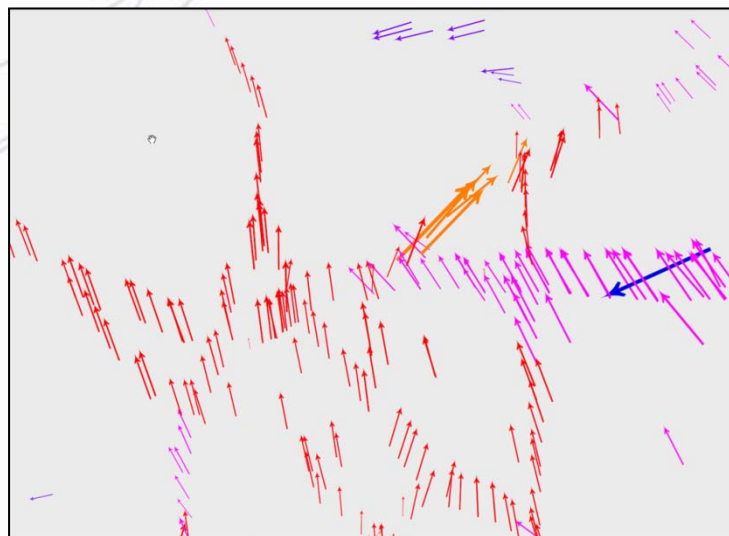
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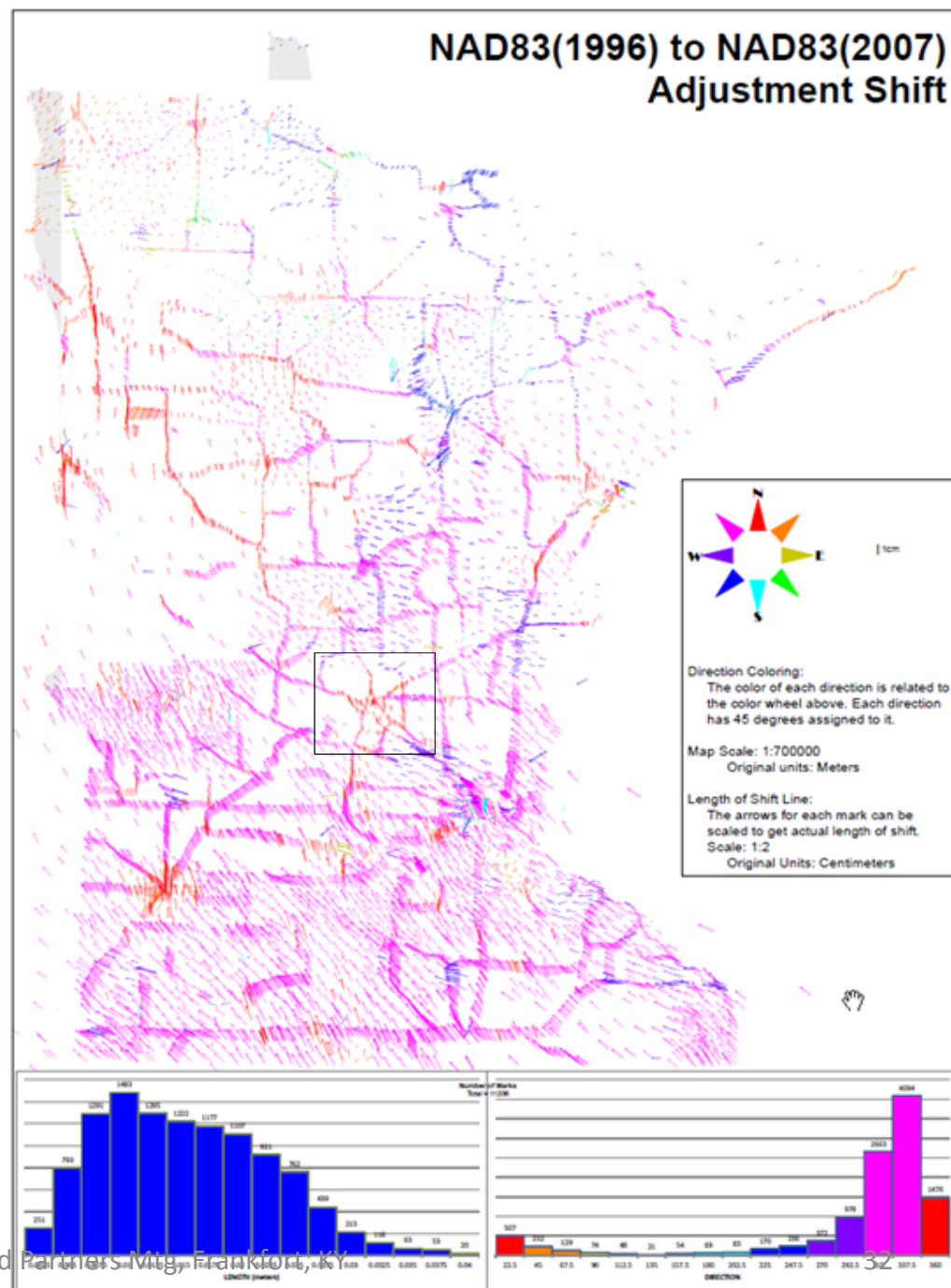
Horizontal Datums and Shifts

- NAD83(1996) -> NAD83(2007)
- 11206 marks
- Shifts of 0 to 0.04 meters
- Azimuth vary from 270 to 22
- Aberrations due to underlying error in previous adjustments.



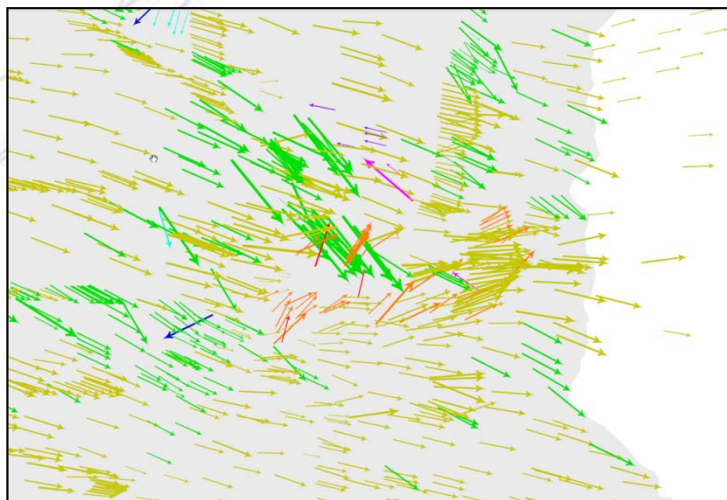
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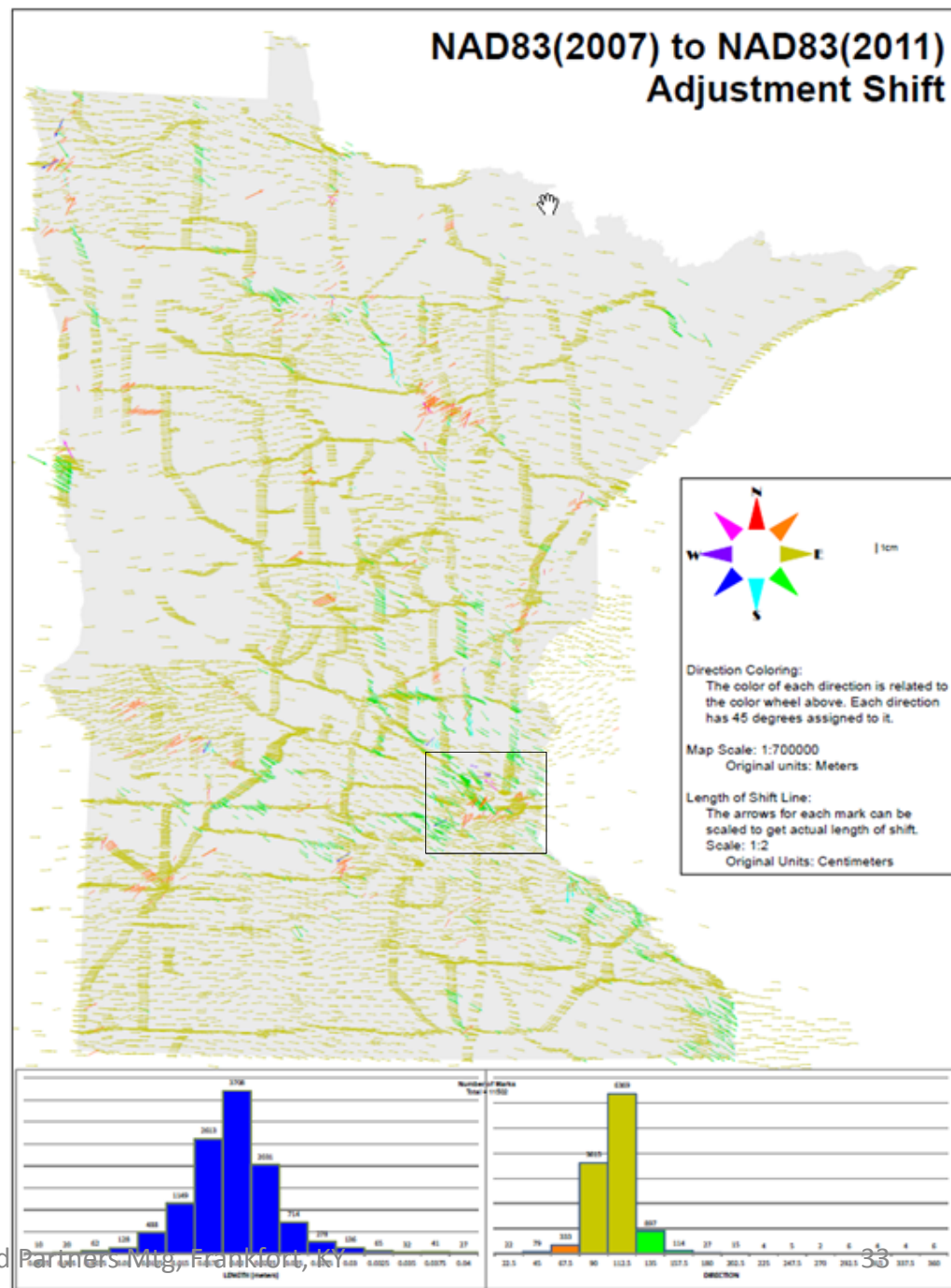
Horizontal Datums and Shifts

