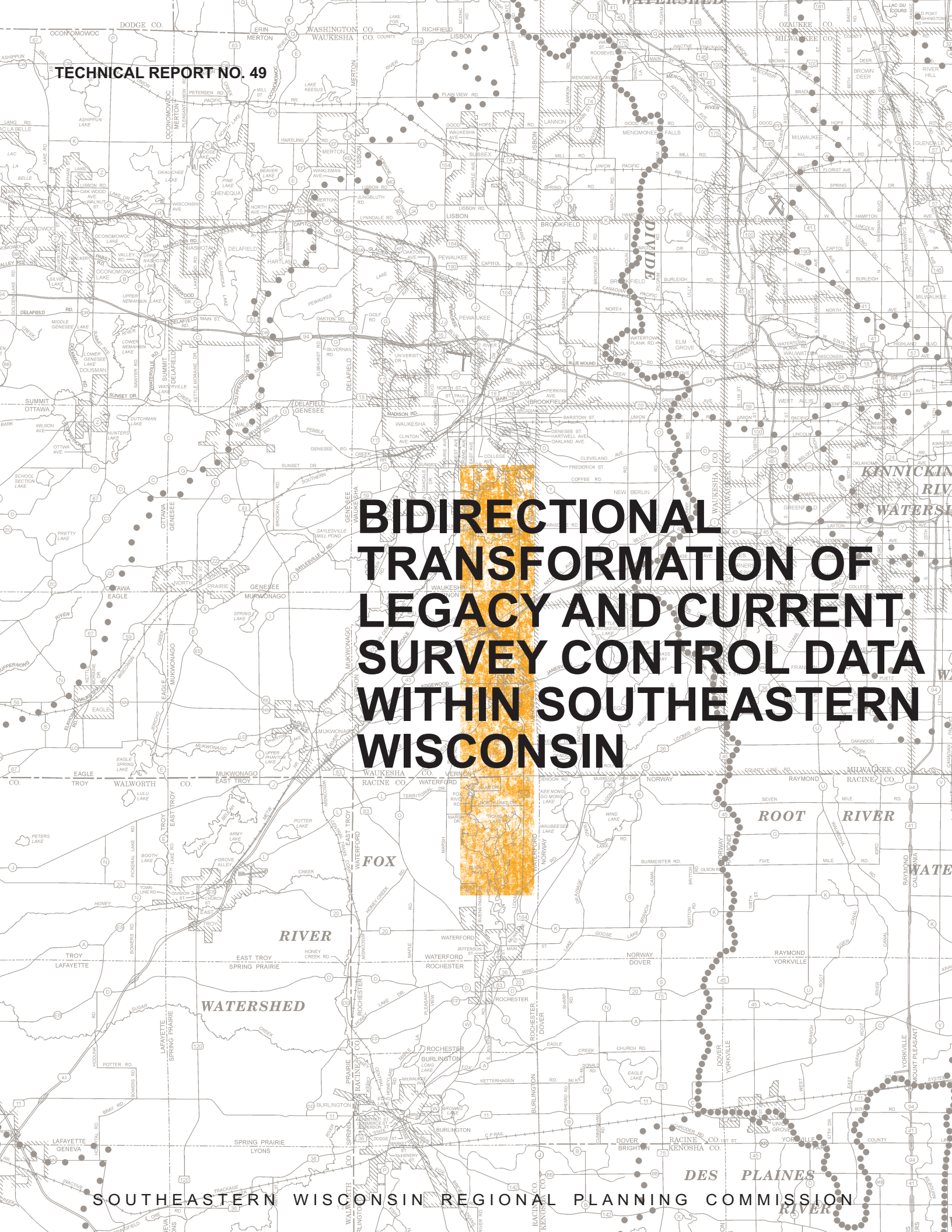
TECHNICAL REPORT NO. 49

BIDIRECTIONAL TRANSFORMATION OF LEGACY AND CURRENT SURVEY CONTROL DATA WITHIN SOUTHEASTERN WISCONSIN



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TECHNICAL REPORT NUMBER 49

BIDIRECTIONAL TRANSFORMATION OF LEGACY AND CURRENT SURVEY CONTROL DATA WITHIN SOUTHEASTERN WISCONSIN

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May 2010

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May 31, 2010

STATEMENT OF THE EXECUTIVE DIRECTOR

Since early 1964, the Regional Planning Commission has recommended to the governmental agencies operating within the Southeastern Wisconsin Region the use of a unique system of survey control as a basis for the compilation of large-scale topographic and cadastral maps; as a basis for the conduct of land and engineering surveys; and, since 1985, as a basis for the development of automated, parcel-based, land information and public works management systems within the Region. The recommended survey control system involves the remonumentation of the U.S. Public Land Survey corners within the Region and the establishment of State Plane Coordinates for those corners in order to provide a reliable horizontal survey control network. The system also includes the establishment of elevations for the remonumented corners and for related auxiliary bench marks to provide a reliable vertical survey control network fully integrated with the horizontal survey control network.

Through the cooperative efforts of the Commission and its constituent counties and municipalities, the recommended horizontal and vertical survey control system has been extended over the entire seven-county Region. All of the 11,753 U.S. Public Land Survey corners within the Region have been monumented, and the locations, coordinate positions, and elevations of the corners have been determined to a high level of accuracy. The resulting survey control network has been widely used in the preparation of large-scale topographic and cadastral maps, in the conduct of land and engineering surveys, and in the creation of parcel-based land information and public works management systems within the Region. All of the horizontal control survey work within the Region has been referenced to the North American Datum of 1927 (NAD 27). All of the vertical survey control work within the Region has been referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29), a datum formerly known as the Sea Level Datum of 1929.

The Federal government in 1973 determined to undertake a readjustment of the national horizontal control survey network, and to adopt a new horizontal datum known as the North American Datum of 1983 (NAD 83). In 1977 the Federal government further determined to undertake a readjustment of the national vertical control survey network and to adopt a new vertical datum, known as the North American Vertical Datum of 1988 (NAVD 88). In order to facilitate the use of the new datums within the Region by such agencies as may determine to do so, the Commission in 1993 undertook the development of procedures that would permit the bidirectional transformation of coordinates between the two horizontal and two vertical datums concerned. The procedures, developed by Mr. Earl F. Burkholder, PS, PE, consulting geodetic survey engineer under contract to the Commission, were documented in SEWRPC Technical Report No. 34, *A Mathematical Relationship Between NAD27 and NAD83(91) State Plane Coordinates in Southeastern Wisconsin,* December 1994, and SEWRPC Technical Report No. 35, *Vertical Datum Differences in Southeastern Wisconsin,* December 1995.

Further changes in surveying and mapping technology since 1993 caused the Commission to again undertake in 2008 a review and evaluation of the regional control survey and mapping program and of the Commission's role in that program. These changes included, among others, the adjustment of the once "new" Federal datums to create NAD 83 (2007) and NAVD 88 (2007) datums; the increasingly widespread use of Global Positioning System (GPS) technology for both horizontal and vertical positioning; and the provision of a network of Continuously Operating Reference Stations (CORS) within the Region by the Wisconsin Department of Transportation to facilitate the use of GPS technology. Following its long-standing practice, the Commission created a Technical Advisory Committee of knowledgeable users of the regional control survey system and asked that Committee to: 1) critically review and evaluate the status and continued utility of the Commission survey network; 2) recommend any needed changes in the network and the means for its perpetuation, maintenance, and use; and 3) recommend the Commission's role, if any, in such perpetuation, maintenance, and use. The findings and recommendations of that Technical Advisory Committee are set forth in SEWRPC Technical Report No. 45, *Technical Review and Reevaluation of the Regional Control Survey Program in Southeastern Wisconsin,* March 2008. Those findings and recommendations may be summarized as:

1. The Commission should continue to utilize NAD 27 and NGVD 29 as the basis for its horizontal and vertical survey control network within the Region;
2. The Commission, in cooperation with its constituent counties, should continue to maintain the monuments that perpetuate the U.S. Public Land Survey System within the Region and the network of bench marks that make available to users accurate State Plane Coordinate positions and elevations; and
3. The Commission should undertake the development of a new methodology for the bidirectional transformation of State Plane Coordinates between NAD 27 and NAD 83 (2007) and elevations between NGVD 29 and NAVD 88 (2007).

On May 8, 2008, the Commission again retained Mr. Burkholder to develop the bidirectional transformation methodology called for in SEWRPC Technical Report No. 45. This report documents the results of Mr. Burkholder's work, carried out with the assistance of a Task Force, the membership of which is listed on the inside front cover of this report.

The new three-dimensional, bidirectional transformation methodology as documented in this report, is significantly better than that documented in SEWRPC Technical Reports Nos. 34 and 35. Consequently, this report supersedes the two aforelisted Technical Reports. The new methodology brings the horizontal and vertical position transformation procedures into conformance with three-dimensional technology. The findings of the test of the new methodologies, as documented in this report, indicate that the transformations provided are clearly reliable for all parcel-based land information and public works management system applications; are clearly reliable for use in vertical surveys made for most routine land surveying and public works engineering purposes; and are generally reliable for use in most horizontal survey applications within the Region.

Where higher order survey accuracies are required the conduct of field surveys referred to the NAD 27 and NGVD 29 datums are recommended. Importantly, this report demonstrates that no conversion of these datums to the newer NAD 83 (2007) and NAVD 88 (2007) is necessary because GPS positioning technology operating within the real time network of Continuously Operating Reference Stations (CORS) established by the Wisconsin Department of Transportation within the Region, can be readily used with the Commission recommended NAD 27 and NGVD 29 datums.

Respectfully submitted,

Kenneth R. Yunker
Executive Director

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February 15, 2009

Mr. Kenneth R. Yunker, Executive Director
Southeastern Wisconsin Regional Planning Commission
P.O. Box 1607
Waukesha, Wisconsin 53187

Dear Mr. Yunker:

Transmitted herewith is the report, "Bidirectional Transformation of Legacy and Current Survey Control Data Within Southeastern Wisconsin." The report specifically fulfills recommendation number 4 contained in SEWRPC Technical Report No. 45 and provides procedures by which NAD 83 (2007) horizontal datum values and NAVD 88 (2007) vertical datum values as used in the Real-Time Global Positioning System (GPS) Network established within the seven-county Region by the Wisconsin Department of Transportation can be transformed to NAD 27 horizontal values and NGVD 29 elevations historically used by the Commission. Implementation of these bidirectional transformations will serve to preserve the value of the survey control networks established by the Commission over the past 40 years and facilitate their continued use. Such implementation will also facilitate the addition of data collected by GPS on the NAD 83 (2007) and NAVD 88 (2007) datums to parcel-based land information and public works management systems based upon the NAD 27 and NGVD 29 datums.

This report is therefore compatible with the other recommendations set forth in TR No. 45regarding continued use and maintenance within the Region of the NAD 27 and NGVD 29 datums along with their values as published on the network of U.S. Public Land Survey System corners and attendant bench marks maintained throughout the Region. As a consequence, the relevance of services the Commission provides its constituents is preserved and enhanced.

This report represents professional collaboration at its best. Mr. Glen R. Schaefer, PE, RLS, Geodetic Engineer with the Wisconsin Department of Transportation and Mr. Robert W. Merry, RLS, Chief Technical Officer of Aero-Metric, Inc. deserve recognition for their careful technical review of the draft report and for their contributions made during preparation of this report. Finally, Dr. Kurt W. Bauer, PE, RLS, Executive Director Emeritus and County Surveyor for Kenosha, Milwaukee, Walworth and Waukesha Counties, and Mr. Donald P. Simon, RLS, of the Commission staff and Deputy County Surveyor both made invaluable contributions to the final version of this report.

Thank you for the opportunity to once again be of service to the Commission.

Yours truly

Earl F. Burkholder

Earl F. Burkholder, PS, PE

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INTRODUCTION

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) has over a period of more than 40 years established and promoted the use of a network of horizontal and vertical survey control stations throughout an approximately 2,700-square-mile Region consisting of Kenosha, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha Counties in Wisconsin. Since publishing SEWRPC Planning Guide No. 2, *Official Mapping Guide*, in 1964, the Commission has provided leadership and guidance in promulgating standards and specifications for the conduct of the surveys necessary to densify the geodetic survey control network within the Region; to collect data for the planning, design, and layout of public works; and for the location of real property corners throughout the Region. Numerous users from both the public and private sectors—including land surveyors, public works engineers, planners, appraisers, attorneys, and abstractors—benefit from those control surveys, and from the related maps and other spatial data referred to a common survey control system known to be reliable to a specified level of accuracy.

During the past 40 years modern positioning technology has evolved from transit and tape surveying methods to include use of electronic distance measuring instruments, digital theodolites, and several generations of satellite based positioning systems. As applicable for civilian use, the global positioning system (GPS) established and operated by the U.S. Department of Defense is used worldwide. The Russians have also deployed a satellite based positioning system known as GLONASS, and the European community is developing another satellite positioning system known as 'Galileo.' These and other satellite positioning systems being developed are referred to collectively as global navigation satellite systems (GNSS). Although the terms GNSS and GPS are often used interchangeably, they are technically different. Other modern positioning technology includes use of remotely sensed data in photogrammetry, pulse laser scanning, infrared imaging, and various forms of radar.

The development of computer technology over the past 40 years has also revolutionized the way society uses and manages information, in this case spatial data. Current computer technology accommodates individual access to large quantities of spatially related data stored in large databases. The integrity of those data is critical to preserving the value to the individual user—especially as the data relate to actual points on the ground.

The control survey networks and the surveying and mapping procedures that have been espoused by the Regional Planning Commission are described in SEWRPC Technical Report No. 7, *Horizontal and Vertical Survey Control in Southeastern Wisconsin (3rd Edition)*, published in August 1996. The survey control system described in that report accommodates both advances in positioning technology—i.e., in geodetic surveying—and in the integration of spatial data into modern parcel based land information and public works management systems. The control survey network has served the Region well for almost 40 years, but a number of changes in surveying practices now suggest the need to address the suitability and usability of data in these control survey networks. Changes in the horizontal and vertical datums, external to and not under the control of, the Commission, affect the use of survey control networks. The Federal government has continued to refine the national survey datums; specifically the North American Datum of 1927 (NAD 27) was replaced by the North American Datum of 1983 (NAD 83). With readjustment of the underlying 3-D GPS network in 2007, the current datum is known as the NAD 83 (2007). The horizontal survey control system described in SEWRPC Technical Report No. 7 is based upon the NAD 27 and ramifications of the Federal adoption of the NAD 83 are described in Appendix G of SEWRPC Technical Report No. 7.

The vertical datum has changed as well. The National Geodetic Vertical Datum of 1929 (NGVD 29) was replaced by the North American Vertical Datum of 1988 (NAVD 88). With recent completion by the Wisconsin Department of Transportation of a height modernization program (WI-HMP), the current vertical datum within the Region is known as the NAVD 88 (2007).

Nationally, the horizontal and vertical survey control network data within the United States have been combined into one system known as the National Spatial Reference System (NSRS). The National Geodetic Survey (NGS) has statutory responsibility for establishing and maintaining the NSRS.

Another significant change related to the generation and use of survey control within the seven-county Region is that GNSS positioning technology is now readily available to potential users. That proliferation of technology needs to be accommodated in a manner that, to the extent possible, preserves the Commission investment in the existing horizontal and vertical survey control networks. Given WI-HMP establishment of a network of GPS continuously operating reference stations (CORS) that broadcasts relevant data to local users, the real-time GPS network (RTN) can be used by anyone. Specific equipment and operating procedures are needed, but it is now possible for a single user carrying portable GNSS equipment mounted on a pole to obtain, within minutes, three-dimensional positions within centimeter accuracy anywhere "open-sky" satellite signals are available. Those observed/computed positions are typically related to the NAD 83 (2007) and NAVD 88 (2007) datums.

The NAD 27 and the NGVD 29 datums are both sufficiently accurate for land surveying, public works engineering, and land information system development purposes within the Region. Some users, however, find it beneficial to be able to transform spatial data between the existing Regional Planning Commission (RPC) values and the Height Modernization Program (HMP) values. Therefore, in 2007, the Commission created a Technical Advisory Committee to review the status of the survey control networks within the Region and to recommend changes needed to accommodate the newer technology while preserving the value of the existing survey control networks. SEWRPC Technical Report No. 45, *Technical Review and Reevaluation of the Regional Control Survey Program in Southeastern Wisconsin*, March 2008, provides a compilation of the deliberations, minutes, and recommendations of the Technical Advisory Committee. A specific recommendation in that report includes development of bidirectional procedures that can be used for transformations of data between the datums concerned. This technical report documents the development of those bidirectional transformations.

BACKGROUND

This section provides a brief summary of the evolution and use of the four different datums routinely encountered in Southeastern Wisconsin: the NAD 27 and NAD 83 horizontal datums and the NGVD 29 and NAVD 88 vertical datums. The NAD 27 and NGVD 29 datums are strictly separate horizontal and vertical datums. While the NAD 83 and NAVD 88 datums can be used as separate datums, they can also be used as a combined three-dimensional datum.

Description of Survey Datums

The NAD 27 is an international geodetic datum established in 1927 using five parameters; the semimajor and semiminor axes define the mathematical ellipsoid concerned; the latitude and longitude of the origin fix the location of the triangulation network concerned on the surface of the earth; and a reference azimuth provides orientation at the origin. The Equator and Greenwich Meridian are the origins for latitude and longitude. The geometrical parameters of the NAD27 are:

a = 6,378,206.4 meters = Semimajor axis of Clarke Spheroid of 1866.
b = 6,356,583.8 meters = Semiminor axis of Clarke Spheroid of 1866.

φ = 39º 13' 26."686 N = Latitude of origin, station MEADES RANCH, Kansas
λ = 98º 32' 30."506 W = Longitude of origin, station MEADES RANCH, Kansas

α_0 = 75º 28' 09."64 = South azimuth from station MEADES RANCH to station WALDO.

Inherent, but unstated, in the definition of a geodetic datum is the assumption that the geoid height and the deflection-of-the-vertical at the origin are both zero, and that the Earth's spin axis is parallel to the minor axis of the ellipse. Subsequent precise measurements and refinements to the mathematical model have shown that these assumptions are not perfect for the NAD 27 and that residual values do exist. However, those imperfections have little, or no, impact on local use of control survey networks based upon the NAD 27. The Clarke Spheroid "fits" the North American continent well, and the NAD 27 has been used by the Commission over the past almost 50 years for all horizontal surveying and mapping operations.

The NAD 83 is a global geodetic datum having its origin at the Earth's center of mass and having the size, shape, and orientation of the mathematical ellipsoid, known as the Geodetic Reference System of 1980 (GRS 80), positioned such that it fits the entire Earth better than does the Clarke Spheroid of 1866. The Equator and Greenwich Meridian are the origins for latitude and longitude and the minor axis of the GRS 80 ellipsoid is parallel with the spin axis of the Earth as defined by the Conventional Terrestrial Pole. Geometrical parameters of the GRS 80 are:

a = 6,378,137 m exactly = Semimajor axis of GRS 1980 ellipsoid
1/f = 298.25722210088 = Reciprocal flattening of the GRS 1980 ellipsoid.

NAD 83 point data were first published by the National Geodetic Survey (NGS) in 1986 and the corresponding latitude and longitude of a point were significantly different than the NAD 27 values for the same point. Additional position data in Wisconsin were acquired in 1990 and the data were adjusted in 1991 on the basis of GPS measurements. Additional data were acquired in 1997 and adjusted in 1997 to reflect improvement in the vertical component; and readjusted again in 2007 to reflect additional vertical data from Height Modernization programs, and to consolidate the various state-specific High Accuracy Reference Networks (HARNs) into a single national adjustment tied to the permanent network of continuously operating reference stations (CORS). The latest refinement of positions on this datum is identified as NAD 83 (2007). Further technological developments are expected to provide the spatial data community more convenient access to, and easier use of, the NAD 83 (2007). In the seven-county Region, such added convenience is being facilitated by the RTN established by the Wisconsin Department of Transportation as part of the WI-HMP.

The NGVD 29, formerly known as the Sea Level Datum of 1929, was based upon tide gage data collected at 26 locations along the ocean coasts—21 of them in the United States and five of them in Canada. The tide gage data were used to determine mean sea level. The presumption was that mean sea level best approximated the geoid, an equipotential surface defined as the origin for vertical data. In the decades following publication of the mean sea level elevations, precise differential-level surveys were completed throughout North America. The differential-leveling surveys showed that mean sea level—as determined by the long-term averages of the individual tide gage data—was at different elevations at different gages. For that and other reasons, the datum name was changed to National Geodetic Vertical Datum of 1929—no published elevations in the SEWRPC region were changed. The name change was intended to emphasize that mean sea level at the individual gage locations was not the same as zero elevation as determined by the differential-leveling surveys.

The NGVD 29 has been used by the Commission over the past almost 50 years for all leveling operations within the seven-county Region. Elevations on topographic maps, flood plain profiles, hydraulic studies, and

grade lines, street and highway, sanitary and storm sewer, water main elevations and grades, and other records in the Commission database are referenced to the NGVD 29.

The NAVD 88 is the result of a comprehensive readjustment of the precise level network covering North America. Zero elevation is still intended to be a close approximation to the geoid but published NAVD 88 elevations are based upon a single bench mark whose elevation was derived from tide gage data at Father's Point, Rimouski, Quebec, Canada. One reason for using the data at Father's Point is that U.S. and Canadian scientists had already agreed upon the elevation at Father's Point as the basis of work being done on the International Great Lakes Datum—in so doing, the dynamic heights of both systems could be made numerically identical, and elevation changes in the U.S. National Mapping Program database due to the datum redefinition would be minimized.

The NAVD 88 datum was first published by the NGS in 1991 and SEWRPC Technical Report No. 35, *Vertical Datum Differences in Southeastern Wisconsin*, December 1995, was prepared by the Commission to address the issue of vertical datum differences. Based upon the 210 common First-Order bench marks listed in Appendix B-4 of SEWRPC Technical Report No. 35, the average difference bench mark elevation change from NGVD 29 to NAVD 88 is -0.195 feet +/- 0.127 feet. That difference is large enough to be significant for precise applications and small enough to be a nuisance in many other applications. The finding in SEWRPC Technical Report No. 35 was that the NGS program "VERTCON" modeled those differences sufficiently well for Third-Order conversions. First- and Second-Order conversions required additional testing and perhaps resurvey.

Through the activities of the WI-HMP, the NAVD 88 elevations in the seven-county Region have been improved and contributed to the NGS 2007 readjustment of the underlying 3-D GPS network. Therefore, the current adjustment of this vertical datum is referred to as the NAVD 88 (2007). These values, along with appropriate geoid modeling, are compatible with operation and use of the RTN within the seven-county Region. Based upon 114 common datum points used to develop the transformations described in this report, the average shift from NGVD 29 to NAVD 88 (2007) is -0.208 feet, plus or minus 0.096 feet.

This section on datum designations also includes two additional terms adopted in this report for reader and user convenience. The two designations are described below.

The term "RPC position" is used in this report for the positional value of a monument historically developed and used by the Regional Planning Commission. It may refer to a position with either or both the NAD 27 horizontal value and/or the NGVD 29 vertical value. The term "RPC vertical position" refers to a position with only a vertical value. The term "RPC horizontal position" refers to a position with only a horizontal value. The term "RPC horizontal and vertical position" refers to a position with a horizontal (State Plane Coordinates) and a vertical value (elevation).

The term "HMP position" is used in this report for those positional values of a monument developed during the WI-HMP campaign and published by the NGS and is intended to be compatible for use with the recently installed RTN. It may refer to a position with both the NAD 83 (2007) three-dimensional value (latitude, longitude, and ellipsoid height) and the NAVD 88 (2007) vertical value (orthometric height). The HMP positions include both horizontal and vertical components and are intended to be consistent with use of the RTN.

It is important to note that while the names—RPC position and HMP position—are new, the names are only convenient abbreviations for the combination of the two "old" datums and the two "new" datums. The bidirectional transformations described herein were developed specifically between the RPC and the HMP positions.

Evolution of Modern Surveying Practice and Use of Survey Datums

In years past, geodetic control surveying in the United States consisted primarily of measuring First-Order arcs of triangulation that stretched from coast to coast and border to border. Scale was provided by precisely measured baselines scattered throughout the network and additional area-wide control points were often

established by Second-Order triangulation measurements within the arcs of First-Order triangles. With development of electronic distance measuring instruments (EDMI) in the late 1950s, trilateration became a viable geodetic surveying method but, since the First- and Second-Order triangulation measurements were largely completed, the additional densification surveys were typically completed using Second-Order traversing techniques—EDMI for distance measurements and theodolites for angle measurements. Those Second-Order traversing techniques were used extensively by the Commission in the 1960s, 1970s, and 1980s to survey the positions of Second-Order monuments throughout the Region and to establish reliable Third-Order State Plane Coordinates on all the monumented U.S. Public Land Survey System section corners, quarter-section corners, and witness and meander corners in the seven-county Region. All of that work was referenced to the NAD 27 horizontal datum.

Vertical control, elevations on permanent bench marks, was established nationwide over the past 150 to 200 years by First-Order geodetic differential level surveys run primarily along railway and major highway rights-of-way. The standards, specifications, equipment, and techniques for First-Order leveling matured early and changed little for many years. Admittedly, even with modern equipment, First-Order leveling is still tedious, time-consuming, and costly. But, over the years, the Commission invested the resources needed to establish an excellent network of Second-Order Class II bench marks throughout the seven-county Region. Elevations were determined for bench marks attendant to each monumented section, quarter section, and witness and meander corner of the U.S. Public Land Survey System within the Region. All of this leveling was referenced to the NGVD 29 vertical datum.

With regard to improvements and use of new technology, GPS was introduced into surveying practice in the mid 1980s and has had an enormous impact on the way spatial data are generated and used. Early on, GPS was used primarily for horizontal positioning and the first readjustment of GPS data on the NAD 83 was made in Wisconsin in 1991 at which time state-wide, high-precision geodetic network (HPGN) data acquired in 1990 and 1991 formed the basis of the readjustment. The redefined coordinate values became known as the NAD 83 (1991). SEWRPC Technical Report No. 34, *A Mathematical Relationship Between NAD 27 and NAD 83 (91) State Plane Coordinates in Southeastern Wisconsin*, December 1994, was developed in response to that readjustment and has served users within the Region and the Commission well for over 15 years. However, the GPS statewide network was observed again in 1997, with a focus on improving the vertical component of the 3-D GPS network. As a result, the horizontal datum was adjusted again and the new values were published as NAD 83 (1997). Part of the evolution since 1990 was a name change in which the HPGN became known as the aforementioned HARN.

Two important developments have occurred since the late 1990s. While the HARN networks served well, they were state-specific and represented a position based upon data collected at a specific time. The very accurate HARN stations have been superseded by the network of Continuously Operating Reference Stations (CORS) which collect GPS data on a continuous basis and post the data to NGS via the Internet. The CORS data are monitored on an on-going basis and the associated positions are very accurate, both nationally and globally. Those CORS positions were used as the basis for the 2007 adjustment of all HARN stations to the CORS network. That readjustment is known as NAD 83 (2007) and the entire United States is now covered by a single highly precise 3-D network readily available to all users via the Internet.

Height Modernization is another development since the late 1990s. What started as a program to address problems with the vertical component in California—due to earthquakes and tectonic movement—was adapted in other states. The Wisconsin Department of Transportation (WisDOT) began a program in 1998 (now known as the Height Modernization Program) to improve the vertical and horizontal survey control networks throughout the State. Subsequently, WisDOT was successful in obtaining and using Federal Height Modernization funds to extend the network systematically statewide, reaching the seven-county Region in 2004. The results of those height modernization surveys also contributed to the 3-D readjustment of the NAD 83 in 2007. Height Modernization Program data are published as NAD 83 (2007) and NAVD 88 (2007) values.

The most recent development which reinforces the need for bidirectional datum transformations is installation and use of the RTN within the Region. A sufficient number of CORS have been established throughout, and

adjacent to, the Region to serve two purposes. The CORS post raw data to NGS via the internet but the CORS are also interconnected and managed such that local corrections can be computed and provided to local users via radio or cell phone. Consequently, a local user with appropriate portable equipment can collect data within minutes at a "sky-visible" point and obtain a position defined by latitude, longitude, ellipsoid height, and orthometric height accurate within centimeters. Productivity and convenience within the spatial data community is enhanced accordingly. One drawback to use of the RTN is the incompatibility of RPC and HMP values for the same position. That problem is addressed via the bidirectional transformations developed and published in this report.

Commission Survey Control and Mapping System

The survey control and mapping system established by the Commission is described elsewhere in detail but it is summarized here for completeness. Maps are an important communication medium, and knowing "where things are" (location) is essential in modern society. Whether developing a framework for cadastral parcels, inventorying natural resources, analyzing patterns of development, creating overlays for land use planning, inventorying sanitary sewerage, water supply, and storm-water management systems, or other applications; responsible administrators and spatial data users rely upon maps to keep track of where things are. Additionally, maps are used extensively for tracking the movement of people, vehicles, goods, and services. The survey control and mapping system established by the Commission was designed to support those applications and many users throughout the Region have come to rely upon the existing control networks. Military applications for maps are just as numerous and essential as civil applications, but are not listed here.

Monumentation

A survey monument is a reference point marking a known location that, subject to access, can be used by anyone. As stated in SEWRPC Technical Report No. 45, a monument should be stable, permanent, readily accessible, and have a reliable written record of its location. In years past, horizontal and vertical geodetic surveying operations were conducted separately and a basic network of geodetic horizontal and vertical control monuments exists within the Region. Those monuments were established and surveyed by the Federal government in support of national mapping priorities. Although Federal and State agencies have established additional survey monuments since then, the basic survey control networks were in place prior to 1961 when the Commission began surveying the subordinate networks. While the Federal geodetic survey control monuments were designed to be stable and permanent, they are relatively few in number within the Region, and their location was dictated primarily by topography. For example, to enhance station-to-station visibility, horizontal geodetic survey control points were typically established on hilltops and, because of the uniform grades, vertical survey control bench marks were located along railway and major highway rights-of-way. Those geodetic points are essential, but local users need ready access to many more reliable survey control points than the basic control survey networks established by Federal agencies. The SEWRPC has established and surveyed the additional points needed throughout the Region.

The Commission, working in cooperation with county and local units of government, has monumented and determined the location, expressed in terms of State Plane Coordinates and mean sea level elevations, of each of the 11,753 corners of the U.S. Public Land Survey System, and of certain accessories thereto, within the Region. That means that reliable survey control is much more accessible than through the basic Federal networks. At most places in the Region, reliable survey control is available within one-quarter mile. State Plane Coordinates were determined for each of the monumented corners and those monuments govern the physical location of real property boundaries, public and private works, and other planimetric features and the preparation of planimetric and topographic maps throughout the Region. Vertical control monuments, termed "bench marks," are used as a reference for the preparation of topographic maps, for the delineation of floodplains and for the establishment of line and grade for public and private works. Elevations have also been determined by SEWRPC for each of the monumented corners of the U.S. Public Land Survey System and for accessories thereto, making each corner monument a point of known horizontal and vertical position.

As noted previously, current state-of-the-art surveying practice includes a network of continuously operating reference stations (CORS) which were established within and adjacent to the seven-county Region by the

WisDOT as part of the WI-HMP. Used in conjunction with appropriate GNSS equipment, the CORS network and associated local corrections, end users are provided access to the NSRS in real time.

It should be noted that approximately 4 percent of the existing SEWRPC network monuments are disturbed or destroyed each year due to construction activities and therefore must be replaced. The Commission in cooperation with four of its constituent counties—Kenosha, Milwaukee, Walworth, and Waukesha—has an active program of maintenance in which monuments are rehabilitated and/or replaced and the user public continues to benefit from a well maintained survey control system.

Horizontal and Vertical Survey Control

Primarily because maps are two-dimensional, and because elevation was typically referenced to mean sea level, the horizontal location and the vertical elevation of a point has, in the past, involved two separate surveying operations. Angles and distances were used to compute the relative location of horizontal survey monuments, and elevation differences between monuments were determined by precise differential leveling operations. However, with the digital revolution and use of modern technology such as electronic total stations, global positioning systems, and photogrammetric and, other forms of remote sensing, horizontal and vertical positions on the surface of the Earth are now increasingly determined simultaneously.

Starting in 1961, the Commission embarked upon an ambitious project of running traverses between the existing First- and Second-Order geodetic control monuments and systematically connecting the monumented corners of the U.S. Public Land Survey System to the national network. Separately, high-quality differential leveling operations were conducted in a similar systematic manner and elevations were established on numerous bench marks in addition to the monumented corners of the U.S. Public Land Survey System. As time and technology progressed, surveying instrumentation evolved to include the use of GPS and other modern positioning instrumentation in which both horizontal and vertical positions are determined simultaneously. Reliable traditional measurements remain valid.

Topographic and Cadastral Mapping

Planning for the orderly and efficient development of communities requires definitive knowledge of the contours of the land and of many external characteristics such as land ownership and the availability of water, sewer, electric power, and transportation facilities. Advanced planning for the development of public works facilities and for the material conservation and wise use of the resource base requires reliable up-to-date maps and databases. Similarly, definitive knowledge of the ownership and of the existing and potential future use of each parcel of land in a community is vital to orderly development. Citizens of the Region have enjoyed the benefits of reliable topographic and cadastral maps that document fully the size, shape, ownership, and other characteristics of land throughout the Region. Continued enjoyment of those benefits will be compromised if no method is found to accurately relate new digital data to the existing one-inch equals 100 feet and one-inch equals 200 feet topographic and companion cadastral maps developed and maintained by the Commission and its constituent counties and municipalities.

Foundation for Parcel-Based Land Information and Public Works Management Systems

The Commission control survey network, and the attendant topographic and cadastral maps based upon that network, provide the essential foundational elements for the creation of sound, computer-manipulatable, parcel-based land information and public works management systems within the Region. Such systems are becoming essential to the efficient and effective conduct of county and municipal planning, engineering, and management, and are profoundly influencing the scope and content and techniques involved in such activities. All of the seven counties comprising the Southeastern Wisconsin Region, and many of the municipalities within the Region, have created parcel-based land information and public works management systems. These systems have been built upon the essential foundational elements provided by the Commission control survey and attendant topographic and cadastral mapping programs. Parcel-based land information systems can accommodate many different types of spatially related data—termed attribute data—forming invaluable automated data banks. The types of data that can be and have been accommodated include, among many others: parcel ownership, street address, and assessed valuation; existing and proposed land use and zoning; soils and related agricultural, engineering, and use suitability classifications; presence of flood hazard; and presence of inflammable and hazardous chemicals and other materials. Such parcel-based land information

systems can also accommodate a plethora of social and economic data useful in school administration, and in municipal police and fire protection, emergency medical service, and social service planning and administration. The public works managements systems based upon the foundational elements can accommodate a wide variety of information important to the planning, design, construction, maintenance, and management of sanitary sewerage, water supply, storm water management and flood control, solid waste collection and disposal, and street and highway and transit system, planning, development, operation, and maintenance.

PURPOSE OF THE PROJECT

Preserve and Enhance Value of SEWRPC Survey Control Networks

The fundamental purpose of this project was to develop bidirectional transformation procedures which can be used to move survey data between the RPC and HMP positions, and thereby preserve and enhance the utility of the Commission established control survey networks within the Region. From its inception, the Commission has been aware of the need for, and importance of, reliable survey control for the conduct of land and engineering surveys, the preparation of large-scale topographic and cadastral maps, and for the development of parcel-based land information and public works management systems. The Commission has been diligent in developing, and in preserving the value of, the survey control networks within the Region. In this effort, the Commission has been insistent on the conduct of high-quality survey measurements in the development of the survey control networks; on monumenting each survey control station comprising the networks; on use of the Wisconsin State Plane Coordinate System and the National Geodetic Vertical Datum for the networks; on establishing a record system that includes a control survey station recovery sheet for each survey monument; on maintaining the system by reestablishing those survey control monuments that are disturbed or destroyed each year; and on insisting that the NAD 27 and NGVD 29 datum values continue to be used as the foundation of the geographic information systems implemented throughout the Region.

The bidirectional procedures developed by this project are intended to permit the reliable transformation of RPC position values to corresponding HMP position values and the transformation of HMP position values to corresponding RPC position values, and to thereby preserve and enhance the value of the Commission survey control networks within the Region. The procedures presented were never intended to be capable of modeling First-Order geodetic survey control relationships between the datums concerned. However, the performance of the procedures has been tested and, with some exceptions, found to be consistent with existing and anticipated uses of survey data in the continued development and expansion of parcel-based land information and public works management systems and in the conduct of land and public works engineering surveys within the Region. The procedures are intended to permit spatial data users in any discipline to bring the legacy RPC position data forward to be compatible with modern GNSS technology operating on the HMP real-time network established by the WisDOT within and adjacent to the Region. The project has developed the equations needed to make that transition for use in the many existing and potential applications of the survey data. Extensive application of the equations in a more cost effective manner may require development of specific software programs.

Adapt SEWRPC Survey Control Networks to Use of New Surveying Technology

GPS technology offers two primary observing options to spatial data users: a Coarse Acquisition (C/A) code option and a carrier phase processing option. The C/A mode of operation is based on the transit time of the signal and is used to determine latitude, longitude, and height that are typically regarded as absolute positions. When considered with respect to the Equator, the Greenwich Meridian, and sea level, the accuracies of the absolute values are impressive. Such absolute positions are useful for mapping and spatial data analyses over large areas such as the continental United States. However, the C/A absolute positions are not precise enough for surveying, mapping, and engineering applications in which the relative position of one point with respect to a nearby point—e.g., the distance and direction between adjacent monumented U.S. Public Land Survey System corners—is more important than the underlying coordinate value. The second carrier phase option relies on observing the carrier frequency phase shift between two points and can provide relative positions within centimeter accuracy, in terms of a vector between the two points. The difference between absolute and relative values can be subtle, but understanding the difference between absolute and relative positioning is

essential when making decisions about how data are to be collected and used. With regard to this project, the existing RPC horizontal values portray relative positions better than they portray absolute positions. Readjustments of the underlying network by the Federal government typically improves the absolute values of the survey control stations on the basis of improved relative values collected as part of new surveys. CORS stations form the basis of the reference used for HMP and the positions provided are of very high quality—both absolute and relative. Therefore, when using the RTN, reliable absolute HMP position values are readily available to the end user.

The end user must be aware of two issues. First, if careless procedures are used when conducting field measurements on the RTN, it is possible to obtain HMP position values that do not meet the specifications required for a particular application. As a result, the quality of absolute and relative positions both suffer. Use of appropriate equipment and proper observing techniques is the responsibility of the user. The second issue arises when transforming coordinate values between RPC and HMP positions. Undoubtedly the absolute values of the RPC points are improved, but not perfected, when transforming RPC position values to HMP position values. However, when transforming RPC horizontal position values to HMP horizontal position values it is unrealistic to expect the relative positions to be improved. An objective in developing the bidirectional transformations was to match the surveyed HMP positions values as closely as possible, and to avoid degrading the relative value of the RPC relationship between adjacent points. Tests utilizing field measurements were conducted as a part of the project, and the performance of the transformation procedures and equations in each of delineated subareas of the Region are herein documented.

Develop Bidirectional Transformation Methodology

Development of the bidirectional transformation methodology as recommended in SEWRPC Technical Report No. 45 required consideration of the overall objectives of the project as well as details of the process. Ultimately, the recommended procedures needed to be rigorous and defensible while at the same time the procedures needed to be practical and easy to use. Given the 2-D NAD 27 horizontal datum and the 1-D NGVD 29 vertical datum defining the RPC positions and the inherent 3-D nature of the HMP positions, the Helmert 3-D transformation appeared to be the obvious choice for modeling the difference between RPC and HMP positions. Two options were considered; use of Helmert equations for the 7-parameter transformation as given by Soler/Snay (2004), and use of Helmert equations for a 9-parameter transformation as given by Hooijberg (2008). Both were tested and the 7-parameter option was selected because the 9-parameter option yielded some unrealistic scale values in modeling distortion in the separate X/Y/Z axes. The least squares best fit computational procedure outlined on page 134 of Mikhail (1976) was used in testing the two options and for final computation of parameters in each of 17 subareas within the seven-county Region.

The Helmert 7-parameter transformation is specifically applicable to transformations between two separate 3-D rectangular coordinate systems such as the ECEF system used as the basis for GPS position computations. Rectangular ECEF coordinates and latitude, longitude, and ellipsoid height values can be computed from each other with mathematical exactness. The fact that elevations had to be used for the vertical component instead of ellipsoid heights presented an issue to be addressed in the development of the desired methodology.

Geoid modeling is required to estimate the difference between elevation and ellipsoid height, and GEOID03, as published by the NGS, was the geoid model used during the early development stages of the project. The GEOID09 model was published by NGS in 2009, and was subsequently used in final computations of the Helmert parameters for each of the 17 subareas within the Region.

Horizontal

Although the Helmert 7-parameter transformation utilizes three spatial data components—two for horizontal and one for vertical—the RPC system required separate bidirectional transformations between NAD 27 SPC and NAD 83 (2007) SPC (horizontal) and between NGVD 29 elevations and NAVD 88 (2007) elevations (vertical). With the Helmert parameters for each of the 17 subareas in hand, those horizontal transformations can be readily accomplished. As documented in Appendix D, the equations are somewhat involved but, using the programs provided, bidirectional transformations between NAD 27 SPC and NAD 83 (2007) SPC can be readily performed and documented.

Vertical

The bidirectional transformation of vertical data can also be readily accomplished using the Helmert transformation procedures. However, as noted, while the Helmert procedures operate specifically on ellipsoid heights, elevations are the RPC system data to be transformed. The problem presented can be overcome by using an appropriate geoid model at each end of the transformation to convert elevation to ellipsoid height and ellipsoid height to elevation. The advantage of using the same geoid model at each end of a transformation is that the effect of whatever geoid model is used effectively cancels out in the computation. However, given reliable RPC and HMP elevations on 114 common control points throughout the seven-county Region, an alternative method of transformation was presented, namely to model the difference between NGVD 29 and NAVD 88 (2007) directly. As described in a subsequent section, the direct modeling approach was developed and used. A comparison of vertical transformation results from both approaches is included in Table 3.

Fulfill Recommendation of SEWRPC Technical Report No. 45

Recommendation number four of the concluding section of SEWRPC Technical Report No. 45 states that: "the Commission should pursue development and publication of transformation procedures by which bidirectional conversions between NAD 27 and NAD 83 (2007) horizontal datums and the NGVD 29 and NAVD 88 (2007) vertical datums can be accomplished." Recommendation number five of that report also stipulates that the Commission should provide technical assistance in using the bidirectional transformations. Both recommendations are addressed in this report. This report presents the parameters and coefficients for both horizontal and vertical transformations, equations for performing, and for writing software for computing the transformations. An example of a single point transformation is also included.

DESCRIPTION OF PROCEDURE

Development of the required transformation procedures was influenced by the characteristics of both the RPC and HMP positions. Accommodating the differences between the two systems required careful considerations. The RPC system, is a 2-D horizontal plus 1-D vertical position system using the Clarke Spheroid of 1866 for horizontal positioning and mean sea level as the origin for elevation. The ECEF geocentric system is a 3-D rectangular X/Y/Z Cartesian coordinate system with an origin at Earth's center of mass. The X and Y axes lie in the plane of the Equator with the X axis at the Greenwich Meridian. The Z axis is parallel to the Earth's spin axis. This rectangular 3-D system is fundamental to operation of the GNSS.

Approach Taken

The approach taken in developing the bidirectional transformations was to identify an underlying model to which all spatial data can be related. That underlying common model is the aforementioned ECEF rectangular coordinate system defined by the U.S. Department of Defense for operation and control of the NAVSTAR global positioning system. The ECEF system is the environment in which computations for operation and maintenance of GNSS are performed. Stated differently, all spatial data computations related to operation of the GNSS are conducted using geocentric X/Y/Z coordinate values. The reason for choosing the ECEF environment for this project is that the Helmert transformation is ideally suited for modeling the transformation of one 3-D system into another 3-D system.

An immediate consequence of choosing the ECEF environment is that traditional 2-D geodetic positions which are conventionally described in terms of latitude and longitude need to be combined with 1-D ellipsoid heights in order to compute geocentric X/Y/Z coordinates. That computation is strictly a mathematical one and does not present a problem. The problem needing careful attention is converting elevations to ellipsoid heights. Geoid modeling becomes important with respect to this conversion. If geoid heights were known at all points, then this too would be a strictly mathematical process. Even though geoid models presently provided by the NGS are now much better than earlier models, geoid modeling is not perfect, and specific accommodations were made in the development process to avoid undue geoid modeling complications.

When using the Helmert transformation parameters derived and reported herein, the bidirectional transformation of horizontal positions between NAD 27 State Plane Coordinates and NAD 83 (2007) State

Plane Coordinates is not significantly affected by nominal uncertainty in geoid heights. Therefore, for the horizontal transformations, an average geoid height of -34.5 meters was used to compute pseudo-ellipsoid heights throughout the seven-county Region. Since RPC and HMP elevations are both well known throughout the seven-county Region, it was possible to model the bidirectional transformations between NGVD 29 and NAVD 88 (2007) elevations directly as a function of HMP State Plane Coordinate location.

Field Survey Data

Development of the bidirectional transformation equations required availability of reliable 3-D RPC and HMP positions on a number of well distributed points—monumented survey stations—throughout the Region. In the past, horizontal control was defined by a network of horizontal survey control stations, while vertical control was defined by a separate network of bench marks. This resulted from the fact that horizontal and vertical positions had two separate physical origins: the Equator and the Greenwich Meridian are the horizontal reference for latitude and longitude, and mean sea level is the vertical reference for elevation. Development of the NSRS by the NGS provides a network of control points having both horizontal and vertical positions on the same monumented survey station. A Helmert transformation requires both RPC and HMP positions on common points throughout the project area.

Recognizing the importance of reliable common control points, the Commission engaged the services of Aero-Metric, Inc. of Sheboygan, Wisconsin, to perform the field surveys needed to obtain dual horizontal and vertical survey control data on 114 monumented survey control stations distributed throughout the seven-county Region. Those stations are shown on Map 1. In some cases, NAD 27 values and/or NGVD 29 values needed to be established for stations already having NAD 83 (2007) horizontal position and/or NAVD 88 (2007) elevations. In other cases, additional field surveying was required to determine NAD 83 (2007) and/or NAVD 88 (2007) values on points already having NAD 27 horizontal positions and/or NGVD 29 elevations. The field surveys were conducted using GPS technology for horizontal positioning and precise differential leveling for elevation. The horizontal positioning surveys were designed and carried out to meet Federal First-Order standards and the vertical positioning surveys were designed and carried out to meet Federal Second-Order Class I standards. The horizontal positions obtained were expressed both in terms of latitude and longitude and State Plane Coordinates for use in the computations. The vertical HMP positions were expressed as orthometric heights, while the RPC vertical positions were expressed as elevations.[1] Survey control values determined by the field surveys for the 114 stations are listed in Appendix A.

Development of Equations and Parameters

Both conceptual and pragmatic issues were discussed during the Technical Advisory Committee meetings as documented in SEWRPC Technical Report No. 45. Broad support for developing the bidirectional transformations emerged—subject to proof-of-concept and successful completion of a pilot test involving a limited number of existing points. Helmert 7-parameter and 9-parameter models were both considered and tested. In each case, the least squares computational procedure for computing the transformation parameters as outlined on page 134 of Mikhail (1976) was used successfully.

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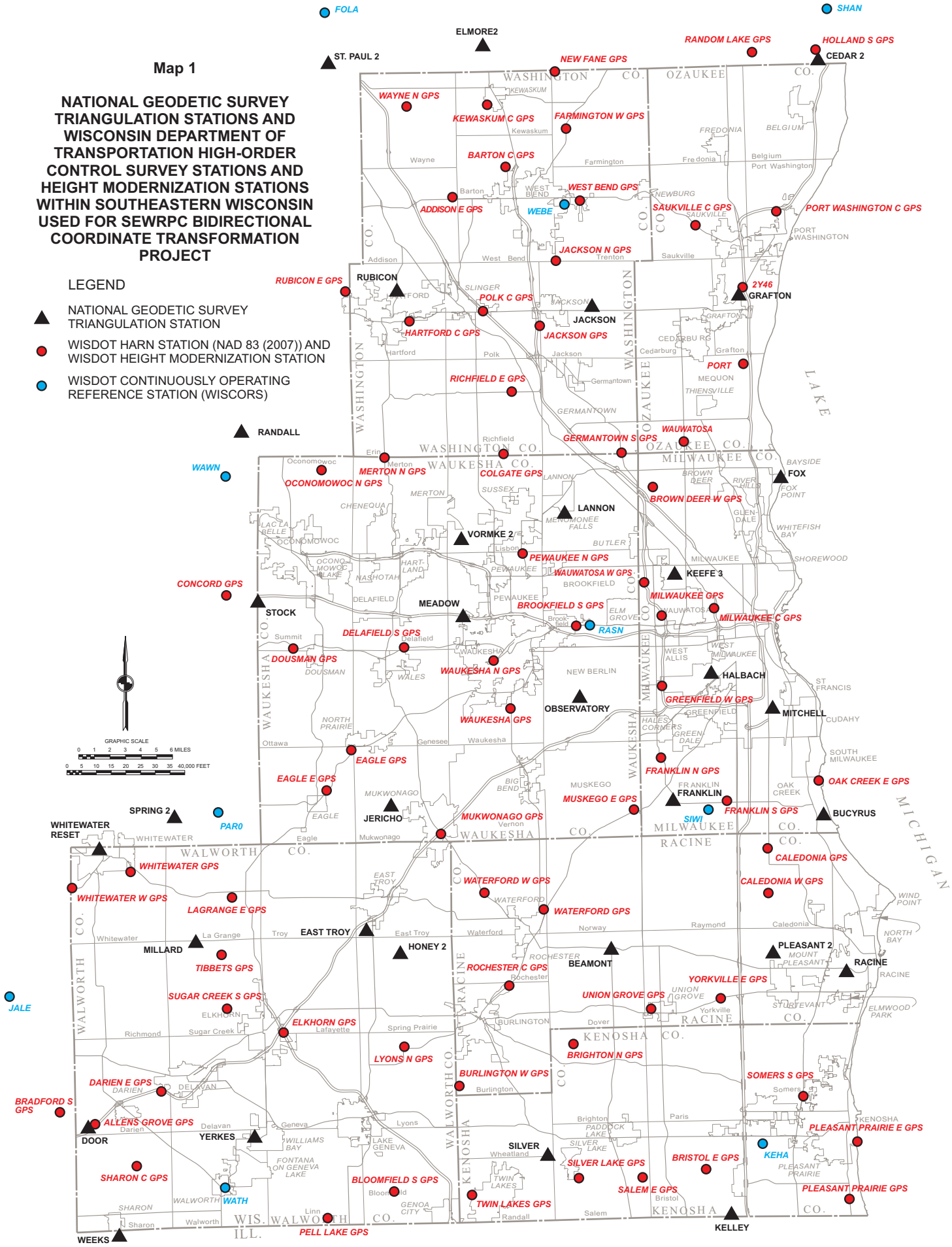
[1] *Elevation may be defined as the distance a point is above a specified surface of constant gravity-potential, measured along the direction of gravity between the point and the surface. The surface is understood to be the geoid unless some other surface is specified. Specifying NGVD 29 as the elevation datum is specifying a reference surface other than the geoid. Orthometric height or orthometric elevation may be defined as the distance from the geoid to a point, measured along the vertical through the point. The geoid surface and the reference surface for NAVD 88, where the orthometric height is zero, are the same surface. The difference between measuring along the direction of gravity between the point and the reference surface versus measuring along the vertical through the point is less than 0.0003 foot difference if the point is 1,000 feet above the surface and the slope of the constant gravity-potential surfaces differs by one minute of arc. For lower elevations and less anomaly, the difference would be less. From a practical standpoint, the difference is immaterial. Simply stated: If the value concerned is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29) then it is an elevation. It is not an orthometric height. If the value is referenced to the North American Vertical Datum of 1988 (NAVD 88) then it is an orthometric height, a specific type of elevation.*

Map 1

NATIONAL GEODETIC SURVEY TRIANGULATION STATIONS AND WISCONSIN DEPARTMENT OF TRANSPORTATION HIGH-ORDER CONTROL SURVEY STATIONS AND HEIGHT MODERNIZATION STATIONS WITHIN SOUTHEASTERN WISCONSIN USED FOR SEWRPC BIDIRECTIONAL COORDINATE TRANSFORMATION PROJECT

LEGEND

- NATIONAL GEODETIC SURVEY TRIANGULATION STATION
- WISDOT HARN STATION (NAD 83 (2007)) AND WISDOT HEIGHT MODERNIZATION STATION
- WISDOT CONTINUOUSLY OPERATING REFERENCE STATION (WISCORS)



NOTE: Due to map scale limitations, stations shown outside of the southeastern Wisconsin Region are shown in approximate locations.

Source: SEWRPC.

A pilot test was conducted to verify appropriateness of the Helmert 7-parameter transformation model and to test the matrix computational procedures. Commission staff identified a group of 15 points—monumented survey stations having common RPC and HMP values—that were to be used in the pilot test. The results of the pilot test were encouraging as to procedure. It was through the pilot test that it became apparent that the Helmert 7-parameter computational model would be the appropriate model to use.

