Wisconsin County Coordinate Systems

Report to the Wisconsin Department of Transportation Technical Services

Phase I

Project 0656-24-00
DOT FOS Object Code 5501

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Executive Summary

The following report describes the results of the development of ground based coordinate projection systems for all 72 counties in Wisconsin. These projection systems are designed to minimize the ground to grid distortion. The units of the projection systems are meters.

Each county is covered by one projection system. In some cases it was possible to cover two or more counties in one projection system and still minimize distortion.

Accompanying the county coordinate projection systems is a basic computer program that allows for conversion from latitude and longitude to northing and easting and the reverse in each system. This program is designed to facilitate analysis of the projection systems and to allow for initial testing. This program was not designed to be a full production software package within the context of Wisconsin DOT's automation and computerization projects.

The maximum distortion design parameters were one part in 50,000 for urban areas and one part in 30,000 for rural areas. All urban areas, including villages as small as 1,000, met the one part in 50,000 requirement, except the village of Ashland in Ashland County which was 1:30,000. There are three areas of the State that fell below the rural 1:30,000. The tops of both Rib Mountain and Mt. Whittlesey and a low area in northwestern Iron county. The design constraint of keeping each county on one projection system limited the ability to meet the maximum distortion requirements in these areas.

The following report contains a summary of the projection design process, the projection system parameters (arranged by county in Appendix A), the supporting program source code (Appendix B), and program operation directions.

Table of Contents

1. Introduction

Mathematically stable coordinate systems are based on the principles of map projections. Map projections are systematic planar representations of all or part of the surface of an ellipsoid or spheroid. They allow accurate flat surface mapping of the round earth. However, it is impossible to represent the earth on a plane surface without distorting either, distances, measurable area, or the shapes of earth's features. Many projections have been devised to minimize these distortions, but no single projection gives an absolutely true picture of the surface of the earth. County wide projections can be developed over a smaller extent of the earth's surface thereby minimizing projection distortions. A coordinate system developed on a county wide projection is precisely relatable to regional coordinate systems such as SPCS and UTM and global systems such as latitude and longitude.

The need for local or county coordinate systems has been recognized from many years to the Wisconsin Department of Transportation (WIDOT).

> "Several districts have demonstrated a need to have ground distances produced directly from computations both for legal property descriptions and field layout work. A project datum which more closely approximates the true earth's surface is required. Such project coordinates can then be used to perform alignment, layout, and right of way computations." Schultz, 1976

Some county wide systems have resolved these distortions by developing localized elevation and scale factors and applying them universally to the ground distances in a region. For example, highway construction sites sometimes have project factors which are automatically applied to all measured distances to relate grid distances to ground distances. Other systems may compute the scale and elevation factors at all National Geodetic Reference System stations in a county and apply the county average to all distances. Average elevation and scale factors are not the same as a mathematically stable county wide projection. A mathematically stable county wide projection and coordinate system is a planar coordinate system developed from a known ellipsoid or spheroid, designed to minimize distortions in a local region.

Many counties in Wisconsin have realized the advantages of county based coordinate systems in implementing elements of the Wisconsin Land Information Program. At the WIDOT a 1976 study (WIDOT, 1976) compared alternatives for local coordinate systems and selected county sized parallel planes that were determined by applying average grid factors to measurements. Burkholder (1993) has reported the results of survey of 46 DOT's across the country and found that nearly half of all DOTs use this same approach.

In Wisconsin an average grid or scale factor improved the ground to grid distortion by roughly a factor of three when compared to State Plane distances. One of the problems was inconsistent application of the factor and confusion among the consuming public over exactly what was shown. There was also confusion over when to multiple and divide the factor as well as problems with tracking when the factor had been applied and when it hadn't been applied.

The State of Minnesota has preceded Wisconsin in developing county-based coordinate systems. In Minnesota many counties have adopted these systems for land records modernization and geographic information system applications. Likewise in Wisconsin many counties have gone ahead with county based systems.