- NAD83(2007) -> NAD83(2011)
- 11502 marks
- Shifts of 0.01 to 0.03 meters
- Azimuth vary from 45 to 135
- Aberrations due to underlying error in previous adjustments.



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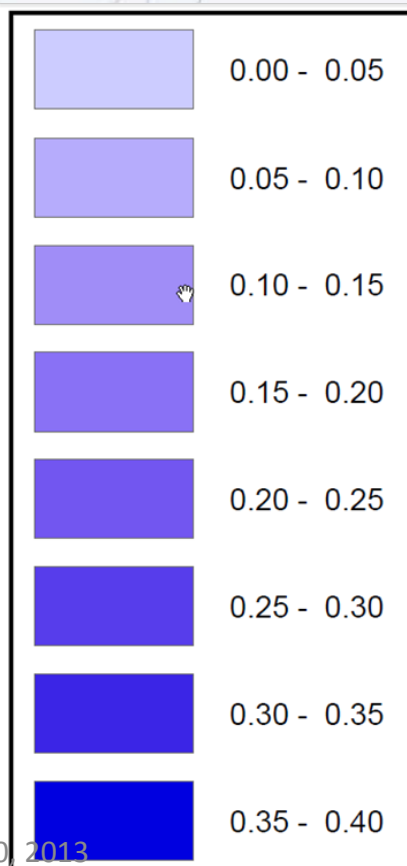
Vertical Datums and Shifts

- Minnesota has had 3 major vertical datums over time
 - 4th General Adjustment of 1912 = GA1912
 - National Geodetic Vertical Datum of 1929 = NGVD29
 - North American Vertical Datum of 1988 = NAVD88
- The datum could only be defined where marks and leveling existed at the time of computation.
 - Therefore, the GA1912 datum has limited extent.

Vertical Datums and Shifts

- GA1912 to NGVD29

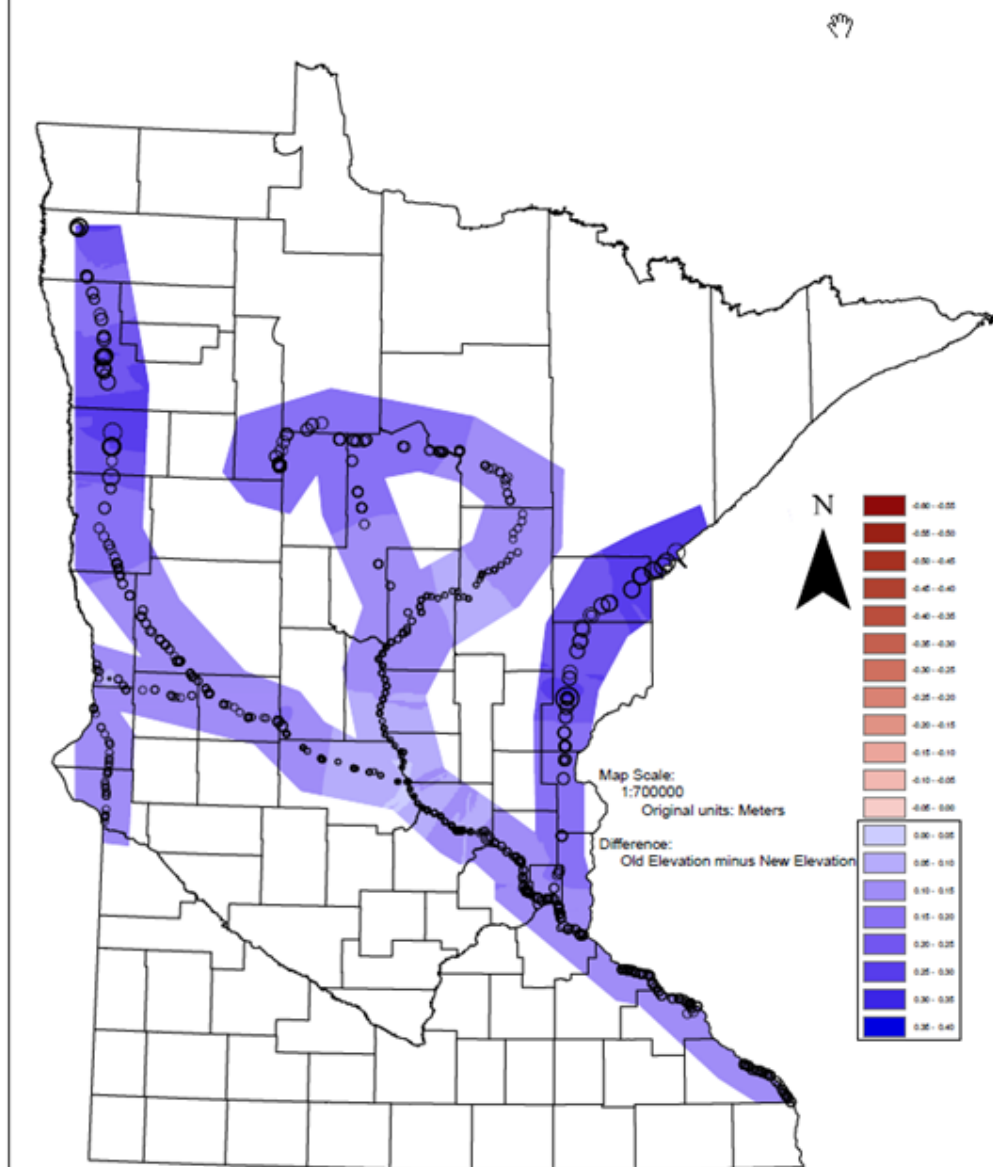
Meters



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Difference GA1912 vs. NGVD29

