Minnesota Department of Transportation
Geodetic Services Unit

Geodetic History in Minnesota

December 2007

This document includes 16 maps of Minnesota displaying geodetic monuments set in each decade from 1860 to 2007

Geodetic History in Minnesota

David Zenk PE, PLS
NGS Advisor in MN
December 31, 2007

Abstract

This paper provides a broad overview of the development of the physical system of geodetic monuments in Minnesota, and provides a general review of the development, naming, and relationships of horizontal and vertical datums in Minnesota. References are cited to more detailed records and other historical viewpoints for interested readers for further research.

Early Geodetic Surveys in the USA and Minnesota

Surveys in Minnesota, like those elsewhere were based on networks, also called arcs, of triangulation surveys. Distances were very difficult and time consuming to measure, so traverse surveys were used sparingly.

These early surveys were isolated from each other because the time, necessity, and accumulated volume of survey work had not yet coalesced into a coast-to-coast framework. In about 1900, the networks had been extended north, south, east, and west far enough that they began to connect.

The early surveys relied on astronomical observations to determine starting and ending latitudes, longitudes, and azimuths. As could be expected, these would be unlikely to agree exactly at points of connection of networks. A national framework was needed, but which one of the many possibilities should be used?

According to Sinclair Weeks (see reference 3):

> *"After much careful study it was decided to extend through the entire net the datum which had been used in New England and along the Atlantic Coast. This decision avoided a large amount of recomputation, of course, and at the same time it happened to give almost the ideal datum for the country as a whole."*

Horizontal Datum of 1913

In 1880, the US Coast and Geodetic Survey (later called the National Geodetic Survey) had adopted the Clarke Spheroid of 1866 as its basis for all computation of geodetic positions. This ellipsoid, by itself, does not form a datum. A datum requires a few more items in order to be defined fully.

The International Ellipsoid of 1909 (also known as the Hayford Ellipsoid), was proposed and adopted by many countries in 1924, but was not adopted by the US for several reasons. First, it would have resulted in recomputing - by hand - all the previous triangulation that had been based on the Clarke Spheroid. Second, there would be very little change in geodetic positions since the two ellipsoids are not greatly different.

Ellipsoid	**Clarke**	**Hayford**
Semi-major axis	6,378,206.4 meters	6,378,388.0 meters
Semi-minor axis	6,356,583.8 meters	6,356,911.9 meters
Flattening ratio	1/294.98	1/297.00

So it was that in 1913, the US Coast and Geodetic Survey adopted the first truly national-scope horizontal datum called the United States Standard Datum. It was defined as follows:

Datum Element	**Description**
Ellipsoid:	Clarke Spheroid of 1866
Initial Station:	Meades Ranch (located in Kansas)
Initial Latitude:	N 39-13-26.686
Initial Longitude:	W 98-32-30.506
North Orientation:	Azimuth to Station Waldo = 75-28-14.52

This same datum was adopted by Mexico and Canada in 1913. In recognition of the continental scope, the datum was also referred to as The North American Datum - no year being attached to it as would become customary later.

Horizontal Datum of 1927

By 1927, it had become evident that a complete readjustment of the horizontal network was needed. The Clarke Spheroid and the choice of Meades Ranch as the origin were still satisfactory, but the stepwise, piecemeal nature of fitting new arcs of triangulation into the existing framework had led to distortions that were beyond the expected errors in the underlying surveys. The only way out of such problems (as it always is) is a fresh, simultaneous adjustment of all the observations that had been collected over time. The exact method was to break down the national network into smaller blocks, so that several teams of computers (human ones!) could solve them. These smaller blocks could then be combined into a continental scale block without loss of mathematical consistency throughout.

The datum itself had not been redefined, only the positions of the stations had changed. In order to keep users from becoming confused, the new positions were tagged with NAD27 to clearly distinguish them from the earlier NAD positions. The difference being small near Meades Ranch and ranging up to 100 feet or more in the State of Washington. The defining azimuth to station Waldo was altered approximately 5 seconds.

Horizontal Datum of 1983

It wasn't too long after the adoption of NAD27 that the same old problems of new data failing to fit with existing data again became evident. All the familiar problems continued to plague geodesists - new work was "forced" to fit older work, better surveying tools and techniques showed that older work was not better than new work, and the new satellite-based geodetic measurements were clearly destined to dominate the terrestrial-based traditional measurements.

By 1969, it was very apparent that a fundamental change was needed.

The National Geodetic Survey, under the direction of John D. Bossler, made a decision to adopt a complete new datum, and adjust all the accumulated data in the NGS archives to fit it. The new datum would eventually be called the North American Datum of 1983, or NAD83.

This summary below is based almost entirely on a paper published at the time, specifically:

> *NOAA Professional Paper NOS 2 - North American Datum of 1983, Charles M. Schwartz Editor, National Geodetic Survey, Rockville, MD, published 1989. The paper is available on the internet at: http://geodesy.noaa.gov/PUBS_LIB/NADof1983.pdf*

The North American Datum of 1983 (NAD83) is the third horizontal geodetic datum of continental extent in North America. It is intended to replace both the original North American Datum (1913) and the North American Datum of 1927 (NAD27) for all purposes.

SCOPE OF TASK

The fundamental task of NAD 83 was a simultaneous least squares adjustment involving 1,785,772 observations and 266,436 stations in the United States, Canada, Mexico, and Central America. Greenland, Hawaii, and the Caribbean islands were connected to the datum through Doppler satellite and Very Long Baseline Interferometry (VLBI) observations.

DEFINING PARAMETERS

The computations were performed with respect to the ellipsoid of the Geodetic Reference System of 1980 (GRS80), recommended by the International Association of Geodesy (IAG).

The parameters of this ellipsoid are:

a = 6,378,137.000 meters (exactly)

1/f = 298.257222101 (to 12 significant digits)

The ellipsoid is positioned in such a way as to be geocentric, and the orientation is that of the Bureau International de l'Heure (BIH) Terrestrial System of 1984 (BTS-84). In these respects, NAD 83 is similar to other modern global reference systems, such as the World Geodetic System of 1984 (WGS 84) of the U.S. Defense Mapping Agency (DMA). The BTS-84 system was realized by applying a shift in Z of 4.5 m, a rotation around the Z axis of -0.814 arc seconds, and a scale correction of -0.6 parts per million, to Doppler-derived coordinates in the Naval Surface Warfare Center (NSWC) 9Z-2 system.

The readjustment project also included the computation of geoid heights and deflections of the vertical at all 193,241 occupied control points. Most of the deflections were computed by the method of astro-gravimetric leveling, using approximately 1.4 million gravity points and 5,000 observed astro-geodetic deflections.

INTERESTING STATISTICS

The U.S. portion of NAD 83 contains 258,982 stations, classified as follows:

First order	39460
Second order	95013
Third order	60821
Intersected landmarks	63234
unclassified	454

These stations were connected by the following inventory of terrestrial data:

First-order directions	392426
Second-order directions	467763
Third-order directions	400912
Fourth-order directions	279989
Astronomic azimuths	4470
EDM distances (lightwave instruments)	124328
EDM distances (microwave instruments)	25642
Taped distances	38659

In addition there were the following other types of data:

Doppler Positions and GPS	655
VLBI	112

INTERESTING COMPUTING REQUIREMENTS
The least squares adjustment generated a system of 928,735 simultaneous linear normal equations in 928,735 unknowns.

In the United States the computations were carried out on an IBM 3081 computer, using an automated system of computation, scheduling, and data management. The specialized software for this purpose was written by NGS programmers in the PL/1 language

The iterative solution process was carried through three cycles of linearization to ensure convergence. Small data corrections were also allowed after the first and second solutions. The three cycles of linearization and solution required more than 940 hours of computer CPU time (IBM 3081). By the last solution, after all data problems had been resolved, the entire cycle could be accomplished in 3 to 4 weeks.

By contrast, the NAD83(NRSR2007) Adjustment took approximately 12 hours to compute!

POSITION SHIFTS
The position shifts in Minnesota from NAD 27 to NAD 83 were about 3 meters southerly and 15 meters westerly. The differences in coordinates have both smooth and random components. The part of the coordinate change which is due to a change of reference ellipsoid is systematic and smooth, while the part which arises from the removal of the distortions in NAD 27 is random and unpredictable. It is the presence of this random component which means that the coordinate differences cannot be predicted or exactly represented by mathematical formulas. Instead, they must be represented by tables or graphs.

INVESTMENT
In the period from July 1, 1974 to July 31, 1986, the NGS:

- designed a geodetic database management system
- converted 4997 legacy survey projects (from 150 years) to machine-readable form
- validated the data entries by preliminary computations of each project
- spent $37,000,000 (about 10% on computation and 25% on new surveys)

Great Lakes Datums

Prior to 1900, surveyors had extended lines of leveling over land between each of the Great Lakes. In addition, water gauges were used to relate these lines of leveling across the Great Lakes themselves. Over extended times of gauging, the disturbing effects of wind, current, temperature, and water density variations would, it was hoped, average out.

Meanwhile, other surveyors had run lines of leveling up the major rivers of the United States.

In 1900, the Coast and Geodetic Survey performed the first of five General Adjustments of the accumulated leveling.

1900 First General Adjustment
1903 Second General Adjustment
1907 Third General Adjustment
1912 Fourth General Adjustment
1929 Fifth General Adjustment

The US Lake Survey adopted the 1903 Adjustment as its first unified datum. It is called USLS 1903 datum.

Some of the previous vertical reference systems used for charting on the Great Lakes are:

USLS 1903 (U.S. Lake Survey 1903 Datum)
USLS 1935
IGLD 1955
IGLD 1985

On the Great Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985 (IGLD 1985).

HISTORY OF THE US LAKE SURVEY

In 1841, Congress created the Lake Survey within the U.S. Army Topographical Engineers, which later became part of the U.S. Army Corps of Engineers.

The Lake Survey, based in Detroit, Michigan, was charged with conducting a hydrographical survey of the Northern and Northwestern Lakes and preparing and publishing nautical charts and other navigation aids. The Lake Survey published its first charts in 1852.

In 1882, after producing 76 charts and completing its Congressional mandate, the Lake Survey was disbanded.

In 1901, as technology evolved and deeper-draft vessels were created, Congress reconstituted the Lake Survey to produce revised charts with deeper depths to allow the new deeper-draft vessels to safely navigate waters. At the same time, the Lake Survey's mission expanded to include the lakes and navigable waters of the New York State Barge Canal System, Lake Champlain, and the Minnesota-Ontario Border Lakes.

The Lake Survey also carried out support activities such as studies on lake levels and river flows. Survey water level and precipitation gauges allowed engineers to forecast lake levels six months in advance.

In 1962, the Great Lakes Research Center was established to expand these monitoring efforts. The Research Center conducted scientific investigations in limnology (fresh water processes), coastal engineering (currents, tides, waves, and shore processes such as sedimentation), and water resources (water quality and quantity and ice and snow conditions). This work was supported by a suite of facilities including the Great Lakes Regional Data Center, a Technical Library and Instrument Office, an Ice and Snow Laboratory, a Chemical Laboratory, and a Sedimentation Laboratory.

In 1970, the Lake Survey, which was responsible for surveying functions on the Great Lakes, was transferred from the U.S. Army Corps of Engineers to National Ocean Survey, under the overall NOAA organization within the Department of Commerce.