The purpose of Wisconsin County Coordinate Systems is to provide a mathematically rigorous method for relating ground measurements to control and other coordinate values. These systems will:

1. provide a means for consistent field reduction methods and reduce the effort required for reduction computations.

2. provide a state resource of defined coordinate systems that will support the Wisconsin Land Information Program and Wisconsin Department of Transportation projects and operations.

3. cover the entire State with these projections such that each county is covered by one coordinate system. One projection system may cover more than one county.

2. Design Process Summary

All coordinate project systems in this project were developed by introducing a local ellipsoid that passed through the median elevation of the area. This method has been suggested by Vincenty (1989) and Burkholder (1992). The steps to developing the correct ellipsoid for each county for this project were as follows.

The 1:100,000 topographic county maps series were used to determine average highs, lows, and elevation profiles of each county. A minimum of fifteen points were selected from each county and either digitized or scaled for latitude, longitude, and elevation. In every county the county seat and populated areas were included in the county profile.

Using the county maximum and minimum latitude and longitude values, a geographic window was determined. This window was then used to "cut out" National Geodetic Survey (NGS) first and second order points in each county. These points were averaged to determined the county's average geodial separation.

The county profile, the computed median elevation, and the county shape were then optimized for each county using a proprietary method developed by David Krohn to optimize the projection type and the exact placement of the central meridians or standards parallels.

After the individual county projections were determined the points in the county profile were run through test programs to verify the design. This step catches any computation or coordinate value interpretation errors. The quality of the projection was also verified against the design constraints.

Opportunities for combining counties were then examined regionally. For example, in the Fox River Valley area, the heavily urbanized areas around Appleton that cross county boundaries were candidates for combined coordinate systems. Also, counties that were known to be working on joint land records projects were combined as possible.

3. Projection System Results

All coordinate systems were developed for individual counties. In some cases more than one county is included in one coordinate system. In no cases does a county have more than one coordinate system.

The following page illustrates the counties that share combined coordinate systems. As a result of these combinations there are 59 separate coordinate systems to cover the 72 counties.

The improvement in ground to grid discrepancies is approximately a factor of ten. This is more than a threefold improvement over the average scale factor approach and is very comparable to the improvements that were experienced in Minnesota.

The maximum distortion design parameters were one part in 50,000 for urban areas and one part in 30,000 for rural areas. All urban areas, including villages as small as 1,000, met the one part in 50,000 requirement, except the village of Ashland in Ashland County which was 1:30,000. There are three areas of the State that fell below the rural one part in 30,000. The tops of both Rib Mountain and Mt. Whittlesey and a low area in northwestern Iron county. The design constraint of keeping each county on one projection system limited the ability to meet the maximum distortion requirements in these areas.

Appendix A contain a listing by county of the projection systems. Notes about each county system are included in the summaries.

4. Program Overview

4.1 Program Purpose

County83.exe performs coordinate conversions between Geodetic (Latitude / Longitude) and Wisconsin County Projection System Coordinates. The county projection systems are based on either a transverse Mercator or a Lambert conic conformal projection. Appendix A of this report contains the full description of each county's projection system.

Projection computations are derived from equations and constants provided by the National Geodetic Survey (NGS) and are referenced to the Geodetic Reference System of 1980 (GRS 80) ellipsoid, Wisconsin High Precision Network.

This program is for projection system testing and initial conversions and start up operations. It is not designed to be fully integrated with Wisconsin DOT's surveying automation projects.

4.2 Computing Environment

County83.exe runs on any IBM® or IBM® compatible, micro-computer under DOS® 2.0, or later, with a minimum of 256k memory. It is written/compiled under QuickBASIC® version 4.5 and will use a math co-processor if one is present or will emulate one if none is present. Input and output file sizes are limited only by the amount of available disk storage.

4.3 Registered Trademarks

IBM® is a registered trademark of International Business Machines Corporation. QuickBASIC® and GW BASIC® are registered trademarks of Microsoft Corporation. TurboBASIC® is a registered trademark of Borland International, Incorporated.