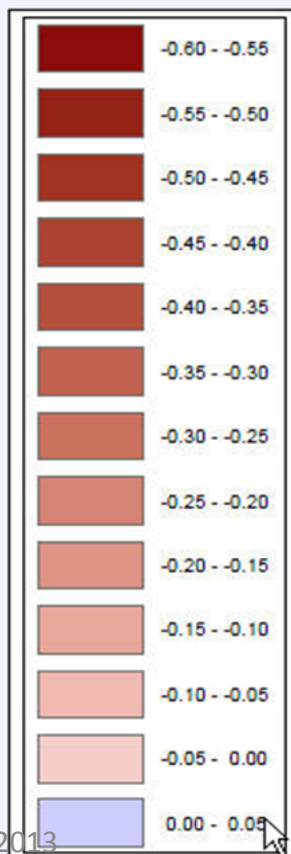


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Vertical Datums and Shifts

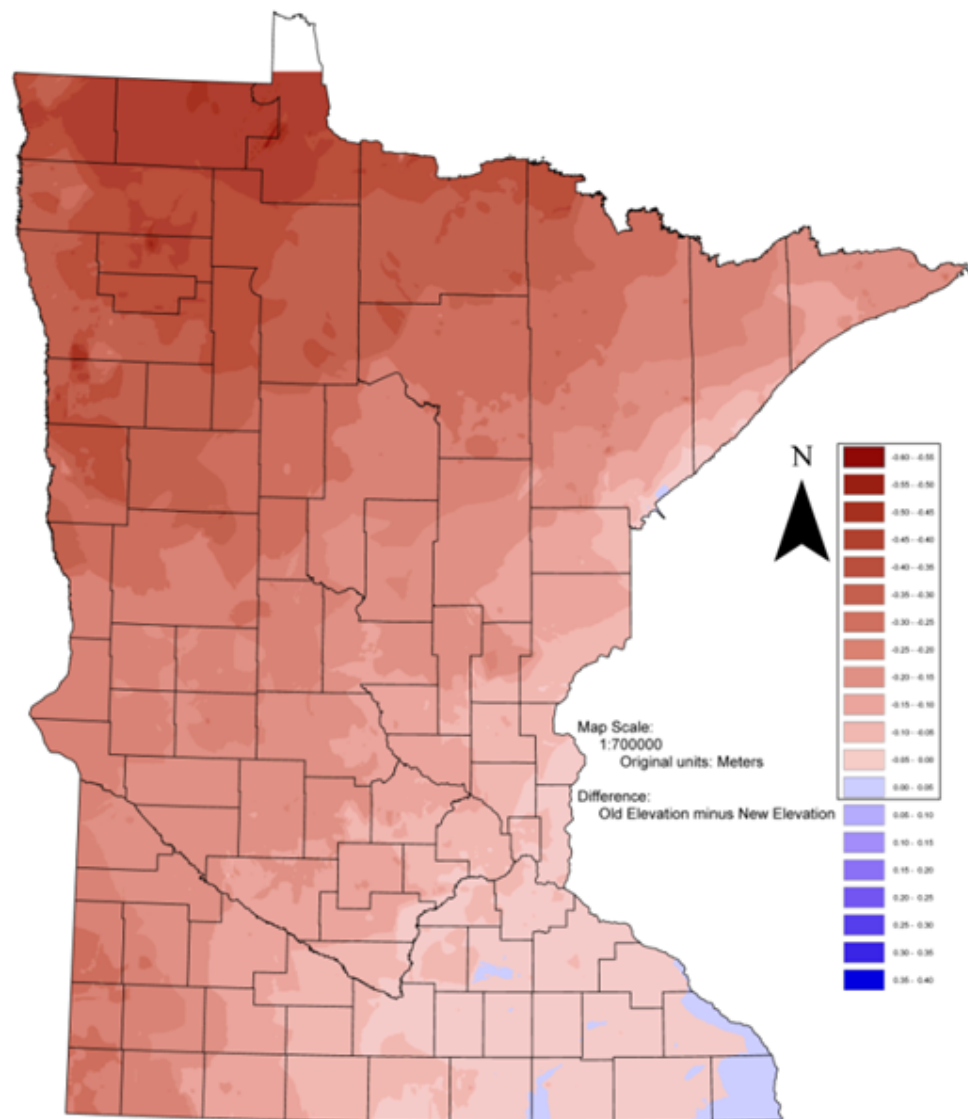
- NGVD29 to NAVD88

Meters



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Difference NGVD29 vs. NAVD88



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GEOID Model Shifts

- Minnesota has had 7 GEOID models of interest
 - GEOID90
 - GEOID93
 - GEOID96
 - GEOID99
 - GEOID03
 - GEOID09
 - GEOID 12 never mind
 - GEOID12A

GEOID Model Shifts

- Each GEOID model is developed in a time frame as a companion of the particular adjustment in effect at the time.
- Therefore, only certain combinations of GEOID model can be applied to certain sets of Ellipsoid Heights

$$\text{EllHt} - \text{Geoid} = \text{Ortho}$$

$$h - N = H$$

GEOID Model Shifts

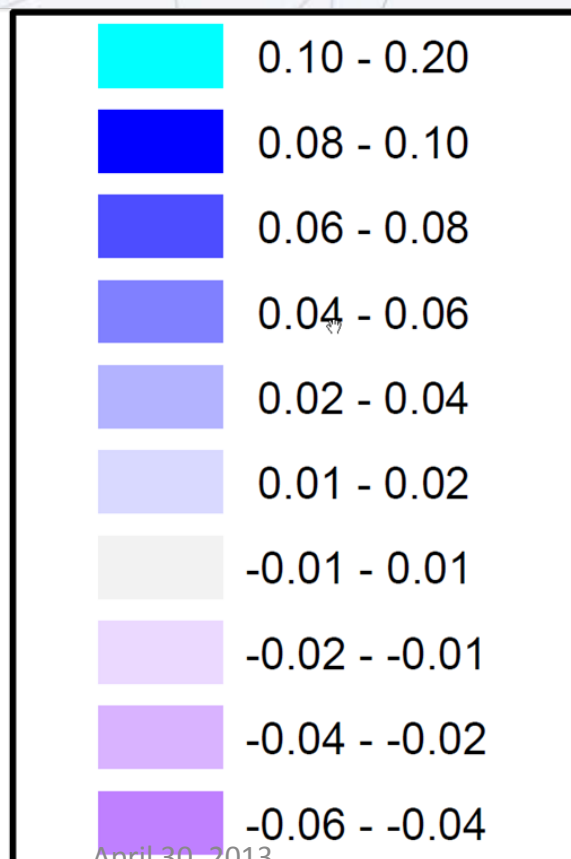
Acceptable GEOID /Adjustment Combinations

Geoid Model	Adjustment
GEOID90	NAD83(1986)
GEOID93	NAD83(1986)
GEOID96	NAD83(1996)
GEOID99	NAD83(1996)
GEOID03	NAD83(1996) ←
GEOID09	NAD83(2007) ←
GEOID12A	NAD83(2011) ←

Note that few ellipsoid height existed in NAD83(1986) and they were generally too uncertain to trust.