The Canadian Hydrographic Service's account of vertical datums on the Great Lakes (see reference 6) is summarized below:

> VERTICAL DATUMS and CHART DATUM
>
> All surveyed features on a navigational chart are positioned on some horizontal datum system such as NAD27 (North American Datum of 1927) or NAD83 (North American Datum of 1983).
>
> In addition to a horizontal datum reference, all charts also require a vertical datum reference.
>
> CHART DATUM
>
> For navigational safety, depths on a chart are shown from a low-water surface or a low-water datum called chart datum.
>
> Chart datum is selected so that the water level will seldom fall below it and only rarely will there be less depth available than what is portrayed on the chart.
>
> The following three criteria place somewhat more restriction on its choice: chart datum should be:
>
> 1. so low that the water level will but seldom fall below it,
> 2. not so low as to cause the charted depths to be unrealistically shallow, and
> 3. it should vary only gradually from area to area and from chart to adjoining chart, to avoid significant discontinuities.

The choice of a chart datum is usually more difficult on inland waters than on coastal waters because inland waters lack the stabilizing influence the huge ocean reservoir exerts on the mean water level.

Chart datum must be set with the low-stage years in mind and may appear pessimistically low during high-stage years. On most lakes a single, level surface is adopted as chart datum over the whole lake. In non-tidal waters, chart datums are often assigned an elevation on some vertical reference system.

On the Great Lakes, water level and chart datum elevations are presently referenced to International Great Lakes Datum 1985.

Some of the previous vertical reference systems used for charting on the Great Lakes are USLS 1903 (U.S. Lake Survey 1903 Datum) and USLS 1935, IGLD 1955, and the current IGLD 1985.

A new reference system is required approximately every 25-30 years to correct for differential movement of the earth's crust in the Great Lakes region. IGLD 1985 was implemented in January 1992 and replaced the previous system, IGLD 1955.

Since the plane of chart datum was not changed, the depths and heights portrayed on the charts are the same for both reference systems. However, the elevation assigned to chart datum is slightly different.

Nautical charts also require a high-water line which is used to define some vertical features and the shoreline on a chart. The high-water line is selected as a level above which the water will seldom rise. For example, a level of 1.3 meters above chart datum is used for the high-water line on Canadian Hydrographic Service charts of Lake Ontario and Lake Erie.

In tidal waters, clearances, elevations and heights of islands are given above high water. In non-tidal waters such as the Great Lakes, heights of islands, clearances, elevation of lights and drying heights are given above chart datum (Fig. 3). Therefore, a knowledge of the present water level relative to chart datum is required to correct these charted heights and all depths to the current conditions. For example, a clearance of 9 meters on an inland chart will only be 8 meters when the water level is one meter above chart datum.

Water-level gauges are referenced to the same vertical datums that are used for charts. Up-to-date water-level information for the Great Lakes is available from water-level bulletins as monthly averages, on marine broadcasts as weekly averages.

Mississippi River Datums

There have been many years of leveling along the Mississippi River and other major tributary rivers, such as the Illinois River. As may be expected, a variety of datums have been in common use. A little reading (see references 7 and 9) will quickly reveal that there are many local and regional datums along the rivers. These datums often are poorly defined, poorly documented, and poorly monumented. Like the Great Lakes, these datums need to be unified. No such unifying relationship will be valid beyond a local area.

Surveyors are explicitly cautioned that the numerical relationships noted in this paper cannot be applied without specific professional research and confirmation in the area of the survey.

Chris Pearson and Dave Mick presented a paper from which this summary is derived (see reference 7). Pearson and Mick also developed a list of approximate datum shifts relative to NAVD88 that may be of some general value to surveyors. Please bear in mind, these shifts are not exact and do vary along the rivers.

Memphis Datum

Because no accurate datum for measuring heights existed in the Mississippi River Valley prior to the establishment of Mean Gulf Level and its propagation up the Mississippi River Valley after 1881, government surveys on the Mississippi conducted in latter part of the 19th century used an arbitrary datum established in Memphis, Tennessee. Memphis Datum minus NAVD88 = 7.7 feet +/- 0.1 feet

Mean Gulf Datum

This was the first sea level datum for the Mississippi. It was based on mean sea level determined by a tide gage in Biloxi, Mississippi established in 1881 by the Mississippi River Commission. These heights were then gradually propagated up the Mississippi by leveling parties. Mean Gulf Datum minus NAVD88 = 0.2 feet

Fourth General Adjustment of 1912

The first datum based on geodetic quality leveling was established in 1900 by the U. S. Coast and Geodetic Survey (USC&GS) holding elevations referenced to local mean sea level (LMSL) fixed at five tide stations (Boston MA, Sandy Hook NJ, Washington DC, New York, NY and Biloxi, MS). Readjustments of the leveling network were performed in 1903, 1907 and 1912. Only the Fourth General Adjustment of 1912 is widely used as a legacy datum in the Mississippi Valley today. It is the basis of all height and water level measurements conducted by the Rock Island office of the US Army Corps of Engineers (USACE) in Wisconsin and Illinois. Fourth General Adjustment minus NAVD88 = 0.7 feet

Cairo Datum

Cairo, Illinois, a town on the Mississippi River at the southern tip of the state of Illinois, served as a reference point for water levels until well into the 20th century. Cairo Datum is no longer used. Old Cairo Datum (1871-1910) was 21.26 above NGVD29, and New Cairo Datum (1910-1929) was 20.434 above NGVD29. NGVD29 can be taken as a good approximation of sea level at the Louisiana coast, although it is no longer used either. *For further comprehensive details, see*

Surveying Little Egypt, A height modernization of the Memphis district by the U.S. Army Corps of Engineers, by Milton Denny.

Biloxi Datum
Very little information was available on the so-called Biloxi Datum. It appears that Biloxi Datum minus NAVD88 = -0.61 feet

City of Minneapolis Datum
The City of Minneapolis had adopted an arbitrary datum of convenience well before the nationwide leveling could be extended up the Mississippi River. The Minneapolis Datum has its zero point about 200 feet below the general surface topography which puts all elevations, even in the Mississippi River gorge, above the zero point. Minneapolis Datum minus NAVD88 = -710.48 feet

City of Saint Paul Datum
The City of Saint Paul had adopted an arbitrary datum of convenience well before the nationwide leveling could be extended up the Mississippi River. The Saint Paul Datum has its zero point about 200 feet below the general surface topography which puts all elevations, even in the Mississippi River gorge, above the zero point. St Paul Datum minus NAVD88 = -694.28 feet

Historical Vertical Datums prior to 1929

As with other geodetic surveys, the vertical network was built up over many years. Eventually the bits and pieces of the separate projects had to be made consistent on a nationwide basis. (see reference 8)

There were 5 General Adjustments: 1900, 1903, 1907, 1912, and 1929
To complete the first general adjustment in 1900, data from the C&GS, the U.S. Army Corps of Engineers, the U.S. Geological Survey, the Massachusetts Topographic Survey, and the Pennsylvania Railroad were all combined. Local mean sea level at five tide gauges was held fixed. Once all of the data were based on the same datum, the organizations could reference each other's data.

As more and more level lines were run, readjustments were completed. Each adjustment was better than the previous one due to the inclusion of more data and more loops of level runs (for error checks) and better weighting of the data based on information gained in previous adjustments. In 1903 and 1907, local mean sea level was held fixed at eight tide gauges, and at nine tide gauges in 1912.

The 1900 adjustment fixed the elevation of 4,200 bench marks and contained about 21,000 kilometers of leveling. The 1907 readjustment was undertaken because the first transcontinental leveling had been completed and the tide gauge in Seattle, Washington, was included. The 1912 adjustment contained about 11,100 bench marks and over 46,000 kilometers of leveling.

National Geodetic Vertical Datum of 1929 (NGVD29)

The Sea Level Datum of 1929 (SLD 29) added more U.S. data and also Canadian data. SLD 29 held local mean sea level (MSL) fixed at 26 tide gauges, including five in Canada, as opposed to the previous adjustments which were based on five, eight, or nine gauges.

The 1929 adjustment is really the first complete general adjustment since 1903, because in the 1907 and 1912 adjustments, the eastern half of the United States was held fixed as adjusted in 1903.

These tide gauges used water-level data recorded over a period of about 19 years to determine local values for MSL, mean high water (MHW), and mean lower low water (MLLW) at each station. This local MSL is the mathematical mean of hourly heights observed over the 19-year time span. Because there are two different low tide levels, the MLLW represents the mathematical mean of the lower low tide over the same 19-year time span. The important thing to remember about tidal levels is that they are only valid for a local area.

C&GS personnel realized that holding local mean sea level fixed at 26 locations would result in discrepancies since it was well known that mean sea level differed from location to location. However, the decision to hold the 26 gauges fixed was made using the assumption that the variations were probably about the same magnitude as observational errors, and that the fixed sea level would help avoid confusion amongst users if benchmarks near the coast did not agree with local mean sea level.

The general adjustment of 1929 established SLD 29 as the entire country's vertical control datum, which meant that all elevations would be determined as heights above SLD 29.

The datum was later renamed the National Geodetic Vertical Datum of 1929 (NGVD 29) to account for the geodetic aspect of the datum. Renaming the datum, however, did not correct the problem of differing local mean sea level values. Despite known deficiencies and distortions, NGVD 29 was the official U.S. datum for vertical surveying until the North American Vertical Datum of 1988 was released in 1991. In fact, some data sets today are still based on NGVD 29.

North American Vertical Datum of 1988 (NAVD88)

North American Vertical Datum of 1988 (NAVD 88) is a newer and more accurate model, referenced to a *single* tide station, Father Point, in the town of Rimouski, Quebec, in Canada. Because NAVD 88 is referenced to one single point, contains more data (625,000 kilometers of additional leveling), and was calculated using rigorous mathematical models, it contains fewer distortions than earlier vertical datums   Fewer distortions result in more accurate elevations. A readjustment was also necessary because many of the benchmarks used for NGVD 29 had changed in elevation due to crustal motion caused by earthquakes, post-glacial rebound (uplift), and oil and water extraction (subsidence).

Many miles of new leveling had been performed in Minnesota throughout the 1930's and the 1960's (see maps) that was used in the NAVD88 adjustment.

Currently, NAVD 88 is the official vertical datum for the United States, against which federal agencies measure elevations.

The International Great Lakes Datum of 1985 (IGLD 85) is the vertical reference for the Great Lakes, and is also based on Father Point. However, slight differences in the definitions of their heights make IGLD 85 and NAVD 88 close but not equal.

Today, elevations derived from leveling can be uniform, regardless of whether you are near the Atlantic, Pacific, or Gulf coast and very close for the Great Lakes coast.

NATIONAL HEIGHT MODERNIZATION

The National Geodetic Survey has long recognized that the Global Positioning System (GPS) can deliver ellipsoid heights and ellipsoid height changes at the 1-centimeter level under proper conditions.

Unfortunately, water does not behave according to ellipsoid heights. Instead water flows according to the laws of gravitational potential energy. Engineers have used "height above sea level" to calculate the energy available in a flowing stream.

Technically, the height above sea level is not constant on a surface of equal gravitational potential energy. In small areas the differences are so small that it can be ignored, since practical slopes of streams and sewers exceed the discrepancy noted.

The general linkage between “height above ellipsoid” and “height above sea level” is accomplished using the notion of a gridded mathematical model called the “geoid”.

In a perfect world, the geoid would be as accurate as or more accurate than GPS and surveyors could use a GPS-derived ellipsoid height, apply the geoid model, and compute the height above sea level. Since this can be done in a near real-time mode using modern GPS equipment, the cost savings over traditional leveling would be huge IF SUCH A GEOID MODEL EXISTED!

The overall goal of the National Height Modernization project is to develop this model and implement it. Details of this long-term goal are available in the NGS 10 Year Plan (see Reference 10).

Contact Information

Dave Zenk PE, PLS
National Geodetic Survey Advisor
Office of Land Management, Geodetic Unit
395 John Ireland Blvd., MS 641
Transportation Building
St. Paul, MN 55155

Office phone: 651-366-3523
NGS email: dave.zenk@noaa.gov

References:

1. NEBRASKA'S EARLY GEODETIC SURVEYS by Jerry Penry, ISBN: 978-0-9679-0411-5, Published by Blue Mound Press, Copyright 2008 by Jerold F. Penry, Standard Copyright License, English.