Using the least squares matrix procedure, the Helmert equations, and the positioned data available for the 114 survey stations, Helmert transformation parameters were computed for 17 subareas of the seven-county Region. Ideally, one set of parameters would be applicable for the entire seven-county Region. Not achieving the desired results there, the next preference would be one set of parameters for each county. It was found that for some counties, two sets of parameters could be used and, finally, four sets of parameters for a county was judged to be a practical limit. A detailed summary of the computed parameters is given in Table 1 which lists one set of parameters for Kenosha County, two sets of parameters each for Milwaukee, Ozaukee, Racine, and Washington Counties, and four sets of parameters each for Walworth and Waukesha Counties. A computer output for each subarea computation is included in Appendix B and the subareas are shown graphically on Map 2.

The Helmert 3-D transformation for computing the 7 parameters in each of the 17 sub-areas of the seven-county Region are given as equation (1) in Soler/Snay (2004) and re-stated here as:

$$X_{HMP} = TX + (1+S)X_{RPC} + \omega_z Y_{RPC} - \omega_y Z_{RPC} \qquad \text{Equation (1.1)}$$

$$Y_{HMP} = TY - \omega_z X_{RPC} + (1+S)Y_{RPC} + \omega_x Z_{RPC} \qquad \text{Equation (1.2)}$$

$$Z_{HMP} = TZ + \omega_y X_{RPC} - \omega_x Y_{RPC} + (1+S)Z_{RPC} \qquad \text{Equation (1.3)}$$

where:

TX, TY, TZ	=	Translations in X/Y/Z at the origin, meters.
ω_x, ω_y, ω_z	=	Rotations about X/Y/Z axes, in radians.
S	=	Scalar for distance expressed in parts per million (ppm).
$X/Y/Z_{RPC}$	=	Pseudo X/Y/Z values defining RPC position, meters.
$X/Y/Z_{HMP}$	=	Pseudo X/Y/Z values defining HMP position, meters.

The Helmert transformation equations can be expressed compactly and computed efficiently (for example within a spreadsheet) using the following matrices:

$$\begin{bmatrix} X_{HMP} \\ Y_{HMP} \\ Z_{HMP} \end{bmatrix} = \begin{bmatrix} TX \\ TY \\ TZ \end{bmatrix} + \begin{bmatrix} 1+S & \omega_z & -\omega_y \\ -\omega_z & 1+S & \omega_x \\ \omega_y & \omega_x & 1+S \end{bmatrix} \begin{bmatrix} X_{RPC} \\ Y_{RPC} \\ Z_{RPC} \end{bmatrix} \qquad \text{Equation (1.4)}$$

Equation (1.4) uses the Helmert parameters and RPC geocentric X/Y/Z coordinates to compute HMP geocentric X/Y/Z coordinates. Equation (1.5) uses a concise matrix formulation for computation of RPC geocentric X/Y/Z coordinates from HMP geocentric X/Y/Z coordinates and the same Helmert parameters. This procedure is further documented and used in the spreadsheet example included in Appendix C. Note, Equation (1.5) uses the matrix inverse which spreadsheet computer formats can readily accommodate.

$$\begin{bmatrix} X_{RPC} \\ Y_{RPC} \\ Z_{RPC} \end{bmatrix} = \begin{bmatrix} X_{HMP} - TX \\ Y_{HMP} - TY \\ Z_{HMP} - TZ \end{bmatrix} \begin{bmatrix} 1+S & \omega_z & -\omega_y \\ -\omega_z & 1+S & \omega_x \\ \omega_y & \omega_x & 1+S \end{bmatrix}^{-1} \begin{bmatrix} X_{HMP} \\ Y_{HMP} \\ Z_{HMP} \end{bmatrix} \qquad \text{Equation (1.5)}$$

Table 1

RECOMMENDED HELMERT PARAMETERS
FOR USE IN THE SOUTHEASTERN WISCONSIN REGION
October 2009

County	Translation (m)	Rotation (sec)	Scale (ppm)		Std. Dev. of Fit
1	TX = -5.3342	ωX= -0.05533224		E:	0.134 ft.
Kenosha	TY = 177.5110	ωY= 1.22892037	S = 9.403879	N:	0.128 ft.
	TZ = 162.7540	ωZ= -0.80666467		U:	0.072 ft.
2	TX = -4.9243	ωX= -0.26194201		E:	0.177 ft.
Milwaukee	TY = 90.4386	ωY= 2.21206070	S = -9.943834	N:	0.146 ft.
(North One-Half)	TZ = 250.0633	ωZ= -1.83327596		U:	0.047 ft.
3	TX = 5.3797	ωX= -0.19204518		E:	0.124 ft.
Milwaukee	TY = 111.6858	ωY= 3.01270238	S = -5.040504	N:	0.153 ft.
(South One-Half)	TZ = 226.6473	ωZ= -2.08484849		U:	0.030 ft.
4	TX = -12.9187	ωX= 0.02776123		E:	0.124 ft.
Ozaukee	TY = 59.6061	ωY= 1.08787888	S = -15.319219	N:	0.195 ft.
(North One-Half)	TZ = 267.5223	ωZ= -1.18004176		U:	0.039 ft.
5	TX = -14.9414	ωX= -0.20590687		E:	0.202 ft.
Ozaukee	TY = 36.8837	ωY= 1.01036380	S = -21.265511	N:	0.441 ft.
(South One-Half)	TZ = 298.7646	ωZ= -1.23877707		U:	0.038 ft.
6	TX = -5.8655	ωX= 0.25865522		E:	0.134 ft.
Racine	TY = 144.2596	ωY= 1.75910117	S = 3.806769	N:	0.188 ft.
(East One-Half)	TZ = 179.2668	ωZ= -1.35954275		U:	0.052 ft.
7	TX = -6.8868	ωX= 0.04563603		E:	0.119 ft.
Racine	TY = 172.0302	ωY= 1.03726444	S = 8.676731	N:	0.241 ft.
(West One-Half)	TZ = 163.6727	ωZ= -0.70657289		U:	0.064 ft.
8	TX = -9.6707	ωX= -0.25751815		E:	0.296 ft.
Walworth	TY = 179.6959	ωY= 2.03970464	S = 9.116148	N:	0.258 ft.
(Northeast	TZ = 167.9729	ωZ= -1.74838854		U:	0.040 ft.
One-Quarter)					
9	TX = -1.2902	ωX= -0.12169368		E:	0.138 ft.
Walworth	TY = 142.3429	ωY= 0.65809194	S = 1.578189	N:	0.172 ft.
(Northwest	TZ = 198.0520	ωZ= -0.15136425		U:	0.072 ft.
One-Quarter)					
10	TX = -6.0199	ωX= -0.08074086		E:	0.133 ft.
Walworth	TY = 155.6349	ωY= 1.23195067	S = 4.654298	N:	0.185 ft.
(SE Quarter)	TZ = 183.6719	ωZ= -0.86889738		U:	0.029 ft.
11	TX = -4.0560	ωX= -0.02940619		E:	0.068 ft.
Walworth	TY = 144.0899	ωY= 1.09728657	S = 2.407191	N:	0.171 ft.
(Southwest	TZ = 192.1968	ωZ= -0.67024382		U:	0.052 ft.
One-Quarter)					
12	TX = -10.9325	ωX= 0.12379140		E:	0.170 ft.
Washington	TY = 77.1219	ωY= 1.69149196	S = -11.030668	N:	0.151 ft.
(North One-Half)	TZ = 246.2009	ωZ= -1.62921022		U:	0.041 ft.

Table 1 (continued)

County	Translation (m)	Rotation (sec)	Scale (ppm)		Std. Dev. of Fit
13	TX = -9.0538	ωX= 0.09153133		E:	0.259 ft.
Washington	TY = 58.1100	ωY= 1.32436160	S = -15.343757	N:	0.327 ft.
(South One-Half)	TZ = 266.0396	ωZ= -1.22880040		U:	0.034 ft.
14	TX = -16.4332	ωX= -0.42818325		E:	0.204 ft.
Waukesha	TY = 85.4608	ωY= 1.58114423	S = -11.768150	N:	0.231 ft.
(Northeast	TZ = 262.1978	ωZ= -1.76628779		U:	0.046 ft.
One-Quarter)					
15	TX = -9.1129	ωX= -0.40938563		E:	0.324 ft.
Waukesha	TY = 94.3466	ωY= 1.16750796	S = -9.870426	N:	0.392 ft.
(Northwest	TZ = 253.7649	ωZ= -1.04181626		U:	0.029 ft.
One-Quarter)					
16	TX = -14.3919	ωX= -0.13107389		E:	0.244 ft.
Waukesha	TY = 111.0432	ωY= 1.14992357	S = -5.045273	N:	0.385 ft.
(Southeast	TZ = 226.7290	ωZ= -1.22974269		U:	0.040 ft.
One-Quarter)					
17	TX = -13.8304	ωX= -0.17771947		E:	0.153 ft.
Waukesha	TY = 138.5538	ωY= 0.48701291	S = 0.548578	N:	0.580 ft.
(Southwest	TZ = 203.9813	ωZ= -0.55505209		U:	0.035 ft.
One-Quarter)					

Note: The number associated with each set of parameters is used in the "RPC_HMP_Batch" program to denote which set of parameters is used in the transformation process.

Source: SEWRPC.

Although the difference between an elevation on the NGVD 29 datum and the NAVD 88 (2007) datum can be modeled closely in the Helmert 3-D transformation, of necessity, that process includes use of a geoid model to reach the underlying environment of the ECEF coordinate system. The Helmert transformation procedure was initially designed to use the same geoid model at each end of the process, effectively canceling out uncertainties associated with the geoid model. That procedure was tested using GEOID09, and the results as documented herein appeared to be quite satisfactory. However, given reliable elevations on both RPC and HMP positions and the HMP SPC location of those elevations, it was found that a simple direct model that does not involve using a geoid model is easier to use and provides approximately the same level of integrity as that obtained using GEOID09 and the Helmert 3-D transformations. Accordingly, the following second degree polynomial equations are recommended for use in transforming elevations from RPC to HMP, and for transforming elevations from HMP to RPC.

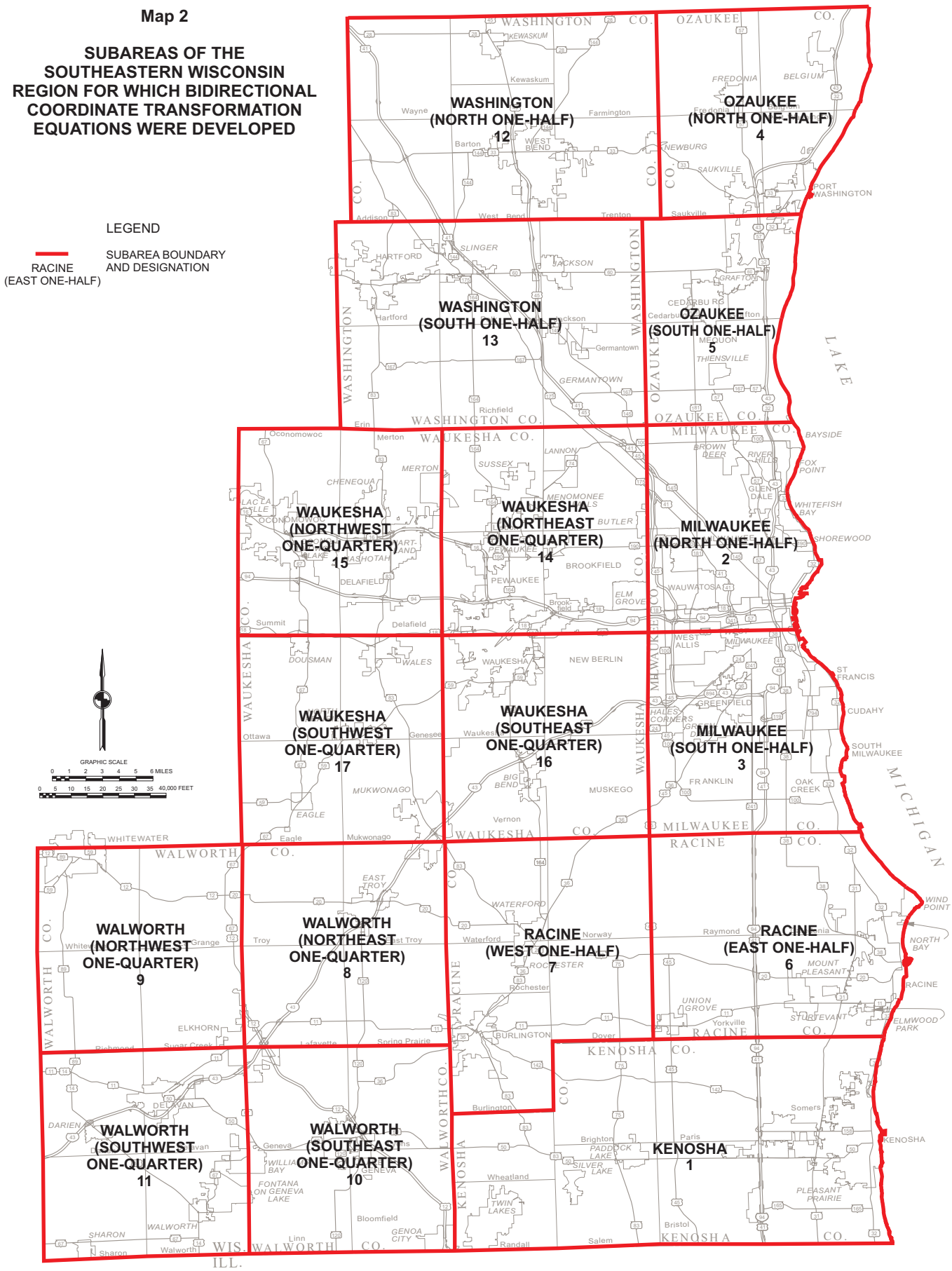
RPC to HMP: $$Elev_{HMP} = Elev_{RPC} + aX^2 + bX + cXY + dY + eY^2 \quad \text{Equation (1.6)}$$

HMP to RPC: $$Elev_{RPC} = Elev_{HMP} - aX^2 - bX - cXY - dY - eY^2 \quad \text{Equation (1.7)}$$

where: $Elev_{HMP}$ = Elevation in feet on HMP.
$Elev_{RPC}$ = Elevation in feet on RPC.
X = HMP state plane easting at a point minus a constant.
Y = HMP state plane northing at a point minus a constant.
$a, b, c, d, \& e$ = Coefficients found in a least squares "best fit" for each county.

Map 2

SUBAREAS OF THE SOUTHEASTERN WISCONSIN REGION FOR WHICH BIDIRECTIONAL COORDINATE TRANSFORMATION EQUATIONS WERE DEVELOPED



Source: SEWRPC.

The values of the coefficients *a, b, c, d,* and *e* are the same for both equation (1.6) and equation (1.7) and are tabulated for each county within the Region. The constant values to be subtracted from the East and North NAD 83 (2007) SPC are listed along with the coefficients. See tabulation of coefficients and constants for each county in Table 2.

Appendix C contains a county-by-county listing of the control points used in computing the direct method coefficients in each county. In addition to the computed coefficients, the HMP State Plane Coordinates are listed, the RPC and the HMP elevations are listed, the actual elevation differences are shown, the modeled elevation is given and the differences of the actual and modeled differences are listed. Finally, the standard deviation of the difference of the differences is given. The standard deviation of the differences of the differences using the direct method is compared with the standard deviation of the vertical component as obtained using the Helmert 3-D transformations as given in Table 1. A tabulation of those standard deviations is listed in Table 3.

The direct method of vertical data transformation as described herein requires HMP State Plane Coordinate values of the bench mark for which the elevation is to be transformed. If HMP State Plane Coordinate values are not readily available for the bench mark, determination of the Coordinate values to within about 10 feet is necessary for use of the method. The HMP State Plane Coordinate values of the bench mark may be determined in several ways:

1. A code-phased, hand-held, GPS receiver with NAD 83 (2007) selected as the datum, can be utilized to obtain HMP coordinate values with sufficient accuracy to support the direct method of vertical data transformation.

2. The position of the bench mark for which transformed elevations are required can be located and marked on a large-scale—one inch equals 100 feet scale or larger—topographic map. Within the SEWRPC planning area, such maps will be based upon the NAD 27 horizontal datum and the NGVD 29 vertical datum, and will—if prepared to SEWRPC specifications—meet National Map Accuracy standards. The NAD 27 coordinate position of the bench mark can then be scaled, and transformed to an HMP coordinate position by application of the method given in this report. The direct method vertical transformation process can then be applied.

3. Using the published NAD 27 State Plane Coordinates and the NGVD 29 elevation (RPC position) of a monumented USPLS section or one-quarter-section corner located near the bench mark concerned, and the horizontal transformation process procedure described in this report, HMP coordinate values can be obtained for the monumented corner. The NGVD 29 elevation of the monumented corner can then be transformed to an NAVD 88 (2007) elevation using the direct method vertical transformation procedure. The NAVD 88 (2007) elevation of the nearby bench mark can then be determined using standard high-order differential leveling procedures.

Geoid Modeling

Geoid modeling is an important geodetic consideration when dealing with the difference between elevation and ellipsoid height. High quality engineering surveys, dealing primarily with relative spatial data, and scientific investigations, typically dealing with both absolute and relative spatial data, must, of necessity, include geoid modeling. Given the use of modern GPS equipment and the task of developing reliable bidirectional transformations between RPC and HMP positions, it would be a mistake to ignore geoid modeling. Issues related to geoid modeling were considered in developing these bidirectional transformations; but, due to the existence of reliable RPC and HMP positions on the 114 common control points throughout the Region, it was possible to develop bidirectional transformations that do not rely on detailed knowledge of the geoid within the Region.

Table 2

VERTICAL TRANSFORMATION COEFFICIENTS AND CONSTANTS FOR USE IN APPLICATION OF THE DIRECT METHOD VERTICAL TRANSFORMATION IN THE SOUTHEASTERN WISCONSIN REGION

County	Coefficients	Constants for modifying HMP SPC values
Kenosha	*a* = 8.43360E-12	*X* = HMP Easting minus 2,400,000 feet
	b = -3.15135E-06	*Y* = HMP Northing minus 185,000 feet
	c = 3.66856E-11	
	d = -5.34262E-06	
	e = 1.58098E-11	
Milwaukee	*a* = 4.30438E-11	*X* = HMP Easting minus 2,400,000 feet
	b = -7.86877E-06	*Y* = HMP Northing minus 300,000feet
	c = -1.21150E-11	
	d = 1.34331E-06	
	e = 5.74893E-12	
Ozaukee	*a* = -1.10868E-12	*X* = HMP Easting minus 2,400,000 feet
	b = -1.81478E-06	*Y* = HMP Northing minus 400,000 feet
	c = 3.16690E-12	
	d = -3.76987E-07	
	e = 2.58500E-14	
Racine	*a* = 9.75797E-12	*X* = HMP Easting minus 2,400,000 feet
	b = -3.30914E-06	*Y* = HMP Northing minus 225,000 feet
	c = 2.02636E-11	
	d = -1.66589E-06	
	e = -1.39584E-11	
Walworth	*a* = 4.00825E-12	*X* = HMP Easting minus 2,200,000 feet
	b = -2.35195E-06	*Y* = HMP Northing minus 175,000 feet
	c = 9.45303E-12	
	d = -1.87160E-06	
	e = 6.59620E-12	
Washington	*a* = -3.71288E-12	*X* = HMP Easting minus 2,350,000 feet
	b = -6.73211E-07	*Y* = HMP Northing minus 430,000 feet
	c = 1.11057E-12	
	d = 7.89350E-07	
	e = -9.42632E-12	
Waukesha	*a* = -6.32130E-13	*X* = HMP Easting minus 2,300,000 feet
	b = -1.86087E-06	*Y* = HMP Northing minus 290,000 feet
	c = 4.66808E-12	
	d = -5.97366E-07	
	e = 7.91542E-12	

Note: Coefficient values are written in scientific notation in which 1.234E-4 = 0.0001234 in decimal format and = 1.234×10^{-4} when written with an exponent.

Source: SEWRPC.

Table 3

COMPARISON OF VERTICAL STANDARD DEVIATIONS FOR HELMERT AND DIRECT METHOD TRANSFORMATIONS

County	Vertical Standard Deviation Using Helmert 3-D Transformation in Feet	Vertical Standard Deviation Using the Direct Method in Feet	Difference in Feet
Kenosha	0.072	0.086	0.014
Milwaukee (North One-Half)	0.047	0.031	-0.016
Milwaukee (South One-Half)	0.030	0.031	0.001
Ozaukee (North One-Half)	0.039	0.045	0.006
Ozaukee (South One-Half)	0.038	0.045	0.007
Racine (East One-Half)	0.052	0.051	-0.001
Racine (West One-Half)	0.064	0.051	-0.007
Walworth (Northeast One-Quarter)	0.040	0.060	0.020
Walworth (Northwest One-Quarter)	0.072	0.060	-0.012
Walworth (Southeast One-Quarter)	0.029	0.060	0.031
Walworth (Southwest One-Quarter)	0.052	0.060	0.008
Washington (North One-Half)	0.041	0.044	0.003
Washington (South One-Half)	0.034	0.044	0.010
Waukesha (Northeast One-Quarter)	0.046	0.039	-0.007
Waukesha (Northwest One-Quarter)	0.029	0.039	-0.010
Waukesha (Southeast One-Quarter)	0.040	0.039	-0.001
Waukesha (Southwest One-Quarter)	0.035	0.039	0.004
		Mean	**0.004**
		Standard Deviation	**0.012**

Source: SEWRPC.

GEOID09 was utilized in developing the Helmert 3-D transformation parameters for each of the 17 subareas within the Region. The Helmert transformation requires geocentric X/Y/Z coordinates in both systems being modeled. As stated earlier, pseudo-geocentric X/Y/Z coordinates were developed for RPC positions on the basis of NAD 27 State Plane Coordinates converted to latitude and longitude; and NGVD 29 elevations converted to pseudo-ellipsoid heights using GEOID09 geoid heights. Geocentric X/Y/Z coordinates were computed for HMP positions based upon NAD 83 (2007) horizontal positions and NAVD 88 (2007) elevations converted to ellipsoid heights also using GEOID09. The transformation parameters for each subarea were then computed using a least squares fit to the common control points in each subarea.

Once the Helmert transformation parameters are computed, there is no need for additional geoid modeling. The horizontal positions in each transformation are only loosely tied to elevation—values within 10 feet vertical are quite sufficient. And, since geoid heights in the entire Region range from approximately -33.5 meters to -35.5 meters an average geoid height of -34.5 meters for the entire Region was used when applying the transformation parameters to convert a RPC position to an HMP position or an HMP position to a RPC position. The specific use of the assumed -35.5 meters geoid height is illustrated in the spreadsheet example included in Appendix D.

Depending upon the procedure used, geoid heights could be critical in transforming elevations from NGVD 29 to NAVD 88 (2007) and NAVD 88 (2007) to NGVD 29. However, since the 114 common control points throughout the Region each have reliable NGVD 29 and NAVD 88 (2007) elevations, it was found that a simple direct second-degree polynomial provides results that are nearly as good as those obtained using the vertical component of the Helmert transformation. The reasons for selecting the direct method over the Helmert vertical component include: 1) the ease with which the direct method can be applied; 2) if used, geoid modeling is an extra tedious step in the transformation process; and 3) the elevation of a vertical point being transformed is only loosely tied to horizontal location. Here again, if the horizontal position of the point for which elevation is being transformed is within about 10 feet, the accuracy of the modeled elevation is not compromised.

However, it would also be a mistake to ignore potential future developments in recommending geoid-free bidirectional transformations. With regard to this issue, one of two, if not both, developments will be realized.

1. The NGS is planning to publish an improved geoid model based upon results of the current NGS "Grav-D" project. It is anticipated that a new geoid release may be tied to publication of a 2015 update to the International Great Lakes Datum.

2. Option four as described on page 11 of SEWRPC Technical Report No. 45 may eventually be implemented in which the spatial locations of points are reliably described with respect to the earth's center of mass and elevation is a derived quantity. This option is technically possible and ultimately would provide for the more efficient collection, manipulation, and use of spatial data.

Regardless of future policies and practices with regard to use of spatial data, the bidirectional transformations described herein are appropriate for preserving the value of existing RPC positions in the context of HMP practices.

GEOID09 geoid heights were not intended to be used in conjunction with NAD 27 latitude and longitude positions. However, geocentric X/Y/Z coordinates representing NAD 27 positions, NGVD 29 elevations, and pseudo-ellipsoid heights were needed for developing the Helmert transformation parameters. Several geoid modeling options and combinations were considered: use no geoid model, use GEOID03, or use GEOID09. Using the same geoid model at each end of the transformation process is desirable because it allows the impact of the geoid modeling to cancel out. However, geoid modeling remains critical when, in the case of the HMP position, the transformation results need to be compatible, as near as possible, with GPS computations based upon NAD 83 (2007) latitude, longitude, and ellipsoid heights.

The following observations are pertinent:

1. The GEOID09 model was used in developing the Helmert 3-D transformation parameters. However, reliable modeling procedures for both horizontal and vertical were identified during the study that do not rely upon accurate knowledge of the geoid.

2. The user should not attempt to develop a geometric interpretation of the RPC pseudo-geocentric X/Y/Z coordinates. It is well known that GEOID09 is not compatible with NAD 27. However, GEOID09 was used at each end of the process when developing the Helmert transformation parameters. Consequently, the impact of using the geoid model was effectively cancelled out and residual imperfections of geoid modeling were absorbed in the computation of the Helmert transformation parameters.

Standards

Standards for spatial data provide a way to judge the quality or to determine the acceptability of estimated, measured, or computed spatial data. In the past, control surveys were categorized by orders and classes. The orders were First-Order, Second-Order, and Third-Order, while the classes, Class I and Class II, were used to describe differences within the orders. Such categories are still applicable as related to working on the NAD 27, traditional surveying procedures, and many routine surveying operations. However, with the advent of GNSS and other three-dimensional measurement systems, the standards for geospatial data were modified to reflect use of the new measurement systems and to make the standards designations more intuitive for the spatial data user.

When GPS surveying came into common use for horizontal positioning, the ratio of precision for the lowest order GPS survey was 1:100,000, the same as the highest order of accuracy for traditional horizontal surveys. With increasing use of GPS, additional orders for GPS positioning were adopted and associated standards were written to accommodate both base error—e.g.: setting up an instrument over a point—and distance dependent error—a traditional ratio-of-precision designation. The ratio-of-precision is not the only—or best—measure of quality. A summary of various accuracy standards pertaining to the use of spatial data within the Region is included in Table 4.

Judging the quality of horizontal data transformations between RPC and HMP positions, is embodied in the following question: "What level of standard deviation (1 sigma) can be tolerated on the coordinates of two U.S. Public Land Survey System section corners one-half mile apart such that the standard deviation of the inverse distance between them can be relied upon to be within 1 part in 10,000 at the 2 sigma—95 percent—confidence level?" The answer obtained by error propagation computations, as illustrated in Appendix E, is 0.093 feet in each directional component—north, south, east, and west. Posing a similar question about allowable vertical discrepancies between Third-Order bench marks one-half mile apart elicits an answer of 0.035 feet.

RESULTS

This report sets forth the findings and recommendations of both field surveys and office work carried out over a period of almost two years. The results of the work include:

- The assembly of published data and the conduct of high-order geodetic surveys to accurately establish as required the horizontal and vertical positions of 114 points distributed throughout the seven-county Region on both the NAD 27 and NAD 83 (2007) horizontal datums and on the NGVD 29 and NAVD 88 (2007) vertical datums. These high-quality control survey points served as the basis for accommodating the bidirectional transformation of data between the datums concerned.

Table 4

SUMMARY OF GEOSPATIAL DATA ACCURACY STANDARDS

I. Source: ***Standards and Specifications for Geodetic Control Networks*** Federal Geodetic Control Committee–September 1984

The standards for traditional horizontal geodetic control surveys are summarized as:

First-order	1 part in 100,000
Second-order, Class I	1 part in 50,000
Second-order, Class II	1 part in 20,000
Third-order, Class I	1 part in 10,000
Third-order, Class II	1 part in 5,000

For traditional vertical geodetic control surveys, the allowable misclosures for a double run section (D = shortest one-way distance in miles, misclosure in feet) are summarized as:

	allowable misclosure
First-order, Class I	0.012 √(D)
First-order, Class II	0.017 √(D)
Second-order, Class I	0.025 √(D)
Second-order, Class II	0.033 √(D)
Third-order	0.050 √(D)

II. Source: ***Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques***, Federal Geodetic Control Committee, 1989.

The distance-dependent (ratio-of-precision) part of the standards is given below. The standards also include a base-error component.

Order AA	1 part in 100,000,000
Order A	1 part in 10,000,000
Order B	1 part in 1,000,000
Order C	1 part in 100,000

III. Source: ***Geospatial Positioning Accuracy Standards Part 2: Standards for Geodetic Networks***, Federal Geodetic Control Subcommittee, Federal Geographic Data Committee, 1998.

These standards are part of a larger document but designed specifically for judging the quality of three-dimensional geodetic control networks. Note that each accuracy statement is equally applicable to horizontal components (both east and north) and vertical components (both orthometric and ellipsoid heights).

Horizontal, Ellipsoid Height, and Orthometric Height

Accuracy Classification	95 Percent Confidence Less than or equal to
1 millimeter	0.001 meters
2 millimeters	0.002 meters
5 millimeters	0.005 meters
1 centimeter	0.010 meters
1 decimeter	0.100 meters
2 decimeters	0.200 meters
5 decimeters	0.500 meters
1 meter	1.000 meters
5 meters	5.000 meters
10 meters	10.000 meters

Table 4 (continued)

IV. Source: ***2005 Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys***, as adopted by the American Land Title Association and the National Society of Professional Surveyors (a member organization of the American Congress on Surveying and Mapping).

The document contains a concise statement on "Allowable Relative Positional Accuracy for Measurements Controlling Land Boundaries on ALTA/ACSM Land Title Surveys" as:

0.07 feet + 50 parts per million (one part in 20,000)

Using that information and applying it to various distances, the ALTA/ACSM allowable tolerances are equivalent to:

Distance	Allowable Tolerance
5,280 feet	0.33 feet
2,640 feet	0.20 feet
1,320 feet	0.14 feet

In contrast to these standards, Section 236.15(2) of the *Wisconsin Statutes* specifies an accuracy standard of one part in 3,000 for land surveys conducted for the creation of land subdivision plats, arguably the most demanding type of land survey. The Commission in its model land division ordinance promulgated for adoption by its constituent counties and municipalities recommends this standard be set at one part in 10,000.

- Parameters, coefficients, constants, equations, procedures, and computer programs for performing the bidirectional transformations of spatial data between the datums concerned were developed and are documented in this report. See Appendix B, Table 1, Table 2 and Appendix D.

- One hundred test points were surveyed using field procedures designed to duplicate use of the Wisconsin Department of Transportation CORS network RTN. The field procedures included verification of measurements against known positions of monumented height modernization stations. The RTN survey results were compared against known values referred to the four datums concerned, and the results evaluated. See Map 3 for the location of the test points and Tables 5 and 6 for comparison of horizontal survey results. For vertical survey results, see Table 7.

- Relative distance comparisons between inter-visible points were also conducted for 12 different point-pairs. See Map 4 for the location of the point-pairs, Table 8 for comparisons of published ground distances compared to measured distances; measured distance compared to RPC transformed coordinate values; and measured distance compared to HMP transformed coordinate values.

The method developed for the desired bidirectional transformations represents the primary result of the project. Following is a summary of the steps needed to transform data from RPC to HMP and from HMP to RPC. The specific steps are more fully documented in the spreadsheet program developed for use in each of 17 delineated subareas of the seven-county Region.

The following steps are used to make a transformation from an RPC position to an HMP position:

1. NAD 27 SPC are converted to latitude and longitude on the Clarke Spheroid of 1866 using the SPC zone constants for Wisconsin South Zone and equations given in USC&GS Publication 62-4. CORPSCON software published by the U.S Army Corps of Engineers can also be used for making those conversions, either one point at a time or in batch mode. Other SPC to latitude/longitude software also exist and can be used. But, whatever software is used for NAD 27 conversions, the results should agree with the results provided by application of the equations given in USC&GS Publication 62-4.

2. The NGVD 29 elevation of a point is converted to meters then to an RPC pseudo-ellipsoid height by using an average geoid height of -34.5 meters for the entire Region. While an average value of geoid height is sufficiently accurate for the horizontal transformations, it is not sufficiently accurate for vertical transformations. The vertical transformation is described and accomplished separately.

3. NAD 27 latitude and longitude are used along with the estimated RPC pseudo-ellipsoid height at the point to compute RPC pseudo-geocentric X/Y/Z coordinates for the point.

4. The Helmert 7-parameter transformation is used to convert the RPC pseudo-geocentric X/Y/Z coordinates to HMP pseudo-geocentric X/Y/Z coordinates using the parameters given in this report for each of the 17 delineated subareas of the Region. The computational environment of HMP geocentric X/Y/Z coordinates—latitude, longitude, and ellipsoid heights—is one and the same as the coordinate computational environment for the entire GPS constellation. This provides the best direct connection with the larger global community of spatial data applications. This computational environment is documented as the 3-D Global Spatial Data Model (GSDM) in the text *The 3-D Global Spatial Data Model*, Earl F. Burkholder, CRC Press, 2008.

5. The HMP pseudo geocentric X/Y/Z coordinates and the GRS 1980 ellipsoid are used to compute HMP latitude and longitude of the point being transformed. Ellipsoid height can also be computed from the HMP geocentric X/Y/Z values, but lack of sufficiently accurate geoid height information precludes computation of a reliable HMP orthometric height based upon the Helmert transformation. A separate procedure using equation (1.6) given previously is used for modeling vertical transformations at a point.

6. CORPSCON, or other SPC conversion software, can be used to convert the HMP position latitude and longitude to NAD 83 (2007) SPC. The equations and zone constants listed in NOAA Manual NOS NGS 5 (Stem 1989) were used in both the computer program and the spreadsheet and are the equations to be used for NAD 83 (2007) SPC conversions. This completes the RPC to HMP portion of the transformation process.

The following steps are used to compute a transformation from an HMP position to an RPC position:

1. NAD 83 (2007) SPC are converted to latitude and longitude on the GRS 1980 ellipsoid. Again, CORPSCON or other reliable software can be used for the conversion. The equations and zone constants listed in NOAA Manual NOS NGS 5, (Stem, 1989) were used in the computer programs developed as part of this work effect, and should be used in any other software written to perform NAD 83 SPC conversions.

2. The NAVD 88 (2007) elevation of a point is converted to meters, then to an HMP pseudo-ellipsoid height by using an average geoid height of -34.5 meters for the entire Region.

3. NAD 83 (2007) latitude and longitude are used along with the HMP pseudo-ellipsoid height at the point to compute HMP pseudo-geocentric X/Y/Z coordinates for the point.

4. The Helmert transformation parameters are applied in reverse to convert the HMP pseudo-geocentric X/Y/Z coordinates to RPC pseudo-geocentric X/Y/Z coordinates in each of the 17 delineated subareas of the Region.

5. The RPC pseudo-geocentric X/Y/Z coordinates are used to compute RPC latitude and longitude on the NAD 27 of the point being transformed. Pseudo ellipsoid height can also be computed from the RPC pseudo geocentric X/Y/Z values, but lack of sufficiently accurate geoid height information precludes computation of a reliable RPC elevation. A separate procedure using equation (1.7) given previously is used for modeling vertical transformations at a point.

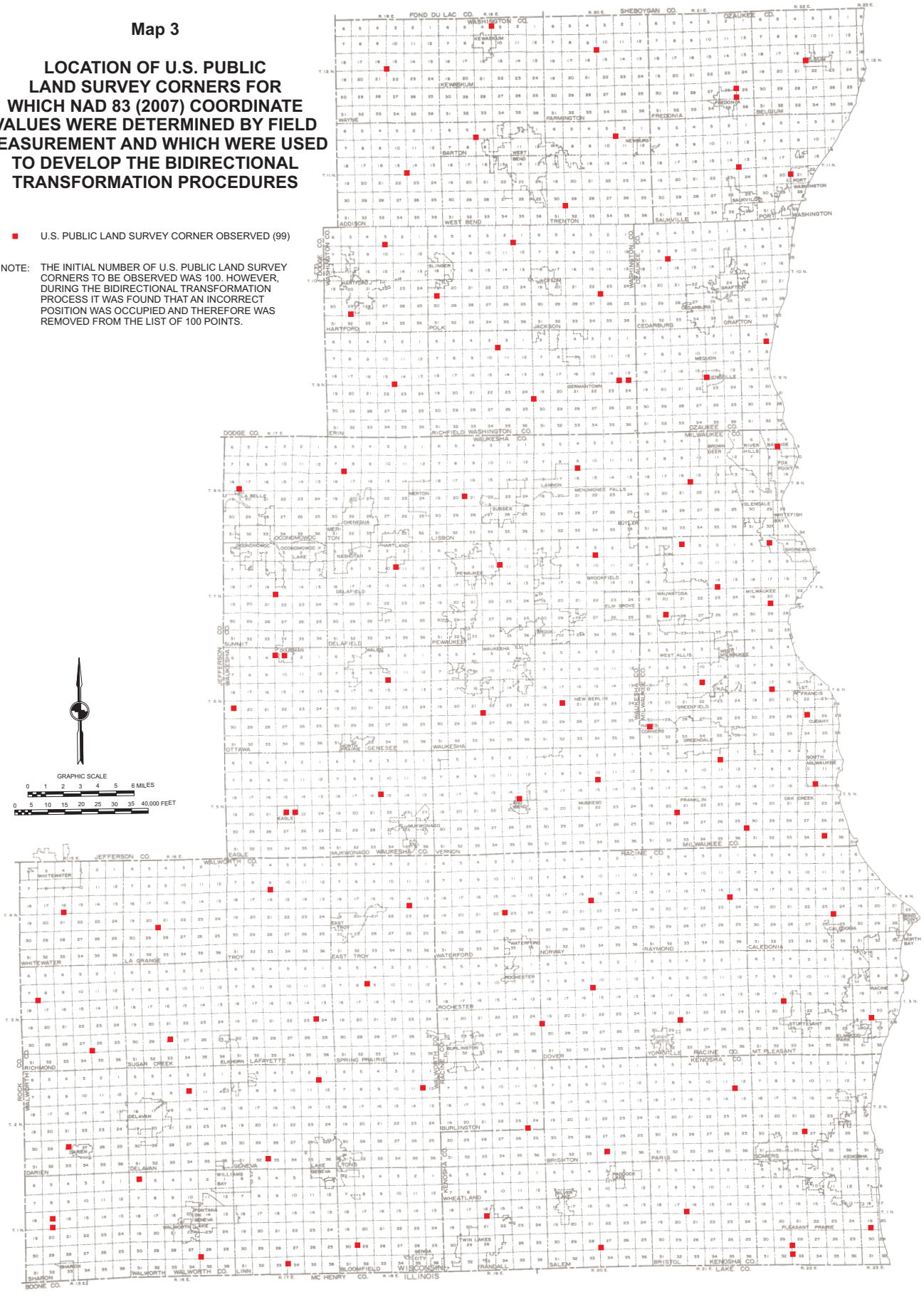
6. CORPSCON, or other SPC conversion software, can be used to convert the RPC latitude and longitude to NAD 27 SPC. The computer programs developed as part of this work effort used the Wisconsin South Zone constants and equations as listed in NGS Publication 62-4 (Claire 1968) and should be used in any other software written to perform the NAD 27 SPC conversion. This completes the HMP to RPC portion of the transformation process.

Map 3

LOCATION OF U.S. PUBLIC LAND SURVEY CORNERS FOR WHICH NAD 83 (2007) COORDINATE VALUES WERE DETERMINED BY FIELD MEASUREMENT AND WHICH WERE USED TO DEVELOP THE BIDIRECTIONAL TRANSFORMATION PROCEDURES

■ U.S. PUBLIC LAND SURVEY CORNER OBSERVED (99)

NOTE: THE INITIAL NUMBER OF U.S. PUBLIC LAND SURVEY CORNERS TO BE OBSERVED WAS 100. HOWEVER, DURING THE BIDIRECTIONAL TRANSFORMATION PROCESS IT WAS FOUND THAT AN INCORRECT POSITION WAS OCCUPIED AND THEREFORE WAS REMOVED FROM THE LIST OF 100 POINTS.



Source: SEWRPC.

Table 5

NAD 27 PUBLISHED COORDINATES AND COMPARISON OF NAD 83 (2007) DERIVED COORDINATES TO SURVEYED COORDINATE VALUES

Point ID No.	U.S. Public Land Survey Location	NAD 27 Published Coordinates		Helmert Transformation of Published NAD 27 to NAD 83 (2007) Values		NAD 83 (2007) Values From Field Surveys		Difference Between NAD 83 (2007) Transformed Value and Field Survey Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Kenosha County								
2001	1-19 S-16	201,107.980	2,470,006.700	201,117.425	2,438,470.130	201,117.520	2,438,469.994	0.095	-0.136
2002	1-20 SE-28	191,615.280	2,504,757.040	191,624.879	2,473,220.863	191,625.053	2,473,220.805	0.174	-0.058
2003	1-21 SE-17	202,719.760	2,530,852.090	202,729.647	2,499,316.081	202,729.858	2,499,316.125	0.211	0.044
2004	1-22 SE-29	192,430.450	2,562,951.570	192,440.466	2,531,415.935	192,440.606	2,531,416.060	0.140	0.125
2005	1-22 E-32	189,788.540	2,563,074.890	189,798.532	2,531,539.275	189,798.657	2,531,539.437	0.125	0.162
2006	1-23 S-19	197,911.990	2,586,576.990	197,922.223	2,555,041.539	197,923.003	2,555,042.582	0.780	1.043
2007	2-20 C-34	220,776.389	2,506,419.877	220,786.275	2,474,883.511	220,789.732	2,474,883.732	0.301	0.221
2008	2-21 SE-11	240,102.900	2,454,441.270	240,113.242	2,513,905.136	240,113.852	2,513,905.631	0.610	0.495
2009	2-22 E-28	227,103.610	2,566,672.930	227,113.979	2,535,137.087	227,114.183	2,535,137.168	0.204	0.081
							Mean	**0.293**	**0.220**
							Standard Deviation	**0.239**	**0.357**
	Milwaukee Co. South One-Half								
2010	5-21 S-2	340,401.830	2,541,226.380	340,412.348	2,509,689.311	340,412.683	2,509,689.463	0.335	0.152
2011	5-21 SE-20	324,249.590	2,528,089.650	324,259.958	2,496,552.931	324,260.049	2,496,552.874	0.091	-0.057
2012	5-21 SE-25	319,498.100	2,549,218.320	319,508.863	2,517,681.578	319,508.790	2,517,681.427	-0.073	-0.151
2013	5-22 E-15	332,935.310	2,570,148.480	332,946.374	2,538,611.396	332,945.934	2,538,611.514	-0.440	0.118
2014	5-22 C-35	317,018.120	2,572,691.590	317,029.309	2,541,154.774	317,028.669	2,541,154.765	-0.640	-0.009
2015	6-21 C-15	363,996.440	2,535,748.020	364,006.743	2,504,210.563	364,007.055	2,504,210.356	0.312	-0.207
2016	6-21 S-30	350,326.230	2,519,940.740	350,336.324	2,488,403.603	350,336.616	2,488,403.539	0.292	-0.064
2017	6-22 S-17	361,847.740	2,556,815.870	361,858.424	2,525,278.345	361,858.368	2,525,278.562	-0.056	0.217
2018	6-22 C-27	354,106.140	2,567,587.690	354,117.053	2,536,050.247	354,116.929	2,536,050.357	-0.124	0.110
							Mean	**-0.034**	**0.012**
							Standard Deviation	**0.339**	**0.145**
	Milwaukee Co. North One-Half								
2019	7-21 C-4	406,141.520	2,529,513.360	406,151.267	2,497,975.346	4061,51.276	2,497,975.279	0.009	-0.067
2020	7-21 S-14	393,121.630	2,540,473.370	393,131.659	2,508,935.428	393,132.056	2,508,935.409	0.397	-0.019
2021	7-21 C-29	384,611.660	2,524,698.780	384,621.554	2,493,161.113	384,621.774	2,493,161.136	0.220	0.023
2022	7-22 C-5	406,635.530	2,556,314.980	406,645.646	2,524,776.692	406,645.148	2,524,777.211	-0.498	0.519
2023	7-22 S-20	388,105.180	2,556,505.740	388,115.482	2,524,967.708	388,115.775	2,524,967.615	0.293	-0.093
2024	8-21 SE-16	425,031.550	2,532,275.120	425,041.148	2,500,736.815	425,040.084	2,500,736.603	-1.064	-0.212
2025	8-22 SE-5	435,866.420	2,558,731.520	435,876.279	2,527,192.801	435,876.060	2,527,193.023	-0.219	0.222
							Mean	**-0.123**	**0.053**
							Standard Deviation	**0.519**	**0.244**
	Ozaukee Co. South One-Half								
2026	9-21 SE-15	457,026.160	2,537,259.260	457,034.618	2,505,720.610	457,034.741	2,505,720.893	0.123	0.283
2027	9-22 S-5	468,021.200	2,555,519.300	468,029.565	2,523,980.177	468,029.508	2,523,980.708	-0.057	0.531
2028	10-21 SE-8	493,459.470	2,525,461.750	493,467.063	2,493,923.071	493,467.493	2,493,921.995	0.430	-1.076
2029[a]	10-22 SE-18	489,359.010	2,552,047.850	--	--	--	--	--	--
							Mean	**0.165**	**-0.087**
							Standard Deviation	**0.246**	**0.865**

Table 5 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 27 Published Coordinates		Helmert Transformation of Published NAD 27 to NAD 83 (2007) Values		NAD 83 (2007) Values From Field Surveys		Difference Between NAD 83 (2007) Transformed Value and Survey Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Ozaukee Co. North One-Half								
2030	11-21 SE-14	521,215.890	2,547,117.970	521,223.154	2,515,578.798	521,222.736	2,515,578.133	-0.418	-0.665
2031	11-21 E-20	519,288.530	2,563,078.100	519,295.947	2,531,538.698	519,295.835	2,531,538.367	-0.112	-0.331
2032	12-21 E-26	545,230.960	2,546,557.590	545,237.852	2,515,018.240	545,237.844	2,515,017.828	-0.008	-0.412
2033	12-21 SE-26	542,569.750	2,546,622.170	542,576.683	2,515,082.840	542,576.669	2,515,082.511	-0.014	-0.329
2034	12-22 SE-16	553,793.820	2,567,602.490	553,800.744	2,536,062.751	553,800.575	2,536,062.569	-0.169	-0.182
							Mean	**-0.144**	**-0.384**
							Standard Deviation	**0.167**	**0.178**
	Racine Co. West One-Half								
2035	2-19 SE-23	227,975.760	2,482,488.130	227,985.375	2,450,951.658	227,986.054	2,450,950.819	0.679	-0.839
2036	3-19 SE-24	259,761.388	2,486,894.706	259,771.306	2,455,358.082	259,771.881	2,455,357.915	0.575	-0.167
2037	3-20 SE-9	270,687.580	2,502,338.450	270,697.686	2,470,801.894	270,698.110	2,470,801.963	0.424	0.069
2041	4-19 E-22	293,837.400	2,475,593.220	293,847.546	2,444,056.293	293,847.563	2,444,055.591	0.017	-0.702
2042	4-20 SE-16	297,341.510	2,501,880.790	297,351.845	2,470,344.070	297,350.962	2,470,342.584	-0.883	-1.486
							Mean	**0.162**	**-0.625**
							Standard Deviation	**0.636**	**0.609**
	Racine Co. East One-Half								
2038	3-21 SE-20	260,886.350	2,528,976.180	260,896.726	2,497,440.019	260,897.107	2,497,440.080	0.381	0.061
2039	3-22 SE-17	266,804.410	2,560,422.660	266,815.144	2,528,886.555	266,815.209	2,528,886.809	0.065	0.254
2040	3-23 SE-19	2616,82.790	2,587,091.440	261,693.790	2,555,555.492	261,693.840	2,555,555.634	0.050	0.142
2043	4-21 SE-14	298,451.280	2,544,080.780	298,461.961	2,512,544.275	298,461.787	2,512,543.826	-0.174	-0.449
2044	4-22 SE-23	293,358.210	2,575,579.550	293,369.208	2,544,043.219	293,369.176	2,544,043.186	-0.032	-0.033
							Mean	**0.058**	**-0.005**
							Standard Deviation	**0.204**	**0.270**
	Walworth Co. Southwest One-Quarter								
2045	1-15 C-17	200,541.690	2,337,692.160	200,550.025	2,306,154.952	200,549.963	2,306,154.785	-0.062	-0.167
2046	1-15 S-17	197,894.760	2,337,706.620	197,903.088	2,306,169.428	197,903.142	2,306,169.290	0.054	-0.138
2047	1-16 C-6	212,500.420	2,363,970.310	212,508.944	2,332,433.092	212,509.076	2,332,432.677	0.132	-0.415
2048	1-16 SE-27	188,877.480	2,383,041.760	188,886.063	2,351,504.733	188,886.611	2,351,504.389	0.548	-0.344
2051	2-15 C-28	222,226.710	2,342,650.000	222,235.128	2,311,112.672	222,235.046	2,311,112.518	-0.082	-0.154
2052	2-16 C-10	239,276.260	2,379,287.780	239,284.943	2,347,750.436	239,285.227	2,347,750.441	0.284	0.005
							Mean	**0.146**	**-0.202**
							Standard Deviation	**0.239**	**0.152**

Table 5 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 27 Published Coordinates		Helmert Transformation of Published NAD 27 to NAD 83 (2007) Values		NAD 83 (2007) Values From Field Surveys		Difference Between NAD 83 (2007) Transformed Value and Survey Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Walworth Co. Southeast One-Quarter								
2049	1-17 E-33	186,716.820	2,409,494.330	186,725.643	2,377,957.551	186,725.926	2,377,959.923	0.283	2.372
2050	1-19 E-30	192,385.070	2,430,631.580	192,394.073	2,399,094.859	192,394.269	2,399,094.255	0.196	-0.604
2053	2-17 SE-2	242,594.160	2,418,891.350	242,603.313	2,387,354.211	242,603.287	2,387,354.237	-0.026	0.026
2054	2-17 E-32	218,721.630	2,403,440.120	218,730.559	2,371,903.081	218,730.685	2,371,902.787	0.126	-0.294
2055	2-18 E-11	240,294.830	2,450,534.330	240,304.201	2,418,997.355	240,305.468	2,418,997.585	1.267	0.230
							Mean	**0.369**	**0.346**
							Standard Deviation	**0.514**	**1.176**
	Walworth Co. Northwest One-Quarter								
2056	3-15 SE-7	266,936.670	2,333,419.950	266,944.982	2,301,882.475	266,945.014	2,301,882.385	0.032	-0.090
2057	3-15 SE-27	251,529.970	2,349,901.490	251,538.304	2,318,364.085	251,538.401	2,318,363.890	0.097	-0.195
2058	3-16 C-28	254,999.140	2,373,561.770	255,007.547	2,342,024.393	255,007.988	2,342,024.272	0.441	-0.121
2061	4-15 S-16	293,783.760	2,341,176.940	293,792.137	2,309,639.401	293,791.973	2,309,639.848	-0.164	0.447
2062	4-16 SE-20	289,072.510	2,369,994.350	289,080.961	2,338,456.870	289,081.261	2,338,456.645	0.300	-0.225
							Mean	**0.141**	**-0.037**
							Standard Deviation	**0.236**	**0.276**
	Walworth Co. Northeast One-Quarter								
2059	3-17 E-23	261,177.990	2,418,183.580	261,187.127	2,386,646.546	261,187.503	2,386,646.350	0.376	-0.196
2060	3-18 E-8	271,886.000	2,433,635.830	271,895.436	2,402,098.798	271,895.660	2,402,098.781	0.224	-0.017
2063	4-17 S-9	300,645.720	2,404,156.850	300,655.035	2,372,619.174	300,655.358	2,372,619.504	0.323	0.330
2064	4-18 S-14	295,748.090	2,446,415.320	295,757.911	2,414,878.093	295,757.927	2,414,878.452	0.016	0.359
							Mean	**0.235**	**0.119**
							Standard Deviation	**0.159**	**0.271**
	Washington Co. South One-Half								
2065	9-18 SE-15	455,067.280	2,442,167.320	455,074.737	2,410,630.196	455,074.997	2,410,629.310	0.260	-0.886
2066	9-19 SE-3	466,269.420	2,473,629.620	466,276.980	2,442,091.915	466,277.674	2,442,091.785	0.694	-0.130
2067	9-19 SE-24	450,519.580	2,484,530.260	450,527.477	2,452,992.525	450,527.979	2,452,992.389	0.502	-0.136
2068	9-20 S-13	456,251.000	2,513,248.760	456,259.060	2,481,710.534	456,259.322	2,481,710.395	0.262	-0.139
2069	9-20 SE-14	456,176.710	2,510,586.870	456,184.748	2,479,048.686	456,185.114	2,479,048.592	0.366	-0.094
2070	10-18 S-3	497,740.210	2,439,277.920	497,746.987	2,407,740.467	497,746.975	2,407,740.843	-0.012	0.376
2071	10-18 S-29	476,531.720	2,428,785.990	476,538.731	2,397,248.883	476,538.527	2,397,248.783	-0.204	-0.100
2072	10-19 SE-2	498,345.320	2,478,345.250	498,352.429	2,446,807.192	498,352.312	2,446,807.424	-0.117	0.232
2073	10-19 S-19	482,222.810	2,455,015.160	482,229.963	2,423,477.601	482,229.580	2,423,477.629	-0.383	0.028
2074	10-20 SE-22	482,666.870	2,505,019.510	482,674.453	2,473,481.180	482,674.401	2,473,481.399	-0.052	0.219
							Mean	**0.132**	**-0.063**
							Standard Deviation	**0.339**	**0.344**

Table 5 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 27 Published Coordinates		Helmert Transformation of Published NAD 27 to NAD 83 (2007) Values		NAD 83 (2007) Values From Field Surveys		Difference Between NAD 83 (2007) Transformed Value and Survey Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Washington Co. North One-Half								
2075	11-18 SE-15	519,520.980	2,446,073.190	519,527.222	2,414,535.282	519,527.185	2,414,535.317	-0.037	0.035
2076	11-19 SE-5	530,489.710	2,467,045.860	530,496.070	2,435,507.595	530,496.702	2,435,506.728	0.632	-0.867
2077	11-20 SE-3	530,812.830	2,509,674.180	530,819.670	2,478,135.441	530,820.158	2,478,135.481	0.488	0.040
2078	11-20 SE-30	509,598.540	2,494,386.890	509,605.441	2,462,848.561	509,605.763	2,462,848.742	0.322	0.181
2079	12-18 SE-16	551,176.740	2,439,898.180	551,182.563	2,408,359.980	551,182.242	2,408,359.799	-0.321	-0.181
2080	12-19 E-4	564,641.530	2,471,820.490	564,647.567	2,440,281.784	564,647.457	2,440,281.880	-0.110	0.096
2081	12-20 S-9	556,992.010	2,501,226.600	556,998.466	2,469,687.657	556,998.449	2,469,687.512	-0.017	-0.145
							Mean	**0.137**	**-0.120**
							Standard Deviation	**0.348**	**0.353**
	Waukesha Co. Southwest One-Quarter								
2082	5-17 E-22	324,126.200	2,411,792.680	324,135.315	2,380,255.398	324,135.681	2,380,255.469	0.366	0.071
2083	5-17 C-22	324,088.910	2,409,170.690	324,098.015	2,377,633.407	324,098.259	2,377,633.480	0.244	0.073
2084	5-18 E-16	329,965.480	2,438,046.890	329,974.691	2,406,509.602	329,975.398	2,406,509.934	0.707	0.332
2087	6-17 E-4	372,032.350	2,405,772.620	372,041.470	2,374,235.164	372,040.970	2,374,235.032	-0.500	-0.132
2088	6-17 C-3	372,031.490	2,408,456.610	372,040.619	2,376,919.156	372,040.160	2,376,919.048	-0.459	-0.108
2089	6-17 C-19	355,990.140	2,392,734.700	355,999.204	2,361,197.294	355,998.938	2,361,197.280	-0.266	-0.014
2090	6-18 S-10	364,483.770	2,440,133.900	364,493.008	2,408,596.490	364,492.957	2,408,596.343	0.051	-0.147
							Mean	**0.006**	**0.011**
							Standard Deviation	**0.452**	**0.169**
	Waukesha Co. Southeast One-Quarter								
2085	5-19 SE-14	328,204.140	2,480,047.280	328,214.049	2,448,510.170	328,213.736	2,448,510.854	-0.313	0.684
2086	5-20 S-10	334,246.980	2,503,868.520	334,257.052	2,472,331.241	334,257.036	2,472,331.436	-0.016	0.195
2091	6-19 SE-21	354,507.900	2,469,042.330	354,517.587	2,437,505.062	354,517.617	2,437,505.125	0.030	0.063
2092	6-20 C-16	363,009.510	2,498,212.840	363,019.391	2,466,675.355	363,019.773	2,466,675.742	0.382	0.387
2101	6-20 SW-2	371,215.630	2,506,072.820	371,225.534	2,474,535.229	371,225.418	2,474,535.300	-0.116	0.071
2102	6-20 S-3	371,084.070	2,503,470.010	371,093.954	2,471,932.433	371,093.779	2,471,932.457	-0.175	0.024
2103	6-20 SW-3	370,974.360	2,500,857.840	370,984.223	2,469,320.277	370,984.131	2,469,320.259	-0.092	-0.018
2104	6-20 C-10	368,443.110	2,503,478.160	368,453.007	2,471,940.605	368,452.959	2,471,940.582	-0.048	-0.023
2105	6-20 E-10	368,556.800	2,506,108.070	368,566.718	2,474,570.500	368,566.774	2,474,570.566	0.056	0.066
2106	6-20 C-12	368,755.320	2,514,149.760	368,765.302	2,482,612.148	368,765.857	2,482,612.674	0.555	0.526
2107	6-20 E-12	368,802.940	2,516,852.080	368,812.944	2,485,314.454	368,813.483	2,485,314.661	0.539	0.207
2108	6-20 SE-12	366,157.000	2,516,834.520	366,167.017	2,485,296.916	366,167.503	2,485,296.989	0.486	0.076
2109	6-20 SE-10	365,899.260	2,506,153.990	365,909.192	2,474,616.442	365,909.440	2,474,616.483	0.248	0.041
							Mean	**0.118**	**0.177**
							Standard Deviation	**0.291**	**0.222**

Table 5 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 27 Published Coordinates		Helmert Transformation of Published NAD 27 to NAD 83 (2007) Values		NAD 83 (2007) Values From Field Surveys		Difference Between NAD 83 (2007) Transformed Value and Survey Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Waukesha Co. Northwest One-Quarter								
2093	7-17 SE-16	390,858.310	2,405,845.320	390,866.612	2,374,308.277	390,866.509	2,374,307.645	-0.103	-0.632
2094	7-18 E-10	399,110.950	2,442,529.100	399,119.450	2,410,991.632	399,119.442	2,410,992.003	-0.008	0.371
2097	8-17 SE-18	422,994.070	2,394,853.440	423,001.971	2,363,316.261	423,002.170	2,363,315.697	0.199	-0.564
2098	8-18 SE-7	428,418.680	2,426,774.570	428,426.771	2,395,237.034	428,426.822	2,395,237.009	0.051	-0.025
							Mean	**0.035**	**-0.212**
							Standard Deviation	**0.127**	**0.474**
	Waukesha Co. Northeast One-Quarter								
2095	7-19 E-10	399,834.270	2,474,242.520	399,843.352	2,442,705.043	399,843.284	2,442,704.970	-0.068	-0.073
2096	7-20 S-3	402,949.840	2,503,351.780	402,959.220	2,471,813.924	402,959.200	2,471,813.978	-0.020	0.054
2099	8-19 E-20	420,840.250	2,463,427.180	420,848.960	2,431,889.589	420,849.067	2,431,889.148	0.107	-0.441
2100	8-20 S-9	429,415.540	2,497,879.320	429,424.545	2,466,341.225	429,424.407	2,466,341.264	-0.138	0.039
							Mean	**-0.030**	**-0.105**
							Standard Deviation	**0.103**	**0.231**

[a] *The coordinate values for Point number 2029, located in the Ozaukee County South One-Half area, were not used as it was found that an incorrect position was occupied in the field survey and therefore the NAD 83 (2007) coordinate values acquired during the survey did not reflect those of the actual southeast corner of Section 18, Township 10 North, Range 22 East.*

Source: SEWRPC.