5 Program Rules

5.1 Units

The NGS NAD 83 equations are developed in metric units and all computations for rectangular coordinates are in meters. Latitudes and Longitudes are treated as positive values, therefore E/W, N/S, or +/- designations are not required.

5.2 Coordinate Expression

When people speak in terms of coordinates, they imply a coordinate expression preference depending on the system being used. Geodetic preference is generally Latitude and Longitude, surveying or state plane coordinates preference is generally North and East (or Northing and Easting), and universal transverse Mercator (or other cartesian systems) is generally X and Y. This program follows these implied conventions. So for input/output purposes, the following rule is used :

Geodetic is Latitude and Longitude
County83 County Coordinates are Northing and Easting

For convenience, another program, called REFORMAT, has been provided with the County83.exe program. REFORMAT will change the order of variables as specified by the user for any formatted ASCII text file.

5.3 User Interaction

County83.exe requires that you press the <Enter> key after any entry you make (except for the "(Press any key to continue)" prompt). This allows you one last chance to change your mind before you commit yourself to something. When selecting from a menu, you are limited to only those options shown on the menu. The program generally error traps for other entries and returns you to the prompt if an incorrect entry is made.

County83.exe is case insensitive. You may use upper or lower case letters for responses to prompts.

5.4 Error Trapping

Basic error trapping is built in and the program normally should not unceremoniously dump you back to DOS® with an obscure message. Usually when an error is detected (such as a non-existent input file) you are returned to the prompt where the error occurred with a chance to correct it. In some cases the error may be severe enough that the program restarts itself. Those errors that are not specifically trapped will result in a screen message indicating the error number. This error number can be found in any IBM BASIC®, GW BASIC®, TurboBASIC®, or QuickBASIC® manual for a more thorough explanation. Normally, there should be no cause for these un-trapped errors to occur unless the County83.exe executable file itself has become corrupted.

6. Program Use Information

6.1 Computations Supported

County83.exe performs three basic computations:

Forward - Latitude/Longitude to Northing/Easting
Inverse - Northing/Easting to Latitude/Longitude
Zone-To-Zone - Northing/Easting to Northing/Easting

6.2 Starting

To begin execution, type County83 followed by <Enter> at the DOS® prompt (you can use drive and/or path specifier prefixes as necessary if County83.exe is not in the current directory). A title screen, shown below, will appear with a momentary flashing message as data arrays are initialized and loaded. When the program is ready to proceed you will see a "(Press any key to continue)" message near the bottom of the screen.

Title Screen

Next you will be presented with the Computation Menu. This is the "master" menu and is the screen you will normally be returned to after computations or other inquiries are completed. The computation menu is shown on the following page.

Each item on the computation menu is described in the following sections.

Computation Menu

Sections 6.3 through 6.10 explain each menu option and subsequent steps within those operations.

6.3 Comp Menu Option 1 - County Forward : Lat/Long to Northing/Easting

This option will convert a file of Latitudes and Longitudes to a county's Northing and Easting coordinates. Each station's output will also include its convergence and scale factor.

After selecting the forward computation you will be presented with list of counties. These are shown in the County Menu below. Select the two digit code for the County followed by <enter>.

County Menu

The next menu will ask you what type of input you are using, data file input or point-by-point input. This is the Data Entry Menu Shown below.

Data Entry Menu

If you select point-by-point you will then be asked if you want to see the projection system parameters for the county you have selected. If you select file input, you are presented with the file input screen. The computation option you selected is displayed in the upper left and right hand corners. The prompt line is:

Name of input file ..... _

Additional screen messages tell you that drive and path are allowed in the file name (this is also true for the output file), and that pressing <Enter> alone without a file name will take you back to the Comp Menu. Also, if you do not remember the file name you can type in a question mark (?) followed by <Enter> to see a directory. When you do this you are asked for the drive or path for which you want to see the files.

When you have identified your input file County83.exe checks for the file's existence. If it does not exist you will see an error message and then be returned to the name of input file prompt.