2. 1912 and 1929 ADJUSTMENTS OF THE UNITED STATES LEVEL NET WAR DEPARTMENT, UNITED STATES ENGINEER OFFICE, 615 Commerce Building, St. Paul, Minnesota, January 26, 1934.

3. HORIZONTAL CONTROL DATA, Special Publication No 227, US Department Of Commerce, Sinclair Weeks, Secretary, Coast And Geodetic Survey, H. Arnold Karo. Director, 1957, Revised 1972

4. NOAA PROFESSIONAL PAPER NOS 2 - NORTH AMERICAN DATUM OF 1983, Charles M. Schwartz Editor, National Geodetic Survey, Rockville, MD, published 1989.

5. VERTICAL CONTROL IN THE GREAT LAKES AREA. Corey Hughes PLS Editor, Michigan Land Surveyor, published on personal website: http://www.coreyhughes.com/index_files/generalinfo.htm

6. VERTICAL DATUMS. Canadian Hydrographic Service website, http://www.lau.chs-shc.gc.ca/english/VerticalDatums.shtml, reviewed March 11, 2005.

7. LEGACY HEIGHT DATUMS ON THE MISSISSIPPI AND ILLINOIS RIVER SYSTEMS. Chris Pearson, National Geodetic Survey, and Dave Mick, Illinois Department of Natural Resources, session paper at American Congress on Surveying and Mapping Conference, St Louis, MO, March 11, 2007.

8. VERTICALLY CHALLENGED: THE PROGRESSION OF VERTICAL DATUMS contributed by Aria Remondi, National Geodetc Survey, 2007. http://celebrating200years.noaa.gov/magazine/vertical_datums/welcome.html

9. INTERAGENCY PERFORMANCE EVALUATION TASKFORCE (IPET) REPORT, VOLUME II - GEODETIC VERTICAL AND WATER LEVEL DATUM, pp 5-23, Dr. Ed Link, IPET Project Director, 2007.

10. NGS 10-YEAR PLAN. David Zilkoski, Director National Geodetic Survey, 2007. http://www.ngs.noaa.gov/INFO/ngs_tenyearplan.pdf

About the maps

Scale: 1:1,075,000
Paper size: 22 inches x 34 inches
Spatial Reference: NAD83 UTM Zone 15N

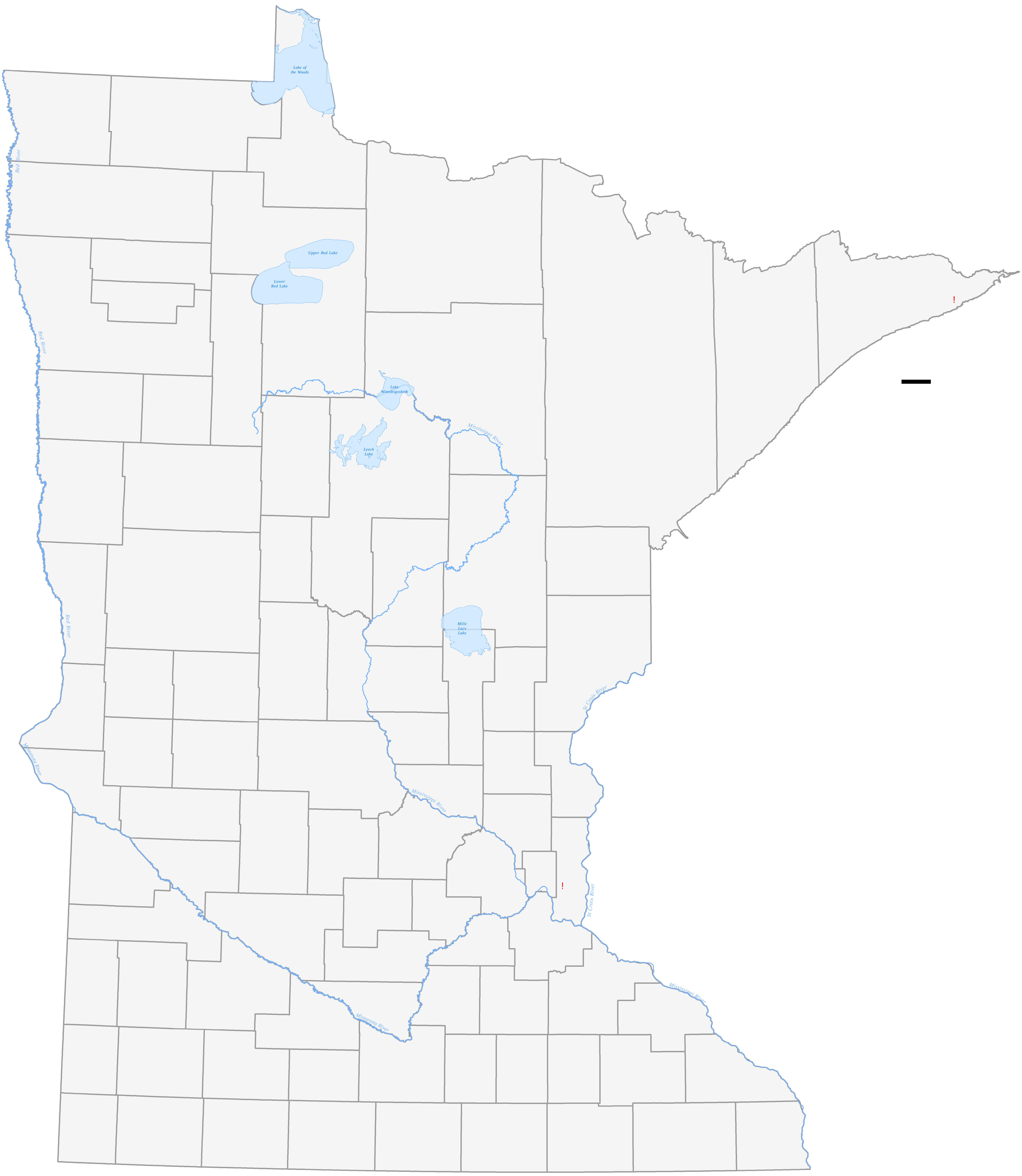
GIS Data included:

- Minnesota Counties (polygons)
- Major Lakes - Lake of the Woods, Upper and Lower Red Lake, Mille Lacs Lake, Leech Lake, and Lake Winnibigoshish (polygons)
- Major Rivers – Mississippi, Minnesota, Red, and St. Croix (lines)
- Minnesota Geodetic Monuments (points)
    - Created from MS Access tables connected to ArcGIS
    - ESRI point events created from a query
        - National Agencies
        - Inter-State and Inter-Province Agencies
        - State, Province, Commonwealth, and Territorial Agencies
        - County Agencies
        - Other Agencies

Maps included by decade:

1860 – 1869
1870 – 1879
1880 – 1889
1890 – 1899
1900 – 1909
1910 – 1919
1920 – 1929
1930 – 1939
1940 – 1949
1950 – 1959
1960 – 1969
1970 – 1979
1980 – 1989
1990 – 1999
2000 – 2007
1860 – 2007

Minnesota Monuments
Set Between 1860 and 1869



0 50 100 Miles

Marks Set in the 1860 Decade

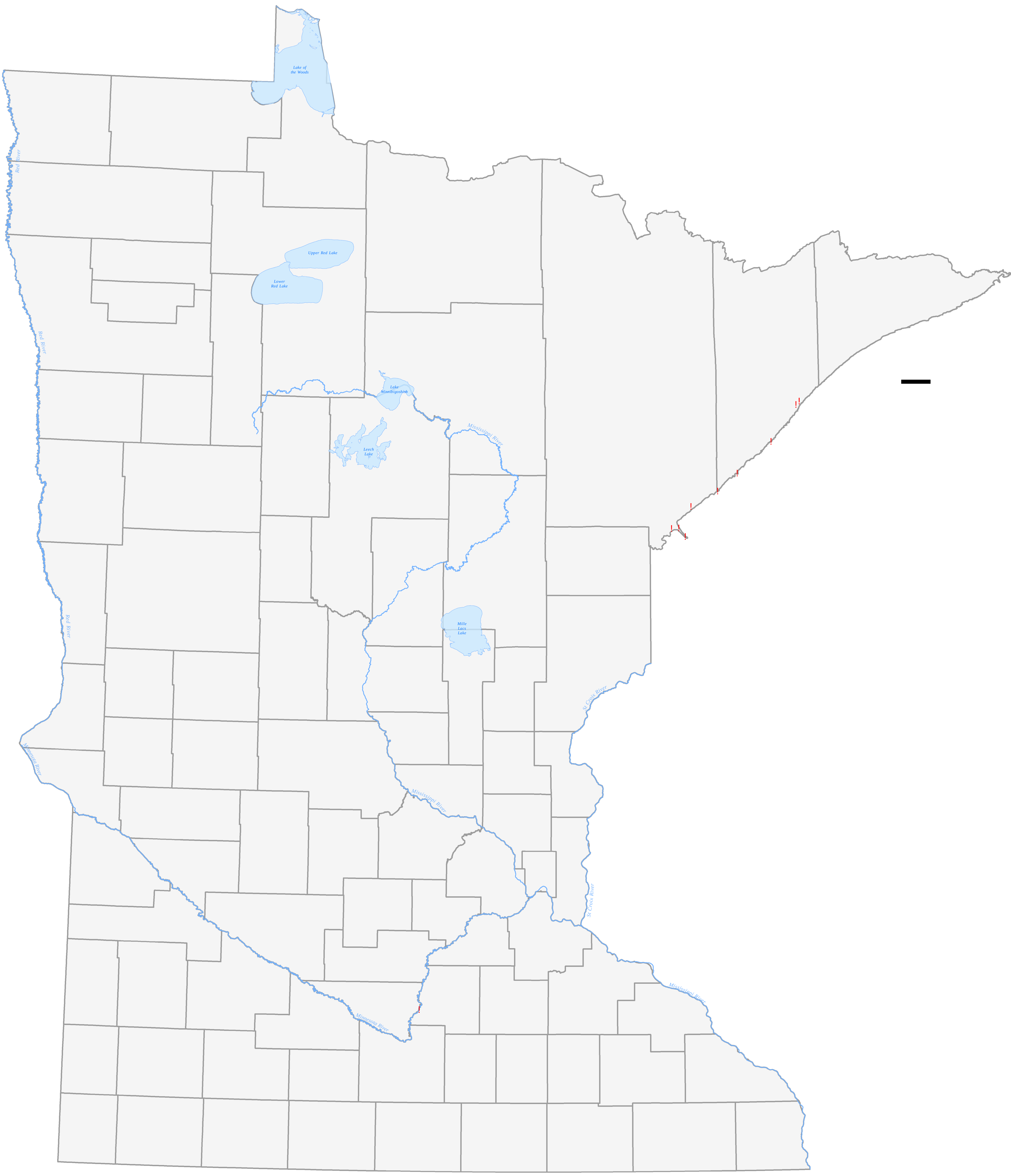
Contributors of Geodetic Control Data and number of marks

!	National Agencies	3
"	Inter-State or Inter Province Agencies	0
#	State, Province, Commonwealth, and Territorial Agencies	0
X	County Agencies	0
^	Other Agencies	0