These procedures are recommended for routine use throughout the seven-county Region. However, caution should be used when converting recently surveyed HMP position values to RPC position values and comparing them to record values as the temptation will be to view the record values as inferior. That may or may not be true, and rules of evidence need to be applied regarding record values, precedence, stability of monument, and quality of data. The danger exists that HMP position values—whether determined by RTN survey or by transformation—will be used to create problems where they do not otherwise exist. Seasoned judgment remains the hallmark of the diligent professional. When faced with a similar dilemma, standard practice in the surveying profession has been to include both "record" and "measured" values on the same plat or document.

Appendix D contains spreadsheet examples. The full spreadsheet for Kenosha County is included in Appendix D, and shows the results of one bidirectional transformation in Kenosha County. Page 1 of this appendix shows the input, output, and qualifying notes and is the only page needed to document a solution. The next six pages are included for those persons wanting to check the computations or to program an equivalent solution on a different computer. The remaining pages of Appendix D provide only a one-page example in each of the other 16 subareas.

Table 6

NAD 83 (2007) GPS DERIVED COORDINATE VALUES AND COMPARISON OF COORDINATE VALUES PRODUCED USING BIDIRECTIONAL TRANSFORMATION TO PUBLISHED NAD 27 COORDINATE VALUES

Point ID No.	U.S. Public Land Survey Location	NAD 83 (2007) Values from Field Surveys		Helmert Transformation of Surveyed NAD 83 (2007) to NAD 27 Values		NAD 27 Published Values		Difference Between NAD 27 Transformed Value and Published Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Kenosha County								
2001	1-19 S-16	201,117.520	2,438,469.994	201,108.075	2,470,006.564	201,107.980	2,470,006.700	-0.095	0.136
2002	1-20 SE-28	191,625.053	2,473,220.805	191,615.454	2,504,756.982	191,615.280	2,504,757.040	-0.174	0.058
2003	1-21 SE-17	202,729.858	2,499,316.125	202,719.971	2,530,852.134	202,719.760	2,530,852.090	-0.211	-0.044
2004	1-22 SE-29	192,440.606	2,531,416.060	192,430.590	2,562,951.695	192,430.450	2,562,951.570	-0.140	-0.125
2005	1-22 E-32	189,798.657	2,531,539.437	189,788.665	2,563,075.052	189,788.540	2,563,074.890	-0.125	-0.162
2006	1-23 S-19	197,923.003	2,555,042.582	197,912.770	2,586,578.033	197,911.990	2,586,576.990	-0.780	-1.043
2007	2-20 C-34	220,786.576	2,474,883.732	220,776.690	2,506,420.098	220,776.389	2,506,419.877	-0.301	-0.221
2008	2-21 SE-11	240,113.852	2,513,905.631	240,103.510	2,545,441.765	240,102.900	2,454,441.270	-0.610	-0.495
2009	2-22 E-28	227,114.183	2,535,137.168	227,103.814	2,566,673.011	227,103.610	2,566,672.930	-0.204	-0.081
							Mean	**-0.293**	**-0.220**
							Standard Deviation	**0.239**	**0.357**
	Milwaukee Co. South One-Half								
2010	5-21 S-2	340,412.683	2,509,689.463	340,402.165	2,541,226.533	340,401.830	2,541,226.380	-0.335	-0.153
2011	5-21 SE-20	324,260.049	2,496,552.874	324,249.681	2,528,089.593	324,249.590	2,528,089.650	-0.091	0.057
2012	5-21 SE-25	319,508.790	2,517,681.427	319,498.027	2,549,218.169	319,498.100	2,549,218.320	0.073	0.151
2013	5-22 E-15	332,945.934	2,538,611.514	332,934.870	2,570,148.598	332,935.310	2,570,148.480	0.440	-0.118
2014	5-22 C-35	317,028.669	2,541,154.765	317,017.480	2,572,691.581	317,018.120	2,572,691.590	0.640	0.009
2015	6-21 C-15	364,007.055	2,504,210.356	363,996.752	2,535,747.813	363,996.440	2,535,748.020	-0.312	0.207
2016	6-21 S-30	350,336.616	2,488,403.539	350,326.522	2,519,940.676	350,326.230	2,519,940.740	-0.292	0.064
2017	6-22 S-17	361,858.368	2,525,278.562	361,847.684	2,556,816.087	361,847.740	2,556,815.870	0.056	-0.217
2018	6-22 C-27	354,116.929	2,536,050.357	354,106.016	2,567,587.800	354,106.140	2,567,587.690	0.124	-0.110
							Mean	**0.034**	**-0.012**
							Standard Deviation	**0.339**	**0.145**
	Milwaukee Co. North One-Half								
2019	7-21 C-4	406,151.276	2,497,975.279	406,141.529	2,529,513.293	406,141.520	2,529,513.360	-0.009	0.067
2020	7-21 S-14	393,132.056	2,508,935.409	393,122.027	2,540,473.351	393,121.630	2,540,473.370	-0.397	0.019
2021	7-21 C-29	384,621.774	2,493,161.136	384,611.880	2,524,698.803	384,611.660	2,524,698.780	-0.220	-0.023
2022	7-22 C-5	406,645.148	2,524,777.211	406,635.032	2,556,315.499	406,635.530	2,556,314.980	0.498	-0.519
2023	7-22 S-20	388,115.775	2,524,967.615	388,105.473	2,556,505.647	388,105.180	2,556,505.740	-0.293	0.093
2024	8-21 SE-16	425,040.084	2,500,736.603	425,030.486	2,532,274.908	425,031.550	2,532,275.120	1.064	0.212
2025	8-22 SE-5	435,876.060	2,527,193.023	435,866.201	2,558,731.742	435,866.420	2,558,731.520	0.219	-0.222
							Mean	**0.123**	**-0.053**
							Standard Deviation	**0.519**	**0.244**
	Ozaukee Co. South One-Half								
2026	9-21 SE-15	457034.741	2505720.893	457026.283	2537259.543	457026.160	2537259.260	-0.123	-0.283
2027	9-22 S-5	468029.508	2523980.708	468021.143	2555519.831	468021.200	2555519.300	0.057	-0.531
2028	10-21 SE-8	493467.493	2493921.995	493459.900	2525460.674	493459.470	2525461.750	-0.430	1.076
2029[a]	10-22 SE-18	--	--	--	--	489359.010	2552047.850	--	--
							Mean	**-0.165**	**0.087**
							Standard Deviation	**0.246**	**0.865**

Table 6 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 83 (2007) Values from Field Surveys		Helmert Transformation of Surveyed NAD 83 (2007) to NAD 27 Values		NAD 27 Published Values		Difference Between NAD 27 Transformed Value and Published Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Ozaukee Co. North One-Half								
2030	11-21 SE-14	521,222.736	2,515,578.133	521,215.472	2,547,117.305	521,215.890	2,547,117.970	0.418	0.665
2031	11-21 E-20	519,295.835	2,531,538.367	519,288.418	2,563,077.769	519,288.530	2,563,078.100	0.112	0.331
2032	12-21 E-26	545,237.844	2,515,017.828	545,230.952	2,546,557.178	545,230.960	2,546,557.590	0.008	0.412
2033	12-21 SE-26	542,576.669	2,515,082.511	542,569.736	2,546,621.841	542,569.750	2,546,622.170	0.014	0.329
2034	12-22 SE-16	553,800.575	2,536,062.569	553,793.651	2,567,602.308	553,793.820	2,567,602.490	0.169	0.182
							Mean	**0.144**	**0.384**
							Standard Deviation	**0.167**	**0.178**
	Racine Co. West One-Half								
2035	2-19 SE-23	227,986.054	2,450,950.819	227,976.439	2,482,487.291	227,975.760	2,482,488.130	-0.679	0.839
2036	3-19 SE-24	259,771.881	2,455,357.915	259,761.963	2,486,894.539	259,761.388	2,486,894.706	-0.575	0.167
2037	3-20 SE-9	270,698.110	2,470,801.963	270,688.004	2,502,338.519	270,687.580	2,502,338.450	-0.424	-0.069
2041	4-19 E-22	293,847.563	2,444,055.591	293,837.417	2,475,592.518	293,837.400	2,475,593.220	-0.017	0.702
2042	4-20 SE-16	297,350.962	2,470,342.584	297,340.627	2,501,879.304	297,341.510	2,501,880.790	0.883	1.486
							Mean	**-0.162**	**0.625**
							Standard Deviation	**0.636**	**0.609**
	Racine Co. East One-Half								
2038	3-21 SE-20	260,897.107	2,497,440.080	260,886.731	2,528,976.241	260,886.350	2,528,976.180	-0.381	-0.061
2039	3-22 SE-17	266,815.209	2,528,886.809	266,804.475	2,560,422.914	266,804.410	2,560,422.660	-0.065	-0.254
2040	3-23 SE-19	261,693.840	2,555,555.634	261,682.840	2,587,091.582	261,682.790	2,587,091.440	-0.050	-0.142
2043	4-21 SE-14	298,461.787	2,512,543.826	298,451.106	2,544,080.331	298,451.280	2,544,080.780	0.174	0.449
2044	4-22 SE-23	293,369.176	2,544,043.186	293,358.178	2,575,579.517	293,358.210	2,575,579.550	0.032	0.033
							Mean	**-0.058**	**0.005**
							Standard Deviation	**0.204**	**0.270**
	Walworth Co. Southwest One-Quarter								
2045	1-15 C-17	200,549.963	2,306,154.785	200,541.628	2,337,691.993	200,541.690	2,337,692.160	0.062	0.167
2046	1-15 S-17	197,903.142	2,306,169.29	197,894.814	2,337,706.482	197,894.760	2,337,706.620	-0.054	0.138
2047	1-16 C-6	212,509.076	2,332,432.677	212,500.552	2,363,969.895	212,500.420	2,363,970.310	-0.132	0.415
2048	1-16 SE-27	188,886.611	2,351,504.389	188,878.028	2,383,041.416	188,877.480	2,383,041.760	-0.548	0.344
2051	2-15 C-28	222,235.046	2,311,112.518	222,226.628	2,342,649.846	222,226.710	2,342,650.000	0.082	0.154
2052	2-16 C-10	239,285.227	2,347,750.441	239,276.544	2,379,287.785	239,276.260	2,379,287.780	-0.284	-0.005
							Mean	**-0.146**	**0.202**
							Standard Deviation	**0.239**	**0.152**

Table 6 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 83 (2007) Values from Field Surveys		Helmert Transformation of Surveyed NAD 83 (2007) to NAD 27 Values		NAD 27 Published Values		Difference Between NAD 27 Transformed Value and Published Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Walworth Co. Southeast One-Quarter								
2049	1-17 E-33	186,725.926	2,377,959.923	186,717.103	2,409,496.702	186,716.820	2,409,494.330	-0.283	-2.372
2050	1-19 E-30	192,394.269	2,399,094.255	192,385.266	2,430,630.976	192,385.070	2,430,631.580	-0.196	0.604
2053	2-17 SE-2	242,603.287	2,387,354.237	242,594.134	2,418,891.376	242,594.160	2,418,891.350	0.026	-0.026
2054	2-17 E-32	218,730.685	2,371,902.787	218,721.756	2,403,439.826	218,721.630	2,403,440.120	-0.126	0.294
2055	2-18 E-11	240,305.468	2,418,997.585	240,296.097	2,450,534.560	240,294.830	2,450,534.330	-1.267	-0.230
							Mean	**-0.369**	**-0.347**
							Standard Deviation	**0.514**	**1.176**
	Walworth Co. Northwest One-Quarter								
2056	3-15 SE-7	266,945.014	2,301,882.385	266,936.702	2,333,419.860	266,936.670	2,333,419.950	-0.032	0.090
2057	3-15 SE-27	251,538.401	2,318,363.890	251,530.067	2,349,901.295	251,529.970	2,349,901.490	-0.097	0.195
2058	3-16 C-28	255,007.988	2,342,024.272	254,999.581	2,373,561.649	254,999.140	2,373,561.770	-0.441	0.121
2061	4-15 S-16	293,791.973	2,309,639.848	293,783.596	2,341,177.387	293,783.760	2,341,176.940	0.164	-0.447
2062	4-16 SE-20	289,081.261	2,338,456.645	289,072.810	2,369,994.125	289,072.510	2,369,994.350	-0.300	0.225
							Mean	**-0.141**	**0.037**
							Standard Deviation	**0.236**	**0.276**
	Walworth Co. Northeast One-Quarter								
2059	3-17 E-23	261,187.503	2,386,646.350	261,178.366	2,418,183.384	261,177.990	2,418,183.580	-0.376	0.196
2060	3-18 E-8	271,895.660	2,402,098.781	271,886.224	2,433,635.813	271,886.000	2,433,635.830	-0.224	0.017
2063	4-17 S-9	300,655.358	2,372,619.504	300,646.043	2,404,157.180	300,645.720	2,404,156.850	-0.323	-0.330
2064	4-18 S-14	295,757.927	2,414,878.452	295,748.106	2,446,415.679	295,748.090	2,446,415.320	-0.016	-0.359
							Mean	**-0.235**	**-0.119**
							Standard Deviation	**0.159**	**0.271**
	Washington Co. South One-Half								
2065	9-18 SE-15	455,074.997	2,410,629.310	455,067.540	2,442,166.434	455,067.280	2,442,167.320	-0.260	0.886
2066	9-19 SE-3	466,277.674	2,442,091.785	466,270.114	2,473,629.49	466,269.420	2,473,629.620	-0.694	0.130
2067	9-19 SE-24	450,527.979	2,452,992.389	450,520.082	2,484,530.124	450,519.580	2,484,530.260	-0.502	0.136
2068	9-20 S-13	456,259.322	2,481,710.395	456,251.262	2,513,248.621	456,251.000	2,513,248.760	-0.262	0.139
2069	9-20 SE-14	456,185.114	2,479,048.592	456,177.076	2,510,586.776	456,176.710	2,510,586.870	-0.366	0.094
2070	10-18 S-3	497,746.975	2,407,740.843	497,740.198	2,439,278.296	497,740.210	2,439,277.920	0.012	-0.376
2071	10-18 S-29	476,538.527	2,397,248.783	476,531.516	2,428,785.890	476,531.720	2,428,785.990	0.204	0.100
2072	10-19 SE-2	498,352.312	2,446,807.424	498,345.202	2,478,345.482	498,345.320	2,478,345.250	0.118	-0.232
2073	10-19 S-19	482,229.580	2,423,477.629	482,222.427	2,455,015.188	482,222.810	2,455,015.160	0.383	-0.028
2074	10-20 SE-22	482,674.401	2,473,481.399	482,666.818	2,505,019.729	482,666.870	2,505,019.510	0.052	-0.219
							Mean	**-0.131**	**0.063**
							Standard Deviation	**0.339**	**0.344**

Table 6 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 83 (2007) Values from Field Surveys		Helmert Transformation of Surveyed NAD 83 (2007) to NAD 27 Values		NAD 27 Published Values		Difference Between NAD 27 Transformed Value and Published Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Washington Co. North One-Half								
2075	11-18 SE-15	519,527.185	2,414,535.317	519,520.943	2,446,073.225	519,520.980	2,446,073.190	-0.037	-0.035
2076	11-19 SE-5	530,496.702	2,435,506.728	530,490.342	2,467,044.993	530,489.710	2,467,045.860	-0.632	0.867
2077	11-20 SE-3	530,820.158	2,478,135.481	530,813.318	2,509,674.220	530,812.830	2,509,674.180	-0.488	-0.040
2078	11-20 SE-30	509,605.763	2,462,848.742	509,598.862	2,494,387.071	509,598.540	2,494,386.890	-0.322	-0.181
2079	12-18 SE-16	551,182.242	2,408,359.799	551,176.419	2,439,897.999	551,176.740	2,439,898.180	0.321	0.181
2080	12-19 E-4	564,647.457	2,440,281.880	564,641.420	2,471,820.586	564,641.530	2,471,820.490	0.110	-0.096
2081	12-20 S-9	556,998.449	2,469,687.512	556,991.993	2,501,226.455	556,992.010	2,501,226.600	0.017	0.145
							Mean	**-0.147**	**0.120**
							Standard Deviation	**0.348**	**0.353**
	Waukesha Co. Southwest One-Quarter								
2082	5-17 E-22	324,135.681	2,380,255.469	324,126.566	2,411,792.751	324,126.200	2,411,792.680	-0.366	-0.071
2083	5-17 C-22	324,098.259	2,377,633.48	324,089.154	2,409,170.763	324,088.910	2,409,170.690	-0.244	-0.073
2084	5-18 E-16	329,975.398	2,406,509.934	329,966.187	2,438,047.222	329,965.480	2,438,046.890	-0.707	-0.332
2087	6-17 E-4	372,040.970	2,374,235.032	372,031.850	2,405,772.488	372,032.350	2,405,772.620	0.500	0.132
2088	6-17 C-3	372,040.160	2,376,919.048	372,031.031	2,408,456.502	372,031.490	2,408,456.610	0.459	0.108
2089	6-17 C-19	355,998.938	2,361,197.280	355,989.874	2,392,734.686	355,990.140	2,392,734.700	0.266	0.014
2090	6-18 S-10	364,492.957	2,408,596.343	364,483.719	2,440133.753	364,483.770	2,440,133.900	0.051	0.147
							Mean	**-0.006**	**-0.011**
							Standard Deviation	**0.452**	**0.169**
	Waukesha Co. Southeast One-Quarter								
2085	5-19 SE-14	328,213.736	2,448,510.854	328,203.827	2,480,047.964	328,204.140	2,480,047.280	0.313	-0.684
2086	5-20 S-10	334,257.036	2,472,331.436	334,246.964	2,503,868.715	334,246.980	2,503,868.520	0.016	-0.195
2091	6-19 SE-21	354,517.617	2,437,505.125	354,507.930	2,469,042.393	354,507.900	2,469,042.330	-0.030	-0.063
2092	6-20 C-16	363,019.773	2,466,675.742	363,009.892	2,498,213.227	363,009.510	2,498,212.840	-0.382	-0.387
2101	6-20 SW-2	371,225.418	2,474,535.300	371,215.514	2,506,072.891	371,215.630	2,506,072.820	0.116	-0.071
2102	6-20 S-3	371,093.779	2,471,932.457	371,083.895	2,503,470.034	371,084.070	2,503,470.010	0.175	-0.024
2103	6-20 SW-3	370,984.131	2,469,320.259	370,974.268	2,500,857.822	370,974.360	2,500,857.840	0.092	0.018
2104	6-20 C-10	368,452.959	2,471,940.582	368,443.062	2,503,478.137	368,443.110	2,503,478.160	0.048	0.023
2105	6-20 E-10	368,566.774	2,474,570.566	368,556.856	2,506,108.136	368,556.800	2,506,108.070	-0.056	-0.066
2106	6-20 C-12	368,765.857	2,482,612.674	368,755.874	2,514,150.286	368,755.320	2,514,149.760	-0.554	-0.526
2107	6-20 E-12	368,813.483	2,485,314.661	368,803.479	2,516,852.287	368,802.940	2,516,852.080	-0.539	-0.207
2108	6-20 SE-12	366,167.503	2,485,296.989	366,157.486	2,516,834.593	366,157.000	2,516,834.520	-0.486	-0.073
2109	6-20 SE-10	365,909.440	2,474,616.483	365,899.508	2,506,154.031	365,899.260	2,506,153.990	-0.248	-0.041
							Mean	**-0.118**	**-0.177**
							Standard Deviation	**0.291**	**0.222**

Table 6 (continued)

Point ID No.	U.S. Public Land Survey Location	NAD 83 (2007) Values from Field Surveys		Helmert Transformation of Surveyed NAD 83 (2007) to NAD 27 Values		NAD 27 Published Values		Difference Between NAD 27 Transformed Values and Published Value	
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)
	Waukesha Co. Northwest One-Quarter								
2093	7-17 SE-16	390,866.509	2,374,307.645	390,858.207	2,405,844.688	390,858.310	2,405,845.320	0.103	0.632
2094	7-18 E-10	399,119.442	2,410,992.003	399,110.942	2,442,529.471	399,110.950	2,442,529.100	-0.008	-0.371
2097	8-17 SE-18	423,002.170	2,363,315.697	422,994.269	2,394,852.876	422,994.070	2,394,853.440	-0.199	0.564
2098	8-18 SE-7	428,426.822	2,395,237.009	428,418.731	2,426,774.545	428,418.680	2,426,774.570	-0.051	0.025
							Mean	**-0.039**	**0.212**
							Standard Deviation	**0.127**	**0.474**
	Waukesha Co. Northeast One-Quarter								
2095	7-19 E-10	399,843.284	2,442,704.970	399,834.202	2,474,242.447	399,834.270	2,474,242.520	0.068	0.073
2096	7-20 S-3	402,959.200	2,471,813.978	402,949.820	2,503,351.834	402,949.840	2,503,351.780	0.020	-0.054
2099	8-19 E-20	420,849.067	2,431,889.148	420,840.357	2,463,426.739	420,840.250	2,463,427.180	-0.107	0.441
2100	8-20 S-9	429,424.407	2,466,341.264	429,415.402	2,497,879.359	429,415.540	2,497,879.320	0.138	-0.039
							Mean	**0.030**	**0.105**
							Standard Deviation	**0.103**	**0.231**

[a] *The coordinate values for Point number 2029, located in the Ozaukee County South One-Half area were not computed during the Bidirectional Transformation process as it was found that an incorrect position was occupied and therefore the NAD 83 (2007) coordinate values shown do not reflect that of the U.S. Public Land Survey Corner for the southeast corner of Section 18, Township 10 North, Range 22 East.*

Source: SEWRPC.

SUMMARY AND CONCLUSIONS

The information provided in this report achieves the collective goals as set forth by the Technical Advisory Committee and listed in Technical Report No. 45. Many persons and users throughout the seven-county Region are familiar with the existence and value of the control survey networks that have been established and maintained by the Southeastern Wisconsin Regional Planning Commission in cooperation with its constituent counties and municipalities over the past almost 50 years. More people are aware of the possible advantages of utilizing the RTN as established by the WisDOT and the Height Modernization Program. It may be expected that, with the ability to make bidirectional transformations of spatial data provided in this report, the dedication of spatial data users throughout the Region will contribute to successful applications involving use of both the RPC and the HMP positions and values. The data in this report also provides the means by which the legacy survey data can be combined with RTN generated spatial data for the continued benefit of both public and private sector uses.

The bidirectional Helmert transformations described in this report are not intended to be used in place of higher order geodetic surveys. When higher order surveys are required, the recommended procedure is to perform a First-Order, or higher quality, geodetic survey tied to proven control points. Additionally, persons using the bidirectional transformations developed and described herein should be aware of the following points:

1. The procedures described in this report preserve 3-D geometrical integrity. If one has reliable 3-D positions to be transformed between RPC and HMP, then the transformation process will preserve the 3-D integrity of the data being transformed. Two corollaries of this assertion are:

Table 7

COMPARISON OF NGVD 29 PUBLISHED ELEVATIONS TO ELEVATIONS DERIVED BY DIRECT TRANSFORMATION METHOD

Point Identification Number	U.S. Public Land Survey Location	NGVD 29 Published Elevation	NGVD 29 Derived Elevation	Difference in Feet
Kenosha County				
2001	1-19 S-16	833.709	833.699	0.010
2002	1-20 SE-28	775.588	775.710	-0.122
2003	1-21 SE-17	770.373	770.547	-0.174
2004	1-22 SE-29	684.913	684.968	-0.055
2005	1-22 E-32	692.427	692.485	-0.058
2006	1-23 S-19	NA	628.127	--
2007	2-20 C-34	835.635	835.724	-0.089
2008	2-21 SE-11	783.420	783.436	-0.016
2009	2-22 E-28	678.005	677.993	0.012
			Mean	**-0.062**
			Standard Deviation	**0.086**
Milwaukee County				
2010	5-21 S-2	723.594	723.580	0.014
2011	5-21 SE-20	777.476	777.441	0.035
2012	5-21 SE-25	733.440	733.344	0.096
2013	5-22 E-15	682.840	682.842	-0.002
2014	5-22 C-35	678.490	678.471	0.019
2015	6-21 C-15	748.996	748.938	0.058
2016	6-21 S-30	790.944	790.803	0.141
2017	6-22 S-17	713.890	713.768	0.122
2018	6-22 C-27	674.049	673.958	0.091
2019	7-21 C-4	753.911	753.823	0.088
2020	7-21 S-14	753.120	753.071	0.049
2021	7-21 C-29	742.808	742.718	0.090
2022	7-22 C-5	659.328	659.258	0.070
2023	7-22 S-20	599.767	599.614	0.153
2024	8-21 SE-16	734.499	734.519	-0.020
2025	8-22 SE-5	673.406	673.289	0.117
			Mean	**0.070**
			Standard Deviation	**0.031**
Ozaukee County				
2026	9-21 SE-15	665.237	665.167	0.070
2027	9-22 S-5	692.114	692.067	0.047
2028	10-21 SE-8	849.206	849.236	-0.030
2029[a]	10-22 SE-18	738.590	739.387	--
2030	11-21 SE-14	760.960	761.108	-0.148
2031	11-22 E-20	705.490	705.039	0.451
2032	12-21 E-26	NA	827.235	--
2033	12-21 SE-26	NA	849.800	--
2034	12-22 SE-16	NA	747.347	--
			Mean	**0.078**
			Standard Deviation	**0.045**

Table 7 (continued)

Point Identification Number	U.S. Public Land Survey Location	NGVD 29 Published Elevation	NGVD 29 Derived Elevation	Difference in Feet
Racine County				
2035	2-19 SE-23	792.326	792.223	0.103
2036	3-19 SE-24	800.223	800.180	0.043
2037	3-20 SE-9	810.371	810.275	0.096
2038	3-21 SE-20	749.996	750.096	-0.100
2039	3-22 SE-17	754.364	754.298	0.066
2040	3-23 SE-19	637.513	637.712	-0.199
2041	4-19 E-22	865.481	865.394	0.087
2042	4-20 SE-16	771.228	771.017	0.211
2043	4-21 SE-14	745.947	745.258	0.689
2044	4-22 SE-23	698.771	698.958	-0.187
			Mean	**0.081**
			Standard Deviation	**0.051**
Walworth County				
2045	1-15 C-17	936.451	936.406	0.045
2046	1-15 S-17	939.166	939.832	
2047	1-16 C-6	1010.314	1010.177	0.137
2048	1-16 SE-27	1005.418	1005.389	0.029
2049	1-17 E-33	990.561	990.388	0.173
2050	1-19 E-30	919.197	918.995	0.202
2051	2-15 C-28	906.611	906.298	0.313
2052	2-16 C-10	955.816	955.700	0.116
2053	2-17 SE-2	994.015	993.938	0.077
2054	2-17 E-32	882.143	881.965	0.178
2055	2-18 E-11	797.795	797.672	0.123
2056	3-15 SE-7	1012.350	1012.143	0.207
2057	3-15 SE-27	947.980	947.896	0.084
2058	3-16 C-28	1011.808	1011.841	-0.033
2059	3-17 E-23	1027.748	1027.610	0.138
2060	3-18 E-8	956.837	956.573	0.264
2061	4-15 S-16	856.073	855.996	0.077
2062	4-16 SE-20	960.716	960.838	-0.122
2063	4-17 S-9	926.616	926.549	0.067
2064	4-18 S-14	820.098	820.133	-0.035
			Mean	**0.069**
			Standard Deviation	**0.060**

Table 7 (continued)

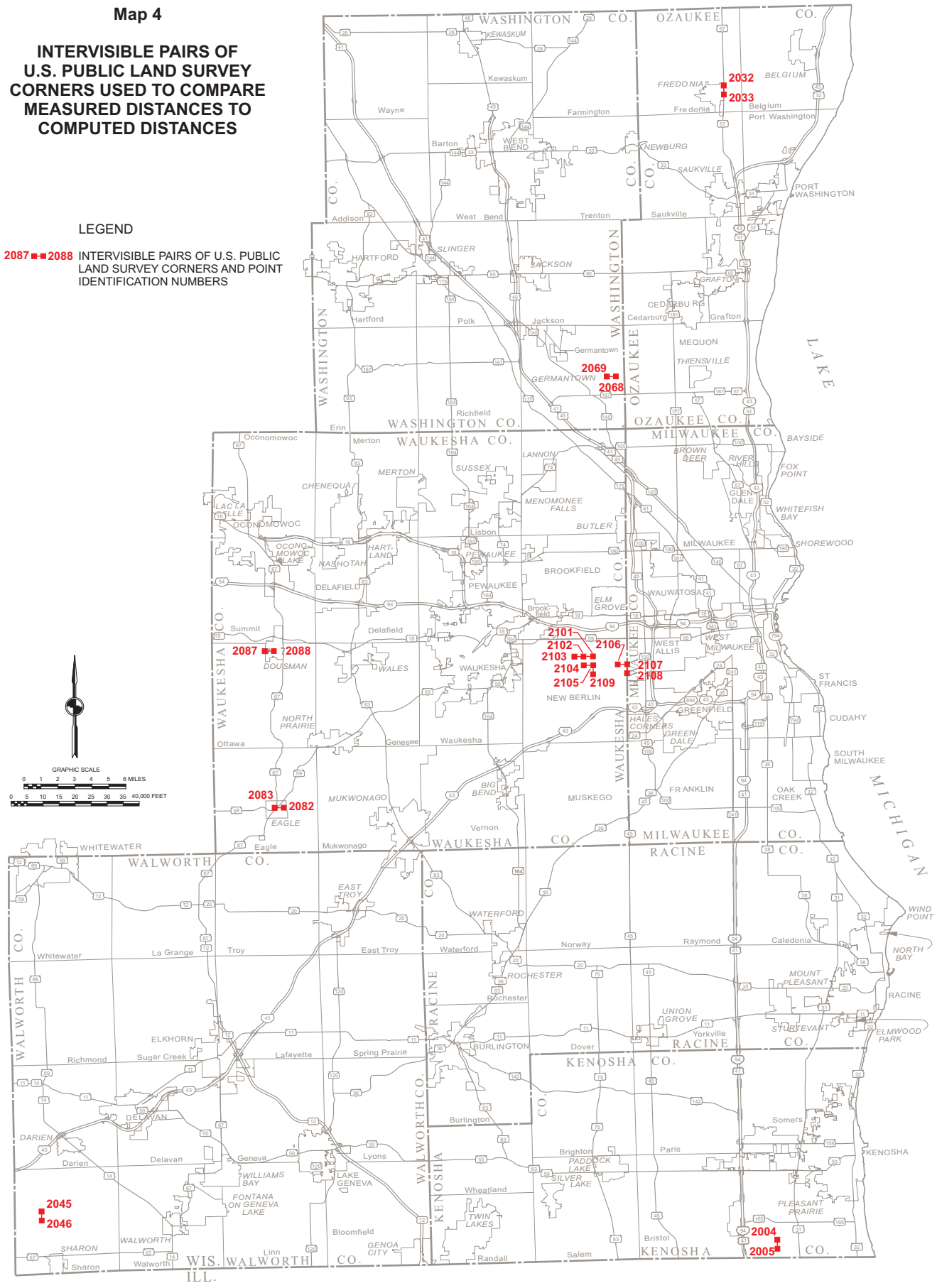
Point Identification Number	U.S. Public Land Survey Location	NGVD 29 Published Elevation	NGVD 29 Derived Elevation	Difference in Feet
Washington County				
2065	9-18 SE-15	1101.938	1101.835	0.103
2066	9-19 SE-3	976.527	976.444	0.083
2067	9-19 SE-24	974.361	974.321	0.040
2068	9-20 S-13	887.607	887.451	0.156
2069	9-20 SE-14	863.535	863.383	0.152
2070	10-18 S-3	1019.806	1019.750	0.656
2071	10-18 S-29	1031.236	1031.003	0.233
2072	10-19 SE-2	1017.744	1017.810	-0.066
2073	10-19 S-19	1112.452	1112.357	0.095
2074	10-20 SE-22	863.063	863.111	-0.048
2075	11-18 SE-15	1109.093	1108.935	0.158
2076	11-19 SE-5	1100.623	1100.406	0.217
2077	11-20 SE-3	875.677	874.999	0.678
2078	11-20 SE-30	962.148	962.047	0.101
2079	12-18 SE-16	1022.326	1022.162	0.164
2080	12-19 E-4	946.929	946.877	0.052
2081	12-20 S-9	1026.037	1025.965	0.072
			Mean	**0.167**
			Standard Deviation	**0.044**
Waukesha County				
2082	5-17 E-22	926.237	926.028	0.209
2083	5-17 C-22	941.704	941.640	0.064
2084	5-18 E-16	992.561	992.352	0.209
2085	5-19 SE-14	829.386	829.524	-0.138
2086	5-20 S-10	785.215	785.242	-0.027
2087	6-17 E-4	866.641	866.580	0.061
2088	6-17 C-3	871.069	871.169	-0.100
2089	6-17 C-19	898.856	898.928	-0.072
2090	6-18 S-10	991.469	991.323	0.146
2091	6-19 SE-21	822.973	822.841	0.132
2092	6-20 C-16	875.109	875.090	0.019
2093	7-17 SE-16	880.836	880.688	0.148
2094	7-18 E-10	972.950	972.829	0.121
2095	7-19 E-10	921.010	920.877	0.133
2096	7-20 S-3	826.876	826.595	0.281
2097	8-17 SE-18	917.851	917.565	0.286
2098	8-18 SE-7	985.179	985.014	0.165
2099	8-19 E-20	989.399	989.247	0.152
2100	8-20 S-9	892.562	892.537	0.025
			Mean	**0.095**
			Standard Deviation	**0.039**

[a] *The elevation values for Point number 2029, located in Ozaukee County, were not computed during the Direct Transformation method as it was found that an incorrect position was occupied and therefore the NAVD 88 (2007) elevation values shown do not reflect that of the U.S. Public Land Survey Corner for the southeast corner of Section 18, Township 10 North, Range 22 East.*

Source: SEWRPC.

Map 4

INTERVISIBLE PAIRS OF U.S. PUBLIC LAND SURVEY CORNERS USED TO COMPARE MEASURED DISTANCES TO COMPUTED DISTANCES



Source: SEWRPC.

Table 8

COMPARISON OF MEASURED AND COMPUTED DISTANCES BETWEEN INTERVISIBLE MONUMENTED U.S. PUBLIC LAND SURVEY SYSTEM CORNERS

COMPARISON OF PUBLISHED GROUND DISTANCES TO MEASURED DISTANCES

Intervisible Points	Published NAD 27 Coordinates				Published Ground Distance (ft.)	Measured Distance (ft.)	Difference (ft.)
	Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)			
2004-2005	192,430.45	2,562,951.57	189,788.54	2,563,074.89	2644.73	2644.84	0.11
2032-2033	545,230.96	2,546,557.59	542,569.75	2,546,622.17	2662.27	2662.29	0.02
2045-2046	200,541.69	2,337,692.16	197,894.76	2,337,706.62	2646.97	2646.98	0.01
2068-2069	456,251.00	2,513,248.76	456,176.71	2,510,586.87	2663.21	2663.16	0.05
2082-2083	324,088.91	2,409,170.69	324,126.20	2,411,792.68	2622.45	2622.44	0.01
2087-2088	372,032.35	2,405,772.62	372,031.49	2,408,456.61	2684.22	2684.22	0.00
2101-2102	371,215.63	2,506,072.82	371,084.07	2,503,470.01	2606.35	2606.40	0.05
2102-2103	371,084.07	2,503,470.01	370,974.36	2,500,857.84	2614.69	2614.76	0.07
2104-2105	368,443.11	2,503,478.16	368,556.80	2,506,108.07	2632.59	2632.70	0.11
2105-2109	368,566.80	2,506,108.07	365,899.26	2,506,153.99	2658.16	2657.97	0.19
2106-2107	368,755.32	2,514,149.76	368,802.94	2,516,852.08	2702.97	2702.66	0.31
2107-2108	368,802.94	2,516,852.08	366,157.00	2,516,834.52	2646.22	2646.27	0.05

COMPARISON OF DISTANCES COMPUTED FROM NAD 27 PUBLISHED COORDINATES TRANSFORMED TO NAD 83 (2007) COORDINATE VALUES TO MEASURED DISTANCES

Intervisible Points	Measured Distance (ft.)	NAD 27 Published Coordinates Transformed to NAD 83 (2007) Coordinate Values				Computed Ground Distances Using NAD 83 (2007) Coordinate Values Transformed from NAD 27 Published Coordinates (ft.)[a]	Difference (ft.)
		Northing (ft.)	Easting(ft.)	Northing (ft.)	Easting (ft.)		
2004-2005	2644.84	192,440.47	2,531,415.94	189,798.53	2,531,539.28	2644.75	0.09
2032-2033	2662.29	545,237.85	2,515,018.24	542,576.68	2,515,082.84	2662.24	0.05
2045-2046	2646.98	200,550.02	2,306,154.95	197,903.09	2,306,169.43	2646.97	0.01
2068-2069	2663.16	456,259.06	2,481,710.53	456,184.75	2,479,048.69	2663.16	0.00
2082-2083	2622.44	324,135.32	2,380,255.40	324,098.02	2,377,633.41	2622.25	0.19
2087-2088	2684.22	372,041.47	2,374,235.16	372,040.62	2,376,919.16	2684.23	0.01
2101-2102	2606.40	371,225.53	2,474,535.23	371,093.95	2,471,932.43	2606.34	0.06
2102-2103	2614.76	371,093.95	2,471,932.43	370,984.22	2,469,320.28	2614.68	0.08
2104-2105	2632.70	368,453.01	2,471,940.60	368,566.72	2,474,570.50	2632.57	0.13
2105-2109	2657.97	368,566.72	2,474,570.50	365,909.19	2,474,616.44	2658.14	0.17
2106-2107	2702.66	368,765.30	2,482,612.15	368,812.94	2,485,314.45	2702.96	0.30
2107-2108	2646.27	368,812.94	2,485,314.45	366,167.02	2,485,296.92	2646.18	0.09

[a] *The inverse distances use an elevation factor and do not use a sea level factor.*

Table 8 (continued)

COMPARISON OF DISTANCES COMPUTED FROM NAD 83 (2007) FIELD MEASURED COORDINATES TRANSFORMED TO NAD 27 COORDINATE VALUES TO MEASURED DISTANCES

Intervisible Points	Measured Distance (ft.)	NAD 83 (2007) Field Measured Coordinates Transformed to NAD 27 Coordinates Values				Computed Ground Distances using NAD 27 Coordinate Values Transformed from NAD 83 (2007) Field Measured Coordinates (ft.)[a]	Difference (ft.)
		Northing (ft.)	Easting (ft.)	Northing (ft.)	Easting (ft.)		
2004-2005	2644.84	192,430.59	2,562,951.70	189,788.66	2,563,075.05	2644.75	0.09
2032-2033	2662.29	545,230.95	2,546,557.18	542,569.74	2,546,621.84	2662.28	0.01
2045-2046	2646.98	200,541.63	2,337,691.99	197,894.81	2,337,706.48	2646.86	0.12
2068-2069	2663.16	456,251.26	2,513,248.62	456,177.08	2,510,586.78	2663.15	0.01
2082-2083	2622.44	324,126.57	2,411,792.75	324,089.15	2,409,170.76	2622.26	0.18
2087-2088	2684.22	372,031.85	2,405,772.49	372,031.03	2,408,456.50	2684.24	0.02
2101-2102	2606.40	371,225.42	2,474,535.30	371,093.78	2,471932.46	2606.39	0.01
2102-2103	2614.76	371,093.78	2,471,932.46	370,984.13	2,469,320.26	2614.72	0.04
2104-2105	2632.70	368,452.96	2,471,940.58	368,566.77	2,474,570.57	2632.67	0.03
2105-2109	2657.97	368,566.77	2,474,570.57	365,909.44	2,474,616.48	2657.95	0.02
2106-2107	2702.66	368,765.86	2,482,612.67	368,813.48	2,485,314.66	2702.64	0.02
2107-2108	2646.27	368,813.48	2,485,314.66	366,167.50	2,485,296.99	2646.26	0.01

[a] *The inverse distances use a sea level factor and do not use an elevation factor.*

Source: SEWRPC.

a. If only horizontal transformations are to be performed, an elevation within 10 feet of the actual elevation of the point will support reliable transformation of the SPC of the point.

b. If only vertical transformations are to be performed, the NAD 83 (2007) SPC of the point being converted need be known only to within 10 feet of the actual position of the point to support reliable transformation of the elevation.

2. GPS computations are performed in the 3-D earth centered, earth fixed (ECEF) environment, but are expressed as NAD 83 (2007) geodetic coordinates. When using the RTN throughout the seven-county Region, the computational environment used in the field is the HMP which includes both the NAD 83 (2007) horizontal positions, and the NAVD 88 (2007) elevations. GEOID09 is the link between NAVD 88 (2007) elevations and the NAD 83 (2007) ellipsoid heights. Although geoid modeling is not needed to make these bidirectional transformations, the concept of geoid modeling remains important and will be encountered routinely when working on and with the RTN.

The bidirectional transformations described in this report can be confidently used to transform parcel-based land information and public works management data between RPC and HMP data bases. Given the mapping scales involved in these applications – typically one inch equals 100 feet and one inch equals 200 feet—the resolution of features on the digital topographic and cadastral base maps and orthophotographs concerned is readily supported by the integrity of the bidirectional transformations.

The bidirectional transformation of vertical data by the Direct Method herein provided is also shown to be of consistent high quality. Table 7 lists the means and standard deviations realized on test points located in each of the seven counties in the Region. The means of the differences found are all less than 0.10 foot except for Washington County where the mean is 0.17 foot. The standard deviations are all less than 0.10 foot.

Based upon these results, it can be expected that the Direct Method transformation of elevations will support most cadastral and routine public works engineering related surveying activities. If geodetic quality elevations are needed, then precise differential leveling surveys should be performed using specialized equipment, careful observation procedures, and meticulous data reduction procedures able to provide the level of accuracy desired.

This report also shows that, for many cadastral and routine public works engineering surveying applications, the bidirectional transformations can be used for horizontal positions in many parts of the seven-county Region. However, some areas of the Region exhibit residual distortions that could not be modeled to the desired levels of accuracy. In those areas, alternate field calibration procedures should be used when attempting to relate RPC values to HMP positions. Such field calibration procedures are described, and an example provided, in Appendix G.

Parameters for the Helmert transformations were derived from the 114 common control points listed in Appendix A. The standard deviations in all three components of the results obtained in the 17 subareas of the Region shown on Map 2 are documented in Table 1. These standard deviation values were determined as set forth for each of the 17 subareas of the Region and represent the precision of the control points used to determine the transformation parameters between RPC values and HMP values. Appendix B also provides the mean in each case, and – except where weights were used – those means are zero because the mean of equally weighted data elements is zero.

In order to document the performance of the bidirectional transformations on USPLSS corners (having both published state plane coordinates and elevations), blind tests were conducted on 100 points (of which 99 were useable) located throughout the seven-county Region. The accuracy of those tests is documented in Tables 5 and 6 for horizontal positions and Table 7 for vertical positions. In these cases, the mean is not zero because the parameters were predetermined and the computed values reflect the ability of the Helmert transformations to model the differences, in which case the mean reflects the accuracy of the transformation while the standard deviation reflects the precision of the transformations. Ideally, both the means and standard deviations should be near zero. A large mean value in a blind test–as listed in Tables 5, 6, and 7–implies a lack of accuracy while a large standard deviation implies a lack of precision.

When evaluating the means and standard deviations set forth in Tables 5, 6, and 7, it is helpful to recall the following relationships between accuracy and precision. (The values for the means and standard deviations in Tables 5 and 6 are the same magnitude but have opposite signs because they reflect different directions of the same transformations).

1. If the data are both accurate and precise, both the mean and standard deviation values will be small.

2. If the data are neither accurate nor precise, both the mean and standard deviation values will be large.

3. If the mean values are small and the standard deviation values are large (by comparison), the implication is that the data represented are more accurate than they are precise. This would be the case if the transformations are performing well but that the distortions in the points being modeled are excessive.

4. If the standard deviation values are small and the means are large (by comparison), that implies the data are more precise than they are accurate. This implies that the points being modeled are

consistent among themselves but that systematic error between RPC and HMP values was imperfectly modeled.

5. If the mean values and the standard deviation values have similar magnitudes, the implication is that the integrity of the transformations and the quality of points being used in the blind test are comparable.

Based upon the findings documented in this report, it may be concluded that the bidirectional transformations developed under this study can be used with confidence in virtually all applications concerning the development and maintenance of parcel-based land information and public works management systems. However, several levels of confidence were identified for consideration with respect to survey applications within each of the 17 subareas of the Region. The highest confidence level is level A, the lowest is level C. The subareas and the attendant confidence levels are shown on Map 5.

Confidence level A. The transformations in the designated subarea may be expected to be adequate for all mapping and for most public works engineering and land surveying related purposes.

Confidence level B. The transformations in the designated subarea may be expected to provide reliable results for all mapping and for most public works and land surveying related purposes. If discrepancies are encountered, investigation of the underlying reason may show that modeling is less than ideal at a specific location. If the difference is significant, then "Recorded" and "Measured" values should be shown and/or reported.

Confidence level C. The transformations in the designated subarea may be expected to be adequate for all mapped purposes and may provide acceptable results for some public works engineering and land surveying related purposes. However, if the user is not satisfied with modeled results, the onsite calibration procedures given in Appendix G should be used. In less demanding circumstances, the practice of showing "Recorded" and "Measured" values as recommended for Level B may be acceptable.