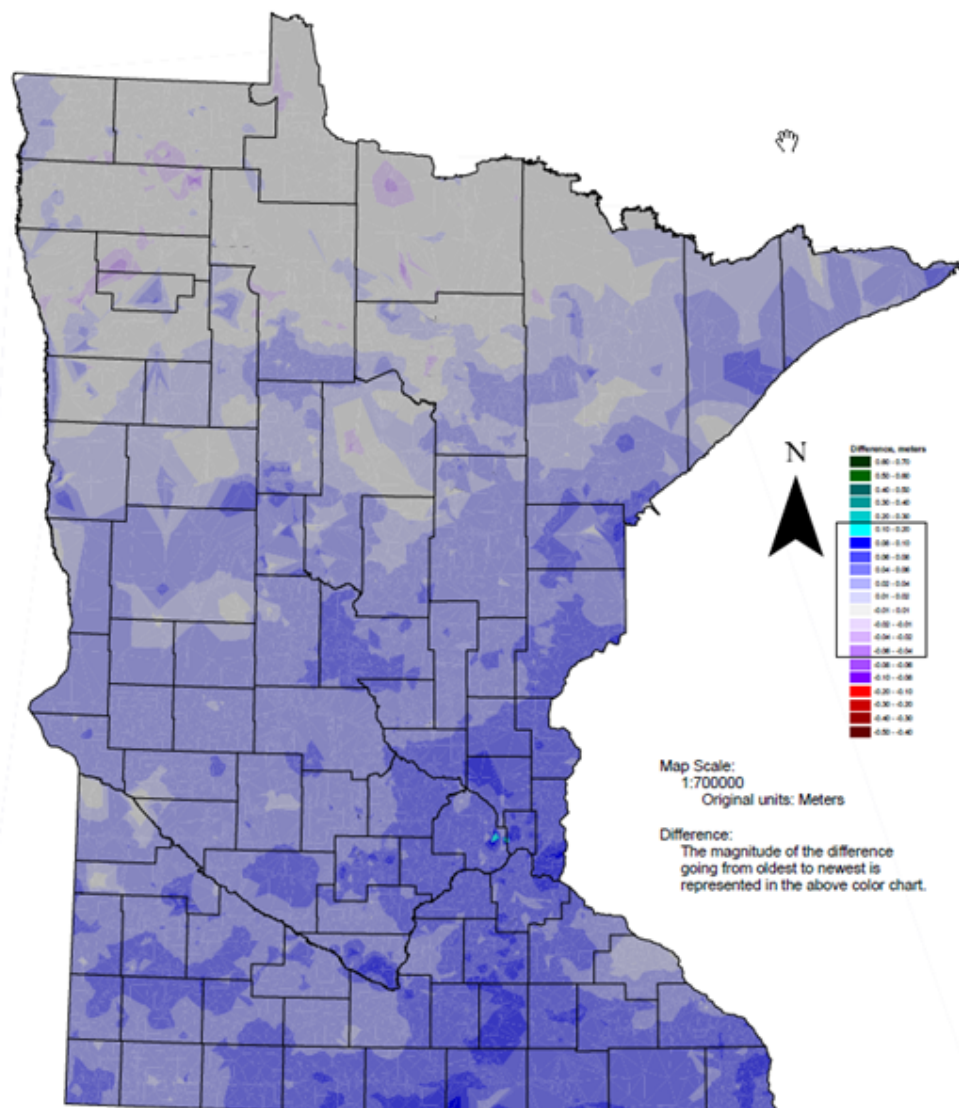
Ellipsoid Height Shifts

- NAD83(1996) to NAD83(2007)
Meters



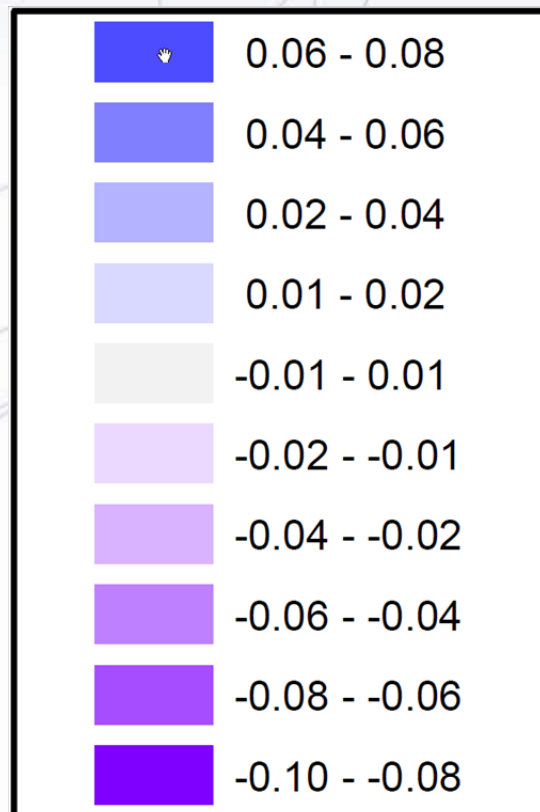
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Ellipsoid Shift NAD83(1996) to NAD83(2007)



Ellipsoid Height Shifts

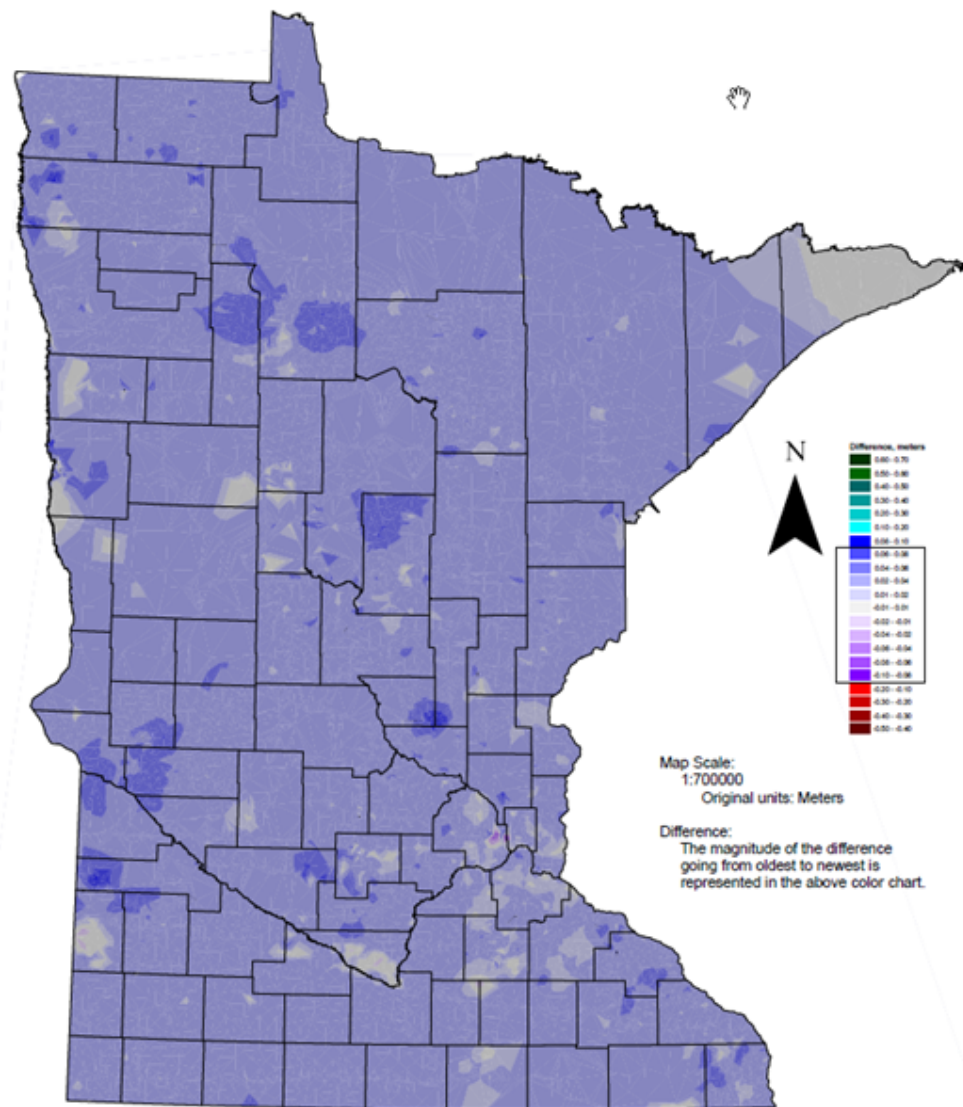
- NAD83(2007) to NAD83(2011)
Meters



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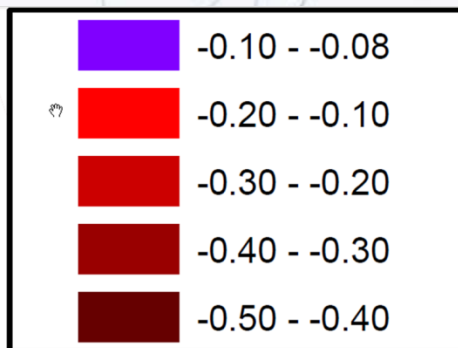
Ellipsoid Shift NAD83(2007) to NAD83(2011)