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1870 and 1879



0 50 100 Miles

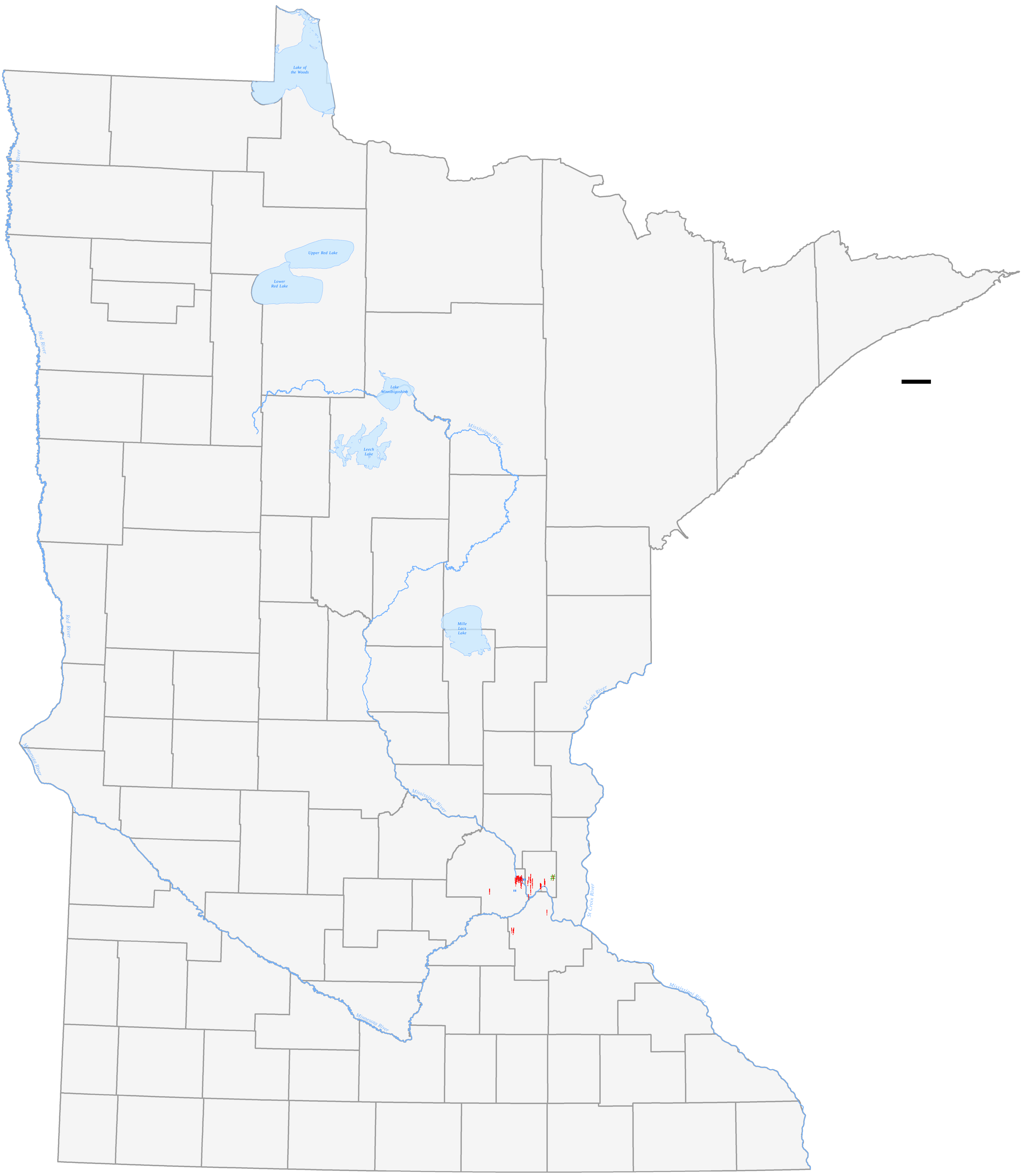
Marks Set in the 1870 Decade

Contributors of Geodetic Control Data and number of marks

!	National Agencies	11
"	Inter-State or Inter Province Agencies	0
#	State, Province, Commonwealth, and Territorial Agencies	0
X	County Agencies	0
^	Other Agencies	0

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Minnesota Monuments
Set Between 1880 and 1889



0 50 100 Miles

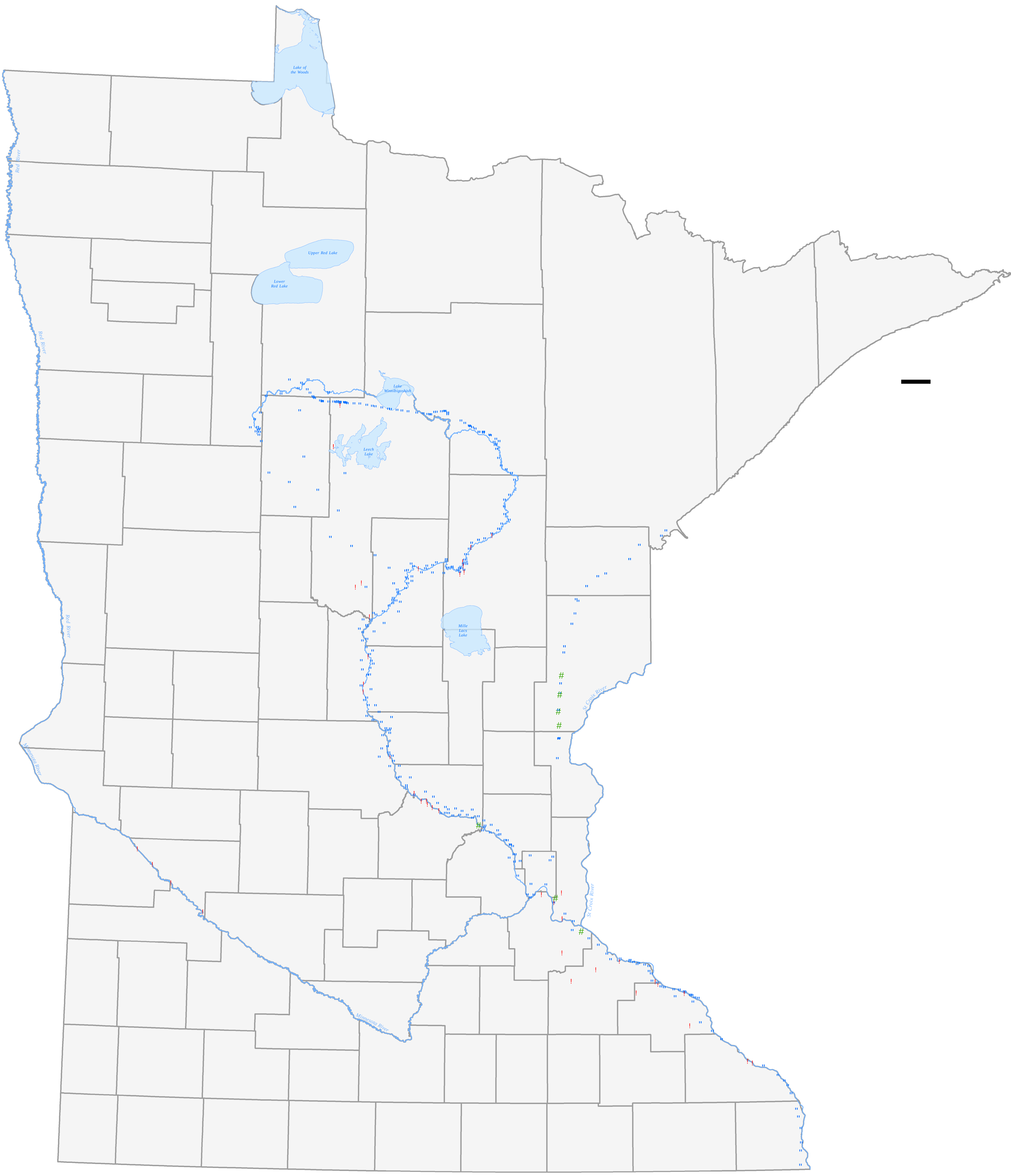
Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Marks Set in the 1880 Decade

Contributors of Geodetic Control Data and number of marks

!	National Agencies	49
"	Inter-State or Inter Province Agencies	5
#	State, Province, Commonwealth, and Territorial Agencies	1
X	County Agencies	0
^	Other Agencies	0

Minnesota Monuments
Set Between 1890 and 1899



0 50 100 Miles

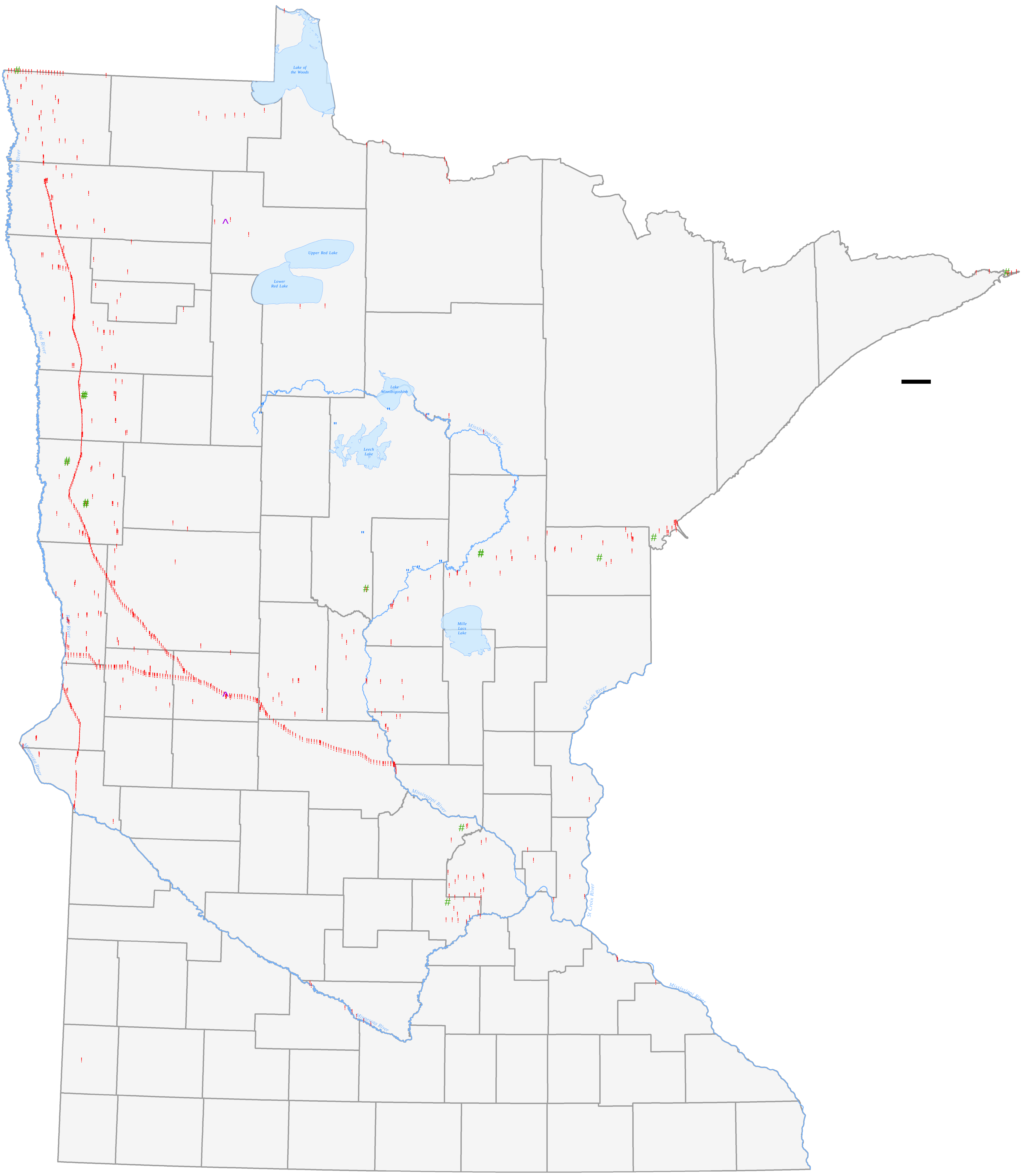
Marks Set in the 1890 Decade

Contributors of Geodetic Control Data and number of marks

!	National Agencies	45
"	Inter-State or Inter Province Agencies	385
#	State, Province, Commonwealth, and Territorial Agencies	7
X	County Agencies	0
^	Other Agencies	0