In considering the blind test comparisons, it should be remembered that the confidence that may be placed in statistical comparisons increases with the size of the data sets concerned. Having more data to compare lends greater confidence to any conclusions to be drawn. Also it should be noted that outliers can lead to faulty conclusions–especially in small data sets. Any comparison discrepancy over 1.0 foot shown in Tables 5 and 6 should be considered as an outlier. With those qualifications, and guided by the test results given in Tables 5 and 6, the following confidence level assignments to subareas of the Region are recommended:

Confidence Level A

- Kenosha County
- Walworth County (Southwest One-Quarter)
- Walworth County (Northwest One-Quarter)
- Waukesha County (Northeast One-Quarter)

Confidence Level B

- Milwaukee County (South One-Half)
- Milwaukee County (North One-Half)
- Ozaukee County (South One-Half)
- Racine County (West One-Half)
- Racine County (East One-Half)
- Walworth County (Southeast One-Quarter)
- Walworth County (Northeast One-Quarter)

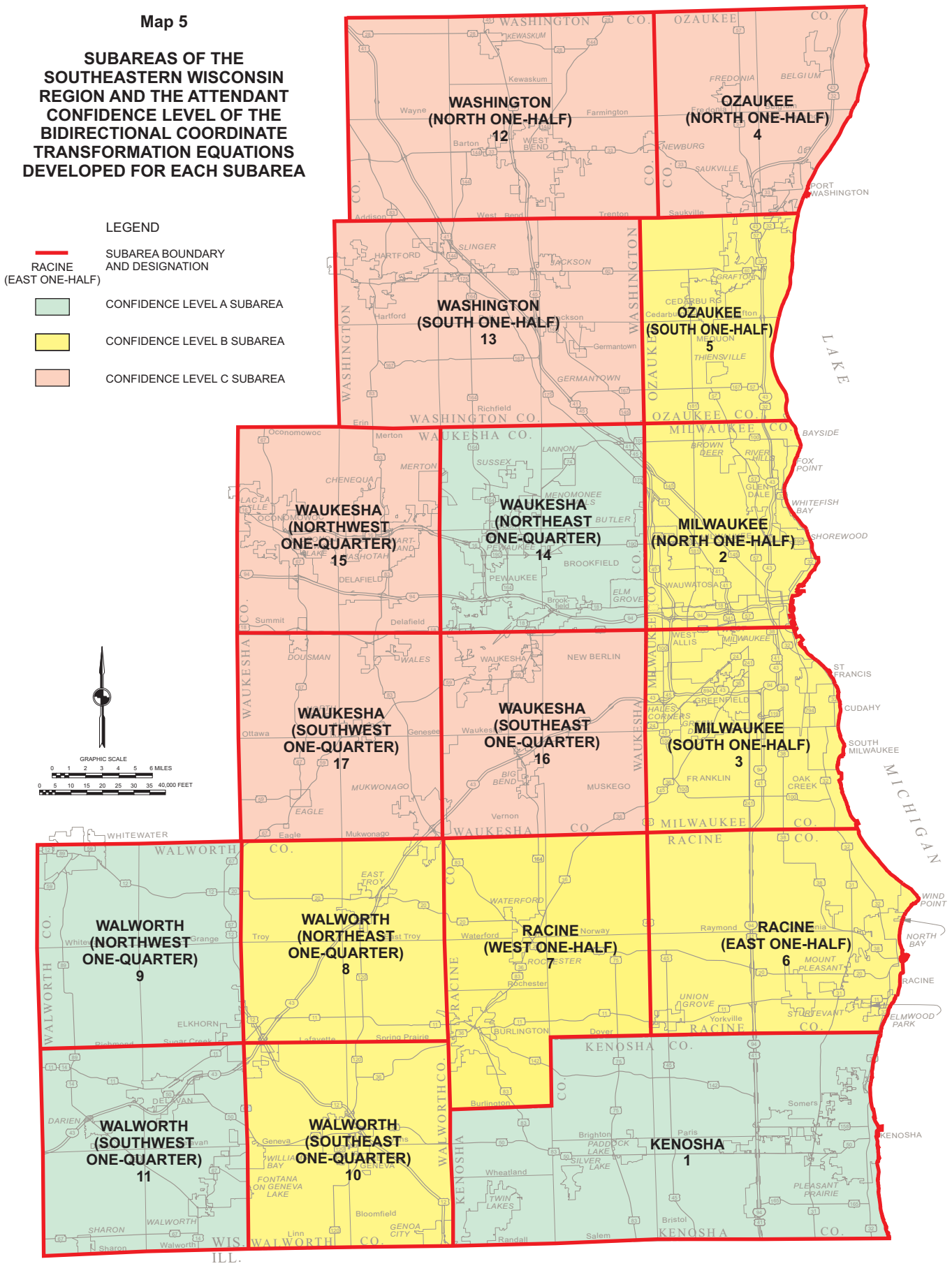
Confidence Level C

- Ozaukee County (North One-Half)
- Washington County (South One-Half)
- Washington County (North One-Half)
- Waukesha County (Southwest One-Quarter)
- Waukesha County (Southeast One-Quarter)
- Waukesha County (Northwest One-Quarter)

Table 8 is particularly instructive in that relative differences are compared between intervisible points. The comparisons given in Tables 5 and 6 are comparisons of absolute positions. Appendix E is included to show that a ratio of 1:10,000 between points located 0.5 mile apart at the 68 percent confidence level will tolerate a standard deviation of 0.18 foot on the north/south and east/west values at each end, and that standard deviations of 0.09 foot can be tolerated at the 95 percent confidence level. While absolute accuracy with respect to the datum as given by the coordinates and their standard deviations is important for some, but not all applications, the relative accuracy of a given point with respect to adjacent points may be of greater importance in many traditional surveying applications—cadastral and routine public works engineering surveys. A relative accuracy of 1:10,000 over a distance of 2,640 feet (0.5 mile) is 0.26 feet. Many of the 12 comparisons listed in Table 8 are within 0.10 foot, most are within 0.21 foot, and only one is in excess of 0.26 foot. The latter however, exceeds the standard by only 0.03 of a foot in a distance of over 2,700 feet. These comparisons of relative accuracy lend additional credence to the validity of using the transformations for cadastral and routine public works engineering survey activities throughout the seven-county SEWRPC Region.

Map 5

SUBAREAS OF THE SOUTHEASTERN WISCONSIN REGION AND THE ATTENDANT CONFIDENCE LEVEL OF THE BIDIRECTIONAL COORDINATE TRANSFORMATION EQUATIONS DEVELOPED FOR EACH SUBAREA



Source: SEWRPC.

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References

Burkholder, E.F. 2004; *Accuracy of Elevation Reduction Factor*, ASCE Journal of Surveying Engineering, Vol. 130, No.3, pp 134-137.

Burkholder, E.F. 2008; *The 3-D Global Spatial Data Model: Foundation of the Global Spatial Data Infrastructure*, CRC Press, Francis & Taylor Group, Boca Raton.

Claire, C.N., 1968; "State Plane Coordinates by Automatic Data Processing," Publication 62-4, National Geodetic Survey, NOAA, Silver Spring, MD.

Hooijberg, M., 2008; *Geometrical Geodesy: Using Information and Computer Technology,* Spring-Verlag, Berlin, Heidelberg, New York.

Mikhail, E., 1976, *Observations and Least Squares*, Harper & Row, New York.

SEWRPC, 1964; SEWRPC Planning Guide No. 2, *Official Mapping Guide*, Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.

- 1994; SEWRPC Technical Report No. 34, *A Mathematical Relationship Between NAD27 and NAD83 (91) State Plane Coordinates in Southeastern Wisconsin,* Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.

- 1995; SEWRPC Technical Report No. 35, *Vertical Datum Differences in Southeastern Wisconsin,* Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.

- 1996; SEWRPC Technical Report No. 7, *Horizontal and Vertical Survey Control in Southeastern Wisconsin (3rd Edition),* Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.

- 2008; SEWRPC Technical Report No. 45, *Technical Review and Reevaluation of the Regional Control Survey Program in Southeastern Wisconsin,* Southeastern Wisconsin Regional Planning Commission, Waukesha, WI.

Soler, T. and R. Snay, 2004; "Transforming Positions and Velocities between the International Terrestrial Reference Frame of 2000 and North American Datum of 1983," ASCE Journal of Surveying Engineering, Vol. 130, No. 2, pp 49-55.

Stem, J. 1989; *State Plane Coordinate System of 1983,* NOAA, NOS, Manual 5, National Geodetic Survey, Silver Spring, MD.

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APPENDICES

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Appendix A

HORIZONTAL POSITIONS AND ELEVATIONS USED IN THE DEVELOPMENT OF THE BIDIRECTIONAL TRANSFORMATIONS

Station Identification	NAD 27 State Plane Coordinates in Survey Feet		NAD 83 (2007) State Plane Coordinates in Survey Feet		Elevation in Feet	
	Northing	Easting	Northing	Easting	NGVD 29	NAVD 88
Kenosha County						
BRIGHTON N GPS	244,226.25	2,494,197.50	244,236.05	2,462,660.89	791.376	791.134
BRISTOL E GPS	202,630.18	2,538,922.17	202,640.19	2,507,386.33	694.261	694.073
KEHA[a]	210,716.68	2,560,622.58	210,726.89	2,529,086.84	783.640	783.380
KELLEY	187,083.72	2,550,594.84	187,093.74	2,519,059.28	785.970	785.740
PLEASANT PRAIRIE GPS	192,585.74	2,587,199.84	211,977.48	2,557,805.08	627.896	627.551
PLEASANT PRAIRIE E GPS	211,967.20	2,589,340.67	192,595.87	2,555,664.31	592.792	592.627
SALEM E GPS	199,890.74	2,517,349.03	199,900.59	2,485,812.84	857.507	857.111
SILVER	206,176.27	2,488,304.69	206,186.03	2,456,768.07	841.980	841.810
SILVER LAKE GPS	199,316.59	2,497,093.42	199,326.30	2,465,556.90	749.226	749.083
SOMERS S GPS	227,434.80	2,571,272.85	227,445.13	2,539,737.11	724.151	723.860
TWIN LAKES GPS	193,835.13	2,459,585.68	193,844.40	2,428,048.91	859.794	859.493
Milwaukee County						
BROWN DEER W GPS	429,693.51	2,521,725.78	429,702.92	2,490,187.63	789.392	789.162
BUCYRUS	321,418.37	2,579,157.88	321,429.72	2,547,620.94	715.150	714.900
FOX	432,631.95	2,564,093.19	432,641.73	2,532,554.22	687.160	686.920
FRANKLIN	325,475.89	2,529,049.03	325,486.36	2,497,512.35	791.620	791.270
FRANKLIN N GPS	338,886.11	2,524,542.64	338,896.37	2,493,005.54	765.976	765.658
FRANKLIN S GPS	324,670.25	2,546,091.10	324,680.75	2,514,554.45	726.831	726.468
GREENFIELD W GPS	363,098.32	2,524,416.24	363,108.57	2,492,878.70	783.166	782.889
HALBACH	367,523.76	2,540,652.26	367,534.31	2,509,114.68	734.540	734.250
KEEFE3	400,866.14	2,529,715.23	400,875.83	2,498,177.30	783.760	783.470
MILWAUKEE GPS	385,885.48	2,525,665.16	385,895.29	2,494,127.43	766.912	766.613
MILWAUKEE C GPS	387,943.11	2,541,586.03	387,953.09	2,510,048.02	668.814	668.476
MITCHELL	356,460.76	2,561,841.97	356,471.43	2,530,304.64	674.100	673.860
SIWI[a]	322,863.17	2,540,735.23	322,873.67	2,509,198.57	740.240	739.880
OAK CREEK E GPS	332,289.12	2,576,256.32	332,300.40	2,544,719.32	672.894	672.670
WAUWATOSA W GPS	398,187.08	2,518,708.25	398,196.78	2,487,170.43	759.435	759.132
Ozaukee County						
CEDAR2	569,954.25	2,576,517.16	569,960.74	2,544,977.16	758.910	758.610
GRAFTON	492,857.81	2,549,951.38	492,865.52	2,518,412.39	812.040	811.860
HOLLAND S GPS	575,212.59	2,574,900.76	575,219.09	2,543,360.75	742.988	742.686
PORT GPS	470,338.18	2,552,815.43	470,346.36	2,521,276.45	682.551	682.266
PORT WASHINGTON C GPS	521,397.86	2,562,580.65	521,405.29	2,531041.46	727.901	727.626
RANDOM LAKE GPS	574,745.61	2,554,253.17	574,752.09	2,522,713.20	860.931	860.628
SAUKVILLE C GPS	516,445.17	2,535,483.80	516,452.75	2,503,944.94	892.327	892.170
SHAN[a]	645,086.68	2,598,532.98	645,093.64	2,566,993.59	619.340	619.090
WAUWATOSA GPS	444,061.73	2,532,303.11	444,071.23	2,500,764.82	707.001	706.764
2Y46 GPS	495,798.56	2,552,522.98	495,806.25	2,520,984.01	762.571	762.397

Appendix A (continued)

Station Identification	NAD 27 State Plane Coordinates in Survey Feet		NAD 83 (2007) State Plane Coordinates in Survey Feet		Elevation in Feet	
	Northing	Easting	Northing	Easting	NGVD 29	NAVD 88
Racine County						
BEAUMONT	276,268.35	2,508,227.69	276,278.75	2,476,691.31	803.310	803.120
BURLINGTON W GPS	230,218.02	2,456,611.35	230,227.36	2,425,074.51	865.187	864.857
CALEDONIA GPS	308,972.24	2,559,421.25	308,983.18	2,527,884.70	680.370	680.061
CALEDONIA W GPS	294,385.80	2,559,763.22	294,396.77	2,528,226.87	720.182	719.880
PLEASANT2	275,168.92	2,562,794.44	275,179.94	2,531,258.41	757.850	757.610
RACINE	269,538.57	2,587,083.53	269,549.66	2,555,547.51	644.550	644.309
ROCHESTER C GPS	263,244.59	2,473,541.69	263,254.55	2,442,004.92	777.671	777.430
UNION GROVE GPS	256,367.82	2,521,072.84	256,378.10	2,489,536.60	801.591	801.344
WATERFORD GPS	288,687.73	2,485,645.05	288,698.06	2,454,108.40	794.381	794.214
WATERFORD W GPS	293,976.32	2,464,963.75	293,986.71	2,433,426.85	816.431	816.245
YORKVILLE E GPS	259,677.11	2,543,783.91	259,687.51	2,512,247.81	794.001	793.533
Walworth County						
ALLENS GROVE GPS	216,819.98	2,335,431.25	216,828.13	2,303,893.91	891.953	891.766
BLOOMFIELD S GPS	195,070.13	2,436,135.42	195,079.22	2,404,598.57	887.003	886.753
BRADFORD S GPS	221,459.41	2,322,969.39	221,467.53	2,291,432.00	855.160	854.923
DARIEN E GPS	228,546.52	2,357,364.26	228,554.89	2,325,826.88	932.265	931.963
DOOR	214,954.04	2,333,391.27	214,962.18	2,301,853.92	875.410	875.002
EAST TROY	281,006.36	2,425,814.00	281,015.73	2,394,276.79	1037.460	1037.230
ELKHORN GPS	245,976.47	2,399,199.60	245,985.25	2,367,662.37	1031.941	1031.678
HONEY2	274,585.69	2,437,496.04	274,595.21	2,405,958.82	992.690	992.460
JALE[a]	260,648.63	2,260,945.51	260,656.78	2,229,407.66	899.590	899.370
LA GRANGE E GPS	292,465.66	2,381,716.96	292,474.23	2,350,179.42	949.086	948.981
LYONS N GPS	242,314.19	2,438,733.75	242,323.39	2,407,196.78	851.268	850.953
MILLARD	278,429.29	2,369,895.27	278,437.61	2,338,357.65	952.070	951.870
PELL LAKE GPS	186,828.67	2,413,598.51	186,837.52	2,382,061.57	991.428	991.120
SHARON C GPS	202,367.04	2,349,700.18	202,375.44	2,318,162.93	955.748	955.520
SPRING2	319,575.98	2,362,924.60	319,584.50	2,331,387.14	795.540	795.360
SUGAR CREEK S GPS	255,445.16	2,380,123.09	255,453.72	2,348,585.77	988.740	988.492
TIBBETS GPS	274,497.57	2,378,106.80	274,505.87	2,346,569.23	943.751	943.558
WATH[a]	195,160.04	2,379,198.08	195,168.82	2,347,661.09	1032.160	1031.890
WEEKS	177,691.16	2,344,993.20	177,699.77	2,313,456.10	1049.190	1048.940
WHITEWATER RESET	309,303.16	2,338,046.62	309,311.25	2,306,509.26	844.191	844.086
WHITEWATER GPS	302,297.89	2,348,859.41	302,306.17	2,317,321.92	871.900	871.510
WHITEWATER W GPS	295,964.50	2,328,493.02	295,972.65	2,296,955.52	880.935	880.727
YERKES	211,590.90	2,389,084.97	211,599.66	2,357,547.85	1040.840	1040.560
Washington County						
ADDISON E GPS	525,029.73	2,456,337.75	525,035.98	2,424,799.48	1173.719	1173.610
BARTON C GPS	534,316.08	2,472,309.80	534,322.41	2,440,771.46	987.064	986.920
ELMORE2	575,158.36	2,464,578.55	575,164.19	2,433,039.93	1064.950	1064.732
FARMINGTON W GPS	546,863.04	2,493,361.61	546,869.49	2,461,823.08	934.046	824.650

Appendix A (continued)

Station Identification	NAD 27 State Plane Coordinates in Survey Feet		NAD 83 (2007) State Plane Coordinates in Survey Feet		Elevation in Feet	
	Northing	Easting	Northing	Easting	NGVD 29	NAVD 88
Washington County (continued)						
FOLA[a]	657,989.01	2,408,555.85	657,995.26	2,377,017.20	763.000	762.910
GERMANTOWN S GPS	440,826.07	2,511,184.16	440,835.30	2,479,646.06	770.872	770.760
HARTFORD C GPS	484,679.67	2,440,037.42	484,686.45	2,408,500.34	1009.886	1009.860
JACKSON	487,970.40	2,500,998.91	487,977.48	2,469,460.83	864.503	864.424
JACKSON GPS	482,626.11	2,483,285.01	482,633.33	2,451,747.12	892.120	892.010
JACKSON N GPS	504,165.00	2,489,112.11	504,171.91	2,457,573.93	943.742	943.623
KEWASKUM C GPS	556,353.27	2,466,616.28	556,359.34	2,435,077.72	996.265	996.077
NEW FANE GPS	567,745.79	2,488,256.16	567,752.17	2,456,717.54	1067.093	1066.996
POLK C GPS	487,419.34	2,464,84.98	487,426.36	2,433,305.17	1113.537	1113.561
RANDALL	460,100.76	2,358,060.97	460,105.92	2,326,524.18	1053.770	1053.730
RICHFIELD E GPS	461,029.93	2,474,356.12	461,037.68	2,442,818.42	1053.212	1053.174
RUBICON	492,503.25	2,436,666.42	492,510.07	2,405,129.36	1072.030	1072.000
RUBICON E GPS	494,867.28	2,418,365.51	494,874.01	2,386,828.34	1056.104	1043.026
ST PAUL2	569,281.76	2,413,195.25	569,287.05	2,381,656.91	1000.310	1000.230
WAYNE N GPS	556,091.87	2,439,846.38	556,097.58	2,408,307.96	1045.591	1045.500
WEST BEND GPS	523,613.25	2,495,574.37	523,619.93	2,464,035.98	883.256	883.062
WEBE[a]	523,198.13	2,491,826.58	523,204.83	2,460,288.17	886.430	886.240
Waukesha County						
BROOKFIELD S GPS	383,326.62	2,496,143.92	383,336.20	2,464,606.26	864.598	864.283
COLGATE GPS	439,885.89	2,471,632.07	439,893.88	2,440,094.38	983.824	983.800
CONCORD GPS	394,829.75	2,377,012.81	394,837.82	2,345,475.29	850.790	850.710
DELAFIELD S GPS	376,150.96	2,439,285.70	376,159.80	2,407,748.35	1012.101	1011.907
DOUSMAN GPS	376,203.85	2,401,219.00	376,212.73	2,369,681.54	852.262	852.187
EAGLE GPS	342,741.55	2,421,509.90	342,750.97	2,389,972.56	974.503	974.404
EAGLE E GPS	328,972.03	2,412,810.72	328,981.64	2,381,273.37	952.802	952.659
JERICHO[b]	323,224.02	2,434,418.29	323,234.63	2,402880.99	1031.941	993.010
LANNON	418,620.40	2,491,874.17	418,629.22	2,460,336.30	993.900	993.710
MEADOW	386,061.29	2,458,836.61	386,040.21	2,427,299.38	1033.830	1033.650
MERTON N GPS	438,663.80	2,432,191.56	438,671.23	2,400,654.11	1011.148	1011.097
MUKWONAGO GPS	315,039.88	2,449,779.05	315,050.40	2,418,241.90	820.922	820.658
MUSKEGO E GPS	321,423.90	2,515,077.09	321,434.24	2,483,540.20	789.445	779.090
OBSERVATORY	358,581.02	2,495,538.29	358,591.28	2,464,000.72	957.900	957.410
OCONOMOWOC N GPS	434,771.64	2,411,139.75	434,779.01	2,379,602.31	932.972	932.934
PAR0[a]	321,657.99	2,377,234.50	321,666.65	2,345,697.08	878.410	878.250
PEWAUKEE N GPS	407,323.79	2,478,343.01	407,332.71	2,446,805.26	856.973	856.839
RASN[a]	383,371.72	2,502,206.06	383,381.31	2,470,668.41	883.550	883.240
STOCK	390,553.64	2,390,732.57	390,561.52	2,359,195.15	901.300	901.220
VORMKE2	411,816.72	2,458,029.98	411,825.44	2,426,492.23	1071.780	1071.650
WAUKESHA GPS	355,823.42	2,474,451.75	355,833.19	2,442,914.33	840.642	840.440
WAUKESHA N GPS	372,208.44	2,469,146.01	372,217.80	2,437,608.67	836.667	836.478
WAWN[a]	430,453.98	2,336,982.76	430,459.91	2,305,445.52	822.100	822.060

[a] *Wisconsin Department of Transportation Continuously Operating Reference Station (CORS).*

[b] *NGS Station JERICHO was believed to be disturbed. The NAD 27 coordinate values shown and used in the Bi-Directional Transformation are those that were produced from a Least-Squares adjustment program.*

Source: SEWRPC.

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Appendix B

COMPUTATION OF HELMERT PARAMETERS COUNTY BY COUNTY

```
PROGRAM:      PARAMETERS - VER 1.08, EFB:08/11/09
USED BY:      Earl F. Burkholder
DATE:         October 26, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT:      Common points with RPC & HMP values in Kenosha County


INPUT FILE:   Kenosha County.dat
OUTPUT FILE:  Kenosha parameters.txt


LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

                          RPC                          HMP
  NO.   PT ID        N        E        U          N        E        U      STATION NAME

   1    7021       0.010    0.010    0.015      0.010    0.010    0.015    BLOOMFIELD S GPS
   2    7023       0.010    0.010    0.015      0.010    0.010    0.015    BRIGHTON N GPS
   3    7024       0.010    0.010    0.015      0.010    0.010    0.015    BRISTOL E GPS
   4    7028       0.010    0.010    0.015      0.010    0.010    0.015    BURLINGTON W GPS
   5    7062       0.010    0.010    0.015      0.010    0.010    0.015    KEHA (WISCORS)
   6    7063       0.010    0.010    0.015      0.010    0.010    0.015    KELLEY
   7    7084       0.010    0.010    0.015      0.010    0.010    0.015    PLEASANT PRAIRIE E
   8    7085       0.010    0.010    0.015      0.010    0.010    0.015    PLEASANT PRAIRIE GPS
   9    7089       0.010    0.010    0.015      0.010    0.010    0.015    RACINE
  10    7097       0.010    0.010    0.015      0.010    0.010    0.015    SALEM E GPS
  11    7101       0.010    0.010    0.015      0.010    0.010    0.015    SILVER
  12    7102       0.010    0.010    0.015      0.010    0.010    0.015    SILVER LAKE GPS
  13    7104       0.010    0.010    0.015      0.010    0.010    0.015    SOMERS S GPS
  14    7110       0.010    0.010    0.015      0.010    0.010    0.015    TWIN LAKES GPS
  15    7111       0.010    0.010    0.015      0.010    0.010    0.015    UNION GROVE GPS
  16    7129       0.010    0.010    0.015      0.010    0.010    0.015    YORKVILLE E GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

                              RPC                HMP
   1    7021        X =     132923.4342        132912.2034      BLOOMFIELD S GPS
                    Y =   -4706313.3856      -4706180.7728
                    Z =    4288606.0771       4288808.6855
                              RPC                HMP
   2    7023        X =     150620.4362        150609.2804      BRIGHTON N GPS
                    Y =   -4695864.2678      -4695731.5175
                    Z =    4299344.6098       4299547.3877
                              RPC                HMP
   3    7024        X =     164243.3564        164232.4356      BRISTOL E GPS
                    Y =   -4704182.2604      -4704049.4893
                    Z =    4289763.0508       4289965.8967
                              RPC                HMP
   4    7028        X =     139166.1983        139154.9709      BURLINGTON W GPS
                    Y =   -4698962.6413      -4698829.9647
                    Z =    4296398.1212       4296600.7692
                              RPC                HMP
   5    7062        X =     170856.9529        170846.0608      KEHA (WISCORS)
                    Y =   -4702408.9226      -4702276.1011
                    Z =    4291477.4598       4291680.3367
                              RPC                HMP
   6    7063        X =     167798.7834        167787.9452      KELLEY
                    Y =   -4707339.0648      -4707206.2927
                    Z =    4286226.8080       4286429.6418
```

Appendix B (continued)

			RPC	HMP	
7	7084	X =	179605.3948	179594.5499	PLEASANT PRAIRIE E
		Y =	-4701933.7090	-4701800.9004	
		Z =	4291553.7421	4291756.6593	
			RPC	HMP	
8	7085	X =	178950.9910	178940.1613	PLEASANT PRAIRIE GPS
		Y =	-4705950.0828	-4705817.2633	
		Z =	4287222.0965	4287424.9430	
			RPC	HMP	
9	7089	X =	178924.5139	178913.5357	RACINE
		Y =	-4690067.8305	-4689934.8380	
		Z =	4304481.9273	4304685.0035	
			RPC	HMP	
10	7097	X =	157670.9762	157659.9482	SALEM E GPS
		Y =	-4704903.9997	-4704771.2152	
		Z =	4289295.4969	4289498.2574	
			RPC	HMP	
11	7101	X =	148821.4387	148810.2785	SILVER
		Y =	-4703759.1693	-4703626.4519	
		Z =	4290849.4806	4291052.2612	
			RPC	HMP	
12	7102	X =	151498.0876	151486.9587	SILVER LAKE GPS
		Y =	-4705106.6384	-4704973.9331	
		Z =	4289246.9687	4289449.7493	
			RPC	HMP	
13	7104	X =	174103.3976	174092.5062	SOMERS S GPS
		Y =	-4698882.6276	-4698749.7771	
		Z =	4295155.7560	4295358.6528	
			RPC	HMP	
14	7110	X =	140069.0614	140057.8540	TWIN LAKES GPS
		Y =	-4706450.7194	-4706318.0658	
		Z =	4288218.1065	4288420.7473	
			RPC	HMP	
15	7111	X =	158811.0039	158799.9578	UNION GROVE GPS
		Y =	-4693213.1888	-4693080.3460	
		Z =	4301930.6877	4302133.5729	
			RPC	HMP	
16	7129	X =	165731.5309	165720.5312	YORKVILLE E GPS
		Y =	-4692399.4972	-4692266.6552	
		Z =	4302549.4344	4302752.3711	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7021	BLOOMFIELD S GPS
2	7023	BRIGHTON N GPS
3	7024	BRISTOL E GPS
4	7028	BURLINGTON W GPS
5	7062	KEHA (WISCORS)
6	7063	KELLEY
7	7084	PLEASANT PRAIRIE E
8	7085	PLEASANT PRAIRIE GPS
9	7089	RACINE
10	7097	SALEM E GPS
11	7101	SILVER
12	7102	SILVER LAKE GPS
13	7104	SOMERS S GPS
14	7110	TWIN LAKES GPS
15	7111	UNION GROVE GPS
16	7129	YORKVILLE E GPS

Appendix B (continued)

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX = -5.3342 M
TRANSLATION IN Y, TY = 177.5110 M
TRANSLATION IN Z, TZ = 162.7540 M

SCALE IN X/Y/Z 9.403879 PPM

ROTATION ABOUT X AXIS = -0.00000027 RAD
-0.05533224 SEC
ROTATION ABOUT Y AXIS = 0.00000596 RAD
1.22892037 SEC
ROTATION ABOUT Z AXIS = -0.00000391 RAD
-0.80666467 SEC

REFERENCE VARIANCE = 6.196456
(SIGMA NAUGHT SQUARED)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7021 X=	132912.203	132912.204	-0.001	E= -0.001 M	= 0.00 FT	BLOOMFIELD S GPS
Y=	-4706180.773	-4706180.763	-0.010	N= -0.010 M	= -0.03 FT	
Z=	4288808.685	4288808.690	-0.005	U= 0.004 M	= 0.01 FT	
7023 X=	150609.280	150609.268	0.013	E= 0.012 M	= 0.04 FT	BRIGHTON N GPS
Y=	-4695731.518	-4695731.480	-0.037	N= -0.058 M	= -0.19 FT	
Z=	4299547.388	4299547.432	-0.044	U= -0.002 M	= -0.01 FT	
7024 X=	164232.436	164232.406	0.030	E= 0.030 M	= 0.10 FT	BRISTOL E GPS
Y=	-4704049.489	-4704049.495	0.006	N= 0.029 M	= 0.10 FT	
Z=	4289965.897	4289965.862	0.035	U= 0.020 M	= 0.07 FT	
7028 X=	139154.971	139154.952	0.019	E= 0.018 M	= 0.06 FT	BURLINGTON W GPS
Y=	-4698829.965	-4698829.927	-0.038	N= -0.083 M	= -0.27 FT	
Z=	4296600.769	4296600.847	-0.077	U= -0.024 M	= -0.08 FT	
7062 X=	170846.061	170846.047	0.014	E= 0.014 M	= 0.05 FT	KEHA (WISCORS)
Y=	-4702276.101	-4702276.116	0.014	N= 0.017 M	= 0.05 FT	
Z=	4291680.337	4291680.327	0.010	U= -0.004 M	= -0.01 FT	
7063 X=	167787.945	167787.899	0.046	E= 0.046 M	= 0.15 FT	KELLEY
Y=	-4707206.293	-4707206.315	0.022	N= 0.040 M	= 0.13 FT	
Z=	4286429.642	4286429.606	0.036	U= 0.009 M	= 0.03 FT	
7084 X=	179594.550	179594.569	-0.019	E= -0.021 M	= -0.07 FT	PLEASANT PRAIRIE E
Y=	-4701800.900	-4701800.863	-0.037	N= -0.027 M	= -0.09 FT	
Z=	4291756.659	4291756.662	-0.003	U= 0.025 M	= 0.08 FT	
7085 X=	178940.161	178940.201	-0.039	E= -0.039 M	= -0.13 FT	PLEASANT PRAIRIE GPS
Y=	-4705817.263	-4705817.276	0.013	N= -0.011 M	= -0.04 FT	
Z=	4287424.943	4287424.971	-0.028	U= -0.029 M	= -0.10 FT	
7089 X=	178913.536	178913.558	-0.023	E= -0.021 M	= -0.07 FT	RACINE
Y=	-4689934.838	-4689934.879	0.041	N= 0.055 M	= 0.18 FT	
Z=	4304685.003	4304684.968	0.035	U= -0.007 M	= -0.02 FT	

Appendix B (continued)

7097	X=	157659.948	157659.969	-0.021	E= -0.019 M	= -0.06 FT	SALEM E GPS
	Y=	-4704771.215	-4704771.267	0.052	N= 0.030 M	= 0.10 FT	
	Z=	4289498.257	4289498.264	-0.007	U= -0.043 M	= -0.14 FT	
7101	X=	148810.278	148810.335	-0.056	E= -0.056 M	= -0.18 FT	SILVER
	Y=	-4703626.452	-4703626.461	0.009	N= 0.045 M	= 0.15 FT	
	Z=	4291052.261	4291052.210	0.051	U= 0.027 M	= 0.09 FT	
7102	X=	151486.959	151487.024	-0.065	E= -0.065 M	= -0.21 FT	SILVER LAKE GPS
	Y=	-4704973.933	-4704973.932	-0.001	N= 0.038 M	= 0.12 FT	
	Z=	4289449.749	4289449.699	0.051	U= 0.034 M	= 0.11 FT	
7104	X=	174092.506	174092.487	0.020	E= 0.019 M	= 0.06 FT	SOMERS S GPS
	Y=	-4698749.777	-4698749.776	-0.001	N= -0.020 M	= -0.07 FT	
	Z=	4295358.653	4295358.678	-0.025	U= -0.015 M	= -0.05 FT	
7110	X=	140057.854	140057.901	-0.047	E= -0.047 M	= -0.15 FT	TWIN LAKES GPS
	Y=	-4706318.066	-4706318.070	0.004	N= -0.004 M	= -0.01 FT	
	Z=	4288420.747	4288420.758	-0.011	U= -0.012 M	= -0.04 FT	
7111	X=	158799.958	158799.887	0.071	E= 0.071 M	= 0.23 FT	UNION GROVE GPS
	Y=	-4693080.346	-4693080.345	-0.001	N= -0.010 M	= -0.03 FT	
	Z=	4302133.573	4302133.584	-0.011	U= -0.005 M	= -0.02 FT	
7129	X=	165720.531	165720.472	0.059	E= 0.058 M	= 0.19 FT	YORKVILLE E GPS
	Y=	-4692266.655	-4692266.619	-0.036	N= -0.031 M	= -0.10 FT	
	Z=	4302752.371	4302752.378	-0.007	U= 0.024 M	= 0.08 FT	

MEAN OF EAST MISCLOSURE =	0.000 FT
STANDARD DEVIATION	0.134 FT
MEAN OF NORTH MISCLOSURE =	0.000 FT
STANDARD DEVIATION =	0.128 FT
MEAN OF UP MISCLOSURE =	0.000 FT
STANRDARD DEVIATION =	0.072 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 30, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - N. Half Milwaukee County

INPUT FILE: N Half Milwaukee County.dat
OUTPUT FILE: Milwaukee County N Half parameters.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7026	0.030	0.030	0.015	0.010	0.010	0.015	BROWN DEER W GPS
2	7045	0.030	0.030	0.015	0.010	0.010	0.015	FOX
3	7049	0.010	0.010	0.015	0.010	0.010	0.015	GERMANTOWN S GPS
4	7051	0.010	0.010	0.015	0.010	0.010	0.015	GREENFIELD W GPS
5	7052	0.010	0.010	0.015	0.010	0.010	0.015	HALBACH
6	7061	0.010	0.010	0.015	0.010	0.010	0.015	KEEFE 3
7	7066	0.010	0.010	0.015	0.010	0.010	0.015	LANNON
8	7071	0.010	0.010	0.015	0.010	0.010	0.015	MILWAUKE C GPS
9	7072	0.010	0.010	0.015	0.010	0.010	0.015	MILWAUKEE GPS
10	7073	0.010	0.010	0.015	0.010	0.010	0.015	MITCHELL
11	7092	0.010	0.010	0.015	0.010	0.010	0.015	RASN (WISCORS)
12	7118	0.030	0.030	0.015	0.010	0.010	0.015	WAUWATOSA
13	7119	0.010	0.010	0.015	0.010	0.010	0.015	WAUWATOSA W GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7026	X =	159020.5053	159008.8754	BROWN DEER W GPS
		Y =	-4657214.2028	-4657081.5433	
		Z =	4340600.9421	4340803.6384	
2	7045	X =	171930.2023	171918.3276	FOX
		Y =	-4656335.3300	-4656202.6120	
		Z =	4341002.7386	4341205.5241	
3	7049	X =	155808.2651	155796.6526	GERMANTOWN S GPS
		Y =	-4654944.8805	-4654812.2837	
		Z =	4343125.5371	4343328.2138	
4	7051	X =	159837.5094	159826.0669	GREENFIELD W GPS
		Y =	-4671065.2343	-4670932.3919	
		Z =	4325760.4256	4325963.3014	
5	7052	X =	164784.8798	164773.4241	HALBACH
		Y =	-4670042.9350	-4669910.0358	
		Z =	4326650.3975	4326853.3346	
6	7061	X =	161454.0696	161442.5098	KEEFE 3
		Y =	-4663177.1502	-4663044.4269	
		Z =	4334145.7140	4334348.4561	
7	7066	X =	149924.6803	149913.1364	LANNON
		Y =	-4659728.6930	-4659596.1629	
		Z =	4338332.8522	4338535.4123	
8	7071	X =	165069.9150	165058.3504	MILWAUKE C GPS
		Y =	-4665775.0668	-4665642.2725	
		Z =	4331181.0827	4331383.8905	

Appendix B (continued)

			RPC	HMP	
9	7072	X =	160219.1143	160207.6131	MILWAUKEE GPS
		Y =	-4666314.9769	-4666182.2202	
		Z =	4330828.1917	4331030.9625	
			RPC	HMP	
10	7073	X =	171240.5960	171229.2184	MITCHELL
		Y =	-4672205.5865	-4672072.6786	
		Z =	4324054.5054	4324257.4821	
			RPC	HMP	
11	7092	X =	153071.0890	153059.6160	RASN (WISCORS)
		Y =	-4666991.5483	-4666858.8301	
		Z =	4330413.1240	4330615.8369	
			RPC	HMP	
12	7118	X =	162243.5200	162231.8483	WAUWATOSA
		Y =	-4654138.8182	-4654006.1455	
		Z =	4343720.8364	4343923.5507	
			RPC	HMP	
13	7119	X =	158099.6092	158088.0830	WAUWATOSA W GPS
		Y =	-4663790.6965	-4663657.9630	
		Z =	4333602.0249	4333804.7687	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7026	BROWN DEER W GPS
2	7045	FOX
3	7049	GERMANTOWN S GPS
4	7051	GREENFIELD W GPS
5	7052	HALBACH
6	7061	KEEFE 3
7	7066	LANNON
8	7071	MILWAUKE C GPS
9	7072	MILWAUKEE GPS
10	7073	MITCHELL
11	7092	RASN (WISCORS)
12	7118	WAUWATOSA
13	7119	WAUWATOSA W GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX = -4.9243 M
TRANSLATION IN Y, TY = 90.4386 M
TRANSLATION IN Z, TZ = 250.0633 M

SCALE IN X/Y/Z -9.943834 PPM

ROTATION ABOUT X AXIS = -0.00000127 RAD
-0.26194201 SEC
ROTATION ABOUT Y AXIS = 0.00001072 RAD
2.21206070 SEC
ROTATION ABOUT Z AXIS = -0.00000889 RAD
-1.83327596 SEC

REFERENCE VARIANCE = 7.179627
(SIGMA NAUGHT SQUARED)

Appendix B (continued)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7026 X=	159008.875	159008.843	0.033	E= 0.033 M	= 0.11 FT	BROWN DEER W GPS
Y=	-4657081.543	-4657081.553	0.009	N= 0.009 M	= 0.03 FT	
Z=	4340803.638	4340803.634	0.004	U= -0.003 M	= -0.01 FT	
7045 X=	171918.328	171918.399	-0.072	E= -0.073 M	= -0.24 FT	FOX
Y=	-4656202.612	-4656202.574	-0.038	N= -0.055 M	= -0.18 FT	
Z=	4341205.524	4341205.566	-0.042	U= -0.003 M	= -0.01 FT	
7049 X=	155796.653	155796.587	0.065	E= 0.065 M	= 0.21 FT	GERMANTOWN S GPS
Y=	-4654812.284	-4654812.285	0.001	N= 0.029 M	= 0.10 FT	
Z=	4343328.214	4343328.173	0.041	U= 0.029 M	= 0.10 FT	
7051 X=	159826.067	159826.121	-0.054	E= -0.053 M	= -0.17 FT	GREENFIELD W GPS
Y=	-4670932.392	-4670932.420	0.028	N= 0.053 M	= 0.18 FT	
Z=	4325963.301	4325963.256	0.045	U= 0.009 M	= 0.03 FT	
7052 X=	164773.424	164773.423	0.001	E= 0.002 M	= 0.01 FT	HALBACH
Y=	-4669910.036	-4669910.088	0.052	N= 0.080 M	= 0.26 FT	
Z=	4326853.335	4326853.274	0.061	U= 0.003 M	= 0.01 FT	
7061 X=	161442.510	161442.505	0.005	E= 0.004 M	= 0.01 FT	KEEFE 3
Y=	-4663044.427	-4663044.411	-0.016	N= -0.035 M	= -0.11 FT	
Z=	4334348.456	4334348.489	-0.033	U= -0.011 M	= -0.03 FT	
7066 X=	149913.136	149913.155	-0.018	E= -0.021 M	= -0.07 FT	LANNON
Y=	-4659596.163	-4659596.096	-0.067	N= -0.085 M	= -0.28 FT	
Z=	4338535.412	4338535.466	-0.054	U= 0.012 M	= 0.04 FT	
7071 X=	165058.350	165058.369	-0.019	E= -0.019 M	= -0.06 FT	MILWAUKE C GPS
Y=	-4665642.272	-4665642.266	-0.007	N= -0.028 M	= -0.09 FT	
Z=	4331383.890	4331383.922	-0.032	U= -0.017 M	= -0.06 FT	
7072 X=	160207.613	160207.625	-0.012	E= -0.013 M	= -0.04 FT	MILWAUKEE GPS
Y=	-4666182.220	-4666182.213	-0.007	N= -0.019 M	= -0.06 FT	
Z=	4331030.963	4331030.982	-0.020	U= -0.009 M	= -0.03 FT	
7073 X=	171229.218	171229.123	0.096	E= 0.095 M	= 0.31 FT	MITCHELL
Y=	-4672072.679	-4672072.658	-0.021	N= -0.011 M	= -0.04 FT	
Z=	4324257.482	4324257.474	0.008	U= 0.023 M	= 0.08 FT	
7092 X=	153059.616	153059.682	-0.066	E= -0.065 M	= -0.21 FT	RASN (WISCORS)
Y=	-4666858.830	-4666858.841	0.011	N= 0.006 M	= 0.02 FT	
Z=	4330615.837	4330615.841	-0.004	U= -0.012 M	= -0.04 FT	
7118 X=	162231.848	162231.765	0.084	E= 0.085 M	= 0.28 FT	WAUWATOSA
Y=	-4654006.145	-4654006.174	0.028	N= 0.028 M	= 0.09 FT	
Z=	4343923.551	4343923.536	0.015	U= -0.008 M	= -0.03 FT	
7119 X=	158088.083	158088.089	-0.006	E= -0.006 M	= -0.02 FT	WAUWATOSA W GPS
Y=	-4663657.963	-4663657.980	0.017	N= 0.012 M	= 0.04 FT	
Z=	4333804.769	4333804.768	0.000	U= -0.012 M	= -0.04 FT	

MEAN OF EAST MISCLOSURE = 0.009 FT
STANDARD DEVIATION 0.177 FT

MEAN OF NORTH MISCLOSURE = -0.004 FT
STANDARD DEVIATION = 0.146 FT

MEAN OF UP MISCLOSURE = 0.000 FT
STANRDARD DEVIATION = 0.047 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 30, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - S half Milwaukee County

INPUT FILE: S Half Milwaukee County.dat
OUTPUT FILE: Milwaukee S Half parameters.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7027	0.010	0.010	0.015	0.010	0.010	0.015	BUCYRUS
2	7029	0.010	0.010	0.015	0.010	0.010	0.015	CALEDONIA GPS
3	7046	0.010	0.010	0.015	0.010	0.010	0.015	FRANKLIN
4	7047	0.010	0.010	0.015	0.010	0.010	0.015	FRANKLIN N GPS
5	7048	0.010	0.010	0.015	0.010	0.010	0.015	FRANKLIN S GPS
6	7051	0.010	0.010	0.015	0.010	0.010	0.015	GREENFIELD W GPS
7	7052	0.010	0.010	0.015	0.010	0.010	0.015	HALBACH
8	7071	0.010	0.010	0.015	0.010	0.010	0.015	MILWAUKE C GPS
9	7072	0.010	0.010	0.015	0.010	0.010	0.015	MILWAUKEE GPS
10	7073	0.010	0.010	0.015	0.010	0.010	0.015	MITCHELL
11	7075	0.010	0.010	0.015	0.010	0.010	0.015	MUSKEGO E GPS
12	7077	0.010	0.010	0.015	0.010	0.010	0.015	OAK CREEK E GPS
13	7092	0.010	0.010	0.015	0.010	0.010	0.015	RASN (WISCORS)
14	7103	0.010	0.010	0.015	0.010	0.010	0.015	SIWI (WISCORS)

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7027	X =	176514.7734	176503.5151	BUCYRUS
		Y =	-4679385.7077	-4679252.6591	
		Z =	4316143.4761	4316346.6080	
			RPC	HMP	
2	7029	X =	170499.7083	170488.5681	CALEDONIA GPS
		Y =	-4682077.5437	-4681944.5576	
		Z =	4313467.9449	4313670.9714	
			RPC	HMP	
3	7046	X =	161246.9831	161235.8052	FRANKLIN
		Y =	-4678854.5374	-4678721.6370	
		Z =	4317343.1045	4317546.0063	
			RPC	HMP	
4	7047	X =	159874.4711	159863.1627	FRANKLIN N GPS
		Y =	-4676090.7072	-4675957.8519	
		Z =	4320355.3344	4320558.2017	
			RPC	HMP	
5	7048	X =	166439.4342	166428.2656	FRANKLIN S GPS
		Y =	-4678910.3812	-4678777.4694	
		Z =	4317058.1559	4317261.0717	
			RPC	HMP	
6	7051	X =	159837.5094	159826.0669	GREENFIELD W GPS
		Y =	-4671065.2343	-4670932.3919	
		Z =	4325760.4256	4325963.3014	
			RPC	HMP	
7	7052	X =	164784.8798	164773.4241	HALBACH
		Y =	-4670042.9350	-4669910.0358	
		Z =	4326650.3975	4326853.3346	

			RPC	HMP	
8	7071	X =	165069.9150	165058.3504	MILWAUKE C GPS
		Y =	-4665775.0668	-4665642.2725	
		Z =	4331181.0827	4331383.8905	
			RPC	HMP	
9	7072	X =	160219.1143	160207.6131	MILWAUKEE GPS
		Y =	-4666314.9769	-4666182.2202	
		Z =	4330828.1917	4331030.9625	
			RPC	HMP	
10	7073	X =	171240.5960	171229.2184	MITCHELL
		Y =	-4672205.5865	-4672072.6786	
		Z =	4324054.5054	4324257.4821	
			RPC	HMP	
11	7075	X =	156989.0379	156977.7951	MUSKEGO E GPS
		Y =	-4679769.5139	-4679636.6313	
		Z =	4316508.5467	4316711.4241	
			RPC	HMP	
12	7077	X =	175631.1208	175619.8434	OAK CREEK E GPS
		Y =	-4677138.4643	-4677005.4299	
		Z =	4318578.8981	4318782.0213	
			RPC	HMP	
13	7092	X =	153071.0890	153059.6160	RASN (WISCORS)
		Y =	-4666991.5483	-4666858.8301	
		Z =	4330413.1240	4330615.8369	
			RPC	HMP	
14	7103	X =	164807.4013	164796.2279	SIWI (WISCORS)
		Y =	-4679319.0237	-4679186.1132	
		Z =	4316686.4581	4316889.3719	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7027	BUCYRUS
2	7029	CALEDONIA GPS
3	7046	FRANKLIN
4	7047	FRANKLIN N GPS
5	7048	FRANKLIN S GPS
6	7051	GREENFIELD W GPS
7	7052	HALBACH
8	7071	MILWAUKE C GPS
9	7072	MILWAUKEE GPS
10	7073	MITCHELL
11	7075	MUSKEGO E GPS
12	7077	OAK CREEK E GPS
13	7092	RASN (WISCORS)
14	7103	SIWI (WISCORS)

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX =	5.3797 M
TRANSLATION IN Y, TY =	111.6858 M
TRANSLATION IN Z, TZ =	226.6473 M
SCALE IN X/Y/Z	-5.040504 PPM
ROTATION ABOUT X AXIS =	-0.00000093 RAD
	-0.19204518 SEC
ROTATION ABOUT Y AXIS =	0.00001461 RAD
	3.01270238 SEC
ROTATION ABOUT Z AXIS =	-0.00001011 RAD
	-2.08484849 SEC
REFERENCE VARIANCE =	6.777856
(SIGMA NAUGHT SQUARED)	

Appendix B (continued)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7027 X=	176503.515	176503.519	-0.004	E= -0.004 M	= -0.01 FT	BUCYRUS
Y=	-4679252.659	-4679252.670	0.011	N= 0.021 M	= 0.07 FT	
Z=	4316346.608	4316346.589	0.019	U= 0.005 M	= 0.02 FT	
7029 X=	170488.568	170488.551	0.017	E= 0.017 M	= 0.06 FT	CALEDONIA GPS
Y=	-4681944.558	-4681944.551	-0.007	N= -0.012 M	= -0.04 FT	
Z=	4313670.971	4313670.981	-0.010	U= -0.001 M	= 0.00 FT	
7046 X=	161235.805	161235.783	0.022	E= 0.023 M	= 0.07 FT	FRANKLIN
Y=	-4678721.637	-4678721.658	0.021	N= 0.026 M	= 0.09 FT	
Z=	4317546.006	4317545.989	0.017	U= -0.003 M	= -0.01 FT	
7047 X=	159863.163	159863.206	-0.043	E= -0.043 M	= -0.14 FT	FRANKLIN N GPS
Y=	-4675957.852	-4675957.858	0.006	N= 0.016 M	= 0.05 FT	
Z=	4320558.202	4320558.186	0.015	U= 0.005 M	= 0.02 FT	
7048 X=	166428.266	166428.213	0.053	E= 0.052 M	= 0.17 FT	FRANKLIN S GPS
Y=	-4678777.469	-4678777.448	-0.021	N= -0.049 M	= -0.16 FT	
Z=	4317261.072	4317261.118	-0.046	U= -0.015 M	= -0.05 FT	
7051 X=	159826.067	159826.115	-0.048	E= -0.047 M	= -0.15 FT	GREENFIELD W GPS
Y=	-4670932.392	-4670932.416	0.024	N= 0.052 M	= 0.17 FT	
Z=	4325963.301	4325963.254	0.047	U= 0.013 M	= 0.04 FT	
7052 X=	164773.424	164773.437	-0.013	E= -0.012 M	= -0.04 FT	HALBACH
Y=	-4669910.036	-4669910.073	0.037	N= 0.054 M	= 0.18 FT	
Z=	4326853.335	4326853.295	0.040	U= 0.000 M	= 0.00 FT	
7071 X=	165058.350	165058.361	-0.011	E= -0.013 M	= -0.04 FT	MILWAUKE C GPS
Y=	-4665642.272	-4665642.227	-0.045	N= -0.085 M	= -0.28 FT	
Z=	4331383.890	4331383.966	-0.075	U= -0.018 M	= -0.06 FT	
7072 X=	160207.613	160207.596	0.017	E= 0.016 M	= 0.05 FT	MILWAUKEE GPS
Y=	-4666182.220	-4666182.183	-0.037	N= -0.057 M	= -0.19 FT	
Z=	4331030.963	4331031.005	-0.042	U= -0.002 M	= -0.01 FT	
7073 X=	171229.218	171229.180	0.038	E= 0.037 M	= 0.12 FT	MITCHELL
Y=	-4672072.679	-4672072.646	-0.033	N= -0.043 M	= -0.14 FT	
Z=	4324257.482	4324257.508	-0.026	U= 0.007 M	= 0.02 FT	
7075 X=	156977.795	156977.881	-0.086	E= -0.084 M	= -0.28 FT	MUSKEGO E GPS
Y=	-4679636.631	-4679636.672	0.041	N= 0.067 M	= 0.22 FT	
Z=	4316711.424	4316711.372	0.052	U= 0.003 M	= 0.01 FT	
7077 X=	175619.843	175619.813	0.031	E= 0.031 M	= 0.10 FT	OAK CREEK E GPS
Y=	-4677005.430	-4677005.449	0.019	N= 0.036 M	= 0.12 FT	
Z=	4318782.021	4318781.988	0.033	U= 0.009 M	= 0.03 FT	
7092 X=	153059.616	153059.619	-0.003	E= -0.004 M	= -0.01 FT	RASN (WISCORS)
Y=	-4666858.830	-4666858.823	-0.007	N= -0.003 M	= -0.01 FT	
Z=	4330615.837	4330615.834	0.003	U= 0.007 M	= 0.02 FT	
7103 X=	164796.228	164796.198	0.030	E= 0.030 M	= 0.10 FT	SIWI (WISCORS)
Y=	-4679186.113	-4679186.105	-0.008	N= -0.025 M	= -0.08 FT	
Z=	4316889.372	4316889.398	-0.026	U= -0.011 M	= -0.04 FT	

