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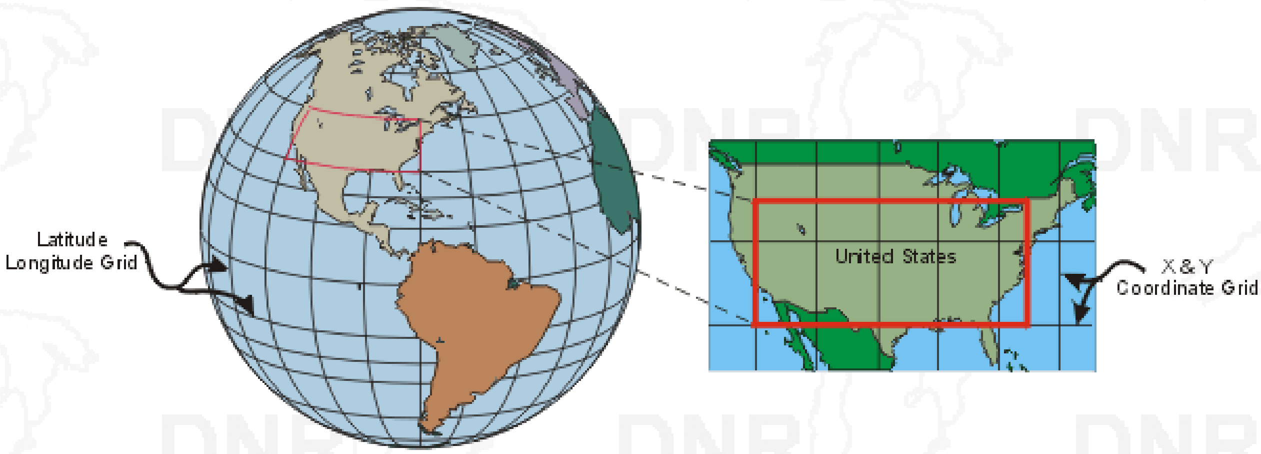
Map Projections

Michigan Department of Natural Resources

What is a Map Projection?

A map projection is a rigorous mathematical means of translating a particular region of our earth's curvaceous three-dimensional surface into a flat two-dimensional representation.

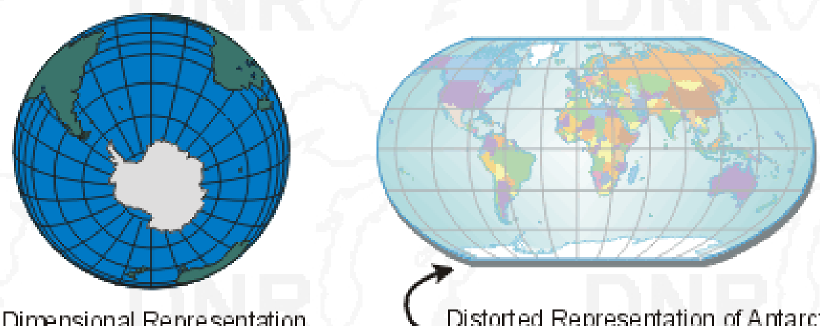
In the translation from a spherical surface to a two-dimensional, flat surface, a change in the expression of points occurs. In the real spherical world, locations are described using two angles (i.e., Latitude & Longitude). In the flattened virtual world of Map Projections, positions can be described in Cartesian Coordinates, where positions are described using two displacements (i.e., X & Y).



Spherical 3-Dimensional Surface

2-Dimensional Representation (Flat Map) of Part of the Earth's Surface

Map PROJECTIONS are named as such because they mathematically simulate a process relatively equivalent to the physical act of PROJECTING the image of a three-dimensional object onto a flat surface, such as flattening a three-dimensional scene onto film when we use a camera to take a picture.



3-Dimensional Representation of Antarctica

Distorted Representation of Antarctica generated using the Robinson Projection

Mathematicians have devised many clever schemes to accomplish the transformation from three to two dimensions, but each and every one of them produces an image that in one way or another distorts the region of the real world's surface that is being projected. As you look at different parts of a projected image, actual distances on the ground are not represented the same everywhere on the projected, flat image.

Generally, larger regions mean more curvature, which means more distortion. Certain maps that attempt to project the entire surface of the earth onto a single flat map produce tremendous distortions. On the other hand, examining a region of earth's surface that is small, for example, only one square foot, would indicate no curvature at all. It would not be difficult to design a projection with virtually no distortion (i.e., Scale would not change from one area of the projected image to another).