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Minnesota Monuments
Set Between 1900 and 1909



0 50 100 Miles

Marks Set in the 1900 Decade

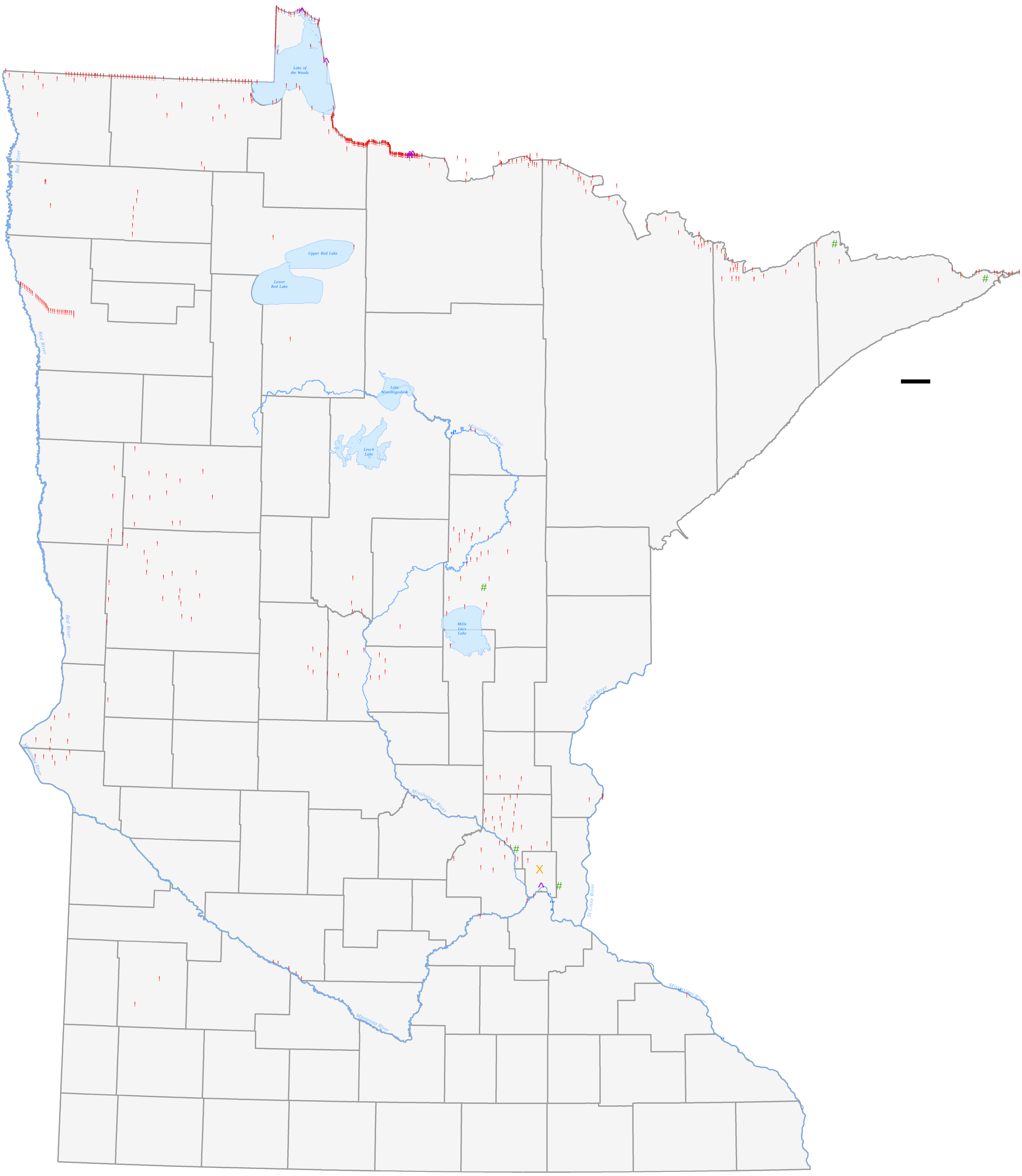
Contributors of Geodetic Control Data and number of marks

!	National Agencies	1020
"	Inter-State or Inter Province Agencies	16
#	State, Province, Commonwealth, and Territorial Agencies	30
X	County Agencies	0
^	Other Agencies	2

Created by: Ben Butzow
Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1910 and 1919



0 50 100 Miles

Marks Set in the 1910 Decade

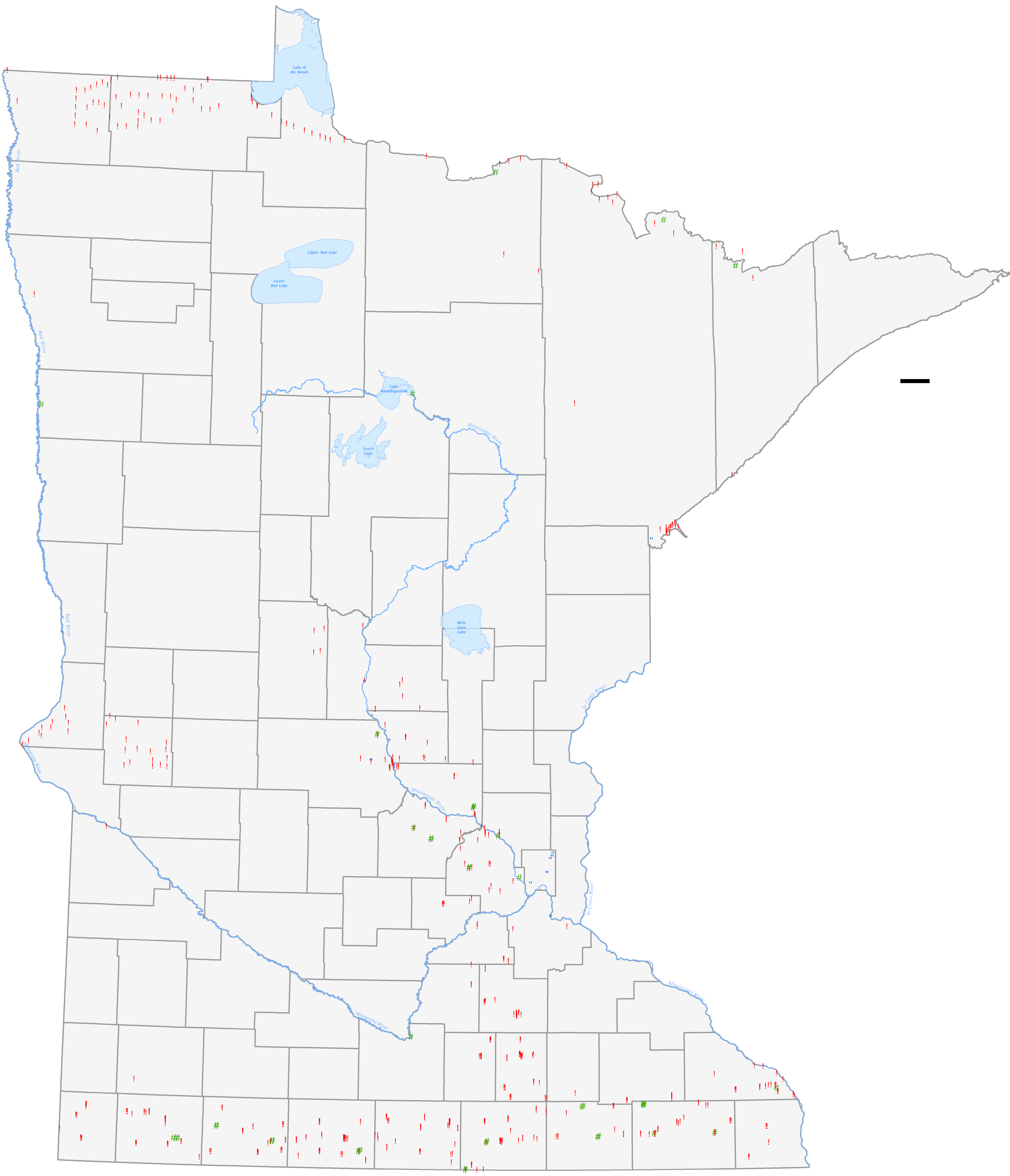
Contributors of Geodetic Control Data and number of marks

!	National Agencies	542
"	Inter-State or Inter Province Agencies	14
#	State, Province, Commonwealth, and Territorial Agencies	6
X	County Agencies	1
^	Other Agencies	6

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1920 and 1929



0 50 100 Miles

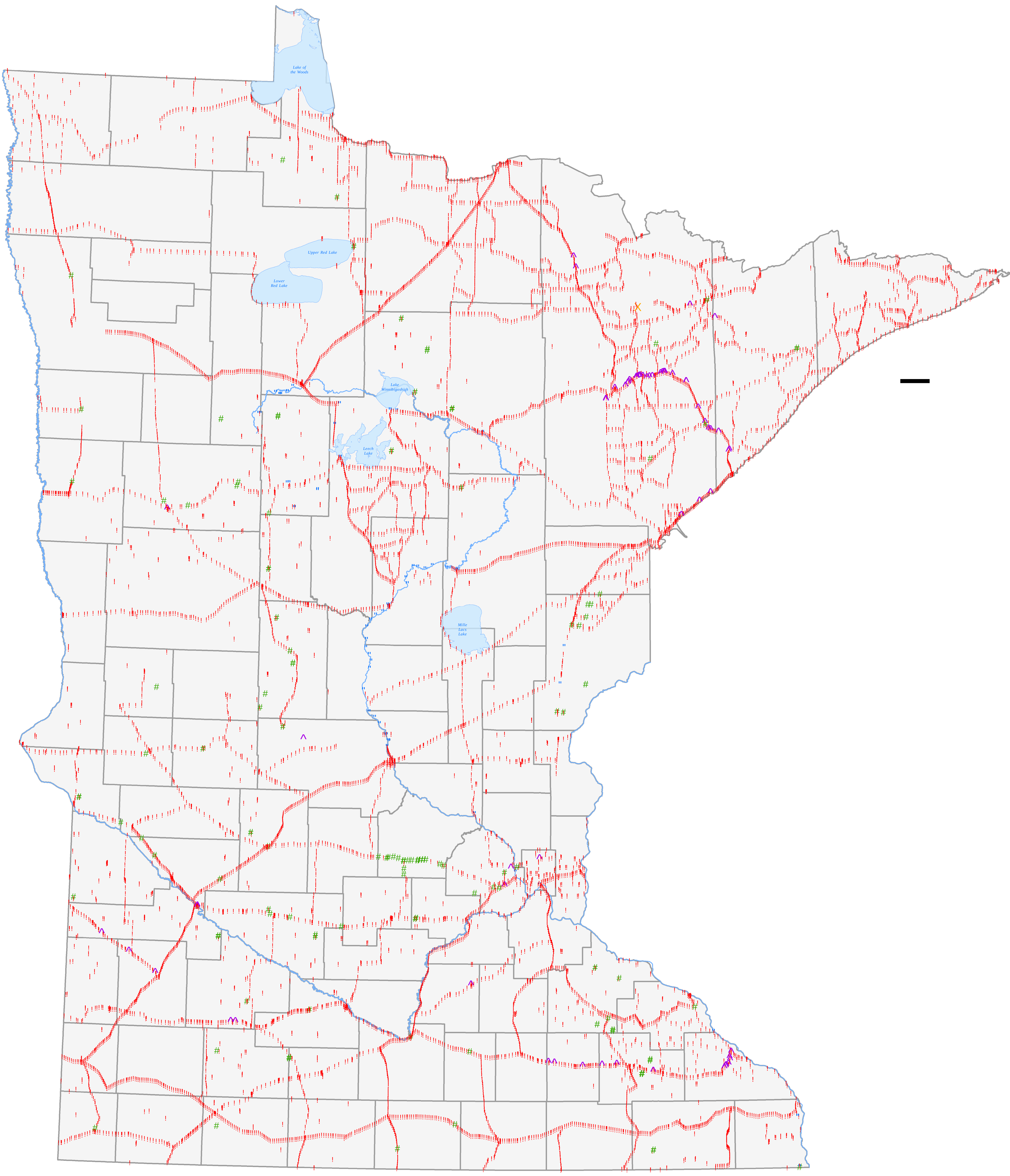
Marks Set in the 1920 Decade

Contributors of Geodetic Control Data and number of marks

!	National Agencies	575
"	Inter-State or Inter Province Agencies	11
#	State, Province, Commonwealth, and Territorial Agencies	51
X	County Agencies	0
^	Other Agencies	0