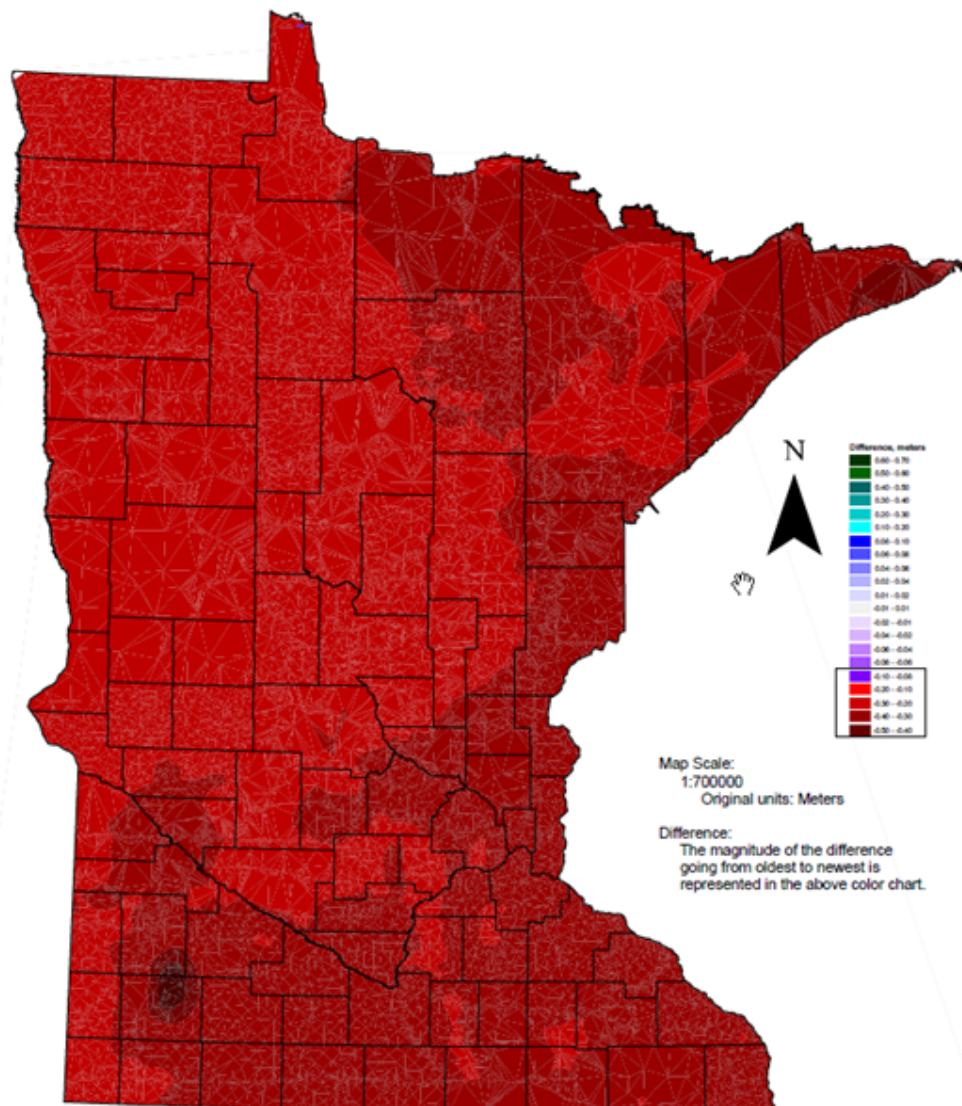
GEOID Model Shifts

- GEOID90 to GEOID93

Meters



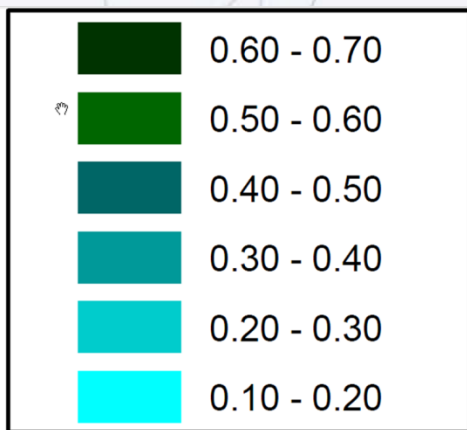
Difference Geoid90 vs. Geoid93



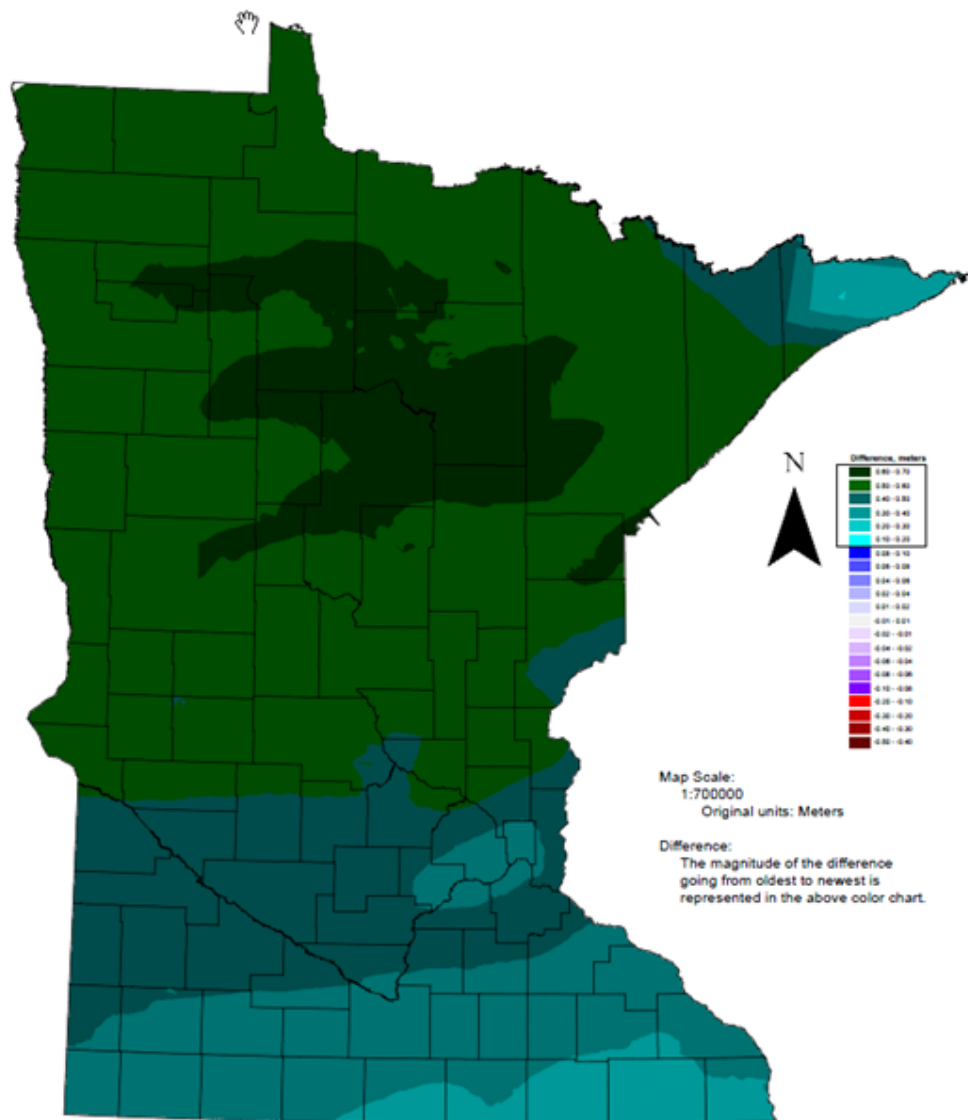
GEOID Model Shifts

- GEOID93 to GEOID96

Meters



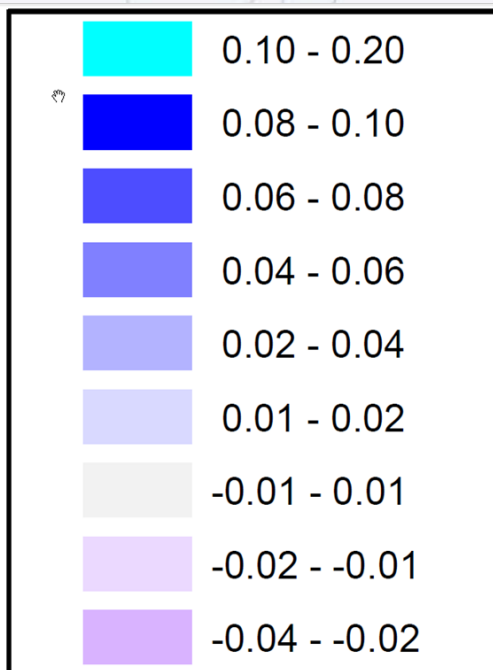
Difference Geoid93 vs. Geoid96