Although a region the size of Michigan would not seem to posses a great deal of curvature, controlling the amount of distortion in a projected image is difficult and involves compromise. One popular compromise has been to subdivide the state into three smaller regions, so that each region possesses even less curvature and is therefore less distorted when projected onto a flat surface.

What is the Michigan State Plane Coordinate System?

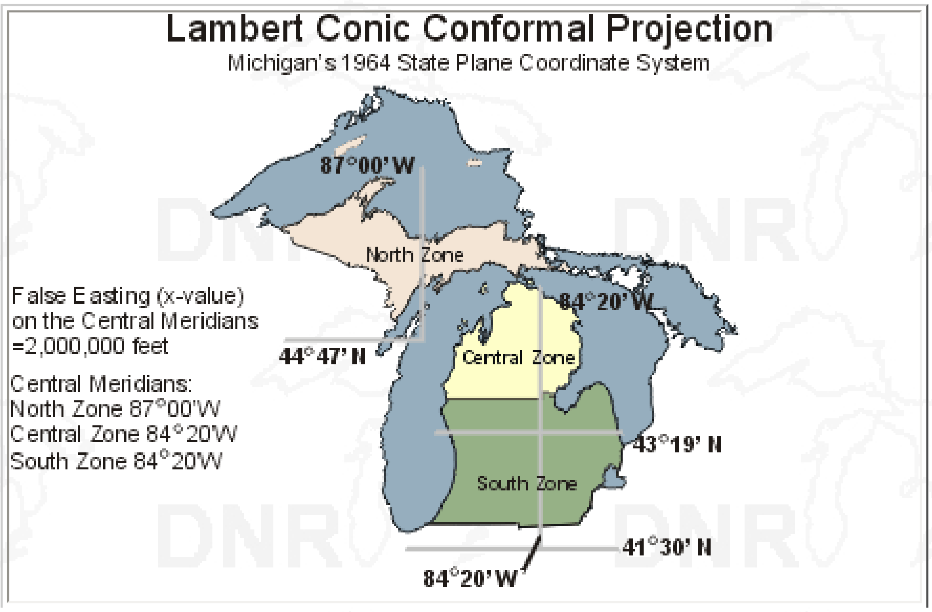
Each state is expected to designate a particular map projection scheme that both the federal government and the state may use as a convention. The federal government specified that these state systems keep distortion within certain limits. For example, a feature with a real length of 10,000 feet should never appear to be shorter than 9,999 feet nor longer than 10,001 feet in the projected image, no matter where in the state that feature appears.

Each state has one of these federally recognized systems. Ohio's system is called Ohio State Plane; Michigan's is called Michigan State Plane, etc.

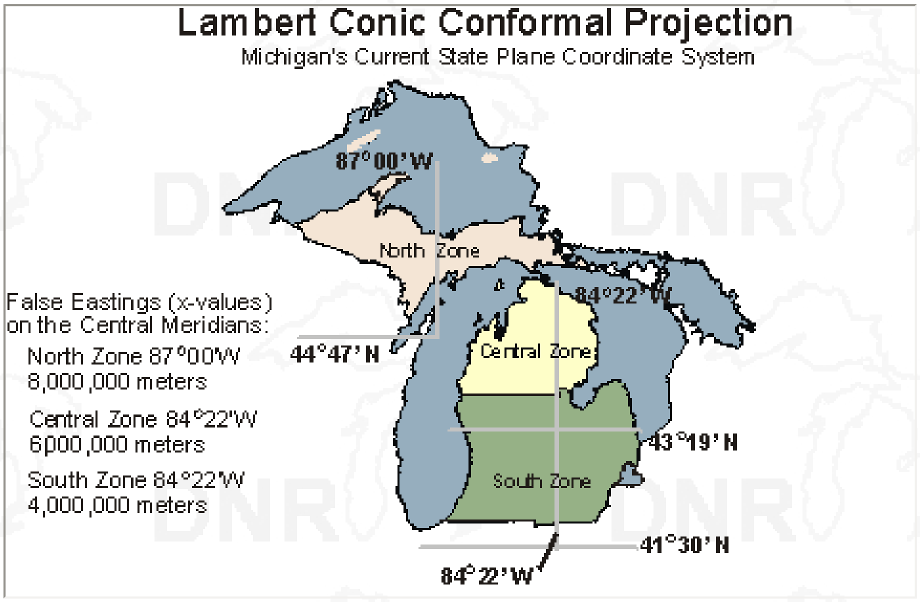
Prior to 1964, Michigan relied on a system that was based on three vertical projection zones. This system was the result of the federal government's initiative, the **State Plane Coordinate System of 1927**. This system, with it's vertically-oriented zones, created an unnecessarily large number of long boundaries between zones, and subdivided both the Lower and Upper Peninsulas.