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Minnesota Monuments
Set Between 1930 and 1939



0 50 100 Miles

Marks Set in the 1930 Decade

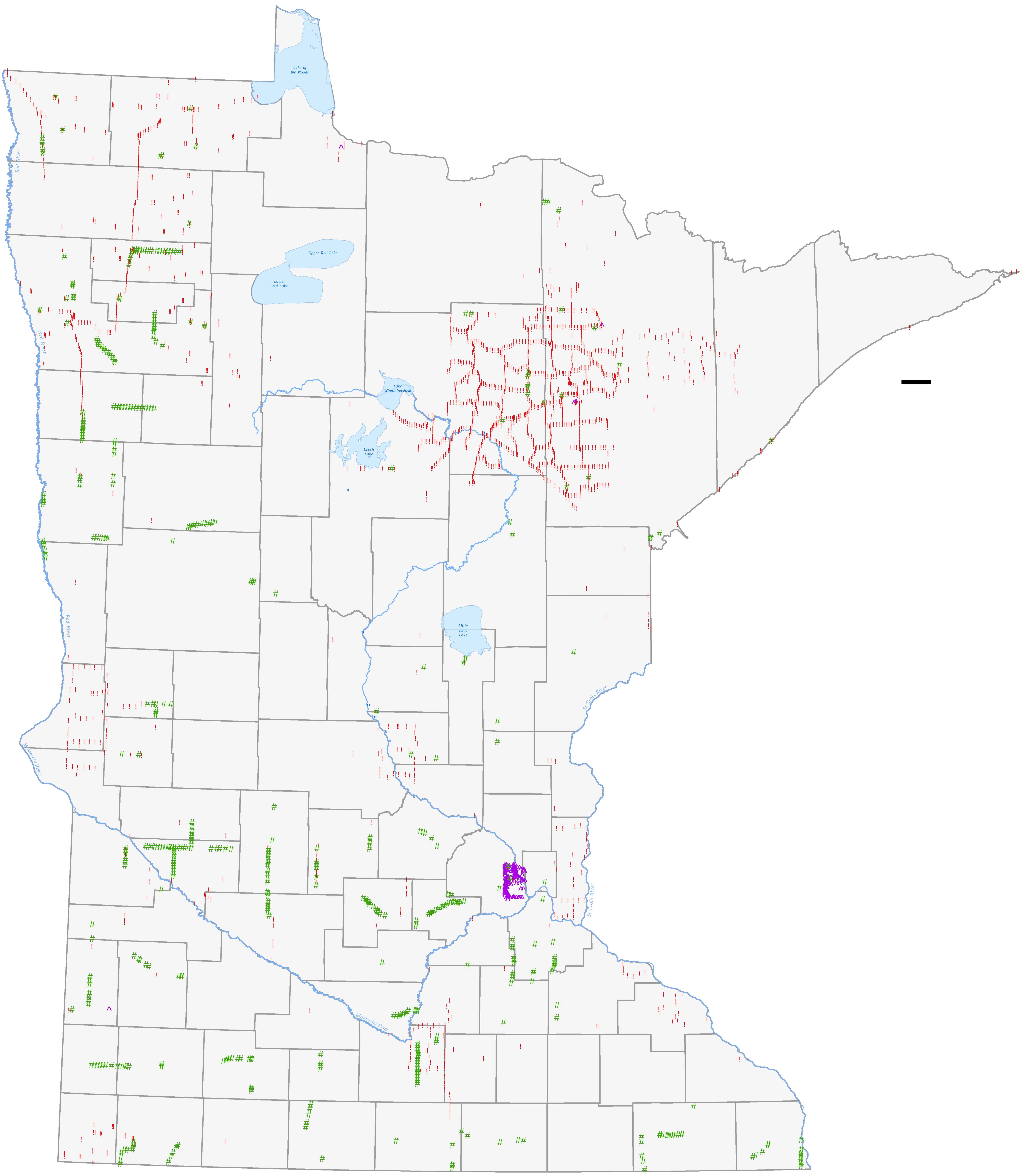
Contributors of Geodetic Control Data and number of marks

!	National Agencies	9309
"	Inter-State or Inter Province Agencies	67
#	State, Province, Commonwealth, and Territorial Agencies	157
X	County Agencies	1
^	Other Agencies	62

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 20, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1940 and 1949



0 50 100 Miles

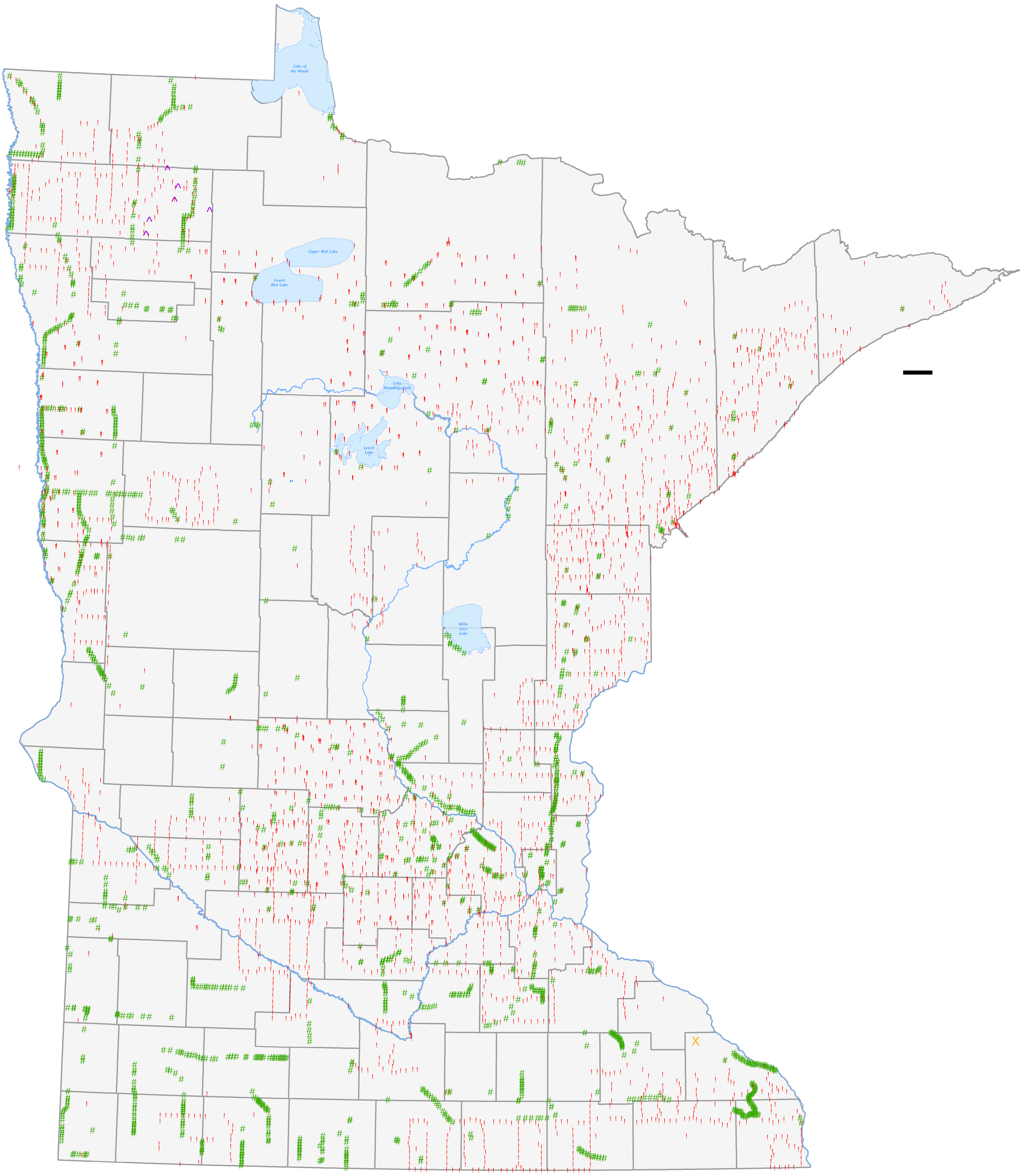
Marks Set in the 1940 Decade

Contributors of Geodetic Control Data and number of marks

!	National Agencies	2024
"	Inter-State or Inter Province Agencies	5
#	State, Province, Commonwealth, and Territorial Agencies	499
X	County Agencies	0
^	Other Agencies	169

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 19, 2007
Revised date: December 28, 2007

Minnesota Monuments
Set Between 1950 and 1959



0 50 100 Miles

Marks Set in the 1950 Decade

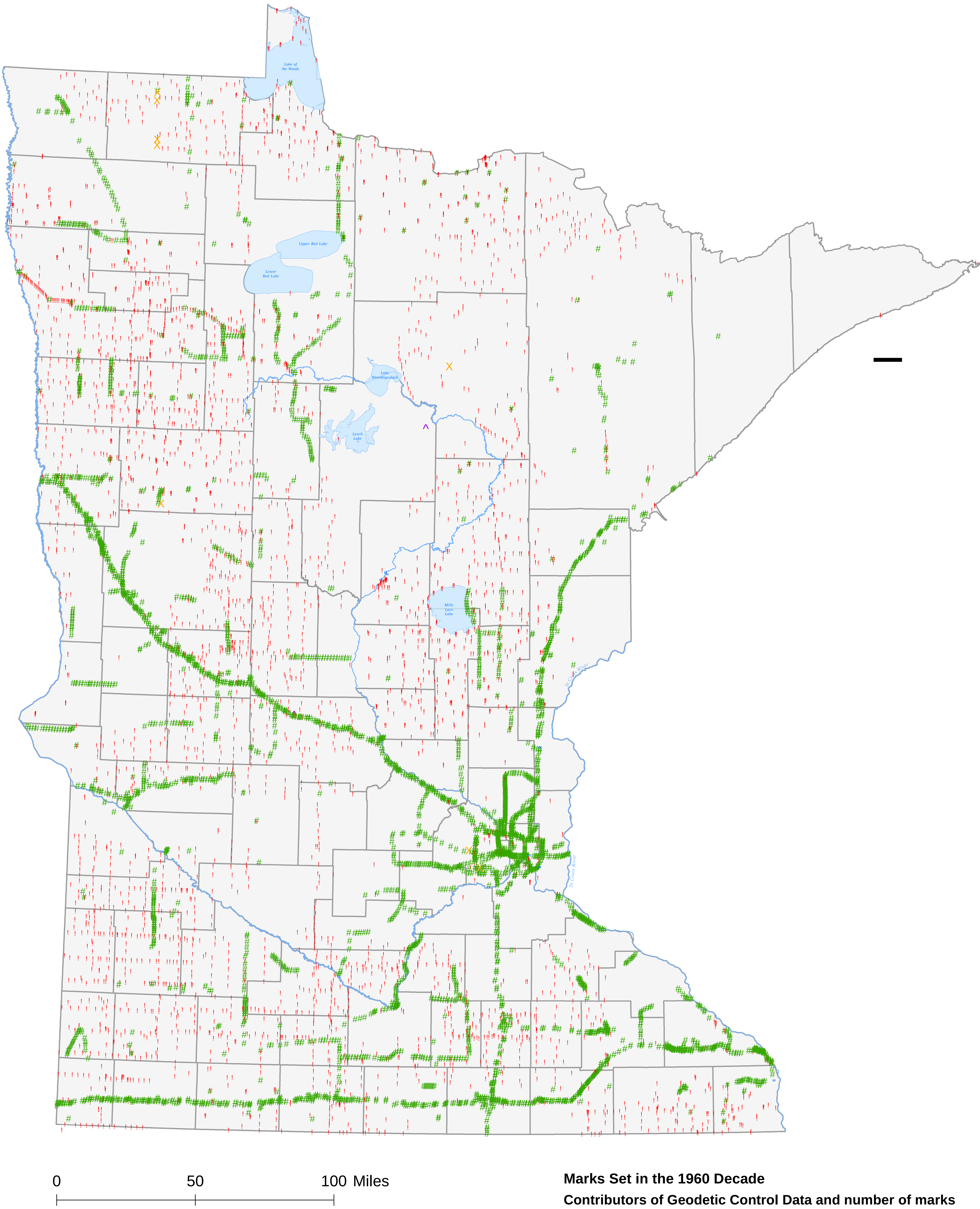
Contributors of Geodetic Control Data and number of marks