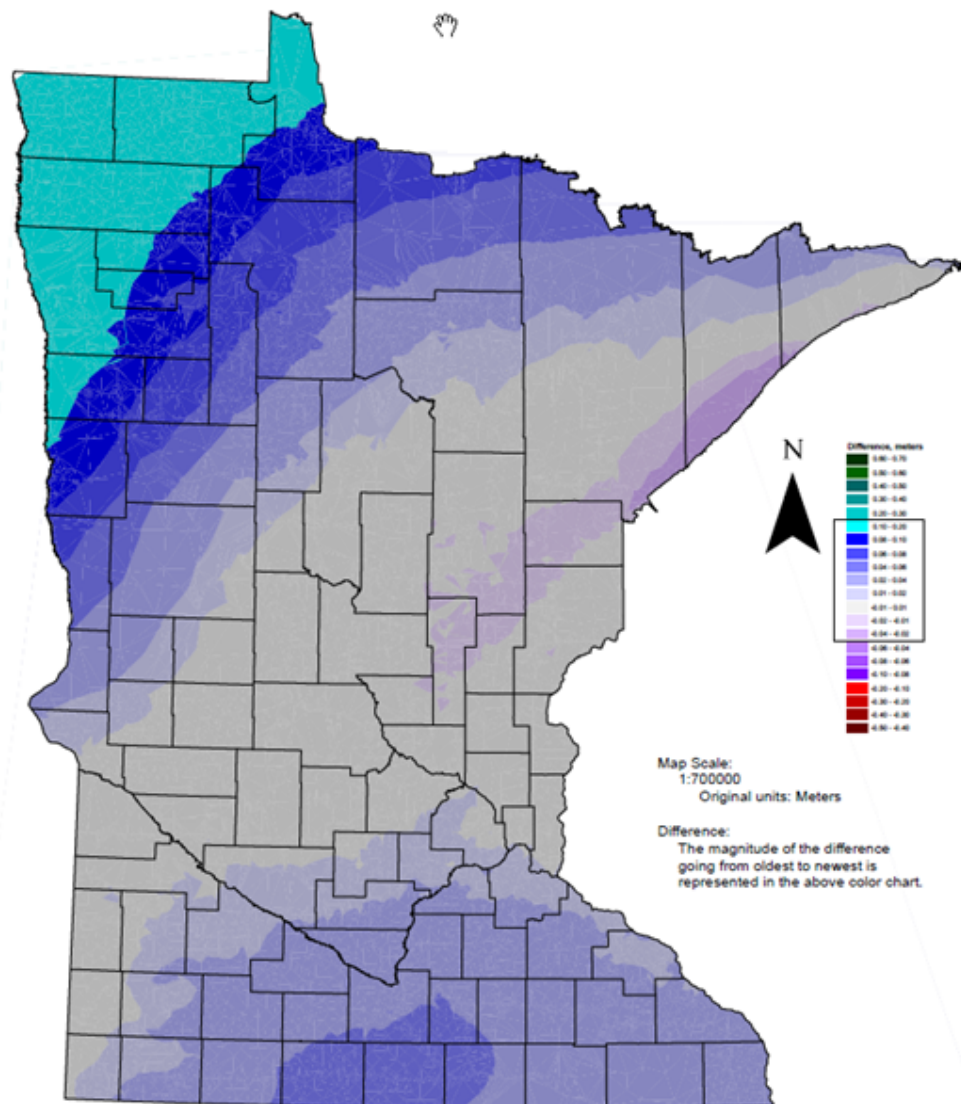
GEOID Model Shifts

- GEOID96 to GEOID99

Meters



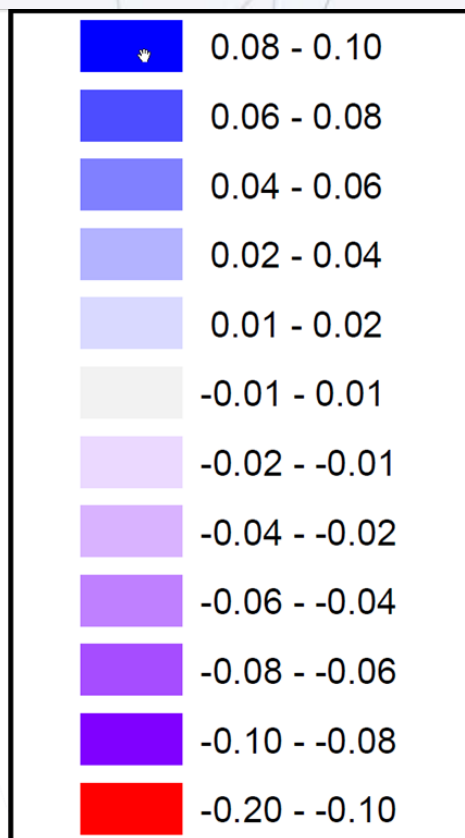
Difference Geoid96 vs. Geoid99



GEOID Model Shifts

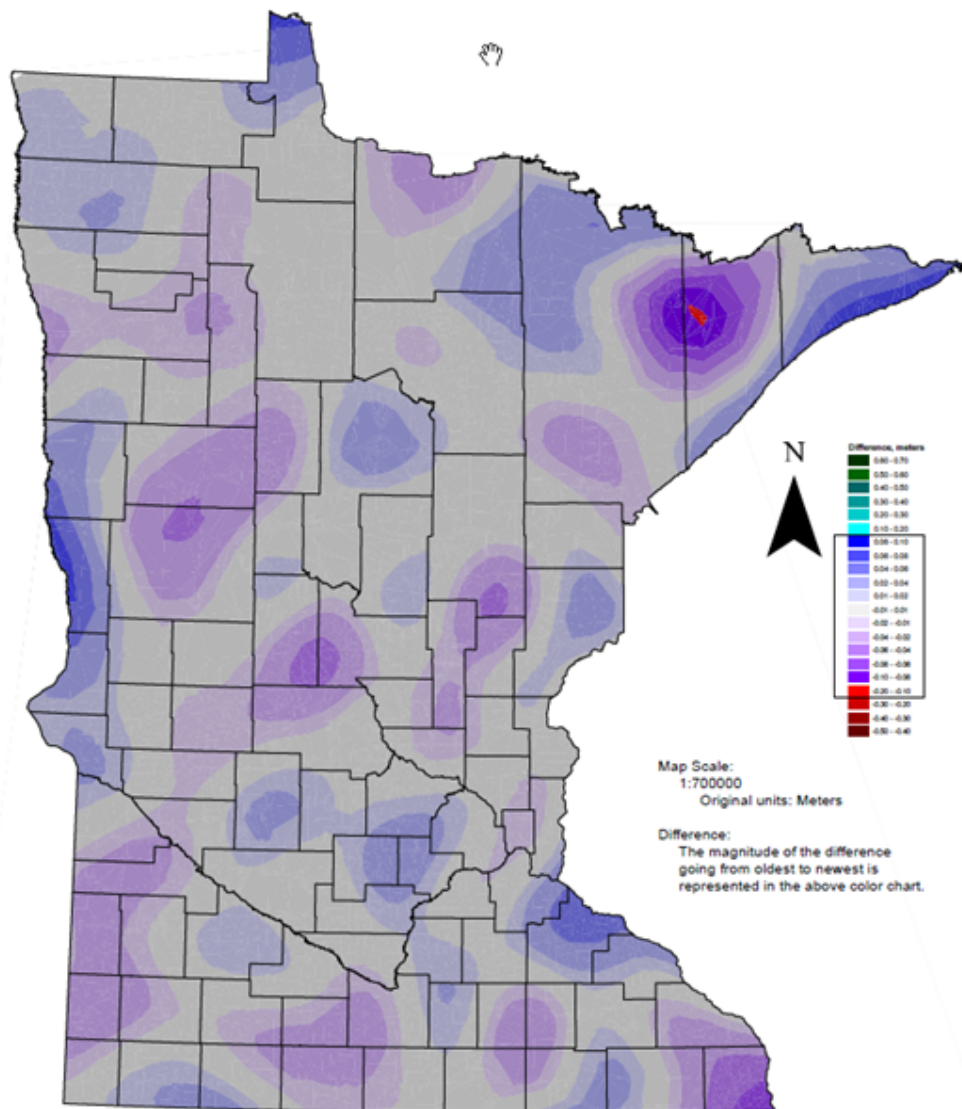
- GEOID99 to GEOID03

Meters



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Difference Geoid99 vs. Geoid03