Today, Michigan achieves the specified limits in distortions by breaking the state into three separate horizontally-oriented projections. The entire Upper Peninsula makes up the northern zone, the northern half of the Lower Peninsula is the central zone, and the southern half of the Lower Peninsula is the southern zone.

There have been two iterations of this system. The first was adopted by the Michigan Legislature in 1964. Then in 1983, the federal government made broad revisions to the entire set of state systems and published these revised standards as the **State Plane Coordinate System of 1983**.



Projection:	Lambert Conformal Conic		
Datum:	NAD27		
Ellipsoid:	Modified Clarke, 1866		
	Equatorial Radius:	6378450.04748448	
	Polar Radius:	6356826.62150116	
Standard Units:	US Survey feet		
Standard Parallels:	North	45° 29' N	47° 05' N
	Central	44° 11' N	45° 42' N
	South	42° 06' N	43° 40' N
Origin:	North	87° 00' W	44° 47' N
	Central	84° 20' W	43° 19' N
	South	84° 20' W	41° 30' N



Projection:	Lambert Conformal Conic		
Datum:	NAD83		
Ellipsoid:	GRS80		
Standard Units:	Meters		
Standard Parallels:	North	45° 29' N	47° 05' N
	Central	44° 11' N	45° 42' N
	South	42° 06' N	43° 40' N
Origin:	North	87° 00' W	44° 47' N
	Central	84° 22' W	43° 19' N
	South	84° 22' W	41° 30' N

What is the Michigan GeoRef Coordinate System?

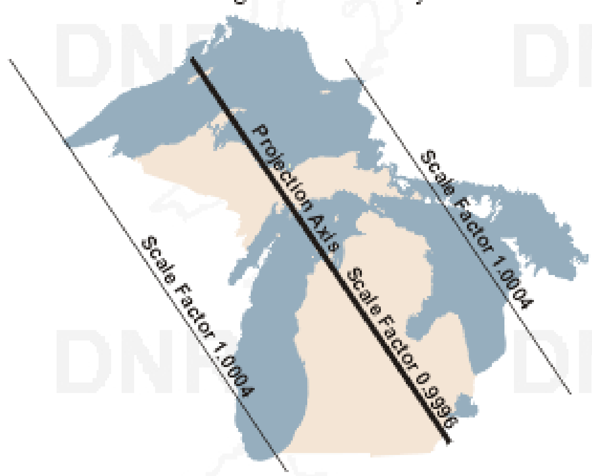
Michigan GeoRef is an alternative to the State Plane Coordinate System. But, unlike Michigan State Plane, GeoRef was designed to project the State using a single zone rather than three zones. Of course, something had to be compromised to achieve a single zone system.

The Michigan State Plane System specifies that 10,000 ft. on the ground can appear as no less than 9,999 ft. and no more than 10,001 ft. (1 part in 10,000) in the projected image or map. The Michigan GeoRef System, on the other hand, allows that same 10,000 ft. to vary from 9,996 ft. to 10,004 ft. (4 parts in 10,000) in apparent length.

Based on an Oblique Mercator projection with special parameters, the Michigan GeoRef System minimizes this increase in distortion by using a fundamentally different kind of map projection than is used by virtually all the State Plane Systems. The State Plane Systems make use of two basically different projection models. One of those projection methods favors regions that extend primarily north and south, and the other method favors regions that extend more in an east and west direction.

This choice for states such as Tennessee (east-west) and Vermont (north-south) was easy and uncompromising. However, Michigan is an odd-shaped state, expansive in a direction angling from the southeast to the northwest. The Map Projection Model used in GeoRef is well-suited to accommodating skewed regions such as Michigan.

Michigan GeoRef System



0,0 origin (NAD 83) 40°24' 05.6528" N, 91° 52' 56.2121" W

Projection:	Oblique Mercator
Datum:	NAD83
Ellipsoid:	GRS80
Standard Units:	Meters
Scale factor at projection's center:	0.9996
Longitude of projection's origin:	86° 00' 00" W
Latitude of projection's origin:	45° 18' 33" N
Azimuth at center of projection:	337.25556
False Easting:	2546731.496
False Northing:	-4354009.816

For some applications, a single-zone system is almost a necessity. Naturally, defined regions like watersheds and forest compartments do not adhere to political boundaries, as does the three-zone Michigan State Plane system. In a multi-zone system, each zone is fundamentally incompatible with any other zone. They can not be brought together in any analytically useful way.