MEAN OF EAST MISCLOSURE = 0.000 FT
STANDARD DEVIATION 0.124 FT

MEAN OF NORTH MISCLOSURE = 0.000 FT
STANDARD DEVIATION = 0.153 FT

MEAN OF UP MISCLOSURE = 0.000 FT
STANRDARD DEVIATION = 0.030 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 30, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - N Half Ozaukee County

INPUT FILE: N Half Ozaukee County.dat
OUTPUT FILE: Ozaukee N Half parameters.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7031	0.010	0.010	0.015	0.010	0.010	0.015	CEDAR 2
2	7043	0.010	0.010	0.015	0.010	0.010	0.015	FARMINGTON W GPS
3	7054	0.010	0.010	0.015	0.010	0.010	0.015	HOLLAND S GPS
4	7058	0.010	0.010	0.015	0.010	0.010	0.015	JACKSON N GPS
5	7076	0.010	0.010	0.015	0.010	0.010	0.015	NEW FANE GPS
6	7088	0.010	0.010	0.015	0.010	0.010	0.015	PORT WASHINGTON C GPS
7	7091	0.010	0.010	0.015	0.010	0.010	0.015	RANDOM LAKE GPS
8	7098	0.010	0.010	0.015	0.010	0.010	0.015	SAUKVILLE C GPS
9	7122	0.010	0.010	0.015	0.010	0.010	0.015	WEBE (WISCORS)
10	7124	0.010	0.010	0.015	0.010	0.010	0.015	WEST BEND GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7031	X =	175717.2123	175705.0212	CEDAR 2
		Y =	-4627527.9386	-4627395.9023	
		Z =	4371373.4236	4371575.4739	
			RPC	HMP	
2	7043	X =	150378.8479	150367.1033	FARMINGTON W GPS
		Y =	-4632885.0155	-4632752.9840	
		Z =	4366751.8437	4366953.8866	
			RPC	HMP	
3	7054	X =	175224.4135	175212.2208	HOLLAND S GPS
		Y =	-4626429.4613	-4626297.4168	
		Z =	4372540.7076	4372742.7642	
			RPC	HMP	
4	7058	X =	149084.0781	149072.4423	JACKSON N GPS
		Y =	-4641859.1981	-4641727.0770	
		Z =	4357324.4327	4357526.5865	
			RPC	HMP	
5	7076	X =	148823.5905	148811.8195	NEW FANE GPS
		Y =	-4628556.5862	-4628424.5845	
		Z =	4371420.0879	4371622.1328	
			RPC	HMP	
6	7088	X =	171470.8922	171458.9466	PORT WASHINGTON C GPS
		Y =	-4637793.1399	-4637660.9016	
		Z =	4360709.2284	4360911.4901	
			RPC	HMP	
7	7091	X =	168933.6737	168921.4922	RANDOM LAKE GPS
		Y =	-4626676.8409	-4626544.7976	
		Z =	4372578.9114	4372780.9574	
			RPC	HMP	
8	7098	X =	163215.0876	163203.2452	SAUKVILLE C GPS
		Y =	-4639024.6072	-4638892.3535	
		Z =	4359795.9595	4359998.2681	

Appendix B (continued)

```
                              RPC                 HMP
   9   7122          X =     149910.8939         149899.1866       WEBE (WISCORS)
                     Y =   -4637845.2883       -4637713.1980
                     Z =    4361513.9676        4361716.0619
                              RPC                 HMP
  10   7124          X =     151052.9993         151041.2979       WEST BEND GPS
                     Y =   -4637738.0240       -4637605.9359
                     Z =    4361586.6911        4361788.7805


POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

  NO.  POINT ID           NAME

    1    7031          CEDAR 2
    2    7043          FARMINGTON W GPS
    3    7054          HOLLAND S GPS
    4    7058          JACKSON N GPS
    5    7076          NEW FANE GPS
    6    7088          PORT WASHINGTON C GPS
    7    7091          RANDOM LAKE GPS
    8    7098          SAUKVILLE C GPS
    9    7122          WEBE (WISCORS)
   10    7124          WEST BEND GPS


 TRANSFORMATION PARAMETERS FOR POINTS SELECTED:


    TRANSLATION IN X, TX =       -12.9187 M
    TRANSLATION IN Y, TY =        59.6061 M
    TRANSLATION IN Z, TZ =       267.5223 M

    SCALE IN X/Y/Z            -15.319219 PPM

    ROTATION ABOUT X AXIS =    0.00000013 RAD
                               0.02776123 SEC
    ROTATION ABOUT Y AXIS =    0.00000527 RAD
                               1.08787888 SEC
    ROTATION ABOUT Z AXIS =   -0.00000572 RAD
                              -1.18004176 SEC


    REFERENCE VARIANCE =          9.871628
    (SIGMA NAUGHT SQUARED)


FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.


 POINT  CONTROL VALUE  COMPUTED VALUE  DIFF IN   DIFF EAST/NORTH/UP     POINT NAME
  ID       HMP (M)         HMP (M)     X/Y/Z (M)   METERS     FEET

 7031 X=   175705.021     175705.020   0.001  E= -0.001 M  =  0.00 FT  CEDAR 2
      Y= -4627395.902   -4627395.849  -0.054  N= -0.077 M  = -0.25 FT
      Z=  4371575.474    4371575.529  -0.056  U=  0.001 M  =  0.00 FT

 7043 X=   150367.103     150367.099   0.004  E=  0.004 M  =  0.01 FT  FARMINGTON W GPS
      Y= -4632752.984   -4632752.989   0.005  N=  0.003 M  =  0.01 FT
      Z=  4366953.887    4366953.887  -0.001  U= -0.004 M  = -0.01 FT

 7054 X=   175212.221     175212.217   0.004  E=  0.003 M  =  0.01 FT  HOLLAND S GPS
      Y= -4626297.417   -4626297.391  -0.026  N= -0.039 M  = -0.13 FT
      Z=  4372742.764    4372742.793  -0.029  U= -0.001 M  =  0.00 FT
```

Appendix B (continued)

```
7058 X=   149072.442     149072.450  -0.008  E= -0.009 M  = -0.03 FT  JACKSON N GPS
     Y= -4641727.077   -4641727.043  -0.034  N= -0.044 M  = -0.14 FT
     Z=  4357526.587    4357526.615  -0.029  U=  0.005 M  =  0.02 FT

7076 X=   148811.820     148811.816   0.003  E=  0.005 M  =  0.02 FT  NEW FANE GPS
     Y= -4628424.584   -4628424.634   0.050  N=  0.093 M  =  0.31 FT
     Z=  4371622.133    4371622.051   0.081  U=  0.020 M  =  0.07 FT

7088 X=  171458.947     171458.880   0.066   E=  0.067 M  =  0.22 FT PORT WASHINGTON C GPS
     Y= -4637660.902   -4637660.919   0.017  N=  0.020 M  =  0.06 FT
     Z=  4360911.490    4360911.477   0.013  U= -0.001 M  =  0.00 FT

7091 X=   168921.492     168921.575  -0.082  E= -0.082 M  = -0.27 FT  RANDOM LAKE GPS
     Y= -4626544.798   -4626544.803   0.005  N=  0.002 M  =  0.01 FT
     Z=  4372780.957    4372780.963  -0.005  U= -0.010 M  = -0.03 FT

7098 X=   163203.245     163203.214   0.031  E=  0.033 M  =  0.11 FT  SAUKVILLE C GPS
     Y= -4638892.354   -4638892.414   0.061  N=  0.106 M  =  0.35 FT
     Z=  4359998.268    4359998.178   0.090  U=  0.018 M  =  0.06 FT

7122 X=   149899.187     149899.208  -0.022  E= -0.022 M  = -0.07 FT  WEBE (WISCORS)
     Y= -4637713.198   -4637713.189  -0.009  N= -0.026 M  = -0.08 FT
     Z=  4361716.062    4361716.090  -0.028  U= -0.013 M  = -0.04 FT

7124 X=   151041.298     151041.295   0.003  E=  0.002 M  =  0.01 FT  WEST BEND GPS
     Y= -4637605.936   -4637605.920  -0.016  N= -0.038 M  = -0.13 FT
     Z=  4361788.781    4361788.818  -0.038  U= -0.014 M  = -0.05 FT

                          MEAN OF EAST MISCLOSURE =     0.000 FT
                          STANDARD DEVIATION            0.124 FT

                          MEAN OF NORTH MISCLOSURE =    0.000 FT
                          STANDARD DEVIATION =          0.195 FT

                          MEAN OF UP MISCLOSURE =       0.000 FT
                          STANRDARD DEVIATION =         0.039 FT
```

Appendix B (continued)

```
PROGRAM:       PARAMETERS - VER 1.08, EFB:08/11/09
USED BY:       Earl F. Burkholder
DATE:          October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT:      Common points with RPC & HMP values - S Half Ozaukee County

INPUT FILE:   S Half Ozaukee County.dat
OUTPUT FILE:  Ozaukee parameters S Half.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS
```

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7016	0.010	0.010	0.015	0.010	0.010	0.015	2Y46
2	7026	0.030	0.030	0.015	0.010	0.010	0.015	BROWN DEER W GPS
3	7045	0.030	0.030	0.015	0.010	0.010	0.015	FOX
4	7049	0.010	0.010	0.015	0.010	0.010	0.015	GERMANTOWN S GPS
5	7050	0.010	0.010	0.015	0.010	0.010	0.015	GRAFTON
6	7056	0.010	0.010	0.015	0.010	0.010	0.015	JACKSON
7	7057	0.010	0.010	0.015	0.010	0.010	0.015	JACKSON GPS
8	7087	0.010	0.010	0.015	0.010	0.010	0.015	PORT
9	7093	0.010	0.010	0.015	0.010	0.010	0.015	RICHFIELD E GPS
10	7118	0.030	0.030	0.015	0.010	0.010	0.015	WAUWATOSA

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7016				
		X =	168406.3335	168394.4573	2Y46
		Y =	-4643221.3136	-4643089.0388	
		Z =	4355102.3692	4355304.7048	
2	7026				
		X =	159020.5053	159008.8754	BROWN DEER W GPS
		Y =	-4657214.2028	-4657081.5433	
		Z =	4340600.9421	4340803.6384	
3	7045				
		X =	171930.2023	171918.3276	FOX
		Y =	-4656335.3300	-4656202.6120	
		Z =	4341002.7386	4341205.5241	
4	7049				
		X =	155808.2651	155796.6526	GERMANTOWN S GPS
		Y =	-4654944.8805	-4654812.2837	
		Z =	4343125.5371	4343328.2138	
5	7050				
		X =	167623.0774	167611.1964	GRAFTON
		Y =	-4643862.6892	-4643730.4122	
		Z =	4354475.1089	4354677.4414	
6	7056				
		X =	152706.0892	152694.4823	JACKSON
		Y =	-4645175.0414	-4645042.8935	
		Z =	4353665.6750	4353867.8669	
7	7057				
		X =	147307.5686	147296.0207	JACKSON GPS
		Y =	-4646379.0136	-4646246.8324	
		Z =	4352562.0591	4352764.2900	
8	7087				
		X =	168494.5130	168482.6321	PORT
		Y =	-4648527.0665	-4648394.6659	
		Z =	4349438.0920	4349640.5129	
9	7093				
		X =	144587.4862	144575.9946	RICHFIELD E GPS
		Y =	-4650980.5338	-4650848.2485	
		Z =	4347852.7485	4348055.1018	

Appendix B (continued)

```
                                RPC                HMP
  10   7118          X =     162243.5200        162231.8483       WAUWATOSA
                     Y =   -4654138.8182       -4654006.1455
                     Z =    4343720.8364        4343923.5507

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

 NO.  POINT ID           NAME

    1    7016          2Y46
    2    7026          BROWN DEER W GPS
    3    7045          FOX
    4    7049          GERMANTOWN S GPS
    5    7050          GRAFTON
    6    7056          JACKSON
    7    7057          JACKSON GPS
    8    7087          PORT
    9    7093          RICHFIELD E GPS
   10    7118          WAUWATOSA


 TRANSFORMATION PARAMETERS FOR POINTS SELECTED:


    TRANSLATION IN X, TX =       -14.9414 M
    TRANSLATION IN Y, TY =        36.8837 M
    TRANSLATION IN Z, TZ =       298.7646 M

    SCALE IN X/Y/Z            -21.265511 PPM

    ROTATION ABOUT X AXIS =  -0.00000100 RAD
                             -0.20590687 SEC
    ROTATION ABOUT Y AXIS =   0.00000490 RAD
                              1.01036380 SEC
    ROTATION ABOUT Z AXIS =  -0.00000601 RAD
                             -1.23877707 SEC


    REFERENCE VARIANCE =        26.474268
    (SIGMA NAUGHT SQUARED)



FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.


 POINT  CONTROL VALUE  COMPUTED VALUE  DIFF IN   DIFF EAST/NORTH/UP     POINT NAME
  ID       HMP (M)        HMP (M)     X/Y/Z (M)   METERS     FEET

 7016 X=   168394.457     168394.364   0.093  E=  0.093 M  =  0.30 FT  2Y46
      Y= -4643089.039   -4643089.026  -0.013  N= -0.015 M  = -0.05 FT
      Z=  4355304.705    4355304.710  -0.005  U=  0.008 M  =  0.03 FT

 7026 X=   159008.875     159008.890  -0.015  E= -0.011 M  = -0.04 FT  BROWN DEER W GPS
      Y= -4657081.543   -4657081.659   0.116  N=  0.158 M  =  0.52 FT
      Z=  4340803.638    4340803.531   0.107  U= -0.012 M  = -0.04 FT

 7045 X=   171918.328     171918.306   0.022  E=  0.026 M  =  0.09 FT  FOX
      Y= -4656202.612   -4656202.728   0.116  N=  0.181 M  =  0.59 FT
      Z=  4341205.524    4341205.383   0.141  U=  0.012 M  =  0.04 FT

 7049 X=   155796.653     155796.693  -0.040  E= -0.036 M  = -0.12 FT  GERMANTOWN S GPS
      Y= -4654812.284   -4654812.407   0.123  N=  0.198 M  =  0.65 FT
      Z=  4343328.214    4343328.059   0.155  U=  0.015 M  =  0.05 FT
```

Appendix B (continued)

```
7050 X=   167611.196     167611.131   0.065  E=  0.064 M  =  0.21 FT  GRAFTON
     Y= -4643730.412   -4643730.392  -0.021  N= -0.028 M  = -0.09 FT
     Z=  4354677.441    4354677.459  -0.017  U=  0.005 M  =  0.02 FT

7056 X=   152694.482     152694.472   0.010  E=  0.007 M  =  0.02 FT  JACKSON
     Y= -4645042.894   -4645042.805  -0.089  N= -0.134 M  = -0.44 FT
     Z=  4353867.867    4353867.968  -0.101  U= -0.004 M  = -0.01 FT

7057 X=   147296.021     147296.079  -0.058  E= -0.060 M  = -0.20 FT  JACKSON GPS
     Y= -4646246.832   -4646246.783  -0.050  N= -0.075 M  = -0.25 FT
     Z=  4352764.290    4352764.347  -0.057  U= -0.005 M  = -0.01 FT

7087 X=   168482.632     168482.601   0.031  E=  0.031 M  =  0.10 FT  PORT
     Y= -4648394.666   -4648394.659  -0.006  N= -0.031 M  = -0.10 FT
     Z=  4349640.513    4349640.548  -0.036  U= -0.019 M  = -0.06 FT

7093 X=   144575.995     144576.105  -0.111  E= -0.112 M  = -0.37 FT  RICHFIELD E GPS
     Y= -4650848.248   -4650848.217  -0.032  N= -0.032 M  = -0.11 FT
     Z=  4348055.102    4348055.119  -0.017  U=  0.009 M  =  0.03 FT

7118 X=   162231.848     162231.803   0.045  E=  0.052 M  =  0.17 FT  WAUWATOSA
     Y= -4654006.145   -4654006.324   0.178  N=  0.247 M  =  0.81 FT
     Z=  4343923.551    4343923.378   0.173  U= -0.011 M  = -0.03 FT

                          MEAN OF EAST MISCLOSURE =     0.018 FT
                          STANDARD DEVIATION            0.202 FT

                          MEAN OF NORTH MISCLOSURE =    0.153 FT
                          STANDARD DEVIATION =          0.441 FT

                          MEAN OF UP MISCLOSURE =       0.000 FT
                          STANRDARD DEVIATION =         0.038 FT
```

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - East Half Racine County

INPUT FILE: Racine County E Half.dat
OUTPUT FILE: Racine parameters E Half.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7020	0.010	0.010	0.015	0.010	0.010	0.015	BEAUMONT
2	7027	0.010	0.010	0.015	0.010	0.010	0.015	BUCYRUS
3	7029	0.010	0.010	0.015	0.010	0.010	0.015	CALEDONIA GPS
4	7030	0.010	0.010	0.015	0.010	0.010	0.015	CALEDONIA W GPS
5	7046	0.010	0.010	0.015	0.010	0.010	0.015	FRANKLIN
6	7075	0.010	0.010	0.015	0.010	0.010	0.015	MUSKEGO E GPS
7	7083	0.010	0.010	0.015	0.010	0.010	0.015	PLEASANT 2
8	7089	0.010	0.010	0.015	0.010	0.010	0.015	RACINE
9	7103	0.010	0.010	0.015	0.010	0.010	0.015	SIWI (WISCORS)
10	7104	0.010	0.010	0.015	0.010	0.010	0.015	SOMERS S GPS
11	7111	0.010	0.010	0.015	0.010	0.010	0.015	UNION GROVE GPS
12	7129	0.010	0.010	0.015	0.010	0.010	0.015	YORKVILLE E GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7020				
		X =	154898.6229	154887.5357	BEAUMONT
		Y =	-4689167.3941	-4689034.5385	
		Z =	4306452.7874	4306655.7054	
2	7027				
		X =	176514.7734	176503.5151	BUCYRUS
		Y =	-4679385.7077	-4679252.6591	
		Z =	4316143.4761	4316346.6080	
3	7029				
		X =	170499.7083	170488.5681	CALEDONIA GPS
		Y =	-4682077.5437	-4681944.5576	
		Z =	4313467.9449	4313670.9714	
4	7030				
		X =	170603.0378	170591.9581	CALEDONIA W GPS
		Y =	-4685106.9349	-4684973.9438	
		Z =	4310213.5126	4310416.5490	
5	7046				
		X =	161246.9831	161235.8052	FRANKLIN
		Y =	-4678854.5374	-4678721.6370	
		Z =	4317343.1045	4317546.0063	
6	7075				
		X =	156989.0379	156977.7951	MUSKEGO E GPS
		Y =	-4679769.5139	-4679636.6313	
		Z =	4316508.5467	4316711.4241	
7	7083				
		X =	171525.2586	171514.2788	PLEASANT 2
		Y =	-4689075.8636	-4688942.8805	
		Z =	4305905.2119	4306108.2667	
8	7089				
		X =	178924.5139	178913.5357	RACINE
		Y =	-4690067.8305	-4689934.8380	
		Z =	4304481.9273	4304685.0035	

Appendix B (continued)

			RPC	HMP	
9	7103	X =	164807.4013	164796.2279	SIWI (WISCORS)
		Y =	-4679319.0237	-4679186.1132	
		Z =	4316686.4581	4316889.3719	
			RPC	HMP	
10	7104	X =	174103.3976	174092.5062	SOMERS S GPS
		Y =	-4698882.6276	-4698749.7771	
		Z =	4295155.7560	4295358.6528	
			RPC	HMP	
11	7111	X =	158811.0039	158799.9578	UNION GROVE GPS
		Y =	-4693213.1888	-4693080.3460	
		Z =	4301930.6877	4302133.5729	
			RPC	HMP	
12	7129	X =	165731.5309	165720.5312	YORKVILLE E GPS
		Y =	-4692399.4972	-4692266.6552	
		Z =	4302549.4344	4302752.3711	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7020	BEAUMONT
2	7027	BUCYRUS
3	7029	CALEDONIA GPS
4	7030	CALEDONIA W GPS
5	7046	FRANKLIN
6	7075	MUSKEGO E GPS
7	7083	PLEASANT 2
8	7089	RACINE
9	7103	SIWI (WISCORS)
10	7104	SOMERS S GPS
11	7111	UNION GROVE GPS
12	7129	YORKVILLE E GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX =	-5.8655 M
TRANSLATION IN Y, TY =	144.2596 M
TRANSLATION IN Z, TZ =	179.2668 M
SCALE IN X/Y/Z	3.806769 PPM
ROTATION ABOUT X AXIS =	0.00000125 RAD
	0.25865522 SEC
ROTATION ABOUT Y AXIS =	0.00000853 RAD
	1.75910117 SEC
ROTATION ABOUT Z AXIS =	-0.00000659 RAD
	-1.35954275 SEC
REFERENCE VARIANCE =	9.607348
(SIGMA NAUGHT SQUARED)	

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	FEET	POINT NAME
7020 X=	154887.536	154887.528	0.008 E=	0.009 M =	0.03 FT	BEAUMONT
Y=	-4689034.538	-4689034.564	0.025 N=	0.058 M =	0.19 FT	
Z=	4306655.705	4306655.649	0.056 U=	0.020 M =	0.06 FT	

Appendix B (continued)

7027	X=	176503.515	176503.613	-0.098	E= -0.097 M	= -0.32 FT	BUCYRUS
	Y=	-4679252.659	-4679252.686	0.026	N= 0.065 M	= 0.21 FT	
	Z=	4316346.608	4316346.547	0.061	U= 0.020 M	= 0.06 FT	
7029	X=	170488.568	170488.566	0.002	E= 0.003 M	= 0.01 FT	CALEDONIA GPS
	Y=	-4681944.558	-4681944.575	0.017	N= 0.022 M	= 0.07 FT	
	Z=	4313670.971	4313670.957	0.014	U= -0.003 M	= -0.01 FT	
7030	X=	170591.958	170591.943	0.015	E= 0.016 M	= 0.05 FT	CALEDONIA W GPS
	Y=	-4684973.944	-4684973.981	0.037	N= 0.048 M	= 0.16 FT	
	Z=	4310416.549	4310416.517	0.032	U= -0.005 M	= -0.02 FT	
7046	X=	161235.805	161235.751	0.054	E= 0.053 M	= 0.17 FT	FRANKLIN
	Y=	-4678721.637	-4678721.612	-0.025	N= -0.049 M	= -0.16 FT	
	Z=	4317546.006	4317546.049	-0.043	U= -0.010 M	= -0.03 FT	
7075	X=	156977.795	156977.803	-0.008	E= -0.008 M	= -0.03 FT	MUSKEGO E GPS
	Y=	-4679636.631	-4679636.621	-0.010	N= -0.027 M	= -0.09 FT	
	Z=	4316711.424	4316711.453	-0.029	U= -0.012 M	= -0.04 FT	
7083	X=	171514.279	171514.231	0.048	E= 0.050 M	= 0.16 FT	PLEASANT 2
	Y=	-4688942.880	-4688942.924	0.044	N= 0.068 M	= 0.22 FT	
	Z=	4306108.267	4306108.213	0.053	U= 0.006 M	= 0.02 FT	
7089	X=	178913.536	178913.533	0.003	E= 0.003 M	= 0.01 FT	RACINE
	Y=	-4689934.838	-4689934.848	0.010	N= 0.018 M	= 0.06 FT	
	Z=	4304685.003	4304684.988	0.016	U= 0.004 M	= 0.01 FT	
7103	X=	164796.228	164796.192	0.036	E= 0.035 M	= 0.12 FT	SIWI (WISCORS)
	Y=	-4679186.113	-4679186.078	-0.035	N= -0.068 M	= -0.22 FT	
	Z=	4316889.372	4316889.431	-0.059	U= -0.013 M	= -0.04 FT	
7104	X=	174092.506	174092.536	-0.030	E= -0.032 M	= -0.10 FT	SOMERS S GPS
	Y=	-4698749.777	-4698749.722	-0.055	N= -0.109 M	= -0.36 FT	
	Z=	4295358.653	4295358.751	-0.098	U= -0.026 M	= -0.09 FT	
7111	X=	158799.958	158799.989	-0.031	E= -0.031 M	= -0.10 FT	UNION GROVE GPS
	Y=	-4693080.346	-4693080.354	0.008	N= 0.008 M	= 0.03 FT	
	Z=	4302133.573	4302133.571	0.002	U= -0.005 M	= -0.02 FT	
7129	X=	165720.531	165720.531	0.000	E= -0.002 M	= -0.01 FT	YORKVILLE E GPS
	Y=	-4692266.655	-4692266.613	-0.042	N= -0.034 M	= -0.11 FT	
	Z=	4302752.371	4302752.378	-0.007	U= 0.027 M	= 0.09 FT	

MEAN OF EAST MISCLOSURE =	0.000 FT
STANDARD DEVIATION	0.134 FT
MEAN OF NORTH MISCLOSURE =	0.000 FT
STANDARD DEVIATION =	0.188 FT
MEAN OF UP MISCLOSURE =	0.000 FT
STANRDARD DEVIATION =	0.052 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - Racine County W. Half

INPUT FILE: Racine County W Half.dat
OUTPUT FILE: Racine parameters W Half.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7020	0.010	0.010	0.015	0.010	0.010	0.015	BEAUMONT
2	7023	0.010	0.010	0.015	0.010	0.010	0.015	BRIGHTON N GPS
3	7028	0.010	0.010	0.015	0.010	0.010	0.015	BURLINGTON W GPS
4	7046	0.010	0.010	0.015	0.010	0.010	0.015	FRANKLIN
5	7055	0.010	0.010	0.015	0.010	0.010	0.015	HONEY 2
6	7067	0.010	0.010	0.015	0.010	0.010	0.015	LYONS N GPS
7	7074	0.030	0.030	0.015	0.010	0.010	0.015	MUKWONAGO GPS
8	7075	0.010	0.010	0.015	0.010	0.010	0.015	MUSKEGO E GPS
9	7094	0.010	0.010	0.015	0.010	0.010	0.015	ROCHESTER C GPS
10	7111	0.010	0.010	0.015	0.010	0.010	0.015	UNION GROVE GPS
11	7113	0.010	0.010	0.015	0.010	0.010	0.015	WATERFORD GPS
12	7114	0.010	0.010	0.015	0.010	0.010	0.015	WATERFORD W GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7020	X =	154898.6229	154887.5357	BEAUMONT
		Y =	-4689167.3941	-4689034.5385	
		Z =	4306452.7874	4306655.7054	
			RPC	HMP	
2	7023	X =	150620.4362	150609.2804	BRIGHTON N GPS
		Y =	-4695864.2678	-4695731.5175	
		Z =	4299344.6098	4299547.3877	
			RPC	HMP	
3	7028	X =	139166.1983	139154.9709	BURLINGTON W GPS
		Y =	-4698962.6413	-4698829.9647	
		Z =	4296398.1212	4296600.7692	
			RPC	HMP	
4	7046	X =	161246.9831	161235.8052	FRANKLIN
		Y =	-4678854.5374	-4678721.6370	
		Z =	4317343.1045	4317546.0063	
			RPC	HMP	
5	7055	X =	133345.4027	133334.0608	HONEY 2
		Y =	-4689911.5769	-4689778.8825	
		Z =	4306449.7930	4306652.4921	
			RPC	HMP	
6	7067	X =	133719.2050	133707.9356	LYONS N GPS
		Y =	-4696546.2268	-4696413.5740	
		Z =	4299187.1288	4299389.7442	
			RPC	HMP	
7	7074	X =	137090.2107	137078.8886	MUKWONAGO GPS
		Y =	-4681435.8065	-4681302.8932	
		Z =	4315406.0030	4315608.9254	
			RPC	HMP	
8	7075	X =	156989.0379	156977.7951	MUSKEGO E GPS
		Y =	-4679769.5139	-4679636.6313	
		Z =	4316508.5467	4316711.4241	

			RPC	HMP	
9	7094	X =	144327.6311	144316.4255	ROCHESTER C GPS
		Y =	-4692035.8645	-4691903.0795	
		Z =	4303702.1728	4303904.9814	
			RPC	HMP	
10	7111	X =	158811.0039	158799.9578	UNION GROVE GPS
		Y =	-4693213.1888	-4693080.3460	
		Z =	4301930.6877	4302133.5729	
			RPC	HMP	
11	7113	X =	148018.0148	148006.8446	WATERFORD GPS
		Y =	-4686713.1316	-4686580.2865	
		Z =	4309341.8124	4309544.7194	
			RPC	HMP	
12	7114	X =	141716.2281	141704.9838	WATERFORD W GPS
		Y =	-4685726.7024	-4685593.8378	
		Z =	4310627.4591	4310830.3728	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7020	BEAUMONT
2	7023	BRIGHTON N GPS
3	7028	BURLINGTON W GPS
4	7046	FRANKLIN
5	7055	HONEY 2
6	7067	LYONS N GPS
7	7074	MUKWONAGO GPS
8	7075	MUSKEGO E GPS
9	7094	ROCHESTER C GPS
10	7111	UNION GROVE GPS
11	7113	WATERFORD GPS
12	7114	WATERFORD W GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX =	-6.8868 M
TRANSLATION IN Y, TY =	172.0302 M
TRANSLATION IN Z, TZ =	163.6727 M
SCALE IN X/Y/Z	8.676731 PPM
ROTATION ABOUT X AXIS =	0.00000022 RAD
	0.04563603 SEC
ROTATION ABOUT Y AXIS =	0.00000503 RAD
	1.03726444 SEC
ROTATION ABOUT Z AXIS =	-0.00000343 RAD
	-0.70657289 SEC
REFERENCE VARIANCE =	11.256940
(SIGMA NAUGHT SQUARED)	

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	FEET	POINT NAME
7020 X=	154887.536	154887.487	0.049	E= 0.050 M	= 0.16 FT	BEAUMONT
Y=	-4689034.538	-4689034.567	0.029	N= 0.065 M	= 0.21 FT	
Z=	4306655.705	4306655.642	0.063	U= 0.023 M	= 0.08 FT	

Appendix B (continued)

```
7023 X=   150609.280     150609.322  -0.041  E= -0.041 M  = -0.14 FT  BRIGHTON N GPS
     Y= -4695731.518   -4695731.515  -0.002  N=  0.003 M  =  0.01 FT
     Z=  4299547.388    4299547.383   0.005  U=  0.004 M  =  0.01 FT

7028 X=   139154.971     139155.010  -0.039  E= -0.039 M  = -0.13 FT  BURLINGTON W GPS
     Y= -4698829.965   -4698829.955  -0.009  N= -0.037 M  = -0.12 FT
     Z=  4296600.769    4296600.812  -0.043  U= -0.023 M  = -0.08 FT

7046 X=   161235.805     161235.812  -0.007  E= -0.008 M  = -0.03 FT  FRANKLIN
     Y= -4678721.637   -4678721.597  -0.040  N= -0.084 M  = -0.28 FT
     Z=  4317546.006    4317546.084  -0.077  U= -0.023 M  = -0.08 FT

7055 X=   133334.061     133334.082  -0.021  E= -0.023 M  = -0.08 FT  HONEY 2
     Y= -4689778.883   -4689778.830  -0.052  N= -0.070 M  = -0.23 FT
     Z=  4306652.492    4306652.540  -0.048  U=  0.006 M  =  0.02 FT

7067 X=   133707.936     133707.947  -0.011  E= -0.012 M  = -0.04 FT  LYONS N GPS
     Y= -4696413.574   -4696413.538  -0.036  N= -0.077 M  = -0.25 FT
     Z=  4299389.744    4299389.816  -0.072  U= -0.022 M  = -0.07 FT

7074 X=   137078.889     137078.849   0.040  E=  0.042 M  =  0.14 FT  MUKWONAGO GPS
     Y= -4681302.893   -4681302.971   0.078  N=  0.112 M  =  0.37 FT
     Z=  4315608.925    4315608.844   0.081  U= -0.001 M  =  0.00 FT

7075 X=   156977.795     156977.837  -0.042  E= -0.043 M  = -0.14 FT  MUSKEGO E GPS
     Y= -4679636.631   -4679636.596  -0.035  N= -0.077 M  = -0.25 FT
     Z=  4316711.424    4316711.497  -0.073  U= -0.025 M  = -0.08 FT

7094 X=   144316.426     144316.427  -0.001  E= -0.001 M  =  0.00 FT  ROCHESTER C GPS
     Y= -4691903.079   -4691903.099   0.020  N=  0.035 M  =  0.12 FT
     Z=  4303904.981    4303904.951   0.030  U=  0.006 M  =  0.02 FT

7111 X=   158799.958     158799.938   0.019  E=  0.021 M  =  0.07 FT  UNION GROVE GPS
     Y= -4693080.346   -4693080.385   0.039  N=  0.062 M  =  0.20 FT
     Z=  4302133.573    4302133.524   0.049  U=  0.005 M  =  0.02 FT

7113 X=   148006.845     148006.796   0.048  E=  0.049 M  =  0.16 FT  WATERFORD GPS
     Y= -4686580.287   -4686580.306   0.020  N=  0.058 M  =  0.19 FT
     Z=  4309544.719    4309544.657   0.062  U=  0.029 M  =  0.09 FT

7114 X=   141704.984     141704.945   0.039  E=  0.040 M  =  0.13 FT  WATERFORD W GPS
     Y= -4685593.838   -4685593.890   0.052  N=  0.100 M  =  0.33 FT
     Z=  4310830.373    4310830.283   0.089  U=  0.023 M  =  0.08 FT

                         MEAN OF EAST MISCLOSURE =     0.009 FT
                         STANDARD DEVIATION            0.119 FT

                         MEAN OF NORTH MISCLOSURE =    0.024 FT
                         STANDARD DEVIATION =          0.241 FT

                         MEAN OF UP MISCLOSURE =       0.000 FT
                         STANRDARD DEVIATION =         0.064 FT
```

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - NE Qtr Walworth County

INPUT FILE: Walworth County NE.dat
OUTPUT FILE: Walworth parameters NE.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7039	0.030	0.030	0.015	0.010	0.010	0.015	EAGLE E GPS
2	7040	0.030	0.030	0.015	0.010	0.010	0.015	EAST TROY
3	7041	0.010	0.010	0.015	0.010	0.010	0.015	ELKHORN GPS
4	7055	0.010	0.010	0.015	0.010	0.010	0.015	HONEY 2
5	7060	0.010	0.010	0.015	0.010	0.010	0.015	JERICHO
6	7065	0.010	0.010	0.015	0.010	0.010	0.015	LA GRANGE E GPS
7	7067	0.010	0.010	0.015	0.010	0.010	0.015	LYONS N GPS
8	7074	0.030	0.030	0.015	0.010	0.010	0.015	MUKWONAGO GPS
9	7094	0.010	0.010	0.015	0.010	0.010	0.015	ROCHESTER C GPS
10	7108	0.010	0.010	0.015	0.010	0.010	0.015	SUGAR CREEK S GPS
11	7109	0.010	0.010	0.015	0.010	0.010	0.015	TIBBETS GPS
12	7114	0.010	0.010	0.015	0.010	0.010	0.015	WATERFORD W GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7039	X =	125825.5528	125814.1682	EAGLE E GPS
		Y =	-4678743.8492	-4678611.1419	
		Z =	4318704.5740	4318907.3078	
2	7040	X =	129786.0315	129774.6908	EAST TROY
		Y =	-4688646.1049	-4688513.4393	
		Z =	4307946.3428	4308149.0050	
3	7041	X =	121672.6836	121661.3352	ELKHORN GPS
		Y =	-4696005.2682	-4695872.7096	
		Z =	4300210.8579	4300413.3809	
4	7055	X =	133345.4027	133334.0608	HONEY 2
		Y =	-4689911.5769	-4689778.8825	
		Z =	4306449.7930	4306652.4921	
5	7060	X =	132410.5736	132399.2194	JERICHO
		Y =	-4679848.5692	-4679715.7517	
		Z =	4317337.9355	4317540.7642	
6	7065	X =	116347.2498	116335.8118	LA GRANGE E GPS
		Y =	-4686441.9217	-4686309.4311	
		Z =	4310669.5255	4310872.0286	
7	7067	X =	133719.2050	133707.9356	LYONS N GPS
		Y =	-4696546.2268	-4696413.5740	
		Z =	4299187.1288	4299389.7442	
8	7074	X =	137090.2107	137078.8886	MUKWONAGO GPS
		Y =	-4681435.8065	-4681302.8932	
		Z =	4315406.0030	4315608.9254	

			RPC	HMP	
9	7094	X =	144327.6311	144316.4255	ROCHESTER C GPS
		Y =	-4692035.8645	-4691903.0795	
		Z =	4303702.1728	4303904.9814	
			RPC	HMP	
10	7108	X =	115859.3985	115848.0208	SUGAR CREEK S GPS
		Y =	-4694117.3606	-4693984.8425	
		Z =	4302397.7437	4302600.2131	
			RPC	HMP	
11	7109	X =	115245.8936	115234.4425	TIBBETS GPS
		Y =	-4690174.9783	-4690042.5265	
		Z =	4306662.1432	4306864.5675	
			RPC	HMP	
12	7114	X =	141716.2281	141704.9838	WATERFORD W GPS
		Y =	-4685726.7024	-4685593.8378	
		Z =	4310627.4591	4310830.3728	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7039	EAGLE E GPS
2	7040	EAST TROY
3	7041	ELKHORN GPS
4	7055	HONEY 2
5	7060	JERICHO
6	7065	LA GRANGE E GPS
7	7067	LYONS N GPS
8	7074	MUKWONAGO GPS
9	7094	ROCHESTER C GPS
10	7108	SUGAR CREEK S GPS
11	7109	TIBBETS GPS
12	7114	WATERFORD W GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX =	-9.6707 M
TRANSLATION IN Y, TY =	179.6959 M
TRANSLATION IN Z, TZ =	167.9729 M
SCALE IN X/Y/Z	9.116148 PPM
ROTATION ABOUT X AXIS =	-0.00000125 RAD
	-0.25751815 SEC
ROTATION ABOUT Y AXIS =	0.00000989 RAD
	2.03970464 SEC
ROTATION ABOUT Z AXIS =	-0.00000848 RAD
	-1.74838854 SEC
REFERENCE VARIANCE =	18.930573
(SIGMA NAUGHT SQUARED)	

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7039 X=	125814.168	125813.982	0.187	E= 0.186 M	= 0.61 FT	EAGLE E GPS
Y=	-4678611.142	-4678611.131	-0.011	N= -0.020 M	= -0.06 FT	
Z=	4318907.308	4318907.320	-0.012	U= 0.004 M	= 0.01 FT	

Appendix B (continued)

7040	X=	129774.691	129774.687	0.004	E=	0.004 M	= 0.01 FT	EAST TROY
	Y=	-4688513.439	-4688513.430	-0.010	N=	-0.016 M	= -0.05 FT	
	Z=	4308149.005	4308149.017	-0.012	U=	-0.001 M	= 0.00 FT	
7041	X=	121661.335	121661.404	-0.068	E=	-0.068 M	= -0.22 FT	ELKHORN GPS
	Y=	-4695872.710	-4695872.719	0.010	N=	0.014 M	= 0.05 FT	
	Z=	4300413.381	4300413.372	0.008	U=	-0.003 M	= -0.01 FT	
7055	X=	133334.061	133334.116	-0.055	E=	-0.055 M	= -0.18 FT	HONEY 2
	Y=	-4689778.883	-4689778.881	-0.001	N=	0.004 M	= 0.01 FT	
	Z=	4306652.492	4306652.487	0.005	U=	0.003 M	= 0.01 FT	
7060	X=	132399.219	132399.085	0.134	E=	0.136 M	= 0.44 FT	JERICHO
	Y=	-4679715.752	-4679715.803	0.052	N=	0.056 M	= 0.18 FT	
	Z=	4317540.764	4317540.733	0.032	U=	-0.013 M	= -0.04 FT	
7065	X=	116335.812	116335.737	0.075	E=	0.073 M	= 0.24 FT	LA GRANGE E GPS
	Y=	-4686309.431	-4686309.344	-0.087	N=	-0.109 M	= -0.36 FT	
	Z=	4310872.029	4310872.095	-0.066	U=	0.021 M	= 0.07 FT	
7067	X=	133707.936	133708.050	-0.114	E=	-0.114 M	= -0.37 FT	LYONS N GPS
	Y=	-4696413.574	-4696413.579	0.005	N=	0.000 M	= 0.00 FT	
	Z=	4299389.744	4299389.752	-0.008	U=	-0.012 M	= -0.04 FT	
7074	X=	137078.889	137078.798	0.091	E=	0.094 M	= 0.31 FT	MUKWONAGO GPS
	Y=	-4681302.893	-4681303.013	0.120	N=	0.152 M	= 0.50 FT	
	Z=	4315608.925	4315608.827	0.099	U=	-0.019 M	= -0.06 FT	
7094	X=	144316.426	144316.490	-0.064	E=	-0.064 M	= -0.21 FT	ROCHESTER C GPS
	Y=	-4691903.079	-4691903.092	0.012	N=	0.034 M	= 0.11 FT	
	Z=	4303904.981	4303904.948	0.033	U=	0.012 M	= 0.04 FT	
7108	X=	115848.021	115848.028	-0.007	E=	-0.007 M	= -0.02 FT	SUGAR CREEK S GPS
	Y=	-4693984.843	-4693984.846	0.004	N=	-0.005 M	= -0.02 FT	
	Z=	4302600.213	4302600.223	-0.010	U=	-0.010 M	= -0.03 FT	
7109	X=	115234.443	115234.442	0.001	E=	-0.002 M	= -0.01 FT	TIBBETS GPS
	Y=	-4690042.526	-4690042.439	-0.088	N=	-0.128 M	= -0.42 FT	
	Z=	4306864.567	4306864.660	-0.093	U=	0.002 M	= 0.01 FT	
7114	X=	141704.984	141704.941	0.043	E=	0.045 M	= 0.15 FT	WATERFORD W GPS
	Y=	-4685593.838	-4685593.903	0.065	N=	0.112 M	= 0.37 FT	
	Z=	4310830.373	4310830.280	0.093	U=	0.017 M	= 0.05 FT	

MEAN OF EAST MISCLOSURE =	0.062 FT
STANDARD DEVIATION	0.296 FT
MEAN OF NORTH MISCLOSURE =	0.026 FT
STANDARD DEVIATION =	0.258 FT
MEAN OF UP MISCLOSURE =	0.000 FT
STANRDARD DEVIATION =	0.040 FT

Appendix B (continued)

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PROGRAM:       PARAMETERS - VER 1.08, EFB:08/11/09
USED BY:       Earl F. Burkholder
DATE:          October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT:      Common points with RPC & HMP values - NW Qtr Walworth County

INPUT FILE:   Walworth County NW.dat
OUTPUT FILE:  Walworth parameters NW.txt


LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

                          RPC                          HMP
  NO.   PT ID        N        E        U          N        E        U      STATION NAME

    1   7022       0.010    0.010    0.015      0.010    0.010    0.015    BRADFORD S GPS
    2   7034       0.010    0.010    0.015      0.010    0.010    0.015    DARIEN E GPS
    3   7041       0.010    0.010    0.015      0.010    0.010    0.015    ELKHORN GPS
    4   7059       0.010    0.010    0.015      0.010    0.010    0.015    JALE (WISCORS)
    5   7065       0.010    0.010    0.015      0.010    0.010    0.015    LA GRANGE E GPS
    6   7070       0.010    0.010    0.015      0.010    0.010    0.015    MILLARD
    7   7080       0.010    0.010    0.015      0.010    0.010    0.015    PAR0  (WISCORS)
    8   7105       0.010    0.010    0.015      0.010    0.010    0.015    SPRING 2
    9   7108       0.010    0.010    0.015      0.010    0.010    0.015    SUGAR CREEK S GPS
   10   7109       0.010    0.010    0.015      0.010    0.010    0.015    TIBBETS GPS
   11   7125       0.010    0.010    0.015      0.010    0.010    0.015    WHITEWATER
   12   7126       0.010    0.010    0.015      0.010    0.010    0.015    WHITEWATER GPS
   13   7127       0.010    0.010    0.015      0.010    0.010    0.015    WHITEWATER W GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

                              RPC                 HMP
    1   7022          X =     98438.0889          98426.6925       BRADFORD S GPS
                      Y =  -4701318.9386       -4701186.4974
                      Z =   4294952.4366        4295154.7991
                              RPC                 HMP
    2   7034          X =    108921.2492         108909.8554       DARIEN E GPS
                      Y =  -4699749.8569       -4699617.3587
                      Z =   4296441.0162        4296643.4308
                              RPC                 HMP
    3   7041          X =    121672.6836         121661.3352       ELKHORN GPS
                      Y =  -4696005.2682       -4695872.7096
                      Z =   4300210.8579        4300413.3809
                              RPC                 HMP
    4   7059          X =     79536.9672          79525.4335       JALE (WISCORS)
                      Y =  -4693425.3636       -4693292.9012
                      Z =   4303926.5815        4304128.9351
                              RPC                 HMP
    5   7065          X =    116347.2498         116335.8118       LA GRANGE E GPS
                      Y =  -4686441.9217       -4686309.4311
                      Z =   4310669.5255        4310872.0286
                              RPC                 HMP
    6   7070          X =    112743.5917         112732.1239       MILLARD
                      Y =  -4689395.6641       -4689263.2083
                      Z =   4307574.4896        4307776.9092
                              RPC                 HMP
    7   7080          X =    114982.3218         114970.9158       PAR0  (WISCORS)
                      Y =  -4680393.2744       -4680260.7516
                      Z =   4317196.2985        4317398.8063
                              RPC                 HMP
    8   7105          X =    110620.5269         110609.1097       SPRING 2
                      Y =  -4680862.5954       -4680730.0975
                      Z =   4316767.0154        4316969.4798
```

Appendix B (continued)

			RPC	HMP	
9	7108	X =	115859.3985	115848.0208	SUGAR CREEK S GPS
		Y =	-4694117.3606	-4693984.8425	
		Z =	4302397.7437	4302600.2131	
			RPC	HMP	
10	7109	X =	115245.8936	115234.4425	TIBBETS GPS
		Y =	-4690174.9783	-4690042.5265	
		Z =	4306662.1432	4306864.5675	
			RPC	HMP	
11	7125	X =	103038.2339	103026.8451	WHITEWATER
		Y =	-4683101.9341	-4682969.4724	
		Z =	4314574.8168	4314777.1336	
			RPC	HMP	
12	7126	X =	106333.2325	106321.8057	WHITEWATER GPS
		Y =	-4684508.4153	-4684375.9782	
		Z =	4312966.2089	4313168.6367	
			RPC	HMP	
13	7127	X =	100125.9038	100114.4742	WHITEWATER W GPS
		Y =	-4685901.7438	-4685769.3036	
		Z =	4311626.7804	4311829.1514	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7022	BRADFORD S GPS
2	7034	DARIEN E GPS
3	7041	ELKHORN GPS
4	7059	JALE (WISCORS)
5	7065	LA GRANGE E GPS
6	7070	MILLARD
7	7080	PAR0 (WISCORS)
8	7105	SPRING 2
9	7108	SUGAR CREEK S GPS
10	7109	TIBBETS GPS
11	7125	WHITEWATER
12	7126	WHITEWATER GPS
13	7127	WHITEWATER W GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX =	-1.2902 M
TRANSLATION IN Y, TY =	142.3429 M
TRANSLATION IN Z, TZ =	198.0520 M
SCALE IN X/Y/Z	1.578189 PPM
ROTATION ABOUT X AXIS =	-0.00000059 RAD
	-0.12169368 SEC
ROTATION ABOUT Y AXIS =	0.00000319 RAD
	0.65809194 SEC
ROTATION ABOUT Z AXIS =	-0.00000073 RAD
	-0.15136425 SEC
REFERENCE VARIANCE =	8.901535
(SIGMA NAUGHT SQUARED)	

Appendix B (continued)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7022 X=	98426.693	98426.701	-0.008	E= -0.009 M	= -0.03 FT	BRADFORD S GPS
Y=	-4701186.497	-4701186.477	-0.020	N= -0.020 M	= -0.06 FT	
Z=	4295154.799	4295154.807	-0.008	U= 0.009 M	= 0.03 FT	
7034 X=	108909.855	108909.872	-0.016	E= -0.016 M	= -0.05 FT	DARIEN E GPS
Y=	-4699617.359	-4699617.386	0.027	N= 0.024 M	= 0.08 FT	
Z=	4296643.431	4296643.423	0.007	U= -0.015 M	= -0.05 FT	
7041 X=	121661.335	121661.312	0.024	E= 0.026 M	= 0.08 FT	ELKHORN GPS
Y=	-4695872.710	-4695872.784	0.075	N= 0.099 M	= 0.33 FT	
Z=	4300413.381	4300413.314	0.067	U= -0.009 M	= -0.03 FT	
7059 X=	79525.433	79525.515	-0.081	E= -0.081 M	= -0.27 FT	JALE (WISCORS)
Y=	-4693292.901	-4693292.909	0.007	N= 0.024 M	= 0.08 FT	
Z=	4304128.935	4304128.911	0.025	U= 0.010 M	= 0.03 FT	
7065 X=	116335.812	116335.829	-0.017	E= -0.017 M	= -0.06 FT	LA GRANGE E GPS
Y=	-4686309.431	-4686309.433	0.002	N= 0.032 M	= 0.11 FT	
Z=	4310872.029	4310871.987	0.042	U= 0.027 M	= 0.09 FT	
7070 X=	112732.124	112732.177	-0.053	E= -0.054 M	= -0.18 FT	MILLARD
Y=	-4689263.208	-4689263.181	-0.028	N= -0.035 M	= -0.12 FT	
Z=	4307776.909	4307776.933	-0.024	U= 0.003 M	= 0.01 FT	
7080 X=	114970.916	114970.874	0.042	E= 0.043 M	= 0.14 FT	PAR0 (WISCORS)
Y=	-4680260.752	-4680260.781	0.029	N= 0.046 M	= 0.15 FT	
Z=	4317398.806	4317398.769	0.037	U= 0.005 M	= 0.02 FT	
7105 X=	110609.110	110609.073	0.036	E= 0.036 M	= 0.12 FT	SPRING 2
Y=	-4680730.098	-4680730.105	0.008	N= 0.011 M	= 0.04 FT	
Z=	4316969.480	4316969.471	0.008	U= 0.001 M	= 0.00 FT	
7108 X=	115848.021	115848.009	0.012	E= 0.013 M	= 0.04 FT	SUGAR CREEK S GPS
Y=	-4693984.843	-4693984.879	0.037	N= 0.045 M	= 0.15 FT	
Z=	4302600.213	4302600.186	0.027	U= -0.008 M	= -0.03 FT	
7109 X=	115234.443	115234.487	-0.044	E= -0.045 M	= -0.15 FT	TIBBETS GPS
Y=	-4690042.526	-4690042.494	-0.033	N= -0.040 M	= -0.13 FT	
Z=	4306864.567	4306864.592	-0.025	U= 0.006 M	= 0.02 FT	
7125 X=	103026.845	103026.777	0.068	E= 0.067 M	= 0.22 FT	WHITEWATER
Y=	-4682969.472	-4682969.452	-0.020	N= -0.096 M	= -0.31 FT	
Z=	4314777.134	4314777.244	-0.110	U= -0.059 M	= -0.19 FT	
7126 X=	106321.806	106321.787	0.019	E= 0.018 M	= 0.06 FT	WHITEWATER GPS
Y=	-4684375.978	-4684375.932	-0.046	N= -0.036 M	= -0.12 FT	
Z=	4313168.637	4313168.643	-0.006	U= 0.030 M	= 0.10 FT	
7127 X=	100114.474	100114.454	0.020	E= 0.019 M	= 0.06 FT	WHITEWATER W GPS
Y=	-4685769.304	-4685769.266	-0.037	N= -0.055 M	= -0.18 FT	
Z=	4311829.151	4311829.192	-0.040	U= 0.000 M	= 0.00 FT	

MEAN OF EAST MISCLOSURE = 0.000 FT
STANDARD DEVIATION 0.138 FT

MEAN OF NORTH MISCLOSURE = 0.000 FT
STANDARD DEVIATION = 0.172 FT

MEAN OF UP MISCLOSURE = 0.000 FT
STANRDARD DEVIATION = 0.072 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - SE Qtr Walworth County

INPUT FILE: Walworth County SE.dat
OUTPUT FILE: Walworth parameters SE.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7021	0.010	0.010	0.015	0.010	0.010	0.015	BLOOMFIELD S GPS
2	7028	0.010	0.010	0.015	0.010	0.010	0.015	BURLINGTON W GPS
3	7041	0.010	0.010	0.015	0.010	0.010	0.015	ELKHORN GPS
4	7055	0.010	0.010	0.015	0.010	0.010	0.015	HONEY 2
5	7067	0.010	0.010	0.015	0.010	0.010	0.015	LYONS N GPS
6	7081	0.010	0.010	0.015	0.010	0.010	0.015	PELL LAKE GPS
7	7094	0.010	0.010	0.015	0.010	0.010	0.015	ROCHESTER C GPS
8	7108	0.010	0.010	0.015	0.010	0.010	0.015	SUGAR CREEK S GPS
9	7110	0.010	0.010	0.015	0.010	0.010	0.015	TWIN LAKES GPS
10	7115	0.010	0.010	0.015	0.010	0.010	0.015	WATH (WISCORS)
11	7128	0.010	0.010	0.015	0.010	0.010	0.015	YERKES

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7021		RPC	HMP	
		X =	132923.4342	132912.2034	BLOOMFIELD S GPS
		Y =	-4706313.3856	-4706180.7728	
		Z =	4288606.0771	4288808.6855	
2	7028		RPC	HMP	
		X =	139166.1983	139154.9709	BURLINGTON W GPS
		Y =	-4698962.6413	-4698829.9647	
		Z =	4296398.1212	4296600.7692	
3	7041		RPC	HMP	
		X =	121672.6836	121661.3352	ELKHORN GPS
		Y =	-4696005.2682	-4695872.7096	
		Z =	4300210.8579	4300413.3809	
4	7055		RPC	HMP	
		X =	133345.4027	133334.0608	HONEY 2
		Y =	-4689911.5769	-4689778.8825	
		Z =	4306449.7930	4306652.4921	
5	7067		RPC	HMP	
		X =	133719.2050	133707.9356	LYONS N GPS
		Y =	-4696546.2268	-4696413.5740	
		Z =	4299187.1288	4299389.7442	
6	7081		RPC	HMP	
		X =	126055.5357	126044.2775	PELL LAKE GPS
		Y =	-4708135.9287	-4708003.3484	
		Z =	4286872.0201	4287074.5561	
7	7094		RPC	HMP	
		X =	144327.6311	144316.4255	ROCHESTER C GPS
		Y =	-4692035.8645	-4691903.0795	
		Z =	4303702.1728	4303904.9814	
8	7108		RPC	HMP	
		X =	115859.3985	115848.0208	SUGAR CREEK S GPS
		Y =	-4694117.3606	-4693984.8425	
		Z =	4302397.7437	4302600.2131	