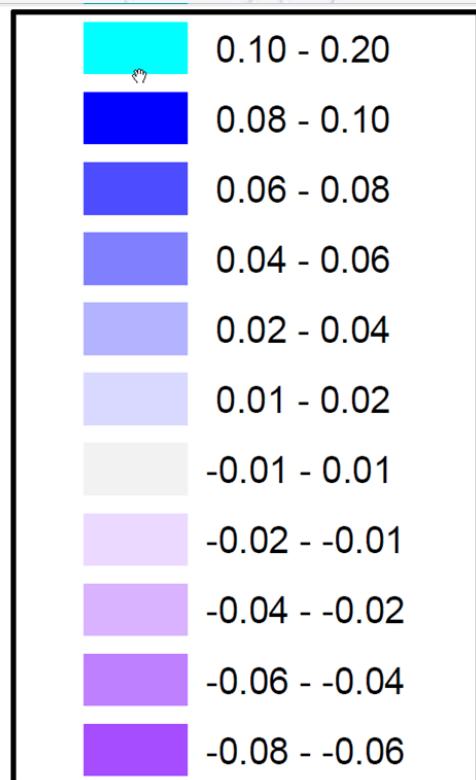


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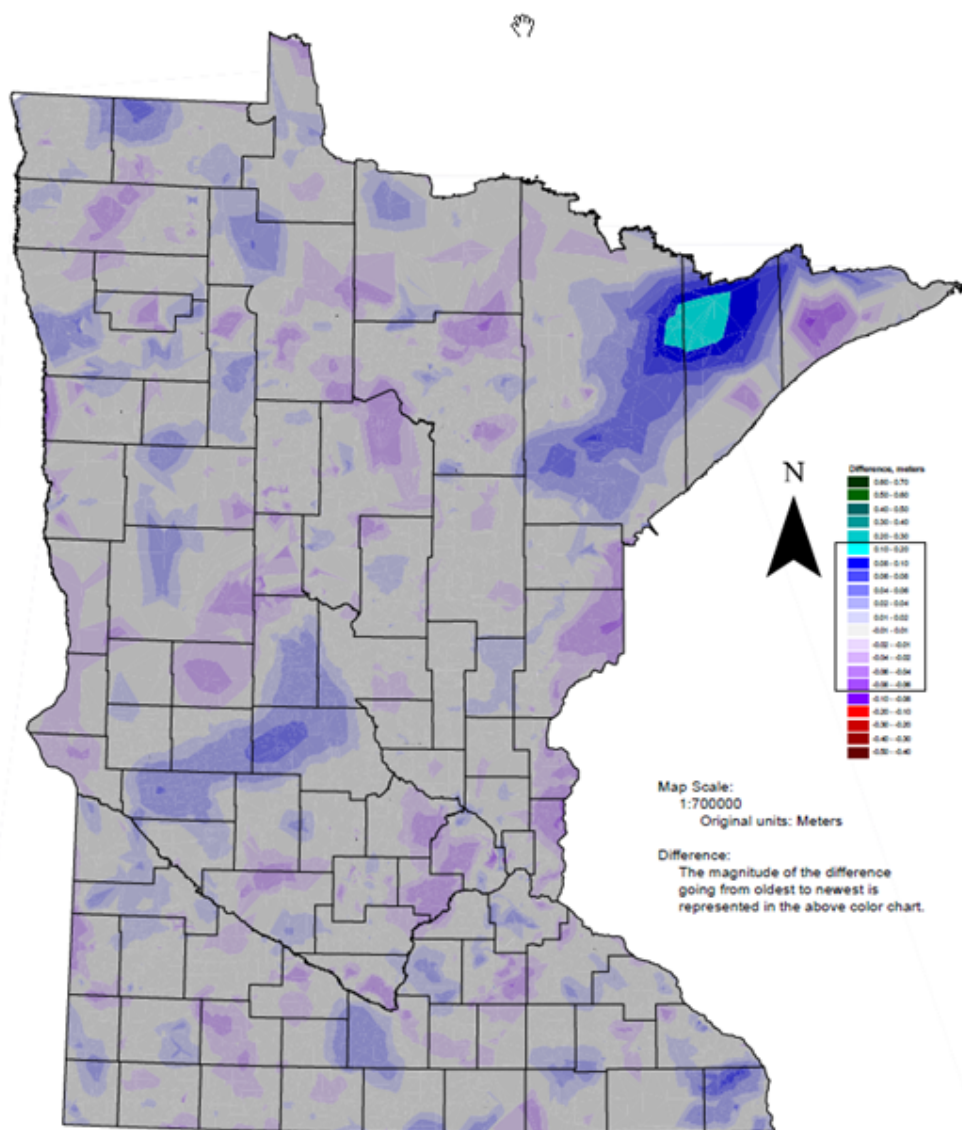
GEOID Model Shifts

- GEOID03 to GEOID09

Meters



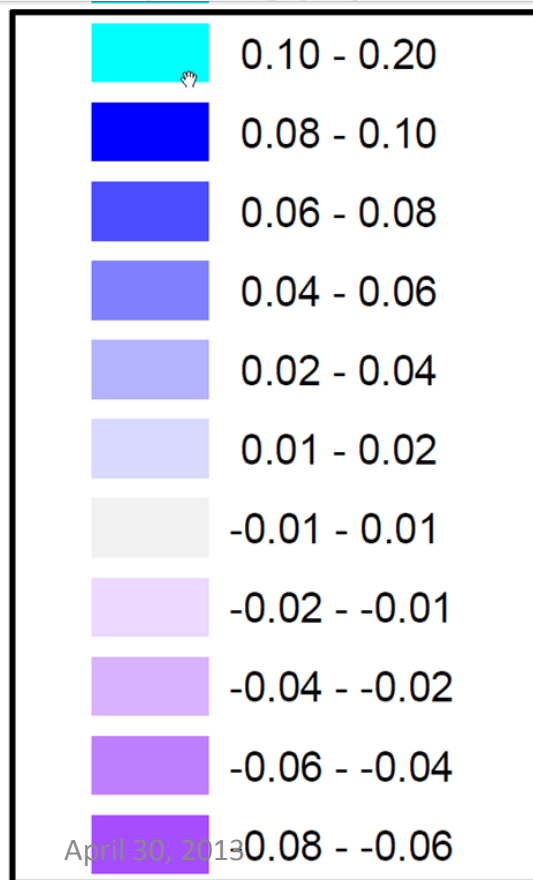
Difference Geoid03 vs. Geoid09



GEOID Model Shifts

- GEOID09 to GEOID12A

Meters

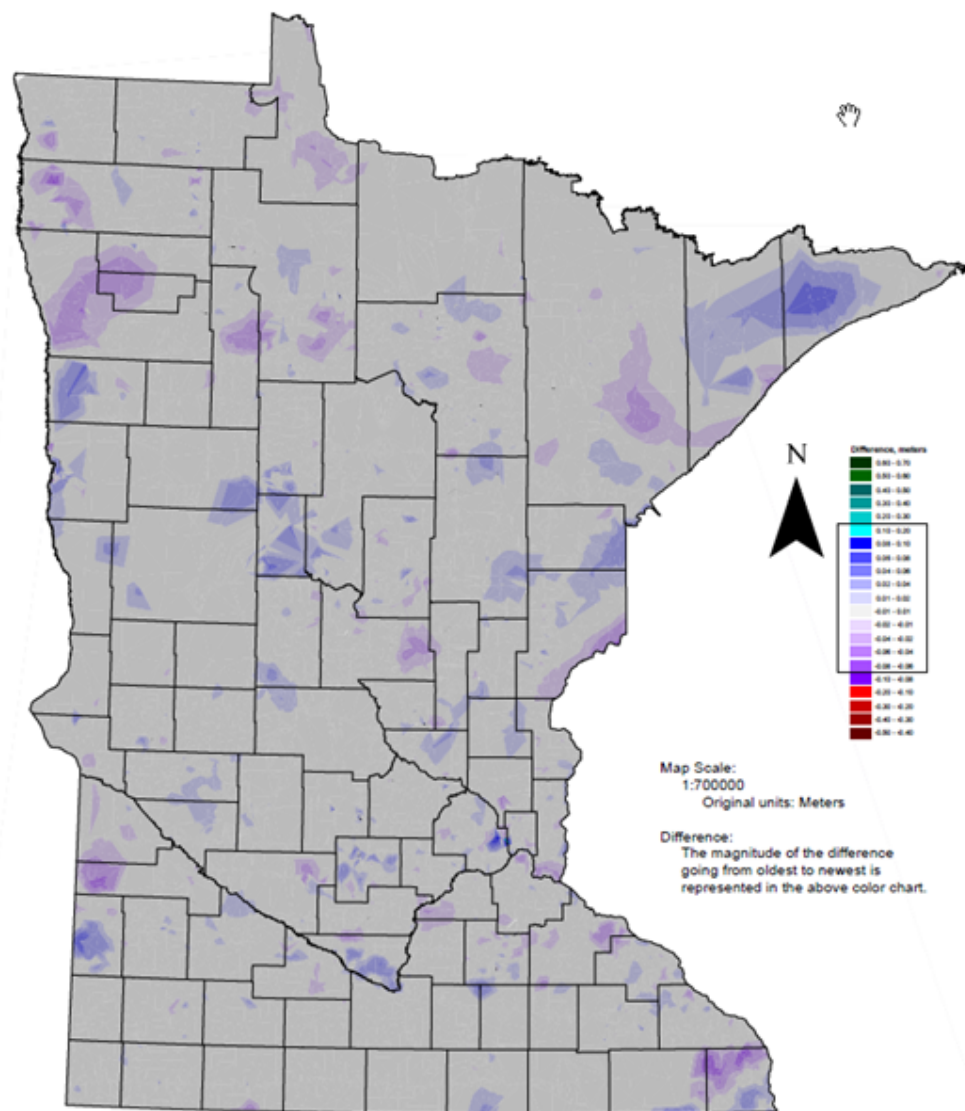


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0.08 - -0.06

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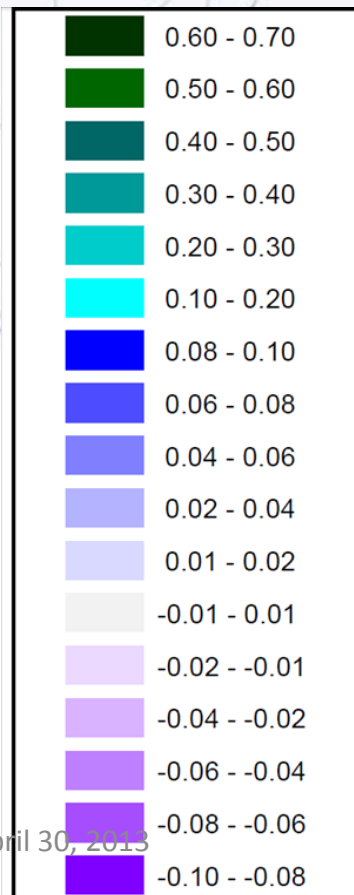
Difference Geoid09 vs. Geoid12A