!	National Agencies	4187
"	Inter-State or Inter Province Agencies	3
#	State, Province, Commonwealth, and Territorial Agencies	1498
X	County Agencies	1
^	Other Agencies	6

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 19, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1960 and 1969



Marks Set in the 1960 Decade

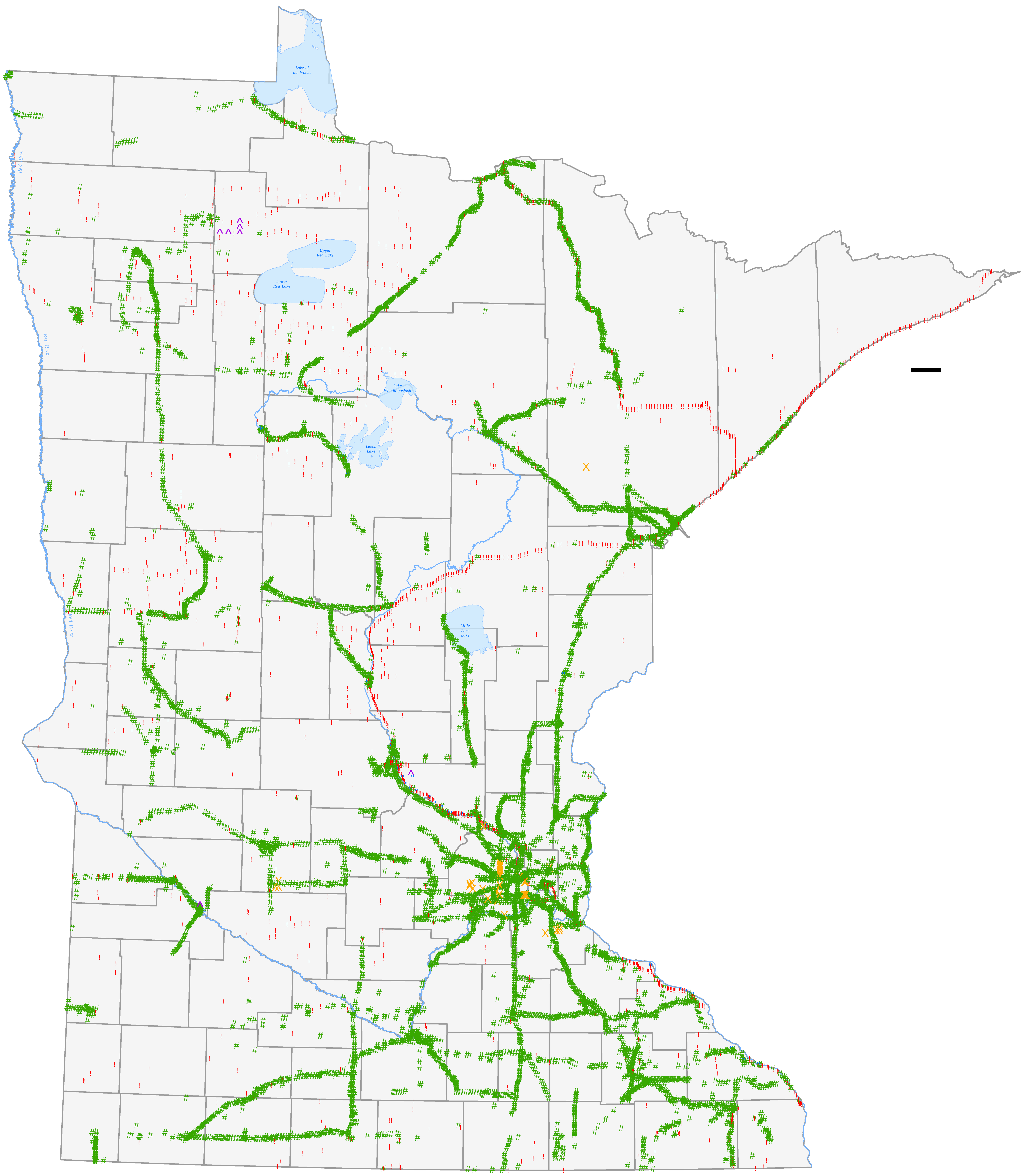
Contributors of Geodetic Control Data and number of marks

!	National Agencies	5037
"	Inter-State or Inter Province Agencies	16
#	State, Province, Commonwealth, and Territorial Agencies	4141
X	County Agencies	8
^	Other Agencies	2

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 19, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1970 and 1979



0 50 100 Miles

Marks Set in the 1970 Decade

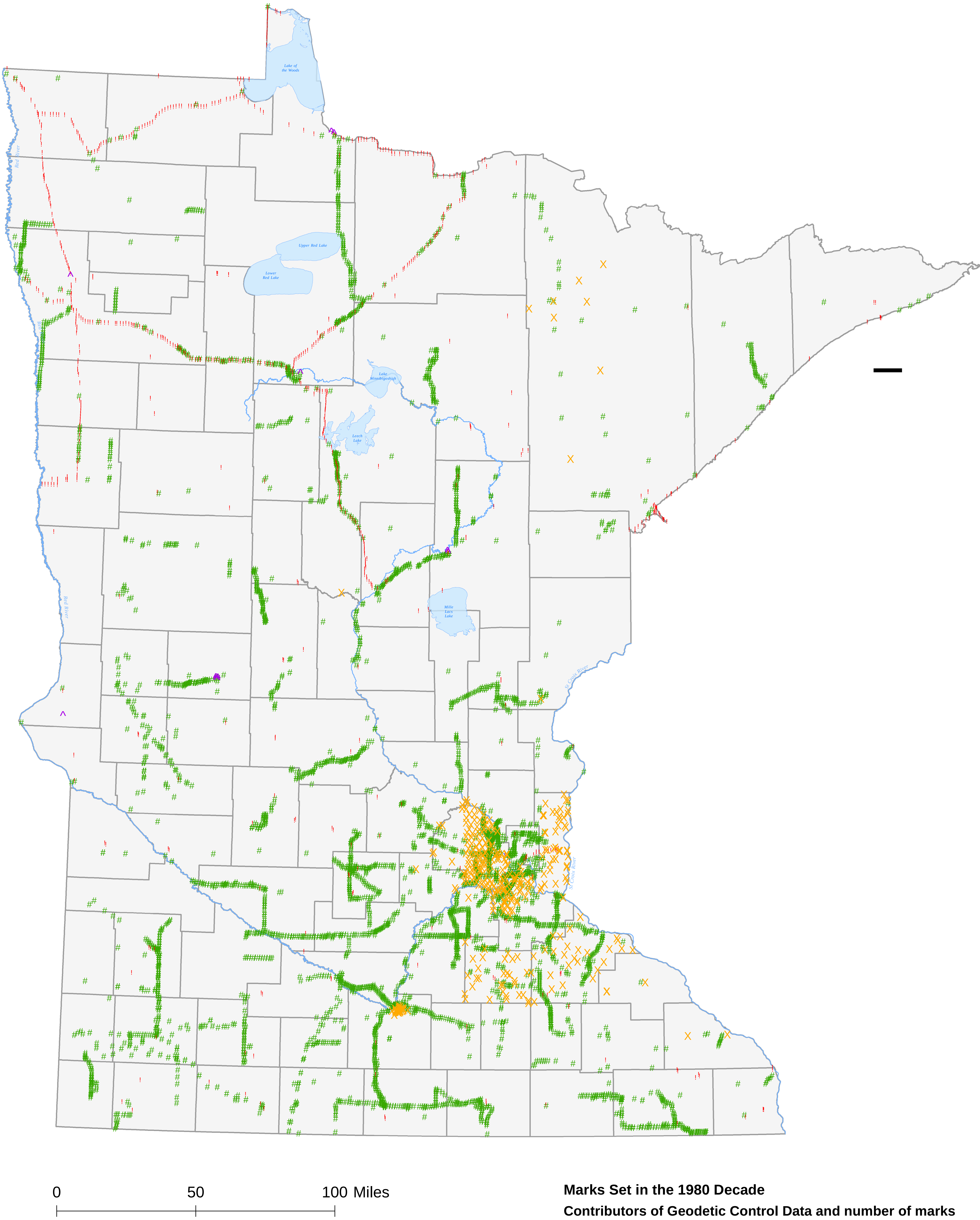
Contributors of Geodetic Control Data and number of marks

!	National Agencies	1820
"	Inter-State or Inter Province Agencies	49
#	State, Province, Commonwealth, and Territorial Agencies	8441
X	County Agencies	40
^	Other Agencies	9

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 19, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1980 and 1989