```
                                RPC                 HMP
    9   7110          X =     140069.0614         140057.8540       TWIN LAKES GPS
                      Y =   -4706450.7194       -4706318.0658
                      Z =    4288218.1065        4288420.7473
                                RPC                 HMP
   10   7115          X =     115573.1979         115561.9245       WATH (WISCORS)
                      Y =   -4706572.8905       -4706440.3251
                      Z =    4288888.2569        4289090.7746
                                RPC                 HMP
   11   7128          X =     118587.6215         118576.3093       YERKES
                      Y =   -4703147.4664       -4703014.9092
                      Z =    4292541.0265        4292743.5353


POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

  NO.  POINT ID           NAME

     1    7021          BLOOMFIELD S GPS
     2    7028          BURLINGTON W GPS
     3    7041          ELKHORN GPS
     4    7055          HONEY 2
     5    7067          LYONS N GPS
     6    7081          PELL LAKE GPS
     7    7094          ROCHESTER C GPS
     8    7108          SUGAR CREEK S GPS
     9    7110          TWIN LAKES GPS
    10    7115          WATH (WISCORS)
    11    7128          YERKES


 TRANSFORMATION PARAMETERS FOR POINTS SELECTED:


     TRANSLATION IN X, TX =        -6.0199 M
     TRANSLATION IN Y, TY =       155.6349 M
     TRANSLATION IN Z, TZ =       183.6719 M

     SCALE IN X/Y/Z              4.654298 PPM

     ROTATION ABOUT X AXIS =  -0.00000039 RAD
                              -0.08074086 SEC
     ROTATION ABOUT Y AXIS =   0.00000597 RAD
                               1.23195067 SEC
     ROTATION ABOUT Z AXIS =  -0.00000421 RAD
                              -0.86889738 SEC


     REFERENCE VARIANCE =         9.316599
     (SIGMA NAUGHT SQUARED)



FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

 POINT  CONTROL VALUE  COMPUTED VALUE  DIFF IN   DIFF EAST/NORTH/UP     POINT NAME
  ID       HMP (M)         HMP (M)     X/Y/Z (M)   METERS     FEET

 7021 X=   132912.203     132912.244  -0.041  E= -0.041 M  = -0.13 FT  BLOOMFIELD S GPS
      Y= -4706180.773   -4706180.774   0.001  N=  0.020 M  =  0.06 FT
      Z=  4288808.685    4288808.661   0.024  U=  0.015 M  =  0.05 FT
```

Appendix B (continued)

```
7028 X=   139154.971     139154.960   0.011  E=  0.011 M  =  0.04 FT  BURLINGTON W GPS
     Y= -4698829.965   -4698829.972   0.008  N= -0.004 M  = -0.01 FT
     Z=  4296600.769    4296600.782  -0.012  U= -0.014 M  = -0.05 FT

7041 X=   121661.335     121661.328   0.007  E=  0.006 M  =  0.02 FT  ELKHORN GPS
     Y= -4695872.710   -4695872.661  -0.049  N= -0.071 M  = -0.23 FT
     Z=  4300413.381    4300413.433  -0.052  U=  0.001 M  =  0.00 FT

7055 X=   133334.061     133334.039   0.022  E=  0.022 M  =  0.07 FT  HONEY 2
     Y= -4689778.883   -4689778.894   0.012  N=  0.025 M  =  0.08 FT
     Z=  4306652.492    4306652.469   0.023  U=  0.007 M  =  0.02 FT

7067 X=   133707.936     133707.914   0.021  E=  0.021 M  =  0.07 FT  LYONS N GPS
     Y= -4696413.574   -4696413.571  -0.003  N= -0.022 M  = -0.07 FT
     Z=  4299389.744    4299389.771  -0.026  U= -0.015 M  = -0.05 FT

7081 X=   126044.277     126044.332  -0.054  E= -0.054 M  = -0.18 FT  PELL LAKE GPS
     Y= -4708003.348   -4708003.354   0.006  N=  0.006 M  =  0.02 FT
     Z=  4287074.556    4287074.554   0.002  U= -0.004 M  = -0.01 FT

7094 X=   144316.426     144316.344   0.082  E=  0.084 M  =  0.27 FT  ROCHESTER C GPS
     Y= -4691903.079   -4691903.144   0.065  N=  0.102 M  =  0.33 FT
     Z=  4303904.981    4303904.901   0.081  U=  0.009 M  =  0.03 FT

7108 X=   115848.021     115847.995   0.026  E=  0.024 M  =  0.08 FT  SUGAR CREEK S GPS
     Y= -4693984.843   -4693984.770  -0.073  N= -0.110 M  = -0.36 FT
     Z=  4302600.213    4302600.295  -0.082  U= -0.001 M  =  0.00 FT

7110 X=   140057.854     140057.907  -0.053  E= -0.053 M  = -0.17 FT  TWIN LAKES GPS
     Y= -4706318.066   -4706318.078   0.013  N=  0.021 M  =  0.07 FT
     Z=  4288420.747    4288420.731   0.016  U=  0.000 M  =  0.00 FT

7115 X=   115561.924     115561.926  -0.002  E= -0.001 M  =  0.00 FT  WATH (WISCORS)
     Y= -4706440.325   -4706440.353   0.028  N=  0.046 M  =  0.15 FT
     Z=  4289090.775    4289090.739   0.036  U=  0.003 M  =  0.01 FT

7128 X=   118576.309     118576.328  -0.019  E= -0.019 M  = -0.06 FT  YERKES
     Y= -4703014.909   -4703014.902  -0.007  N= -0.011 M  = -0.04 FT
     Z=  4292743.535    4292743.544  -0.009  U= -0.001 M  =  0.00 FT

                         MEAN OF EAST MISCLOSURE =     0.000 FT
                         STANDARD DEVIATION            0.133 FT

                         MEAN OF NORTH MISCLOSURE =    0.000 FT
                         STANDARD DEVIATION =          0.185 FT

                         MEAN OF UP MISCLOSURE =       0.000 FT
                         STANRDARD DEVIATION =         0.029 FT
```

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - SW Qtr Walworth County

INPUT FILE: Walworth County SW.dat
OUTPUT FILE: Walworth parameters SW.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7018	0.010	0.010	0.015	0.010	0.010	0.015	ALLENS GROVE GPS
2	7022	0.010	0.010	0.015	0.010	0.010	0.015	BRADFORD S GPS
3	7034	0.010	0.010	0.015	0.010	0.010	0.015	DARIEN E GPS
4	7036	0.010	0.010	0.015	0.010	0.010	0.015	DOOR
5	7041	0.010	0.010	0.015	0.010	0.010	0.015	ELKHORN GPS
6	7059	0.010	0.010	0.015	0.010	0.010	0.015	JALE (WISCORS)
7	7081	0.010	0.010	0.015	0.010	0.010	0.015	PELL LAKE GPS
8	7100	0.010	0.010	0.015	0.010	0.010	0.015	SHARON C GPS
9	7108	0.010	0.010	0.015	0.010	0.010	0.015	SUGAR CREEK S GPS
10	7115	0.010	0.010	0.015	0.010	0.010	0.015	WATH (WISCORS)
11	7123	0.010	0.010	0.015	0.010	0.010	0.015	WEEKS
12	7128	0.010	0.010	0.015	0.010	0.010	0.015	YERKES

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7018	X =	102235.8901	102224.5080	ALLENS GROVE GPS
		Y =	-4702241.0244	-4702108.5622	
		Z =	4293878.1203	4294080.4719	
			RPC	HMP	
2	7022	X =	98438.0889	98426.6925	BRADFORD S GPS
		Y =	-4701318.9386	-4701186.4974	
		Z =	4294952.4366	4295154.7991	
			RPC	HMP	
3	7034	X =	108921.2492	108909.8554	DARIEN E GPS
		Y =	-4699749.8569	-4699617.3587	
		Z =	4296441.0162	4296643.4308	
			RPC	HMP	
4	7036	X =	101613.9729	101602.5860	DOOR
		Y =	-4702629.4374	-4702496.9634	
		Z =	4293462.8361	4293665.1643	
			RPC	HMP	
5	7041	X =	121672.6836	121661.3352	ELKHORN GPS
		Y =	-4696005.2682	-4695872.7096	
		Z =	4300210.8579	4300413.3809	
			RPC	HMP	
6	7059	X =	79536.9672	79525.4335	JALE (WISCORS)
		Y =	-4693425.3636	-4693292.9012	
		Z =	4303926.5815	4304128.9351	
			RPC	HMP	
7	7081	X =	126055.5357	126044.2775	PELL LAKE GPS
		Y =	-4708135.9287	-4708003.3484	
		Z =	4286872.0201	4287074.5561	

Appendix B (continued)

			RPC	HMP	
8	7100	X =	106583.7743	106572.4218	SHARON C GPS
		Y =	-4705184.0770	-4705051.5900	
		Z =	4290598.4019	4290800.8375	
			RPC	HMP	
9	7108	X =	115859.3985	115848.0208	SUGAR CREEK S GPS
		Y =	-4694117.3606	-4693984.8425	
		Z =	4302397.7437	4302600.2131	
			RPC	HMP	
10	7115	X =	115573.1979	115561.9245	WATH (WISCORS)
		Y =	-4706572.8905	-4706440.3251	
		Z =	4288888.2569	4289090.7746	
			RPC	HMP	
11	7123	X =	105147.8636	105136.5543	WEEKS
		Y =	-4710305.6560	-4710173.1237	
		Z =	4285090.7372	4285293.2112	
			RPC	HMP	
12	7128	X =	118587.6215	118576.3093	YERKES
		Y =	-4703147.4664	-4703014.9092	
		Z =	4292541.0265	4292743.5353	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7018	ALLENS GROVE GPS
2	7022	BRADFORD S GPS
3	7034	DARIEN E GPS
4	7036	DOOR
5	7041	ELKHORN GPS
6	7059	JALE (WISCORS)
7	7081	PELL LAKE GPS
8	7100	SHARON C GPS
9	7108	SUGAR CREEK S GPS
10	7115	WATH (WISCORS)
11	7123	WEEKS
12	7128	YERKES

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX = -4.0560 M
TRANSLATION IN Y, TY = 144.0899 M
TRANSLATION IN Z, TZ = 192.1968 M

SCALE IN X/Y/Z 2.407191 PPM

ROTATION ABOUT X AXIS = -0.00000014 RAD
-0.02940619 SEC
ROTATION ABOUT Y AXIS = 0.00000532 RAD
1.09728657 SEC
ROTATION ABOUT Z AXIS = -0.00000325 RAD
-0.67024382 SEC

REFERENCE VARIANCE = 6.169346
(SIGMA NAUGHT SQUARED)

Appendix B (continued)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7018 X=	102224.508	102224.517	-0.009	E= -0.010 M	= -0.03 FT	ALLENS GROVE GPS
Y=	-4702108.562	-4702108.534	-0.029	N= -0.060 M	= -0.20 FT	
Z=	4294080.472	4294080.527	-0.055	U= -0.016 M	= -0.05 FT	
7022 X=	98426.693	98426.698	-0.006	E= -0.007 M	= -0.02 FT	BRADFORD S GPS
Y=	-4701186.497	-4701186.458	-0.039	N= -0.046 M	= -0.15 FT	
Z=	4295154.799	4295154.826	-0.026	U= 0.011 M	= 0.04 FT	
7034 X=	108909.855	108909.871	-0.015	E= -0.016 M	= -0.05 FT	DARIEN E GPS
Y=	-4699617.359	-4699617.339	-0.020	N= -0.038 M	= -0.13 FT	
Z=	4296643.431	4296643.465	-0.034	U= -0.009 M	= -0.03 FT	
7036 X=	101602.586	101602.602	-0.016	E= -0.016 M	= -0.05 FT	DOOR
Y=	-4702496.963	-4702496.950	-0.014	N= -0.064 M	= -0.21 FT	
Z=	4293665.164	4293665.238	-0.074	U= -0.040 M	= -0.13 FT	
7041 X=	121661.335	121661.304	0.032	E= 0.031 M	= 0.10 FT	ELKHORN GPS
Y=	-4695872.710	-4695872.700	-0.009	N= -0.009 M	= -0.03 FT	
Z=	4300413.381	4300413.384	-0.003	U= 0.006 M	= 0.02 FT	
7059 X=	79525.433	79525.458	-0.024	E= -0.024 M	= -0.08 FT	JALE (WISCORS)
Y=	-4693292.901	-4693292.927	0.026	N= 0.049 M	= 0.16 FT	
Z=	4304128.935	4304128.893	0.042	U= 0.010 M	= 0.03 FT	
7081 X=	126044.277	126044.277	0.001	E= 0.002 M	= 0.00 FT	PELL LAKE GPS
Y=	-4708003.348	-4708003.374	0.025	N= 0.032 M	= 0.11 FT	
Z=	4287074.556	4287074.536	0.021	U= -0.005 M	= -0.02 FT	
7100 X=	106572.422	106572.439	-0.017	E= -0.017 M	= -0.06 FT	SHARON C GPS
Y=	-4705051.590	-4705051.579	-0.011	N= 0.003 M	= 0.01 FT	
Z=	4290800.838	4290800.823	0.014	U= 0.018 M	= 0.06 FT	
7108 X=	115848.021	115847.987	0.034	E= 0.033 M	= 0.11 FT	SUGAR CREEK S GPS
Y=	-4693984.843	-4693984.807	-0.035	N= -0.047 M	= -0.16 FT	
Z=	4302600.213	4302600.244	-0.031	U= 0.005 M	= 0.02 FT	
7115 X=	115561.924	115561.898	0.027	E= 0.028 M	= 0.09 FT	WATH (WISCORS)
Y=	-4706440.325	-4706440.366	0.041	N= 0.066 M	= 0.22 FT	
Z=	4289090.775	4289090.722	0.053	U= 0.006 M	= 0.02 FT	
7123 X=	105136.554	105136.571	-0.016	E= -0.015 M	= -0.05 FT	WEEKS
Y=	-4710173.124	-4710173.174	0.050	N= 0.089 M	= 0.29 FT	
Z=	4285293.211	4285293.137	0.074	U= 0.013 M	= 0.04 FT	
7128 X=	118576.309	118576.298	0.011	E= 0.012 M	= 0.04 FT	YERKES
Y=	-4703014.909	-4703014.925	0.015	N= 0.024 M	= 0.08 FT	
Z=	4292743.535	4292743.517	0.019	U= 0.002 M	= 0.01 FT	

MEAN OF EAST MISCLOSURE = 0.000 FT
STANDARD DEVIATION 0.068 FT

MEAN OF NORTH MISCLOSURE = 0.000 FT
STANDARD DEVIATION = 0.171 FT

MEAN OF UP MISCLOSURE = 0.000 FT
STANRDARD DEVIATION = 0.052 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - N Half Washington County

INPUT FILE: Washington County N Half.dat
OUTPUT FILE: Washington parameters N Half.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7017	0.010	0.010	0.015	0.010	0.010	0.015	ADDISON E GPS
2	7019	0.010	0.010	0.015	0.010	0.010	0.015	BARTON C GPS
3	7042	0.010	0.010	0.015	0.010	0.010	0.015	ELMORE 2
4	7043	0.010	0.010	0.015	0.010	0.010	0.015	FARMINGTON W GPS
5	7058	0.010	0.010	0.015	0.010	0.010	0.015	JACKSON N GPS
6	7064	0.010	0.010	0.015	0.010	0.010	0.015	KEWASKUM C GPS
7	7076	0.010	0.010	0.015	0.010	0.010	0.015	NEW FANE GPS
8	7091	0.010	0.010	0.015	0.010	0.010	0.015	RANDOM LAKE GPS
9	7098	0.010	0.010	0.015	0.010	0.010	0.015	SAUKVILLE C GPS
10	7107	0.010	0.010	0.015	0.010	0.010	0.015	ST PAUL 2
11	7121	0.010	0.010	0.015	0.010	0.010	0.015	WAYNE N GPS
12	7122	0.010	0.010	0.015	0.010	0.010	0.015	WEBE (WISCORS)
13	7124	0.010	0.010	0.015	0.010	0.010	0.015	WEST BEND GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7017				
		X =	139097.4216	139085.7566	ADDISON E GPS
		Y =	-4637702.7952	-4637570.8048	
		Z =	4362147.7809	4362349.7846	
2	7019				
		X =	143963.7543	143952.0670	BARTON C GPS
		Y =	-4635636.1740	-4635504.1669	
		Z =	4364089.4847	4364291.5036	
3	7042				
		X =	141607.5551	141595.7844	ELMORE 2
		Y =	-4627117.9449	-4626986.0279	
		Z =	4373169.5864	4373371.4732	
4	7043				
		X =	150378.8479	150367.1033	FARMINGTON W GPS
		Y =	-4632885.0155	-4632752.9840	
		Z =	4366751.8437	4366953.8866	
5	7058				
		X =	149084.0781	149072.4423	JACKSON N GPS
		Y =	-4641859.1981	-4641727.0770	
		Z =	4357324.4327	4357526.5865	
6	7064				
		X =	142228.4366	142216.6812	KEWASKUM C GPS
		Y =	-4631042.5582	-4630910.5959	
		Z =	4368991.1943	4369193.1464	
7	7076				
		X =	148823.5905	148811.8195	NEW FANE GPS
		Y =	-4628556.5862	-4628424.5845	
		Z =	4371420.0879	4371622.1328	

			RPC	HMP	
8	7091	X =	168933.6737	168921.4922	RANDOM LAKE GPS
		Y =	-4626676.8409	-4626544.7976	
		Z =	4372578.9114	4372780.9574	
			RPC	HMP	
9	7098	X =	163215.0876	163203.2452	SAUKVILLE C GPS
		Y =	-4639024.6072	-4638892.3535	
		Z =	4359795.9595	4359998.2681	
			RPC	HMP	
10	7107	X =	125947.3462	125935.6594	ST PAUL 2
		Y =	-4628576.6425	-4628444.8569	
		Z =	4372083.4629	4372285.2432	
			RPC	HMP	
11	7121	X =	134070.3028	134058.5918	WAYNE N GPS
		Y =	-4631236.5354	-4631104.6619	
		Z =	4369065.0293	4369266.9128	
			RPC	HMP	
12	7122	X =	149910.8939	149899.1866	WEBE (WISCORS)
		Y =	-4637845.2883	-4637713.1980	
		Z =	4361513.9676	4361716.0619	
			RPC	HMP	
13	7124	X =	151052.9993	151041.2979	WEST BEND GPS
		Y =	-4637738.0240	-4637605.9359	
		Z =	4361586.6911	4361788.7805	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7017	ADDISON E GPS
2	7019	BARTON C GPS
3	7042	ELMORE 2
4	7043	FARMINGTON W GPS
5	7058	JACKSON N GPS
6	7064	KEWASKUM C GPS
7	7076	NEW FANE GPS
8	7091	RANDOM LAKE GPS
9	7098	SAUKVILLE C GPS
10	7107	ST PAUL 2
11	7121	WAYNE N GPS
12	7122	WEBE (WISCORS)
13	7124	WEST BEND GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX =	-10.9325 M
TRANSLATION IN Y, TY =	77.1219 M
TRANSLATION IN Z, TZ =	246.2009 M
SCALE IN X/Y/Z	-11.030668 PPM
ROTATION ABOUT X AXIS =	0.00000060 RAD
	0.12379140 SEC
ROTATION ABOUT Y AXIS =	0.00000820 RAD
	1.69149196 SEC
ROTATION ABOUT Z AXIS =	-0.00000790 RAD
	-1.62921022 SEC
REFERENCE VARIANCE =	9.109120
(SIGMA NAUGHT SQUARED)	

Appendix B (continued)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7017 X=	139085.757	139085.814	-0.058	E= -0.058 M	= -0.19 FT	ADDISON E GPS
Y=	-4637570.805	-4637570.800	-0.005	N= -0.005 M	= -0.02 FT	
Z=	4362349.785	4362349.788	-0.004	U= 0.000 M	= 0.00 FT	
7019 X=	143952.067	143952.061	0.006	E= 0.006 M	= 0.02 FT	BARTON C GPS
Y=	-4635504.167	-4635504.162	-0.005	N= -0.008 M	= -0.03 FT	
Z=	4364291.504	4364291.509	-0.006	U= 0.000 M	= 0.00 FT	
7042 X=	141595.784	141595.746	0.038	E= 0.039 M	= 0.13 FT	ELMORE 2
Y=	-4626986.028	-4626986.040	0.012	N= -0.002 M	= -0.01 FT	
Z=	4373371.473	4373371.487	-0.013	U= -0.017 M	= -0.06 FT	
7043 X=	150367.103	150367.040	0.063	E= 0.063 M	= 0.21 FT	FARMINGTON W GPS
Y=	-4632752.984	-4632752.981	-0.003	N= -0.006 M	= -0.02 FT	
Z=	4366953.887	4366953.890	-0.003	U= 0.001 M	= 0.00 FT	
7058 X=	149072.442	149072.433	0.009	E= 0.010 M	= 0.03 FT	JACKSON N GPS
Y=	-4641727.077	-4641727.081	0.004	N= 0.009 M	= 0.03 FT	
Z=	4357526.587	4357526.578	0.009	U= 0.003 M	= 0.01 FT	
7064 X=	142216.681	142216.686	-0.005	E= -0.004 M	= -0.01 FT	KEWASKUM C GPS
Y=	-4630910.596	-4630910.607	0.011	N= 0.007 M	= 0.02 FT	
Z=	4369193.146	4369193.148	-0.002	U= -0.009 M	= -0.03 FT	
7076 X=	148811.820	148811.727	0.092	E= 0.093 M	= 0.30 FT	NEW FANE GPS
Y=	-4628424.584	-4628424.609	0.025	N= 0.062 M	= 0.20 FT	
Z=	4371622.133	4371622.067	0.065	U= 0.029 M	= 0.10 FT	
7091 X=	168921.492	168921.565	-0.072	E= -0.075 M	= -0.25 FT	RANDOM LAKE GPS
Y=	-4626544.798	-4626544.725	-0.073	N= -0.109 M	= -0.36 FT	
Z=	4372780.957	4372781.042	-0.084	U= -0.008 M	= -0.02 FT	
7098 X=	163203.245	163203.244	0.001	E= 0.003 M	= 0.01 FT	SAUKVILLE C GPS
Y=	-4638892.354	-4638892.408	0.054	N= 0.093 M	= 0.31 FT	
Z=	4359998.268	4359998.192	0.077	U= 0.013 M	= 0.04 FT	
7107 X=	125935.659	125935.730	-0.071	E= -0.071 M	= -0.23 FT	ST PAUL 2
Y=	-4628444.857	-4628444.846	-0.011	N= -0.010 M	= -0.03 FT	
Z=	4372285.243	4372285.247	-0.004	U= 0.004 M	= 0.01 FT	
7121 X=	134058.592	134058.643	-0.051	E= -0.052 M	= -0.17 FT	WAYNE N GPS
Y=	-4631104.662	-4631104.647	-0.015	N= -0.011 M	= -0.04 FT	
Z=	4369266.913	4369266.915	-0.003	U= 0.008 M	= 0.03 FT	
7122 X=	149899.187	149899.173	0.013	E= 0.013 M	= 0.04 FT	WEBE (WISCORS)
Y=	-4637713.198	-4637713.206	0.008	N= -0.001 M	= 0.00 FT	
Z=	4361716.062	4361716.071	-0.009	U= -0.012 M	= -0.04 FT	
7124 X=	151041.298	151041.265	0.033	E= 0.033 M	= 0.11 FT	WEST BEND GPS
Y=	-4637605.936	-4637605.934	-0.002	N= -0.018 M	= -0.06 FT	
Z=	4361788.781	4361788.803	-0.022	U= -0.013 M	= -0.04 FT	

MEAN OF EAST MISCLOSURE = 0.000 FT
STANDARD DEVIATION 0.170 FT

MEAN OF NORTH MISCLOSURE = 0.000 FT
STANDARD DEVIATION = 0.151 FT

MEAN OF UP MISCLOSURE = 0.000 FT
STANRDARD DEVIATION = 0.041 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - S Half Washington County

INPUT FILE: Washington County S Half.dat
OUTPUT FILE: Washington parameters S Half.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7017	0.010	0.010	0.015	0.010	0.010	0.015	ADDISON E GPS
2	7032	0.010	0.010	0.015	0.010	0.010	0.015	COLGATE GPS
3	7049	0.010	0.010	0.015	0.010	0.010	0.015	GERMANTOWN S GPS
4	7050	0.010	0.010	0.015	0.010	0.010	0.015	GRAFTON
5	7053	0.010	0.010	0.015	0.010	0.010	0.015	HARTFORD C GPS
6	7056	0.010	0.010	0.015	0.010	0.010	0.015	JACKSON
7	7057	0.010	0.010	0.015	0.010	0.010	0.015	JACKSON GPS
8	7058	0.010	0.010	0.015	0.010	0.010	0.015	JACKSON N GPS
9	7069	0.010	0.010	0.015	0.010	0.010	0.015	MERTON N GPS
10	7086	0.010	0.010	0.015	0.010	0.010	0.015	POLK C GPS
11	7093	0.010	0.010	0.015	0.010	0.010	0.015	RICHFIELD E GPS
12	7095	0.010	0.010	0.015	0.010	0.010	0.015	RUBICON
13	7096	0.010	0.010	0.015	0.010	0.010	0.015	RUBICON E GPS
14	7098	0.010	0.010	0.015	0.010	0.010	0.015	SAUKVILLE C GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7017	X =	139097.4216	139085.7566	ADDISON E GPS
		Y =	-4637702.7952	-4637570.8048	
		Z =	4362147.7809	4362349.7846	
2	7032	X =	143756.4106	143744.9231	COLGATE GPS
		Y =	-4655393.8921	-4655261.5605	
		Z =	4343155.4382	4343357.8490	
3	7049	X =	155808.2651	155796.6526	GERMANTOWN S GPS
		Y =	-4654944.8805	-4654812.2837	
		Z =	4343125.5371	4343328.2138	
4	7050	X =	167623.0774	167611.1964	GRAFTON
		Y =	-4643862.6892	-4643730.4122	
		Z =	4354475.1089	4354677.4414	
5	7053	X =	134128.4813	134117.1834	HARTFORD C GPS
		Y =	-4646192.7361	-4646060.6446	
		Z =	4353247.4355	4353449.5628	
6	7056	X =	152706.0892	152694.4823	JACKSON
		Y =	-4645175.0414	-4645042.8935	
		Z =	4353665.6750	4353867.8669	
7	7057	X =	147307.5686	147296.0207	JACKSON GPS
		Y =	-4646379.0136	-4646246.8324	
		Z =	4352562.0591	4352764.2900	

Appendix B (continued)

			RPC	HMP	
8	7058	X =	149084.0781	149072.4423	JACKSON N GPS
		Y =	-4641859.1981	-4641727.0770	
		Z =	4357324.4327	4357526.5865	
			RPC	HMP	
9	7069	X =	131736.6272	131725.2159	MERTON N GPS
		Y =	-4655843.3833	-4655711.1519	
		Z =	4343067.7751	4343270.0431	
			RPC	HMP	
10	7086	X =	141689.0174	141677.4961	POLK C GPS
		Y =	-4645523.9767	-4645391.8563	
		Z =	4353764.3777	4353966.5775	
			RPC	HMP	
11	7093	X =	144587.4862	144575.9946	RICHFIELD E GPS
		Y =	-4650980.5338	-4650848.2485	
		Z =	4347852.7485	4348055.1018	
			RPC	HMP	
12	7095	X =	133101.5641	133090.2697	RUBICON
		Y =	-4644585.2761	-4644453.1784	
		Z =	4355009.6997	4355211.8316	
			RPC	HMP	
13	7096	X =	127523.8055	127512.4745	RUBICON E GPS
		Y =	-4644166.8051	-4644034.7134	
		Z =	4355605.8151	4355807.9218	
			RPC	HMP	
14	7098	X =	163215.0876	163203.2452	SAUKVILLE C GPS
		Y =	-4639024.6072	-4638892.3535	
		Z =	4359795.9595	4359998.2681	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7017	ADDISON E GPS
2	7032	COLGATE GPS
3	7049	GERMANTOWN S GPS
4	7050	GRAFTON
5	7053	HARTFORD C GPS
6	7056	JACKSON
7	7057	JACKSON GPS
8	7058	JACKSON N GPS
9	7069	MERTON N GPS
10	7086	POLK C GPS
11	7093	RICHFIELD E GPS
12	7095	RUBICON
13	7096	RUBICON E GPS
14	7098	SAUKVILLE C GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX =	-9.0538 M
TRANSLATION IN Y, TY =	58.1100 M
TRANSLATION IN Z, TZ =	266.0396 M
SCALE IN X/Y/Z	-15.343757 PPM
ROTATION ABOUT X AXIS =	0.00000044 RAD
	0.09153133 SEC
ROTATION ABOUT Y AXIS =	0.00000642 RAD
	1.32436160 SEC
ROTATION ABOUT Z AXIS =	-0.00000596 RAD
	-1.22880040 SEC
REFERENCE VARIANCE =	30.135503
(SIGMA NAUGHT SQUARED)	

Appendix B (continued)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID		CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	FEET	POINT NAME
7017	X=	139085.757	139085.854	-0.098	E= -0.099 M	= -0.32 FT	ADDISON E GPS
	Y=	-4637570.805	-4637570.761	-0.044	N= -0.068 M	= -0.22 FT	
	Z=	4362349.785	4362349.840	-0.055	U= -0.008 M	= -0.03 FT	
7032	X=	143744.923	143744.999	-0.076	E= -0.076 M	= -0.25 FT	COLGATE GPS
	Y=	-4655261.560	-4655261.567	0.007	N= 0.023 M	= 0.07 FT	
	Z=	4343357.849	4343357.826	0.023	U= 0.009 M	= 0.03 FT	
7049	X=	155796.653	155796.666	-0.014	E= -0.007 M	= -0.02 FT	GERMANTOWN S GPS
	Y=	-4654812.284	-4654812.491	0.207	N= 0.296 M	= 0.97 FT	
	Z=	4343328.214	4343328.003	0.211	U= -0.007 M	= -0.02 FT	
7050	X=	167611.196	167611.158	0.038	E= 0.037 M	= 0.12 FT	GRAFTON
	Y=	-4643730.412	-4643730.394	-0.018	N= -0.035 M	= -0.12 FT	
	Z=	4354677.441	4354677.472	-0.030	U= -0.006 M	= -0.02 FT	
7053	X=	134117.183	134117.098	0.086	E= 0.084 M	= 0.28 FT	HARTFORD C GPS
	Y=	-4646060.645	-4646060.605	-0.039	N= -0.058 M	= -0.19 FT	
	Z=	4353449.563	4353449.603	-0.040	U= 0.003 M	= 0.01 FT	
7056	X=	152694.482	152694.412	0.070	E= 0.068 M	= 0.22 FT	JACKSON
	Y=	-4645042.894	-4645042.815	-0.078	N= -0.119 M	= -0.39 FT	
	Z=	4353867.867	4353867.955	-0.088	U= -0.002 M	= -0.01 FT	
7057	X=	147296.021	147295.988	0.032	E= 0.031 M	= 0.10 FT	JACKSON GPS
	Y=	-4646246.832	-4646246.802	-0.031	N= -0.045 M	= -0.15 FT	
	Z=	4352764.290	4352764.322	-0.032	U= 0.001 M	= 0.00 FT	
7058	X=	149072.442	149072.413	0.029	E= 0.028 M	= 0.09 FT	JACKSON N GPS
	Y=	-4641727.077	-4641727.043	-0.034	N= -0.057 M	= -0.19 FT	
	Z=	4357526.587	4357526.632	-0.045	U= -0.006 M	= -0.02 FT	
7069	X=	131725.216	131725.403	-0.187	E= -0.188 M	= -0.62 FT	MERTON N GPS
	Y=	-4655711.152	-4655711.123	-0.029	N= -0.049 M	= -0.16 FT	
	Z=	4343270.043	4343270.088	-0.045	U= -0.013 M	= -0.04 FT	
7086	X=	141677.496	141677.511	-0.015	E= -0.016 M	= -0.05 FT	POLK C GPS
	Y=	-4645391.856	-4645391.811	-0.045	N= -0.037 M	= -0.12 FT	
	Z=	4353966.577	4353966.585	-0.008	U= 0.027 M	= 0.09 FT	
7093	X=	144575.995	144576.005	-0.011	E= -0.010 M	= -0.03 FT	RICHFIELD E GPS
	Y=	-4650848.248	-4650848.270	0.021	N= 0.039 M	= 0.13 FT	
	Z=	4348055.102	4348055.068	0.034	U= 0.008 M	= 0.02 FT	
7095	X=	133090.270	133090.176	0.094	E= 0.094 M	= 0.31 FT	RUBICON
	Y=	-4644453.178	-4644453.175	-0.003	N= -0.005 M	= -0.02 FT	
	Z=	4355211.832	4355211.833	-0.001	U= 0.003 M	= 0.01 FT	
7096	X=	127512.474	127512.496	-0.022	E= -0.021 M	= -0.07 FT	RUBICON E GPS
	Y=	-4644034.713	-4644034.744	0.030	N= 0.035 M	= 0.11 FT	
	Z=	4355807.922	4355807.903	0.019	U= -0.010 M	= -0.03 FT	
7098	X=	163203.245	163203.173	0.072	E= 0.074 M	= 0.24 FT	SAUKVILLE C GPS
	Y=	-4638892.354	-4638892.410	0.057	N= 0.079 M	= 0.26 FT	
	Z=	4359998.268	4359998.210	0.058	U= 0.001 M	= 0.00 FT	

Appendix B (continued)

```
MEAN OF EAST MISCLOSURE =      0.000 FT
STANDARD DEVIATION             0.259 FT

MEAN OF NORTH MISCLOSURE =     0.000 FT
STANDARD DEVIATION =           0.327 FT

MEAN OF UP MISCLOSURE =        0.000 FT
STANRDARD DEVIATION =          0.034 FT
```

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - NE Qtr Waukesha County

INPUT FILE: Waukesha County NE.dat
OUTPUT FILE: Waukesha parameters NE.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7025	0.010	0.010	0.015	0.010	0.010	0.015	BROOKFIELD S GPS
2	7026	0.030	0.030	0.015	0.010	0.010	0.015	BROWN DEER W GPS
3	7032	0.010	0.010	0.015	0.010	0.010	0.015	COLGATE GPS
4	7049	0.010	0.010	0.015	0.010	0.010	0.015	GERMANTOWN S GPS
5	7051	0.010	0.010	0.015	0.010	0.010	0.015	GREENFIELD W GPS
6	7061	0.010	0.010	0.015	0.010	0.010	0.015	KEEFE 3
7	7066	0.010	0.010	0.015	0.010	0.010	0.015	LANNON
8	7068	0.010	0.010	0.015	0.010	0.010	0.015	MEADOW
9	7072	0.010	0.010	0.015	0.010	0.010	0.015	MILWAUKEE GPS
10	7078	0.010	0.010	0.015	0.010	0.010	0.015	OBSERVATORY
11	7082	0.010	0.010	0.015	0.010	0.010	0.015	PEWAUKEE N GPS
12	7092	0.010	0.010	0.015	0.010	0.010	0.015	RASN (WISCORS)
13	7112	0.010	0.010	0.015	0.010	0.010	0.015	VOR MKE 2
14	7117	0.010	0.010	0.015	0.010	0.010	0.015	WAUKESHA N GPS
15	7119	0.010	0.010	0.015	0.010	0.010	0.015	WAUWATOSA W GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7025	X =	151223.5788	151212.0995	BROOKFIELD S GPS
		Y =	-4667028.7082	-4666895.9873	
		Z =	4330429.3951	4330632.1037	
			RPC	HMP	
2	7026	X =	159020.5053	159008.8754	BROWN DEER W GPS
		Y =	-4657214.2028	-4657081.5433	
		Z =	4340600.9421	4340803.6384	
			RPC	HMP	
3	7032	X =	143756.4106	143744.9231	COLGATE GPS
		Y =	-4655393.8921	-4655261.5605	
		Z =	4343155.4382	4343357.8490	
			RPC	HMP	
4	7049	X =	155808.2651	155796.6526	GERMANTOWN S GPS
		Y =	-4654944.8805	-4654812.2837	
		Z =	4343125.5371	4343328.2138	
			RPC	HMP	
5	7051	X =	159837.5094	159826.0669	GREENFIELD W GPS
		Y =	-4671065.2343	-4670932.3919	
		Z =	4325760.4256	4325963.3014	
			RPC	HMP	
6	7061	X =	161454.0696	161442.5098	KEEFE 3
		Y =	-4663177.1502	-4663044.4269	
		Z =	4334145.7140	4334348.4561	
			RPC	HMP	
7	7066	X =	149924.6803	149913.1364	LANNON
		Y =	-4659728.6930	-4659596.1629	
		Z =	4338332.8522	4338535.4123	

Appendix B (continued)

			RPC	HMP	
8	7068	X =	139855.5377	139844.1909	MEADOW
		Y =	-4666691.8774	-4666559.3191	
		Z =	4331245.1797	4331447.7535	
			RPC	HMP	
9	7072	X =	160219.1143	160207.6131	MILWAUKEE GPS
		Y =	-4666314.9769	-4666182.2202	
		Z =	4330828.1917	4331030.9625	
			RPC	HMP	
10	7078	X =	151038.4840	151027.0364	OBSERVATORY
		Y =	-4672198.7515	-4672065.9145	
		Z =	4324936.7297	4325139.6052	
			RPC	HMP	
11	7082	X =	145799.7479	145788.2422	PEWAUKEE N GPS
		Y =	-4662121.9835	-4661989.4385	
		Z =	4335856.9868	4336059.5818	
			RPC	HMP	
12	7092	X =	153071.0890	153059.6160	RASN (WISCORS)
		Y =	-4666991.5483	-4666858.8301	
		Z =	4330413.1240	4330615.8369	
			RPC	HMP	
13	7112	X =	139610.8935	139599.3888	VOR MKE 2
		Y =	-4661334.0925	-4661201.5868	
		Z =	4336996.4595	4337199.0031	
			RPC	HMP	
14	7117	X =	142995.4215	142984.0422	WAUKESHA N GPS
		Y =	-4669473.2169	-4669340.5617	
		Z =	4328076.7466	4328279.4275	
			RPC	HMP	
15	7119	X =	158099.6092	158088.0830	WAUWATOSA W GPS
		Y =	-4663790.6965	-4663657.9630	
		Z =	4333602.0249	4333804.7687	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7025	BROOKFIELD S GPS
2	7026	BROWN DEER W GPS
3	7032	COLGATE GPS
4	7049	GERMANTOWN S GPS
5	7051	GREENFIELD W GPS
6	7061	KEEFE 3
7	7066	LANNON
8	7068	MEADOW
9	7072	MILWAUKEE GPS
10	7078	OBSERVATORY
11	7082	PEWAUKEE N GPS
12	7092	RASN (WISCORS)
13	7112	VOR MKE 2
14	7117	WAUKESHA N GPS
15	7119	WAUWATOSA W GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX = -16.4332 M
TRANSLATION IN Y, TY = 85.4608 M
TRANSLATION IN Z, TZ = 262.1978 M

SCALE IN X/Y/Z -11.768150 PPM

Appendix B (continued)

```
    ROTATION ABOUT X AXIS =  -0.00000208 RAD
                             -0.42818325 SEC
    ROTATION ABOUT Y AXIS =   0.00000767 RAD
                              1.58114423 SEC
    ROTATION ABOUT Z AXIS =  -0.00000856 RAD
                             -1.76628779 SEC


    REFERENCE VARIANCE =         15.715485
    (SIGMA NAUGHT SQUARED)


FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.
```

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7025 X=	151212.100	151212.135	-0.036	E= -0.035 M	= -0.11 FT	BROOKFIELD S GPS
Y=	-4666895.987	-4666896.020	0.032	N= 0.024 M	= 0.08 FT	
Z=	4330632.104	4330632.103	0.001	U= -0.024 M	= -0.08 FT	
7026 X=	159008.875	159008.808	0.067	E= 0.069 M	= 0.23 FT	BROWN DEER W GPS
Y=	-4657081.543	-4657081.584	0.041	N= 0.047 M	= 0.15 FT	
Z=	4340803.638	4340803.610	0.028	U= -0.009 M	= -0.03 FT	
7032 X=	143744.923	143744.858	0.065	E= 0.061 M	= 0.20 FT	COLGATE GPS
Y=	-4655261.560	-4655261.431	-0.130	N= -0.173 M	= -0.57 FT	
Z=	4343357.849	4343357.963	-0.114	U= 0.018 M	= 0.06 FT	
7049 X=	155796.653	155796.567	0.086	E= 0.087 M	= 0.29 FT	GERMANTOWN S GPS
Y=	-4654812.284	-4654812.321	0.038	N= 0.066 M	= 0.22 FT	
Z=	4343328.214	4343328.156	0.058	U= 0.015 M	= 0.05 FT	
7051 X=	159826.067	159826.035	0.032	E= 0.033 M	= 0.11 FT	GREENFIELD W GPS
Y=	-4670932.392	-4670932.415	0.023	N= 0.055 M	= 0.18 FT	
Z=	4325963.301	4325963.246	0.056	U= 0.022 M	= 0.07 FT	
7061 X=	161442.510	161442.444	0.066	E= 0.066 M	= 0.21 FT	KEEFE 3
Y=	-4663044.427	-4663044.427	0.000	N= -0.007 M	= -0.02 FT	
Z=	4334348.456	4334348.464	-0.008	U= -0.004 M	= -0.01 FT	
7066 X=	149913.136	149913.129	0.007	E= 0.006 M	= 0.02 FT	LANNON
Y=	-4659596.163	-4659596.118	-0.045	N= -0.075 M	= -0.24 FT	
Z=	4338535.412	4338535.472	-0.060	U= -0.008 M	= -0.03 FT	
7068 X=	139844.191	139844.219	-0.028	E= -0.029 M	= -0.09 FT	MEADOW
Y=	-4666559.319	-4666559.292	-0.027	N= -0.046 M	= -0.15 FT	
Z=	4331447.753	4331447.791	-0.038	U= -0.007 M	= -0.02 FT	
7072 X=	160207.613	160207.556	0.057	E= 0.057 M	= 0.19 FT	MILWAUKEE GPS
Y=	-4666182.220	-4666182.221	0.000	N= -0.003 M	= -0.01 FT	
Z=	4331030.963	4331030.965	-0.003	U= -0.001 M	= 0.00 FT	
7078 X=	151027.036	151027.129	-0.093	E= -0.090 M	= -0.30 FT	OBSERVATORY
Y=	-4672065.914	-4672065.992	0.078	N= 0.139 M	= 0.46 FT	
Z=	4325139.605	4325139.490	0.115	U= 0.020 M	= 0.06 FT	
7082 X=	145788.242	145788.285	-0.042	E= -0.043 M	= -0.14 FT	PEWAUKEE N GPS
Y=	-4661989.439	-4661989.410	-0.028	N= -0.031 M	= -0.10 FT	
Z=	4336059.582	4336059.599	-0.017	U= 0.008 M	= 0.03 FT	
7092 X=	153059.616	153059.624	-0.008	E= -0.007 M	= -0.02 FT	RASN (WISCORS)
Y=	-4666858.830	-4666858.844	0.014	N= 0.003 M	= 0.01 FT	
Z=	4330615.837	4330615.846	-0.009	U= -0.017 M	= -0.06 FT	

Appendix B (continued)

```
7112 X=   139599.389     139599.488  -0.099  E= -0.099 M  = -0.32 FT  VOR MKE 2
     Y= -4661201.587   -4661201.584  -0.003  N= -0.007 M  = -0.02 FT
     Z=  4337199.003    4337199.013  -0.010  U= -0.007 M  = -0.02 FT

7117 X=   142984.042     142984.114  -0.072  E= -0.071 M  = -0.23 FT  WAUKESHA N GPS
     Y= -4669340.562   -4669340.565   0.003  N=  0.014 M  =  0.05 FT
     Z=  4328279.428    4328279.414   0.014  U=  0.005 M  =  0.02 FT

7119 X=   158088.083     158088.033   0.050  E=  0.051 M  =  0.17 FT  WAUWATOSA W GPS
     Y= -4663657.963   -4663657.994   0.031  N=  0.030 M  =  0.10 FT
     Z=  4333804.769    4333804.755   0.014  U= -0.012 M  = -0.04 FT

                          MEAN OF EAST MISCLOSURE =     0.012 FT
                          STANDARD DEVIATION            0.204 FT

                          MEAN OF NORTH MISCLOSURE =    0.008 FT
                          STANDARD DEVIATION =          0.231 FT

                          MEAN OF UP MISCLOSURE =       0.000 FT
                          STANRDARD DEVIATION =         0.046 FT
```

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - NW Qtr Waukesha County

INPUT FILE: Waukesha County NW.dat
OUTPUT FILE: Waukesha parameters NW.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7032	0.010	0.010	0.015	0.010	0.010	0.015	COLGATE GPS
2	7035	0.010	0.010	0.015	0.010	0.010	0.015	DELAFIELD S GPS
3	7037	0.010	0.010	0.015	0.010	0.010	0.015	DOUSMAN GPS
4	7068	0.010	0.010	0.015	0.010	0.010	0.015	MEADOW
5	7069	0.010	0.010	0.015	0.010	0.010	0.015	MERTON N GPS
6	7079	0.010	0.010	0.015	0.010	0.010	0.015	OCONOMOWOC N GPS
7	7082	0.010	0.010	0.015	0.010	0.010	0.015	PEWAUKEE N GPS
8	7106	0.010	0.010	0.015	0.010	0.010	0.015	STOCK
9	7112	0.010	0.010	0.015	0.010	0.010	0.015	VOR MKE 2
10	7117	0.010	0.010	0.015	0.010	0.010	0.015	WAUKESHA N GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7032	X =	143756.4106	143744.9231	COLGATE GPS
		Y =	-4655393.8921	-4655261.5605	
		Z =	4343155.4382	4343357.8490	
2	7035	X =	133896.6921	133885.3107	DELAFIELD S GPS
		Y =	-4668835.6987	-4668703.1448	
		Z =	4329127.4199	4329329.9763	
3	7037	X =	122294.3204	122282.9047	DOUSMAN GPS
		Y =	-4668958.1995	-4668825.6553	
		Z =	4329265.9047	4329468.4852	
4	7068	X =	139855.5377	139844.1909	MEADOW
		Y =	-4666691.8774	-4666559.3191	
		Z =	4331245.1797	4331447.7535	
5	7069	X =	131736.6272	131725.2159	MERTON N GPS
		Y =	-4655843.3833	-4655711.1519	
		Z =	4343067.7751	4343270.0431	
6	7079	X =	125320.1066	125308.6966	OCONOMOWOC N GPS
		Y =	-4656731.9867	-4656599.7645	
		Z =	4342275.2853	4342477.5366	
7	7082	X =	145799.7479	145788.2422	PEWAUKEE N GPS
		Y =	-4662121.9835	-4661989.4385	
		Z =	4335856.9868	4336059.5818	
8	7106	X =	119099.1426	119087.7353	STOCK
		Y =	-4666026.8722	-4665894.5337	
		Z =	4332513.9584	4332716.3057	

Appendix B (continued)

```
                              RPC                HMP
   9   7112          X =     139610.8935        139599.3888       VOR MKE 2
                     Y =   -4661334.0925      -4661201.5868
                     Z =    4336996.4595       4337199.0031
                              RPC                HMP
  10   7117          X =     142995.4215        142984.0422       WAUKESHA N GPS
                     Y =   -4669473.2169      -4669340.5617
                     Z =    4328076.7466       4328279.4275


POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

  NO.  POINT ID           NAME

    1    7032          COLGATE GPS
    2    7035          DELAFIELD S GPS
    3    7037          DOUSMAN GPS
    4    7068          MEADOW
    5    7069          MERTON N GPS
    6    7079          OCONOMOWOC N GPS
    7    7082          PEWAUKEE N GPS
    8    7106          STOCK
    9    7112          VOR MKE 2
   10    7117          WAUKESHA N GPS


 TRANSFORMATION PARAMETERS FOR POINTS SELECTED:


    TRANSLATION IN X, TX =        -9.1129 M
    TRANSLATION IN Y, TY =        94.3466 M
    TRANSLATION IN Z, TZ =       253.7649 M

    SCALE IN X/Y/Z              -9.870426 PPM

    ROTATION ABOUT X AXIS =  -0.00000198 RAD
                             -0.40938563 SEC
    ROTATION ABOUT Y AXIS =   0.00000566 RAD
                              1.16750796 SEC
    ROTATION ABOUT Z AXIS =  -0.00000505 RAD
                             -1.04181626 SEC


    REFERENCE VARIANCE =         47.106822
    (SIGMA NAUGHT SQUARED)


FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.