If in a particular application the need for a single-zone system outweighs the need for 1:10000 degree of accuracy, Michigan GeoRef may serve as a more practical basis for that work.

Need to Convert Your Data to Michigan GeoRef?

For ArcView users, an extension is available that offers the capability of converting data to and from Michigan GeoRef. It can be downloaded from the "Software Tips" page.

For ArcInfo users, listed below are links to projection files that provide the information necessary to reproject your data to Michigan GeoRef.

Projection	File
Geographic (Latitude/Longitude) To GeoRef	Download
Geographic (Latitude/Longitude) NAD83 To GeoRef	Download
State Plane Zone 2111, NAD27 Datum To GeoRef	Download
State Plane Zone 2112, NAD27 Datum To GeoRef	Download
State Plane Zone 2113, NAD27 Datum To GeoRef	Download
State Plane Zone 2111, NAD83 Datum To GeoRef	Download
State Plane Zone 2112, NAD83 Datum To GeoRef	Download
State Plane Zone 2113, NAD83 Datum To GeoRef	Download
Lambert Projection (Custom), NAD27 Datum To GeoRef	Download
UTM Zone 15, NAD27 Datum To GeoRef	Download
UTM Zone 16, NAD27 Datum To GeoRef	Download
UTM Zone 17, NAD27 Datum To GeoRef	Download
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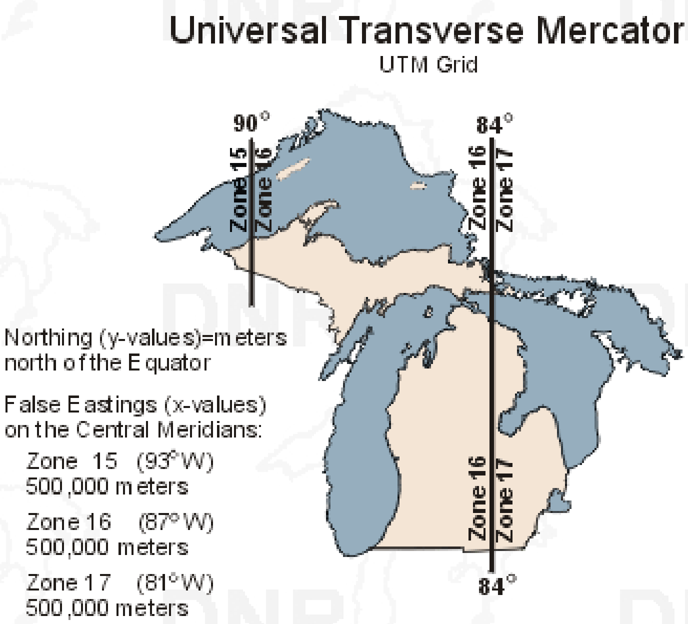
UTM Zone 16, NAD83 Datum To GeoRef	Download
UTM Zone 17, NAD83 Datum To GeoRef	Download



What is a Reference System?

A map projection will transform, or alter, two angles (latitude and longitude) in three dimensions, to x and y Cartesian coordinates in two dimensions. How do we come up with the latitude and longitude for a particular location? We tend to think of latitudes and longitudes as absolutes, but they are not. The angles that we call latitude and longitude are based on measurements that are relative to a specified origin and based on a model that has a precise shape and vertex.

Even in a simple two-dimensional case, trying to describe the location of a point with only an angular distance is useless, unless we know the location of the angle's vertex and the location of measurement.

A reference system is used to transform a physical location somewhere on earth to a specific latitude and longitude. A reference system, also referred to as a Datum, provides the necessary model of the planet, the necessary origin points, and physical measurements to describe where a point of origin is relative to other points of origin.

There are two reference systems commonly used in Michigan: the North American Datum of 1927 (NAD27), and the North American Datum of 1983 (NAD83).

The NAD83 system represents a readjustment and refinement of the NAD27 system, providing more accuracy and better compatibility with satellite-based navigation systems. Because of this, the latitude and longitude of any particular point specified with respect to the NAD27 system is not the same as the latitude and longitude of the same point specified with respect to the NAD83 system.

Conversion tables and computer programs have been developed to translate between points based in NAD27 and NAD83.