If the file does exist, you will be prompted for the name of the output file. If the output file exists, the program will ask you if want to overwrite it.

Once you have successfully identified your output file, the program continues with the computation sequence. If you are doing point by point entry you will be prompted for the station name, latitude degrees, latitude minutes, latitude seconds, longitude degrees, longitude minutes, and longitude seconds. The Point-by-Point input menu is shown below.

Point-by-Point Input Prompts for Geographic Coordinates

Once the station data are collected the computation process continues. If you are doing point-by-point you will asked if you want to convert another station. For file input, when the computation is completed you are taken back to the Computation Menu.

6.4 Comp Menu Option 2 - County Inverse : Northing/Easting to Lat/Long

This option will convert a file of County Northing and Easting coordinates to latitudes and longitudes.

The steps are identical to the forward computation.

6.5 Comp Menu Option 3 - Send File to Printer

This option allows you to send a file to a printer if the printer is connected to LPT1. There are many other programs that will provide better file printing capabilities. The files are ASCII and can be read most other programs.

6.6 Comp Menu Option 4 - County to County

The County to County option allows for the conversion of single points from one county system to another. In State Plane Coordinate terminology this is the zone-to-zone conversion. This program is designed for point-by-point entry only. For file transfers, zone-to-zone conversions can be handled by first completing an inverse computation in the From County and then a Forward computation in the To County. The file transfer is not included in this option because all the same information would be needed. The point by point was included because in the normal forward and inverse options point-by- point output is not saved.

Specific menus guide you through which data to enter. The intermediate latitude and longitude results are shown on the screen.

6.7 Comp Menu Option 5 - Create a new data file

This option was added to accommodate faster data conversions and more easily saved data. This is not a full text editor and will only capture data entry files for this program.

6.8 Comp Menu Option F - File format information

If you select F in the Comp Menu you are presented with the file formats as shown below

File Information Screen

6.8 Comp Menu Option Q - Quit program

This is the way the program is normally terminated. When you select this option you are shown a successful program termination message as well as the session start and session end times (these times are read from your computer system's internal time).

6.9 File Formats

A free format approach is used for the input and output formats. Each station has its own data line with data elements delimited with commas. The program reads in a whole data line at once as a string. Then, knowing commas separate individual data elements, it starts at the left end of the string and picks out what it needs for the particular computation being performed.

Any extraneous data is ignored. This format allows you to use the output file from one computation (eg, Wood County Forward) as an input file for another (eg, Wood County Inverse).

This format is easily generated by database management packages, text editors, word processors, other computation programs, and even spreadsheets.

County83.exe opens the input file and reads data until it encounters an end-of-file marker (EOF, also shown as ^Z) or a blank data line. This eliminates the need for a header line stating how many stations are in the file. If a blank line is encountered before the EOF the program will stop, close all open files, and tell you it detected a data format error. If the problem is just a blank line then all computations to that point will be correct. Usually the most inconspicuous culprit is one or more blank lines at the beginning of your input file or after the end of your data but before the EOF.

6.9.1 County Forward

Input data line :

Name, LatDeg, LatMin, LatSec, LongDeg, LongMin, LongSec
NE4016, 45, 59, 1.330, 92, 17, 6.283

Output data line :

Name, Northing, Easting, Scale, +/-, ConDeg, ConMin, ConSec
NE4016, 253905.0676, 226072.9579, 0.9999959169, +, 0, 7, 26.4616

Note: name of the station can contain any character except a comma.

Remember: one station per data line and data elements separated with commas.

6.9.2 County Inverse

Input data line :

Name, Northing, Easting
NE4016, 253905.0676, 226072.9579 (may have other data on the line)

Output data line :

Name, LatDeg, LatMin, LatSec, LongDeg, LongMin, LongSec
NE4016, 45, 59, 1.330000, 92, 17, 6.283000

Note: name of the station can contain any character except a comma.

Remember: one station per data line and data elements separated with commas.

7. References

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