 POINT  CONTROL VALUE  COMPUTED VALUE  DIFF IN   DIFF EAST/NORTH/UP     POINT NAME
  ID       HMP (M)         HMP (M)     X/Y/Z (M)   METERS     FEET

 7032 X=   143744.923     143744.809   0.114  E=  0.112 M  =  0.37 FT  COLGATE GPS
      Y= -4655261.560   -4655261.489  -0.072  N= -0.095 M  = -0.31 FT
      Z=  4343357.849    4343357.908  -0.059  U=  0.014 M  =  0.05 FT

 7035 X=   133885.311     133885.335  -0.025  E= -0.024 M  = -0.08 FT  DELAFIELD S GPS
      Y= -4668703.145   -4668703.185   0.040  N=  0.050 M  =  0.16 FT
      Z=  4329329.976    4329329.946   0.030  U= -0.009 M  = -0.03 FT


 7037 X=   122282.905     122283.078  -0.173  E= -0.171 M  = -0.56 FT  DOUSMAN GPS
      Y= -4668825.655   -4668825.743   0.088  N=  0.152 M  =  0.50 FT
      Z=  4329468.485    4329468.363   0.122  U=  0.016 M  =  0.05 FT
```

Appendix B (continued)

7068	X=	139844.191	139844.099	0.092	E= 0.093 M	= 0.30 FT	MEADOW
	Y=	-4666559.319	-4666559.359	0.040	N= 0.048 M	= 0.16 FT	
	Z=	4331447.753	4331447.723	0.031	U= -0.006 M	= -0.02 FT	
7069	X=	131725.216	131725.147	0.069	E= 0.065 M	= 0.21 FT	MERTON N GPS
	Y=	-4655711.152	-4655711.036	-0.116	N= -0.178 M	= -0.58 FT	
	Z=	4343270.043	4343270.177	-0.134	U= -0.006 M	= -0.02 FT	
7079	X=	125308.697	125308.699	-0.002	E= -0.005 M	= -0.02 FT	OCONOMOWOC N GPS
	Y=	-4656599.764	-4656599.662	-0.103	N= -0.158 M	= -0.52 FT	
	Z=	4342477.537	4342477.657	-0.120	U= -0.007 M	= -0.02 FT	
7082	X=	145788.242	145788.202	0.041	E= 0.042 M	= 0.14 FT	PEWAUKEE N GPS
	Y=	-4661989.439	-4661989.489	0.050	N= 0.074 M	= 0.24 FT	
	Z=	4336059.582	4336059.527	0.055	U= 0.002 M	= 0.01 FT	
7106	X=	119087.735	119087.899	-0.163	E= -0.165 M	= -0.54 FT	STOCK
	Y=	-4665894.534	-4665894.467	-0.066	N= -0.091 M	= -0.30 FT	
	Z=	4332716.306	4332716.373	-0.067	U= 0.000 M	= 0.00 FT	
7112	X=	139599.389	139599.398	-0.009	E= -0.008 M	= -0.02 FT	VOR MKE 2
	Y=	-4661201.587	-4661201.639	0.052	N= 0.071 M	= 0.23 FT	
	Z=	4337199.003	4337198.955	0.048	U= -0.006 M	= -0.02 FT	
7117	X=	142984.042	142983.984	0.058	E= 0.061 M	= 0.20 FT	WAUKESHA N GPS
	Y=	-4669340.562	-4669340.649	0.087	N= 0.127 M	= 0.42 FT	
	Z=	4328279.428	4328279.333	0.094	U= 0.002 M	= 0.01 FT	

MEAN OF EAST MISCLOSURE =	0.000 FT
STANDARD DEVIATION	0.324 FT
MEAN OF NORTH MISCLOSURE =	0.000 FT
STANDARD DEVIATION =	0.392 FT
MEAN OF UP MISCLOSURE =	0.000 FT
STANRDARD DEVIATION =	0.029 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - SE Qtr Waukesha County

INPUT FILE: Waukesha County SE.dat
OUTPUT FILE: Waukesha parameters SE.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7025	0.010	0.010	0.015	0.010	0.010	0.015	BROOKFIELD S GPS
2	7035	0.010	0.010	0.015	0.010	0.010	0.015	DELAFIELD S GPS
3	7038	0.010	0.010	0.015	0.010	0.010	0.015	EAGLE GPS
4	7047	0.010	0.010	0.015	0.010	0.010	0.015	FRANKLIN N GPS
5	7051	0.010	0.010	0.015	0.010	0.010	0.015	GREENFIELD W GPS
6	7060	0.010	0.010	0.015	0.010	0.010	0.015	JERICHO
7	7068	0.010	0.010	0.015	0.010	0.010	0.015	MEADOW
8	7074	0.030	0.030	0.015	0.010	0.010	0.015	MUKWONAGO GPS
9	7075	0.010	0.010	0.015	0.010	0.010	0.015	MUSKEGO E GPS
10	7078	0.010	0.010	0.015	0.010	0.010	0.015	OBSERVATORY
11	7092	0.010	0.010	0.015	0.010	0.010	0.015	RASN (WISCORS)
12	7116	0.030	0.030	0.015	0.010	0.010	0.015	WAUKESHA GPS
13	7117	0.010	0.010	0.015	0.010	0.010	0.015	WAUKESHA N GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7025	X =	151223.5788	151212.0995	BROOKFIELD S GPS
		Y =	-4667028.7082	-4666895.9873	
		Z =	4330429.3951	4330632.1037	
2	7035	X =	133896.6921	133885.3107	DELAFIELD S GPS
		Y =	-4668835.6987	-4668703.1448	
		Z =	4329127.4199	4329329.9763	
3	7038	X =	128477.5630	128466.1842	EAGLE GPS
		Y =	-4675851.9758	-4675719.3172	
		Z =	4321746.3587	4321949.0622	
4	7047	X =	159874.4711	159863.1627	FRANKLIN N GPS
		Y =	-4676090.7072	-4675957.8519	
		Z =	4320355.3344	4320558.2017	
5	7051	X =	159837.5094	159826.0669	GREENFIELD W GPS
		Y =	-4671065.2343	-4670932.3919	
		Z =	4325760.4256	4325963.3014	
6	7060	X =	132410.5736	132399.2194	JERICHO
		Y =	-4679848.5692	-4679715.7517	
		Z =	4317337.9355	4317540.7642	
7	7068	X =	139855.5377	139844.1909	MEADOW
		Y =	-4666691.8774	-4666559.3191	
		Z =	4331245.1797	4331447.7535	
8	7074	X =	137090.2107	137078.8886	MUKWONAGO GPS
		Y =	-4681435.8065	-4681302.8932	
		Z =	4315406.0030	4315608.9254	

			RPC	HMP	
9	7075	X =	156989.0379	156977.7951	MUSKEGO E GPS
		Y =	-4679769.5139	-4679636.6313	
		Z =	4316508.5467	4316711.4241	
			RPC	HMP	
10	7078	X =	151038.4840	151027.0364	OBSERVATORY
		Y =	-4672198.7515	-4672065.9145	
		Z =	4324936.7297	4325139.6052	
			RPC	HMP	
11	7092	X =	153071.0890	153059.6160	RASN (WISCORS)
		Y =	-4666991.5483	-4666858.8301	
		Z =	4330413.1240	4330615.8369	
			RPC	HMP	
12	7116	X =	144611.5602	144600.1535	WAUKESHA GPS
		Y =	-4672853.8539	-4672721.1166	
		Z =	4324399.7175	4324602.4875	
			RPC	HMP	
13	7117	X =	142995.4215	142984.0422	WAUKESHA N GPS
		Y =	-4669473.2169	-4669340.5617	
		Z =	4328076.7466	4328279.4275	

POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

NO.	POINT ID	NAME
1	7025	BROOKFIELD S GPS
2	7035	DELAFIELD S GPS
3	7038	EAGLE GPS
4	7047	FRANKLIN N GPS
5	7051	GREENFIELD W GPS
6	7060	JERICHO
7	7068	MEADOW
8	7074	MUKWONAGO GPS
9	7075	MUSKEGO E GPS
10	7078	OBSERVATORY
11	7092	RASN (WISCORS)
12	7116	WAUKESHA GPS
13	7117	WAUKESHA N GPS

TRANSFORMATION PARAMETERS FOR POINTS SELECTED:

TRANSLATION IN X, TX = -14.3919 M
TRANSLATION IN Y, TY = 111.0432 M
TRANSLATION IN Z, TZ = 226.7290 M

SCALE IN X/Y/Z -5.045273 PPM

ROTATION ABOUT X AXIS = -0.00000064 RAD
-0.13107389 SEC
ROTATION ABOUT Y AXIS = 0.00000557 RAD
1.14992357 SEC
ROTATION ABOUT Z AXIS = -0.00000596 RAD
-1.22974269 SEC

REFERENCE VARIANCE = 27.984857
(SIGMA NAUGHT SQUARED)

Appendix B (continued)

FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.

POINT ID	CONTROL VALUE HMP (M)	COMPUTED VALUE HMP (M)	DIFF IN X/Y/Z (M)	DIFF EAST/NORTH/UP METERS	DIFF EAST/NORTH/UP FEET	POINT NAME
7025 X=	151212.100	151212.106	-0.007	E= -0.008 M	= -0.02 FT	BROOKFIELD S GPS
Y=	-4666895.987	-4666895.969	-0.019	N= -0.049 M	= -0.16 FT	
Z=	4330632.104	4330632.153	-0.050	U= -0.020 M	= -0.07 FT	
7035 X=	133885.311	133885.325	-0.015	E= -0.017 M	= -0.06 FT	DELAFIELD S GPS
Y=	-4668703.145	-4668703.053	-0.092	N= -0.143 M	= -0.47 FT	
Z=	4329329.976	4329330.087	-0.111	U= -0.008 M	= -0.03 FT	
7038 X=	128466.184	128466.306	-0.122	E= -0.122 M	= -0.40 FT	EAGLE GPS
Y=	-4675719.317	-4675719.322	0.005	N= 0.030 M	= 0.10 FT	
Z=	4321949.062	4321949.028	0.034	U= 0.017 M	= 0.06 FT	
7047 X=	159863.163	159863.065	0.097	E= 0.098 M	= 0.32 FT	FRANKLIN N GPS
Y=	-4675957.852	-4675957.864	0.012	N= 0.018 M	= 0.06 FT	
Z=	4320558.202	4320558.186	0.016	U= 0.004 M	= 0.01 FT	
7051 X=	159826.067	159826.044	0.023	E= 0.024 M	= 0.08 FT	GREENFIELD W GPS
Y=	-4670932.392	-4670932.420	0.028	N= 0.054 M	= 0.18 FT	
Z=	4325963.301	4325963.253	0.049	U= 0.013 M	= 0.04 FT	
7060 X=	132399.219	132399.346	-0.126	E= -0.123 M	= -0.40 FT	JERICHO
Y=	-4679715.752	-4679715.869	0.117	N= 0.168 M	= 0.55 FT	
Z=	4317540.764	4317540.647	0.118	U= -0.009 M	= -0.03 FT	
7068 X=	139844.191	139844.116	0.075	E= 0.071 M	= 0.23 FT	MEADOW
Y=	-4666559.319	-4666559.208	-0.111	N= -0.163 M	= -0.53 FT	
Z=	4331447.753	4331447.871	-0.117	U= 0.003 M	= 0.01 FT	
7074 X=	137078.889	137078.979	-0.091	E= -0.086 M	= -0.28 FT	MUKWONAGO GPS
Y=	-4681302.893	-4681303.069	0.176	N= 0.251 M	= 0.82 FT	
Z=	4315608.925	4315608.749	0.176	U= -0.011 M	= -0.04 FT	
7075 X=	156977.795	156977.690	0.105	E= 0.106 M	= 0.35 FT	MUSKEGO E GPS
Y=	-4679636.631	-4679636.667	0.036	N= 0.040 M	= 0.13 FT	
Z=	4316711.424	4316711.399	0.025	U= -0.007 M	= -0.02 FT	
7078 X=	151027.036	151027.074	-0.038	E= -0.035 M	= -0.12 FT	OBSERVATORY
Y=	-4672065.914	-4672065.984	0.069	N= 0.117 M	= 0.38 FT	
Z=	4325139.605	4325139.511	0.094	U= 0.013 M	= 0.04 FT	
7092 X=	153059.616	153059.607	0.009	E= 0.008 M	= 0.03 FT	RASN (WISCORS)
Y=	-4666858.830	-4666858.798	-0.032	N= -0.063 M	= -0.21 FT	
Z=	4330615.837	4330615.893	-0.056	U= -0.014 M	= -0.05 FT	
7116 X=	144600.153	144600.190	-0.036	E= -0.036 M	= -0.12 FT	WAUKESHA GPS
Y=	-4672721.117	-4672721.121	0.004	N= 0.020 M	= 0.06 FT	
Z=	4324602.487	4324602.466	0.022	U= 0.011 M	= 0.04 FT	
7117 X=	142984.042	142984.018	0.024	E= 0.022 M	= 0.07 FT	WAUKESHA N GPS
Y=	-4669340.562	-4669340.513	-0.049	N= -0.064 M	= -0.21 FT	
Z=	4328279.428	4328279.469	-0.042	U= 0.008 M	= 0.03 FT	

MEAN OF EAST MISCLOSURE = -0.024 FT
STANDARD DEVIATION 0.244 FT

MEAN OF NORTH MISCLOSURE = 0.054 FT
STANDARD DEVIATION = 0.385 FT

MEAN OF UP MISCLOSURE = 0.000 FT
STANRDARD DEVIATION = 0.040 FT

Appendix B (continued)

PROGRAM: PARAMETERS - VER 1.08, EFB:08/11/09
USED BY: Earl F. Burkholder
DATE: October 31, 2009

ORGANIZATION: Southeastern Wisconsin Regional Planning Commission
PROJECT: Common points with RPC & HMP values - SW Qtr Waukesha County

INPUT FILE: Waukesha County SW.dat
OUTPUT FILE: Waukesha parameters SW.txt

LISTING OF COMMON CONTROL POINTS AVAILABLE FOR USE AND THE
STANDARD DEVIATIONS ASSOCIATED WITH EACH IN METERS

		RPC			HMP			
NO.	PT ID	N	E	U	N	E	U	STATION NAME
1	7035	0.010	0.010	0.015	0.010	0.010	0.015	DELAFIELD S GPS
2	7037	0.010	0.010	0.015	0.010	0.010	0.015	DOUSMAN GPS
3	7038	0.010	0.010	0.015	0.010	0.010	0.015	EAGLE GPS
4	7039	0.030	0.030	0.015	0.010	0.010	0.015	EAGLE E GPS
5	7060	0.010	0.010	0.015	0.010	0.010	0.015	JERICHO
6	7065	0.010	0.010	0.015	0.010	0.010	0.015	LA GRANGE E GPS
7	7068	0.010	0.010	0.015	0.010	0.010	0.015	MEADOW
8	7074	0.030	0.030	0.015	0.010	0.010	0.015	MUKWONAGO GPS
9	7080	0.010	0.010	0.015	0.010	0.010	0.015	PAR0 (WISCORS)
10	7116	0.030	0.030	0.015	0.010	0.010	0.015	WAUKESHA GPS
11	7117	0.010	0.010	0.015	0.010	0.010	0.015	WAUKESHA N GPS

PSEUDO-RPC AND HMP GEOCENTRIC COORDINATES OF COMMON CONTROL POINTS IN METERS

			RPC	HMP	
1	7035	X =	133896.6921	133885.3107	DELAFIELD S GPS
		Y =	-4668835.6987	-4668703.1448	
		Z =	4329127.4199	4329329.9763	
			RPC	HMP	
2	7037	X =	122294.3204	122282.9047	DOUSMAN GPS
		Y =	-4668958.1995	-4668825.6553	
		Z =	4329265.9047	4329468.4852	
			RPC	HMP	
3	7038	X =	128477.5630	128466.1842	EAGLE GPS
		Y =	-4675851.9758	-4675719.3172	
		Z =	4321746.3587	4321949.0622	
			RPC	HMP	
4	7039	X =	125825.5528	125814.1682	EAGLE E GPS
		Y =	-4678743.8492	-4678611.1419	
		Z =	4318704.5740	4318907.3078	
			RPC	HMP	
5	7060	X =	132410.5736	132399.2194	JERICHO
		Y =	-4679848.5692	-4679715.7517	
		Z =	4317337.9355	4317540.7642	
			RPC	HMP	
6	7065	X =	116347.2498	116335.8118	LA GRANGE E GPS
		Y =	-4686441.9217	-4686309.4311	
		Z =	4310669.5255	4310872.0286	
			RPC	HMP	
7	7068	X =	139855.5377	139844.1909	MEADOW
		Y =	-4666691.8774	-4666559.3191	
		Z =	4331245.1797	4331447.7535	
			RPC	HMP	
8	7074	X =	137090.2107	137078.8886	MUKWONAGO GPS
		Y =	-4681435.8065	-4681302.8932	
		Z =	4315406.0030	4315608.9254	

```
                              RPC                HMP
   9   7080         X =     114982.3218        114970.9158       PAR0  (WISCORS)
                    Y =   -4680393.2744      -4680260.7516
                    Z =    4317196.2985       4317398.8063
                              RPC                HMP
  10   7116         X =     144611.5602        144600.1535       WAUKESHA GPS
                    Y =   -4672853.8539      -4672721.1166
                    Z =    4324399.7175       4324602.4875
                              RPC                HMP
  11   7117         X =     142995.4215        142984.0422       WAUKESHA N GPS
                    Y =   -4669473.2169      -4669340.5617
                    Z =    4328076.7466       4328279.4275


POINTS SELECTED FOR DEVELOPING THE TRANSFORMATIONS:

  NO.  POINT ID           NAME

    1    7035          DELAFIELD S GPS
    2    7037          DOUSMAN GPS
    3    7038          EAGLE GPS
    4    7039          EAGLE E GPS
    5    7060          JERICHO
    6    7065          LA GRANGE E GPS
    7    7068          MEADOW
    8    7074          MUKWONAGO GPS
    9    7080          PAR0  (WISCORS)
   10    7116          WAUKESHA GPS
   11    7117          WAUKESHA N GPS


 TRANSFORMATION PARAMETERS FOR POINTS SELECTED:


    TRANSLATION IN X, TX =       -13.8304 M
    TRANSLATION IN Y, TY =       138.5538 M
    TRANSLATION IN Z, TZ =       203.9813 M

    SCALE IN X/Y/Z              0.548578 PPM

    ROTATION ABOUT X AXIS =  -0.00000086 RAD
                             -0.17771947 SEC
    ROTATION ABOUT Y AXIS =   0.00000236 RAD
                              0.48701291 SEC
    ROTATION ABOUT Z AXIS =  -0.00000269 RAD
                             -0.55505209 SEC


    REFERENCE VARIANCE =        38.782627
    (SIGMA NAUGHT SQUARED)



FOLLOWING IS A COMPARISON OF KNOWN POINTS AND COMPUTED VALUES FOR THE POINT.


 POINT  CONTROL VALUE  COMPUTED VALUE  DIFF IN   DIFF EAST/NORTH/UP     POINT NAME
  ID       HMP (M)         HMP (M)     X/Y/Z (M)   METERS     FEET

 7035 X=   133885.311     133885.277   0.033  E=  0.031 M  =  0.10 FT  DELAFIELD S GPS
      Y= -4668703.145   -4668703.076  -0.069  N= -0.116 M  = -0.38 FT
      Z=  4329329.976    4329330.069  -0.093  U= -0.012 M  = -0.04 FT

 7037 X=   122282.905     122282.899   0.005  E=  0.004 M  =  0.01 FT  DOUSMAN GPS
      Y= -4668825.655   -4668825.608  -0.047  N= -0.063 M  = -0.21 FT
      Z=  4329468.485    4329468.527  -0.042  U=  0.006 M  =  0.02 FT
```

Appendix B (continued)

```
7038 X=   128466.184     128466.182   0.003  E=  0.004 M  =  0.01 FT  EAGLE GPS
     Y= -4675719.317   -4675719.365   0.048  N=  0.089 M  =  0.29 FT
     Z=  4321949.062    4321948.985   0.077  U=  0.017 M  =  0.06 FT

7039 X=   125814.168     125814.185  -0.017  E= -0.014 M  = -0.05 FT  EAGLE E GPS
     Y= -4678611.142   -4678611.244   0.103  N=  0.156 M  =  0.51 FT
     Z=  4318907.308    4318907.190   0.118  U=  0.005 M  =  0.01 FT

7060 X=   132399.219     132399.215   0.004  E=  0.009 M  =  0.03 FT  JERICHO
     Y= -4679715.752   -4679715.946   0.194  N=  0.278 M  =  0.91 FT
     Z=  4317540.764    4317540.566   0.199  U= -0.007 M  = -0.02 FT

7065 X=   116335.812     116335.916  -0.105  E= -0.107 M  = -0.35 FT  LA GRANGE E GPS
     Y= -4686309.431   -4686309.340  -0.091  N= -0.119 M  = -0.39 FT
     Z=  4310872.029    4310872.108  -0.080  U=  0.011 M  =  0.04 FT

7068 X=   139844.191     139844.115   0.075  E=  0.073 M  =  0.24 FT  MEADOW
     Y= -4666559.319   -4666559.239  -0.080  N= -0.124 M  = -0.41 FT
     Z=  4331447.753    4331447.846  -0.093  U= -0.003 M  = -0.01 FT

7074 X=   137078.889     137078.864   0.025  E=  0.033 M  =  0.11 FT  MUKWONAGO GPS
     Y= -4681302.893   -4681303.170   0.277  N=  0.396 M  =  1.30 FT
     Z=  4315608.925    4315608.642   0.284  U= -0.009 M  = -0.03 FT

7080 X=   114970.916     114970.956  -0.040  E= -0.041 M  = -0.14 FT  PAR0  (WISCORS)
     Y= -4680260.752   -4680260.698  -0.053  N= -0.095 M  = -0.31 FT
     Z=  4317398.806    4317398.887  -0.081  U= -0.017 M  = -0.05 FT

7116 X=   144600.153     144600.173  -0.020  E= -0.017 M  = -0.06 FT  WAUKESHA GPS
     Y= -4672721.117   -4672721.200   0.084  N=  0.131 M  =  0.43 FT
     Z=  4324602.487    4324602.386   0.101  U=  0.007 M  =  0.02 FT

7117 X=   142984.042     142984.016   0.026  E=  0.026 M  =  0.09 FT  WAUKESHA N GPS
     Y= -4669340.562   -4669340.569   0.007  N=  0.012 M  =  0.04 FT
     Z=  4328279.428    4328279.417   0.011  U=  0.003 M  =  0.01 FT