GEOID Model Shifts

- GEOID90 to GEOID12A

Meters

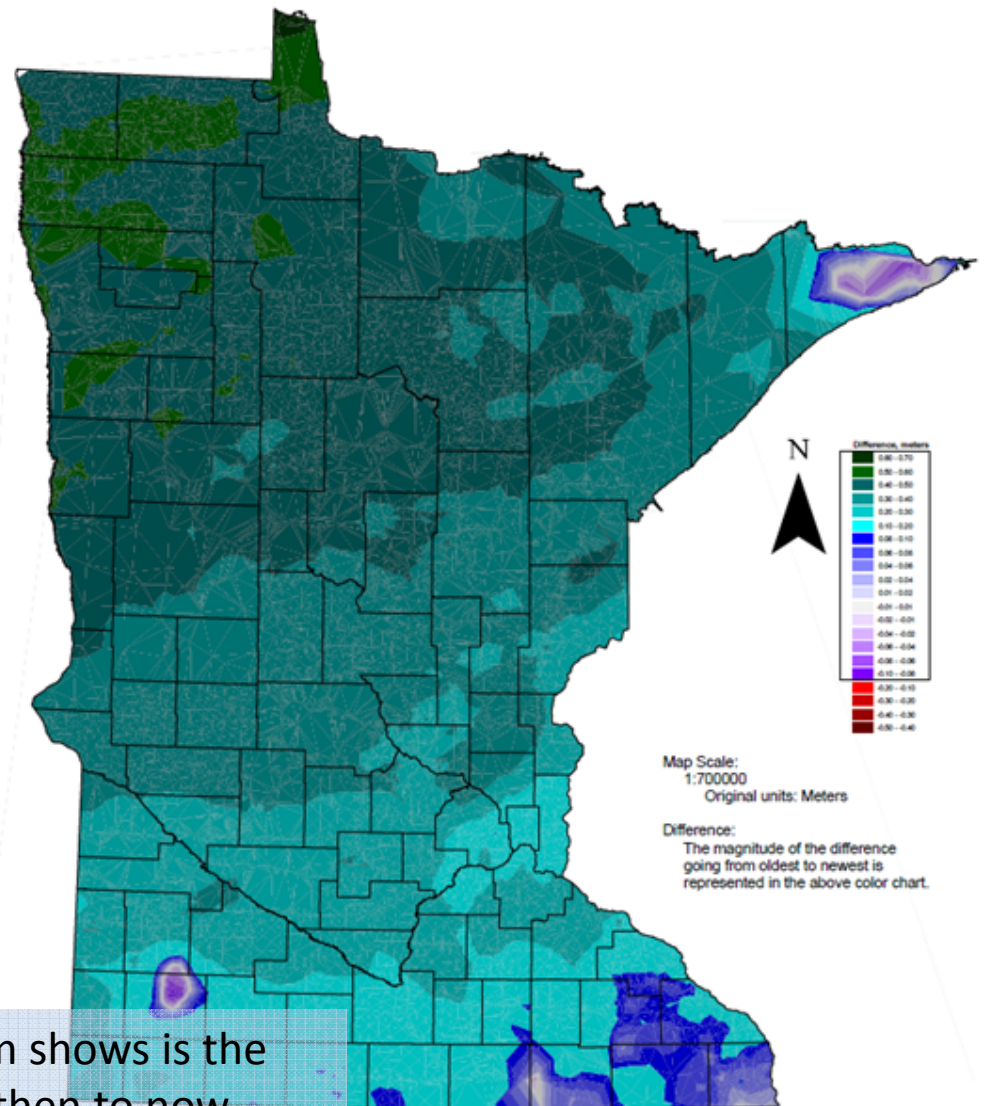


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What this diagram shows is the net change from then to now. In other words – how bad was the past compared to today?

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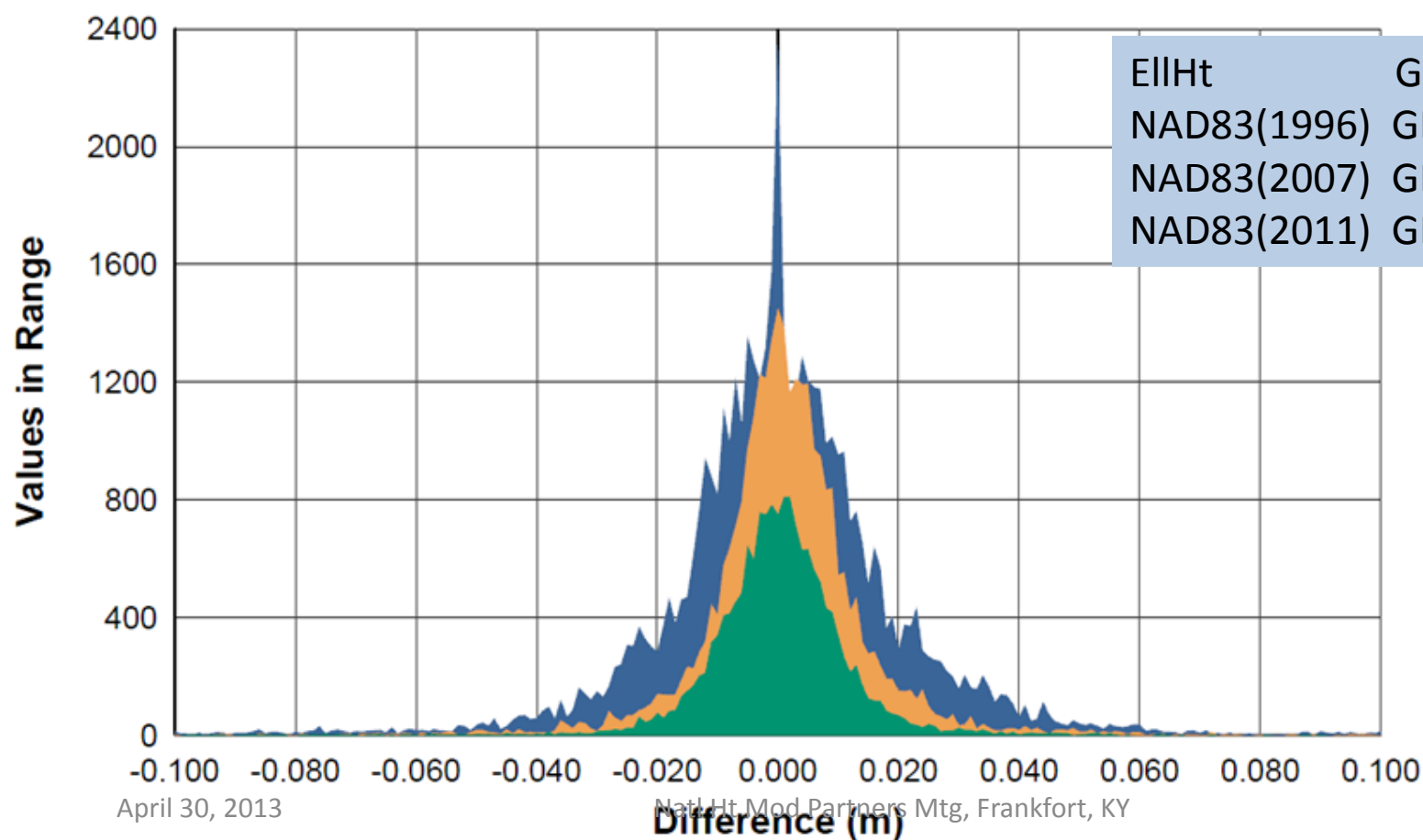
Difference Geoid90 vs. Geoid12A



Benefit of Height Modernization

Leveled NAVD88 - GPS Derived

Outliers (>.1m different) disregarded



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Where to Improve Next?

- If each component of an equation has an error budget, what limits the validity of the result?
 - NAD83(2011) Ellipsoid Heights are (+/- 1 cm?)
 - GEOID12A is (+/- 1 cm?)
 - Ortho Heights are (+/- 2 to 4 cm) in MN
- Minnesota looks forward to new national or regional orthometric adjustment!

$$h - N - H = 0 ?$$