Marks Set in the 1980 Decade

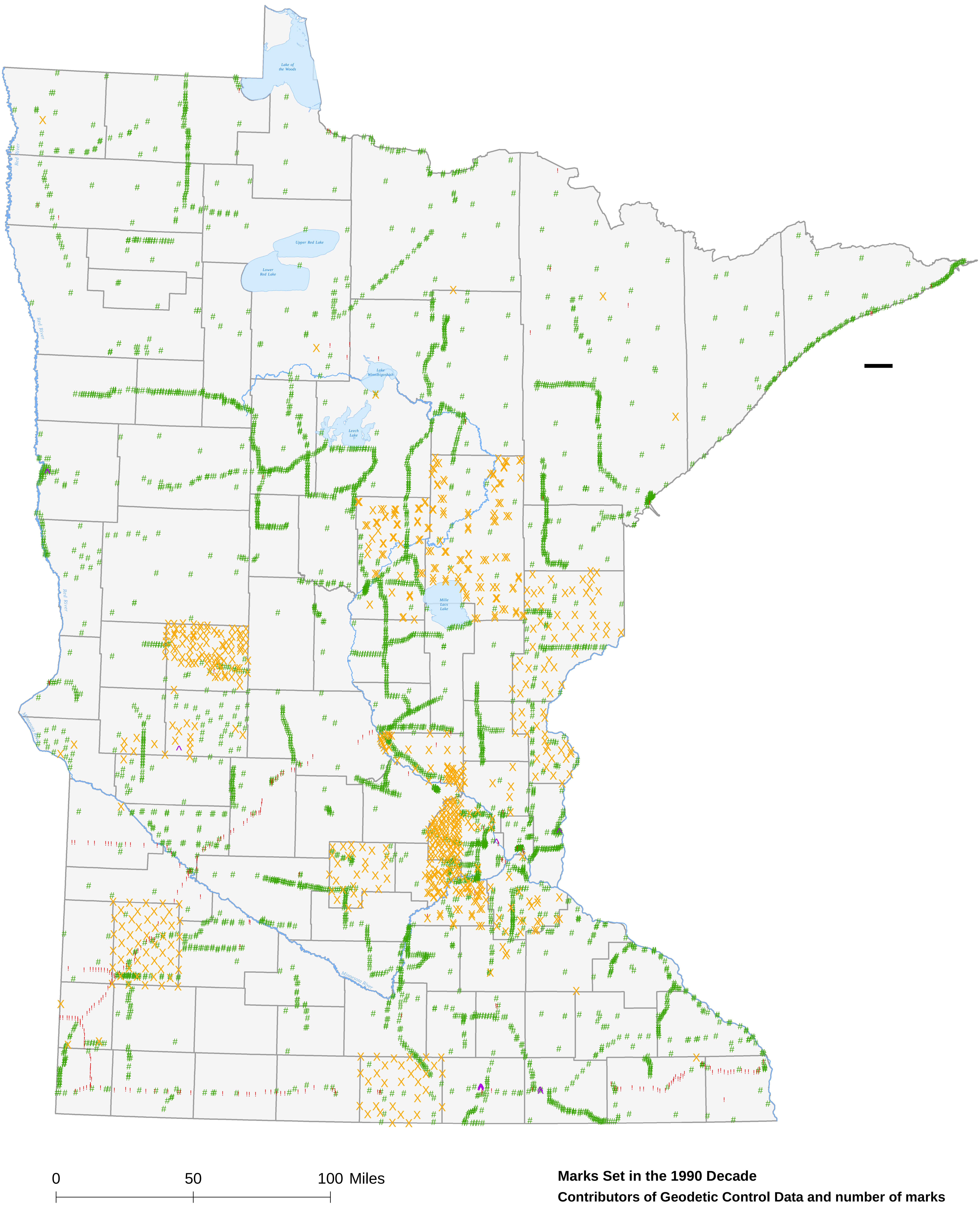
Contributors of Geodetic Control Data and number of marks

		Number of marks
!	National Agencies	765
"	Inter-State or Inter Province Agencies	1
#	State, Province, Commonwealth, and Territorial Agencies	4566
X	County Agencies	325
^	Other Agencies	11

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 19, 2007
Revised date: December 28, 2007

Minnesota Monuments

Set Between 1990 and 1999



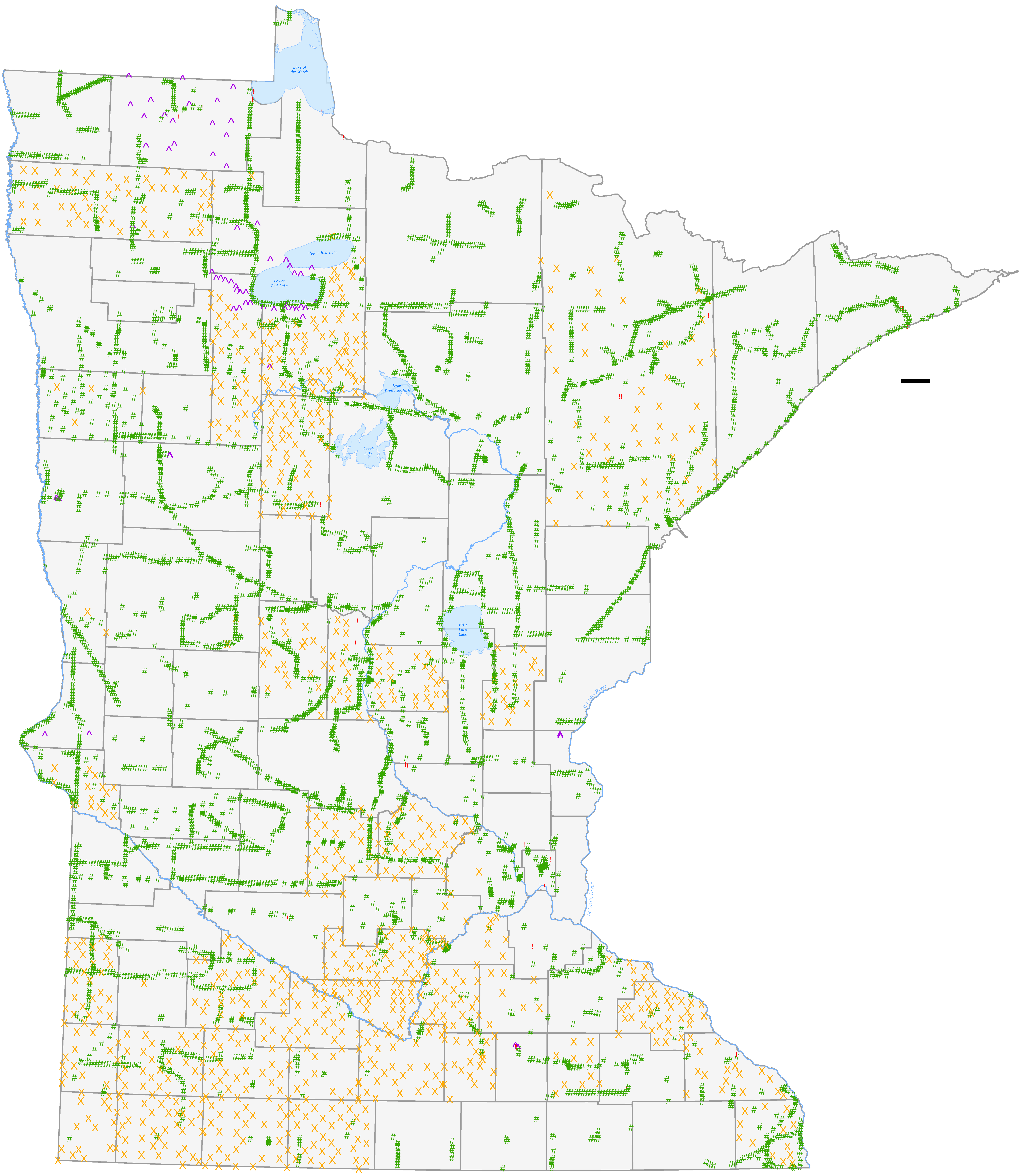
Marks Set in the 1990 Decade

Contributors of Geodetic Control Data and number of marks

!	National Agencies	267
"	Inter-State or Inter Province Agencies	1
#	State, Province, Commonwealth, and Territorial Agencies	3475
X	County Agencies	694
^	Other Agencies	11

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 19, 2007
Revised date: December 28, 2007

Minnesota Monuments
Set Between 2000 and 2007



0 50 100 Miles

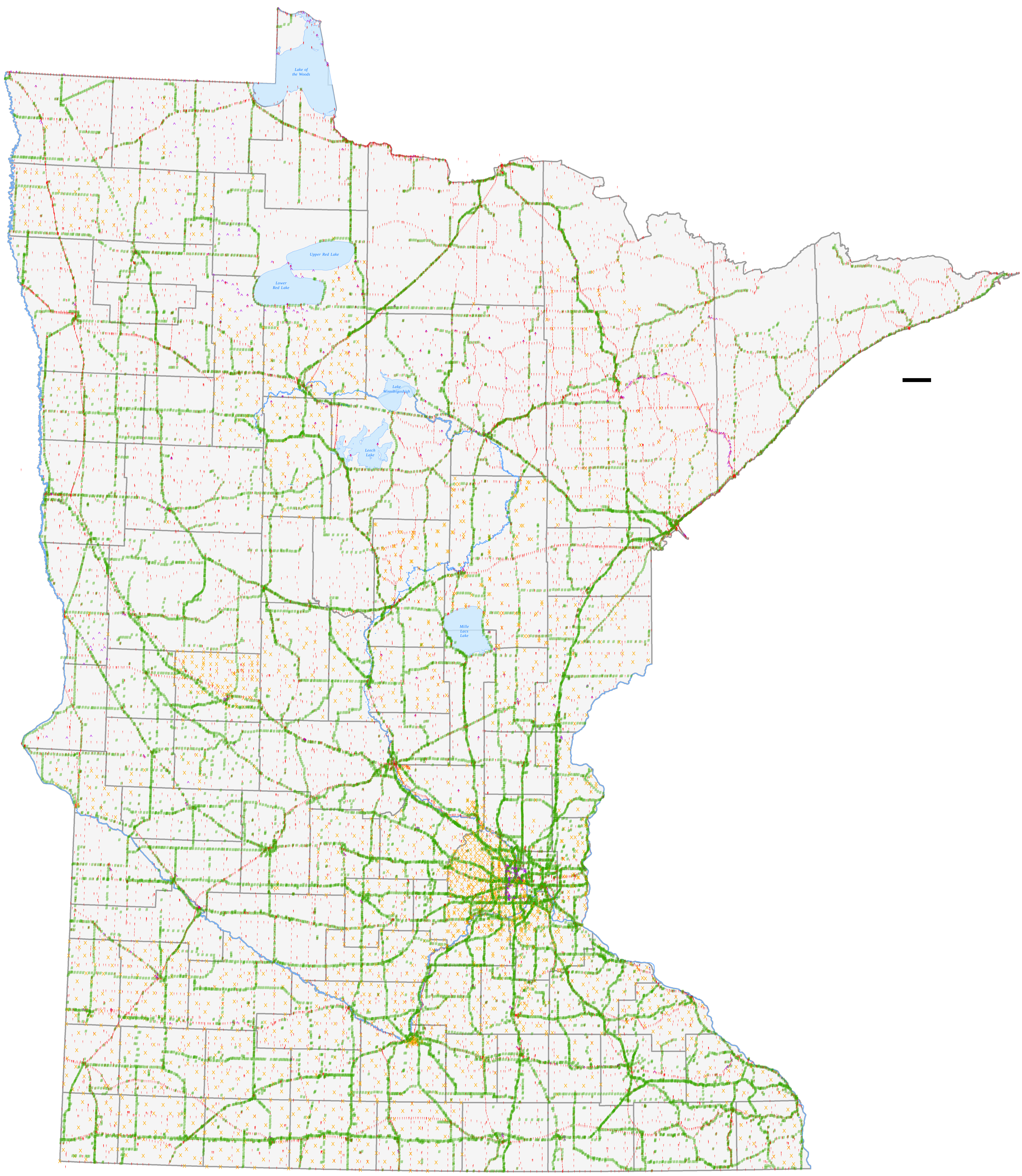
Marks Set in the 2000 Decade

Contributors of Geodetic Control Data and number of marks

!	National Agencies	47
"	Inter-State or Inter Province Agencies	0
#	State, Province, Commonwealth, and Territorial Agencies	4448
X	County Agencies	979
^	Other Agencies	63

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: November 19, 2007
Revised date: December 28, 2007

Minnesota Monuments
Set Between 1860 - 2007



0 50 100 Miles

All Set Monuments in Minnesota

Contributors of Geodetic Control Data

National Agencies	26005
Inter-State or Inter Province Agencies	604
State, Province, Commonwealth, and Territorial Agencies	27484
County Agencies	2056
Other Agencies	567

Created by: Minnesota Department of Transportation
Office of Land Management
Geodetic Unit
Sources: Minnesota Department of Transportation
Spatial Reference: NAD83 UTM Zone 15N
Creation date: December 27, 2007
Revised date: December 28, 2007