                          MEAN OF EAST MISCLOSURE =     0.001 FT
                          STANDARD DEVIATION            0.153 FT

                          MEAN OF NORTH MISCLOSURE =    0.163 FT
                          STANDARD DEVIATION =          0.580 FT

                          MEAN OF UP MISCLOSURE =       0.000 FT
                          STANRDARD DEVIATION =         0.035 FT
```

Appendix C

EQUATIONS AND COEFFICIENTS FOR VERTICAL POSITION TRANSFORMATION AND RESULTS OF MODELING DIFFERENCES BETWEEN RPC AND HMP ELEVATIONS FOR COMMON POINTS BY COUNTY IN THE SOUTHEASTERN WISCONSIN REGION

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin 53187

Evaluation of Vertical Modeling - Kenosha County, WI

Coefficients for Kenosha County:

a =	8.43360E-12
b =	-3.15135E-06
c =	3.66856E-11
d =	-5.34262E-06
e =	1.58098E-11

Polynomial modeling equation is:

$$Elev_{HMP} = El_{RPC} + aX^2 + bX + cXY + dY + eY^2$$

where: X = Easting minus 2,400,000 feet
Y = Northing minus 185,000 feet

Sta ID	Station Name	NAD 83 (2007) SPC Easting (ft)	NAD 83 (2007) SPC Northing (ft)	RPC NGVD 29 El. - feet	HMP NAVD 88 El. feet	Known Differ 29→88 feet	Modeled HMP Elev. Ft	Modeled Diffter. 29→88 feet	Differ. of Differ. feet
7021	BLOOMFIELD S GPS	2404598.570	195079.220	887.000	886.750	-0.25	886.935	-0.065	-0.185
7023	BRIGHTON N GPS	2462660.890	244236.050	791.380	791.130	-0.25	791.091	-0.289	0.039
7024	BRISTOL E GPS	2507386.330	202640.190	694.260	694.070	-0.19	693.999	-0.261	0.071
7028	BURLINGTON W	2425074.510	230227.360	865.190	864.860	-0.33	864.949	-0.241	-0.089
7062	KEHA (WISCORS)	2529086.840	210726.890	783.640	783.380	-0.26	783.369	-0.271	0.011
7063	KELLY	2519059.280	187093.740	785.970	785.740	-0.23	785.712	-0.258	0.028
7084	PLEASANT PRAIRIE E GPS	2557805.080	211977.480	592.790	592.630	-0.16	592.526	-0.264	0.104
7085	PLEASANT PRAIRIE GPS	2555664.310	192595.870	627.900	627.550	-0.35	627.618	-0.282	-0.068
7089	RACINE	2555547.510	269549.660	644.550	644.310	-0.24	644.408	-0.142	-0.098
7097	SALEM E GPS	2485812.840	199900.590	857.510	857.110	-0.40	857.272	-0.238	-0.162
7101	SILVER	2456768.070	206186.030	841.980	841.810	-0.17	841.766	-0.214	0.044
7102	SILVER LAKE GPS	2465556.900	199326.300	749.230	749.080	-0.15	749.021	-0.209	0.059
7104	SOMERS S GPS	2539737.110	227445.130	724.150	723.860	-0.29	723.894	-0.256	-0.034
7110	TWIN LAKES GPS	2428048.910	193844.400	859.790	859.490	-0.30	859.671	-0.119	-0.181
7111	UNION GROVE GPS	2489536.600	256378.100	801.590	801.340	-0.25	801.309	-0.281	0.031
7129	YORKVILLE E GPS	2512247.810	259687.510	794.000	793.850	-0.15	793.749	-0.251	0.101
7130	1L05	2530868.108	226742.005	685.991	685.720	-0.27	685.728	-0.263	-0.008
7131	1L06	2545919.650	226212.724	655.256	654.930	-0.33	655.003	-0.253	-0.073
7132	1X04	2425351.133	225055.187	841.708	841.390	-0.32	841.482	-0.226	-0.092

Mean feet =	-0.026
Std. Dev. Feet =	**0.092**

Appendix C (continued)

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin 53187

Evaluation of Vertical Modeling - Milwaukee County, WI

Coefficients for Milwaukee County:

a =	4.30438E-11
b =	-7.86877E-06
c =	-1.21150E-11
d =	1.34331E-06
e =	5.74893E-12

Polynomial modeling equation is:

$$Elev_{HMP} = El_{RPC} + aX^2 + bX + cXY + dY + eY^2$$

where: X = Easting - 2,400,000.00 ft
Y= Northing - 300,000.00 ft

Sta ID	Station Name	NAD 83 (2007) SPC Easting (ft)	NAD 83 (2007) SPC Northing (ft)	RPC NGVD 29 El. - feet	HMP NAVD 88 El. feet	Known Differ 29→88 feet	Modeled HMP Elev. Ft	Modeled Diffter. 29→88 feet	Differ. of Differ. feet
7026	BROWN DEER W GPS	2490187.630	429702.920	789.390	789.16	-0.23	789.160	-0.230	0.000
7027	BUCYRUS	2547620.940	321429.720	715.150	714.90	-0.25	714.920	-0.230	-0.020
7029	CALEDONIA GPS	2527884.700	308983.180	680.370	680.06	-0.31	680.066	-0.304	-0.006
7045	FOX	2532554.220	432641.730	687.160	686.92	-0.24	686.940	-0.220	-0.020
7046	FRANKLIN	2497512.350	325486.360	791.620	791.27	-0.35	791.270	-0.350	0.000
7047	FRANKLIN N GPS	2493005.540	338896.370	765.980	765.66	-0.32	765.638	-0.342	0.022
7048	FRANKLIN S GPS	2514554.450	324680.750	726.830	726.47	-0.36	726.496	-0.334	-0.026
7049	GERMANTOWN S GPS	2479646.060	440835.300	770.870	770.76	-0.11	770.684	-0.186	0.076
7051	GREENFIELD W GPS	2492878.700	363108.570	783.160	782.89	-0.27	782.837	-0.323	0.053
7052	HALBACH	2509114.680	367534.310	734.540	734.25	-0.29	734.222	-0.318	0.028
7061	KEEFE 3	2498177.300	400875.830	783.760	783.47	-0.29	783.476	-0.284	-0.006
7066	LANNON	2460336.300	418629.220	993.900	993.71	-0.19	993.735	-0.165	-0.025
7071	MILWAUKE C GPS	2510048.020	387953.090	668.810	668.48	-0.33	668.511	-0.299	-0.031
7072	MILWAUKEE GPS	2494127.430	385895.290	766.910	766.61	-0.30	766.611	-0.299	-0.001
7073	MITCHELL	2530304.640	356471.430	674.100	673.86	-0.24	673.811	-0.289	0.049
7075	MUSKEGO E GPS	2483540.200	321434.240	779.440	779.09	-0.35	779.093	-0.347	-0.003
7077	OAK CREEK E GPS	2544719.320	332300.400	672.900	672.67	-0.23	672.655	-0.245	0.015
7092	RASN (WISCORS)	2470668.410	383381.310	883.550	883.24	-0.31	883.289	-0.261	-0.049
7103	SIWI (WISCORS)	2509198.570	322873.670	740.240	739.88	-0.36	739.897	-0.343	-0.017
7118	WAUWATOSA	2500764.820	444071.230	707.000	706.76	-0.24	706.781	-0.219	-0.021
7119	WAUWATOSA W GPS	2487170.430	398196.780	759.430	759.13	-0.30	759.155	-0.275	-0.025

Mean feet = 0.000
Std. Dev. feet = **0.031**

Appendix C (continued)

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin 53187

Evaluation of Vertical Modeling - Ozaukee County, WI

Coefficients for Ozaukee County:

a =	-1.10868E-12
b =	-1.81478E-06
c =	3.16690E-12
d =	-3.76987E-07
e =	2.58500E-14

Polynomial modeling equation is:

$$Elev_{HMP} = El_{PRC} + aX^2 + bX + cXY + dY + eY^2$$

where: X = Easting - 2,400,000.00 ft
Y= Northing - 400,000.00 ft

Sta ID	Station Name	NAD 83 (2007) SPC Easting (ft)	NAD 83 (2007) SPC Northing (ft)	RPC NGVD 29 El. - feet	HMP NAVD 88 El. feet	Known Differ 29→88 feet	Modeled HMP Elev. Ft	Modeled Diffter. 29→88 feet	Differ. of Differ. feet
7016	2Y46	2520984.010	495806.250	762.570	762.40	-0.17	762.335	-0.235	0.065
7026	BROWN DEER W GPS	2490187.630	429702.920	789.390	789.16	-0.23	789.215	-0.175	-0.055
7031	CEDAR 2	2544977.160	569960.740	758.910	758.61	-0.30	758.638	-0.272	-0.028
7043	FARMINGTON W GPS	2461823.080	546869.490	934.050	933.88	-0.17	933.908	-0.142	-0.028
7045	FOX	2532554.220	432641.730	687.160	686.92	-0.24	686.901	-0.259	0.019
7049	GERMANTOWN S GPS	2479646.060	440835.300	770.870	770.76	-0.11	770.713	-0.157	0.047
7050	GRAFTON	2518412.390	492865.520	812.040	811.86	-0.18	811.810	-0.230	0.050
7054	HOLLAND S GPS	2543360.750	575219.090	742.990	742.69	-0.30	742.721	-0.269	-0.031
7056	JACKSON	2469460.830	487977.480	892.120	892.01	-0.11	891.975	-0.145	0.035
7057	JACKSON GPS	2451747.120	482633.330	864.500	864.42	-0.08	864.386	-0.114	0.034
7058	JACKSON N GPS	2457573.930	504171.910	943.740	943.62	-0.12	943.612	-0.128	0.008
7076	NEW FANE GPS	2456717.540	567752.170	1067.090	1067.00	-0.09	1066.951	-0.139	0.049
7087	PORT	2521276.450	470346.360	682.550	682.27	-0.28	682.314	-0.236	-0.044
7088	PORT WASHINGTON C GPS	2531041.460	521405.290	727.900	727.63	-0.27	727.648	-0.252	-0.018
7091	RANDOM LAKE GPS	2522713.200	574752.090	860.930	860.63	-0.30	860.693	-0.237	-0.063
7093	RICHFIELD E GPS	2442818.420	461037.680	1053.210	1053.17	-0.04	1053.116	-0.094	0.054
7098	SAUKVILLE C GPS	2503944.940	516452.750	892.330	892.17	-0.16	892.124	-0.206	0.046
7099	SHAN (WISCORS)	2566993.590	645093.640	619.340	619.09	-0.25	619.045	-0.295	0.045
7118	WAUWATOSA	2500764.820	444071.230	707.000	706.76	-0.24	706.803	-0.197	-0.043
7122	WEBE (WISCORS)	2460288.170	523204.830	886.430	886.24	-0.19	886.294	-0.136	-0.054
7124	WEST BEND GPS	2464035.980	523619.930	883.260	883.06	-0.20	883.118	-0.142	-0.058

Mean feet = 0.001
Std. Dev. Feet = **0.045**

Appendix C (continued)

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin 53187

Evaluation of Vertical Modeling - Racine County, WI

Coefficients for Racine County:

a =	9.75797E-12
b =	-3.30914E-06
c =	2.02636E-11
d =	-1.66589E-06
e =	-1.39584E-11

Polynomial modeling equation is:

$$Elev_{HMP} = El_{RPC} + aX^2 + bX + cXY + dY + eY^2$$

where: X = Easting - 2,400,000.00 ft
Y= Northing - 225,000.00 ft

Sta ID	Station Name	NAD 83 (2007) SPC Easting (ft)	NAD 83 (2007) SPC Northing (ft)	RPC NGVD 29 El. - feet	HMP NAVD 88 El. feet	Known Differ 29→88 feet	Modeled HMP Elev. Ft	Modeled Diffter. 29→88 feet	Differ. of Differ. feet
7020	BEAUMONT	2476691.310	276278.750	803.310	803.12	-0.19	803.071	-0.239	0.049
7023	BRIGHTON N GPS	2462660.890	244236.050	791.380	791.13	-0.25	791.198	-0.182	-0.068
7027	BUCYRUS	2547620.940	321429.720	715.150	714.90	-0.25	714.872	-0.278	0.028
7029	CALEDONIA GPS	2527884.700	308983.180	680.370	680.06	-0.31	680.086	-0.284	-0.026
7030	CALEDONIA W GPS	2528226.870	294396.770	720.180	719.88	-0.30	719.914	-0.266	-0.034
7046	FRANKLIN	2497512.350	325486.360	791.620	791.27	-0.35	791.280	-0.340	-0.010
7055	HONEY 2	2405958.820	274595.210	992.690	992.46	-0.23	992.560	-0.130	-0.100
7074	MUKWONAGO GPS	2418241.900	315050.400	820.920	820.66	-0.26	820.633	-0.287	0.027
7075	MUSKEGO E GPS	2483540.200	321434.240	779.440	779.09	-0.35	779.104	-0.336	-0.014
7083	PLEASANT 2	2531258.410	275179.940	757.850	757.61	-0.24	757.598	-0.252	0.012
7089	RACINE	2555547.510	269549.660	644.550	644.31	-0.24	644.310	-0.240	0.000
7094	ROCHESTER C GPS	2442004.920	263254.550	777.670	777.43	-0.24	777.497	-0.173	-0.067
7103	SIWI (WISCORS)	2509198.570	322873.670	740.240	739.88	-0.36	739.915	-0.325	-0.035
7104	SOMERS S GPS	2539737.110	227445.130	724.150	723.86	-0.29	723.881	-0.269	-0.021
7111	UNION GROVE GPS	2489536.600	256378.100	801.590	801.34	-0.25	801.363	-0.227	-0.023
7113	WATERFORD GPS	2454108.400	288698.060	794.380	794.21	-0.17	794.137	-0.243	0.073
7114	WATERFORD W GPS	2433426.850	293986.710	816.430	816.25	-0.18	816.196	-0.234	0.054
7129	YORKVILLE E GPS	2512247.810	259687.510	794.000	793.85	-0.15	793.756	-0.244	0.094

Mean feet = -0.003
Std. Dev. Feet = **0.051**

Appendix C (continued)

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin 53187

Evaluation of Vertical Modeling - Walworth County, WI

Coefficients for Walworth County:

a =	4.00825E-12
b =	-2.35195E-06
c =	9.45303E-12
d =	-1.87160E-06
e =	6.59620E-12

Polynomial modeling equation is:

$$Elev_{HMP} = El_{RPC} + aX^2 + bX + cXY + dY + eY^2$$

where: X = Easting - 2,200,000.00 ft
Y= Northing - 175,000.00 ft

Sta ID	Station Name	NAD 83 (2007) SPC Easting (ft)	NAD 83 (2007) SPC Northing (ft)	RPC NGVD 29 El. - feet	HMP NAVD 88 El. feet	Known Differ 29→88 feet	Modeled HMP Elev. Ft	Modeled Diffter. 29→88 feet	Differ. of Differ. feet
7021	BLOOMFIELD S GPS	2404598.570	195079.220	887.000	886.75	-0.25	886.690	-0.310	0.060
7022	BRADFORD S GPS	2291432.000	221467.530	855.160	854.92	-0.24	854.946	-0.214	-0.026
7028	BURLINGTON W GPS	2425074.510	230227.360	865.190	864.86	-0.33	864.898	-0.292	-0.038
7034	DARIEN E GPS	2325826.880	228554.890	932.270	931.96	-0.31	932.020	-0.250	-0.060
7039	EAGLE E GPS	2381273.370	328981.640	952.800	952.66	-0.14	952.637	-0.163	0.023
7040	EAST TROY	2394276.790	281015.730	1037.460	1037.23	-0.23	1037.225	-0.235	0.005
7041	ELKHORN GPS	2367662.370	245985.250	1031.940	1031.68	-0.26	1031.671	-0.269	0.009
7055	HONEY 2	2405958.820	274595.210	992.690	992.46	-0.23	992.449	-0.241	0.011
7065	LA GRANGE E GPS	2350179.420	292474.230	949.090	948.98	-0.11	948.865	-0.225	0.115
7067	LYONS N GPS	2407196.780	242323.390	851.270	850.95	-0.32	850.991	-0.279	-0.041
7070	MILLARD	2338357.650	278437.610	952.070	951.87	-0.20	951.834	-0.236	0.036
7074	MUKWONAGO GPS	2418241.900	315050.400	820.920	820.66	-0.26	820.754	-0.166	-0.094
7080	PAR0 (WISCORS)	2345697.080	321666.650	878.410	878.25	-0.16	878.222	-0.188	0.028
7081	PELL LAKE GPS	2382061.570	186837.520	991.430	991.12	-0.31	991.134	-0.296	-0.014
7094	ROCHESTER C GPS	2442004.920	263254.550	777.670	777.43	-0.24	777.424	-0.246	0.006
7100	SHARON C GPS	2318162.930	202375.440	955.750	955.52	-0.23	955.512	-0.238	0.008
7105	SPRING 2	2331387.140	319584.500	795.540	795.36	-0.18	795.347	-0.193	0.013
7108	SUGAR CREEK S GPS	2348585.770	255453.720	988.740	988.49	-0.25	988.484	-0.256	0.006
7110	TWIN LAKES GPS	2428048.910	193844.400	859.790	859.49	-0.30	859.470	-0.320	0.020
7114	WATERFORD W GPS	2433426.850	293986.710	816.430	816.25	-0.18	816.233	-0.197	0.017
7123	WEEKS	2313456.100	177699.770	1049.190	1048.94	-0.25	1048.973	-0.217	-0.033
7125	WHITEWATER	2306509.260	309311.250	871.900	871.51	-0.39	871.698	-0.202	-0.188
7126	WHITEWATER GPS	2317321.920	302306.170	844.190	844.09	-0.10	843.979	-0.211	0.111
7127	WHITEWATER W GPS	2296955.520	295972.650	880.940	880.73	-0.21	880.731	-0.209	-0.001
7128	YERKES	2357547.850	211599.660	1040.840	1040.56	-0.28	1040.564	-0.276	-0.004

Mean feet = -0.001
Std. Dev. Feet = **0.060**

Appendix C (continued)

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin 53187

Evaluation of Vertical Modeling - Washington County, WI

Coefficients for Washington County:

a =	-3.71288E-12
b =	-6.73211E-07
c =	1.11057E-12
d =	7.89350E-12
e =	-9.42632E-12

Polynomial modeling equation is:

$$Elev_{HMP} = El_{RPC} + aX^2 + bX + cXY + dY + eY^2$$

where: X = Easting - 2,350,000.00 ft
Y= Northing - 430,000.00 ft

Sta ID	Station Name	NAD 83 (2007) SPC Easting (ft)	NAD 83 (2007) SPC Northing (ft)	RPC NGVD 29 El. - feet	HMP NAVD 88 El. feet	Known Differ 29→88 feet	Modeled HMP Elev. Ft	Modeled Diffter. 29→88 feet	Differ. of Differ. feet
7017	ADDISON E GPS	2424799.480	525035.980	1173.720	1173.61	-0.11	1173.572	-0.148	0.038
7026	BROWN DEER W GPS	2490187.630	429702.920	789.390	789.16	-0.23	789.223	-0.167	-0.063
7032	COLGATE GPS	2440094.380	439893.880	983.820	983.80	-0.02	983.729	-0.091	0.071
7042	ELMORE 2	2433039.930	575164.190	1064.950	1064.73	-0.22	1064.683	-0.267	0.047
7043	FARMINGTON W GPS	2461823.080	546869.490	934.050	933.88	-0.17	933.814	-0.236	0.066
7049	GERMANTOWN S GPS	2479646.060	440835.300	770.870	770.76	-0.11	770.721	-0.149	0.039
7050	GRAFTON	2518412.390	492865.520	812.040	811.86	-0.18	811.796	-0.244	0.064
7053	HARTFORD C GPS	2408500.340	484686.450	1009.890	1009.86	-0.03	1009.813	-0.077	0.047
7056	JACKSON	2469460.830	487977.480	892.120	892.01	-0.11	891.963	-0.157	0.047
7057	JACKSON GPS	2451747.120	482633.330	864.500	864.42	-0.08	864.373	-0.127	0.047
7058	JACKSON N GPS	2457573.930	504171.910	943.740	943.62	-0.12	943.582	-0.158	0.038
7064	KEWASKUM C GPS	2435077.720	556359.340	996.260	996.08	-0.18	996.037	-0.223	0.043
7069	MERTON N GPS	2400654.110	438671.230	1011.150	1011.10	-0.05	1011.106	-0.044	-0.006
7076	NEW FANE GPS	2456717.540	567752.170	1067.090	1067.00	-0.09	1066.813	-0.277	0.187
7079	OCONOMOWOC N GPS	2379602.310	434779.010	932.970	932.93	-0.04	932.947	-0.023	-0.017
7086	POLK C GPS	2433305.170	487426.360	1113.540	1113.56	0.02	1113.432	-0.108	0.128
7091	RANDOM LAKE GPS	2522713.200	574752.090	860.930	860.63	-0.30	860.533	-0.397	0.097
7093	RICHFIELD E GPS	2442818.420	461037.680	1053.210	1053.17	-0.04	1053.110	-0.100	0.060
7095	RUBICON	2405129.360	492510.070	1072.030	1072.00	-0.03	1071.949	-0.081	0.051
7096	RUBICON E GPS	2386828.340	494874.010	1043.080	1043.03	-0.05	1043.013	-0.067	0.017
7098	SAUKVILLE C GPS	2503944.940	516452.750	892.330	892.17	-0.16	892.083	-0.247	0.087
7107	ST PAUL 2	2381656.910	569287.050	1000.310	1000.23	-0.08	1000.107	-0.203	0.123
7121	WAYNE N GPS	2408307.960	556097.580	1045.590	1045.50	-0.09	1045.396	-0.194	0.104
7122	WEBE (WISCORS)	2460288.170	523204.830	886.430	886.24	-0.19	886.240	-0.190	0.000
7124	WEST BEND GPS	2464035.980	523619.930	883.260	883.06	-0.20	883.064	-0.196	-0.004

Mean feet = 0.052
Std. Dev. Feet = **0.052**

Appendix C (continued)

Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin 53187

Evaluation of Vertical Modeling - Waukesha County, WI

Coefficients for Waukesha County:

a =	-6.32130E-13
b =	-1.86087E-06
c =	4.66808E-12
d =	-5.97366E-07
e =	7.91542E-12

Polynomial modeling equation is:

$$Elev_{HMP} = El_{RPC} + aX^2 + bX + cXY + dY + eY^2$$

where: X = Easting - 2,300,000.00 ft
Y= Northing - 290,000.00 ft

Sta ID	Station Name	NAD 83 (2007) SPC Easting (ft)	NAD 83 (2007) SPC Northing (ft)	RPC NGVD 29 El. - feet	HMP NAVD 88 El. feet	Known Differ 29→88 feet	Modeled HMP Elev. Ft	Modeled Diffter. 29→88 feet	Differ. of Differ. feet
7026	BROWN DEER W GPS	2490187.630	429702.920	789.390	789.16	-0.23	789.208	-0.182	-0.048
7032	COLGATE GPS	2440094.380	439893.880	983.820	983.80	-0.02	983.733	-0.087	0.067
7035	DELAFIELD S GPS	2407748.350	376159.800	1012.100	1011.91	-0.19	1011.943	-0.157	-0.033
7037	DOUSMAN GPS	2369681.540	376212.730	852.260	852.19	-0.07	852.163	-0.097	0.027
7038	EAGLE GPS	2389972.560	342750.970	974.500	974.40	-0.10	974.340	-0.160	0.060
7039	EAGLE E GPS	2381273.370	328981.640	952.800	952.66	-0.14	952.648	-0.152	0.012
7049	GERMANTOWN S GPS	2479646.060	440835.300	770.870	770.76	-0.11	770.732	-0.138	0.028
7051	GREENFIELD W GPS	2492878.700	363108.570	783.160	782.89	-0.27	782.842	-0.318	0.048
7060	JERICHO	2402880.990	323234.630	993.230	993.01	-0.22	993.037	-0.193	-0.027
7065	LA GRANGE E GPS	2350179.420	292474.230	949.090	948.98	-0.11	948.994	-0.096	-0.014
7066	LANNON	2460336.300	418629.220	993.900	993.71	-0.19	993.736	-0.164	-0.026
7068	MEADOW	2427299.380	386040.210	1033.830	1033.65	-0.18	1033.656	-0.174	-0.006
7069	MERTON N GPS	2400654.110	438671.230	1011.150	1011.10	-0.05	1011.112	-0.038	-0.012
7074	MUKWONAGO GPS	2418241.900	315050.400	820.920	820.66	-0.26	820.695	-0.225	-0.035
7075	MUSKEGO E GPS	2483540.200	321434.240	779.440	779.09	-0.35	779.093	-0.347	-0.003
7078	OBSERVATORY	2464000.720	358591.280	957.640	957.41	-0.23	957.367	-0.273	0.043
7079	OCONOMOWOC N GPS	2379602.310	434779.010	932.970	932.93	-0.04	932.951	-0.019	-0.021
7080	PAR0 (WISCORS)	2345697.080	321666.650	878.410	878.25	-0.16	878.319	-0.091	-0.069
7082	PEWAUKEE N GPS	2446805.260	407332.710	856.970	856.84	-0.13	856.802	-0.168	0.038
7092	RASN (WISCORS)	2470668.410	383381.310	883.550	883.24	-0.31	883.302	-0.248	-0.062
7106	STOCK	2359195.150	390561.520	901.300	901.22	-0.08	901.235	-0.065	-0.015
7112	VOR MKE 2	2426492.230	411825.440	1071.780	1071.65	-0.13	1071.651	-0.129	-0.001
7116	WAUKESHA GPS	2442914.330	355833.190	840.640	840.44	-0.20	840.400	-0.240	0.040
7117	WAUKESHA N GPS	2437608.670	372217.800	836.670	836.48	-0.19	836.459	-0.211	0.021
7119	WAUWATOSA W GPS	2487170.430	398196.780	759.430	759.13	-0.30	759.182	-0.248	-0.052

Mean = -0.002
Std. Dev. = **0.039**

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Appendix D

State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet.
HMP positions consist of NAD 83 (2007) state plane coordinates and NAVD 88 (2007) elevations in feet.

Kenosha County, Wisconsin

Computations performed by: Earl F. Burkholder Date: December 19, 2009

RPC to HMP Name of Station **2001 1-19 S-16**

	Input (RPC)				Output (HMP)			
Northing = y =	201,107.980	ft			Northing =	201,117.425	ft	
Easting = x =	2,470,006.700	ft			Easting =	2,438,470.130	ft	
Elevation =	833.709	ft			Elevation =	833.541	ft	
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	32	17.85711		Latitude =	42	32	17.93053
Longitude =	88	15	22.00525		Longitude =	88	15	22.31650

HMP to RPC Name of Station **2001 1-19 S-16**

	Input (HMP)				Output (RPC)			
Northing =	201,117.520	ft			Northing = y =	201,108.075	ft	
Easting =	2,438,469.994	ft			Easting = x =	2,470,006.564	ft	
Elevation =	833.531	ft			Elevation =	833.699	ft	
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	32	17.93150		Latitude =	42	32	17.85808
Longitude =	88	15	22.31829		Longitude =	88	15	22.00703

Notes:

1. This spreadsheet can be used to convert RPC data base values to HMP compatible values and HMP values to RPC values one point at a time using Helmert transformation parameters. Two conversions (one each way) can be performed/documented on this page.

2. There is a different set of transformation parameter for each of 17 different areas within the seven-county Region. The user must choose/use the spreadsheet written specifically for that area.

3. The transformations are valid for both horizontal and vertical positions. The user must input both state plane coordinates and an elevation in one system for each point being transformed. Results are displayed in the other system.

4. If the user desires to convert only state plane coordinates, then an approximate elevation (within the nearest 10 feet) can be used. The resulting transformed elevation is likewise approximate.

5. If the user desires to convert only elevation, then approximate values of state plane coordinates (within 10 feet) can be used. The resulting transformed state plane coordinates are likewise approximate.

Appendix D (continued)

Constants and Parameters used in the spreadsheet include:

SPR = seconds per radian = 206264.806247096

Clarke Spheroid of 1866 (RPC)

a =	6,378,206.400	m
b =	6,356,583.800	m
e^2 =	0.0067686579973	

GRS 1980 (HMP)

a =	6,378,137.000	m
1/f =	298.25722210088	
e^2 =	0.0066943800229	

Wisconsin South Zone - NAD 27 SPC

See UGS&GS Pub 62-4

L1 =	2,000,000.000	ft
L2 =	324,000.000	seconds
L3 =	22,161,432.250	ft
L4 =	22,672,134.660	ft
L5 =	0.99993254740	
L6 =	0.68710324230	
L7 =	2,595.000	minutes
L8 =	20.01691	seconds
L9 =	3.80761	
L10 =	4.30274	
L11 =	0.00000	

Wisconsin South Zone - NAD 83

See NOAA Manual NOS NGS 5

	Deg	Min	
North Standard Parallel =	44	4	
South Standard Parallel =	42	44	
Latitude of Origin =	42	0	
Longitude of Origin =	90	0	
False Easting on CM =	600,000.000		m
False Northing at Origin =	0.000		m

Computed values for Wisconsin South Zone #4803

Lat. of Cent. Parallel, φ_0	43.4012400263	D.D
Lat. of Cent. Parallel, φ_0	0.75749453791	rad
Mapping radius at φ_0	6,754,625.8558	m
R_b = origin mapping radius	6,910,290.1546	m
K = equator mapping radius	12,012,072.0457	m
Scale factor at φ0	0.999932547079	

Helmert 3-D Transformation Parameters - used for both RPC to HMP and HMP to RPC positions.

Kenosha County - Parameters Set No. 1

Translation in ECEF X	-5.3342	m	Rotation about X axis =	-0.05533224	sec
Translation in ECEF Y	177.5110	m	Rotation about Y axis =	1.22892037	sec
Translation in ECEF Z	162.7540	m	Rotation about Z axis =	-0.80666467	sec

Scale in parts per million = 9.403879

Direct Method Elevation Coefficients and SPC Modifier Constants - **Kenosha County**:
(Used for both RPC to HMP and HMP to RPC positions)

a =	8.43360E-12	Easting Constant =	2,400,000.000	ft.
b =	-3.15135E-06	Northing Constant =	185,000.000	ft.
c =	3.66856E-11			
d =	-5.34262E-06			
e =	1.58098E-11			

NAD 27 State plane to latitude/longitude:

$$theta = \arctan\left(\frac{x - L_1}{L_4 - y}\right)$$ θ = 0.02091307106 rad

$$R = \frac{L_4 - y}{\cos\theta}$$ 22,475,941.501 ft.

$$Longitude = \frac{L_2}{SPR} - \frac{theta}{L_6}$$ λ = 1.5403597493 W
4.7428255579 E

$$s_1 = \frac{L_4 - L_3 - y + 2R\sin^2\left(\frac{\theta}{2}\right)}{L_5}$$ s_1 = 314,530.467 ft

$$s_2 = \frac{s_1}{1 + \left(\frac{s_1}{10^8}\right)^2 L_9 - \left(\frac{s_1}{10^8}\right)^3 L_{10} + \left(\frac{s_1}{10^8}\right)^4 L_{11}}$$ s_2 = 314,518.661 ft

$$s_3 = \frac{s_1}{1 + \left(\frac{s_2}{10^8}\right)^2 L_9 - \left(\frac{s_2}{10^8}\right)^3 L_{10} + \left(\frac{s_2}{10^8}\right)^4 L_{11}}$$ s_3 = 314,518.662 ft

$$s = \frac{s_1}{1 + \left(\frac{s_3}{10^8}\right)^2 L_9 - \left(\frac{s_3}{10^8}\right)^3 L_{10} + \left(\frac{s_3}{10^8}\right)^4 L_{11}}$$ s = 314,518.662 ft

$$A = \frac{s_1}{10^8} \quad B = \frac{s_2}{10^8} \quad C = \frac{s_3}{10^8}$$

A^2 = 9.89294145E-06
A^3 = 3.11163149E-08
A^4 = 9.78702906E-11

B^2 = 9.8921988E-06
B^3 = 3.1112811E-08
B^4 = 9.7855598E-11

C^2 = 9.8921989E-06
C^3 = 3.1112812E-08
C^4 = 9.7855599E-11

$$\omega' = L_7 - 600 \qquad \omega'' = 36{,}000 + L_8 - 0.009873675553 * s \qquad \text{and} \quad \omega = \omega' + \omega'' \qquad \text{Note: must be in radians for Excel}$$

ω' = 1,995.000 minutes ω" = 32914.56168 seconds ω = 0.739896274403 rad

$$\phi' = L_7 - 600, \quad \phi'' = \omega'' + \left[1{,}047.54671 + \left(6.19276 + 0.050912\cos^2\omega\right)\cos^2\omega\right]\sin\omega\,\cos\omega \quad \text{and} \quad \phi = \phi' + \phi'' \quad \text{must be in radians.}$$

φ' = 1,995.000 minutes φ" = 33437.85711 seconds φ = 0.74243328223 rad

NAD 27 latitude and longitude and NGVD 29 Elevation to pseudo RPC X/Y/Z using N = - 34.5m.
(Based upon Clarke Spheroid of 1866)

Pseudo-ellipsoid height in meters = h = NGVD29 elevation / 3.280833333333 - 34.5 m 219.615 m

Ellipsoid normal = $$N = \frac{a}{\sqrt{1 - e^2\sin^2\phi}}$$ N = 6,388,096.0315 m

Pseudo-geocentric X/Y/Z coordinates =

$$X_{RPC} = (N + h)\cos\phi\cos\lambda$$
$$Y_{RPC} = (N + h)\cos\phi\sin\lambda$$
$$Z_{RPC} = [N(1 - e^2) + h]\sin\phi$$

X = 143,245.1269 m
Y = -4,704,894.6595 m
Z = 4,289,797.3975 m

Compute HMP pseudo-geocentric X/Y/Z coordinates using Helmert 3-D transformation parameters.

$$X_{HMP} = TX_1 + (1 + S)X_{RPC} + \omega_z Y_{RPC} - \omega_y Z_{RPC}$$
$$Y_{HMP} = TY_1 - \omega_z X_{RPC} + (1 + S)Y_{RPC} + \omega_x Z_{RPC}$$
$$Z_{HMP} = TZ_1 + \omega_y X_{RPC} - \omega_x Y_{RPC} + (1 + S)Z_{RPC}$$

X_{HMP} = 143,233.9813 m
Y_{HMP} = -4,704,761.9834 m
Z_{HMP} = 4,290,000.0835 m

The same pseudo-geocentric X/Y/Z coordinates can be computed using matrices as:

$$\begin{bmatrix} X_{HMP} \\ Y_{HMP} \\ Z_{HMP} \end{bmatrix} = \begin{bmatrix} TX_1 \\ TY_1 \\ TZ_1 \end{bmatrix} + \begin{bmatrix} 1+S & \omega Z & -\omega Y \\ -\omega Z & 1+S & \omega X \\ \omega Y & -\omega X & 1+S \end{bmatrix} \begin{bmatrix} X_{RPC} \\ Y_{RPC} \\ Z_{RPC} \end{bmatrix}$$

Compute latitude and longitude on NAD 83 from HMP geocentric X/Y/Z coordinates.
Based upon the GRS 1980 ellipsoid)

Longitude in radians = arctan (Y/X) with due regard to quadrant = 4.74282404883 E
1.54036125835 W

Latitude must be iterated on the GRS 1980 ellipsoid:

$P = \sqrt{X^2 + Y^2} =$ 4,706,941.8196 m

To start: $\phi_0 = \arctan\left(\frac{Z}{P(1-e^2)}\right)$ $N_0 = \frac{a}{\sqrt{1-e^2\sin^2\phi}}$

φ_0 = 0.74243375355 rad
N_0 = 6,387,917.7584 m

Then iterate to convergence using:

$$\phi_i = \arctan\left(\frac{Z}{P}\right)\left(1+\frac{e^2 N_{i-1}\sin\phi_{i-1}}{Z}\right) \text{ and } N_i = \frac{a}{\sqrt{1-e^2\sin^2\phi_i}}$$

φ_1 = 0.74243363859 rad
N_1 = 6,387,917.7560 m
φ_2 = 0.74243363817 rad
N_2 = 6,387,917.7560 m
φ_3 = 0.74243363817 rad
N_3 = 6,387,917.7560 m

Compute HMP NAD 83 (2007) state plane coordinates from latitude and longitude positions:
(NOAA Manual NOS NGS 5)

$$Q_\phi = \frac{1}{2}\left[\ln\left(\frac{1+\sin\phi}{1-\sin\phi}\right) - e\ln\left(\frac{1+e\sin\phi}{1-e\sin\phi}\right)\right] =$$

1.643727781 0.110746192

Q_φ = 0.817333309

$$R_\phi = \frac{K}{\exp(Q_\phi \sin\phi_0)} =$$ 6,850,487.2905 m

$$N = R_b + N_b - R_\phi\cos(conv) =$$ 61,300.714 m

$$conv = (\lambda_0 - \lambda)\sin\phi_0 =$$ 0.02091203400 rad

$$E = E_0 + R_\phi\sin(conv) =$$ 743,247.182 m

Compute HMP elevation using Direct Method:

$$Elev_{HMP} = Elev_{RPC} + aX^2 + bX + cXY + dY + eY^2$$ = 833.541 ft

Where X = Easting - 2,400,000 ft
Y = Northing - 185,000 ft

X = 38,470.129 ft
Y = 16,117.425 ft

This is end of RPC to HMP Computations.

Page 5

This is beginning of HMP to RPC Computations.

Convert HMP SPC to Latitude and Longitude:

$$R' = R_b - N + N_b$$
$$E' = E - E_0$$
$$\gamma = \tan^{-1}\frac{E'}{R'}$$
$$R_\phi = \sqrt{R'^2 + E'^2}$$
$$Q_\phi = \frac{\ln\left(\frac{K}{R_\phi}\right)}{\sin\phi_0}$$
$$\chi = 2\tan^{-1}\left(\frac{\exp(Q_\phi) - 1}{\exp(Q_\phi) + 1}\right)$$

$$c_2 = \frac{e^2}{2} + \frac{5e^4}{24} + \frac{e^6}{12} + \frac{13e^8}{360} + \frac{3e^{10}}{160}$$
$$c_4 = \frac{7e^4}{48} + \frac{29e^6}{240} + \frac{811e^8}{11520} + \frac{81e^{10}}{160}$$
$$c_6 = \frac{7e^6}{120} + \frac{81e^8}{1120} + \frac{3029e^{10}}{53760}$$
$$c_8 = \frac{4279e^8}{161280} + \frac{883e^{10}}{20160}$$
$$c_{10} = \frac{2087e^{10}}{161280}$$

c_2 =	0.003356551
c_4 =	6.57187E-06
c_6 =	1.76464E-08
c_8 =	5.33438E-11
c_{10} =	1.73978E-13

R' = 6,848,989.4119 m

E' = 143,247.141 m

R_φ = 6,850,487.2606 m

$$F_0 = 2*(c_2 - 2c_4 + 3c_6 - 4c_8 + 5c_{10})$$
$$F_2 = 8*(c_4 - 4c_6 + 10c_8 - 20c_{10})$$
$$F_4 = 32*(c_6 - 6c_8 + 21c_{10})$$
$$F_6 = 128*(c_8 - 8c_{10})$$
$$F_8 = 512c_{10}$$

F_0 =	0.006686921
F_2 =	5.20145E-05
F_4 =	5.5456E-07
F_6 =	6.64985E-09
F_8 =	8.90766E-11

Conv = γ = 0.020912028 rad Q_φ = 0.8173333149

Chi = χ = 0.739090283 rad $\cos^2\chi$ = 0.5462417060

$$\phi = \chi + \sin\chi\cos\chi(F_0 + \cos^2\chi(F_2 + \cos^2\chi(F_4 + \cos^2\chi(F_6 + F_8\cos^2\chi))))$$ = 0.74243364286 rad

$$\lambda = \lambda_0 - \frac{\gamma}{\sin\phi_0}$$ = 1.5403612670 rad W
4.7428240402 rad E

NAD 83 latitude and longitude and NAVD 88 Elevation to pseudo HMP X/Y/Z using N = - 34.5m.
(Based upon GRS 1980 ellipsoid)

Ellipsoid height in meters = h = NAVD 88 elevation / 3.280833333333 - 34.5 m = 219.561 m

Ellipsoid normal = $N = \frac{a}{\sqrt{1 - e^2\sin^2\phi}}$ N = 6,387,917.7561 m

Pseudo-geocentric X/Y/Z coordinates =

$$X_{HMP} = (N + h)\cos\phi\cos\lambda$$
$$Y_{HMP} = (N + h)\cos\phi\sin\lambda$$
$$Z_{HMP} = [N(1 - e^2) + h]\sin\phi$$

X =	143,233.9406 m
Y =	-4,704,761.9831 m
Z =	4,290,000.1227 m

Pseudo-geocentric RPC X/Y/Z are obtained using Helmert 3-D transformation and parameters.

143,245.0862 m

In matrix notation, [**$X/Y/Z_{RPC}$**] = [R^{-1}] [HMP-T] **[$X/Y/Z_{RPC}$] =** -4,704,894.6592 m

(see page opposite for matrix operations) 4,289,797.4366 m

Compute latitude and longitude on NAD 27 from RPC pseudo-geocentric X/Y/Z coordinates.
(Based upon the Clarke Spheroid of 1866)

Longitude in radians = arctan (Y/X) with due regard to quadrant = -1.540359758
4.742825549 E
1.540359758 W

Latitude must be iterated on the Clarke Spheroid of 1866:

To start: $\phi_0 = \arctan\left(\frac{Z}{P(1-e^2)}\right)$ $N_0 = \frac{a}{\sqrt{1-e^2\sin^2\phi}}$ $P = \sqrt{X^2+Y^2} =$ 4,707,074.7720 m

φ_0 = 0.74243340363 rad

N_0 = 6,388,096.0341 m

Then iterate to convergence using:

$$\phi_i = \arctan\left(\frac{Z}{P}\right)\left(1+\frac{e^2 N_{i-1}\sin\phi_{i-1}}{Z}\right) \text{ and } N_i = \frac{a}{\sqrt{1-e^2\sin^2\phi_i}}$$

φ_1 = 0.74243328735 rad
N_1 = 6,388,096.0316 m
φ_2 = 0.74243328692 rad
N_2 = 6,388,096.0316 m
φ_3 = 0.74243328692 rad
N_3 = 6,388,096.0316 m

Compute RPC NAD 27 state plane coordinates from latitude and longitude positions:
(USC&GS Publication 62-4)

$$s = 101.2794065\{60(L_7 - \phi') + L_8 - \phi'' + [1052.893882 - (4.483344 - 0.023520\cos^2\phi)\cos^2\phi]\sin\phi\cos\phi\}$$

Part 1 = 2582.15883 Part 2 = 1050.466753 s = 314518.564 ft

$$R = L_3 + sL_5\left\{1+\left(\frac{s}{10^8}\right)^2\left[L_9 - \left(\frac{s}{10^8}\right)L_{10} + \left(\frac{s}{10^8}\right)^2 L_{11}\right]\right\}$$

$A = \left(\frac{s}{10^8}\right) =$ 0.003145186

R = 22,475,941.403 ft

A^2 = 9.89219E-06

$$\theta = L_6(L_2 - \lambda),\quad x = L_1 + R\sin\theta,\quad \text{and } y = L_4 - R + 2R\sin^2\left(\frac{\theta}{2}\right)$$

θ = 0.020913065 rad

x = Easting = 2,470,006.564 ft
y = Northing = 201,108.075 ft

Compute RPC elevation using Direct Method:

$$Elev_{RPC} = Elev_{HMP} - aX^2 - bX - cXY - dY - eY^2$$ = 833.699 ft

Where X = Easting - Easting Constant
Y = Northing - Northing Constant

X = 38,469.994 ft
Y = 16,117.520 ft

This is the end of the spreadsheet program.
Written by: Earl F. Burkholder, PS, PE Global COGO, Inc. Las Cruces, NM 88003 - December 2009

Note:	**This section is here because Excel permits matrix operations only on un-merged cells.**			
Rotation Matrix is:	$R = \begin{bmatrix} 1+S & \omega Z & -\omega Y \\ -\omega Z & 1+S & \omega X \\ \omega Y & -\omega X & 1+S \end{bmatrix}$			
	1.000009404	-3.91082E-06	-5.95797E-06	
R =	3.91082E-06	1.000009404	-2.68258E-07	
	5.95797E-06	2.68258E-07	1.000009404	
R^{-1} =	0.999990596	3.91075E-06	5.95786E-06	
	-3.91075E-06	0.999990596	2.6823E-07	
	-5.95786E-06	-2.68277E-07	0.999990596	
Identity	1.0000000000	0.0000000000	0.0000000000	
(check)	0.0000000000	1.0000000000	0.0000000000	
	0.0000000000	0.0000000000	1.0000000000	
[HMP-T] =	143,239.2748			
	-4,704,939.4941			
	4,289,837.3687			

Note: The entire spreadsheet is shown for Kenosha County. The remaining six counties, Milwaukee, Ozaukee, Racine, Walworth, Washington, and Waukesha, show only the first page of each spreadsheet.

State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet.
HMP positions consist of NAD 83 (2007) state plane coordinates and NAVD 88 (2007) elevations in feet.

Milwaukee County North One-Half

Computations performed by: Earl F. Burkholder Date: December 14, 2009

RPC to HMP Name of Station **2019 7-21 C-4**

	Input (RPC)				Output (HMP)			
Northing = y =	406,141.520 ft				Northing =	406,151.267 ft		
Easting = x =	2,529,513.360 ft				Easting =	2,497,975.346 ft		
Elevation =	753.911 ft				Elevation =	753.635 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	5	49.48628		Latitude =	43	5	49.53895
Longitude =	88	1	2.33542		Longitude =	88	1	2.64439

HMP to RPC Name of Station **2019 7-21 C-4**

	Input (HMP)				Output (RPC)			
Northing =	406,151.276 ft				Northing =	406,141.529 ft		
Easting =	2,497,975.279 ft				Easting =	2,529,513.293 ft		
Elevation =	753.547 ft				Elevation =	753.823 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	5	49.53906		Latitude =	43	5	49.48638
Longitude =	88	1	2.64529		Longitude =	88	1	2.33632

Notes:

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2. There is a different set of transformation parameter for each of 17 different areas within the seven-county Region. The user must choose/use the spreadsheet written specifically for that area.

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4. If the user desires to convert only state plane coordinates, then an approximate elevation (within the nearest 10 feet) can be used. The resulting transformed elevation is likewise approximate.

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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Milwaukee County South One-Half

Computations performed by: Earl F. Burkholder Date: December 14, 2009

RPC to HMP Name of Station **2010 5-21 S-2**

	Input (RPC)				Output (HMP)			
Northing = y =	340,401.830 ft				Northing =	340,412.348 ft		
Easting = x =	2,541,226.380 ft				Easting =	2,509,689.311 ft		
Elevation =	723.594 ft				Elevation =	723.259 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	54	57.53890		Latitude =	42	54	57.60682
Longitude =	87	58	45.97718		Longitude =	87	58	46.26841

HMP to RPC Name of Station **2010 5-21 S-2**

	Input (HMP)				Output (RPC)			
Northing =	340,412.683 ft				Northing =	340,402.165 ft		
Easting =	2,509,689.463 ft				Easting =	2,541,226.533 ft		
Elevation =	723.245 ft				Elevation =	723.580 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	54	57.61009		Latitude =	42	54	57.54217
Longitude =	87	58	46.26625		Longitude =	87	58	45.97502

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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Ozaukee County North One-Half

Computations performed by: Earl F. Burkholder Date: December 19, 2009

RPC to HMP Name of Station **2030 11-21 SE-14**

	Input (RPC)				Output (HMP)			
Northing = y =	521,215.890 ft				Northing =	521,223.154 ft		
Easting = x =	2,547,117.970 ft				Easting =	2,515,578.798 ft		
Elevation =	760.960 ft				Elevation =	760.734 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	24	41.58198		Latitude =	43	24	41.59769
Longitude =	87	56	26.82799		Longitude =	87	56	27.14718

HMP to RPC Name of Station **2030 11-21 SE-14**

	Input (HMP)				Output (RPC)			
Northing =	521,222.736 ft				Northing =	521,215.472 ft		
Easting =	2,515,578.133 ft				Easting =	2,547,117.305 ft		
Elevation =	760.882 ft				Elevation =	761.108 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	24	41.59373		Latitude =	43	24	41.57802
Longitude =	87	56	27.15632		Longitude =	87	56	26.83714

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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HMP positions consist of NAD 83 (2007) state plane coordinates and NAVD 88 (2007) elevations in feet.

Ozaukee County South One-Half

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2027 9-22 S-5**

	Input (RPC)				Output (HMP)			
Northing = y =	468,021.200 ft				Northing =	468,029.565 ft		
Easting = x =	2,555,519.300 ft				Easting =	2,523,980.177 ft		
Elevation =	692.114 ft				Elevation =	691.873 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	15	54.25913		Latitude =	43	15	54.29171
Longitude =	87	54	51.06647		Longitude =	87	54	51.38111

HMP to RPC Name of Station **2027 9-22 S-5**

	Input (HMP)				Output (RPC)			
Northing =	468,029.508 ft				Northing =	468,021.143 ft		
Easting =	2,523,980.708 ft				Easting =	2,555,519.831 ft		
Elevation =	691.826 ft				Elevation =	692.067 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	15	54.29101		Latitude =	43	15	54.25843
Longitude =	87	54	51.37396		Longitude =	87	54	51.05931

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet.
HMP positions consist of NAD 83 (2007) state plane coordinates and NAVD 88 (2007) elevations in feet.

Racine County East One-Half

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2038 3-21 SE-20**

	Input (RPC)				Output (HMP)			
Northing = y =	260,886.350 ft				Northing =	260,896.725 ft		
Easting = x =	2,528,976.180 ft				Easting =	2,497,440.019 ft		
Elevation =	749.996 ft				Elevation =	749.759 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	41	55.22202		Latitude =	42	41	55.29781
Longitude =	88	1	55.77129		Longitude =	88	1	56.05476

HMP to RPC Name of Station **2038 3-12 SE-20**

	Input (HMP)				Output (RPC)			
Northing =	260,897.107 ft				Northing =	260,886.731 ft		
Easting =	2,497,440.080 ft				Easting =	2,528,976.241 ft		
Elevation =	749.859 ft				Elevation =	750.096 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	41	55.30156		Latitude =	42	41	55.22577
Longitude =	88	1	56.05382		Longitude =	88	1	55.77035

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet.
HMP positions consist of NAD 83 (2007) state plane coordinates and NAVD 88 (2007) elevations in feet.

Racine County West One-Half

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2036 3-19 SE-24**

	Input (RPC)				Output (HMP)			
Northing = y =	259,761.388 ft				Northing =	259,771.306 ft		
Easting = x =	2,486,894.706 ft				Easting =	2,455,358.082 ft		
Elevation =	800.223 ft				Elevation =	800.034 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	41	53.53101		Latitude =	42	41	53.60199
Longitude =	88	11	19.48297		Longitude =	88	11	19.78876

HMP to RPC Name of Station **2036 3-19 SE-24**

	Input (HMP)				Output (RPC)			
Northing =	259,771.881 ft				Northing =	259,761.963 ft		
Easting =	2,455,357.915 ft				Easting =	2,486,894.539 ft		
Elevation =	799.991 ft				Elevation =	800.180 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	41	53.60771		Latitude =	42	41	53.53672
Longitude =	88	11	19.79082		Longitude =	88	11	19.48504

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet.
HMP positions consist of NAD 83 (2007) state plane coordinates and NAVD 88 (2007) elevations in feet.

Walworth County Northeast One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2063 4-17 S-9**

	Input (RPC)				Output (HMP)			
Northing = y =	300,645.720 ft				Northing =	300,655.035 ft		
Easting = x =	2,404,156.850 ft				Easting =	2,372,619.174 ft		
Elevation =	926.616 ft				Elevation =	926.403 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	48	53.55371		Latitude =	42	48	53.61285
Longitude =	88	29	37.35780		Longitude =	88	29	37.70958

HMP to RPC Name of Station **2063 4-17 S-9**

	Input (HMP)				Output (RPC)			
Northing =	300,655.358 ft				Northing =	300,646.043 ft		
Easting =	2,372,619.504 ft				Easting =	2,404,157.180 ft		
Elevation =	926.336 ft				Elevation =	926.549 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	48	53.61599		Latitude =	42	48	53.55685
Longitude =	88	29	37.70508		Longitude =	88	29	37.35330

Notes:

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State Plane Coordinate and Elevation
Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet
HMP positions consist of NAD 83 (2007) state plane coordinates and NAVD 88 (2007) elevations in feet.

Walworth County Northwest One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2056 3-15 SE-7**

	Input (RPC)				Output (HMP)			
Northing = y =	266,936.670 ft				Northing =	266,944.982 ft		
Easting = x =	2,333,419.950 ft				Easting =	2,301,882.475 ft		
Elevation =	1012.350 ft				Elevation =	1,012.124 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	43	32.13728		Latitude =	42	43	32.18961
Longitude =	88	45	33.02136		Longitude =	88	45	33.39720

HMP to RPC Name of Station **2056 3-15 SE-7**

	Input (HMP)				Output (RPC)			
Northing =	266,945.014 ft				Northing =	266,936.702 ft		
Easting =	2,301,882.385 ft				Easting =	2,333,419.860 ft		
Elevation =	1,011.917 ft				Elevation =	1012.143 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	43	32.18994		Latitude =	42	43	32.13761
Longitude =	88	45	33.39840		Longitude =	88	45	33.02256

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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Walworth County Southeast One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2053 2-17 SE-2**

	Input (RPC)				Output (HMP)			
Northing = y =	242,594.160 ft				Northing =	242,603.313 ft		
Easting = x =	2,418,891.350 ft				Easting =	2,387,354.211 ft		
Elevation =	994.015 ft				Elevation =	993.738 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	39	17.55803		Latitude =	42	39	17.62280
Longitude =	88	26	34.25076		Longitude =	88	26	34.58932

HMP to RPC Name of Station **2053 2-17 SE-2**

	Input (HMP)				Output (RPC)			
Northing =	242,603.287 ft				Northing =	242,594.134 ft		
Easting =	2,387,354.237 ft				Easting =	2,418,891.376 ft		
Elevation =	993.661 ft				Elevation =	993.938 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	39	17.62253		Latitude =	42	39	17.55776
Longitude =	88	26	34.58897		Longitude =	88	26	34.25042

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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Walworth County Southwest One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2046 1-15 S-17**

	Input (RPC)				Output (HMP)			
Northing = y =	197,894.760 ft				Northing =	197,903.088 ft		
Easting = x =	2,337,706.620 ft				Easting =	2,306,169.428 ft		
Elevation =	939.166 ft				Elevation =	938.945 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	32	9.60422		Latitude =	42	32	9.66535
Longitude =	88	44	49.49661		Longitude =	88	44	49.86629

HMP to RPC Name of Station **2046 1-15 S-17**

	Input (HMP)				Output (RPC)			
Northing =	197,903.142 ft				Northing =	197,894.814 ft		
Easting =	2,306,169.290 ft				Easting =	2,337,706.482 ft		
Elevation =	939.611 ft				Elevation =	939.832 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	32	9.66590		Latitude =	42	32	9.60477
Longitude =	88	44	49.86812		Longitude =	88	44	49.49844

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet.
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Washington County North One-Half

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2075 11-18 SE-15**

	Input (RPC)				Output (HMP)			
Northing = y =	519,520.980 ft				Northing =	519,527.222 ft		
Easting = x =	2,446,073.190 ft				Easting =	2,414,535.282 ft		
Elevation =	1109.093 ft				Elevation =	1,109.036 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	24	47.21353		Latitude =	43	24	47.21771
Longitude =	88	19	15.98414		Longitude =	88	19	16.32558

HMP to RPC Name of Station **2075 11-18 SE-15**

	Input (HMP)				Output (RPC)			
Northing =	519,527.185 ft				Northing =	519,520.943 ft		
Easting =	2,414,535.317 ft				Easting =	2,446,073.225 ft		
Elevation =	1,108.878 ft				Elevation =	1108.935 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	24	47.21734		Latitude =	43	24	47.21316
Longitude =	88	19	16.32511		Longitude =	88	19	15.98367

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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Washington County South One-Half

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2065 9-18 SE-15**

	Input (RPC)				Output (HMP)			
Northing = y =	455,067.280 ft				Northing =	455,074.737 ft		
Easting = x =	2,442,167.320 ft				Easting =	2,410,630.196 ft		
Elevation =	1101.938 ft				Elevation =	1,101.899 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	14	11.47986		Latitude =	43	14	11.50300
Longitude =	88	20	26.26829		Longitude =	88	20	26.59982

HMP to RPC Name of Station **2065 9-18 SE-15**

	Input (HMP)				Output (RPC)			
Northing =	455,074.997 ft				Northing =	455,067.540 ft		
Easting =	2,410,629.310 ft				Easting =	2,442,166.434 ft		
Elevation =	1,101.796 ft				Elevation =	1101.835 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	14	11.50574		Latitude =	43	14	11.48260
Longitude =	88	20	26.61172		Longitude =	88	20	26.28019

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

RPC positions consist of NAD 27 state plane coordinates and NGVD 29 elevations, both in feet.
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Waukesha County Northeast One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2095 7-19 E-10**

	Input (RPC)				Output (HMP)			
Northing = y =	399,834.270 ft				Northing =	399,843.352 ft		
Easting = x =	2,474,242.520 ft				Easting =	2,442,705.043 ft		
Elevation =	921.010 ft				Elevation =	920.835 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	4	59.50212		Latitude =	43	4	59.54811
Longitude =	88	13	28.93951		Longitude =	88	13	29.26265

HMP to RPC Name of Station **2095 7-19 E-10**

	Input (HMP)				Output (RPC)			
Northing =	399,843.284 ft				Northing =	399,834.202 ft		
Easting =	2,442,704.970 ft				Easting =	2,474,242.447 ft		
Elevation =	920.702 ft				Elevation =	920.877 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	4	59.54746		Latitude =	43	4	59.50147
Longitude =	88	13	29.26365		Longitude =	88	13	28.94052

Notes:

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Waukesha County Northwest One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **2097 8-17 SE-18**

	Input (RPC)				Output (HMP)			
Northing = y =	422,994.070 ft				Northing =	423,001.971 ft		
Easting = x =	2,394,853.440 ft				Easting =	2,363,316.261 ft		
Elevation =	917.851 ft				Elevation =	917.831 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	9	3.52697		Latitude =	43	9	3.55752
Longitude =	88	31	13.03022		Longitude =	88	31	13.38031

HMP to RPC Name of Station **2097 8-17 SE-18**

	Input (HMP)				Output (RPC)			
Northing =	423,002.170 ft				Northing =	422,994.269 ft		
Easting =	2,363,315.697 ft				Easting =	2,394,852.876 ft		
Elevation =	917.545 ft				Elevation =	917.56 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	9	3.55959		Latitude =	43	9	3.52904
Longitude =	88	31	13.38786		Longitude =	88	31	13.03777

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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Waukesha County Southeast One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **7078 Observatory**

	Input (RPC)				Output (HMP)			
Northing = y =	358,581.020 ft				Northing =	358,590.902 ft		
Easting = x =	2,495,538.290 ft				Easting =	2,464,000.855 ft		
Elevation =	957.640 ft				Elevation =	957.367 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	58	7.53704		Latitude =	42	58	7.59603
Longitude =	88	8	54.38493		Longitude =	88	8	54.69885

HMP to RPC Name of Station **7078 Observatory**

	Input (HMP)				Output (RPC)			
Northing =	358,591.280 ft				Northing =	358,581.398 ft		
Easting =	2,464,000.720 ft				Easting =	2,495,538.155 ft		
Elevation =	957.410 ft				Elevation =	957.683 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	42	58	7.59979		Latitude =	42	58	7.54080
Longitude =	88	8	54.70055		Longitude =	88	8	54.38663

Notes:

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State Plane Coordinate and Elevation Transformations Between RPC and HMP Positions

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Waukesha County Southwest One-Quarter

Computations performed by: Earl F. Burkholder Date: December 16, 2009

RPC to HMP Name of Station **7037 Dousman**

	Input (RPC)				Output (HMP)			
Northing = y =	376,203.850 ft				Northing =	376,212.956 ft		
Easting = x =	2,401,219.000 ft				Easting =	2,369,681.527 ft		
Elevation =	852.260 ft				Elevation =	852.163 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	1	20.29960		Latitude =	43	1	20.34761
Longitude =	88	29	58.52779		Longitude =	88	29	58.87869

HMP to RPC Name of Station **7037 Dousman**

	Input (HMP)				Output (RPC)			
Northing =	376,212.730 ft				Northing =	376,203.624 ft		
Easting =	2,369,681.540 ft				Easting =	2,401,219.013 ft		
Elevation =	852.190 ft				Elevation =	852.287 ft		
	Deg	Min	Sec			Deg	Min	Sec
Latitude =	43	1	20.34537		Latitude =	43	1	20.29737
Longitude =	88	29	58.87856		Longitude =	88	29	58.52766

Notes:

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Appendix E

SUMMARY OF STANDARD DEVIATION DETERMINATION

What level of standard deviation (1 sigma – 68 percent level) can be tolerated on the coordinates of two section corners one-half mile apart such that the standard deviation of the inverse distance between them can be relied upon to be within 1 part in 10,000 at the 2 sigma—95 percent—level?

The equation for computing the standard deviation of the inversed distance between points (Equation 13, Burkholder 1990) is:

$$\sigma_L = \sqrt{\left(\frac{X_2 - X_1}{L}\right)^2 \left(\sigma_{X_2}^2 + \sigma_{X_1}^2\right) + \left(\frac{Y_2 - Y_1}{L}\right)^2 \left(\sigma_{Y_2}^2 + \sigma_{Y_1}^2\right)}$$

where: L = Inversed distance between points 1 and 2.
σ_L = Standard deviation of distance at 1 sigma (68 percent) level.
X_1 and Y_1 are the coordinates of point 1.
X_2 and Y_2 are the coordinates of point 2
σ_{X1} and σ_{Y1} are the standard deviations of coordinates of point 1.
σ_{X2} and σ_{Y2} are the standard deviations of coordinates of point 2.

The equation above is valid but it presumes no statistical correlation between the X and the Y coordinates at each point or between the two points. A measure of local accuracy that includes correlation can be computed using matrix equation (1.36) in Burkholder (2008). Additional information on the derivation of equation (1.36) can be found in Burkholder (1999).

The following assumptions were used in developing an answer to the question concerned.

1. The standard deviation at the 2 sigma (95 percent) confidence level is twice the standard deviation at the 1 sigma (68 percent) confidence level.

2. The standard deviation of both the X and Y coordinates at each point are assumed to be the same and the standard deviations of both points are assumed to be equal.

3. The inversed line lies either in the east-west direction (in which case $Y_2 - Y_1$ is zero) or in the north-south direction (in which case the $X_2 - X_1$) value is zero. In either case, the length of the one-half mile line is the same as the ΔX or the ΔY value for the line.

4. 1:10,000 = 0.0001*(L) = standard deviation of half-mile at 95 percent confidence level = 0.264'.

5. The standard deviation at the 1sigma level (68 percent) is one half that at the 2 sigma level (95 percent) or, for 1/2 mile, 1 sigma = 0.132 ft.

These assumptions will give the same answer as using the entire equation on a non-cardinal line. Given those simplifications, the standard deviation of the length of the inversed distance (1/2 mile) can be written as:

$\sigma_{\text{L-68 percent}} = \frac{1}{2}\,\sigma_{\text{L-90 percent}} = \frac{1}{2}\,(0.264) = 0.132$ ft

$$\sigma_{L-68\%}^2 = \left(\frac{\Delta X}{L}\right)^2 \left(\sigma_{X_1}^2 + \sigma_{X_2}^2\right) + \left(\frac{0}{L}\right)^2 \left(\sigma_{Y_1}^2 + \sigma_{Y_2}^2\right) = 2\sigma_X^2 \qquad \text{imples that } \sigma_X = \frac{\sigma_{L-68\%}}{\sqrt{2}} = \frac{0.132}{\sqrt{2}} = 0.093'$$

Conclusion, a 1 sigma standard deviation of 0.093 feet can be tolerated on the coordinates of each of two points half mile apart and, 95 percent of the time, the inversed distance will be accurate within 1:10,000.

References

1. Burkholder, E.F., 1990; "Using Error Propagation to Protect an Investment in GPS Technology," Proceedings of ACSM Annual Meeting, Denver, Colorado, March, 1990.

2. Burkholder, E.F., 1999; "Spatial Data Accuracy as Defined by the GSDM," Surveying and Land Information Systems, Vol. 59, No. 1, pp 26-30.

3. Burkholder, E.F., 2008; *The 3-D Global Spatial Data Model: Foundation of the Spatial Data Infrastructure,* CRC Press, Taylor & Francis Group, Boca Raton.

Appendix F

LIST OF ACRONYMS AND ABBREVIATIONS

1.	CORPSCON	Program written by U.S. CORPS of Engineers for coordinate and datum transformations.
2.	CORS	Continuously Operating Reference Stations - permanent GPS receiver installations.
3.	DOD	U.S. Department of Defense
4.	EDMI	Electronic Distance Measurement Instrument
5.	ECEF	Earth-centered Earth-fixed - rectangular geocentric coordinates used by DOD for GPS.
6.	FGCC	Federal Geodetic Control Committee
7.	FGCS	Federal Geodetic Control Subcommittee represents various Federal agencies
8.	FGDC	Federal Geographic Data Committee - interagency organization responsible for the NSDI.
9.	Galileo	Satellite positioning system being built by the European community.
10.	GEOIDxx	Geoid height interpolation programs published by NGS in 19XX and 20XX.
11.	GLONASS	Russian satellite navigation system similar to the U.S. GPS system.
12.	GNSS	Global Navigation Satellite System - includes GPS, GLONASS, and Galileo systems.
13.	GPS	Global Positioning System - satellite system built by U.S. DOD and used worldwide.
14.	GRS 80	Geodetic Reference System 1980 - ellipsoid used for the NAD 83 datum and with the ITRF.
15.	HARN	High Accuracy Reference Network as established by NGS.
16.	HMP	Combination of NAD 83 (2007) horizontal data and NAVD 88 (2007) vertical data within Region.
17	ITRF	International Terrestrial Reference Frame
18.	NAD 27	North American Datum of 1927 - horizontal datum established by NGS.
19.	NAD 83	North American Datum of 1983 - horizontal datum established by NGS.
20.	NAD 83 (1986)	Original NAD 83 values as computed and published in 1986.
21.	NAD 83 (1991)	NAD 83 values adjusted by NGS in 1991 for points in Wisconsin.
22.	NAD 83 (1997)	NAD 83 values adjusted by NGS in 1997 for points in Wisconsin.
23.	NAD 83 (2007)	NAD 83 values resulting from a national readjustment and published by NGS in 2007.
24.	NAD 83 (xxxx)	NAD 83 values as published in a yet unknown future year.
25.	NADCON	NGS program used to perform datum conversions between NAD 27 and NAD 83 (1991).
26.	NAVD 88	North American Vertical Datum of 1988 - published and maintained by NGS.
27.	NAVD 88 (1991)	Original adjustment of the new national vertical datum for Wisconsin.
28.	NAVD 88 (2007)	Adjustment of the NAVD 88 resulting from the WI-HMP.
29.	NGS	National Geodetic Survey - responsible for national survey control network.
30.	NGVD 29	National Geodetic Vertical Datum of 1929 - vertical datum published by NGS.
31.	NSDI	National Spatial Data Infrastructure - the underlying framework of spatial data policies.
32.	NSRS	National Spatial Reference System - combined horizontal/vertical survey control network.
33.	P.O.B.	Point of Beginning
34.	Region	Seven-county area served by the SEWRPC.
35.	RPC	Combination of NAD 27 horizontal data and NGVD 29 vertical data within Region.
36.	RTK	Real-Time Kinematic, a mode of using GPS to establish survey positions in real time.
37.	RTN	Real-Time Network of GPS CORS stations providing support for real-time positioning.
38.	SEWRPC	Southeastern Wisconsin Regional Planning Commission
39.	USC&GS	U.S. Coast & Geodetic Survey - predecessor to NGS.
40.	USGS	United States Geological Survey - responsible for national mapping program in the U.S.
41.	USPLSS	U.S. Public Land Survey System
42.	VERTCON	Program written by NGS to perform datum conversions between NGVD 29 and NAVD 88.
43.	WGS 84	World Geodetic System of 1984 - DOD datum and ellipsoid used for GPS.
44.	WI-HMP	Wisconsin Height Modernization program.
45.	WisDOT	Wisconsin Department of Transportation

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Appendix G

CALIBRATION TEST AND DEMONSTRATION OF USE OF A GPS UNIT AND A REAL-TIME NETWORK (RTN) PROVIDED BY THE CONTINOUSLY OPERATING REFERENCE STATION (CORS) NETWORK OPERATED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION WITHIN THE SOUTHEASTERN WISCONSIN REGION

OBJECTIVE

The objective of the calibration test was to demonstrate the feasibility of obtaining reliable NAD 27 State Plane Coordinate values and NGVD 29 elevations using GPS observations. The demonstration involved 16 U.S. Public Land Survey quarter-section corner monuments and two center of section monuments in Sections 10 and 12 in Township 6 North, Range 20 East, City of New Berlin, Waukesha County, Wisconsin. For each of the two sections concerned, the SEWRPC published NAD 27 coordinate values and the SEWRPC published NGVD 29 elevation values for the four section corner monuments (northeast, northwest, southeast, and southwest) were held as "fixed" values. A GPS Trimble R-8 Model 3 Receiver and TSC2 Data Collector were then used to obtain observed State Plane Coordinate position and NGVD 29 elevation values for the eight quarter-section corner monuments and the two center of section monuments considered as "free" stations. The test results are provided in Tables G-1 through G-4.

PROCEDURES AND RESULTS

The calibration—also known as site localization—and demonstration survey procedure consisted of the following steps:

1. Identify SEWRPC control survey stations in the area to be surveyed and conduct field reconnaissance and recovery of control survey stations to be held as "fixed" positions with published SEWRPC NAD 27 State Plane Coordinates and NGVD 29 elevations. For the demonstration this involved the recovery of four monumented control survey stations to be held "fixed" and five other monumented stations in each of the two sections for which position and elevation values were to be established. Copies of SEWRPC "Record of U.S. Public Land Survey Control Station" sheets were obtained for all of the monumented corners concerned. These sheets provided the NAD 27 published State Plane Coordinate values and NGVD 29 elevations for the monumented corners. The tie distances to the witness marks concerned were measured and compared to the recorded tie distances for each corner to verify that the monument marking the corner had not been disturbed. The elevation of the monuments concerned were checked by differential level survey from attendant referenced bench marks and compared to the published elevations.

2. Best practice dictates that at least four fixed control stations should be used in a GPS field calibration. The four control stations should be located outside of, but as near as practicable to, the points for which coordinates and elevations are to be determined. The published coordinates and elevations of the fixed control stations, along with a station identification number, should then be uploaded to the GPS instrument data collector through the use of a previously prepared ASCII or text file. This was done for the eight fixed control stations involved in the demonstration. At least four fixed station control stations should be used in a GPS field calibration for horizontal control and at least four should be used for vertical—elevation or orthometric height—control. The horizontal and vertical "calibration" does not need to be on the same stations for the horizontal and vertical "calibration."

3. The field operation was initiated by connecting the GPS unit to the WisDOT CORS network computer servers using a cellular telephone equipped with Bluetooth technology. Once the connection had been established, the GPS unit was ready to begin the initialization sequence. In the initialization

sequence the GPS unit collected information from available satellites to orient the unit to its initial location and orientation relative to the NAD 83 (2007) and NAVD 88 (2007) datums. It is correct to initialize the GPS unit on the first station occupied. However, for safety, or other reasons, the initialization need not occur on a known point.

4. Following initialization, the first fixed control survey station in the survey area concerned was occupied and the receiver antenna leveled. For the initial observation the unit and the observer face approximately north. During a station occupation it is possible to view certain data on the collector screen. These data included the number of satellites available during the observation; the strength and quality of the data being received from the available satellites—known as the positional dilution of position (PDOP) values; and the status of the operation of the communication link. The accuracy of the measurements is dependent upon the GPS antenna being carefully centered and leveled over the point being observed, and upon the antenna height above the occupied survey station being accurately measured. The later is usually done by use of a mounting pole having a fixed predetermined length, or by use of a graduated, extendable mounting pole. Built in software uses the input antenna height to compute the position of the occupied monument instead of the position of the receiving antenna. Although sequence is a matter of efficiency and preference, in the demonstration the first fixed control survey stations occupied were the Northwest corner of each of the sections concerned.

5. An initial set of measurements was completed and the data were stored in the collector. The GPS unit was then rotated so that the observer' s position changed to face approximately south and a second set of measurements was obtained in the interest of redundancy and verification. Two sets of measurements were obtained in this way at each of the fixed control survey stations for each section concerned. This observational procedure was followed at each of the two initial and each of the attendant three fixed stations for each section included in the demonstration.

6. Upon completion of the occupation and observations at each of the four fixed control stations for a section, the GPS unit was considered to be calibrated to the "local" coordinate system, and vertical datum, in the case of the demonstration, the NAD 27 SPC system and the NGVD 29 datum. Using the now calibrated instrument, the four quarter-section corner monuments and the center of section monument for which NAD 27 coordinate values and NGVD 29 elevation values were to be determined were then occupied and the observed data stored in the data collector.

   The measurements obtained on each monument were paired with the corresponding known coordinates using the software incorporated in the data collector. The information generated from these data, is used to generate a localized projection and the user is presented with residuals for each of the pairings. The user can evaluate whether the solution meets the required level of horizontal and vertical accuracy of each point at this time. If necessary, individual horizontal and vertical points can be removed from the calculation in order to obtain a better fit, horizontally, vertically, or both.

The foregoing survey procedure was carried out in Sections 10 and 12 in Township 6 North, Range 20 East. The results are provided in Tables G-1 through G-4.

If a survey extends over a significant period of time, the continued validity of the initial calibration should be periodically checked. This involves returning to one of the initial calibration points, or to a point determined subsequent to a calibration, and noting that the repeat observation values are within the tolerance of the application. Any time a "check" fails to meet the determined tolerance, the system should be recalibrated. Good practice would include performing "checks" at the end of work each day on each project. Checks should not be postponed beyond a reasonable time limit.

CONCEPTS

The computations that permit the GPS unit to convert 3-D measurements referenced to the NAD 83 (2007) to NAD 27 SPC, are preprogrammed and carried out in the data collector component of the unit. Conceptually, the calibration process, in effect, fits a pseudoplane and attendant coordinates to the curved surface of the earth at the survey site. After the initialization step orients the instrument with respect to the latitude and longitude of the initially occupied fixed station referenced to NAD 83 (2007), and the control values referenced to the desired datums are entered into the data collector, the unit, through occupation of the remaining three fixed stations, adjusts the pseudoplane and attendant grid to best fit the entered coordinates on the desired datum. The unit then provides what are, in effect, pseudo State Plane Coordinates computed on the plane surface.

More specifically, in GPS surveys conducted within a CORS network, after calibration to known control points, coordinate positions of unknown points are calculated utilizing vectors from known nearby control points. The coordinate position of an unknown point is then calculated utilizing vectors from the nearby known points. The NAD 83 (2007) geocentric X/Y/Z coordinates of the nearby stations are known and the "error" of the GPS measured value at the known station is determined based on observations at CORS stations. The "error" is then used to determine the corrector to be applied to the GPS measured value at the unknown station. The vectors between the position of the known station and the corrected measured value at the unknown station are computed in terms of the relative $\Delta X/\Delta Y/\Delta Z$ components by utilizing the relative observed positions of the unknown points with respect to the given CORS values. Although the $\Delta X/\Delta Y/\Delta Z$ components of each vector are actually computed in the WGS 84 coordinate system, the results are expressed as NAD 83 (2007) coordinate differences because, for practical purposes on local networks, the WGS 84 $\Delta X/\Delta Y/\Delta Z$ components are the same as in the NAD 83 (2007). The origins of the WGS 84 and NAD 83 datums are slightly different but, for local networks, the $\Delta X/\Delta Y/\Delta Z$ and related vector values are almost identical. Therefore, the NAD 83 position of each unknown point is computed by adding the NAD 83 vector components to the known NAD 83 (2007) geocentric X/Y/Z coordinates of the nearby known stations.

In a network, multiple vectors are used to compute the position of an unknown point, the difference in the multiple positions obtained being resolved by a least squares adjustment which also models corrections needed to give the best possible solution. The satellite signals used to determine the vectors from each known station to the unknown points include errors inherent in satellite positioning such as clock time, ionosphere effects, and uncertainties in the satellite orbits. Although such errors are typically quite small the CORS stations provide a combined set of "corrections" to be applied in real time by each roving unit. Therefore, the GPS receiving unit—the rover—must be in communication with the CORS network through a central "server" via the Internet using cell phone technology. This communication is essential when using the WI-HMP RTN—the WISCORS network.

Using the RTN as described determines geocentric X/Y/Z NAD 83 (2007) coordinates for the station occupied. Latitude, longitude, and ellipsoid height are computed from those X/Y/Z values and, by user choice, Wisconsin South Zone NAD 83 (2007) State Plane Coordinates are computed from the latitude and longitude. Obtaining NAD 27 State Plane Coordinates for the same point involves either application of the bidirectional transformation parameters as described in this report or by utilization of the calibration procedure described in this Appendix.

It should be noted that in the State Plane Coordinate system—whether based upon NAD 83 (2007) or the NAD 27 datums—the coordinate positions are expressed as grid coordinates on the plane provided by the system projection. Inverse computations between known grid coordinate positions, therefore, provide grid distances. If ground level distances are required, the grid distances can be readily converted to ground level distances by application of the combination factor—the product of the scale factor and the sea level reduction factor—provided by the Commission in SEWRPC Technical Report No. 7, Third Edition, *Horizontal and Vertical Survey Control in Southeastern Wisconsin,* August 1996. These factors provide the reductions relative to mean sea level rather than to an ellipsoid of reference. The factors are provided for the centers of

six - two by three - section areas within each survey township within the seven-county Region. The factors are also available on the Commission's website.[1]

This process is relatively straight-forward with respect to the computation and provision of the horizontal position values. When using the RTN, the NAD 88 (2007) elevation for a surveyed point is obtained from the ellipsoid height by applying the current geoid model as promulgated by the NGS—GEOID09. In order to obtain elevations on the NGVD 29 datum, either the appropriate bidirectional transformation procedure or the calibration procedure described herein should be used. When using the bidirectional direct modeling method, the NAD 83 (2007) State Plane Coordinates are required as input along with the elevation being transformed—either NAVD 88 (2007) to NGVD 29 or vice versa. If elevations are being determined by the calibration procedures described herein, the vendor proprietary calibration software models, in a best fit scenario, the field observed height differences to the elevation differences defined by the control point elevations input by the user. These procedures make it possible to utilize GPS instrumentation to obtain accurate elevations on NGVD 29 throughout the seven-county Region.

For higher order work and applications, there is no substitute for re-survey on the datum of choice. The procedure utilized in the demonstration survey as herein described, is recommended for use whenever higher orders of survey accuracy relating RPC and HMP positions are required than can be provided by the application of the data transformation procedures provided in this report. In utilizing the procedure it is important to determine that the GPS antenna is positioned so that clear obstruction-free sights exist to the available satellites. If a "free" station is located in an area where interference with the satellite signals may exist—such as in a wooded area, near high-rise buildings, near high voltage transmission lines, or next to a chain-link fence—it may become necessary to utilize conventional survey techniques to carry the coordinates and elevations from a supplementary GPS station located in a nearby obstruction-free area to the free station concerned.

EQUIPMENT AND CREW, DATE OF SURVEY, WEATHER CONDITIONS

The GPS equipment used for this demonstration was provided by Mr. Terrance J. Lueschow, RLS, of Seiler Instruments and consisted of a Trimble R-8 Model 3 Receiver, a TSC2 Data Collector, and Trimble Geomatics software package. The test was conducted on Wednesday, February 17, 2010, under cloudy skies and an average temperature of about 30ºF. The field crew consisted of Mr. Lueschow, Mr. Donald P. Simon, RLS, Southeastern Wisconsin Regional Planning Commission staff, and Mr. Andrew J. Traeger, CSTIII, also of the Southeastern Wisconsin Regional Planning Commission staff.

[1] *It is technically more correct to use a combination scale and elevation factor, which provide the reduction relative to the ellipsoid of reference, when working with NAD 83 (2007) coordinates. However, based upon use of equation (6) in Burkholder (2004), it can be shown that the difference in using the combination scale and elevation factor in place of the combination scale and sea level factor promulgated by SEWRPC is less than 1:200,000 in the seven-county SEWRPC Region. Therefore, continued use of the combination scale and sea level reduction is acceptable within the Region.*

Table G-1

COMPARISON OF PUBLISHED NAD 27 COORDINATE VALUES TO PSEUDO NAD 27 COORDINATE VALUES OBTAINED USING GPS CALIBRATION PROCEDURE WITHIN SECTION 10, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NAD 27 Published Coordinates		NAD 27 Coordinate Values Obtained Using GPS Calibration Procedure		Difference Between NAD 27 Published and GPS Calibration Procedure Values	
		Northing Feet	Easting Feet	Northing Feet	Easting Feet	Northing Feet	Easting Feet
2101[a]	6-20 NW-10	371,215.630	2,506,072.820	- -	- -	- -	- -
2102	6-20 N-10	371,084.070	2,503,470.010	371,083.905	2,503,470.014	-0.165	0.004
2103[a]	6-20 NW-10	370,974.360	2,500,857.840	- -	- -	- -	- -
2104	6-20 C-10	368,443.110	2,503,478.160	368,443.059	2,503,478.073	-0.051	-0.087
2105	6-20 E-10	368,556.800	2,506,108.070	368,556.789	2,506,108.071	-0.011	0.001
2109[a]	6-20 SE-10	365,899.260	2,506,153.990	- -	- -	- -	- -
2110[a]	6-20 SW-10	365,678.930	2,500,819.830	- -	- -	- -	- -
2113	6-20 W-10	368,330.000	2,500,827.260	368,329.959	2,500,827.230	-0.041	-0.030
2114[b]	6-20 S-10	365,802.790	2,503,483.210	365,803.061	2,503,483.018	0.271	0.192
					Mean	**0.001**	**0.016**
					Standard Deviation	**0.162**	**0.105**

[a]*Monumented Control Station Coordinate value held as fixed.*

[b]*Monumented Corner located near chain link fence. Probable multipath of satellite signal.*

Source: SEWRPC.

Table G-2

COMPARISON OF PUBLISHED NAD 27 COORDINATE VALUES TO PSEUDO NAD 27 COORDINATE VALUES OBTAINED USING GPS CALIBRATION PROCEDURE WITHIN SECTION 12, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NAD 27 Published Coordinates		NAD 27 Coordinate Values Obtained Using GPS Calibration Procedure		Difference Between NAD 27 Published and GPS Calibration Procedure Values	
		Northing Feet	Easting Feet	Northing Feet	Easting Feet	Northing Feet	Easting Feet
2106	6-20 C-12	368,755.320	2,514,149.760	368,755.304	2,514,149.984	-0.016	0.224
2107	6-20 E-12	368,802.940	2,516,852.080	368,802.957	2,516,851.982	0.017	-0.098
2108[a]	6-20 SE-12	366,157.000	2,516,834.520	- -	- -	- -	- -
2111[a]	6-20 NE-12	371,475.330	2,516,869.030	- -	- -	- -	- -
2112[a]	6-20 NW-12	371,364.620	2,511,433.760	- -	- -	- -	- -
2115[b]	6-20 N-12	371,427.630	2,514,150.270	371,428.156	2,514,150.858	0.526	0.588
2116	6-20 S-12	366,083.260	2,514,150.960	366,083.234	2,514,151.141	-0.026	0.181
2117	6-20 W-12	368,685.050	2,511,456.710	368,684.934	2,511,456.877	-0.116	0.167
2118[a]	6-20 SW-12	366,025.240	2,511,468.700	- -	- -	- -	- -
					Mean	**0.077**	**0.212**
					Standard Deviation	**0.256**	**0.245**

[a]*Monumented Control Station Coordinate value held as fixed.*

[b]*Monumented Corner located in wooded area. Probable multipath of satellite signal.*

Source: SEWRPC.

Table G-3

COMPARISON OF NGVD 29 ELEVATION VALUES OBTAINED FROM DIFFERENTIAL LEVELING WITH ELEVATION VALUES OBTAINED DURING THE GPS CALIBRATION PROCEDURE FOR SECTION 10, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NGVD 29 Elevation Derived from Differential Leveling	Elevation Derived During GPS Calibration Procedure	Difference
2101[a]	6-20 NE-10	864.205	--	--
2102	6-20 N-10	845.693	845.751	0.058
2103[a]	6-20 NW-10	866.418	--	--
2104	6-20 C-10	867.408	867.393	-0.015
2105	6-20 E-10	891.122	891.129	0.007
2109[a]	6-20 SE-10	863.383	--	--
2110[a]	6-20 SW-10	868.444	--	--
2113	6-20 W-10	888.024	887.969	-0.055
2114[b]	6-20 S-10	882.691	882.671	-0.020
			Mean	**-0.005**
			Standard Deviation	**0.044**

[a]*Monumented Control Station elevation value held as fixed.*

[b]*Monumented Corner located near chain link fence. Probable multipath of satellite signal.*

Source: SEWRPC.

Table G-4

COMPARISON OF NGVD 29 ELEVATION VALUES OBTAINED FROM DIFFERENTIAL LEVELING WITH ELEVATION VALUES OBTAINED DURING THE GPS CALIBRATION PROCEDURE FOR SECTION 12, TOWNSHIP 6 NORTH, RANGE 20 EAST

Point ID No.	U.S. Public Land Survey Designation	NGVD 29 Elevation Derived from Differential Leveling	Elevation Derived During GPS Calibration Procedure	Difference
2106	6-20 C-12	793.046	793.057	0.011
2107	6-20 E-12	760.684	760.644	-0.040
2108[a]	6-20 SE-12	772.039	--	--
2111[a]	6-20 NE-12	758.648	--	--
2112[a]	6-20 NW-12	832.648	--	--
2115[b]	6-20 N-12	783.491	783.873	0.382
2116	6-20 S-12	813.615	813.682	0.067
2117	6-20 W-12	841.825	841.785	-0.040
2118[a]	6-20 SW-12	865.090	--	--
			Mean	**0.076**
			Standard Deviation	**0.122**

[a]*Monumented Control Station elevation value held as fixed.*

[b]*Monumented Corner located in wooded area. Probable multipath of satellite signal.*

Source: SEWRPC.